**Boston Edison**

Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

**Henry V. Oheim**
General Manager - Technical Section

April 25, 1996
BECo 96-025

NPDES Programs (SPA)
U.S. Environmental Protection Agency
P.O. Box 8127
Boston, MA 02114-3127

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. 47 is submitted. This covers the period from January through December, 1995.

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H. V. Oheim

Attachment: Semi-Annual Marine Ecology Report No. 47

HVO/RDA/nas/ECOLRPT



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Rocky Hill Road
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General Manager - Technical Section

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Mass. Department of Environmental Protection
Regulatory Branch - 7th Floor
One Winter Street
Boston, MA 02108

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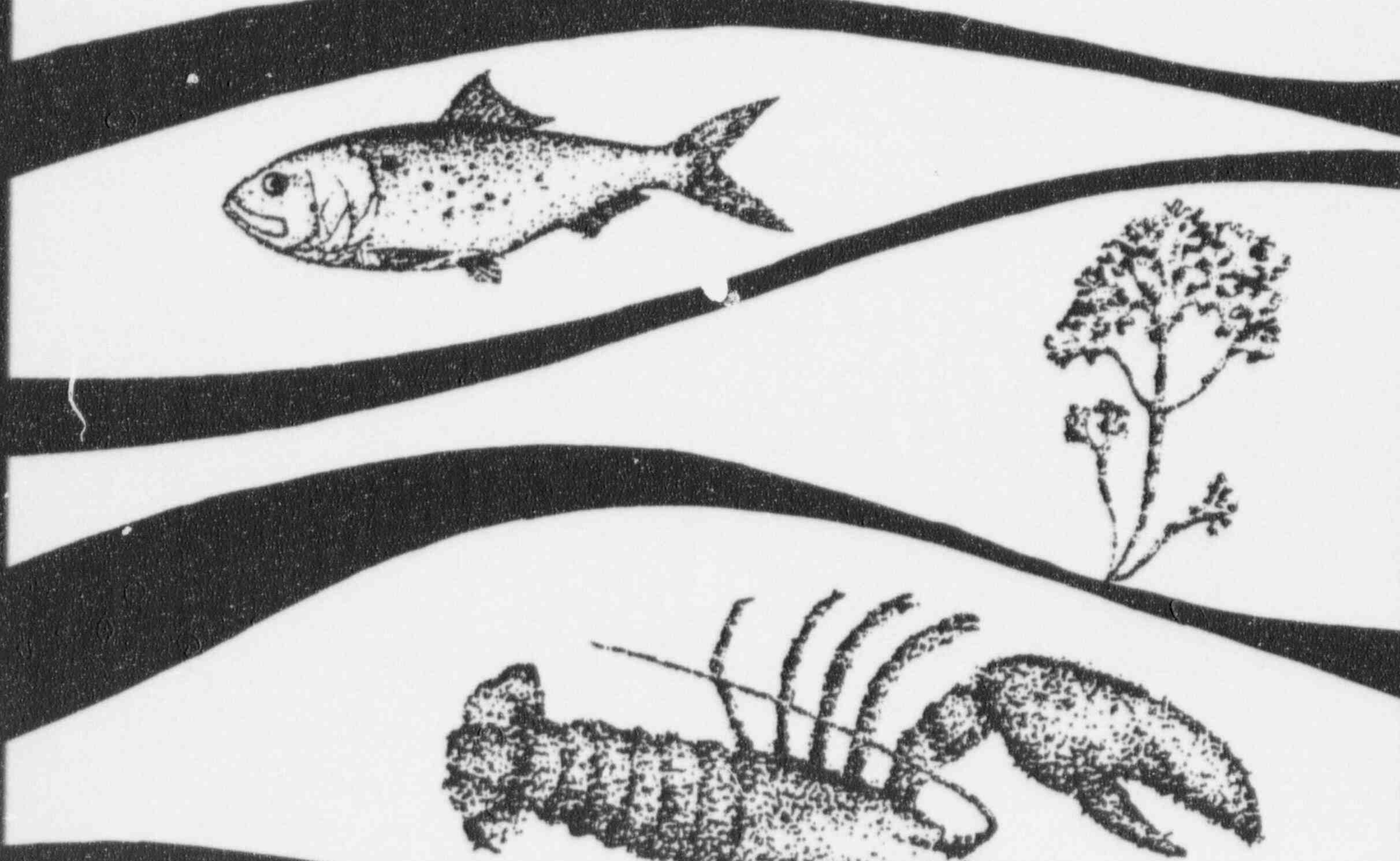
# marine ecology studies

## Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 47
JANUARY 1995 – DECEMBER 1995



BOSTON EDISON COMPANY
REGULATORY AFFAIRS DEPARTMENT

Boston Edison

**MARINE ECOLOGY STUDIES**

**RELATED TO OPERATION OF PILGRIM STATION**

**SEMI-ANNUAL REPORT NO. 47**

**REPORT PERIOD: JANUARY 1995 THROUGH DECEMBER 1995**

**DATE OF ISSUE: APRIL 30, 1996**

Compiled and Reviewed by:

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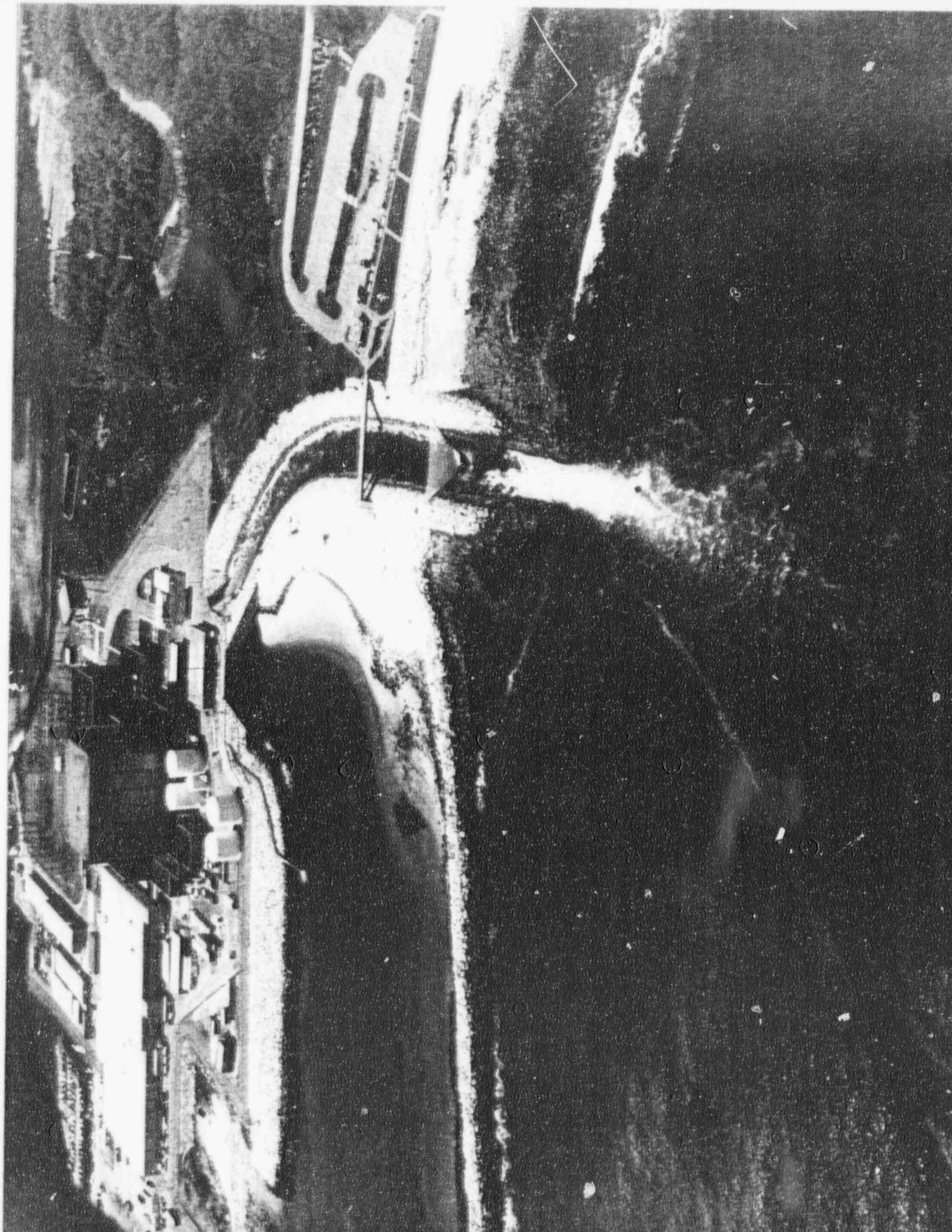

# marine ecology studies

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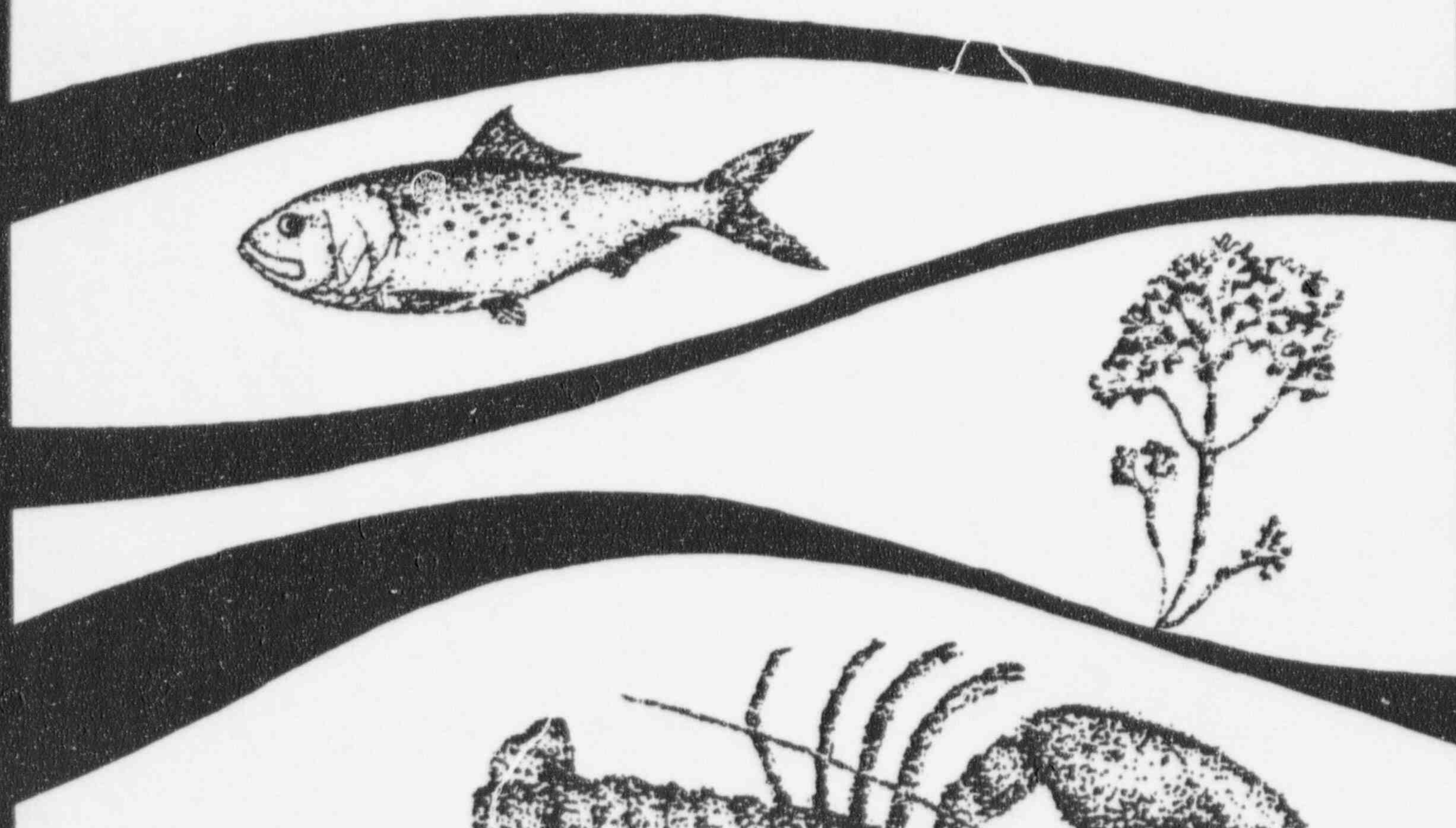

BOSTON EDISON COMPANY
REGULATORY AFFAIRS DEPARTMENT

Boston Edison

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## SUMMARY

Highlights of the Environmental Surveillance and Monitoring Program results obtained over this reporting period (January - December 1995) are presented below. (Note: PNPS was operating at high power level during most of January - December 1995 with the exception of a refueling outage in April and May).

Marine Fisheries Monitoring:

1. In the July-November 1995 shorefront sportfish survey at Pilgrim Station, angler visits accounted for 548 fishes caught. Striped bass (58%), bluefish (39%) and winter flounder (3%) comprised the sportfish catch. The presence of a strong thermal discharge component during most of 1990-1995 resulted in good sportfishery success compared with outage and low power years covering the shorefront angling season.

2. Trawl catches for 1995 in the Pilgrim area recorded benthic fish species with winter flounder, little skate, longhorn sculpin, Atlantic cod and windowpane composing most of the total. 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, and 1993 groundfish diving transect results recorded the highest abundance of winter flounder in the intake embayment.

3. In late July-mid October 1995 fish observational dive surveys, fish species were observed in the thermal plume area. Striped bass and tautog were the most numerous fishes seen, being abundant in the path of the Pilgrim discharge current. Striped bass observations peaked in late September/early October, tautog were consistent and no bluefish or winter flounder were detected.

4. A total of 6,121 cunner were tagged from 1990-1995 and 1,264 (21%) 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 ~8,000 - 12,000 individuals for 1995.

5. Prelimary winter flounder tagging around the Plymouth-Kingston-Duxbury Bay (PKDB) estuary vicinity to estimate adult population size and Pilgrim Station impact accounted for 2,066 fish with 78 (4%) tag returns in 1995. Initial population estimates based on an Area Swept Method in sampling for the PKDB area were ~ 124,000 adult winter flounder and ~259,000 total flounder. This equates to roughly an 8% adult population impact from PNPS entrainment of flounder larvae. When enough tag data is available additional population size estimates will be generated.

6. Rainbow smelt egg restocking of the Jones River (Kingston), to mitigate for the high PNPS smelt impingement (5,100 fish) in December 1993, accounted for 600,000 fertilized eggs being transplanted in 1994, and 1,200,000 in 1995 for hatchng to supplement the River's spawning population of this species. Another large smelt impingement occurred in December 1994 when 5,300 smelt were caught on Pilgrim intake screens. These impingment incidents have the potential of impacting the local smelt population.

Impingement Monitoring:

1. The mean January - December 1995 impingement collection rate was 5.87 fish/hr. The rate ranged from 0.08 fish/hr (October) to 57.08 fish/hr. (September) with alewife comprising 52.4% of the catch, followed by Atlantic silverside 30.8%, rainbow smelt 4.5%, and winter flounder 2.6%. Fish impingement rates in 1985, 1986 and 1989 - 1995 were several times higher than in 1984, 1987 and 1988

when Pilgrim Station outages had both circulating water pumps off and reduced pumping capacity for long periods of time.

2. In September 1995, alewife impingement accounted for 98% of this species annual collection. They have been a relatively abundant species impinged on an annual basis at Pilgrim Station.

3. One large, fish impingement incident was noted on September 8/9 resulting in an estimated mortality of approximately 13,100 alewife.

4 The mean January - December 1995 invertebrate collection rate was 1.52+/hr, with ctenophores and jellyfish dominating. Sevenspine bay shrimp (45.8%), longfin squid (14.5%) and worms (13.5%) accounted for 74% of the catch. Forty-one American lobsters were sampled. The invertebrate impingement rates in 1985, 1986 and 1989 - 1995 were similar to those recorded at Pilgrim Station during the 1987 and 1988 outage years, despite much lower circulating water pump availability in these outage years.

5. Impinged fish, initial survival in the Pilgrim Station intake sluiceway was approximately 55% during static screen washes and 87% during continuous washes. Six of the dominant species showed greater than 50% survival, overall.

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 extended shutdown. These surveys noted delineated, denuded impact areas in fall 1989 - 1995, 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 1198 $m^2$ (early May) to 2,043 $m^2$ (October) in 1995. The denuded and total affected areas by the thermal plume in October 1995, 2,043 $m^2$ and 2,348 $m^2$ respectively, were the largest ever seen during this study; in part due to heavy mussel settlement on Irish moss and high PNPS operating capacity on a consistent basis.

Entrainment Monitoring:

1. A total of 42 species of fish eggs and/or larvae were found in the January - December 1995 entrainment collections (17-eggs, 40-larvae).

2. Seasonal egg collections for 1995 were dominated by Atlantic cod, yellowtail flounder, American plaice and winter flounder (winter - early spring); Atlantic mackerel and labrids (late spring - early summer); hake, windowpane and labrids (late summer - autumn).

3. Seasonal larval collections for 1995 were dominated by grubby, rock gunnel and sand lance (winter - early spring); Atlantic mackerel, fourbeard rockling, cunner and radiated shanny (late spring - early summer); cunner, Atlantic herring and hake (late summer - autumn).

4. One lobster larva was collected in the entrainment samples for 1995.

5. In 1995 an estimated $1.565 \times 10^9$ fish eggs and $2.601 \times 10^8$ fish larvae were entrained at Pilgrim Station, assuming full flow capacity of all seawater pumps. On an annual basis, eggs were dominated by Atlantic mackerel and the labrid - Pleuronectes group, and larvae by sand lance sp. and sculpin spp.

6. Entrainment sampling, net mesh size efficiency comparisons were conducted showing 0.202 mm mesh more efficient in capturing cunner eggs than 0.333 mm mesh. Both meshes were comparable in sampling cunner larvae.

7. On several occasions in 1995 "unusually abundant" ichthyoplankton densities were recorded including Atlantic menhaden, Atlantic herring, Atlantic mackerel and hake larvae for extended time periods, reflecting strong annual spawning production for these species.

8. The mean annual losses attributable to PNPS entrainment for the adult stage of three abundant species of fish over the period 1987-1995 were as follows: cunner, 663,135; Atlantic mackerel, 8,513; winter flounder, 750-7,239. None of these losses for the species concerned were found to be significant in the context of preliminary population or fishery effects; however; comprehensive population/impact studies are presently being conducted for cunner and winter flounder in the Pilgrim area.

## INTRODUCTION

### A. Scope and Objective

This is the forty-seventh 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-fifth 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 Department of Environmental Protection (#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. Department of Environmental Protection in 1995, and whose membership includes representatives from the University of Massachusetts, the Mass. Department of Environmental Protection, the Mass. Division of Marine Fisheries, the National Marine Fisheries Service (NOAA), the Mass. Office of Coastal Zone Management, the U.S. Environmental Protection Agency and Boston Edison Company. Copies of the Minutes of the

Pilgrim Station Administrative-Technical Committee meetings held during this reporting period are included in Section IV.

B. Marine Biota Studies

1. Marine Fisheries Monitoring

A modified version of the marine fisheries monitoring, concentrating on indicator species populations' impacts, is being conducted by the Commonwealth of Massachusetts, Division of Marine Fisheries (DMF).

The occurrence and distribution of primarily cunner and winter flounder around Pilgrim Station and in adjacent areas are being determined. Population parameters and related life history statistics are being studied to address Pilgrim Station impacts from entrainment of ichthyoplankton, and impingement of juveniles and adults.

Smelt eggs were stocked in the Jones River (Kingston) in March/April 1995, as was done in 1994, to mitigate for the large impingement of 5,000+ rainbow smelt on Pilgrim Station intake screens in December 1993. Mitigation for another 5,000+ smelt impingement in December 1994 and 13, 000+ alewives in September 1995, at Pilgrim, is being considered.

A finfish observational dive program was initiated in June 1978. SCUBA gear is utilized on biweekly dives from May-October at 6 stations in the PNPS thermal plume area.

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

2. Benthic Monitoring

The benthic monitoring described in this report was conducted by ENSR Consulting and Engineering, Woods Hole, Massachusetts.

Benthic thermal plume analyses were completed, and a final report submitted in June 1995 by EG&G for the Benthic Subcommittee to recommend the most applicable future benthic 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. Plankton Monitoring

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). 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 1995 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 Sections 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.

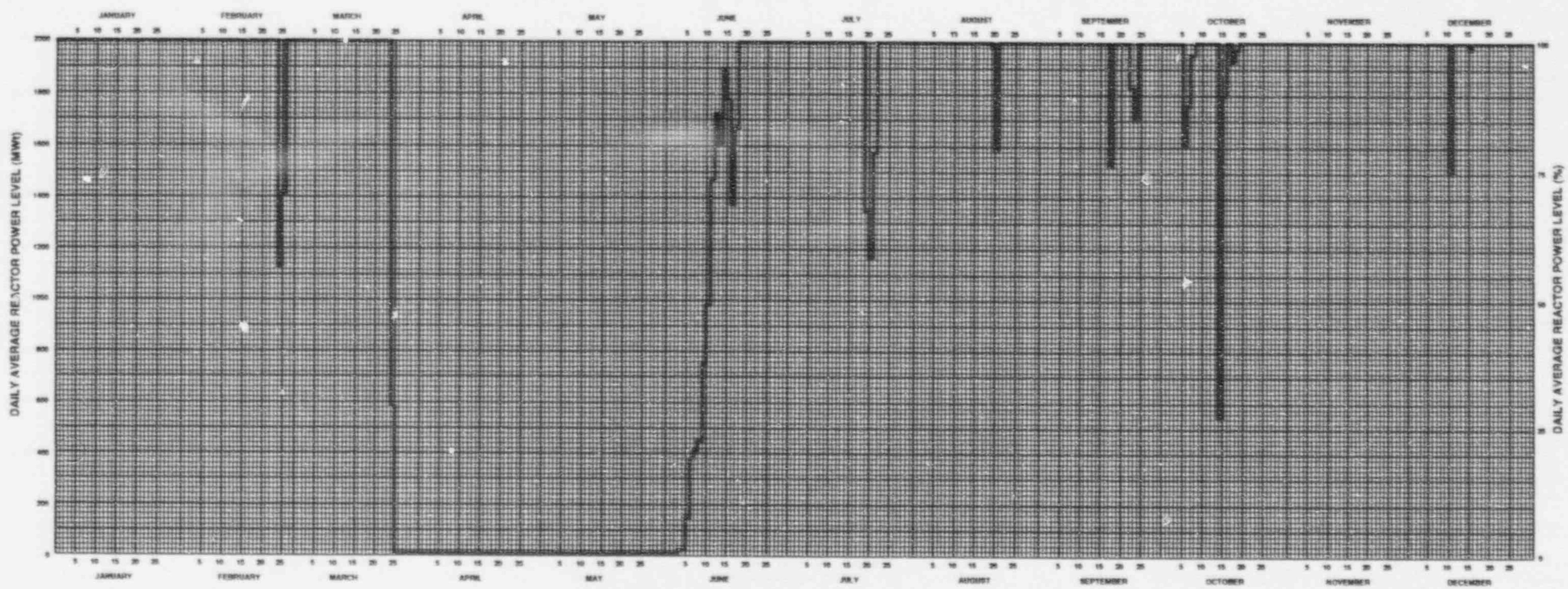
D. Station Operation History

The daily average reactor thermal power levels from January through December 1995 are shown in Figure 1. As can be seen, PNPS was in a high operating stage during most of this reporting period, except April and May, with a 1995 capacity factor (MDC) of 76.4%. Cumulative capacity factor from 1973-1995 is 52.0%. Capacity factors for the past 15 years are summarized in Table 1.

E. <u>1996 Environmental Programs</u>

A planning schedule bar chart for 1996 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1995 - June 1997, is included after Table 1.

JANUARY - DECEMBER 1995




JANUARY - DECEMBER 1995

Figure 1. Daily Average Reactor Thermal Power Level (MWt and %) from January - December 1995 for Pilgrim Nuclear Power Station

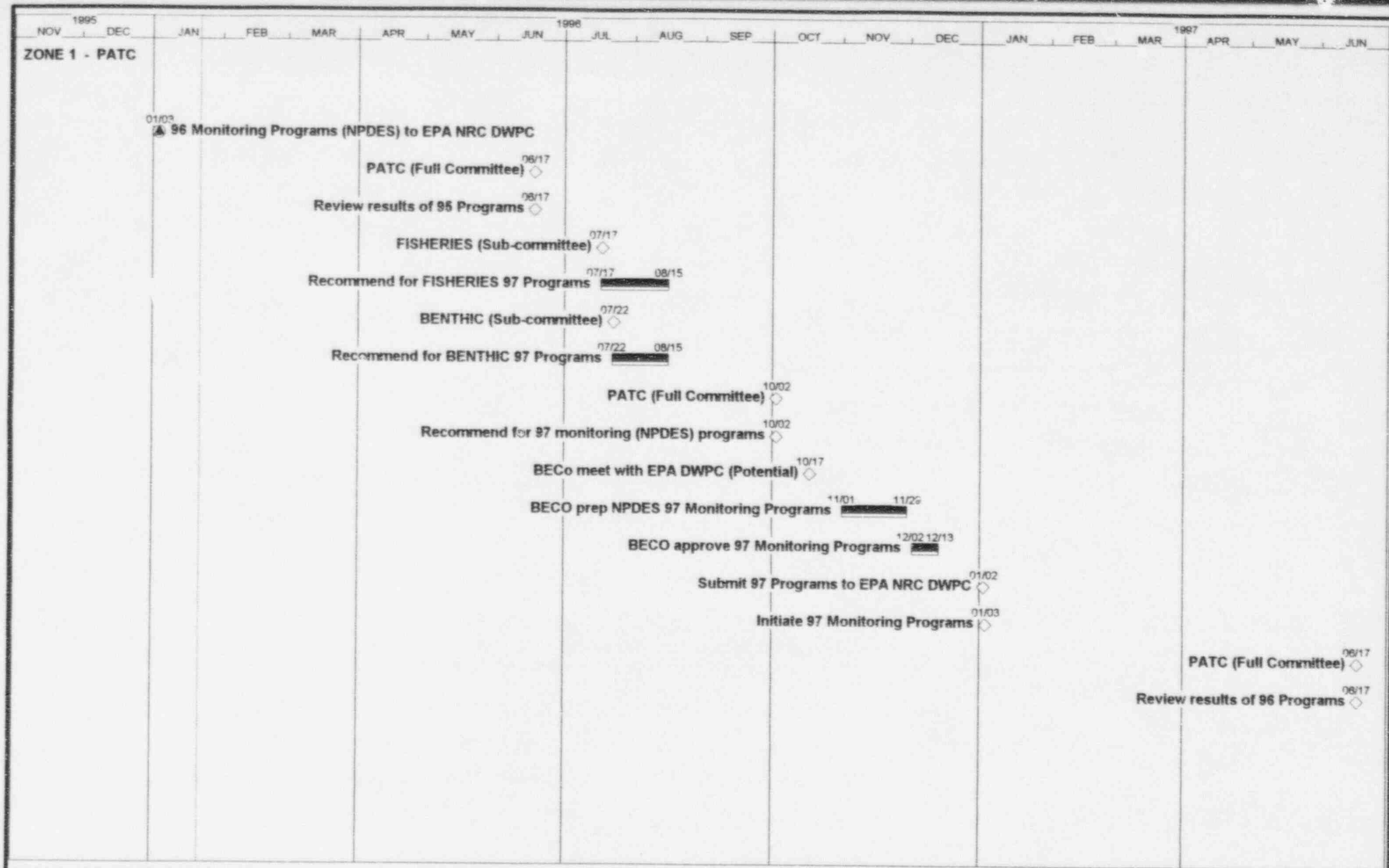
Table 1: PILGRIM NUCLEAR POWER STATION UNIT 1 CAPACITY FACTOR USING MDC NET%
(Roughly approximates thermal loading to the environment: 100%=32 Degrees F Δ T)

| Month | 1995 * | 1994 * | 1993 | 1992 | 1991 | 1990 | 1989 * | 1988 * | 1987 | 1986 | 1985 * | 1984 | 1983 | 1982 | 1981 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 99.1 | 98.8 | 99.0 | 96.6 | 95.4 | 99.4 | 0.0 | 0.0 | 0.0 | 79.5 | 54.0 | 0.0 | 98.0 | 0.0 | 85.7 |
| February | 96.3 | 72.5 | 96.7 | 99.4 | 88.9 | 97.4 | 0.0 | 0.0 | 0.0 | 97.7 | 59.3 | 0.0 | 90.0 | 0.0 | 67.0 |
| March | 74.4 | 79.5 | 83.2 | 80.4 | 84.6 | 30.0 | 10.7 | 0.0 | 0.0 | 26.9 | 81.8 | 0.0 | 97.3 | 0.0 | 65.6 |
| April | 0.0 | 63.3 | 6.4 | 53.5 | 92.7 | 5.4 | 10.5 | 0.0 | 0.0 | 11.9 | 90.8 | 0.0 | 89.7 | 44.1 | 90.7 |
| May | 0.0 | 94.5 | 0.4 | 97.8 | 0.0 | 77.9 | 4.6 | 0.0 | 0.0 | 0.0 | 94.3 | 0.0 | 97.3 | 80.1 | 94.6 |
| June | 65.1 | 97.2 | 77.5 | 97.8 | 0.0 | 96.3 | 16.4 | 0.0 | 0.0 | 0.0 | 85.0 | 0.0 | 66.2 | 87.5 | 95.0 |
| July | 95.7 | 97.6 | 80.3 | 97.4 | 0.0 | 55.1 | 28.6 | 0.0 | 0.0 | 0.0 | 96.9 | 0.0 | 80.5 | 97.2 | 59.8 |
| August | 97.7 | 88.2 | 86.9 | 97.4 | 28.5 | 94.5 | 50.8 | 0.0 | 0.0 | 0.0 | 96.5 | 0.0 | 83.1 | 75.7 | 72.1 |
| September | 96.7 | 0.0 | 84.8 | 94.1 | 96.4 | 21.6 | 52.5 | 0.0 | 0.0 | 0.0 | 71.4 | 0.0 | 86.5 | 68.3 | 75.4 |
| October | 94.3 | 0.0 | 98.0 | 72.8 | 94.2 | 98.7 | 30.1 | 0.0 | 0.0 | 0.0 | 95.4 | 0.0 | 79.0 | 39.9 | 0.0 |
| November | 99.5 | 0.2 | 80.0 | 13.7 | 23.7 | 96.8 | 66.0 | 0.0 | 0.0 | 0.0 | 88.1 | 0.0 | 78.6 | 88.9 | 0.0 |
| December | 98.8 | 87.7 | 94.8 | 65.2 | 98.1 | 94.5 | 77.1 | 0.0 | 0.0 | 0.0 | 99.1 | 0.7 | 18.1 | 87.1 | 0.0 |
| ANNUAL% | 76.4 | 65.2 | 74.0 | 80.6 | 58.4 | 72.3 | 28.9 | 0.0 | 0.0 | 17.5 | 84.4 | 0.1 | 80.3 | 56.0 | 58.7 |

CUMULATIVE CAPACITY FACTOR (1973 - 1995) = 52.0%

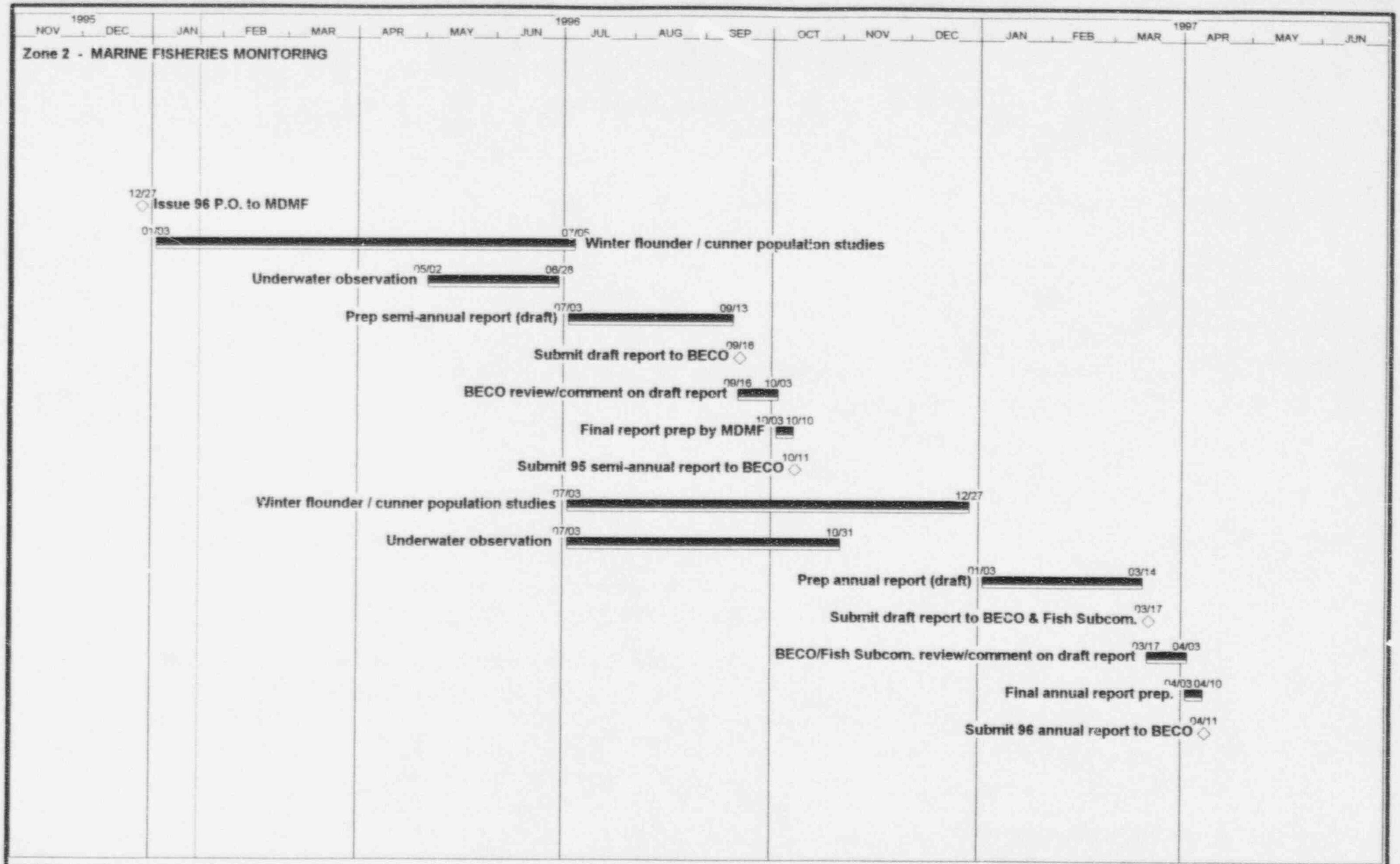
________________ = OUTAGES > 2 MONTHS

* = NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 27 MARCH - 13 AUGUST, 1984
= NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 18 FEBRUARY - 8 SEPTEMBER, 1987
= NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 14 APRIL - 5 JUNE, 1988
= NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 9 OCTOBER - 16 NOVEMBER, 1994
= NO CIRCULATING SEAWATER PUMPS IN OPERATION FROM 30 MARCH - 15 MAY, 1995




# PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)

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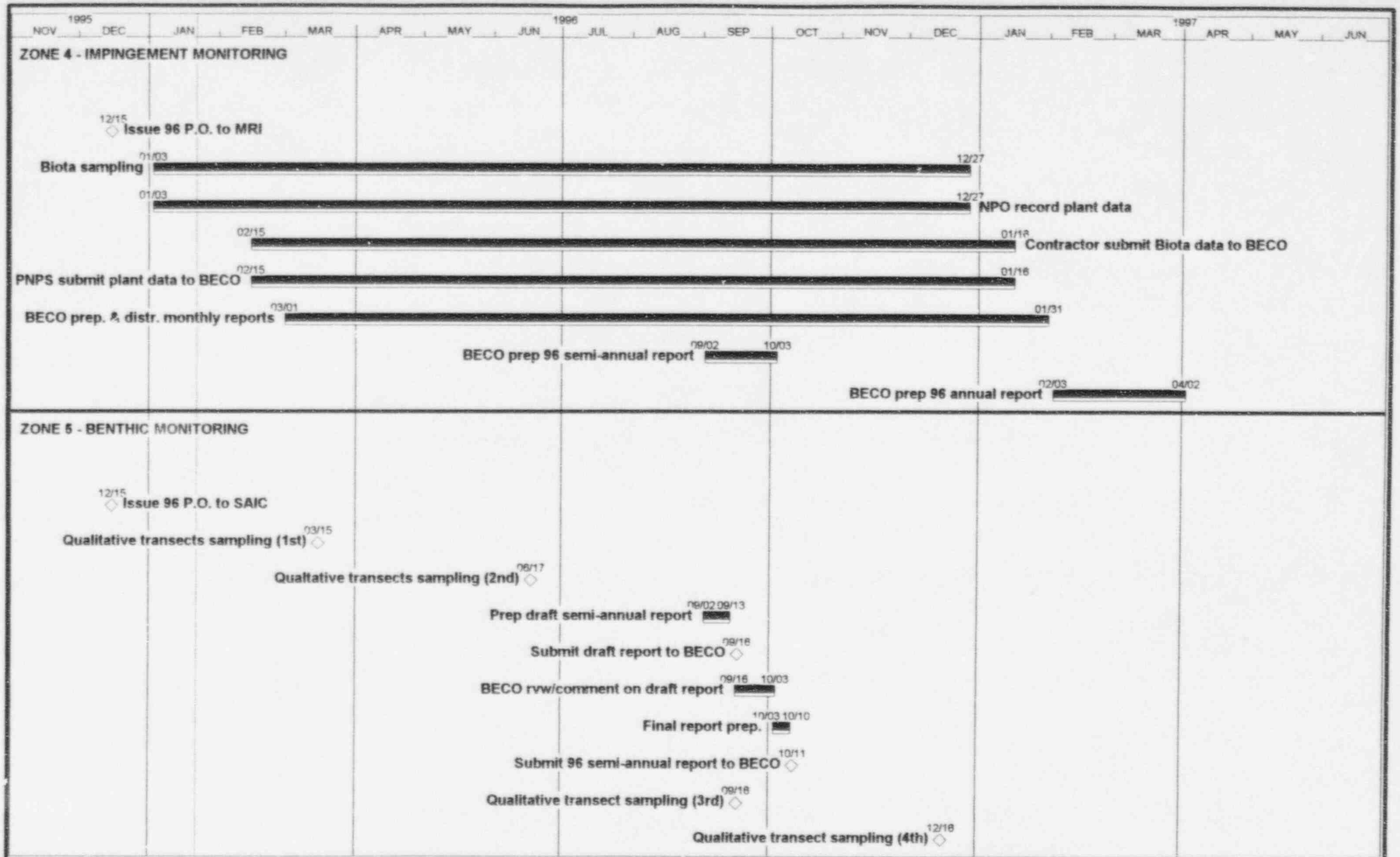


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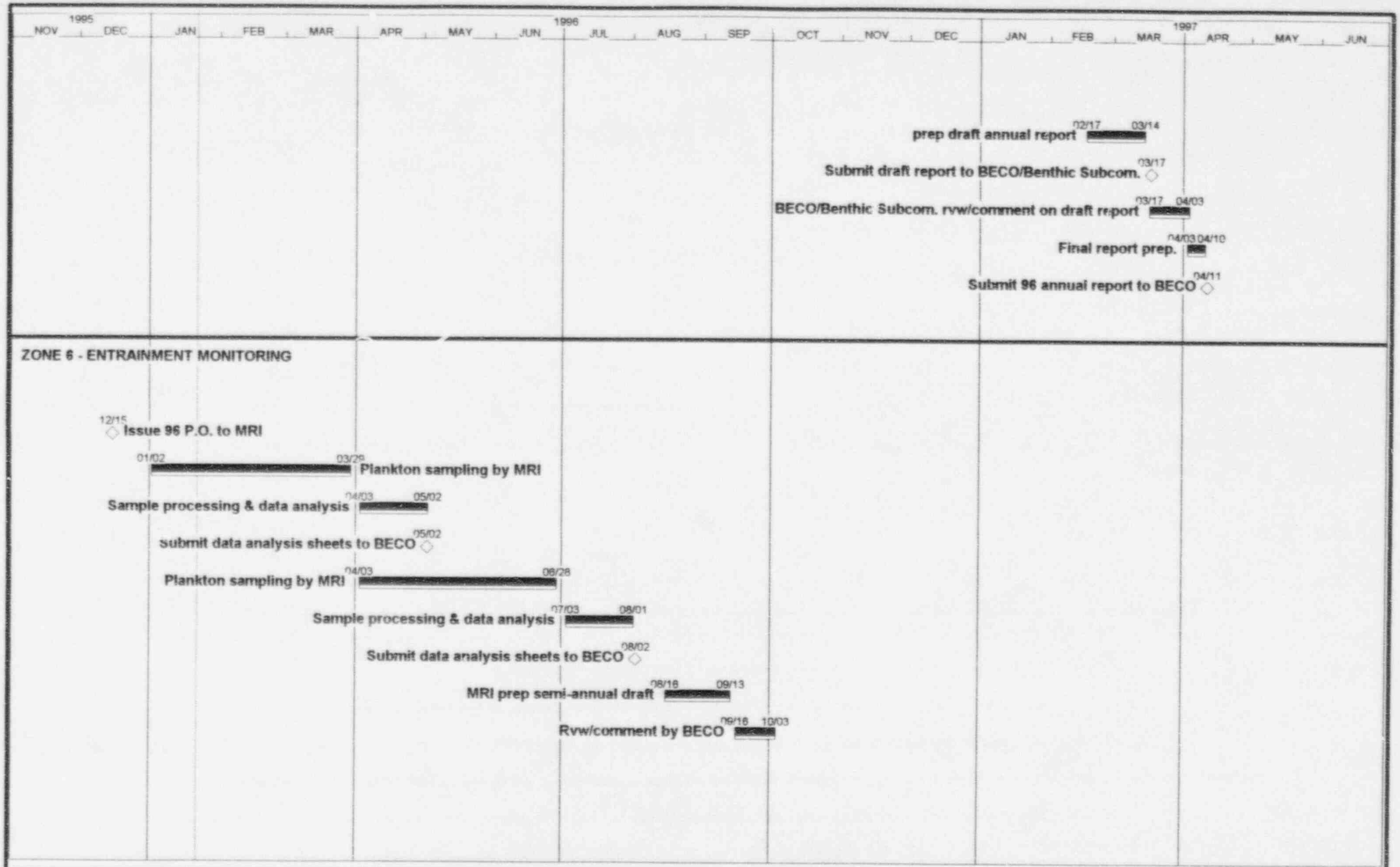


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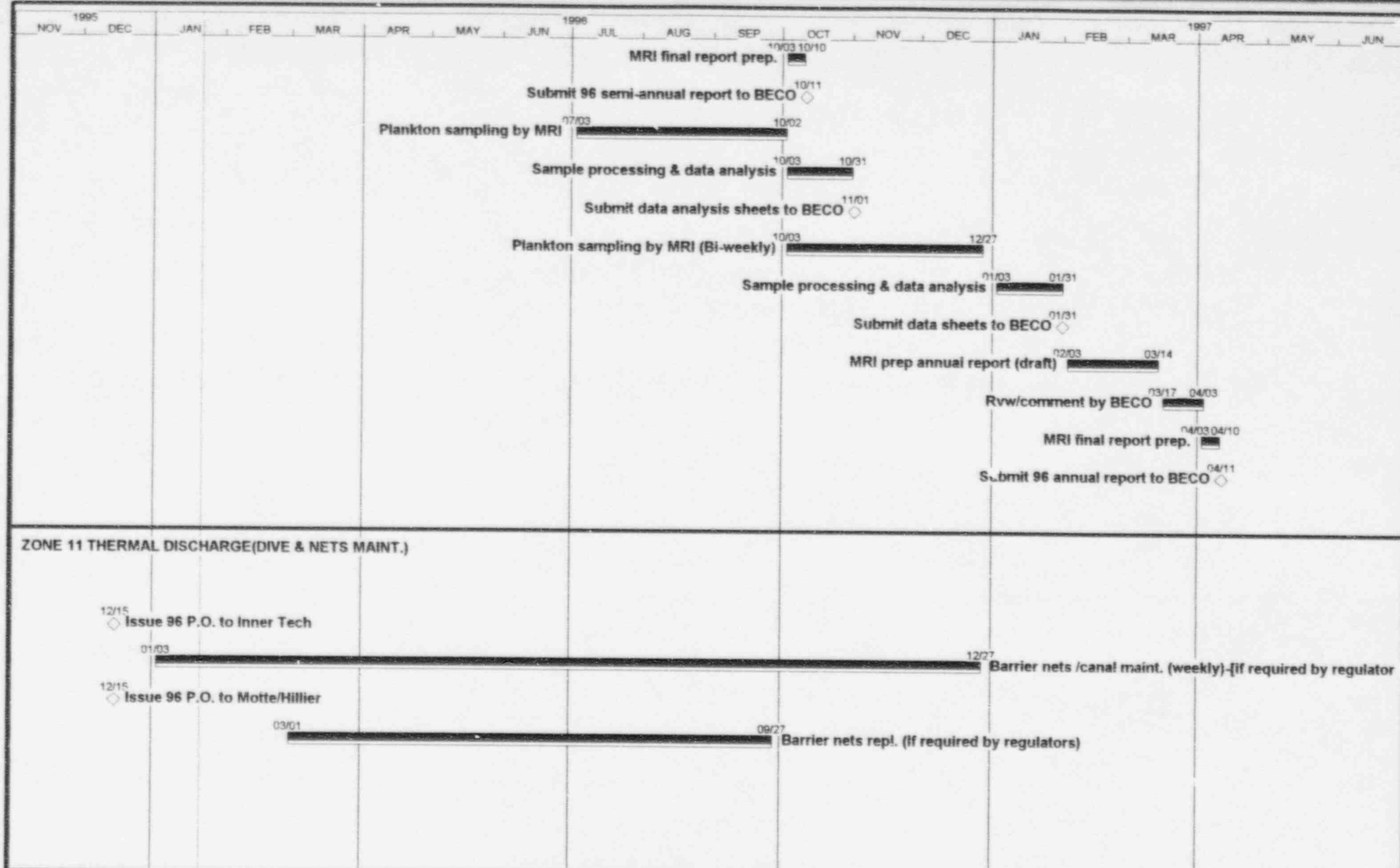


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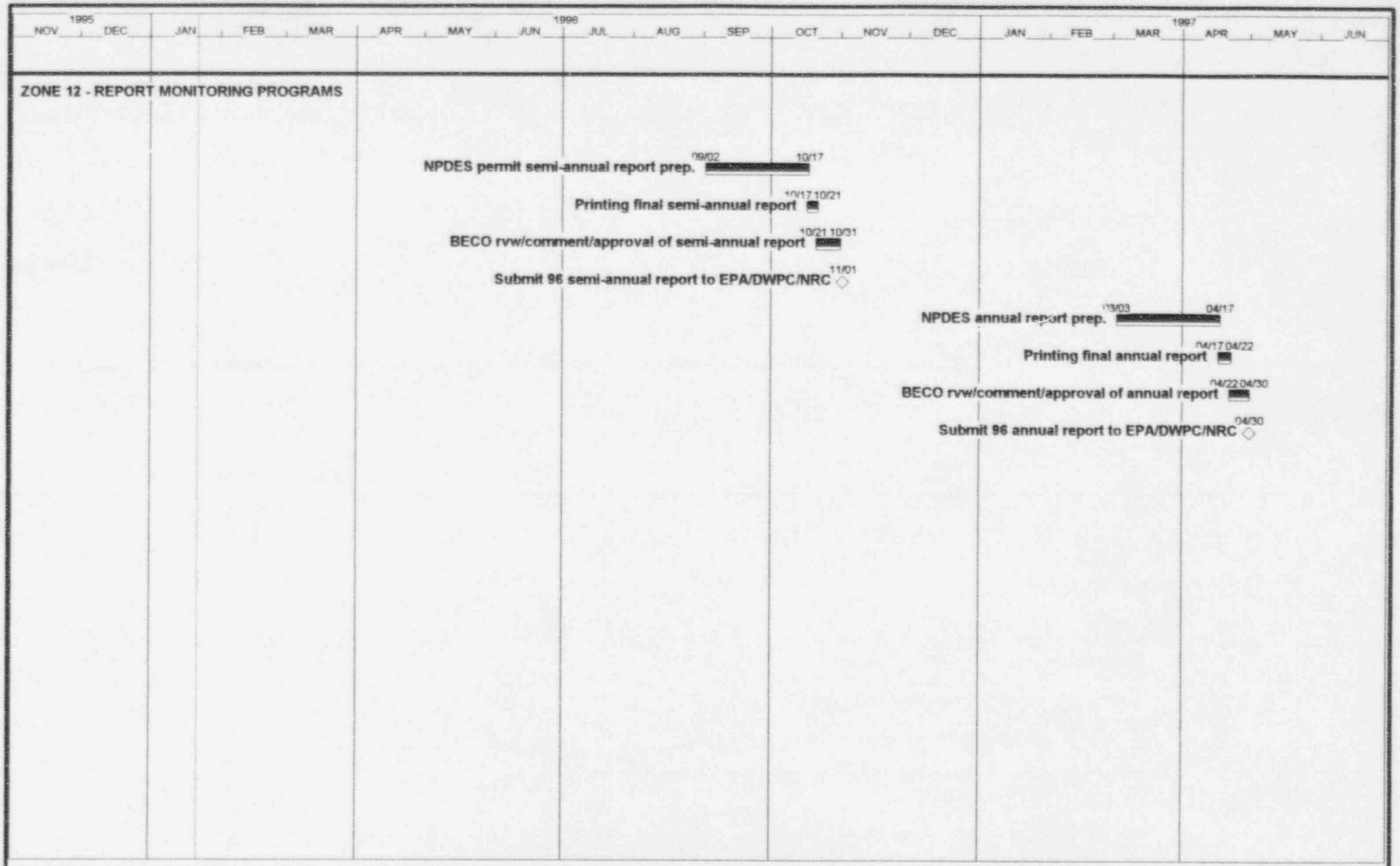


# PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)

# ANNUAL REPORT
# ON ASSESSMENT AND MITIGATION
# OF IMPACT OF THE PILGRIM
# NUCLEAR POWER STATION ON FINFISH
# POPULATIONS IN WESTERN CAPE COD BAY

Project Report No. 60 (January to December 1995)

By

Robert Lawton, Brian Kelly,
Vincent Malkoski, John Chisholm,
Paul Nitschke, and John Boardman

April 1996
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 1995 highlights of findings on selected species. For additional information, please refer to the Conclusions' section at the end of this report.

### Cunner

- Cunner (*Tautogolabrus adspersus*) larval abundance in the Pilgrim Station area appeared relatively high in 1995, with larval entrainment being four-fold higher than in 1994.
- Length and age-specific fecundity relationships were determined for cunner in the Pilgrim area, which were used to refine adult equivalency estimates.
- Impingement of cunner at Pilgrim Station was relatively light (288 fish) in 1995. However, the entrainment of cunner eggs and larvae was equivalent to the loss of 970,000 adults from the local population.
- A total of 2,133 adult cunner (≥ 90 mm total length) was tagged in 1995 at three locations in the Pilgrim Station area. No definitive population estimate of cunner in the Pilgrim area has been generated yet from the tag recapture data. We are evaluating different population models for suitability.

### Rainbow Smelt

- Impingement of rainbow smelt (*Osmerus mordax*) at Pilgrim Station for 1993-95 was estimated at 9,560, 10,644, and 2,335 fish, respectively. Presently, low population size makes the consequences of impingement more dire.
- To augment local instream egg production, about 1.2 million smelt eggs were stocked in the Jones River in spring of 1995. This was a remedial measure to compensate for high impingement at the Station in 1993.
- Smelt spawning habitat in the Jones River was enhanced by deployment of artificial plant substrate with high surface area in the form of portable egg trays filled with unprocessed sphagnum moss.
- Fouling macroalgae on the upper spawning ground became a problem the last two years.

## Winter Flounder

- Plymouth, Kingston, Duxbury Bay is an estuarine spawning ground for winter flounder (*Pleuronectes americanus*) in the Pilgrim Station area. Winter flounder appear to form discrete, resident populations; however, they also exhibit seasonal movements which appear to be temperature-driven.
- Commercial landings and research trawl surveys have documented declining winter flounder abundance since the early 1980's in Massachusetts coastal waters.
- In 1995, an estimated 16.4 million flounder larvae were entrained at Pilgrim Station, which equates to an equivalent loss of 9,879 age-3 adults from the local population.
- An estimated 1,326 winter flounder - mostly young-of-the-year and yearlings - were impinged in 1995 at Pilgrim Station.
- During the 1995 DMF seine survey directed at sampling young winter flounder, nearly 7,800 fish representing 9 species were captured. Only 11 winter flounder were taken, with 54% being young-of-the-year. Swimmers using snorkeling equipment surveyed transects of known area inside Plymouth, Kingston, Duxbury Bay to supplement haul seine data on juvenile flounder.
- Winter flounder ranked third in recreational angler catches at Pilgrim Shorefront in 1995. No winter flounder reportedly were angled in 1994.
- In 1995, we tagged 2,266 winter flounder with Petersen tags. As of the end of the year, we recaptured 24 tagged flounder during our sampling, and we received information on 78 tag returns from commercial and recreational fishermen. Most were retaken by commercial draggers (53%), although 32% were reported from fish processing plants. The remainder came from recreational anglers, including two flounder caught off Newport, RI.
- Density extrapolation using the Area Swept Method provided an estimate of adult winter flounder population size for the study area portrayed in Figure 1 (fish ≥ 280 mm TL, i.e., age 3 and older fish). This estimate was 123,831 adults.

## Other Species

- With trawling effort focused on winter flounder, data collected on other species were limited. Little skate (*Raja erinacea*), longhorn sculpin (*Myoxocephalus octodecemspinosus*), Atlantic cod (*Gadus morhua*), windowpane (*Scophthalmus aquosus*) and sea raven (*Hemitripterus americanus*) were among the more commonly collected species (excluding winter flounder) of the survey bottom-trawl catch.
- Striped bass (*Morone saxatilis*) and tautog (*Tautoga onitis*) dominated the SCUBA finfish sightings off Pilgrim Station. No bluefish (*Pomatomus saltatrix*) or winter flounder were seen by divers in 1995.
- Striped bass, bluefish, and winter flounder were the only species reported in the recreational catch at the Pilgrim Shorefront.
- The haul-seine catch was comprised primarily of Atlantic silversides (*Menidia menidia*) and mummichogs (*Fundulus heteroclitus*).

## II. INTRODUCTION

The power plant study team of the Massachusetts Division of Marine Fisheries (DMF) conducts field investigative programs to assess and mitigate impact of Pilgrim Nuclear Power Station (PNPS). Presently, we are working with three finfish species in the offsite inshore waters of western Cape Cod Bay. This work is funded by Boston Edison Company under Purchase Order No. LSP001698 for 1995.

Focusing on cunner, winter flounder, and rainbow smelt, we have employed a variety of gear types and techniques to collect spatio-temporal data and to conduct restorative efforts. Measurements, counts, percentages, and estimates of abundance are used to quantify our work. Descriptive statistics are summarized in tables and displayed in graphs and plots. Statistical procedures are used when appropriate for data analyses.

In this, our annual report, sampling design including methodology along with findings to date are presented. Progress achieved in surveys and ongoing projects is highlighted for indicator species in the Pilgrim area.

## III. Methods and Materials

The study area is delimited in Figure 1.

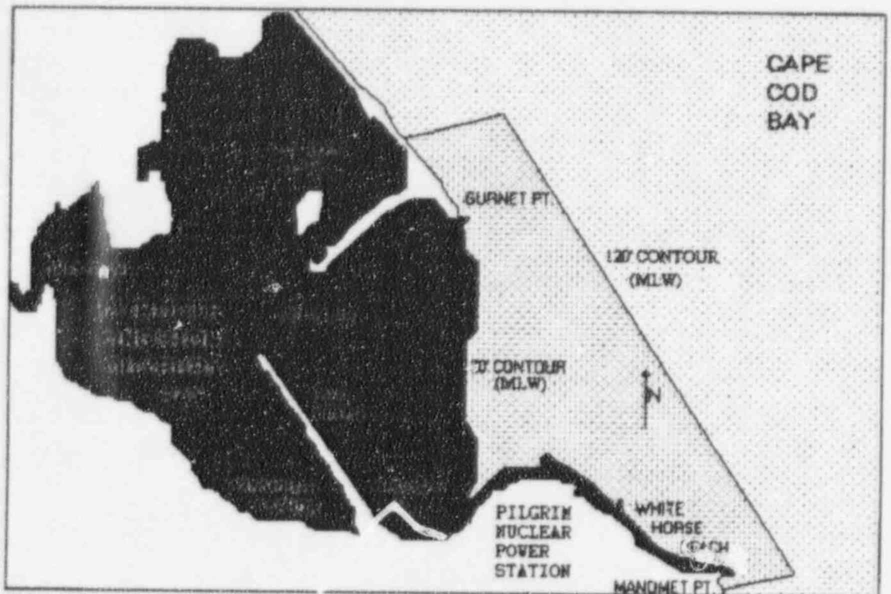


Figure 1. Investigative area inside and outside the estuary (shaded areas) for rainbow smelt, winter flounder, and cunner investigations, January to December 1995.

From field studies to date, it is evident that mechanical effects at Pilgrim Station, i.e., from entrainment followed by impingement, pose greater impact threats than does the thermal discharge.

We have targeted cunner, winter flounder, and rainbow smelt for investigative programs (Table 1). The Pilgrim Station area serves as cunner spawning, nursery, and feeding grounds. Cunner are structure oriented, territorial, and sedentary. They have been important in the local sportfishery at Pilgrim Shorefront in the past and are good indicators of local stress. Winter flounder also spawn in the Pilgrim area which likewise serves as nursery and feeding grounds. This flatfish is fished locally by commercial and recreational fishermen. Rainbow smelt is an important recreational species in the Pilgrim area. Several incidents

Table 1. Important indicator species off the Pilgrim Nuclear Power Station.*

| Species | Background History | Basis for Selection as an Indicator species | Possible Sources Of Impact | Most significant source of Impact (Based on results to Date) |
|---|---|---|---|---|
| Cunner | RIS | d,r,s | I,E,T/C | Entrainment - is number one in egg collection at PNPS |
| Rainbow smelt | RIS | r,s | I,T/C | Impingement - large incidents in December of '74,'93,'94 |
| Winter flounder | RIS | d,r,c,s | I,E,T/C | Entrainment - large number of larvae collected |

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 because they have shown the most potential for impact off Pilgrim Station and may be indicative of power plant induced stresses to other marine fish species.

of high rainbow smelt impingement have occurred at Pilgrim Station in recent years.

## Cunner

Eggs and Larvae. Entrainment of cunner eggs and larvae is monitored at Pilgrim Station by Marine Research, Inc. (see Entrainment section in this report). The Adult Equivalent Model has been used to equate entrained eggs and larvae to adults lost from the local population by power plant impact.

Cunner fecundity by age, length, and weight has been investigated since 1994. This study was conducted by a UMass-Amherst graduate student working with our cooperation. Funding was provided by Boston Edison Company.

Information on the hydrodynamics of western Cape Cod Bay, i.e., the residual and variance flow patterns that constitute circulation and resultant dispersion of ichthyofauna is being compiled by a consultant. Areas of origin for cunner eggs and larvae that are entrained at Pilgrim Station primarily June through August need to be identified. Cunner recruitment to the Pilgrim vicinity may be affected, in part, by the status of cunner elsewhere, therefore, we need to define the geographical boundaries of the local cunner population. Our definition of the local population may in actuality be more of an abstraction than a natural unit. From our capture-recapture study, it is evident that adult cunner in the Pilgrim area have a narrow home range, and presumably the only substantial recruitment to this temperate-reef population results from settlement of their planktonic larvae, following metamorphosis.

Juveniles. To address the relationship between recruits and adults, settlement and post-settlement processes affecting recruitment needed to be addressed. An underwater SCUBA survey was undertaken to assess if the operation of Pilgrim Station (PNPS) affects cunner recruitment. Stations with similar habitats were selected for study, since it is known that habitat type is important to recruitment success (Levin 1991; Tupper unpublished). We did not want to mask possible power plant effects by sampling different habitats. Recruitment processes are affected by different environmental conditions and demographics; however, we believe that one year of comprehensive data collection, together with preliminary data obtained in 1994, would reveal important insights into local recruitment processes and possible power plant perturbation of these processes.

The density of juvenile recruits was quantified at a site just off PNPS and at fixed locations away from the plant (Figure 2). Our null hypothesis was that the power plant did not significantly affect recruitment. If the plant is "cropping" young cunner, it is reasonable to assume that recruitment at similar habitats should increase with increasing distance away from PNPS. With our sampling design, we could collect information on post-settlement regulation by observing recruits through time in similar habitats but in spatially different areas. If early settlement differed spatially, we could test the effects of density on recruitment at the end

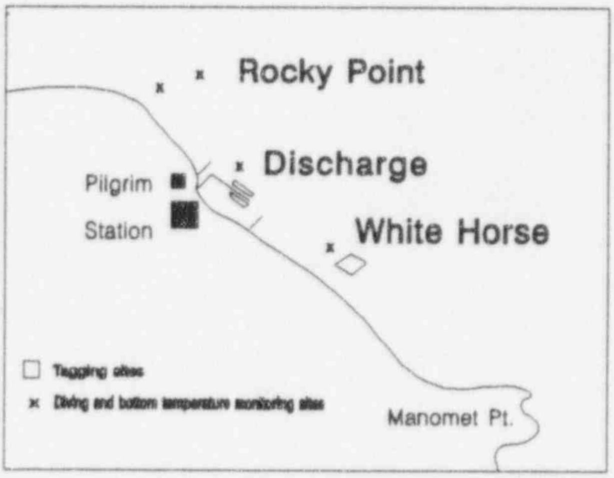

Figure 2. Station locations for cunner juvenile recruitment and tagging studies, and bottom temperature monitoring, June to November 1995.

of the recruitment period. Here, we can examine an assumption of the adult equivalent model, viz., that there is a direct relationship between the pelagic egg and benthic adult stages. If this is true, then there should be a direct relationship between the amount of recruits at the beginning of the season and those remaining at the end. A second hypothesis states that initial settlement is correlated with recruitment at the end of the season. Abiotic factors, including temperature and visibility, were measured because of their importance to recruitment.

Four sites of similar substrate and depth were selected for study. One site was near the power station, about 20 m southeast of the discharge canal. The other three locations were further from the power plant - two 0.5 km northwest at Rocky Point, and the other 1.5 km southeast at White Horse Beach. Rocky Point began with a single site, but a second was added shortly when substantial sea urchin grazing of the macro-algae was noted at the original site. Both sites were sampled until the termination of the study. The center point of each fixed station location was established with a mooring block and buoy. Painted yellow rocks also were placed on the bottom beside each mooring to aid in locating the site in case of buoy loss. At each site, 10 sampling transects were placed so as to radiate out from the center point. To insure that diving activity would not bias counts along other transects, the beginning of each transect was located five meters from the center block and marked with a numbered, painted rock. Transects were evenly spaced at 36° intervals using an underwater compass starting with a heading of 000° magnetic.

Prior to the diver recruit surveys, and at the end of the sampling program, the benthic habitat at each station was characterized to measure similarity between sites and habitat stability over the course of the study. A 1 x 1 m quadrat, divided by strings into 16 25 x 25 cm squares, was placed on the bottom at 50 randomly selected stations at each site. A metered line was laid out on each fixed transect to provide a reference for positioning the quadrat. Habitat within the quadrat was quantified by visually estimating percent composition of the dominant substrate including algal types in each square. Categories included filamentous algae, fleshy algae, crustose algae, sand, and cobble. Cobble was defined as small rocks (≤ 15 cm) with no algal cover. All boulders were covered with algae. We recorded the algal type under the intersection point of adjacent sampling squares (16 squares produced nine intersection points).

Rugosity and algal canopy height also were measured. To gauge rugosity, an index of structural complexity, a 10-m fine-linked brass chain was laid on the substrate so that the chain conformed to the contours of the bottom. A straight-line measurement of the distance covered by the chain was made using a metered tape, and the process was repeated along the entire length of each transect. The ratio of the sum of measured chain distances required to sample the transect to linear distance (10 m per transect) is the estimate of rugosity for that area. Algal canopy height was measured with a ruler at each meter mark on the transect line.

Juvenile cunner (recruits) were visually counted by a SCUBA diver along each transect line. To delineate the width of the transect, a one-meter wide t-bar sampling tool (Figure 3), with attached compass and line-reel was pushed ahead of the swim path by a diver. A second diver recorded numbers of juvenile cunner while swimming above and slightly in front of the navigator. This position insured good visual coverage of the swath of the transect. To avoid counting variability between divers, the same person made the counts throughout the survey.

Weather permitting, daily sampling was conducted on weekdays from 24 July (early in the settlement period) until 7 November. Enumeration was completed at all sites within a sampling day to avoid temporal variation within a sampling event. Thermographs, placed on the bottom near each sampling location, continuously recorded temperature data. Underwater visibility was measured using a Secchi disk after all counts were completed. Analysis of this work will be completed and reported in the annual report for 1996.

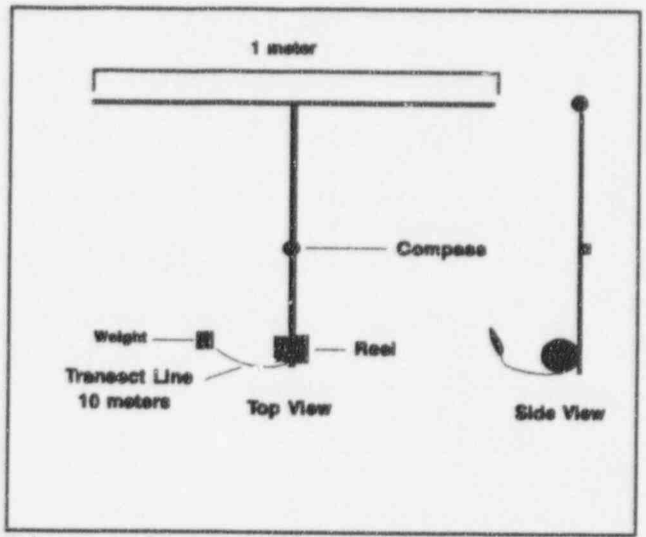

Figure 3. Survey tool used by divers to estimate abundance of juvenile cunner in the Pilgrim Station area.

Adults. In 1995, the cunner mark and recapture study continued with the objectives of estimating cunner survival and population size. Entrainment mortality at Pilgrim Station will be compared with population estimates. Mature cunner (≥ 90 mm total length (TL)) were tagged during the months of June to September at three sites: the Pilgrim Station Intake embayment, the outer Pilgrim Breakwater, and White Horse Beach (Figure 2). To identify individual fish, we used the Floy FD-94 Fine Fabric T-bar anchor tag (Figure 4), which is 40 mm (1.6 in) long and weighs 0.10 g (3.5 x $10^{-3}$ oz). The tags are printed with individual numbers and our agency telephone number. Three tag colors were used to differentiate the three tagging sites off Pilgrim Station - orange was used for the outer intake breakwater, yellow for inside the intake embayment, and blue at White Horse Beach.

Methods follow: cunner were captured in baited traps fished overnight, since they forage most actively at dusk and dawn. All captures and recaptures were measured to the nearest millimeter (TL), and sex noted, when possible, through ripeness and/or dichromatism. A numbered tag was inserted into the dorsal musculature via a tagging gun (Figure 4), and fish were released in the area of capture. We are conducting a census of capture and recapture which allows for multiple recaptures.

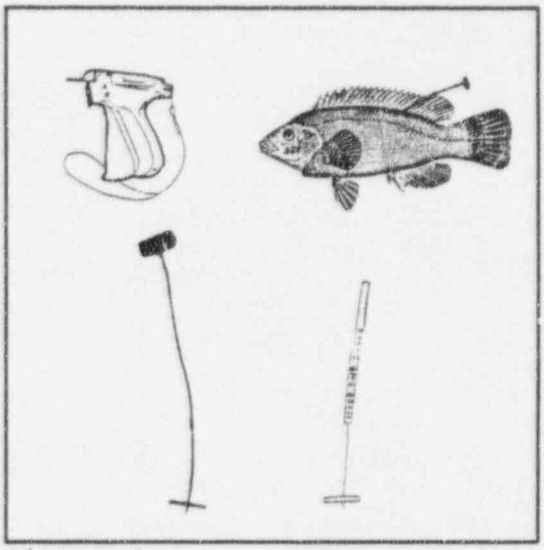
Figure 4. Tagging gun and styles of t-bar anchor tags used by DMF to mark cunner (shown above) off Pilgrim Nuclear Power Station.

The age structure of the local population (included one year-olds on up) was examined by aging otoliths taken from selected specimens collected in 1994. This information was incorporated into the fecundity analyses performed by the UMass graduate student to calculate local cunner egg production and relate it to egg entrainment at Pilgrim Station. Each cunner was weighed and measured. Otoliths were removed, cleared of attached membranes, labeled, and stored dry in glass vials. Unprocessed otoliths were viewed sulcus side down under a dissecting scope with reflected light, and annular rings were counted. This was a practical approach for most fish through three or four years of age. Annulus formation in cunner has recently been validated by researchers in Newfoundland (John Green, personal communication)[1]. We are, therefore, confident that the clear hyaline bands read by us are in fact annuli.

Otoliths from older fish or younger fish difficult to age were mounted in Pro-Texx medium on a microscope slide sulcus side up and allowed

[1]John Green, Biology Department, Memorial University, St. Johns, Newfoundland

to dry at least two days. The mounted otolith then was ground down with 320 grit sandpaper until the annular rings could be differentiated. Each otolith was aged independently a minimum of three times. If concurrence occurred on the three readings, that age was assigned to the fish. When disagreement occurred amongst the three readings, a fourth reading was obtained. A fish was considered successfully aged if there was agreement in at least three of the four readings; otherwise, this record was discarded from the age analysis.

A total of 392 cunner was collected for aging; some otoliths (171 fish) were mounted on slides and hand-ground prior to analysis. Ten individuals (2%) had crystallized unreadable otoliths, while three (1%) could not reliably be assigned an age. In 22% (n=83) of the 379 fish successfully aged, the three initial readings of age did not agree, necessitating a fourth. Corrobative ageing conducted by an independent reader agreed with the original assessment in 89% of the cases in a subsample of 18 fish. Subsequent reageing by us of a subsample of 88 whole otoliths 8 months after the initial reading showed agreement in 98% of the cases. The von Bertalanffy growth equation was calculated by sex using empirical length and age data following Ricker (1975) and using the FISHPARM program (Saila et al. 1988).

Fecundity. Seventeen collections were made between June 1-28, 1994. A total of 433 cunner was collected for fecundity analysis, ranging in length from 53 to 185 mm (TL). Ninety-five percent of the fish were collected the first two weeks of June. Identified running ripe males were released. Cunner were trapped in fish pots baited with cod racks and soaked for at least one night. The traps were set near the outer intake breakwater off Pilgrim Station, at depths of 2-5 m.

All fish were measured to the nearest mm and weighed to the nearest

0.001 g, while otoliths were extracted from 95% of the fish collected for age assessment. We determined the age of all females by enumerating annual growth rings on the extracted otoliths. These data also were used to calculate the von Bertalanffy growth equation. Ovaries were extracted, weighed, and placed into individual jars containing Gilson's fluid, a preservative solution used to harden the eggs and break down ovarian tissue (Bagenal and Braum 1971). The jars were periodically shaken to help break apart the ovaries, which were allowed to soak for at least five months before examination (Jessop 1993). Somatic weight of the females also was measured and the gonadosomatic index (GSI) was determined for fish used in fecundity determinations. GSI is a measure of gonadal development and is simply the weight of the gonads expressed as a percentage of the body weight, i.e., GSI = [gonad weight/body weight]*100 (Snyder 1983; Wooton 1990; Dee and Parrish 1994).

Fecundity was estimated gravimetrically for 210 females (Bagenal and Braum 1971). This method has proven to give more precise estimates than the volumetric method since it is difficult to keep eggs homogeneously distributed in a volume of water so that a representative sub-sample can be extracted (Snyder 1983). Eggs were first washed and then dried in a drying oven. Next, the eggs were weighed to the nearest 0.0001 g on a balance scale. Three sub-samples of (100 to 1000) eggs were taken and then weighed on a balance scale and counted using a dissecting microscope. Only eggs larger than 0.05 mm were counted. Smaller eggs were not enumerated because they were deemed to be immature. The count and weight were extrapolated to estimate total number of eggs. The average of the three sub-samples was used to estimate total eggs, if the counts did not differ by more than ten percent of the mean (Griswold and Silverman 1992; Jessop 1993). If estimates differed by more than ten percent of their mean, then another count was done until three estimates were within accepted limits.

## Smelt

Eggs and Larvae. Smelt eggs transplanted into the Jones River came from the Weweantic and Back Rivers' smelt runs. The former is located on the south site of Cape Cod, while the latter is on the north shore. We monitored pH and water temperature in each of the three river systems during the spawning season.

A total of 96 egg collecting units (each was a tray consisting of a 35.6 x 45.7 cm (14 x 18 inch) weighted wooden frame, enclosed with chicken wire and filled with unprocessed sphagnum moss as substrate for egg deposition) was deployed in the two source streams to collect smelt eggs for transplanting (Figure 5). After the transplanted eggs hatched, the larvae were expected to be retained downstream of the Jones River in the waters of the Plymouth, Kingston, Duxbury Bay and as adults to home to this estuary, ascending the Jones River and possibly other tributaries to spawn.

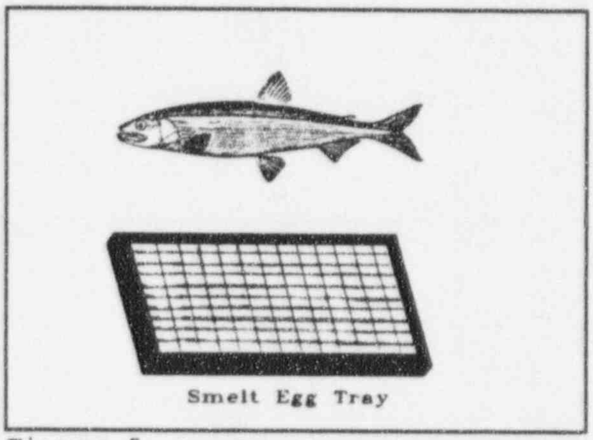


Figure 5. A collecting unit of the type used to transplant smelt eggs (smelt shown above) into the Jones River.

In our trays, we employed plant substrate (sphagnum moss) with high relief and extensive surface area to optimize egg sets. Eggs were transplanted into selected riffle areas on the Jones River spawning ground. Besides transplanting eggs from one river system to another, we placed an additional 75 egg trays into the Jones to collect eggs spawned there naturally. This measure was to improve natal egg survival to hatching.

The sphagnum provides three dimensional surface and collects eggs at higher densities than on natural hard bottom, e.g., sand, gravel, cobble. The only surface competing for comparable egg sets and survival is endemic attached river plants, which comprised less than 25% of the available substrate on the Jones River spawning ground.

Egg trays placed into the Jones River were inspected every few days, serviced, and monitored for egg development and survival. Fouling macroalgae were removed from the trays and discarded downstream of the spawning ground. We endeavored to minimize egg disturbance on the river bed and on our trays during this process.

Juveniles. There have been three unusually large smelt impingement incidents at Pilgrim Station; all occurred in the month of December in 1978, '93, and '94. The majority of fish have been young-of-the-year (age-0+) juveniles. Impingement data are collected routinely by Marine Research, Inc. (see this volume: section on Impingement).

Adults. Adult smelt (Figure 5) also are impinged at Pilgrim Station (see Impingement section).

## Winter Flounder

Eggs and larvae. These two life stages (primarily larvae, for the eggs are demersal) are collected and quantified by Marine Research, Inc. in their entrainment sampling at Pilgrim Station (see Entrainment section, this report).

Juveniles. We renewed our seine survey in June to monitor recruitment of winter flounder. Sampling continued through August inside Plymouth, Kingston, Duxbury Bay and outside this estuary in the intertidal coastal waters off Pilgrim Station. The objective was to estimate relative abundance of young-of-the-year (YOY) winter flounder (recruits) by measuring their density (no./$m^2$) following peak metamorphosis recruitment to the bottom. Yearlings also were enumerated. YOY indices can be compared to estimates of larval entrainment at the power plant.

At metamorphosis, winter flounder settle from the water column and begin a demersal existence, inhabiting mainly shoal waters during their first year of life. The young are basically sedentary, remaining inactive on the bottom for extended periods of time. There is no evidence of aggregation or territoriality in their distribution (Pearcy 1962). When disturbed, juvenile winter flounder often cover themselves with sediment and remain motionless. This behavior makes then vulnerable to bottom trawls and beach seines. Another flounder strategy is to dart ahead of a moving net, alternating between short bursts of activity and pauses on the bottom.

Sampling was conducted at fixed shore sites using a nylon beach seine (6.1-m length, 1.8-m depth, 4.8-mm mesh) outfitted with a double lead-weighted footrope to optimize the capture of demersal fish. In September, a larger seine (15.2 m in length) was used. Replicate (two or three) shore-zone hauls were made perpendicular to shore at 11 sampling stations (initially selected haphazardly) (Figure 6). Depending on station depth, the distance hauled ranged from about 6 to 33 m. Sampling was conducted twice a month in June and July and once in September during a period of ± 2 hours of flood tide. All finfish were identified to species, counted, and up to 50 individuals of each species were measured to the nearest millimeter. The relative abundance (density) of juvenile winter flounder is expressed as number/$m^2$.

Adults. Our objectives are to determine the discreteness (delimit boundaries) of the local winter flounder population and then to estimate

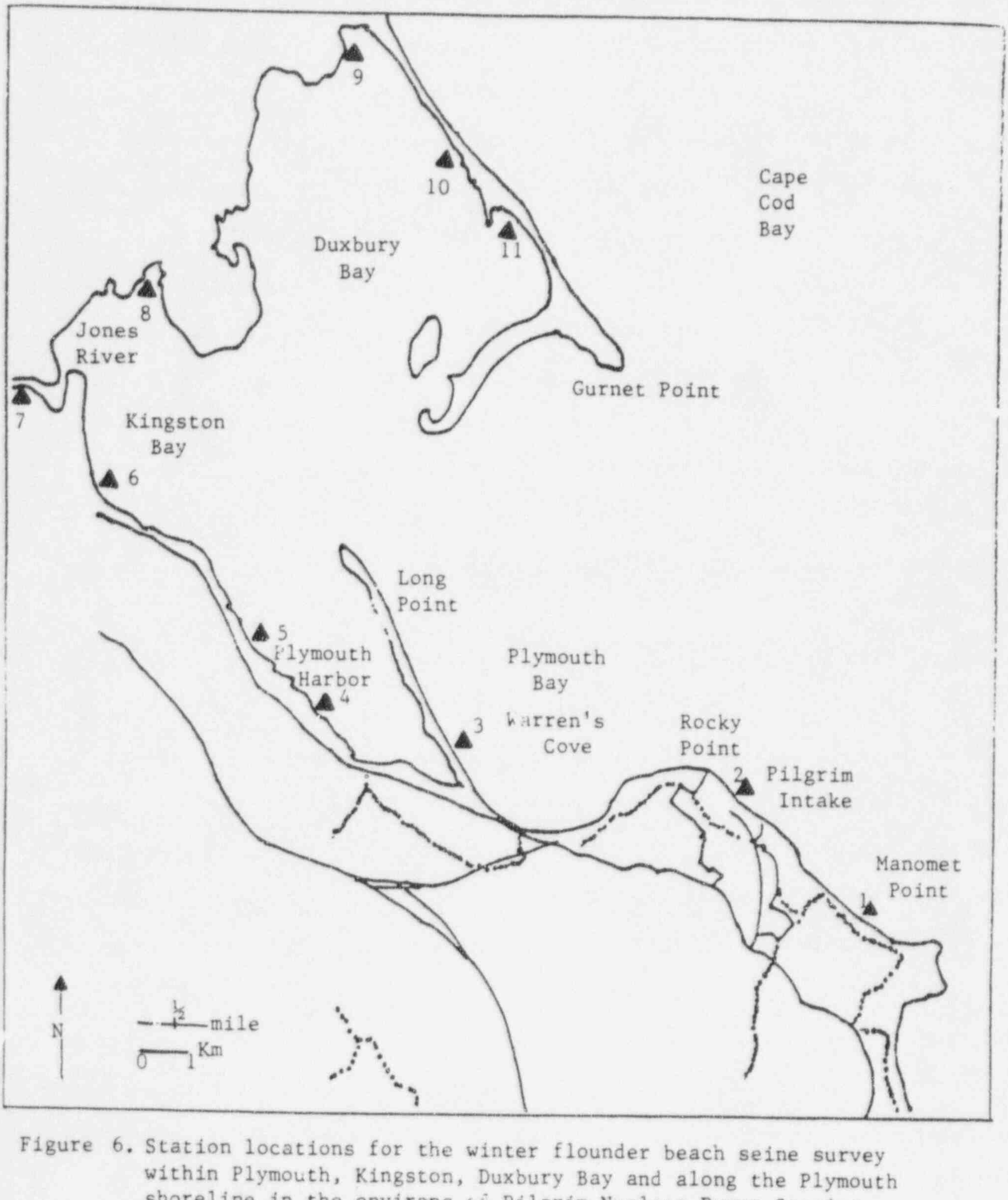


Figure 6. Station locations for the winter flounder beach seine survey within Plymouth, Kingston, Duxbury Bay and along the Plymouth shoreline in the environs of Pilgrim Nuclear Power Station.

absolute abundance. This information will be used to assess impact of flounder entrainment at Pilgrim Station. When time allowed, we also collected catch data on other groundfish in the area. Summaries of trawl catches (winter flounder and other species) appear in this annual report.

During the flounder spawning season (about March to June), winter flounder may move in and/or out of Plymouth, Kingston, Duxbury Bay (PKDB), and there is evidence of spawning both inside and outside the estuary. Flounder also may aggregate in pre-spawning staging areas out in deeper water, with some moving into the estuary at night on a flood tide to spawn in the shallows. The area (Figure 1) inside the estuary and portions of the nearshore waters (Warren Cove and the waters between Rocky and Manomet Points out to the 9-m contour) were sampled with a DMF boat and Wilcox trawl net. The area offshore (out to the 36.6-m depth contour) and nearshore waters (Figure 1) were sampled using a commercial fishing vessel and Yankee bottom trawl.

## Small Vessel Trawling

On a navigational chart and topographical map, we have gridded PKDB, Warren Cove, and other nearshore waters of ≤ 9 m MLW (30 ft) from Rocky Point to Manomet Point into 1000-m square quadrats. This enabled us to position randomly selected small vessel trawl station locations in the field using land ranges and compass bearings. Quadrats were numbered, and some stations were randomly selected.

Following the trawling procedures established in 1994 (Lawton et al. 1995), we completed 49 bottom otter trawl tows in 1995 using a Wilcox trawl of the following dimensions: 9.8-m sweep, 7-m headrope, 10.2-cm wings, 13-cm cod-end mesh fitted with a 6.4-mm stretch mesh liner. Thirty-one tows were made inside PKDB, while the other 18 were located in the nearshore waters along the Plymouth shoreline (Figure 1). Our sampling design emphasized towing in areas believed to have concentrations of winter flounder. More than half the trawl tows were randomly selected, with the unit of effort standardized at 400 m of linear towing distance. The other stations were haphazardly selected, with the unit of effort being 15 minutes of bottom towing time. During the winter flounder spawning season, we tagged (Petersen disc) winter flounder (Figure 7) both inside PKDB and outside the estuary.

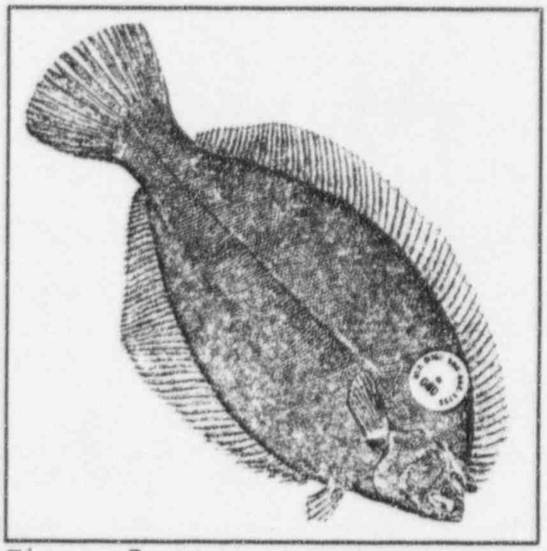

Figure 7. Winter flounder with Petersen disc tag attached (tag not to scale).

Large Vessel Trawling

In April 1995 we contracted a commercial fishing vessel, the F/V *Frances Elizabeth*, to sample for winter flounder, in order to collect data for density extrapolation and to collect winter flounder for tagging. The boundaries of our sampling were extended to include the waters between High Pines Ledge and the Mary Ann buoy from nearshore out to the 36.6 m (120 ft) (MLW) depth contour (Figure 1). The outer depth boundary was selected based on work of the DMF Resource Assessment coastal trawl project. A Yankee otter trawl (18.5-m sweep and 14.8-m headrope, with 15.2-cm stretch mesh and a 7.6-cm mesh liner), which was fished with 12.9-m legs and 60.9-m ground cables, was used. Trawl doors were made of steel and measured 1.8 m X 1.1 m, with a weight of 990 kg each. Warp length varied with the depth fished, ranging from 73.8 to 92.3 m.

Catches were processed following the same protocol as our small vessel trawling (i.e., winter flounder length measurements, sex, and evidence of maturity were recorded, and Petersen disc tags attached to winter flounder ≥ 20 cm TL). Tow duration averaged 30 minutes, while tow length averaged 1.6 km.

We generated an estimate of winter flounder population size (instantaneous abundance) from the 1995 commercial vessel trawl catch data using an area-swept approach, which involves a density extrapolation. As trawl gear efficiency in our sampling was unknown, we estimated it to be 50%. To estimate flounder density, the catch of winter flounder by tow was divided by the area of bottom covered. Tow length was determined, while tow width was estimated from the otter doors' spread. Door spread is used as a measure of the width because of the "herding" action caused by the sediment cloud produced by the doors and legs during towing. Catch per area was calculated for individual tows. Estimates computed for adult winter flounder [≥ 280 mm (TL)] and for all sizes of winter flounder captured were doubled to reflect the assumed 50% efficiency.

Density estimates (number per square meter) were multiplied by the total bottom acreage in the study area to obtain population estimates. Bottom acreage was obtained using a dot grid and navigational charts and was estimated by two people, with the results averaged. For this report, acreage was converted to square meters by multiplying by 4,047.

## Other Species

Eggs and Larvae. Eggs and larvae information for other finfish species entrained at Pilgrim Station are obtained from Marine Research, Inc. (see this report).

Juveniles. We collected data on juveniles of species in addition to winter flounder via haul seining, SCUBA diving, snorkeling, and bottom trawling; impingement data were obtained from Marine Research, Inc. and BECo.

Adults. Bottom trawl tows provided general abundance data for other groundfish.

## IV. 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 marine environment. This factor has historical relevance when assessing long-term thermal impact on marine organisms in the receiving waters. By regulation, the power plant is allowed a maximum temperature rise (Δ T) in the effluent of 18° C (32° F) above ambient. For the 23-year history of plant operations, the long-term mean MDC at Pilgrim Station is 52.0%, with yearly averages ranging from 0.0% (outage years) to 84.4% in 1985 (Figure 8). The annual power level increased from 65.2% in 1994 to 76.4% in 1995. Average monthly thermal values in 1995 ranged from 0.0% in April and May (outage months) to 99.5% in November.

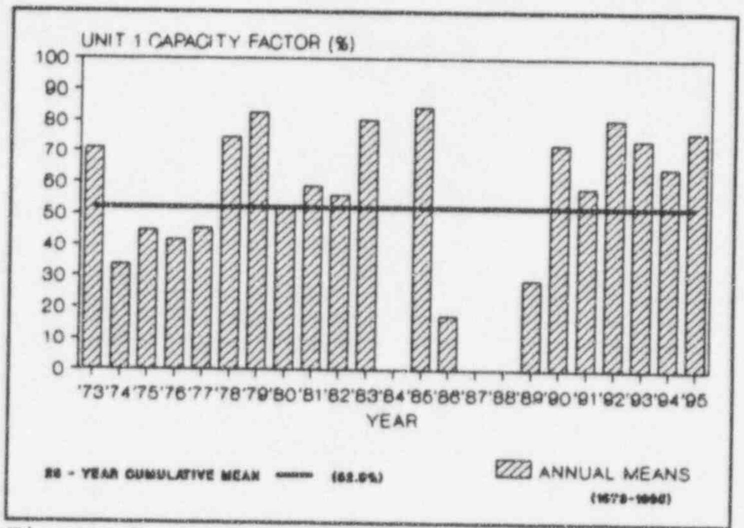


Figure 8. Annual means and 23-year cumulative Mean Capacity Factor (MDC Net %) for Pilgrim Nuclear Power Station, 1973 through 1995.

#### 2. Pump Operations

The once-through, open-cycle cooling water system at Pilgrim Station induces a localized current flow. Two circulating seawater pumps (155,000 gpm each) withdraw water from the Intake embayment; this cooling water circulates through the condenser tubes before being discharged into the waters of Cape Cod Bay laden with waste heat. At low tide, effluent velocities can exceed 2.1 m per second (7 ft per second) at the mouth of the discharge canal. This results in scouring of the benthos and concomitant erosion of substrate along the bottom path of the discharge plume.

Throughout the operational history of the power plant, there have been outages, when one or both circulating pumps were not operated (Figure 9). Such periods have occurred sporadically and generally are short-lived;

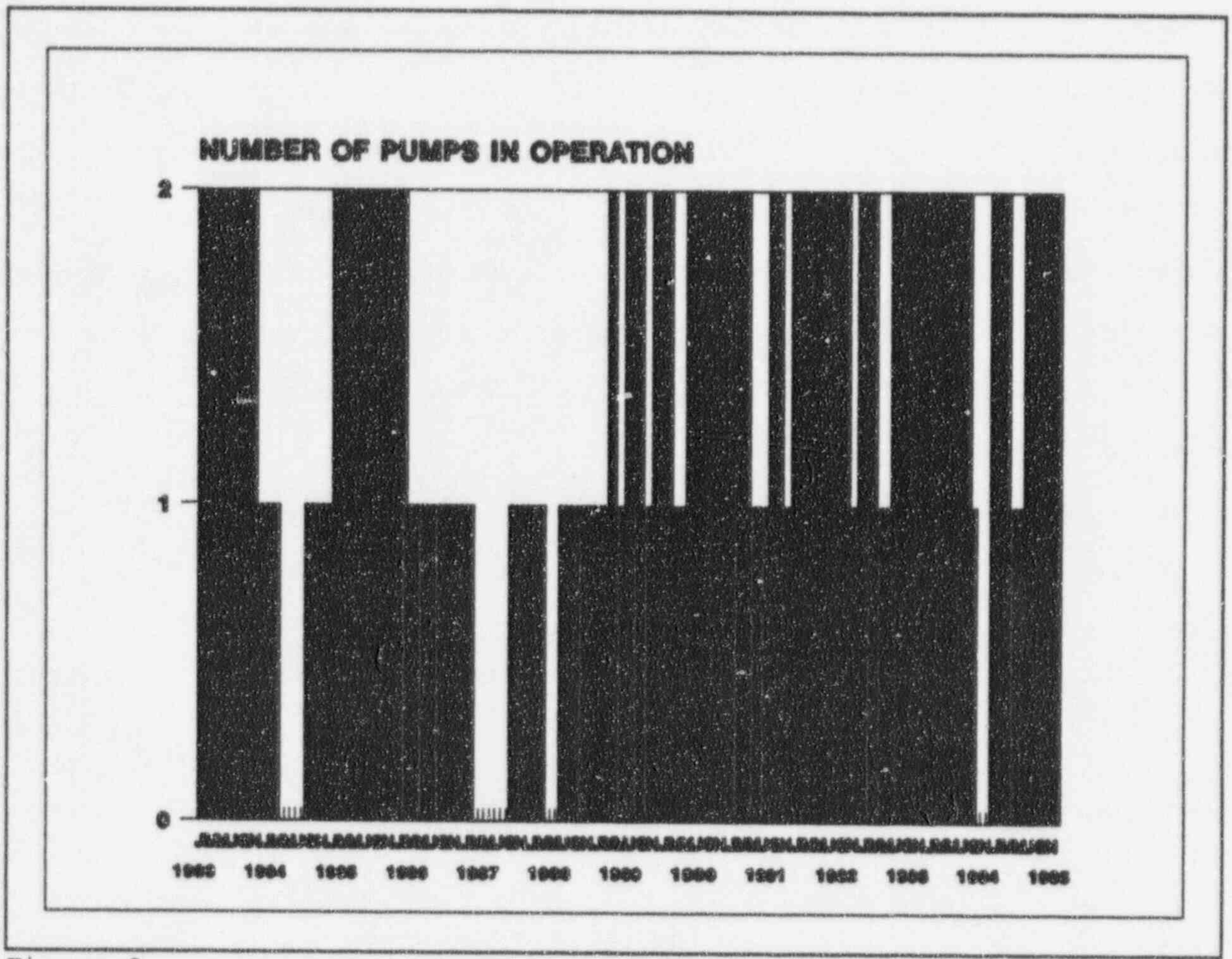


Figure 9. Operational history of the two circulating seawater pumps at Pilgrim Station by month for the years, 1983 through 1995.

however, prolonged outages occurred in 1984 and from 1986-1988 (Figure 9). During 1995, both circulating seawater pumps were operated from January - March, and from June - December. Only one pump was in operation in April and May during a refueling outage.

3. Water Temperature

Bottom water temperature (outside the thermal plume) was continuously recorded from early May through mid-November by thermistors located on the seabed at three locations: one about 20 m southeast of the discharge canal, another 0.5 km northwest of the power station at Rocky Point, and the third 1.5 km southeast of the plant off White Horse Beach (Figure 2). All three locations basically had the same temporal temperature profile, which is depicted in Figure 10 for the location southeast of the discharge canal. Within the data record, it is evident that there is a fairly extensive diel temperature variation during the warmer months. Probably related, for one, to tidal stage, temperature differentials of up to 5°C occurred within a given day. Bottom temperatures reached over 23°C in August and were relatively high into early October.

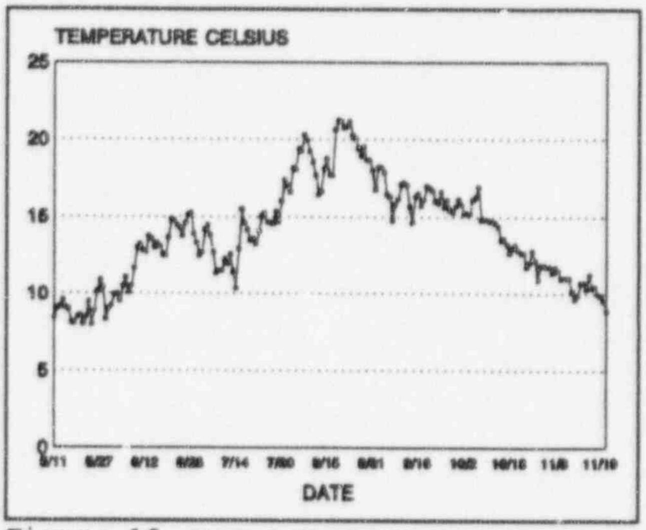

Figure 10. Mean daily bottom water temperatures recorded May to November 1995, at the cunner recruit station near the discharge canal.

## B. FINFISH SPECIES OF IMPORT

### 1. Cunner

#### Background

Cunner (*Tautogolabrus adspersus*) are temperate reef fish that are shelter-dependent, residing near structure, e.g., pilings, jetties, and ledges. They commonly are found within 10 km of shore and do not undergo extensive migrations (Green and Farwell 1971; Olla et al. 1975), although seasonal movements to deeper water and back occur as a result of fluctuating water temperatures. Cunner curtail their activities when water temperatures drop below 8°C (Bigelow and Schroeder 1953; Green and Farwell 1971), while Olla et al. (1975) reported that at 5-6°C, they become inactive and then torpid until the water again warms above 6°C.

Cunner have small home ranges (Green 1975), are highly territorial, and are inexorably linked to the structure to which they recruited (Olla et al. 1975). They occur in highly localized aggregates, where a population may be spatially separated into subunits. Therefore, a resident population of cunner is vulnerable to local perturbations (e.g., point-source pollution or sportfishing mortality). Especially sensitive to stress after dark, they enter a sleep-phase, which is characteristic of the labrid family. This reduces their responsiveness to environmental stimuli.

At Pilgrim Station, the intake breakwaters and discharge canal jetties augment naturally occurring structure, creating additional habitat. Large boulders with attached macroalgae found off the discharge are examples of natural structure. Refuge areas are imperative to the cunner's sleep phase, providing protection from predators. These areas also provide foraging opportunities. Eddies are created at the locations of boulders in the discharge area, which enable cunner to reside in the vicinity of the power plant's effluent, where current velocities would normally limit their maneuverability.

Relative abundance data collected from gill-net, SCUBA diving, and creel sampling reveal that the cunner is a numerically dominant fish species in the Pilgrim Station area. The density of cunner varies spatially in the Pilgrim area. Highest densities of adults have been found on the seaward side of the outer intake breakwater. Our tagging work confirms their site tenacity. Cunner, therefore, has the requisites for a good indicator to assess power plant impact.

## Eggs and Larvae

Cunner are impacted by Pilgrim Station, for one, by entrainment of their pelagic eggs and larvae during late spring and summer, when they spawn in western Cape Cod Bay. Having captured running ripe male and female cunner off Pilgrim Station in May and June, we conclude that spawning occurs in the immediate vicinity.

In 1995, cunner eggs and larvae were entrained at Pilgrim Station from May to September. Over the years of station operation, the Labridae-Pleuronectidae grouping has dominated fish egg entrainment at Pilgrim Station, often comprising over 90% of egg collections. Substantially more cunner eggs than larvae are collected which is probably related, at least in part, to egg mortality.

Large numbers of cunner eggs and, to a lesser extent, the larvae have been entrained historically at Pilgrim Station (Figures 11 and 12). For analysis, it is assumed they are lost to the local population (Marine Research, Inc. 1992). In 1994, Pilgrim Station entrained an estimated

1,759.3 X $10^6$ cunner eggs and 8.773 X $10^6$ cunner larvae, which equates to 319,694 future adults lost to the population, as estimated by the Adult Equivalency Model utilizing the newly determined average cunner lifetime fecundity of 13,946 (Mike Scherer, personal communication)[1]. In 1995, an estimated 4,647.652 X $10^6$ cunner eggs and 39.489 X $10^6$ cunner larvae were entrained, equating to an adult equivalency of 969,667. The eggs entrained in 1994 were over 50% lower than in 1993, while larval entrainment declined 38%. The resulting equivalent adult estimate concomitantly fell 49 percent in 1994. Conversely, 1995 egg and larval entrainment values were up three- and four-fold, respectively, from 1994 levels, and the resultant equivalent adult estimate tripled. Anecdotal SCUBA observations indicated that recruits were much more abundant in the Pilgrim Station vicinity in 1995 than the previous year, which corroborates the larval entrainment values reported at the plant for these two years.

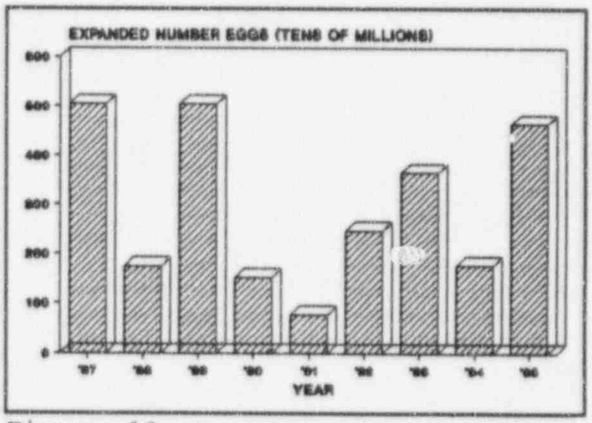

Figure 11. Expanded number of cunner eggs entrained at Pilgrim Station, 1987-1995.

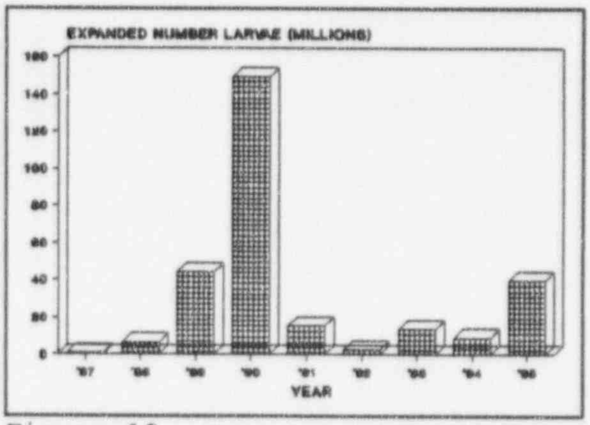

Figure 12. Expanded number of cunner larvae entrained at Pilgrim Station, 1987-1995.

While the magnitude of entrainment loss is substantial, its significance to the local cunner population has yet to be determined. We must delimit the geographical bounds of this population,

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

which includes all recruitment sources. Work is presently ongoing regarding hydrodynamic modeling and cunner egg and larval dispersion in the Pilgrim area, so that population limits can be determined. At a temperature of 15.6°C, cunner eggs hatch in two to three days, while the larvae remain in the water column for 18-30 days. It is likely that some cunner larvae recruit into the Pilgrim area from offsite spawning grounds, while a portion of the larvae hatched from eggs produced in the immediate area of Pilgrim Station are advected from this area by prevailing currents.

<u>Juveniles</u>

Juvenile cunner, as well as adults, are vulnerable to impingement on the traveling-water screens at Pilgrim Station. Among the dominants (Lawton and Anderson et al. 1984), cunner typically are impinged June through September. In 1995, an estimated 288 fish, with 60% being YOY (41-66 mm TL), were impinged in November and December. In 1979, impingement monitoring at Pilgrim Station was reduced to three sampling days each week, with each sample representing an 8-hour collection period (Bridges and Anderson 1984). Impingement numbers from 1979 to 1995 have fluctuated but with a decline overall (Figure 13); the low was in 1992 and the high in 1980. Annual impingement rates (fish collected per year), which are adjusted from the number of hours of actual sampling, are graphed in Figure 14. Survival experiments of impinged cunner at Pilgrim Station revealed initial survival rates of 24% in 1989 (Anderson 1990) and 100% in 1992 (Anderson 1993). Influencing factors include intake velocity and the

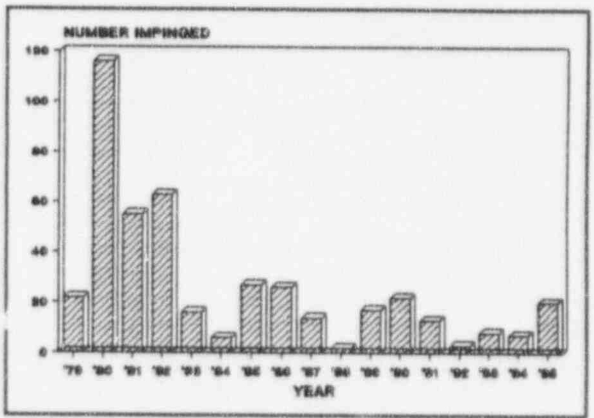


Figure 13. Annual totals for cunner collected during impingement sampling at Pilgrim Station, 1979 to 1995.

operational mode of the screen wash system (static vs. continuous). High impingement can impact a local population, particularly when combined with sportfishing and entrainment mortality.

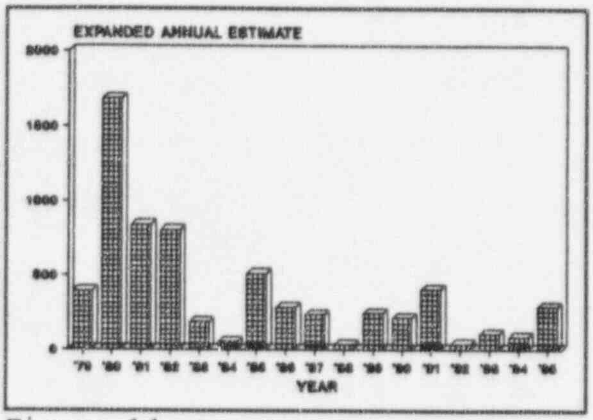

Figure 14. Annual estimated impingement rates (fish per year) for cunner collected from the intake screens at Pilgrim Station, 1979 to 1995.

The thermal discharge, with its high velocity current, waste heat, and periodic chlorine load, can influence all cunner life stages - particularly the distribution of juveniles in the receiving waters. The fast-flowing current can be limiting to their maneuverability. Small cunner, e.g., 20-30 mm YOY, which do not stray far from home shelter, ordinarily avoid the discharge current at Pilgrim Station, which on an ebbing tide can exceed 2.1 m/sec (7 ft/sec) at the egress of the discharge canal. When the power station is operational, small cunner most often are seen in a control area just outside the thermal discharge. Auster (1987) found that large cunner forage further from reef substrate and on current-exposed surfaces for longer time periods than do the juveniles. As current decreases, smaller cunner move up into the water column out of the reef infrastructure and onto current-exposed surfaces to feed. This process is reversed as current velocity increases.

Adults

Adults, as well as juveniles, are impinged at Pilgrim Station, but the number has rarely been large. Qualitative underwater observations during summer of 1995 noted no adult cunner in the discharge canal. A review of temperature tolerance data on cunner (Kinne 1969) suggests the presence of an exclusion area within and just outside the discharge canal during summer and fall and when the plant is fully operational. However, routine cunner kills have not been documented (Lawton et al. 1993). Our SCUBA observations in the thermal discharge area at flood tide in summers past revealed the occurrence of far fewer cunner inside the mouth of the discharge canal than 60 m immediately seaward. We have measured bottom temperatures exceeding 30°C at the mouth of the discharge. It appears that cunner basically avoid the immediate area of the discharge in late summer.

Adults are caught by anglers off the outer intake breakwater. In the past, cunner have led the shore-based sportfish catch at Pilgrim Shorefront. None were reported landed the last several years, but this may be attributed to incomplete reporting by anglers during informal creel surveys conducted at the Shorefront. Because of their small home range (Green 1975), cunner are especially susceptible to sportfishing mortality. Cunner caught at Pilgrim Shorefront by anglers are often left to die. In 1983 and 1985, for example, an estimated 2,600 and 3,500 cunner, respectively, were caught at the Shorefront. We have encouraged fishermen, via posters placed at the Shorefront, to release their catch alive if not kept for consumption.

Tag returns over the years from our capture-recapture program indicate that adult cunner are site-tenacious, at least during the warmer months off Pilgrim Station. The main objective of the tagging study is to estimate absolute abundance of the adult segment of the local population. We are using the Jolly-Seber, an open population model, which allows for recruitment, mortality, and movement to occur during the experiment, and the Schumacher-Eschmeyer, a closed model. In a cooperative venture with UMass Amherst, a graduate student, with our assistance, investigated cunner fecundity off Pilgrim Station; this parameter is needed for the Adult Equivalent Model. We conducted cunner aging work and developed a synoptic age-length key used to establish an age-specific fecundity relationship.

From June through September 1995, 6,070 cunner (includes multiple recaptures) were captured in baited traps. There were three capture/release areas along the Plymouth shoreline in 1995: (1) Outer Breakwater, which is seaward of the outer intake breakwater of Pilgrim Station, (2) White Horse Beach, and (3) Pilgrim Intake, which is just landward of the outer breakwater at Pilgrim Station. The Intake site was added in 1994, while the Rocky Point site of 1993-1994 was deleted due to recapture rates being very low. Of the fish caught, a total of 2,135 adults (≥ 90 mm total length) was tagged and released over 46 sampling days.

During the past six years, we have tagged 6,121 cunner in the Pilgrim area. There is abundant evidence of site fidelity within a year and for consecutive years. In 1995, we recaptured 554 (26%) cunner tagged in that year, with nearly all returns (98%) coming from the respective tagging areas. There were multiple recaptures, e.g., 122 cunner tagged in 1995 were recaptured more than once; one individual was retaken seven times. In 1995, we also recaptured two tagged fish (one twice) marked 1992 and at large for three years, 10 (one or more times) marked in 1993, and 93 (representing 135 recaptures) tagged in 1994. All but two were recovered from where they had been released.

Retention can be a problem when external tags are used. While some tag loss occurred in 1993, no loss was observed for 1994 and 1995; however, we conducted fewer observational dives at tagging sites the last two years. Cunner often take refuge under rocky outcrops and within crevices, so there is the potential for snagging and tag loss. In 1992 and 1993, we observed a few shed tags on the bottom in tagging areas, as well as several fish apparently scarred from tag wounds, and a few double-tagged fish with one missing tag.

In many finfish tagging programs, the percentage of recoveries typically ranges from 3 to 10% (Matthews and Reavis 1990). Our technique of trapping cunner and recapturing them in fish traps rendered an overall 9% tag return in 1992, 31% in 1993, 11% in 1994, and 26% in 1995 (includes multiple recaptures). By recapturing our own tagged fish, we eliminated any failure to report tag returns.

An open population model allows for additions (births and/or immigrants) and deletions (deaths and/or emigrants) in the population during the tagging study period. A closed population is one where permanent deletions or additions do not occur; i.e., the population has a constant size. Population estimators (survival rate, recruitment rate, population size) obtained from closed population models, such as the Schumacher and Eschmeyer method, or from open models, such as the Jolly-Seber, necessitate certain assumptions be met. Violations of model assumptions have different consequences for different estimators and for different models (Pollock et al. 1990).

Closed and open population models require, in common, the following. Marked individuals should not lose their tags. Marked and unmarked animals need to experience the same natural mortality, i.e., have the same probability of surviving from one sample to the next. All samples should be taken instantaneously and releases made immediately following the sampling. Both marked and unmarked organisms should be equally vulnerable to capture during any sampling date (equal catchability), given they are alive during that period. For open models, losses to the population through emigration should be permanent.

Tag retention has been investigated. The first tag we used (1990 and 1991) was evaluated under control conditions and had a short-term tag loss of only seven percent, but was deemed ungainly for the size of fish being tagged. However, the modified T-bar anchor tag used in 1992 and 1993 had a controlled tag loss of 13% and 65%, respectively. The latter was unacceptable. In 1994 and 1995, we opted for a scaled down version of the anchor tag (Floy FD-94 Fine Fabric), which caused no mortality and had a tag loss of 15% on small cunner (90-115 mm) held under controlled conditions for 4 months, the length of time of our field experiment.

We tested our 1995 trap recapture data at each of the three sampling sites for equal catchability using Leslie's test (Krebs 1989). Each data set displayed unequal catchability, which is common with baited-trap recapture information from many biological populations (Pollock et al. 1990). Unequal catchability will slightly bias survival estimates generated from capture/recapture models, but population estimates are more substantially impacted with a negative bias (Cormack 1972; Carothers 1979).

Krebs (1989) discusses strategies to consider if accurate population estimates using mark and recapture are difficult to achieve because of failed model assumptions. One option is to report the models used and the estimates, recognizing that results may be biased. As to abundance, when there are deviations from model assumptions, estimates should be used primarily as indices of population size. Another alternative is to use other population estimate methods, such as line transects or quadrat sampling. Mark and recapture models may not be appropriate for some species. Additional option is to employ a general, empirical model for population estimation, especially useful for intensive, short-term sampling of a closed population. This method is based on a zero-truncated frequency distribution of individual capture/recaptures. Statistical distributions are fitted to these data until a best fit is found through use of a computer program called CAPTURE (Otis et al. 1978).

Population estimates reported herein from tagging data are considered to be biased due to failure of certain model assumptions, and should be used with caution. We will include line transects in 1996 sampling, using SCUBA to generate density estimates (number per unit area) for our population sub-units. We then will extrapolate over the sub-area under investigation to estimate size of this sub-unit of the local population (Begon 1979). We also will conduct intensive, short-term mark and recapture sampling at one of the sites, assuming a closed population, and utilize the CAPTURE program for analysis (see above).

Abundance estimates of adult cunner (≥90 mm TL) from capture/recapture data were generated using the Schumacher-Eschmeyer closed population model (Krebs 1989) for our tag and release sites in 1994 and 1995. Estimates are for sub-units of the local population. Precision was greatest for the areas outside the outer breakwater and inside the Intake embayment, for which abundance estimates are reported in Table 2. The ratio of marked to unmarked fish at the outer breakwater and Intake sites in 1994 was 8% and 7%, respectively, while tag recapture rates were 15%

**Table 2. Schumacher-Eschmeyer abundance estimates, with 95% confidence intervals, of adult cunner (≥ 90 mm TL) from capture/recapture data collected at the Outer Breakwater and Intake sites off Pilgrim Station, 1994-95.**

| Site | Year | Number | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| Outer Breakwater | 1994 | 3,628 | 2,984 | 4,265 |
| | 1995 | 5,833 | 4,745 | 7,569 |
| Intake | 1994 | 3,780 | 2,810 | 5,772 |
| | 1995 | 3,467 | 2,990 | 4,127 |

and 14%, respectively. In 1995, the ratio of marked to unmarked fish at these two sites was, respectively, 10% and 16%, while tag recapture rates were 16% and 41%. The estimate of abundance at the outer breakwater for

1994 was lower than for 1995. Abundance estimates for the Intake embayment were similar in 1994 and 1995.

Recaptures in 1994 were low at White Horse Beach. The population estimate of 5,436 cunner for this site lacked precision. This was likewise the case at Rocky Point. The 1995 estimate at White Horse was 2,838 cunner which had tighter confidence limits (2,324 and 3,641); the marked to unmarked ratio was 12%, while the recapture rate was 16%.

The Schumacher-Eschmeyer model has the assumptions of no additions or deletions to the population over the course of the study. As we sampled each site for two to three months, recruitment of smaller fish into the minimal tagging size (≥90 mm TL) would have occurred, and would have added a negative bias to the population size estimator.

Sub-unit population estimates and 95% confidence intervals at the three sampling locations for 1995, using the Jolly-Seber open Model A option, which allows for death and for immigration/recruitment, were as follows: (1) seaward of the outer breakwater - 4,543 (2,514-6,571), (2) Intake embayment - 983 (650-1317), and (3) White Horse Beach - 1,277 (501-2,053). However, the model adequately fits the data only at the White Horse site ($P = 0.16$), using the Chi-square Goodness of Fit test, with $P < 0.001$ at the other sites. It appears that we generally do not have adequate recapture rates for the Jolly-Seber model, which is relatively "data hungry" as compared to some closed population models (Jay Hestbeck, personal communication)[2]. A high sampling probability ($P > 0.10$) of an animal being captured on a given sampling trip is considered a requirement to obtain reliable estimates of population size and survival (Nichols et al. 1981; Hightower and Gilbert 1984). The Jolly- Seber model has been

[2]Jay Hestbeck, UMass Coop Unit, UMass, Amherst, MA

used mostly in terrestrial applications, where recapture rates frequently exceed 50%. We are far short of this.

A comparison of the two models' population estimates within an area follows. Jolly-Seber estimates in 1995 were always less than corresponding population estimates from the Schumacher-Eschmeyer model. Schumacher-Eschmeyer estimates for cunner in the Intake for both 1994 and 1995 were similar (3,780 and 3,500, respectively), while numbers estimated for the Outer Breakwater for these years (3,600 and 5,800) differed considerably. Consistency in estimates for the Intake may be related to the limited spatial scale of the area sampled, and the resultant high sampling intensity, with a recapture rate of 41% in 1995.

A total of 392 cunner (41 to 230 mm TL) from the Pilgrim area was collected for ageing in 1994; of these, 379 were successfully assigned an age using otoliths. The oldest fish were ten years of age. Annulus formation occurs in May or June, as recently validated for oxytetracycline-injected cunner kept in cages in the field under ambient temperatures by researchers in Newfoundland (John Green, personal communication)[3]. This coincides with the timing of annulus formation reported by Serchuk and Cole (1974) and Dew (1976), who used scales for cunner ageing.

Corroboration of our ageing technique for age-1 fish was provided by comparison of estimated lengths of cunner recruits in the fall with measured length-frequency data collected in the spring. From June through November 1995, weekly SCUBA surveys of abundance for new recruits (YOY) were undertaken in the Plymouth area. By the end of the investigation in late autumn, recruits were estimated visually to average about 60 mm TL. These fish will lay down their first annulus in May or June 1996. We began

[3]John Green, Biology Department, Memorial University, St. Johns, Newfoundland A1B3X9

trapping cunner in 1995 in the late spring and early summer. We presumed that fish caught in the spring at the size range of 60-75 mm were one-year olds. The mean length of our age 1 fish from sampling in 1994 was 69 mm (Table 3).

Table 3. Total length (mm) at age for cunner from the vicinity of Pilgrim station, Cape Cod Bay

| Age | Males[1] | Females[1] | Males[2] | Females[2] |
|---|---|---|---|---|
| 1 | --- | 69 | 65 | 65 |
| 2 | 93 | 87 | 94 | 88 |
| 3 | 120 | 107 | 119 | 109 |
| 4 | 137 | 128 | 140 | 126 |
| 5 | 162 | 141 | 158 | 141 |
| 6 | 171 | 160 | 173 | 154 |
| 7 | 175 | 166 | 186 | 166 |
| 8 | 191 | 165 | 197 | 175 |
| 9 | --- | 182 | 207 | 184 |
| 10 | 223 | 198 | 215 | 191 |

[1]mean length at capture
[2]predicted lengths from von Bertalanffy equation

Annuli for whole otoliths could only be read reliably for fish up to four years of age. The benefit of using ground otoliths to accurately age cunner is most apparent for fish age-5 and older.

The von Bertalanffy growth function was fitted by sex using empirical length and age data following Ricker (1975) and employing the FISHPARM program (Saila et al. 1988). Respective length at age curves (Figure 15) were generated, which were subsequently utilized for age-specific and length-specific cunner fecundity relationships developed for the study area.

## Fecundity

Fecundity is important to the dynamics of fish populations (Conover 1985). Reproductive potential or fecundity has direct bearing on population abundance. In addition, fecundity will play an important role in determining a species resiliency, i.e., the ability to counteract effects of a disturbance.

Size specific fecundity previously had not been determined for cunner (Auster 1989). This species has requisite characteristics to be an ideal indicator to measure effects of local perturbation (Olla et al. 1975; Levin 1991; Tupper and Boutilier 1995). Fecundity is an essential parameter when assessing environmental effects on this species via the use of predictive modeling.

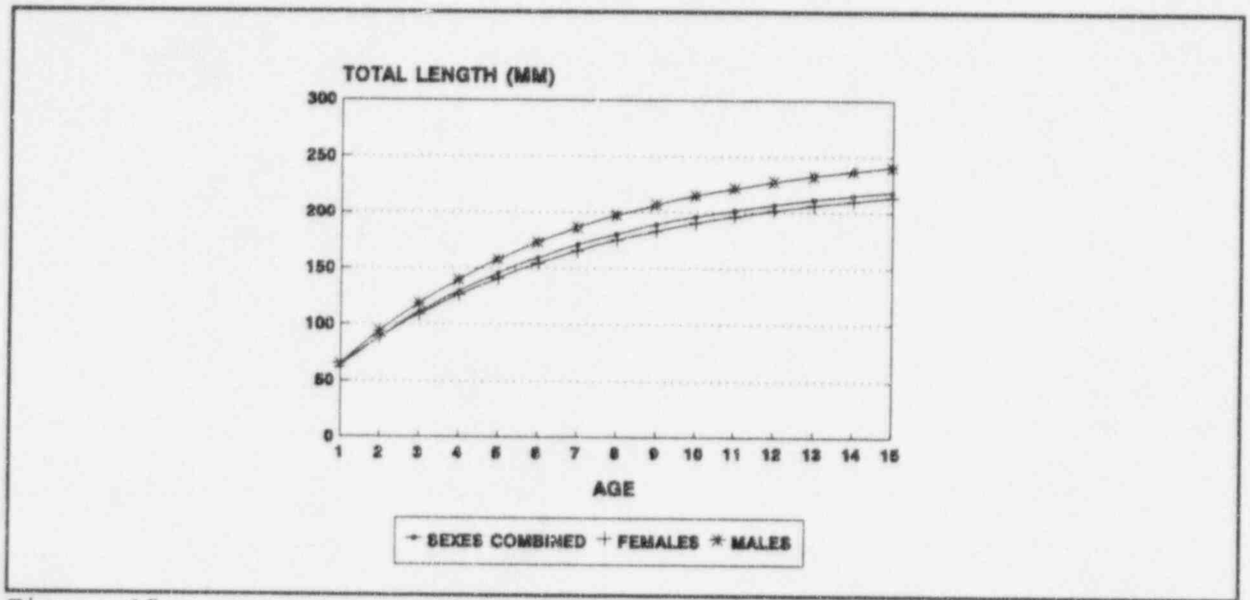


Figure 15. Length at age from the von Bertalanffy growth curve for cunner in the vicinity of Pilgrim Station.

Cunner in western Cape Cod Bay spawn predominantly from June through August, with the majority of eggs deposited during the second and third weeks of July. It is advantageous for most of the spawning to occur during the first half of the reproductive season in order for recruits to be of sufficient size to survive the following winter. Spawning, however, does not occur immediately after winter hibernation due to physiological constraints (Green and Farwell 1971; Wooton 1990; Tupper 1994). Each individual first must replenish its energy reserves, which are depleted during winter hibernation. Energy then can be allocated to the development of gametes. In Newfoundland, Pottle and Green (1979a) found cunner were active for at least 40 days prior to spawning, with most reproduction occurring within a 2-3 week period. Even in the warmer waters of New Jersey, all spawning was observed to occur within the two months of June and July (Wicklund 1970). Spawning time can be back calculated knowing the period of settlement and by using the known 18 to 30 day larval stage and the 2 to 3 day egg stage durations (Johansen 1925; Gleason and Recksiek 1990).

The gonadosomatic index (GSI) was calculated. GSI as a measure of gonadal development is insightful to determine if the fish were collected at the appropriate time for fecundity measurements and at what size maturity occurs. The overall goal was to use a large sample size (210 fish), consisting of a wide size range (53 to 183 mm), which was collected in June 1994 to calculate size, weight, and age fecundity relationships for cunner in western Cape Cod Bay.

In some species, the estimation of fecundity can be problematic. First, in most oviparous fishes, a size-based relationship predicts fecundity better than one based on age (Bagenal 1978). Second, fecundity is more difficult to estimate in multiple-batch spawning species (Bagenal and Braum 1971; Bagenal 1978; DeMartini and Foutain 1981; Conover 1985). In these cases, a batch of mature eggs already can be spawned, while ova are developing to be spawned at a later date. Eggs left in the ovary at the end of the season can be reabsorbed by the body. Therefore, estimating total eggs in the ovary at any one particular time may give an inaccurate estimate of the total eggs produced and spawned that reproductive season.

Cunner are multiple spawners, but a relatively short spawning season in the northern part of its range makes it relatively easier to determine fecundity accurately. Back calculations from our cunner recruitment survey showed that most spawning occurred within the second and third weeks of July. Since spawning occurred within a relatively short period of time, we believed the most accurate way to estimate fecundity for cunner in western Cape Cod Bay was to treat a large sample consisting of a wide range of sizes in June as a single analysis unit. We observed cunner to be fully active in June, an optimal time to capture large numbers of cunner before peak spawning occurred. The time frame proved to be appropriate for ova to be developing and large enough to be accurately enumerated. The collection period was also early enough to insure that no eggs had yet been spawned and that all eggs present would have sufficient time to mature and be spawned out and not be reabsorbed.

The GSI should be low in the beginning of the spawning season because gonads are developing and again low at the end of spawning because eggs and sperm have been expelled or reabsorbed. No relationship existed between GSI and day of collection (Figure 16), suggesting that the ovaries were developed enough to estimate fecundity accurately, but spawning had not yet commenced. Second, a sharp rise in GSI at a particular length should indicate age at maturity and time of first spawning (Figure 17) (Dee and Parrish 1994). The GSI data indicate that maturity occurred at about 65 mm total length.

Egg diameter ranged from 0.05 to 0.30 mm. Egg size after spawning ranges from 0.6 to 0.9 mm (Bigelow and Schroeder 1953). Translucent, hydrated eggs are seen often in fish which have begun spawning (Griswold and Silverman 1992). Based on this criteria, spawning had not occurred in fish used in our fecundity analysis, since no fish had translucent, hydrated eggs.

The smaller, younger fish (e.g., age-one) were not abundant in our cunner collection for fecundity. From representative length-frequency

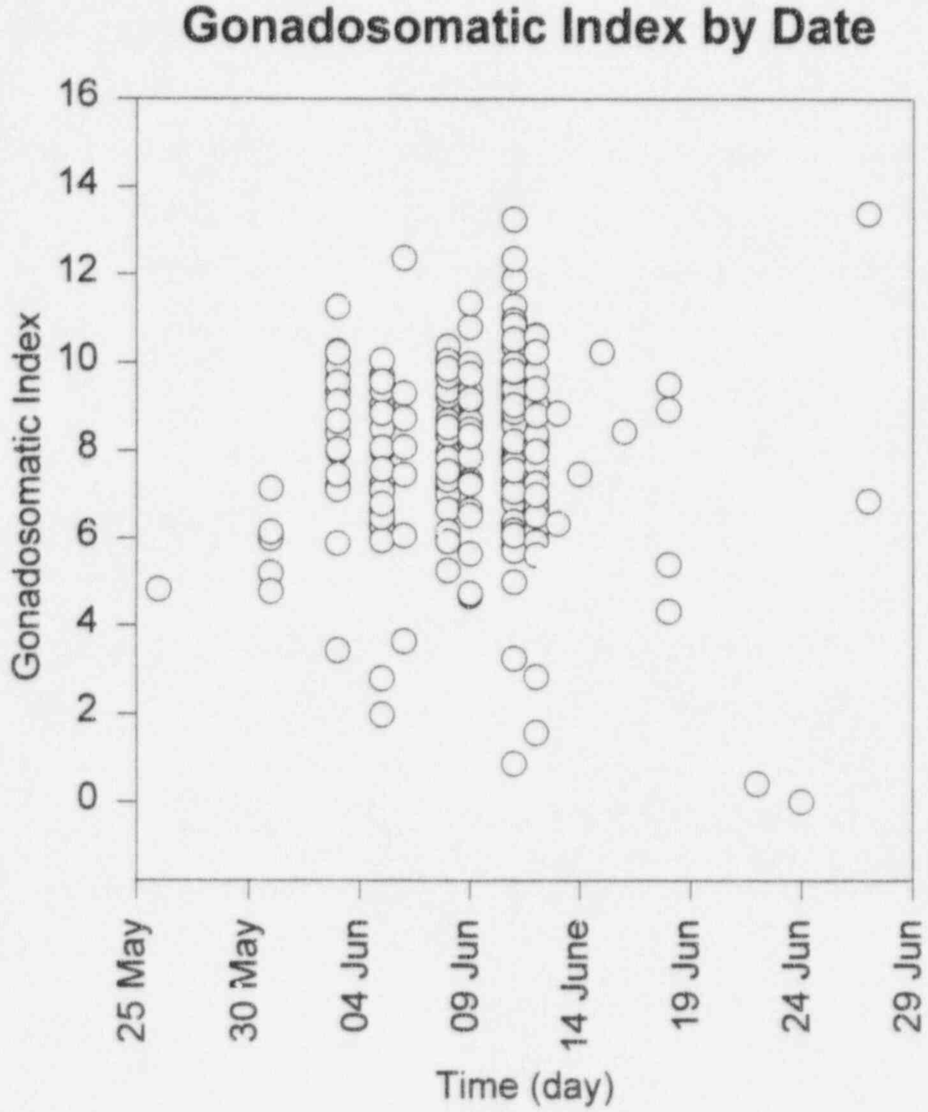


FIG. 16. Gonadosomatic index over time for female cunner collected in the Pilgrim Station area, 1994.

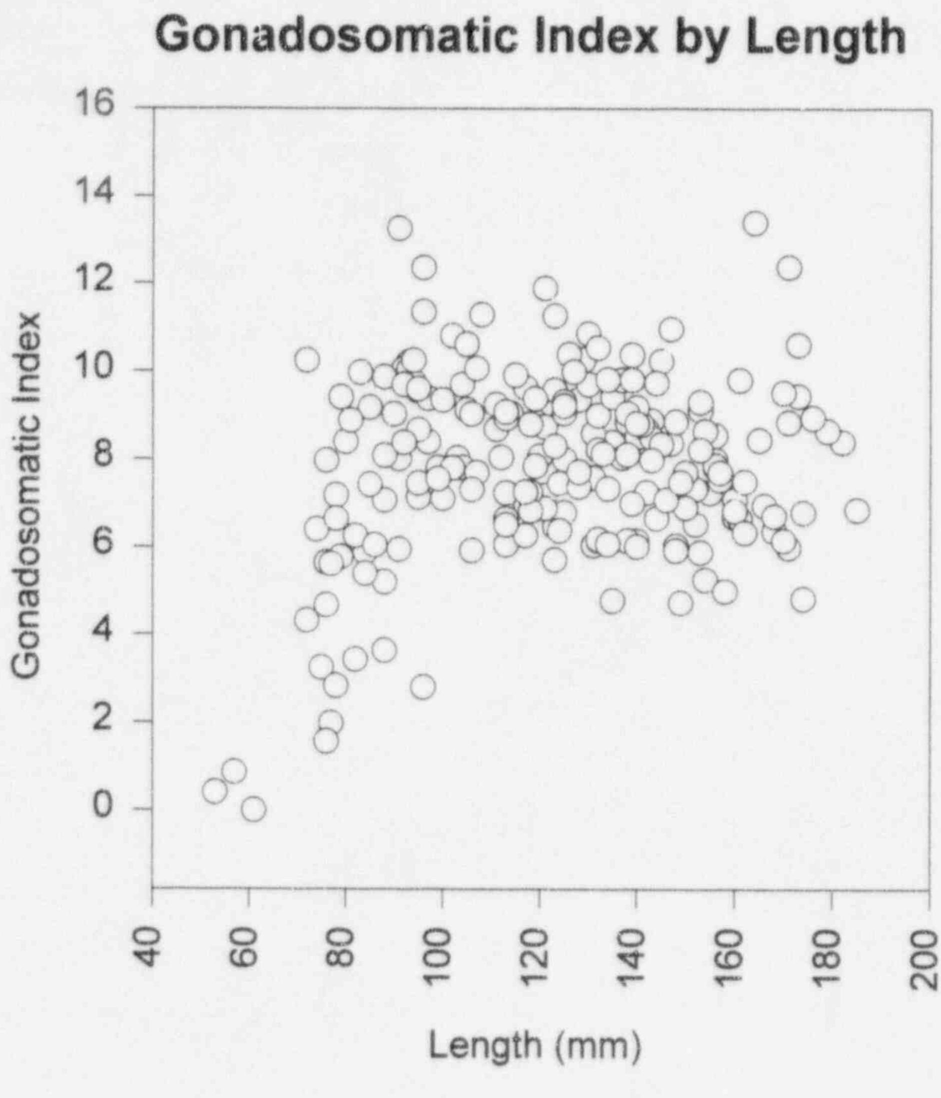


FIG. 17. Gonadosomatic index by length for female cunner collected in the Pilgrim Station area, 1994.

distributions of catches in June over the years 1993-1995, we can see that the number of first year fish at the time of our fecundity collection in 1994 was relatively low when compared with 1995 (Figure 18). Because fish were collected by the same method all three years, these representative length frequencies reflect yearly variation in recruitment. The mode in age-one fish (60-80 mm TL) is distinct in 1995 relative to 1993 and 1994 (Figure 18), suggesting that age-one fish are in relatively low abundance in the fecundity sample collected in 1994, because of lower recruitment in the year (1993) prior to our procuring cunner.

Fecundity increased dramatically with small increases in length, ranging from 110 eggs for a 53 mm TL female to 84,400 eggs for a 171 mm TL fish. The length-specific fecundity relationship provided a better fit to the data tnan did weight-specific fecundity. The weight-specific fecundity model does not represent smaller fish sizes accurately and, therefore, is not as good a predictor (Figure 19). Log transformations of length- and weight-specific fecundity data did not provide a representative model over the entire range of fish sizes. Length-specific fecundity was estimated for 210 fish - Fecundity = 450.81(length) - 29978.64, with an $r^2$ of 0.62 and $P < 0.001$.

This length-specific fecundity relationship changes at the smallest size-classes, where fecundity is disproportionally low for these fish less than 66 mm in total length (Figure 20). The change in estimated overall fecundity for the population probably is not important due to the small length interval (50-65 mm) within which fecundity is underestimated, and because only 50% of the fish within this interval were mature. A total of twenty-six fish (including males and females) fell into this class interval; we estimated fecundity for four. It is in this interval where cunner apparently make the transition to maturity. Fish smaller than 50

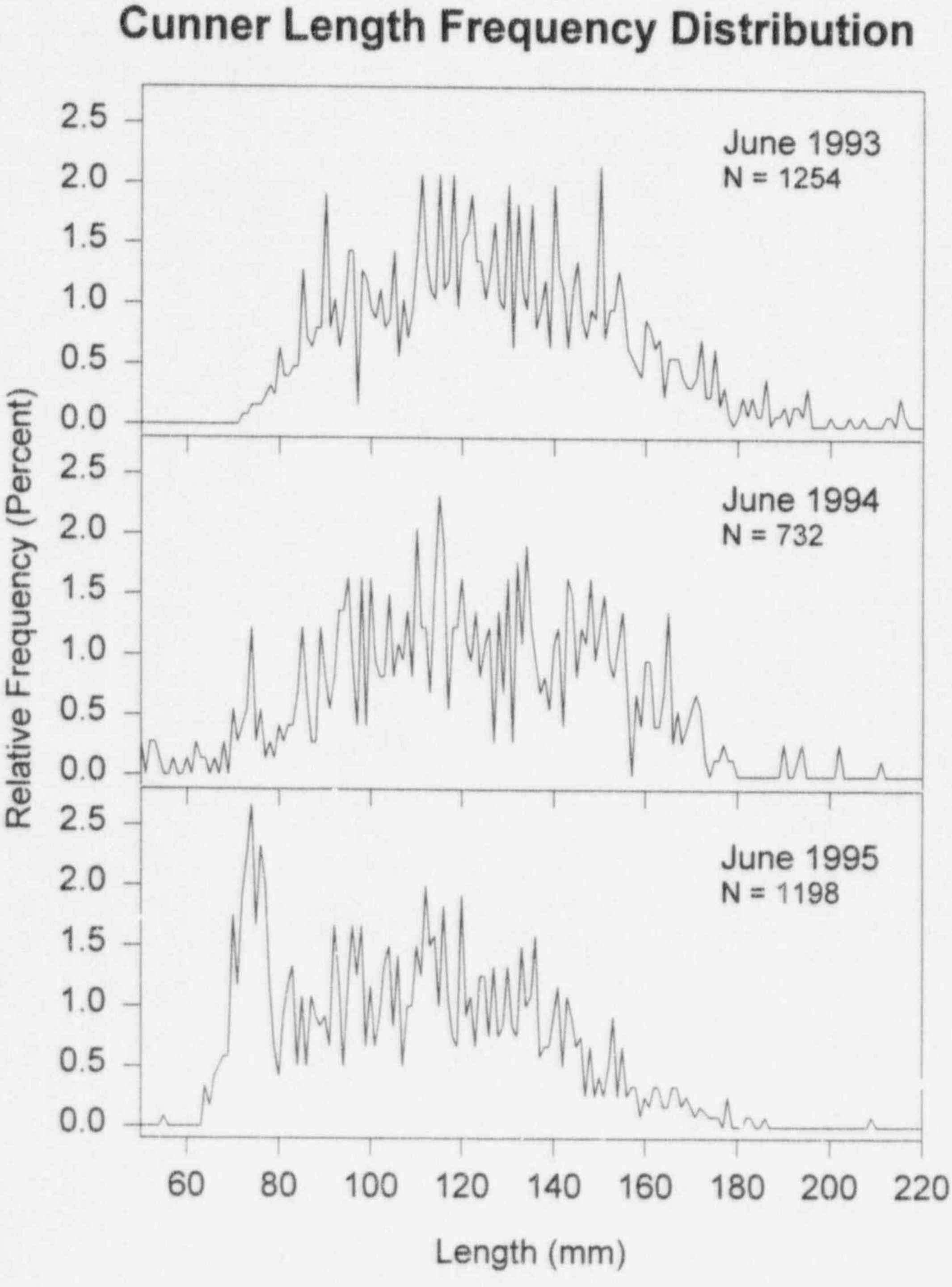


FIG. 18. Relative cunner length-frequency distribution over three years for the month of June from the Pilgrim Station area.

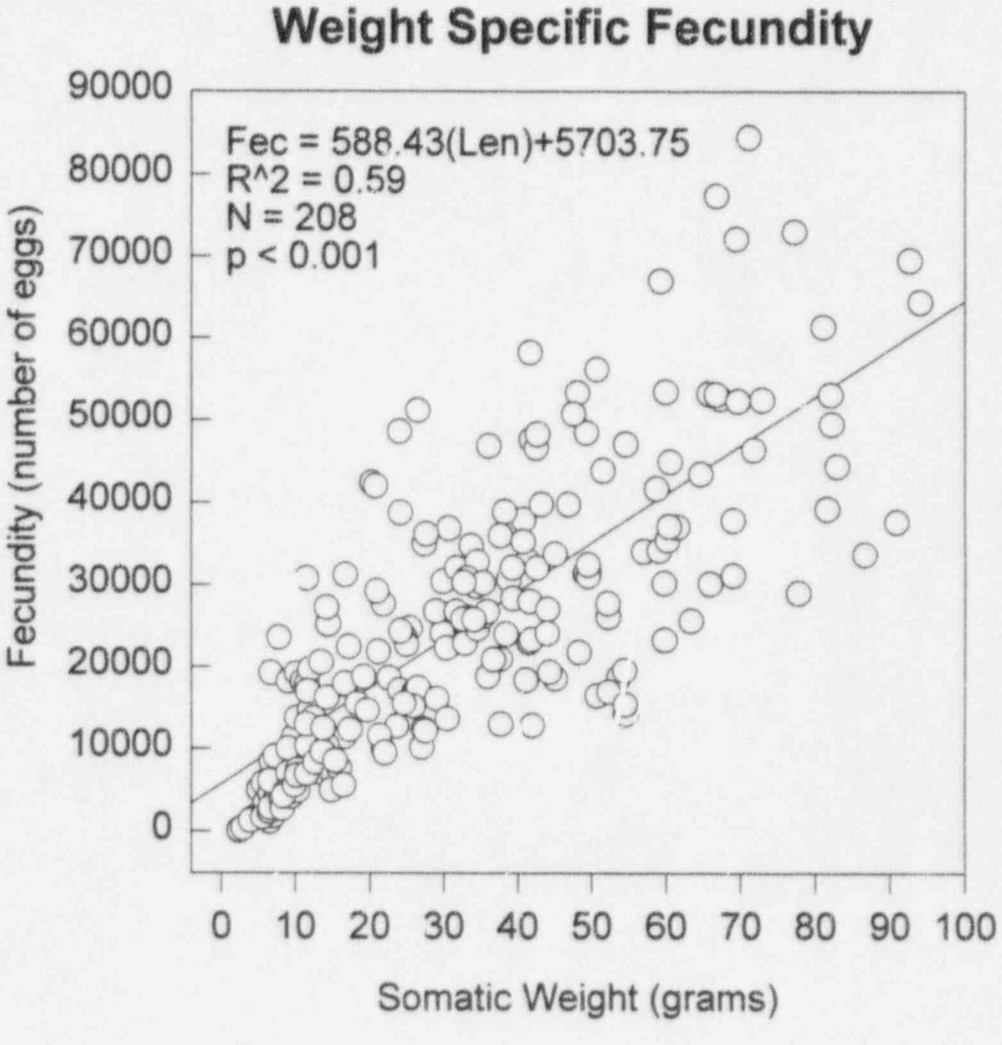


FIG. 19. Weight-specific fecundity for the entire size range of cunner collected in the Pilgrim Station area, 1994.

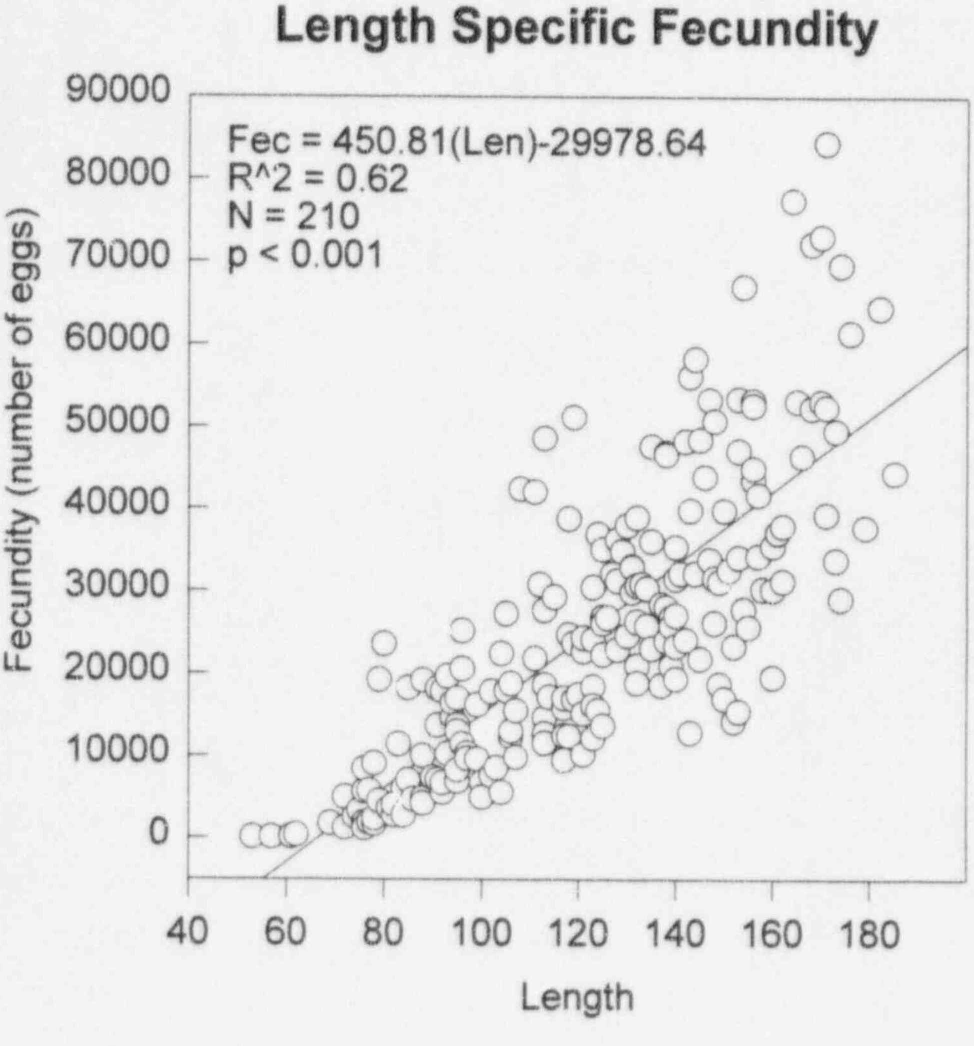


FIG. 20. Length-specific fecundity for the entire size range of cunner collected in the Pilgrim Station area, 1994.

mm were immature; however, all individuals larger than 65 mm and older than age-one were mature. Even the relatively low GSI index for the smaller size fish indicates that fish 50-65 mm TL have not fully reached sexual maturity. Since a large number of fish covering a broad size range were used in the fecundity analysis, the change from immaturity to maturity is seen in the data plot. The omission of the four small fish does not significantly change the function, due to the smaller sample size in these length categories (Figure 21). It would make intuitive sense to remove these outliers from the regression analysis and treat them as a single value (mean fecundity of 195) for their size range (50-65 mm) in the conceptional model, because fecundity does not change much with size within this interval. Outliers at the beginning or end of the range of values have more of an influence than using the mean. The single fecundity model would underestimate fecundity since it predicts zero fecundity for these small size-classes.

Fecundity also was determined by age for those fish where age and fecundity data were available (n = 182). This analysis had a significant relationship ($P < 0.001$) and a good fit of the second order model ($r^2 = 0.70$), when the data were log transformed (Figure 22). A second-order relationship significantly explained more of the variability than the linear (straight line) model. The lengths of these 182 fish then were converted to age from the derived von Bertalanffy growth equation. Another second-order, age-specific fecundity model was determined from the data. These two age-specific models were compared. The only difference between them was that in one, the actual age was used and in the other, age was determined by the conversion of length to age. Therefore, the small difference between the two model outputs suggests that the von Bertalanffy equation is accurately predictive, and that a representative sample had

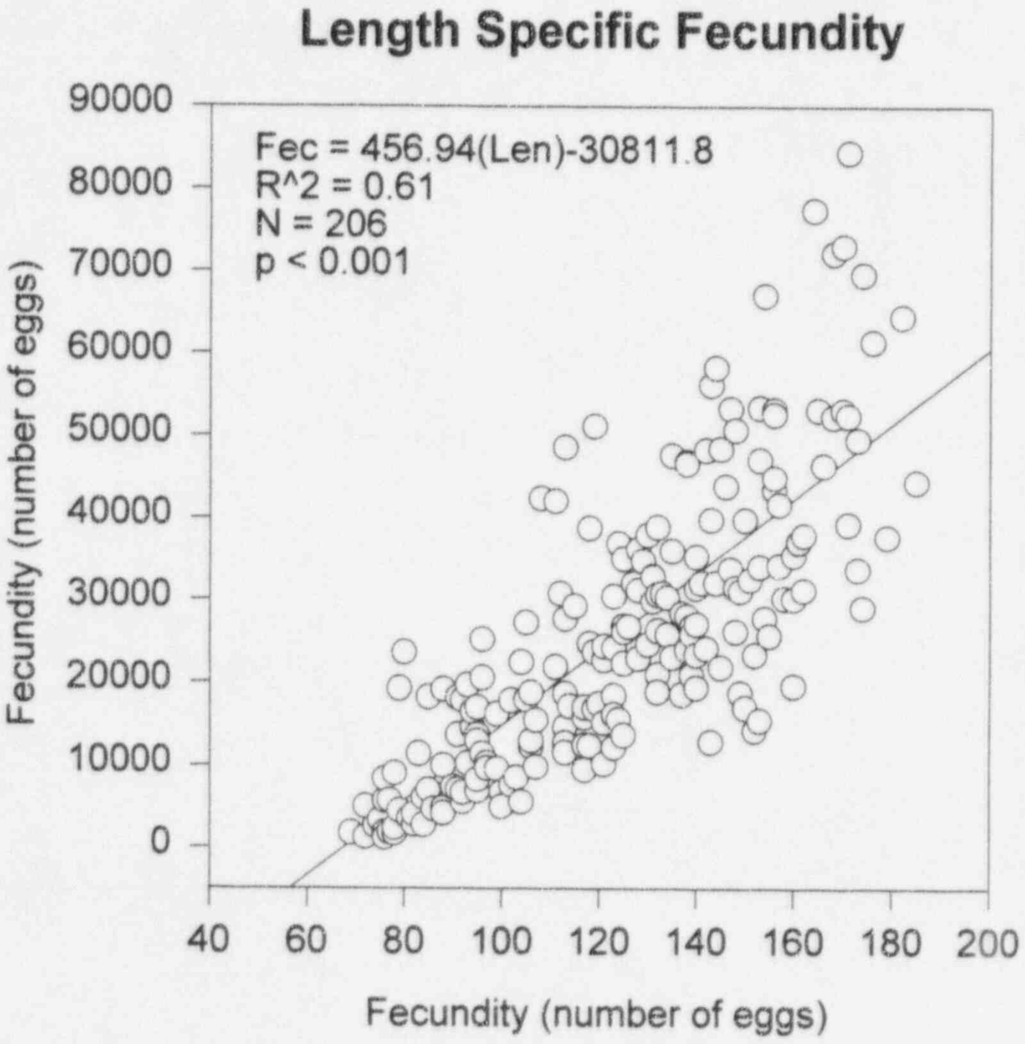


FIG. 21. Length-specific fecundity of cunner in the Pilg. m Statio. area, 1994 (with the four smallest sizes taken out of the model).

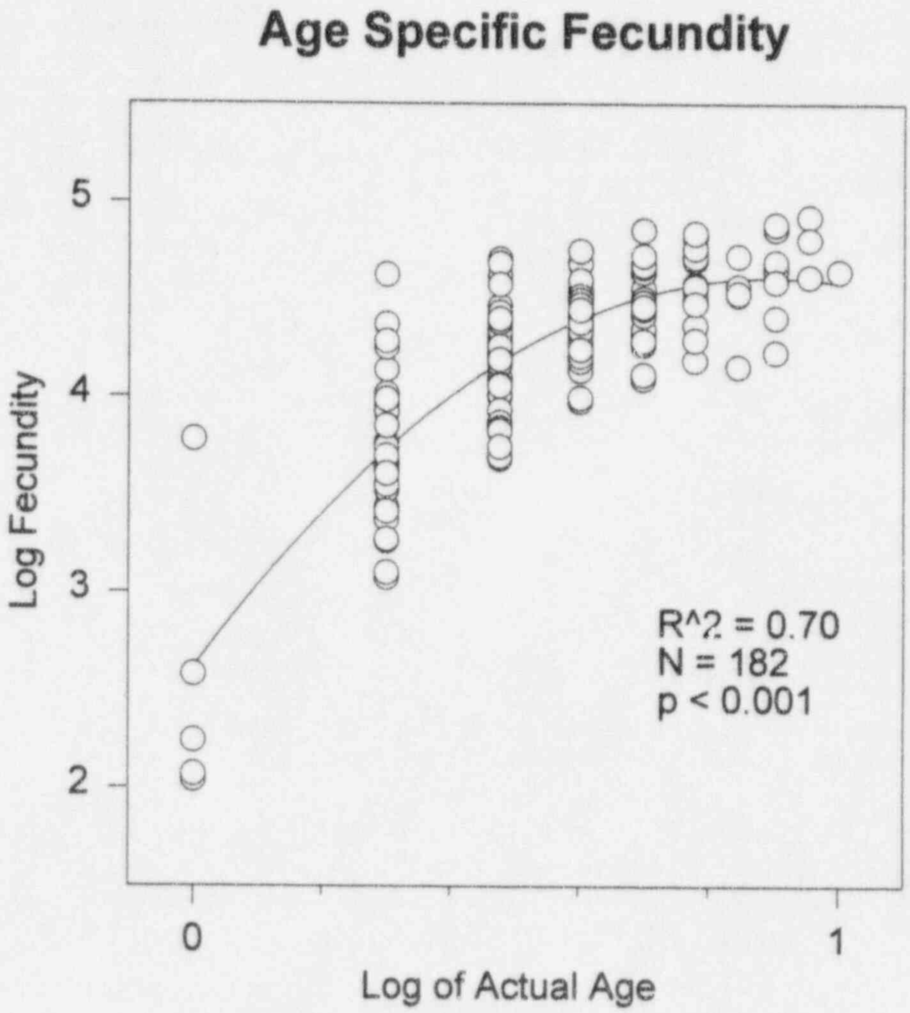


FIG. 22. Age-specific fecundity of cunner which have both an age and fecundity estimate.
log F = 4.46(log A)-2.49(log A)^2+2.61

been collected for fecundity analysis. The differences between the models are probably due to the small sample of age-1 fish used to estimate fecundity (Figures 22 and 23). A smaller sample size of age-1 fish relative to other ages affects the difference between the models as a result of random error. Twenty-eight fish, which were not aged but for which fecundity had been estimated, were included in the second age-specific model by also converting length to age via the von Bertalanffy equation (Figure 23). This addition to the sample size did not change the predicted model's output. This provides additional corroboration to the accuracy of fecundity estimates.

The original length-specific fecundity model was converted to age-specific fecundity, with the model split at the smallest age-classes (50-65 mm) and with an average taken for the interval (195). The small contribution to fecundity at these small sizes can be seen when compared with the rest of the distribution in the length-specific fecundity model (Figure 24). All three models of length, actual age, and derived age from length conversion rendered similar predictions (Figure 24). The small difference between the two second order age-specific models is reflected in age-1 to age-4 fish in the predictive models since an error at age-1 will affect the entire model (Figure 24). There is good reason to split a regression analysis when there is evidence of a change in the relationship between variables, as observed in the cunner length-specific relationship. The age-specific fecundity models are similar to the length-specific estimates, except for the oldest age-classes. Several additive factors led to this difference between models, namely the increased probability of error when aging older fish, the increased error of model predictive capability with distance from the mean, and the difference in predictions between first and second order regression models. The small

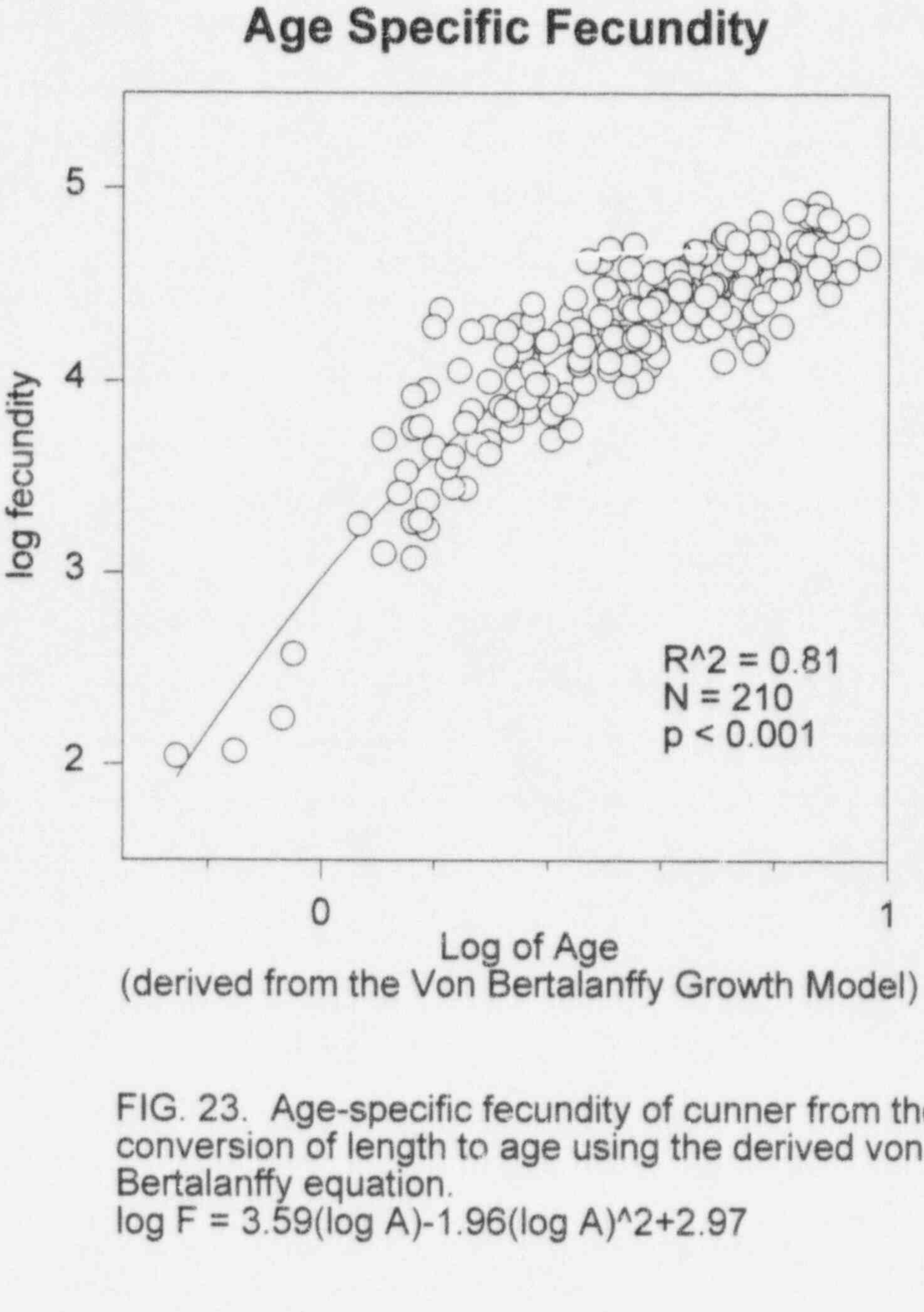


FIG. 23. Age-specific fecundity of cunner from the conversion of length to age using the derived von Bertalanffy equation.
$\log F = 3.59(\log A) - 1.96(\log A)^2 + 2.97$

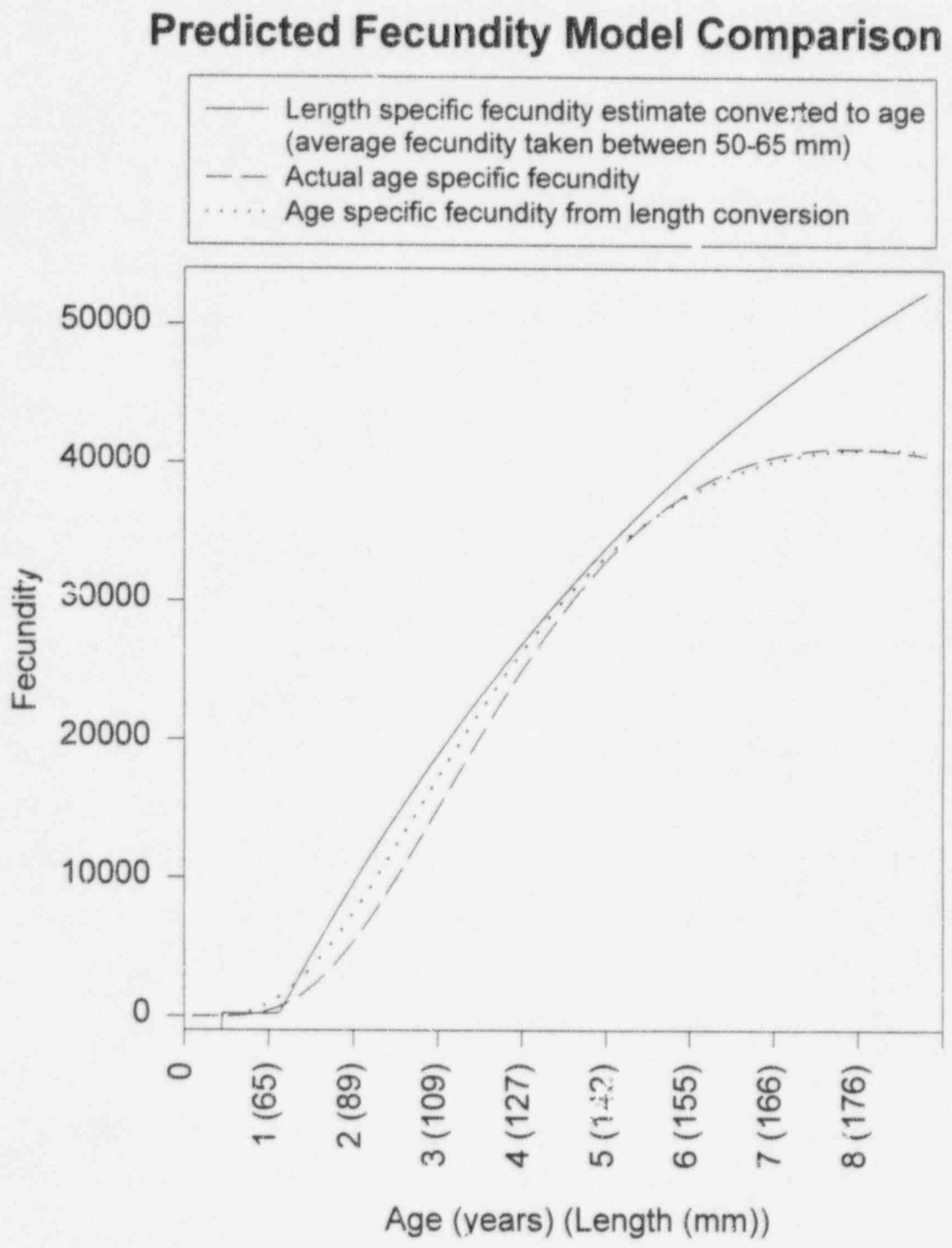


FIG. 24. Correspondence of the three predicted fecundity models over the range of cunner ages and sizes.

difference between the models for fish length adds validity to predicted fecundity model estimates.

In conclusion, either the age-specific or the length-specific fecundity model can be used in the predictive modeling of cunner population dynamics. The age-specific model is somewhat more complicated then the length-specific one, since it uses an additional parameter, with the data being log transformed. The estimation of each parameter in a model has its own source of variation and error term. Therefore, it is parsimonious to use the simpler length-specific relationship.

2. Rainbow Smelt

Background

On the western Atlantic coast, rainbow smelt (*Osmerus mordax*) range from Labrador, Canada south to the Delaware River, Pennsylvania, U.S.A. The largest populations are found in the southern Maritime Provinces of Canada and in Maine. Anadromous rainbow smelt are inshore fish, usually residing within 1.6 km (1 mile) of land. In summer, they emigrate to deeper water outside estuaries but return in the fall to remain through the spring spawning season, when they ascend rivers to spawn. There also are landlocked populations, such as found in the Great Lakes and the Quabbin and Wachusett Reservoirs, Massachusetts.

The U.S. Environmental Protection Agency and the Massachusetts Division of Water Pollution Control selected rainbow smelt as one of 13 representative important species (RIS) to assess environmental impact of Pilgrim Nuclear Power Station. Rainbow smelt are impinged at PNPS and have been involved in recent relatively high annual mortalities there (1993 - 9,500 smelt; '94 - 10,600 smelt). Impinged fish are assumed to be members of a local population, originating from nearby Plymouth, Kingston, Duxbury Bay (PKDB) estuary [8.1 km (5 mi) northwest of PNPS]. Iwanowicz et al. (1974) reported that the major rainbow smelt spawning ground within this estuary was in the Jones River tributary, which historically, has been the location of one of the largest runs in Massachusetts. The Division of Marine Fisheries once used this river as a source of rainbow smelt - adults and eggs -for stocking programs throughout the Commonwealth.

Inception of rainbow smelt spawning in Massachusetts ranges from late February south of the Cape to late-March in areas to the north. Rainbow smelt spawn at night and, although there is no evidence of daylight spawning, small numbers (mostly males) do remain on spawning grounds during the daytime. Rainbow smelt are most abundant on the runs at night, with the overall sex ratio as high as nine males to one female. The higher percentage of males is due to individual males remaining on the spawning grounds for up to eight nights, while the maximum activity of females spans four nights.

River spawning occurs in freshwater or water of low salinity, with fertilization taking place externally. A female spawns up to 44,000 eggs, depending upon age and size. The eggs sink to the bottom where they adhere to gravel, rocks, and vegetation. Egg deposition is not uniform over the bottom. Most spawners move downriver after spawning, and no parental care is rendered to the eggs. Spawning is concluded by mid-May, and adults emigrate from the spawning grounds to disperse in saltwater.

Egg survival is influenced, amongst other things, by overcrowding of the eggs, which subjects them to reduced water circulation, reduced oxygen, and increased susceptibility to fungal and disease infestations. Other limiting factors are predators, inappropriate substrate, diminished water flows, egg dislodgment and loss from the river, lack of fertilization, sedimentation, salinity, pH (a measure of acidity and alkalinity), and pollutants in some rivers, e.g., untreated stormwater runoff from roads.

Egg incubation is inversely related to water temperature. Newly hatched larvae are transported by river current to nursery grounds, including bays, harbors, and river mouths. While there is general downstream advection, the pelagic larvae are carried back and forth by tidal action in the estuary. Several days following hatching, light repels the larvae, which results in greater larval densities near the bottom diurnally. This diel migration reduces the amount of larvae lost from nursery grounds. Following metamorphosis, the juveniles remain in the estuary until autumn, when they emigrate seaward.

Adult rainbow smelt return to harbors and bays in the fall and overwinter there before beginning their spring spawning migration to freshwater as the spawning stream warms in temperature. Some precocious rainbow smelt mature at one year of age and migrate to the spawning grounds along with older fish. Five age groups (ages 1 to 5) have been present in the Jones River spawning run. The first three age groups constitute most of the spawning fish, with two-year olds (fully mature) predominating.

<u>Eggs and larvae</u>

In the second year of a two-year stocking program of smelt eggs into the Jones River, we transplanted 1.2 million eggs (conservative estimate). Last spring we stocked about 600,000 eggs into the river. This is a remedial measure aimed at compensating (environmental mitigation) for recent high impingements of smelt at PNPS. The Jones River smelt spawning run has been in a depressed state, and the magnitude of recent mortalities (assuming all impinged fish die) at PNPS could impact smelt recruitment to the local population. Most impinged smelt have been immature young-of-the-year, with highest numbers taken in December.

The overall goal of our stocking is to increase the number of adult smelt in the local population, which presumably is impacted by PNPS. The objectives of restoration were to augment natal egg production and to enhance spawning habitat in the Jones River. Transplanted eggs came from two genetically isolated, wild, anadromous populations - one from the Weweantic River, Wareham and the other from Back River, Weymouth.

To address the second objective - that of spawning habitat enhancement - our use of portable sphagnum moss egg collecting trays increased the amount of plant material for egg deposition in the Jones River. Compacted sphagnum has spaces between the plant fibers providing depth and thus three-dimensional habitat. Fertilized smelt eggs that land on the trays attach to the surface of the moss and within the interstices, creating a micro-environment that provides protection, reduces egg "turnover" (loss), yet maintains aeration as water can seep through the porous surface delivering oxygen to the embryos and washing away metabolic wastes.

Sutter (1980) found that smelt egg deposition was higher on attached river plants than on other substrate types and in areas of high river flow. He reported egg survival to hatching was about 10% on vegetation and only 1% on hard surfaces. The most sensitive parameter affecting smelt population growth has been found to be egg survival (Saunders 1981).

Hydrographical measurements from the Back and Weweantic Rivers revealed that pH and temperature profiles were comparable to Jones River readings. These two environmental variables should not have been limiting to the success of the transplant.

Proliferation of algae has become problematic the last few years in the upper spawning area of the Jones River, where much of the smelt spawning occurs. This area appears to become "weed-choked" during the spring with the following flora, which includes several diatoms: *Fragilaria* spp. (chain forming), *Synedra* spp., *Gomphonema* spp., and *Achnanthes* spp. Three genera of filamentous green algae also were present: *Draparnaldia*, *Vlothrix*, and *Stigeoclon*. Eggs that settled on the composite algae became entangled in the long hair-like plant filaments. We believe this reduced water flow to those eggs and also to eggs which settled on moss in the egg trays and became fouled with algae. Diminished water flow could hinder egg development and survival.

## Juveniles

Unusually large impingement incidents of rainbow smelt occurred in December of 1978, '93, and '94, when an estimated 6,200, 5,100 and 5,300 smelt, respectively, were entrapped on the intake screens at PNPS. In these incidents, the majority of fish were age-0+ juveniles ($\bar{X}$ total length of 105 mm). In 1993 and 1994, an estimated annual total of 9,560 and 10,644 smelt, respectively, were impinged at PNPS; whereas in 1995, about 2,335 smelt were impinged. Mortalities of the magnitude that occurred in 1993 and 1994, under the existing condition of low stock size, may have markedly impacted the local population. Whereas, the impingement of 6,200 rainbow smelt in 1978 would have decreased by less than 1% the spawning population at the time of the incident.

## Adults

The number of spawning adults in the local population has been depressed throughout the late 1980's and early 1990's. It was difficult to catch spawning-run smelt in the Jones River in the late '80's and into the '90's, with most fish captured within the span of one week on the run. It appears that parent stock reduction will adversely affect future catchable stocks.

3. Winter Flounder

## Background

Winter flounder (*Pleuronectes americanus*) range along the northwest Atlantic coast from the Gulf of St. Lawrence to Chesapeake Bay (Bigelow and Schroeder 1953). Eurythermal and euryhaline, they are found in waters between 0°-25°C temperature and 4-30‰ salinity. As a species, it is generally believed to be population rich, with relatively distinct populations occurring in bays and estuaries. The work of Perlmutter (1947), Saila (1961), and Howe and Coates (1975) led to the contention that winter flounder can form discrete, resident populations, notwithstanding localized seasonal movements. Homing patterns have been documented in estuarine systems (NUSCO 1986; Black et al. 1988; Scarlett 1988; Phelan 1992; Powell, RI Div. Of Fish. and Wildl., unpub.). In addition, most of the historical tagging studies (Lobell 1939; Perlmutter 1947; Saila 1961; Howe and Coates 1975) provided evidence of winter flounder homing to specific embayments to spawn following offshore migrations. Perlmutter (1947) reported 94% of his recaptures were from the study's tagging area. Saila (1961) documented a return probability of over 90% under certain conditions. Howe and Coates (1975) obtained a 58% recapture rate of winter flounder tagged north of Cape Cod on spawning grounds off Boston Harbor.

Seasonal migrations appear to be temperature driven (McCracken 1963); whereas, mature flounder emigrate from shoal waters in spring when water temperatures rise above 15°C and return in autumn as waters cool below 15°C. Their preferred temperature range is 12-15°C during the warmer months. Mark-recapture studies in Rhode Island (Powell, unpub. data) and southern New Jersey (Scarlett 1988) support McCracken's finding. Pearcy (1962) likewise found that adults move out of the shallows of estuaries into deeper water after the winter-spring spawning season. Scarlett (1988) added that adult winter flounder in southern New Jersey moved to offshore summering grounds in May. Phelan (1992) collected no adults in the Navesink and Shrewsbury Rivers of the Inner New York bight during the non-spawning months of June to December.

Although adult winter flounder appear to vacate rivers in summer, their year-round presence in some estuaries also has been noted (Olla et al. 1969; Wilk et al. 1977), even at water temperatures as high as 17-24°C. Earlier, Lobell (1939) speculated that some winter flounder are "bay" fish that spend all their lives in estuaries, only moving to deeper water as the shallows warmed. Evidently, there are estuarine areas that provide adults with acceptable year-round habitat.

Phelan (1992) reported a seasonally directed return of winter flounder from the ocean to inshore areas in the Inner New York Bight for spawning; fish tagged offshore in the autumn returned to inshore waters during the spring. Those fish that return from offshore areas may exhibit what Howe and Coates (1975) described as having occupied a 'transitional position'.

McCracken (1963) observed that inshore movements can be relatively diffuse. Howe and Coates (1975), Phelan (1992), and others have reported that some winter flounder disperse to distant locations, e.g., Phelan (1992) found that several marked fish were recaptured >40 km away from the tagging area. Saila (1961) proposed that random searching for natal spawning grounds may lead to movement into other estuaries. McCracken (1963) suggested that intermixing of winter flounder from different populations was due to random food searches. Phelan (1992) speculated that if movements are temperature related, but somewhat random in direction, and if populations are discrete only during spawning, it is possible for catches to be mixed at other times, i.e., random intermixing. By way of contrast, if the search for natal spawning grounds is somewhat random and not altogether reliable, winter flounder could also be found in non-natal locations during the spawning period.

Phelan (1992) was first to describe the presence of adult winter flounder during all seasons in an offshore area, which strongly suggests the presence also of nonmigrating individuals offshore.

Pierce and Howe (1977), using meristics, stated that estuarine groups of winter flounder do not constitute separate genetic or biological units; a group may be comprised of an assemblage of adjacent estuarine spawning units, of which some appear to be more geographically isolated. Phelan (1992) concluded from capture-recapture work that, in the Inner New York Bight, winter flounder form a dynamic assemblage consisting of a reproductively discrete spawning population that "homes" to natal spawning grounds in the Navesink and Shrewsbury Rivers, an aggregation of other flounder in Sandy Hook and Raritan Bays, and a group of fish found in offshore waters, with all three intermixing.

Lux et al. (1970), Howe and Coates (1975), and Pierce and Howe (1977), from meristic and tagging work, concluded that for management purposes off Massachusetts, there are three stocks of winter flounder - one north of Cape Cod, another south and east of Cape Cod, and the third on Georges Bank. Extensive tagging of winter flounder (over 12,000 fish) in Massachusetts (21 tagging locations) during the 1960's by Howe and Coates (1975) revealed that flounder migration generally encompasses relatively short distances; however, some extensive movement of tagged fish did occur. Bottom water temperature is likely the primary factor affecting their distribution. Flounder dispersal was more extensive south of Cape Cod, where many areas are shoal (<18.3 m - 10 fathoms), and waters warm considerably during summer. Whereas, overall returns from release sites north of Cape Cod showed limited movement with many marked fish recovered in respective sub-area release sites, even years later.

Flounder spawning apparently occurs at night when water temperatures are at or near nadir for the year during late winter and early spring. Most of the spawning transpires below 6°C. The reproductive and nursery areas are found in estuaries, bays, over shoals outside estuaries, and on offshore banks. The eggs are demersal and adhesive, while the larvae are relatively non-buoyant and can move vertically in the water column, thus offsetting the effects of a diffusive pelagic environment. Young-of-the-year juveniles are demersal and remain in nursery areas (Buckley 1982).

Plymouth, Kingston, Duxbury Bay is an estuarine spawning ground for flounder in the Pilgrim area. It also is evident that there is spawning outside the estuary. Seasonal inshore and offshore movements of the fish accompany water temperature changes. The local population is exploited by a regulated trawl fishery that is open from 1 November to 31 January; the minimum legal size is 305 mm TL (12 in). In past years, the fishery was open into the spring, but declining flounder abundance prompted a mandated reduction in effort.

The National Marine Fisheries Service reported downward trends for Gulf of Maine winter flounder landings, commercial and recreational, during the 1980's and early 90's (NEFSC 1993). In 1992, combined landings were at a low for the data time series. Trawl surveys conducted by the Massachusetts Division of Marine Fisheries off Pilgrim Station (Lawton et al. 1992) and region-wide, including Cape Cod and Massachusetts Bays (Witherell et al. 1990) documented declining flounder relative abundance after 1983 (Howell et al. 1992). Overfishing has greatly impacted winter flounder stocks, with overexploitation evident (NEFSC 1993).

Spawning success, recruitment, and population coherence are maintained where physiography and oceanographic circulation enhance larval retention in specific geographic areas. Size of spawning grounds and larval retention areas limits absolute abundance. Winter flounder population size is a function of the size of the physical system underlying larval retention. Large populations are found in large bays and on offshore banks; whereas, smaller populations are associated with coastal ponds and estuarine river systems (Howell et al. 1992). Clearly, the impact of a given mortality is inversely related to the absolute abundance of the population affected.

Habitat quality can be an issue on inshore flounder spawning grounds because these areas are especially subject to anthropogenic alterations and environmental degradation. The different flounder life stages are greatly influenced by energetics which can be impacted by the dredging and filling of wetlands, toxicants, disease infestation, and power plant-induced mortality. Direct mortality or the loss of reproductive and growth potentials can result.

Impingement and entrainment of winter flounder can add to total mortality. Impingement losses are especially problematic when power plant intakes are located in or near nursery grounds (Normandeau 1979). All life stages of flounder seasonally inhabit Pilgrim's Intake embayment which simulates a cove, providing a mini-nursery ground for several species of fish. Young-of-the-year winter flounder inhabit shallow coves, which probably is related to phototaxis. Saucerman and Deegan (1991) reported that young flounder are sedentary while on nursery grounds.

<u>Eggs and Larvae</u>

The larvae of winter flounder are more susceptible to power plant entrainment than are their eggs which are demersal and adhesive. The benthi-pelagic larvae are generally more abundant near the bottom of the water column and, thus, are especially vulnerable to entrainment as bottom water is drawn into the intake. At Pilgrim Station, entrainment of winter flounder larvae has ranged from an estimated 3.5 million to 20.6 million annually over the last 9 years (1987 to 1995). The high was obtained in 1994. Entrainment in 1995 was estimated to be 16.4 million larvae.

Larval entrainment (staged) mortality at Pilgrim Station in 1995, assuming no survival and using the Adult Equivalent Analysis, which assumes population equilibrium and no density-dependent compensation, equates to the loss of 9,879 age-3 winter flounder from the area's population. Gibson (1994) examined data for a number of winter flounder populations and found that after taking into account adult mortality, recruitment rates were lowest in the three populations (located in Mt. Hope Bay, Niantic River, and off Plymouth) that are subject to entrainment by nearby power plants.

The source of entrained flounder larvae at Pilgrim Station is important when establishing population boundaries, i.e., to delimit the geographic extent of the local population. Pilgrim Station entrains larval winter flounder produced in PKDB, but also from sites outside the estuary (Marine Research, Inc. 1988). Evidence of winter flounder spawned outside the estuary complicates estimating adult stock size and assessment of power plant impact.

Juveniles

In 1995, an estimated 1,326 winter flounder were impinged at Pilgrim Station. The majority were juveniles (YOY and yearlings). Over the years, winter flounder have been impinged throughout the year.

During the summer of 1995, we conducted surveys - seine and snorkeling - to sample juvenile (YOY & yearling) winter flounder inside and outside the PKDB estuary. A total of 7,797 fish comprising 9 species was captured or visually observed during our sampling.

Winter flounder occurred at 4 of the 11 seine sampling stations, with 11 individuals seined; 54% were YOY. The catch index (density in number/$m^2$) of flounder, and where sampled, was: Manomet Point - 0.001, Powder Point - 0.003, Jones River - 0.003, and Gray's Beach - 0.006. The overall index of relative abundance for flounder was 0.001, whereas for YOY, it was 0.0006. These indices are exactly the same as in 1994 (0.001 overall, and 0.0006 for YOY).

Snorkeling was conducted in August to visually sample juvenile flounder in the study area. We swam through the area covered by seining at all sampling stations. Only winter flounder were enumerated, and lengths were estimated. A total of 17 flounder was observed at 4 of the 11 sites. Of these, 88% were YOY. The densities (number of fish/$m^2$) of winter flounder observed at these sites were: Gray's Beach - 0.01, Stephen's Field - 0.03, Nelson's Field - 0.02, and Plymouth Beach - 0.004. Overall relative abundance for pooled winter flounder was 0.004; for YOY, it was 0.003.

Since the area covered by snorkeling was known for each site, we equated this to the equivalent number of hauls to cover the same area by the equation: $H = A/(DxK)$, where H is the number of hauls; A, the area covered by snorkelers; D, distance from shore used at each site for seining (which was known); and K, a constant, 6.1 (width of the seine). Once the equivalent number of hauls was calculated, the catch per effort for snorkeling could be compared to seining.

The catch per seine haul (CPH) for winter flounder at all stations was 0.1, while for snorkeling at all stations, the visual index was 0.3. Both indices are generally corroborative, reflecting the scarceness of juvenile winter flounder at the stations sampled in the study area in 1995.

## Adults

A lesser concern is the effects of waste heat and current on the occurrence, distribution, and behavior of winter flounder in the outfall area off Pilgrim Station. Direct mortalities of winter flounder have been rare in the area of the thermal plume. Olla et al. (1969) observed winter flounder to burrow into the substrate and become inactive when the bottom water temperature was above 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. When exposed to high water temperatures, flounder may vacate an area, if possible, or try to avoid thermal stress by burying into the bottom which would be lower in temperature than the overlying water (Olla et al. 1969). As previously mentioned, mature flounder often leave the shore zone when bottom water temperatures exceed 15°C (McCracken 1963). On several occasions during past summers, 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 thermal stress from the immediate vicinity of the Pilgrim discharge during late summer and early fall. This impact area is small and is believed to be under 4,047 $m^2$ (1 acre).

Winter flounder were caught by anglers at Pilgrim Shorefront, and ranked third in the recreational catch in 1995. This species previously ranked amongst the top five sportfish angled in the recreational fishery off the power plant in the 1970's and early '80's.

As previously described (see Methods Section, this report), two different vessel/net combinations were used to bottom trawl for winter flounder in the study area in 1995. Using the Wilcox net fished from a small boat, we completed 49 tows: 31 tows inside PKDB and 18 outside the estuary along the Plymouth shoreline. We captured 118 winter flounder (69 to 468 mm TL), of which 19 (≥ 200 mm TL) were tagged with yellow Petersen discs. Aboard the F/V *Frances Elizabeth*, we completed 57 tows in the waters outside the PKDB estuary out to 36.9 m (MLW). From these catches, we tagged 2,047 flounder (≥200 mm TL) of the total 2,881 captured. Winter flounder length measurements from these catches ranged from 69 to 468 mm TL. No tagged flounder were recaptured during fishing with the Wilcox net; 24 tagged fish were recaptured by the F/V *Frances Elizabeth*. Smaller (< 200 mm) unmarked flounder may have been subject to multiple recaptures, particularly with the larger vessel.

In 1994, using only the Wilcox net, we tagged 226 winter flounder (27 inside and 199 outside PKDB) with Petersen disc tags. They ranged in total length (TL) from 204 to 425 mm, which included 2 to 8 year-old fish. Whereas, in 1993, we finclipped 206 flounder (17 inside and 189 outside the estuary).

As of 31 December 1995, we had received 78 tag returns. Of these, 53% (41 tags)came from commercial fishermen who fish in the western inshore sector of Cape Cod Bay. Other returns were reported from the Provincetown, MA area (1 fish) and Billingsgate Shoal off Wellfleet, MA (1 fish). We assume these fish were kept and thus removed from the local population. Thirty-two percent (25 tags) were reported from fish processing plants. Some of these winter flounder were attributed to a particular fisherman or location; however, as many of these tags were recovered from cutting room floors, such information must be considered suspect. Among the latter was one return purported to have been caught in the Great South Channel off Nantucket. The remaining 13% (10 tags) came from recreational fishermen. Of these, 7 flounder were caught in the Plymouth area, two off Newport, RI, and one on Billingsgate Shoal. Ten of the returns came from winter flounder tagged in 1994, the remainder were tagged in 1995.

Analysis, to date, of the recapture information is greatly hampered by the relatively small number of tagged fish (2,273 since 1994), the limited number of returns (4% of all tagged fish) and the restrictions placed on commercial fishing. With so many recaptures coming from commercial fishermen, their exclusion from inshore waters from 1 April through 31 October effectively removes a significant source of recaptures during this period.

Density extrapolations (Area Swept Method) were made from data collected on the F/V *Frances Elizabeth* to estimate winter flounder population size - one for flounder ≥ 280 mm TL (age-3 and older adults), the other for winter flounder of all sizes (Table 4). The areal measurement was estimated for mean low water (MLW).

**Table 4. Estimated numbers (bottom area calculated at MLW), with 95% confidence intervals, of winter flounder ≥ 280 mm (TL) and for pooled lengths, collected by otter trawl (not adjusted for gear efficiency) in the Pilgrim study area, April 1995.**

| | Area (square meters) | Numbers | Upper 95% CI | Lower 95% CI |
|---|---|---|---|---|
| Flounder ≥ 280 mm T.L. | 155,460,127 | 61,915 | 111,924 | 11,907 |
| All Flounder | 155,460,127 | 129,316 | 263,630 | -4,997 |

Our estimate of flounder numbers for the area sampled (see Methods section, this report) using this approach was 61,915 age-3+ (≥ 280 mm TL) fish and 129,316 total flounder (all ages and sizes). These estimates are based on a trawl gear efficiency of 100%. As gear efficiency is probably ≤ 50%, the adjusted estimates would be 123,831 adults and 258,633 total flounder. As might be expected, precision varied widely (Table 4). Some of the variation around the pooled estimate can be attributed to gear selectivity. As we were using a 7.6 mm mesh cod-end, few small fish were retained. An expanded estimate of abundance is, therefore, biased toward larger fish. It should be noted that the adult estimate for the study area does not necessarily equal the total number of adults in the entire local population.

To calculate a percent loss of adult winter flounder, we used the estimate of equivalent adults (9,879) obtained from entrainment monitoring and our estimated number of adults (123,831) residing in the study area in 1995. The equivalent adult loss because of entrainment represents approximately 7% of the possible adults within the Pilgrim Station study area during the 1995 winter flounder spawning season. A review conducted by Marine Research, Inc. (1986) of winter flounder early-life studies at Pilgrim Station concluded that stock reductions of 0.7 - 2.2% (relative to stock size at that time) were possible. Given that coast-wide winter flounder stocks are severely depressed, entrainment could be a significant cause of mortality to a very localized population. However, we must be cautious in drawing this conclusion as we have not yet fully defined the boundaries of the local population.

4. <u>OTHER SPECIES</u>

Data on other species also were obtained by trawl, SCUBA, seine, and Pilgrim Shorefront creel surveys.

During nearshore trawling with the Wilcox net to obtain winter flounder for the mark/recapture program, we collected a total of 310 finfish, comprising 19 species (other than winter flounder). There were 32 tows made inside PKDB, with the other 20 located along the Plymouth shoreline in the inshore sector of western Cape Cod Bay (Figure 1). As tow times and distances varied widely, no CPUE values were calculated for these species.

Five species: little skate (*Raja erinacea*), longhorn sculpin (*Myoxocephalus octodecemspinosus*), Atlantic cod (*Gadus morhua*), windowpane (*Scophthalmus aquosus*), and sea raven (*Hemitripterus americanus*), comprised 87% of the overall catch. Percent composition, numbers of fish, size ranges, and mean size for each species can be found in Table 5.

Table 5. Trawl catch, percent composition, size range, and mean size of finfish captured during nearshore trawling in the Pilgrim study area, January through May 1995.

| Species | Total Catch | Percent of Catch | Size Range (cm) | Mean Size |
|---|---|---|---|---|
| Little skate | 87 | 28 | 20-52 | 41.5 |
| Longhorn sculpin | 76 | 25 | 23-37 | 28.2 |
| Atlantic cod | 62 | 20 | 3-8 | 4.9 |
| Windowpane | 38 | 12 | 9-31 | 20.8 |
| Sea raven | 8 | 3 | 20-35 | 29 |
| Other spp.* | 39 | 13 | | |
| Total Catch | 310 | | | |
| Number of tows | 52 | | | |

* Represent combined totals from 14 species of low catch

For purposes of comparison, catch totals from the same period in 1994 can be found in Table 6. It should be noted, however, that 1995 sampling was

Table 6. Trawl catch, percent composition, size range, and mean size of finfish captured by nearshore trawling in the Pilgrim study area, January through May 1994.

| Species | Total Catch | Percent of Catch | Size Range (cm) | Mean Size |
|---|---|---|---|---|
| Little skate | 421 | 56 | 18-63 | 41.1 |
| Windowpane | 143 | 19 | 7-34 | 25.6 |
| Atlantic cod | 46 | 6 | 2-6 | 3.8 |
| Yellowtail flounder | 42 | 6 | 7-36 | 21.8 |
| Longhorn sculpin | 23 | 3 | 5-32 | 25.1 |
| Other spp.* | 77 | 10 | | |
| Total Catch | 724 | | | |
| Number of tows | 92 | | | |

* Represent combined totals from 15 species of low catch

focused more on the capture of winter flounder inside PKDB than on comprehensive coverage of the study area. Further, as greater effort was directed toward sampling using a larger commercial fishing vessel, less than one-half as many tows were made with the Wilcox net as in 1994.

In 1995, little skate ranked first numerically in overall trawl catch for the entire study area, although most (97%) were captured at the stations inside PKDB. Ranked second overall, longhorn sculpin also were more abundant inside PKDB. Likewise, catches of juvenile Atlantic cod (the third most common species), and windowpane (the fourth) were higher inside PKDB. Ranked fifth overall, sea raven were caught exclusively inside PKDB.

In summary, general abundances (pooled catches) for most species appear to be lower than in 1994. However, while we acknowledge that regional groundfish stocks have declined in abundance, much of the apparent decline in our catches is probably due to changes in our sampling design.

As described in Section III (Methods and Materials), in the spring of 1995, we contracted a commercial fishing vessel to sample winter flounder in the coastal waters of Plymouth and Duxbury. During this effort, we attempted to maintain catch records of other groundfish in the area. Ultimately, this proved too time-consuming. However, we did record species data from 11 tows made over 3 of the sampling days. As the catch was sorted, individual fish were separated by species and enumerated. Length measurements were recorded for sub-samples of selected species as time permitted. Species composition (excluding winter flounder), catch numbers, and length measurements can be found in Table 7.

Similar to the groundfish assemblage represented in the Wilcox catches, little skate, longhorn sculpin, windowpane, and Atlantic cod were among the more commonly collected species. The presence of large numbers

Table 7. Species composition, catch, and selected size ranges of finfish captured during 11 tows by the F/V *Frances Elizabeth* in the study area, April 14-21, 1995.

| Species | Sampled Catch | Size Range (cm) |
|---|---|---|
| Little skate | 2,607 | 19-54 |
| Longhorn sculpin | 1,314 | 20-29 |
| Ocean pout | 765 | 28-78 |
| Yellowtail flounder | 381 | 11-44 |
| Windowpane | 182 | 13-33 |
| Atlantic cod | 107 | 23-64 |
| Sea raven | 17 | |
| Atlantic herring | 5 | |
| Shorthorn sculpin | 3 | |
| Fourspot flounder | 1 | |
| Northern sea robin | 1 | |
| Striped bass | 1 | |
| White hake | 1 | |
| Total Catch | 5,385 | |
| Number of tows | 11 | |

of ocean pout (*Macrozoarces americanus*) and yellowtail flounder (*Pleuronectes ferrugineus*) is characteristic of the deeper water sampled by the larger vessel.

Our underwater finfish observational program provided visual data on the occurrence and general abundance of finfish in the immediate area of the thermal effluent. From late-July through mid-October (a period of high ambient water temperature), nine SCUBA-dives were made within the mouth of the discharge canal and adjacent area. Striped bass (*Morone saxatilis*) and tautog (*Tautoga onitis*) were the species most commonly observed, although small aggregations of cunner also were observed.

Striped bass were recorded on all dives. Abundance increased over the summer, peaking in late September/early October when divers commonly observed 75 to 125 individuals on each dive. Tautog also were observed on all dives. Their numbers were relatively consistent over the season, ranging from 24 to 36 individuals per dive. Despite their prominence in recreational angler catches, no bluefish (*Pomatomus saltatrix*) or winter flounder were observed in the observation area during our dives.

The 1995 creel survey at the Pilgrim Shorefront Recreational Area was conducted between 10 July and 26 November, with data collected during 106 sampling days. Our objectives were to obtain information on effort expended, species and abundance caught, and catch per angler visit. There were two data collectors, who were seasonal public relations personnel from Boston Edison Company; they conducted the survey in addition to other duties.

The monthly average number of shore-based angler trips per day ranged from 2 to 17. The total catch recorded was 548, comprising three species: striped bass, bluefish, and winter flounder. The overall average number of fish caught per angler trip was 0.8, while the monthly average ranged from 0.0 (November) to 1.4 (October).

The average number of anglers visiting the site on one day in 1995 peaked at 17 in July. Effort decreased over time (July through November). Catch rates (average catch per angler per day) were highest in July (1.1) and October (1.4), when high catches of both striped bass and bluefish were recorded.

In 1995, the percent composition of the recreational finfish catch overall was 58% striped bass, 39% bluefish, and 3% winter flounder. Bass dominated monthly landings during July and August, comprising more than 75% of the catch. Bluefish led the monthly catch in September and October. Flounder were caught in July and September. No fish were reportedly caught in November when few anglers fished at the Shorefront.

Catches from our haul-seine survey included species in addition to winter flounder. The most abundant fish species collected was the Atlantic silverside (*Menidia menidia*), with 6,866 individuals caught, followed by the mummichog (*Fundulus heteroclitus*) - 897. These two species comprised 99% of all the seined fish.

## 5. IMPACT PERSPECTIVE

Cunner, winter flounder, and rainbow smelt were selected for investigative work, which includes assessing impact of Pilgrim Station (Table 8). The response of these species to perturbation may be indicative of power plant induced stresses to other marine finfish.

In 1993 and 1994, rainbow smelt impingement at Pilgrim Station was relatively high - about 9,500 and 10,600 fish, respectively. Impingements of that magnitude under the condition of low stock size may have significant impact on the local smelt population. As a remedial measure to offset plant impact, Boston Edison Co. funded the stocking of over 600,000 and 1.2 million smelt eggs into the nearby Jones River in 1994 and '95, respectively. We also placed additional egg collection trays into this stream to enhance spawning habitat and ultimately egg survival.

Entrainment of cunner eggs and larvae in 1995 at Pilgrim Station equated, by the Equivalent Adult Analysis model, to the loss of about 970,000 adults from the local population. This entrainment is substantial, but the magnitude of loss to the local cunner population is as yet undetermined. We, first, must delimit geographical bounds of the local population, which includes all major recruitment sources, before we can determine absolute population abundance. At present, we have estimates of abundance for sub-units of this population only using mark and capture-recapture techniques.

Larval winter flounder entrainment in 1995 equaled an estimated 9,879

Table 8. A summary of mechanical impact of Pilgrim Nuclear Power Station and any mitigation efforts for selected finfish species in the inshore waters of western Cape Cod Bay.

| Species | Impact of Pilgrim Nuclear Power Station | Comments/Mitigation |
|---|---|---|
| Rainbow smelt | High impingement incidents occurred in December 1978, '93, '94. In 1993 and '94, alone, over 20,000 smelt were estimated to be impinged at the plant. | To remunerate for 1993 impingement losses, we stocked over 1.8 million smelt eggs over the years - 1994 and '95 - into the nearby Jones River smelt spawning ground.<br><br>As a form of aquaculture, we enhanced spawning habitat on the Jones River smelt run by adding artificial plant substrate for egg deposition to improve instream egg survival. This helps compensate for the 1993 and 1994 impingement losses. |
| Winter flounder | In 1995, an estimated 16.4 million winter flounder larvae were entrained, which equates to the loss of 9,879 age-3 flounder from the local population.<br><br>Entrainment losses, as related to adults, equaled 7% of the possible adults in the study area.<br><br>An estimated 1,326 flounder were impinged in 1995; the majority were juveniles. | Absolute abundance of adult winter flounder in the study area during the spring spawning period of 1995 was estimated to be 123,831 fish.<br><br>Fortuitously, there was a scheduled plant outage in April and May 1995 (flounder spawning months), when only one circulating water pump was in operation. This reduced the cooling water volume drawn into the plant by 50% and concomitantly entrainment of winter flounder larvae. |
| Cunner | In 1995, an estimated 4,647.652 x $10^6$ cunner eggs and 39.489 x $10^6$ larvae were entrained, which equates to the loss of 970,000 adults from the local population.<br><br>An estimated 288 cunner were impinged in 1995. | Of the reef areas (natural and artificial) sampled in the study area for cunner tagging, the largest sub-unit of the local population per unit area occurs off the outer breakwater, where estimates of cunner adults approach 5,000 fish. Constructed to protect the intake from wave-related damage, the breakwater provides an abundance of the structurally complex habitat critical to the survival of cunner. As such, construction of this structure may have allowed local abundance to flourish beyond what could be supported naturally. |
| Alewife | In 1995, about 13,100 juvenile alewives were impinged and presumed to have died. | Natural reproduction is the exclusive means by which the lost alewives will be replaced, and no restocking is recommended. However, we do recommend a measure of habitat rehabilitation. To improve the passage of spawning-run alewives in local streams, we recommend that BECo help fund the repair of fish ladders in the Pilgrim Station area. |
| Atlantic silverside | An estimated total of 11,900 Atlantic silversides were impinged in 2 separate incidents at PNPS, occurring in late November and late December 1995. | No compensatory action was taken because the Atlantic silverside is a short-lived, prolific species. |

equivalent adults lost to the population. We estimated population size in 1995 (123,831 adults) by an area swept approach (density extrapolation) using a bottom trawl. We do not know if we sampled the entire spatial range of the local population and, thus, may have underestimated total abundance; consequently, the impact of the power plant might be overestimated. In 1995, we estimated population abundance by expanding the average fish density obtained by trawl over the study area. This equates to entrainment losses of 7% of the possible adults in the area. Several years of capture-recapture data will be necessary to generate an independent estimate of population size because of the low numbers of winter flounder at the present time.

In 1994, there were two large impingement incidents of Atlantic silversides at Pilgrim Station: 28-29 November - 5,800 fish and 26-28 December - 6,100 fish. No mitigative action was taken because the Atlantic silverside is a prolific annual species and has no commercial or recreational value.

A relatively high impingement incident of alewives (*Alosa pseudoharengus*) occurred at Pilgrim Station 8-9 September 1995, when an estimated 13,100 individuals died on the Intake screens. The alewife is an important anadromous fish that is used as bait for the lobster fishery and by recreational fishermen, while its roe and flesh are used for human consumption. Employing a special publication of the American Fisheries Society (1992), we assessed the monetary valuation of the fish kill to be about $5,000.00. The Division of Marine Fisheries is negotiating with Boston Edison Co. for this sum of money to be transferred to the Division to be used for habitat rehabilitation, i.e., the money would go toward rebuilding or repairing river herring fish ladders in the local area.

V. CONCLUSIONS

Cunner

1. Annual impingement rates have been relatively low since 1980, when an estimated 1,683 cunner were impinged; impingement in 1995 totaled ~288 fish.
2. Large numbers of cunner eggs and larvae are entrained at Pilgrim Station. In 1995, the number entrained was calculated to equal ~970,000 adult fish lost from the local population.
3. Stressful high water temperatures cause cunner to avoid the area of the discharge canal and near-thermal plume during late summer/early fall.
4. The effluent at the Station is of sufficient velocity to cause a small-scale shift in the distribution of cunner by size, with only larger cunner residing in the path of the discharge current, when observed at flood tide.
5. No cunner were reported to be caught by anglers at the Pilgrim Station Shorefront in 1995; however, this is likely due in part to incomplete reporting.
6. The tagging of 2,133 cunner this year and subsequent recapture data confirm that this species is sedentary and shows high reef fidelity.
7. Schumacher-Eschmeyer closed model population estimates for the tagging sites varied in precision, with the estimates for the Intake being similar for 1994 and 1995. This is likely related to the limited spatial scale of the area sampled there and resultant high sampling intensity. Of the Jolly-Seber open model population estimates only recapture data at the White Horse site fit the model, and then only marginally.
8. A total of 379 cunner (selected sample) from the Pilgrim area was

aged, with fish ranging from one to ten-years old. Cunner fecundity at age and fecundity at length relationships were established using the ageing results.

## Rainbow Smelt

1. High impingement incidents of smelt occurred at Pilgrim Station in December of 1978, '93, and '94. For the last three years (1993-1995), smelt impingement at the power plant was estimated to total about 22,500 fish, which is a substantial loss to the local population.
2. To partially compensate for a large impingement of rainbow smelt that occurred at Pilgrim Station in 1993, we stocked 1.2 million smelt eggs in 1995 into the Jones River, a tributary to the Plymouth, Kingston, Duxbury Bay estuary, where the local population is assumed to originate. This measure augmented instream egg production.
3. To enhance the quality of spawning habitat on the Jones River, we employed artificial substrate with three-dimensional surface area. Specially-designed egg-collecting trays filled with sphagnum moss, that were placed into the Jones River, increased the collection of eggs spawned on good habitat, so as to maximize egg survival.

## Winter Flounder

1. The nearby location of winter flounder spawning (retention) grounds, the relatively limited movement patterns of flounder north of Cape Cod, and the apparent discreetness of the local population make this species especially sensitive to impacts from entrainment and impingement at Pilgrim Station.
2. In late summer, water temperatures in the immediate vicinity of

Pilgrim Station's thermal discharge can exceed the upper thermal tolerance (26.5° to 28°C) for winter flounder and would exclude them from this relatively small [< 4,047 $m^2$ (1 ac)] area of stress.

3. The winter flounder stock north of Cape Cod has been overexploited by commercial and recreational fishing.

4. In 1995, an estimated 16.4 million winter flounder larvae were entrained at Pilgrim Station, which equates to the equivalent loss of 9,879 age-3 winter flounder from the local population.

5. In 1995, an estimated 1,326 winter flounder were impinged at Pilgrim Station; the majority were juveniles. Impingement is not considered as significant a source of mortality as entrainment.

6. Only 11 juvenile winter flounder were sampled during our 1995 seine survey directed at age-0 winter flounder. Density estimates obtained by snorkelers visually sampling along transects of known area also were low. There were not large numbers of juvenile winter flounder residing in the shallow inter-tidal areas of the Plymouth, Kingston, Duxbury Bay estuary.

7. We tagged 2,266 winter flounder in 1995, obtaining 24 recaptures during our sampling operations. In 1995, we also have obtained 78 tag returns from commercial and recreational fishermen. Our recovery rate is hampered by the relatively small number of tagged fish for the size of the area and the sporadic reporting of tagged fish. In 1996, we again will contract a fishing vessel to tag even larger numbers of winter flounder.

8. We estimated by density extrapolation that in the Pilgrim study area (Figure 1) in spring 1995, winter flounder numbered 123,831 adults (≥ 280 mm TL). It is noted, however, that precision of the estimate was not high.

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FINAL
SEMI-ANNUAL REPORT
Number 47

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

January-December 1995

to

BOSTON EDISON COMPANY
Regulatory Affairs Department
Pilgrim Nuclear Power Station
Plymouth, Massachusetts 02360

From

ENSR
89 Water Street
Woods Hole, MA 02543
(508)457-7900

1 April 1996

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## EXECUTIVE SUMMARY

This report presents results of qualitative surveys taken in 1995 of benthic algae in the area affected by thermal effluent from the Pilgrim Nuclear Power Station (PNPS), and summarizes the impact of the PNPS on algal distributions near the discharge canal. Field studies for 1995 were confined to qualitative transect surveys used to map algal cover in the area of water outflow and were conducted in early May, late June, and October 1995 and February 1996. These investigations constitute the most recent phase of long-term monitoring of thermal effluent effects on benthic algal communities within and just offshore of the PNPS discharge canal. Field survey techniques remained identical to those used in prior years.

The qualitative transect studies performed to evaluate the *Chondrus crispus* (Irish moss) community in the thermal plume area indicated that in May and June 1995 the size and appearance of the denuded and total affected areas was similar to that seen in years prior to 1995 when the power plant was in full or nearly full operation. The denuded area (1198 $m^2$) measured on May 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), and, thus, was unaffected by the power outage which had been in effect for only the month of April. A dense population of newly settled mussels (*Mytilus edulis*) similar to that seen in the June 1990, 1992, and 1994 surveys was also observed in June 1995. Damage to *Chondrus* plants from extensive mussel settlement appears related to an increase in area of denuded and total affected *Chondrus* zones between the spring and summer surveys and indeed, by June, the denuded zone had increased 17% to 1405 $m^2$; again a size well within the range seen in previous summer surveys. However, in October 1995, the areas encompassed by the denuded (2043$m^2$) and total affected zones (2348 $m^2$) were larger than had been seen in any survey since 1983 (previous maxima from autumn surveys were a denuded area of 1648 $m^2$ in Sept. 1993 and a total affected area of 1908 $m^2$ in Sept. 1992). Likewise, in February, the areas of the denuded zone (1961 $m^2$) and total affected area (2328 $m^2$) were larger than in any prior winter inspection, although as in both earlier February surveys, they were smaller than the previous fall.

A two-month power plant outage (April and May) was followed by five months averaging a high monthly capacity factor of 89.9% just prior to the fall survey, and nine months averaging a very high monthly capacity factor of 93.3% by the time of the winter survey. The short spring power outage appears to have had little effect on the size of either the denuded or total affected *Chondrus* zones probably due to the lag period between plant shutdown or startup and noticeable recovery or impact (BECo, 1986). On the other hand, the high plant capacity in effect since June 1995, in combination with high mussel settlement, may have contributed to the largest denuded and totally affected *Chondrus* zones observed since the present monitoring regime began in December 1982.

## 1.0 INTRODUCTION

The presence of hundreds of square meters of seafloor where the normally abundant red alga species *Chondrus crispus* (Irish Moss) 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, particularly *Chondrus crispus*, in the nearfield discharge area.

This report represents a continuation of long-term (22 yr) benthic studies at Pilgrim Nuclear Power Station (PNPS) designed to monitor the effects of the thermal effluent. The 1995 monitoring program was identical to those performed since 1992 and involved qualitative SCUBA surveys of algal cover in the nearfield thermal plume of the effluent, within and beyond the discharge canal (Figure 1), that were planned for March, June, September, and December. Currently, no quantitative assessments of benthic algae or fauna are being performed. This Semi-Annual Report includes qualitative observations recorded in early May, late June, and October 1995 and February 1996 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 LSP003397 in accordance with requirements of the PNPS NPDES Permit No. MA 0003557.

PNPS is a base-load, nuclear-powered electrical generating unit designed to produce 670 megawatts of electrical energy when operating at full capacity. The condenser is cooled by water withdrawn from Cape Cod Bay and subsequently 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) by warming ambient waters, 2) through chemical discharge (mainly $Cl_2$), and, 3) by scouring of the seabed by the rapid flow regime. 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 rock surfaces to become barren and devoid of macroscopic marine life.

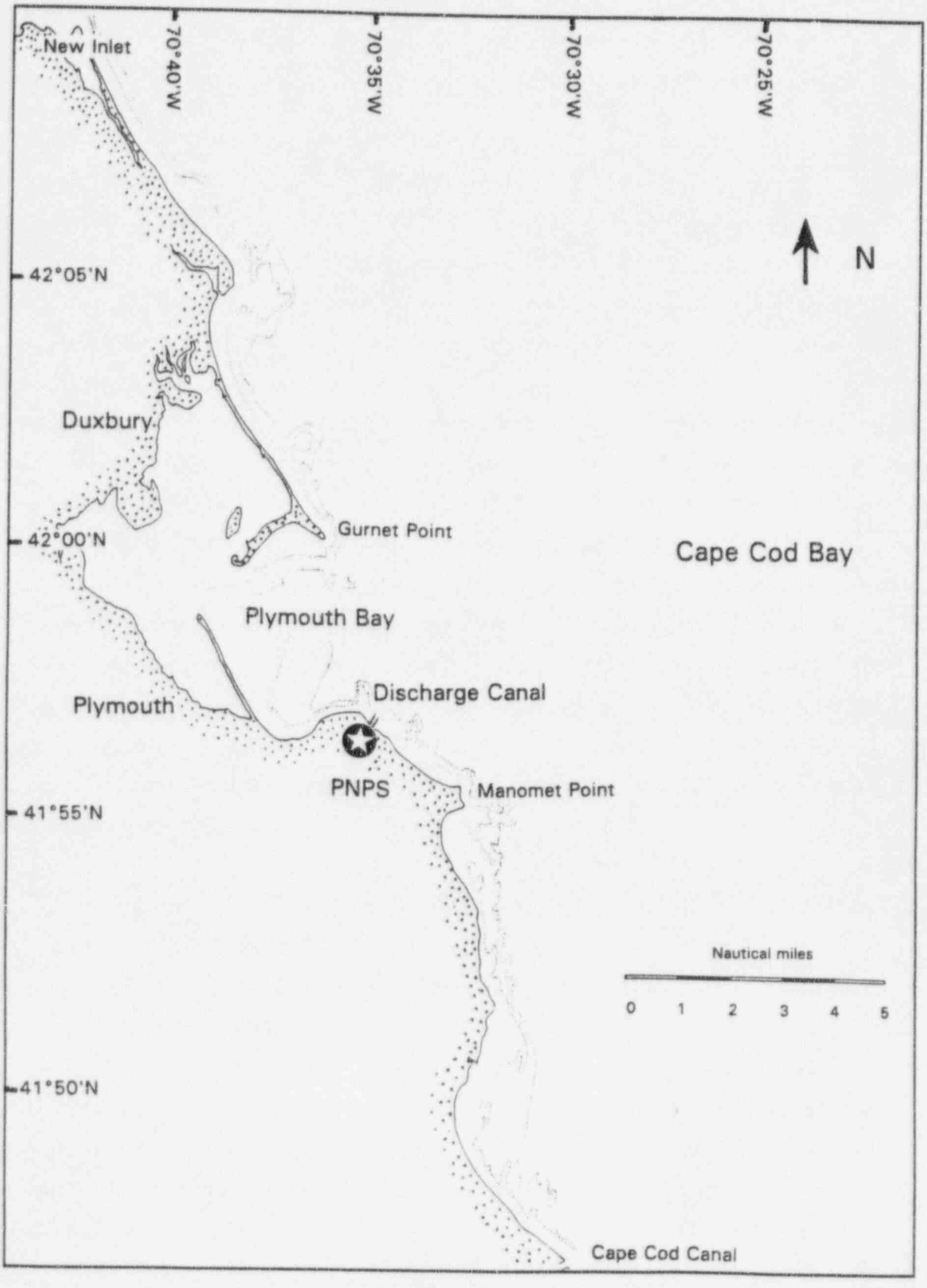


Figure 1. Location of Pilgrim Nuclear Power Station Discharge Canal.

# 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 14 years ago. The effluent area is surveyed by two or three SCUBA-equipped biologists operating from a small boat. Up until the latest winter survey the divers have been able to launch their boat from the regular fisherman's launching site within the PNPS facility. Because this area has been scoured by winter storms, leaving a jumble of large rocks, the divers located an alternate boat launching site, Priscilla Beach, about one mile south of the PNPS, which they used in February 1996. 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, sparse, 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 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.

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

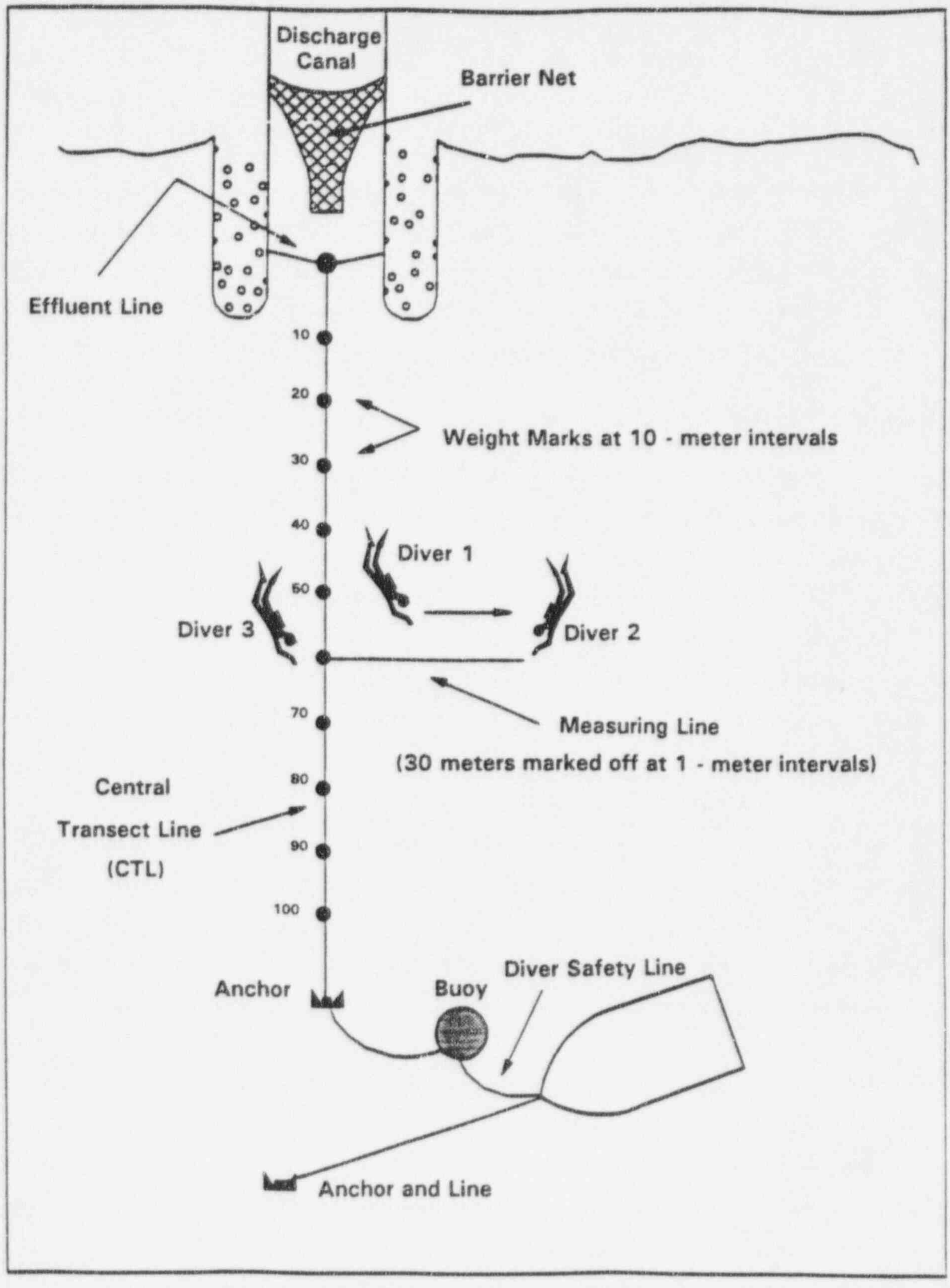


Figure 2. Design of the Qualitative Transect Survey.

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.

Beginning in 1996 Quarterly Progress reports will be submitted to Boston Edison Company. These reports will present the areal results of the most recent SCUBA survey and summarize previously measured maximal sizes of *Chondrus* denuded and totally affected zones for each season. Particular attention will be paid to changes in the sizes of impacted regions that exceed earlier results by more than 15%.

## 2.2 RESULTS

Qualitative transect surveys of acute nearfield impact zones began in January 1980 and have been conducted quarterly since 1983. Four surveys were performed (May 2, June 30, October 11, 1995 and February 21, 1996) during the current reporting period, bringing the total number of surveys conducted since 1980 to 60. 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 1994, including a review of the four performed in 1994, was presented in Semi-Annual Report No. 45 (BECo, 1995). The present report summarizes the early May and late June 1995 surveys and presents detailed results of the October 1995 and February 1996 surveys.

Figures 3 to 7 show the results of the 1995 transect surveys performed by SCUBA divers. The denuded zone is essentially devoid of *Chondrus crispus* while the sparse zones are those in which normal looking *Chondrus* is sparsely distributed. In 1995, the divers did not delineate any *Chondrus* regions as "stunted". Dislodged jetty boulders encountered by the divers along their transects are indicated. 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 MAY 1995 TRANSECT SURVEY

The denuded and sparse *Chondrus crispus* areas mapped on May 2, 1995, immediately offshore of the PNPS, are shown in Figure 3. The denuded region extended 84 m along the transect line and, as often seen before, was asymmetrically distributed with 65% of the denuded area north of the line. The *Chondrus* denuded area was 1198 $m^2$ in May while the sparse *Chondrus* zone covered 450 $m^2$ for a total affected area of 1648 $m^2$. The sparse *Chondrus* zone in May 1995 was double that seen in April 1994 but still fell well within the range (90 - 901 $m^2$) encountered during prior spring surveys. The total affected area (1648 $m^2$) was slightly smaller than in February 1995 but was larger than in any previous spring survey since March 1984. Other algae seen included the warm water indicator, *Gracilaria*, near the discharge canal and a cold

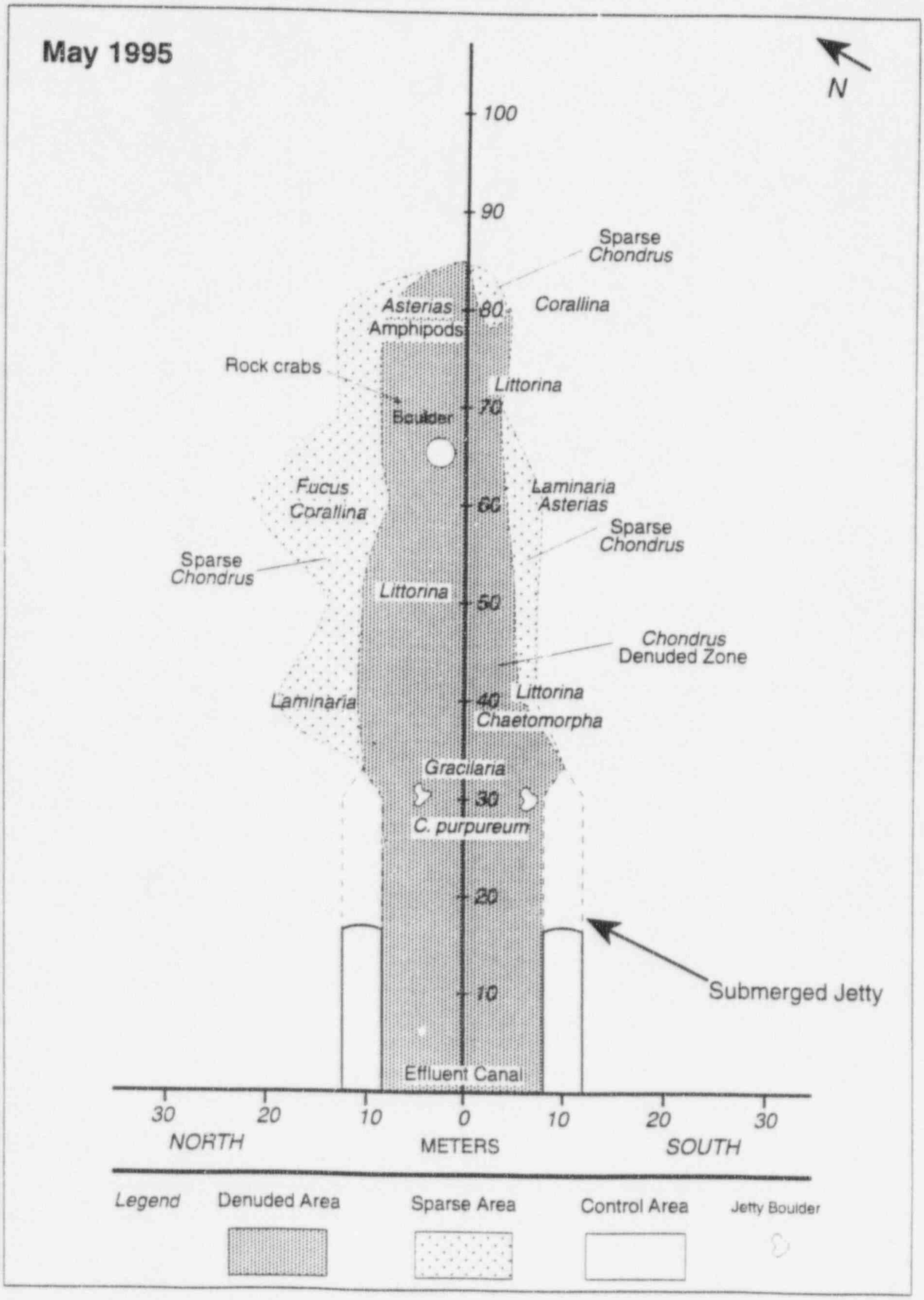


**Figure 3.** Denuded and Sparse *Chondrus* Zones Observed in May 1995.

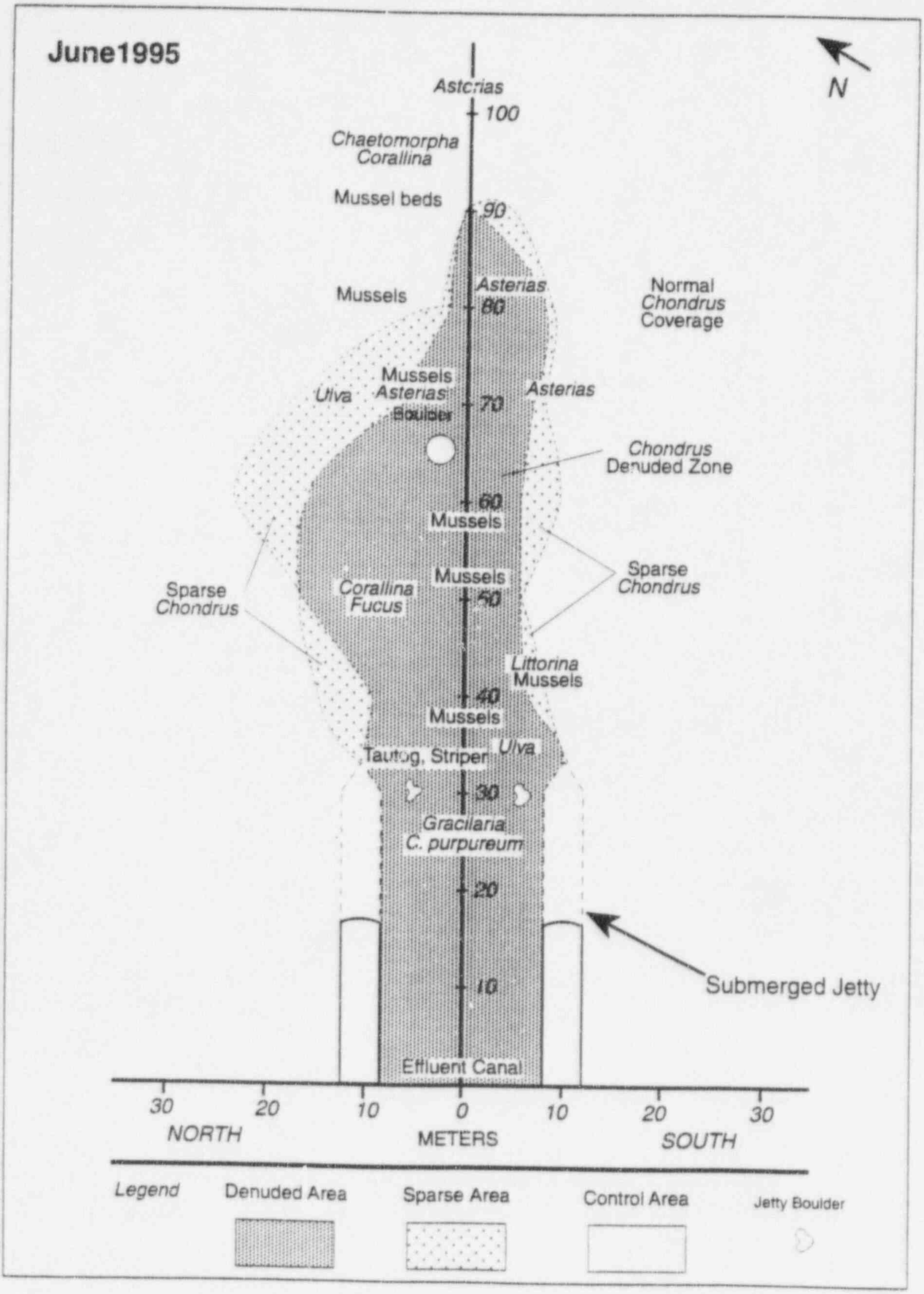


**Figure 4.** **Denuded and Sparse *Chondrus* Zones Observed in June 1995.**

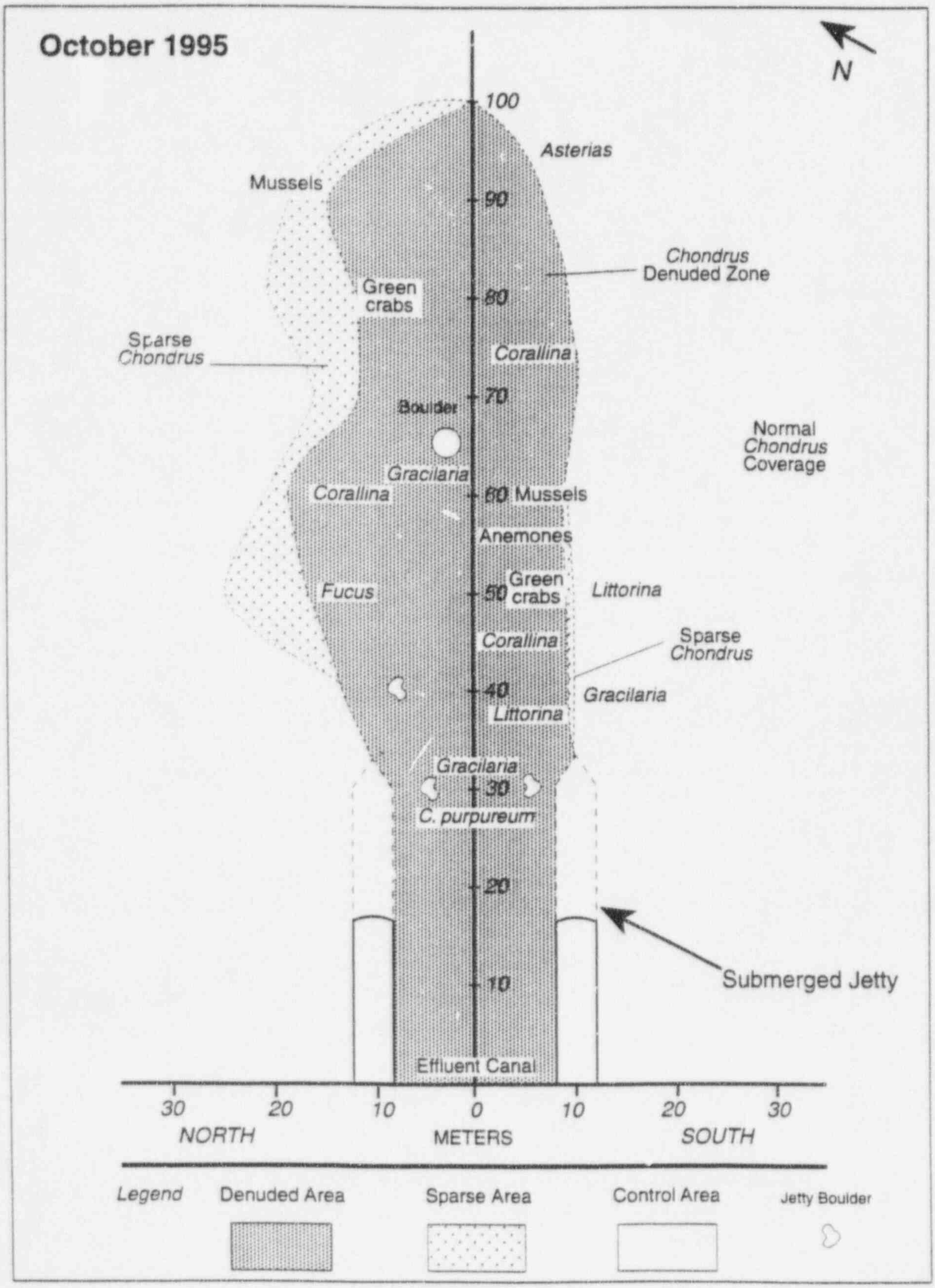


Figure 5. Denuded and Sparse *Chondrus* Zones Observed in October 1995.

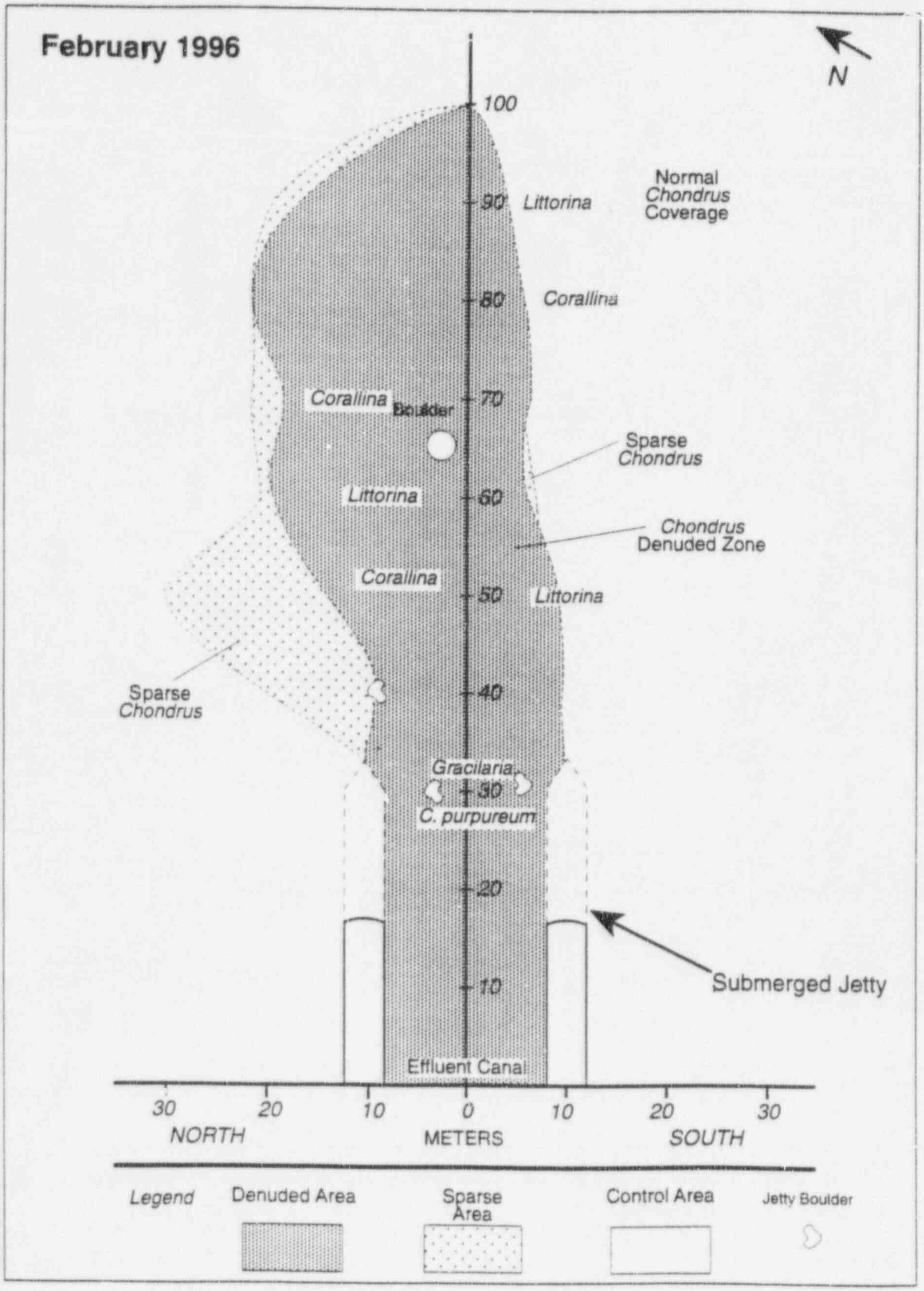


**Figure 6.** **Denuded and Sparse *Chondrus* Zones Observed in February 1996.**

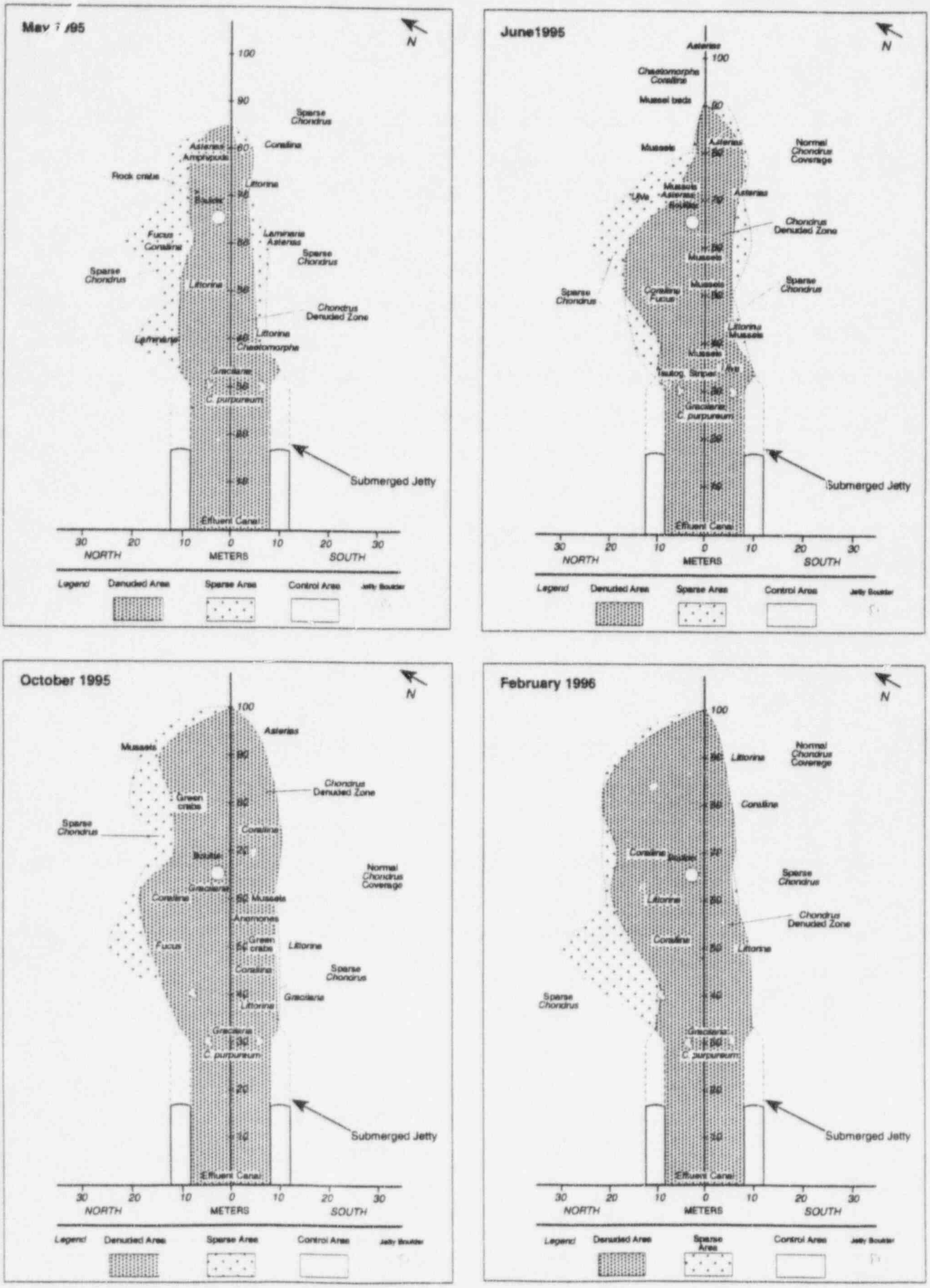


Figure 7. **Results of the 1995 Qualitative Transect Surveys of the PNPS Acute Impact Zone off the Discharge Canal taken in May, June, and October 1995 and February 1996.**

water indicator, the kelp *Laminaria*, further offshore. Invertebrates included: a low density of blue mussels, *Mytilus edulis*, and their starfish predators, *Asterias forbesi;* snails, *Littorina littoria;* and two species of crab, *Cancer irroratus* and the common green crab, *Carcinus maenas*. No fish were seen.

## 2.2.2 JUNE 1995 TRANSECT SURVEY

Results of the divers' survey for June 30, 1995 are mapped in Figure 4. The *Chondrus* denuded zone (1405 $m^2$) extended 90 m along the central transect line and was larger than that measured two months earlier, in May 1995, and than seen in June 1994. The sparse *Chondrus* area (367 $m^2$) was smaller than in early May 1995 but larger than in June 1994. Both the denuded and sparse *Chondrus* zones contributed to the asymmetrical distribution of the entire affected area. The total affected area (1772 $m^2$) was slightly larger than in May 1995 and midway in areal dimension between the affected area in June 1993 (2058 $m^2$) and June 1994 (1472 $m^2$). Sea lettuce, *Ulva lactuca*, was common and along with *Gracilaria* and *Chaetomorpha purpureum*, dominated the flora at the head of the effluent canal. Rockweed, *Fucus*, was present but kelp, *Laminaria*, was not observed. A dense array of juvenile blue mussels (*Mytilus edulis*), similar to that seen in prior June surveys was present from the 40-m mark seaward. Two winter flounder (*Pleuronectes americanus*), one tautog (*Tautoga*) and one striped bass (*Morone saxatilis)* were seen.

## 2.2.3 OCTOBER 1995 TRANSECT SURVEY

Figure 5 shows the results of the transect survey conducted on October 11, 1995. The denuded zone extended just to the 100-m mark on the transect line. As has been often seen in the past, the denuded zone was asymmetrical around the transect line, with more of the area north (64%) of the line than south (36%) of the line. The greatest lateral extent of the denuded zone was more than 19 m to the north of the transect line at the 60-m mark. The area (2043 $m^2$) of the denuded zone was much larger than that measured in June 1995 (1405 $m^2$) or than seen in the previous fall survey (1208 $m^2$, BECo, 1995). Indeed, the denuded zone in Oct. 1995 was the largest ever seen since the current series of observations (1983-1995) were initiated.

The area of the sparse *Chondrus* zone was 305 $m^2$ in October, slightly smaller than the sparse area (367 $m^2$) measured in June and half that seen in Oct. 1994. The total affected area seen in October was 2348 $m^2$, which, paralleling the very large denuded zone, was the largest total affected area measured during the current series (1983-1995) and thus well outside the range (1003 $m^2$ to 1908 $m^2$) seen in prior autumn surveys when the plant was in full operation.

Despite the large set of mussels observed in June, by October only thin, isolated patches remained. A few mussels were seen south of the transect line from the 50-m to 60-m marks. Very few starfish (*Asterias forbesi*) were seen because of the very low density of their prey, mussels. Other invertebrates included: snails (*Littorina littorea*), rock crabs (*Cancer irroratus*), a moderate number of green crabs (*Carcinus maenus*), and many unidentified juvenile anemones around the 60-m mark. Only one demersal fish, a winter flounder (*Pleuronectes americanus*), was observed during the entire survey, although striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*) were being caught off the jetties.

As usual, the algal species seen within the discharge canal were *Gracilaria* spp., and *Cystoclonium purpureum*. The warm water alga, *Gracilaria* spp., was the dominant plant species occurring close to the central transect line out to the 70-m mark. Rockweed (*Fucus* sp.) co-occurred with the encrusting red alga, *Corallina*, from the 40-m to the 60-m mark, 10 to 20 meters north of the transect. The only other named species of alga was *Chaetomorpha linum* growing north of the transect line between the 70-m and 90-m marks.

### 2.2.4 FEBRUARY 1996 TRANSECT SURVEY

The results of the 1995 winter dive, performed on February 21, 1996, are mapped in Figure 6. The denuded zone extended beyond the 90-m but not quite to the 100-m mark on the transect line. The shape of the mapped denuded zone was highly asymmetrical around the transect line with 70% of the area north of the line and 30% south of the line. The greatest lateral extent of the denuded zone observed by the divers extended 22 m north of the transect line at the 80-m mark (the full transect north of the 40-m mark was not extended beyond boulders encountered at about 9 m from the CTL). The area (1961 $m^2$) of the denuded zone decreased only slightly from that seen in October and was larger than observed in any earlier winter survey conducted when the power plant was in full operation (29% larger than the previous winter maximum denuded zone area of 1523 $m^2$ measured in December 1993) .

The area inhabited by sparse *Chondrus* (367 $m^2$) was only slightly larger than that measured in October 1995 (305 $m^2$) and like the denuded zone was arranged asymmetrically around the central transect line with nearly all (98%) of the area north of the line, especially in a northward bulge at the 50-m mark. Indeed, the divers reported that they had not yet reached a normal *Chondrus* zone by the end of their 30-m transect. The total affected area (2328 $m^2$) in February 1996 was slightly smaller than measured in October 1995 (2348 $m^2$) but larger than seen in any prior winter survey (previous maximum was 2243 $m^2$ in December 1993), when the plant was in full operation.

*Gracilaria* and *Cystoclonium purpureum* were present at the head of the effluent canal. *Gracilaria* was seen near the transect line to the 50-m mark north of the transect. *Corallina officinalis* was the most abundant alga seen and was present from 50 meters to the end of the transect line. No *Laminaria* were observed. The divers reported a paucity of benthic vegetation. Snails, *Littorina littorea*, were extremely abundant throughout the entire area surveyed. In contrast, only one blue mussel, *Mytilus edulis*, was seen and consequently, the starfish, *Asterias forbesi*, that feed on the mussels were reduced in number. No crustaceans or fish were seen.

The divers reported further deterioration of the south jetty from winter storm activity. More stones have been dislodged from the jetty and were found lying on the bottom. The haphazard locations of these various boulders cause some confusion to the divers' sense of location as they swim out laterally from the central 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 sometimes less obvious but the sparse zones observed in 1995 were delineated with no difficulty. In early May and late June 1995, the areas of the denuded and total affected zones were well within those seen previously (1983, 1985, 1989-1994) when the power plant was in full or nearly full operation. The two-month spring power plant outage (April and May) appears to have had little effect on the area of either the denuded zone or the totally affected region observed in the May or June survey. This is in agreement with the known six to nine month delay in response of the acute impact zone to changes in thermal effluent discharge (BECo, 1986). In June 1995, a dense mussel mat, similar to those seen in June 1990, 1992, 1993, and 1994 was seen. The areas of the denuded and totally affected zones were greater in June than they had been in April, the usual trend when early summer growth of *Chondrus* is adversely affected by high mussel settlement.

In contrast, the areas of the denuded and totally affected zones in October and February were the largest recorded since the quarterly surveys began in 1983. The high plant capacity in effect since June 1995, in combination with high mussel settlement, may have contributed to the large size of the *Chondrus* affected regions. The direction of change (decrease) seen in size of the denuded and totally affected zones between the October and February surveys has been seen in earlier surveys (1990, 1992, and 1994) although this is not always the case.

## 3.0 IMPACT OF EFFLUENT DISCHARGE AT PNPS ON ALGAL DISTRIBUTION

### 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 high 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 8). 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 resumed electrical generation at full operating capacity, with the consequent thermal discharge and consistent use of one or both circulating pumps, assessed 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 conducted through 1991. In 1992, community studies of the benthic algae and fauna were discontinued. From 1992 through 1995, the monitoring program consisted of seasonal qualitative surveys of the discharge area.

PNPS operated at high capacity in 1995. Figure 8 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 and approximates thermal loading to the marine environment. A maximum MDC value of 100% equates to the highest allowable change in ambient temperature for water discharged to Cape Cod Bay (18°C$\Delta$T). In 1995, the monthly maximum dependable capacity factor was greater than 94% for 8 months, between 53% and 75% for 2 months, and was 0% for 2 months. These monthly capacity factors resulted in an annual capacity factor of 76.4% for 1995, an amount exceeded in only three previous years (1983, 1985, and 1992) since 1980. In addition, both pumps were in operation for 10 months of the year; for most of April no pumps were operating, and in May only one pump operated.

### 3.2 QUALITATIVE TRANSECT SURVEYS: 1983-1995

Results of the qualitative transect surveys from 1983 through 1995 are summarized in Figure 9. A detailed enlargement showing the most recent 7 years (1989 - 1995) is presented in Figure 10. The total acute impacted area (denuded and sparse), the area of the denuded zone only, and the monthly PNPS

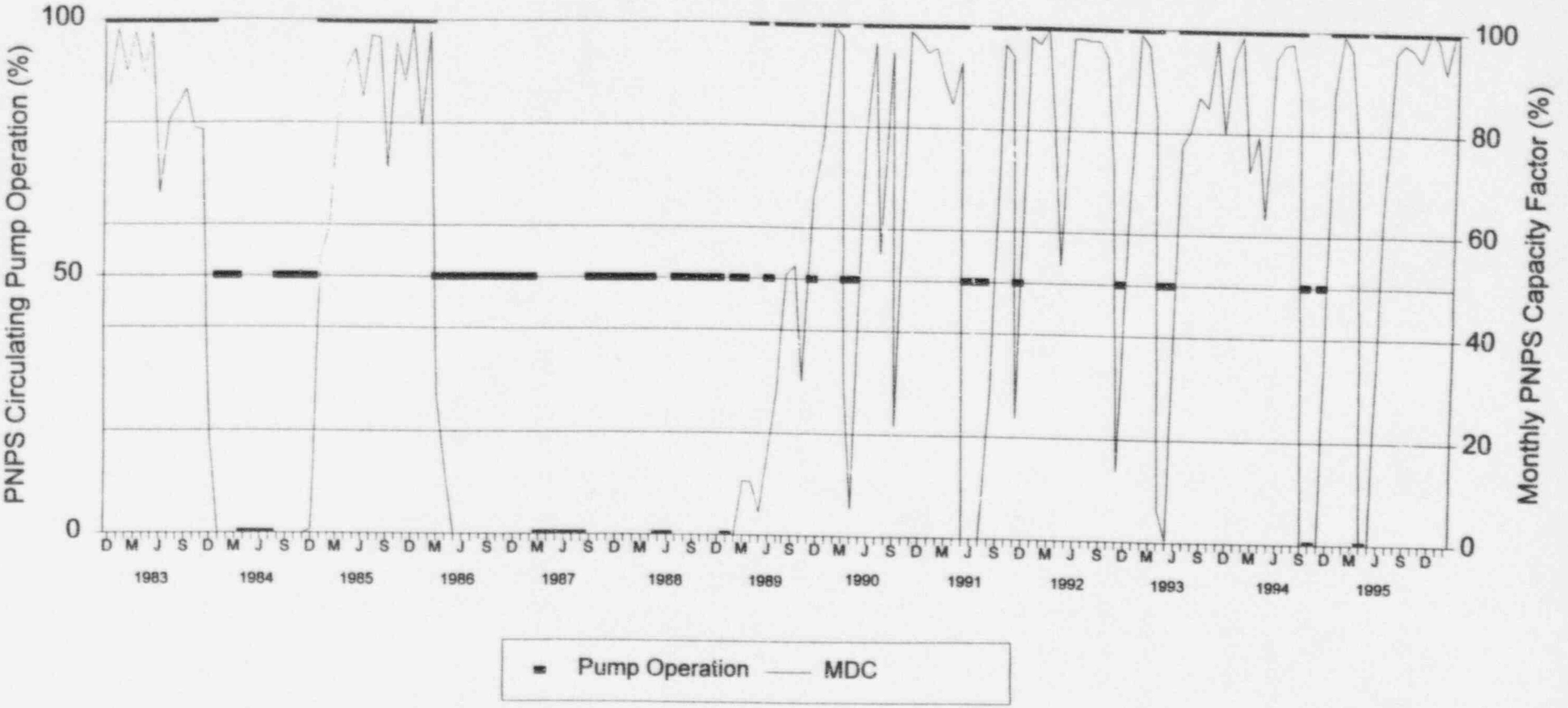


**Figure 8.** **Monthly PNPS Capacity Factor (dashed lines) and Circulating Pump Activity (black bars at 100% = 2 pumps; at 50% = 1 pump; at 0% = 0 pumps) Plotted for the Period 1983 Through 1994.**

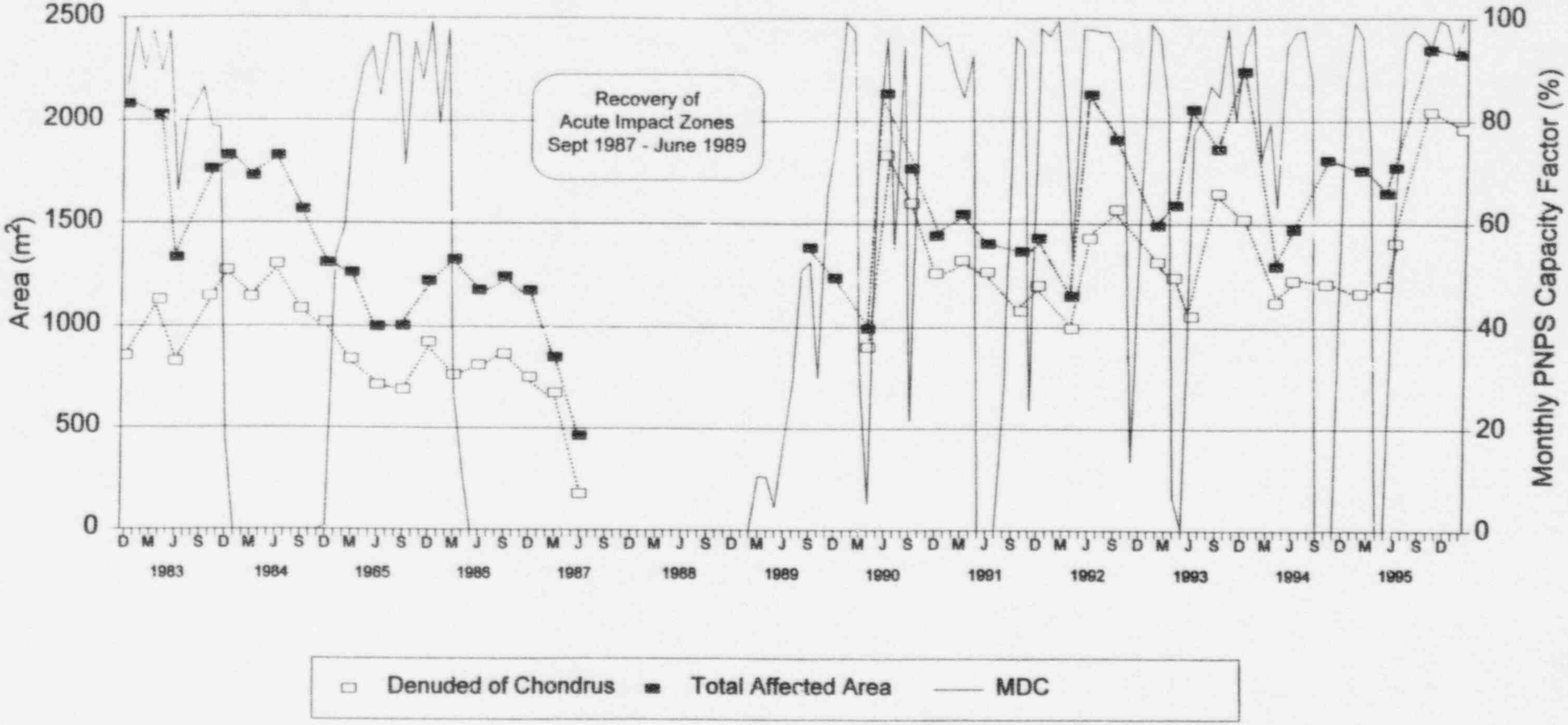


**Figure 9.** **Area of the Denuded and Totally Affected Zones in the Vicinity of the PNPS Effluent Canal Plotted with the Monthly PNPS Capacity Factor (MDC) for the Period 1983 Through 1995. No area measurements were made from September 1987 through June 1989 because definitive demarcations of denuded and stunted zones were absent.**

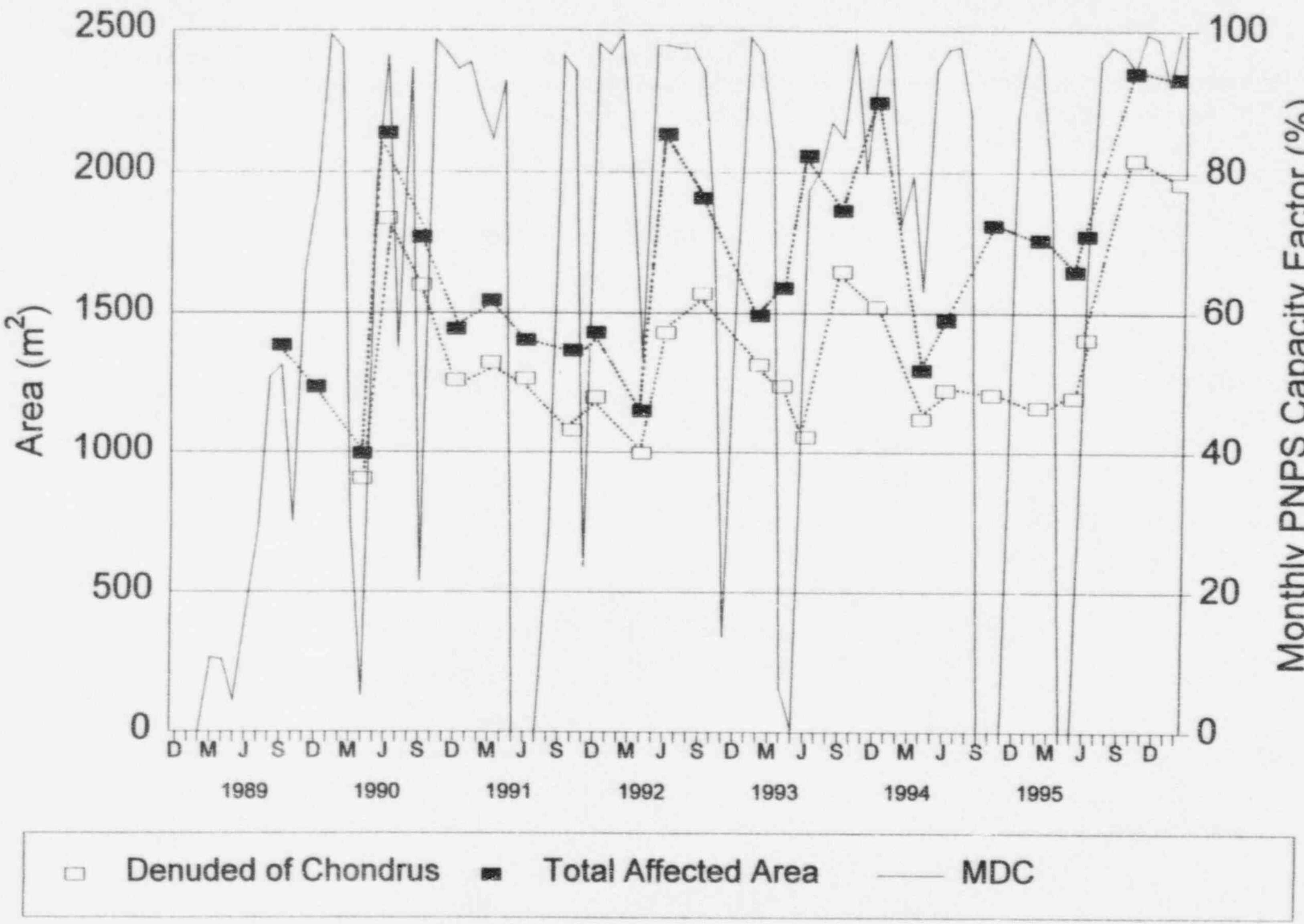


**Figure 10.** **Area of the Denuded and Totally Affected Zones in the Vicinity of the PNPS Effluent Canal Plotted with the Monthly PNPS Capacity Factor (MDC) for the Period 1989 Through 1995.**

capacity factor (MDC) are plotted. The difference between the denuded and total acute impact zones represents the sparse 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 in response to the absence of thermal discharge and reduced circulating water pump operation 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 and normal circulating pump operation. These results confirmed a delay of 6-9 months between the causal factors (cessation or resumption of thermal effluent discharge and pump operation) and associated responses (decrease or increase in size of the acute impact zone). In 1987, in response to the 1986-1987 outage, 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 large size reduction of the denuded zone between December 1986 and June 1987 was primarily the result of the shutdown of the circulating water pumps in late February 1987 that continued throughout the spring (BECo, 1988). Apparently, water current scouring is a greater stress to algal colonization than increased water temperature. Scouring denudes the substratum, whereas elevated temperature results in stunted growth (Bridges and Anderson, 1984).

In 1988, low circulating water pump activity caused few thermal loading and scouring effects. The 1988 transect surveys showed such an increase in recolonization of formerly denuded and stunted zones by *Chondrus*, because of the continuing outage, that divers could not detect zonal boundaries or make area measurements. In March and June 1989, divers were still unable to detect boundaries of 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 with 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 until more recently a correlation was made between the appearance of enormous numbers of juvenile mussels and the occurrence of large denuded and total affected zones. The divers did note remarkable numbers of juvenile mussels present during the June 1990 dive and thus the large affected zones result, at least partly, from damage suffered by the *Chondrus* plants due to the massive settlement of mussels.

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 the 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 no longer needs to be considered 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, the June mussel set that hampers *Chondrus* growth was not as dense as those that occurred in 1990 or 1992, so that the denuded zone was smaller in June than it had been in April, the opposite of the situation seen in 1990 and 1992 (BECo, 1994). The area of the denuded zone in September was slightly larger than it had been in September of 1990 and 1992, but the denuded zone in December was much larger than in previous years. In addition, the total affected area in December was the largest seen since 1983, rivaling the areas measured in the summers of 1990 and 1992; this may be partly due to the very early date (Dec. 2) of the survey and partly to damage imposed by a heavy infestation of the encrusting bryozoan *Membranipora membranacea*.

In 1994, the denuded and total affected *Chondrus* areas in all four seasons were similar in size to those found during prior surveys at times of full or nearly full power plant operation. The dense mussel settlement seen in June obscured the boundary between the denuded and sparse/stunted regions and damage caused by the mussels to the *Chondrus* plants contributed to the enlargement of both *Chondrus* zones between the April and June survey. The three-month fall power plant outage (September through November) appeared to have had no effect on the size of either the denuded or total affected *Chondrus* zone. In 1995, the sizes of the denuded and total affected *Chondrus* areas were within the ranges seen in earlier surveys only for the early May and late June surveys. The impacted areas measured in October 1995 and February 1996 were much larger than those measured during any earlier fall and winter survey and most closely approximated the impacted areas seen in September and December 1993. The two-month (April/May) spring power outage appeared to have no effect on the size of the *Chondrus* affected areas seen in May or June. However, the high plant operating capacity in effect from June 1995 through February 1996, in conjunction with a high mussel set in June, may have contributed to the largest denuded and totally affected *Chondrus* zones seen since the current monitoring program began in 1983.

## 4.0 CONCLUSIONS

- The sizes of the denuded and total affected *Chondrus* areas of the acutely impacted region in early May and late June were similar to those observed in the same seasons during prior surveys at times of full power plant operation.

- The areas of the denuded and total affected zones were greater in June than they were in April, the trend usually observed when early summer *Chondrus* growth is adversely affected by high mussel settlement.

- The two-month spring power plant outage (April and May) appears to have had little effect on the size of either the denuded or total affected zone measured in May or June probably because of the recovery/impact delay period of 6 to 9 months noted in previous years.

- The high plant capacity in effect from June 1995 through February 1996, in combination with high mussel settlement in June, may have contributed to the largest denuded and totally affected *Chondrus* zones measured since the present monitoring program began in 1983.

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# ICHTHYOPLANKTON ENTRAINMENT MONITORING

# AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1995

Volume 1 of 2

(Monitoring)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

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*Available upon request.

## SECTION I

## EXECUTIVE SUMMARY


Sampling for entrained ichthyoplankton at PNPS followed the revised protocol begun in April 1994. In January, February, and October through December six single samples were taken each month. From March through September single samples were taken three times every week.

Over the course of the year a total of 42 species were represented in the collections, four more than the 20-year average of 38. Numerical dominants included American plaice, winter flounder, yellowtail flounder, sand lance, grubby, and rock gunnel during winter-early spring; tautog/cunner, mackerel, radiated shanny, fourbeard rockling, and cunner in late spring-early summer; and tautog/cunner, windowpane, hake, and Atlantic herring during late summer-autumn.

Multi-year comparisons indicated that Atlantic cod and rockling eggs were uncommon in 1995, a significant downward trend being apparent for both over the 1975-1995 time series. In contrast Atlantic mackerel, Atlantic herring, radiated shanny, and sand lance production appears to have been good in the PNPS area in 1995. In the case of tautog and cunner eggs and larvae, 1995 showed an increase in abundance compared with 1994. Overall a significant long-term upward trend was apparent for mackerel consistent with estimates of spawning stock biomass.

Extrusion studies with 0.333 and 0.202-mm mesh netting were repeated in 1995 to improve the data base for cunner eggs and larvae. Cunner eggs were more likely to be retained by the finer mesh, a ratio of 1.41:1 being obtained overall. Results for larval cunner were variable making conclusions difficult to reach. Summing densities of stage 1 and 2 larvae indicated they were essentially identical with the two meshes.

A single larval lobster was taken in 1995, bringing the 22-year total to 13.

## 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 1995. Work was carried out by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. LPS001616 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Department of Environmental Protection).

Program enhancements implemented in 1995 included conversion from 0.333 to 0.202-mm mesh from late March through late May to improve retention of early-stage larval winter flounder and collection of additional 0.202-mm mesh samples for larval cunner to supplement the mesh extrusion data base begun in 1994 (MRI 1995).

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

### Monitoring

Entrainment sampling at PNPS has historically been completed twice per month during January, February, October-December; weekly during March through September. Following a PNPS fisheries monitoring review workshop in early 1994, the sampling regime was modified beginning April 1994. In January, February, and October through December during two alternate weeks each month, single samples were taken on three separate occasions. Beginning with March and continuing through September single samples were taken three times every week. During autumn and winter months when sampling frequency was reduced, sampling was postponed during onshore storms, the delayed sample being taken during the subsequent week; six samples were ultimately taken each month.

To minimize costs, sampling was linked to the impingement monitoring schedule so that collections were made Monday morning, Wednesday afternoon, and Friday night regardless of tide. All sampling was completed with a 60-cm diameter plankton net streamed from rigging mounted approximately 30 meters from the headwall of the discharge canal (Figure 1). Standard mesh was 0.333-mm except from late March through late May when 0.202-mm mesh was employed to improve retention of early-stage larval winter flounder (*Pleuronectes americanus*). Sampling time in each case varied from 8 to 20 minutes depending on tide, higher tide requiring a longer interval due to lower discharge stream velocities. In most cases, a minimum

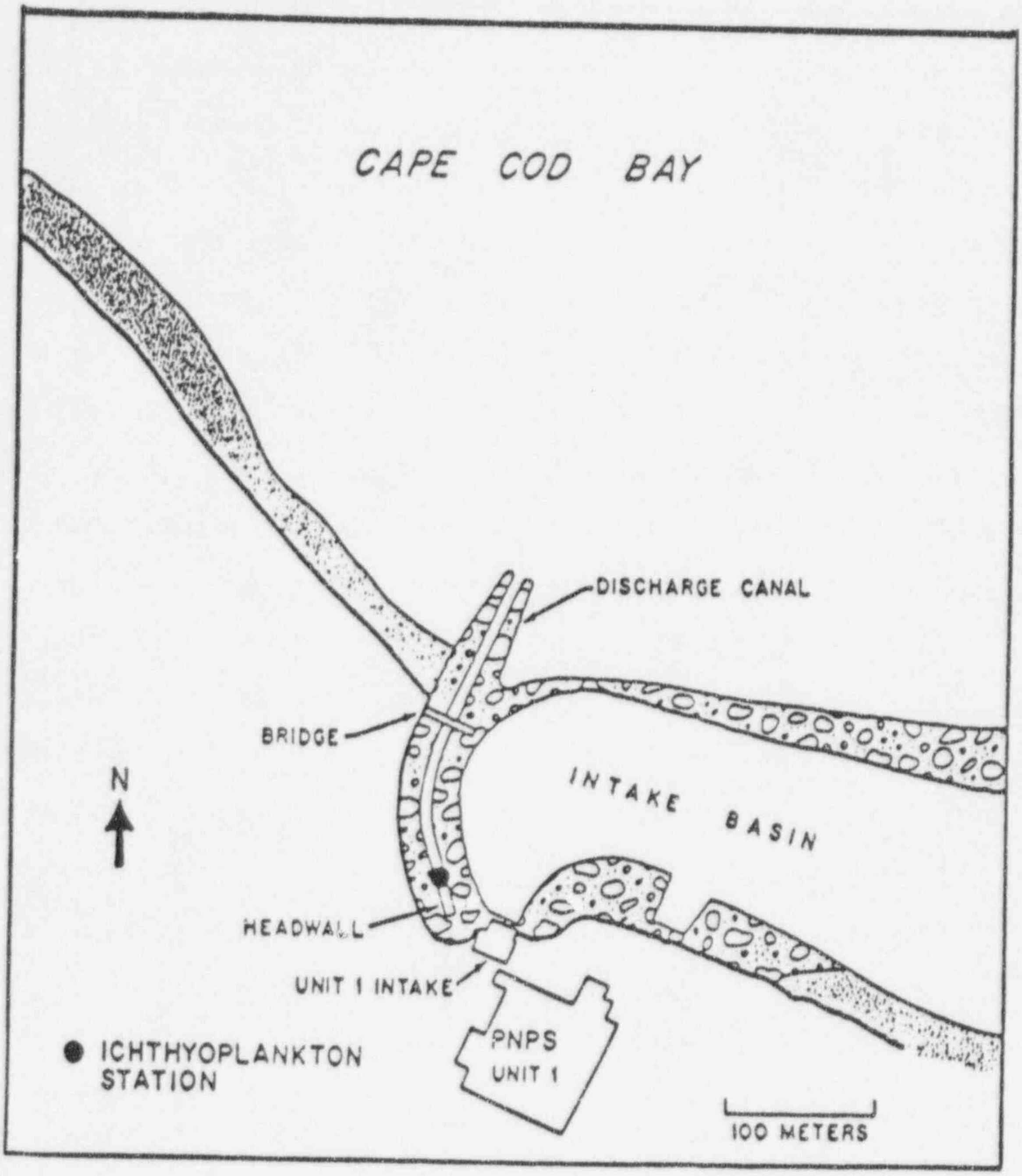


Figure 1. Entrainment sampling station in PNPS discharge canal.

quantity of 100 $m^3$ of water was sampled although at astronomical high tides it proved difficult to collect this amount even with long sampling intervals. Exact filtration volumes were calculated using a General Oceanics Model 2030R digital flowmeter mounted in the mouth of the net. Near times of high water a 2030 R2 rotor was employed to improve sensitivity at low velocities.

PNPS was taken out of service in late March for refueling and maintenance which lasted until early June. During this period only one of two main circulating water system pumps was in use on an intermittent basis. Sampling followed the above regime unless both pumps were out of service in which case no sample could be taken.

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). As in past years, larval winter flounder were enumerated in four developmental stages as follows:

Stage 1 - from hatching until the yolk sac is fully absorbed (2.3-2.8 mm TL).

Stage 2 - from the end of stage 1 until a loop or coil forms in the gut (2.6-4 mm TL).

Stage 3 - from the end of stage 2 until the left eye migrates past the midline of the head during transformation (3.5-8 mm TL).

Stage 4 - from the end of stage 3 onward (7.3-8.2 mm TL).

Similarly larval cunner (Tautogolabrus adspersus) were enumerated in three developmental stages:

Stage 1 - from hatching until the yolk sac is fully absorbed (1.6-2.6 mm TL).

Stage 2 - from the end of stage 1 until dorsal fin rays become visible (1.8-6.0 mm TL).

Stage 3 - from the end of stage 2 onward (6.5-14.0 mm TL).

Notification Provisions

When the Cape Cod Bay ichthyoplankton study was completed in 1976, provisions were added to the entrainment monitoring program to identify unusually high densities of fish eggs and larvae. Once identified and, if requested by regulatory personnel, additional sampling could be conducted to monitor the temporal and/or spatial extent of the unusual occurrence. An offshore array of stations was established which could be used 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. The impact attributable to any large entrainment event would clearly be greater if ichthyoplankton densities were particularly high only - close to the PNPS shoreline. In past years when high densities were identified, additional entrainment sampling was requested by regulatory personnel and the unusual density in most cases was found to be of short duration (<2 days). With the change in 1994 to Monday, Wednesday, Friday sampling the temporal extent of any unusual density can be more clearly discerned without additional sampling effort.

Until 1994 "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 to the current year. Restricting comparisons to monthly periods damped the large seasonal variation so readily apparent with ichthyoplankton. Starting with 1994 "unusually abundant" was redefined. On a month-by-month basis for each of the numerically dominant species all previous mean densities were examined and tested for normality following logarithmic transformation. For 1974-March 1994 replicates were first averaged. Beginning with April 1994 individual observations were added to the data base which will be updated each year. Where data sets (for example, mackerel eggs taken in June) fit the log-normal distribution, then "unusually large" was defined by the overall log mean density plus 2 or 2.58 standard deviations.* In cases where data sets did not fit the log-normal distribution (generally months when a species was frequently but not always absent, i.e., many zeros occurred), the mean and standard deviation was computed using the delta-distribution (see for example Pennington 1983). The same mean plus standard deviation guideline was applied.

The decision to rely on 2 standard deviations or 2.58 standard deviations was based on the relative importance of each species.

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*Normal distribution curve theory states that 2.5% of the measurements in a normally distributed population exceed the mean plus 1.96 standard deviations (= s, we rounded to 2 for simplicity), 2.5% lie below the mean minus 1.96 standard deviations. Stated another way 95% of the population lies within that range and 97.5% lies below the mean plus 1.96s. Likewise 0.5% of measurements exceed the mean plus 2.58s, 99% lie within the range of the mean ± 2.58s, 99.5% lie above the mean + 2.58s.

The more critical criterion was applied to species of commercial, recreational, or biological interest, the less critical to the remaining species (i.e., relatively greater densities were necessary to trigger notification). Species of commercial, recreational, or biological interest include Atlantic menhaden (Brevoortia tyrannus), Atlantic herring (Clupea harengus), Atlantic cod (Gadus morhua), tautog and cunner (the labrids; Tautoga onitis/Tautogolabrus adspersus), sand lance (Ammodytes sp.), Atlantic mackerel (Scomber scombrus), windowpane (Scophthalmus aquosus), American plaice (Hippoglossoides platessoides), and winter flounder. Table 1 provides summary data for each species of egg and larva by month within these two categories showing the 1995 notification level.

A scan of Table 1 will indicate that, in cases where the long-term mean amounts to 1 or 2 eggs or larvae per 100 $m^3$, the critical level is also quite small. This situation occurred during months when a given species was obviously uncommon and many zeros were present in the data set with an inherent small standard deviation. The external reference distribution methodology of Box et al. (1975) was also employed. This procedure relies on a dotplot of all previous densities for a species within month to produce a reference distribution. Densities exceeding either 97.5 or 99.5% of the reference set values were considered unusually high with this procedure.

Mesh Extrusion

To potentially improve enumeration of cunner eggs and larvae in PNPS entrainment samples, preliminary sampling was conducted in 1994 to see if eggs and young larvae are extruded through the standard 0.333-mm mesh netting. The smallest stage 1 larvae were not present in 1994 and slightly larger stage 2 larvae were uncommon. The limited data available suggested that substantial extrusion can occur. Therefore on three occasions in June 1995 collections were made in triplicate with both 0.333 and 0.202-mm mesh nets. Dates were selected based on previous samples and historical data to correspond to the likely period of occurrence of small, early-stage cunner. All samples were taken at low water when velocity and potential extrusion would be greatest, each collection six to eight minutes in duration. Nets were alternately attached to the rigging until six samples had been taken. Methodology followed that described for the routine sampling.

Table 1. PNPS ichthyoplankton entrainment notification levels for 1995 by species category and month. See text for details.

| Densities per 100 m³ of water: | Long-term Mean[1] | Mean + 2 std.dev. | Mean + 2.58 std.dev. |
|---|---|---|---|
| <u>January</u> | | | |
| LARVAE | | | |
| Atlantic herring[2] | 0.2 | 0.9 | |
| Sculpin | | | |
| Rock gunnel | 0.8 | | 1.4 |
| Sand lance[2] | 5 | 11 | |
| <u>February</u> | | | |
| LARVAE | | | |
| Atlantic herring[2] | 0.1 | 0.8 | |
| Sculpin | 2 | | 65 |
| Rock gunnel | 3 | | 99 |
| Sand lance[2] | 9 | 16 | |
| <u>March</u> | | | |
| EGGS | | | |
| American plaice[2] | 2 | 3 | |
| LARVAE | | | |
| Atlantic herring[2] | 0.9 | 1.3 | |
| Sculpin | 17 | | 608 |
| Seasnails | 0.6 | | 1 |
| Rock gunnel | 10.7 | | 723 |
| Sand lance[2] | 7 | 164 | |
| Winter flounder[2] | 0.4 | 0.7 | |
| <u>April</u> | | | |
| EGGS | | | |
| American plaice[2] | 3 | 32 | |
| LARVAE | | | |
| Atlantic herring[2] | 1 | 2 | |
| Sculpin | 15 | | 391 |
| Seasnails | 6 | | 10 |
| Radiated shanny | 3 | | 6 |
| Rock gunnel | 4 | | 142 |
| Sand lance[2] | 21 | 998 | |
| Winter flounder[2] | 7 | 12 | |
| <u>May</u> | | | |
| EGGS | | | |
| Labrids[2] | 36 | 3514 | |
| Mackerel[2] | 16 | 3405 | |
| Windowpane[2] | 9 | 147 | |
| American plaice[2] | 2 | 15 | |

Table 1 (continued).

| Densities per 100 m³ of water: | Long-term Mean[1] | Mean + 2 std.dev. | Mean + 2.58 std.dev. |
|---|---|---|---|
| May | | | |
| LARVAE | | | |
| Atlantic herring | 0.7 | 1.1 | |
| Fourbeard rockling | 2 | | 5 |
| Sculpin | 3 | | 4 |
| Radiated shanny | 7 | | 236 |
| Sand lance[2] | 22 | 32 | |
| Winter flounder[7] | 9 | 123 | |
| June | | | |
| EGGS | | | |
| Atlantic menhaden[2] | 4 | 6 | |
| Searobins | 3 | | 4 |
| Labrids[2] | 958 | 21599 | |
| Mackerel[2] | 63 | 3515 | |
| Windowpane[2] | 27 | 261 | |
| American plaice[2] | 1 | 2 | |
| LARVAE | | | |
| Atlantic menhaden[2] | 6 | 10 | |
| Fourbeard rockling | 9 | | 634 |
| Cunner[2] | 6 | 265 | |
| Radiated shanny | 1 | | 15 |
| Mackerel[2] | 50 | 83 | |
| Winter flounder[2] | 2 | 20 | |
| July | | | |
| EGGS | | | |
| Atlantic menhaden[2] | 2 | 4 | |
| Labrids[2] | 615 | 13349 | |
| Mackerel[2] | 9 | 16 | |
| Windowpane[2] | 12 | 156 | |
| LARVAE | | | |
| Atlantic menhaden[2] | 2 | 3 | |
| Tautog[2] | 2 | 2 | |
| Cunner[2] | 7 | 318 | |
| Mackerel[2] | 2 | 3 | |
| August | | | |
| EGGS | | | |
| Searobins | 4 | | 6 |
| Labrids[2] | 23 | 936 | |
| Windowpane[2] | 15 | 136 | |
| LARVE | | | |
| Fourbeard rockling | 6 | | 10 |
| Hake | 2 | 4 | |
| Tautog[2] | 1.6 | 2.2 | |
| Cunner[2] | 10 | 15 | |

Table 1 (continued).

| Densities per 100 m³ of water: | Long-term Mean[1] | Mean + 2 std.dev. | Mean + 2.58 std.dev. |
|---|---|---|---|
| September | | | |
| EGGS | | | |
| Labrids[2] | 2 | 3 | |
| Windowpane[2] | 11 | 159 | |
| LARVAE | | | |
| Fourbeard rockling | 4 | | 6 |
| Hake | 5 | | 9 |
| Tautog[2] | 1 | 2 | |
| Cunner[2] | 1 | 2 | |
| October | | | |
| EGGS | | | |
| Windowpane[2] | 1 | 2 | |
| LARVAE | | | |
| Atlantic menhaden[2] | 0.6 | 1 | |
| Fourbeard rockling | 1 | | 16 |
| November | | | |
| LARVAE | | | |
| Atlantic herring[2] | 4 | 8 | |
| December | | | |
| LARVAE | | | |
| Atlantic herring[2] | 2 | 3 | |

[1]Geometric or Delta Mean.

[2]Species of commercial, recreational, or biological interest for which more critical notification level will be used.

# SECTION IV

# RESULTS AND DISCUSSION

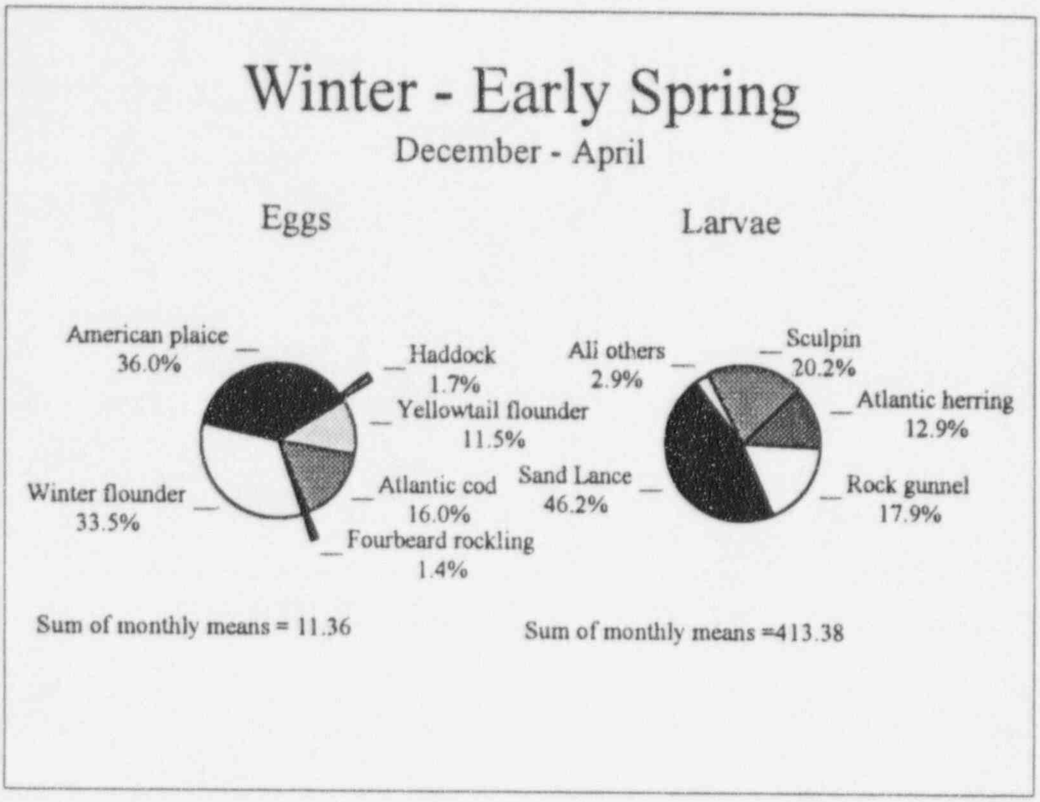
## A. Ichthyoplankton Entrained - 1995

Population densities per 100 $m^3$ of water for each species by sampling date in 1995 are presented in Appendix A (available upon request). Table 2 lists all species represented in the 1995 collections and indicates the months eggs and/or larvae of each species were found.

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 2 shows the dominant species of eggs and larvae and their percent contribution within each season for 1995.

### 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 increased from seven in January to eight in February, eleven in March and fifteen in April; December collections contained three species. Many species of fish spawning at this time of year employ a reproductive strategy relying on demersal, adhesive eggs which are not normally entrained. As a result, more species are typically represented by larvae than by eggs. Over the season as a whole, egg collections contained six species, American plaice , winter flounder, yellowtail flounder (*Pleuronectes ferrugineus*), and Atlantic cod contributing the



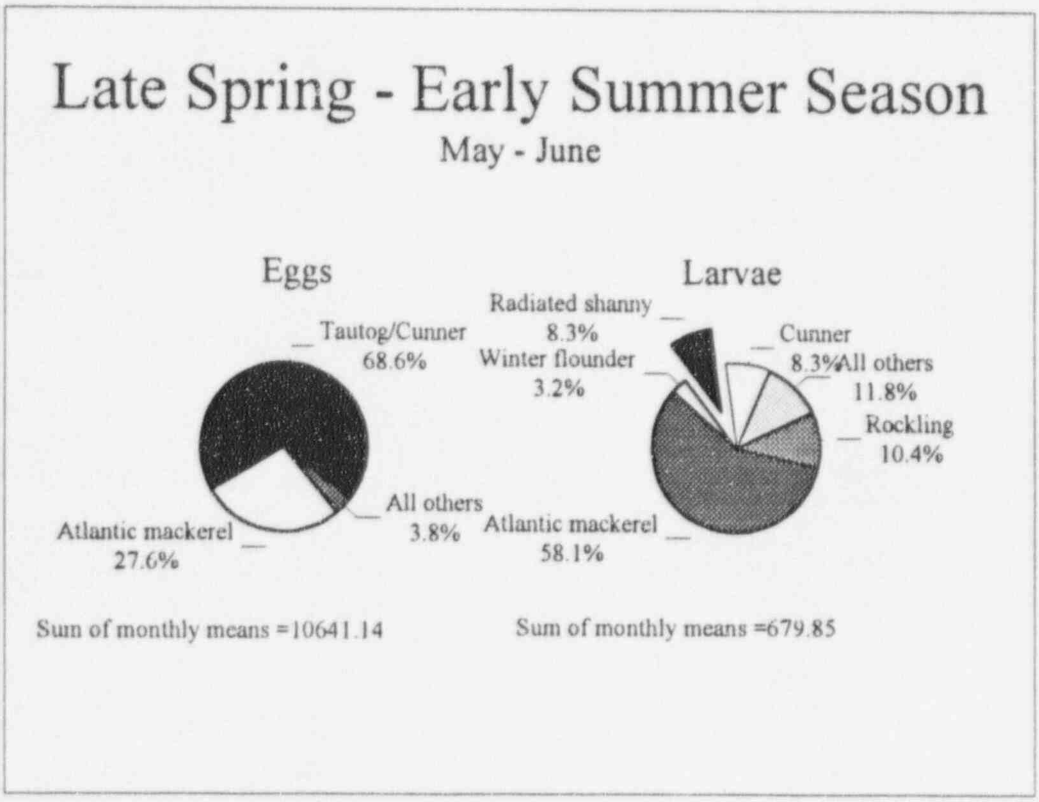




Figure 2. Dominant species of fish eggs and larvae found in PNPS ichthyoplankton samples by season for 1995. Percent of total and summed monthly means for all species are also shown.

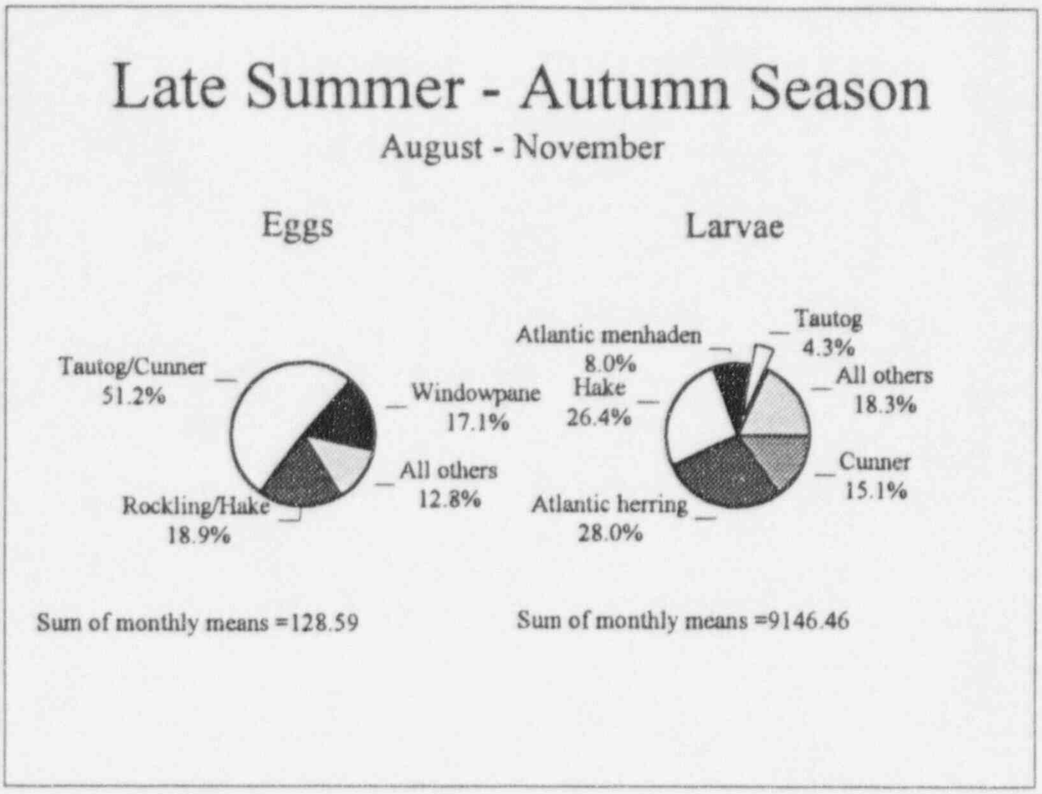



Figure 2 (continued).

majority. Plaice eggs were present in March and April accounting for 10 and 45% of those months' egg totals with monthly geometric means of 0.1 and 3.8 per 100 $m^3$ of water, respectively. Winter flounder eggs were also taken only in March and April. Their monthly geometric mean densities of 0.2 and 1.5 per 100 $m^3$ of water accounted for 10 and 41% of their respective monthly totals. Yellowtail eggs were present in January, April, and December; cod eggs in January, March, April, and December. Monthly mean densities were less than 0.7 per 100 $m^3$ in each case.

Since they are demersal and adhesive, winter flounder eggs are not typically entrained by water intake systems. 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 and perhaps other fish and large invertebrates.

Larval collections during the winter-early spring season contained 14 species overall. Sand lance ,grubby (Myoxocephalus aenaeus), and rock gunnel (Pholis gunnellus) contributed the most individuals. Sand lance were taken during each weekly sampling period January-April (they were absent in December) accounting for 40% of the total larval catch in January, 76% in February, 41% in March, and 44% in April; monthly geometric mean densities amounted to 1.3, 29.6, 26.2, and 44.2 per 100 $m^3$ respectively. Larval grubby first appeared in February and increased in number into April. They accounted for 7% of all larvae in February with a monthly geometric mean of 4.4 per 100 $m^3$, 17% of all larvae in

March with a mean of 13.6, and 28% of all larvae in April with a mean of 31.3 per 100 $m^3$. Rock gunnel were present each week with the exception of the first week in January and the month of December. They represented an additional 48% of the February total with a geometric mean density of 6.4, 29% of the March total with a mean of 8.2, and 18% of April's total with a mean of 8.9 per 100 $m^3$ of water.

Late Spring-Early Summer (May-July)

During this season egg and larval densities, particularly among species with pelagic eggs, increase with expanding day length and rising water temperature. Pooling eggs and larvae, 18 species were represented in the May collections, 20 were represented in June and in July. Atlantic mackerel ranked second among 12 egg types over the season as a whole (Figure 2) but clearly dominated in May. They accounted for 70% of that month's total with a monthly geometric mean of 73.2 per 100 $m^3$ of water. In June and July they represented 10 and 0.4% of all eggs with monthly geometric means of 25 and 0.3 per 100 $m^3$, respectively. Tautog/ cunner eggs, the seasonal dominant, exchanged rank order with mackerel accounting for 23% of all eggs in May, increasing to 88% in both June and July. Monthly geometric means were 27.6, 1179.3, and 216.5 per 100 $m^3$, respectively.

Larval samples contained 29 species, considering the season as a whole, 17 in May, 17 in June, and 20 in July. Collections were dominated by mackerel, fourbeard rockling (Enchelyopus cimbrius), radiated shanny (Ulvaria subbifurcata), and cunner. Larval mackerel were most abundant in June when they accounted for 73% of all larvae with a monthly geometric mean of 76.8 per 100 $m^3$ of water. They also contributed 26% of the larval total in July with a monthly geometric mean of 1.6 per 100 $m^3$ of water, and 0.5% of the May total with a geometric mean of 0.3 per 100 $m^3$. Fourbeard rockling were taken all three months with respective monthly geometric means of 2.4, 26.7, and 1.9 per 100 $m^3$. These values represented 6,11, and 12% of the respective monthly totals. Radiated shanny, a small bottom-dwelling fish found on rocky habitat, were taken only in May and June at which time they accounted for 47 and 0.4% of total with geometric monthly means of 29.5 and 0.8 per 100 $m^3$, respectively. Lastly, cunner were represented each month although June collections contained the most individuals. Monthly geometric means were 0.1, 14.7, and 4.5 per 100 $m^3$, densities which represented 0.1, 9, and 18% of the respective monthly totals.

Late Summer-Autumn Spawners (August-November)

This is typically a period of pronounced decline in both overall ichthyoplankton density and number of species. Overall species counts declined from 19 in August to 18 in September, 11 in October, and 6 in November. Numerical dominants among 12 species of eggs included tautog/cunner, windowpane (assuming they accounted for most in the *Paralichthys*-*Scophthalmus* egg group), and hake (*Urophycis* spp.). Tautog and cunner were found in August and September only. They contributed 62% of the August total with a geometric monthly mean of 14.5, and 19% of the September total with geometric monthly mean of 0.7 per 100 $m^3$. Windowpane accounted for an additional 11% of total in August with a mean of 8.0 per 100 $m^3$, 33% in September with a mean of 6.4 per 100 $m^3$ and 61% in October with a mean of 0.9 per 100 $m^3$. Hake eggs were common in August, declined in number during September, and were absent in October and November. In August they represented 10% of all eggs taken with a monthly geometric mean of 3.6 per 100 $m^3$. Densities declined in September to a mean of 0.8 per 100 $m^3$ which represented 6% of total. Additional early-stage hake eggs were also taken during these months no doubt, but they were indistinguishable from fourbeard rockling eggs and therefore classified as *Enchelyopus-Urophycis-Peprilus*.

Late summer-autumn larval collections consisted of 22 species but were dominated by hake, cunner, and Atlantic herring. Hake larval densities declined over the season from a high geometric mean of 3.6 per 100 $m^3$ in August and September to 0.9 per 100 $m^3$ in October; they were absent in November. During the three months they were taken hake represented 40, 53, and 8% of each monthly total, respectively. Larval cunner were similarly in decline during the season, dropping from a geometric mean of 10.2 per 100 $m^3$ in August to 0.4 in September, 0.1 in October, and 0 in November. These densities represented 30, 5, and 1% of the respective monthly totals. Atlantic herring did not appear until November but were relatively abundant at that time; a monthly geometric mean density of 15.3 per 100 $m^3$ was recorded which accounted for 97% of the month's total.

B. Multi-year Ichthyoplankton Comparisons

Table 3 presents a master species list for ichthyoplankton collected from the discharge canal at PNPS and indicates the years that each species was represented from 1975 through 1995. 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 42 species was represented in the 1995 collections, four more than the 20-year average of 38. Notable in 1995 was the collection of two striped cusk-eel (Ophidion marginatum) larvae and one smooth flounder (Pleuronectes putnami) larva. Striped cusk-eel were last collected at PNPS in 1975 and smooth flounder in 1981 and 1982. The striped cusk-eel is found in bays, estuaries, and the near-shore oceanic zone primarily from New York to Florida. It is a bottom-dwelling, burrowing species, most active at night (Cohen and Nielsen 1978, Robins and Ray 1986, Fahay 1992). The smooth flounder is a more northern species occurring from Quebec to Rhode Island. It is found chiefly over muddy bottoms near shore and in estuaries (LaRoche 1980). The appearance of a larva in November appears to be unusually early since they typically begin spawning in December (LaRoche 1980; Paul Lindsey, Normandeau Associates, Inc., personal communication).

Appendix B was prepared to facilitate comparison of densities among years. Geometric mean monthly densities along with 95% confidence limits were computed for each of the numerically dominant types of fish eggs, those accounting for 99% of the 1995 egg total, along with total eggs (all species combined) for each year dating back to 1985. Geometric means are reported because they more accurately reflect the true population mean when the distribution of sample values are skewed to the right as is commonly the case with plankton data. Generally low values obtained for both eggs and larvae during April-June 1987 were shaded because low through-plant water volumes during those months probably affected densities of ichthyoplankton (MRI 1994). Shaded values were omitted from the following discussion. Entrainment data collected from 1975-1984 remain in an outdated computer format requiring conversion before geometric mean densities can be generated. These years were therefore excluded from Appendix B but are discussed in the multi-year comparisons if noteworthy.

To help compare values over the 11-year period, egg data were plotted in Figure 3. 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 geometric mean obtained from 1985 through 1994 were joined by solid lines as were the lowest monthly geometric means, and the area between was shaded, indicating the range of these values. Monthly geometric mean values for 1995 were joined by a solid 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. One set of bars was based on geometric monthly means (1985-1995) and the other, longer time series, on arithmetic monthly means (1975-1995). Appendix B and Figure 4 contain corresponding data for the 13 numerically dominant species of fish larvae, those accounting for 97% of the 1995 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 as mentioned above.

In many cases densities of fish eggs and larvae vary considerably from year to year. For example, over the 11-year geometric mean time series the highest annual abundance index divided by the lowest for Atlantic menhaden eggs amounted to 292. In spite of such variation, no consistent upward or downward trend was apparent for many species such as Atlantic menhaden eggs and larvae, windowpane (Paralichthys-Scophthamus) eggs, seasnail (Liparis spp.) larvae, and rock gunnel larvae. Following are additional comments and observations concerning the multi-year time series:

1. Atlantic cod eggs were typically collected in low numbers (5 per 100 $m^3$ of water) at PNPS during winter months from 1975-1987. Following 1987 they have rarely been collected during January and February. None were taken either month in 1993 or 1994 and only one was taken in 1995. The gadidae-Glyptocephalus group has shown a significant decline from 1975 to 1995 ($p<0.001$) based on a nonparametric sign test which is consistent with the downward trend reported for Atlantic cod and witch flounder stocks apparently due, at least in part, to overexploitation (NOAA 1995). Over the year as a whole the

annual arithmetic abundance index for the gadidae-Glyptocephalus group in 1995 (240) ranked twelfth over the 21-year time series.

2. Fourbeard rockling and hake eggs (grouped in the early developmental stages with far less common butterfish as Enchelyopus-Urophycis-Peprilus) have been uncommon in recent years with a significant downward trend apparent through 1994 (sign test $p < 0.004$). Densities in 1995 showed an increase for the first time in four years although they remained well below the 1976-1981 period. 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 on the other hand contribute to the commercial bottom fishery and stocks in the Gulf of Maine and northern Georges Bank are considered to be underexploited. In spite of this the Northeast Fisheries Center survey index showed a sharp decline following 1991 (NOAA 1995) which might explain, at least in part, the apparent decline in egg abundance.

3. Tautog/cunner eggs, composed primarily of cunner (Scherer 1984) appeared to be in a downward trend from the late 1970's through 1994 although a sign test fell short of the conventional 95% significance level ($p = 0.055$). The arithmetic and geometric indices both showed an increase in density in 1995. The two values varied widely due to a single exceptionally

high density in June (37,282 per 100 m³ of water) which biased the arithmetic mean for that month. The general downward trend preceding 1995 is consistent with finfish observations in the PNPS area (Lawton et al. 1995). Whether 1995 densities signal a reversal in trend remains to be seen.

4. The arithmetic index for mackerel eggs clearly indicates greater abundance from 1988 to 1995 compared with the 1975-1987 period, an upward trend confirmed by a sign test ($p = 0.001$). In 1995 both indices were quite different, the arithmetic value showing a sharp increase, the geometric value a slight decrease relative to 1994. The arithmetic index was biased by a single high density of 19,203 eggs per 100 $m^3$ recorded on May 26. The abundance of mackerel eggs in recent years is consistent with a dramatic rise in stock biomass attributable to reductions in foreign fishing and underexploitation by U.S. fishermen (Overholtz 1993, NOAA 1995).
5. American plaice eggs appeared to decline in number from the late 1970's to a low point in 1986. Following that low they gradually but steadily increased from 1987 through 1995. This appears to be consistent with NOAA survey results. A strong year class was produced in 1987 and the stock has been slowly increasing since that time at least through 1993 (NOAA 1995).
6. Larval Atlantic herring were exceptionally abundant in 1994 and surpassed even that level in 1995. Over the 1985-1995 time series the 1994 geometric index (564) exceeded the previous high observed in 1990 (223) by a factor of 2.5. The

1995 index (776) exceeded 1994 by a factor of 1.4; record monthly mean densities were recorded in November and December (see also Notification Plan, Section IIIA in Volume 2). The recent increase in abundance of larval herring is consistent with recent increases in herring stock biomass on Georges Bank and Nantucket Shoals (NOAA 1995).

7. Larval tautog densities were notably low in 1994 particularly in June. Overall densities improved in 1995, the geometric index (136) ranking third out of eleven years, the arithmetic index ranking fifth out of 21 years.
8. Similar results were obtained for larval cunner, the 1995 index showing an increase over the relatively low 1994 value. Over the entire time series, 1995 (2393) ranked fifth and within the shorter 1985-1995 period ranked third.
9. Larval radiated shanny reached record average numbers in May (30 per 100 $m^3$), their month of peak density, leading to a near record arithmetic index in 1995. The geometric index (927) ranked highest over the 1985-1995 time series and the arithmetic index (1727) second over the 21-year time series surpassed only by 1975 (2178).
10. Larval sand lance were more abundant in 1994 (arithmetic index = 26276) than any other year, exceeding the previous high arithmetic index (14944 in 1978) by a factor of 1.8. Over the shorter time series the geometric index (12490) exceeded the previous high recorded in 1992 (2389) by a factor of 5.2. The indices for 1995 suggest that year was productive for larvae

also, the arithmetic index ranking fifth, the geometric second. Sand lance populations in New England waters as well as on Georges Bank have generated some interest in the past because their numbers increased dramatically between 1974 and 1979 (Smith et al. 1978; Meyer et al. 1979; Sherman et al. 1981) following a 50% decline in biomass of principal commercial fishes on the northeast continental shelf (Clark and Brown 1977; Sherman et al. 1983). More recently, 1988-1993, they have been in a period of decline in what is referred to as a "biomass flip" as Atlantic herring and mackerel populations returned following reductions in foreign fishing (Smith and Sherman 1993, Sherman 1994). Herring and mackerel apparently outcompete sand lance for zooplankton prey and probably also prey directly on sand lance eggs and larvae (Fogarty et al. 1991).

The increase in adult sand lance populations noted in the late 1970's was apparent in the PNPS larval sand lance data. A decline in larval abundance occurred after 1982 and densities remained more or less low until 1992. Relatively high larval production in 1992 and 1994 appears inconsistent with the adult outlook. It is also interesting to note that 1994 and 1995 indices include night samples for the first time, several of these ranked among the seasonal high values (see also Section IIIA, Volume 2).

11. Atlantic mackerel larvae were very abundant in June, July, and August 1995 the overall arithmetic index exceeding all

previous years (see also Section IIIA, Volume 2). Since larval mackerel typically display tall, narrow peaks, the arithmetic and geometric indices often differ by a wide margin. The less biased geometric index ranked second in 1995 over the 1985-1995 time series.

12. Winter flounder remain a species of great concern since adult stock size estimates are at historical low levels (NOAA 1995). In 1995 larval production, based on PNPS entrainment densities, was strong, the geometric index (621) ranking highest over the 1985-1995 period (Figure 4). The arithmetic index, while somewhat biased, ranked eighth over the 21-year data set.

Cunner and mackerel densities, the two most abundant species for which both eggs and larvae are entrained, were examined over time to see if egg and larval indices were correlated. Arithmetic curve indices were used to provide the longest time series (1975-1995). In both cases egg and larval densities were not found to be correlated ($p>0.05$) in either straight or log scales. Correlation coefficients were 0.217 and 0.163 for cunner, 0.169 and 0.384 for mackerel, respectively. While this is not uncommon in dynamic marine systems, it points out how variable survival rates and advective forces likely are in the PNPS area.

C. Mesh Extrusion

Densities per 100 $m^3$ of water for tautog/cunner eggs and cunner larvae by stage for both 0.333 and 0.202-mm mesh collections completed in both 1994 and 1995 appear in Table 4. Paired sample t-tests on log-transformed data indicated tautog/cunner eggs were significantly more abundant in the 0.202-mesh samples ($p < 0.005$; $n = 21$ pairs). Since the data were highly skewed by high densities on June 28, 1995, geometric means were calculated over the 21 samples within each mesh category. The ratio of these was 1.41:1.

Results for larval cunner were variable making meaningful conclusions difficult to reach. The smallest stage 1 individuals were present in five sample pairs. On June 16 cunner stage 1 densities were consistently higher in the 0.333 samples while the reverse was true on June 26 (paired t, $n = 5$, $p = 0.61$). Geometric means within mesh over all samples were 9.1 for 0.333, 14.8 for 0.202, providing a ratio of 1.64:1. For somewhat larger stage 2 larvae comparative data were available for nine pairs; 0.202-mesh densities were greater in six of the nine, however respective geometric means were identical at 10.0 per 100 $m^3$. Summing stage 1 and 2 densities and calculating geometric means over all pairs indicated that densities were essentially identical in the two meshes (11.8 vs 12.0, paired $t = 0.96$). Collections of larger stage 3 cunner averaged somewhat higher in the larger mesh (7.1 vs 5.7 per 100 $m^3$ of water, paired $t = 0.51$). These data suggest that small larval cunner are not consistently extruded through 0.333 mesh. Pairs showing greater densities in the larger mesh may have resulted from random error inherent in a system with naturally high variability among ichthyoplankters or perhaps to clogging of the finer mesh. The 0.202-mm mesh visibly collects greater amounts of small planktonic forms such as diatoms and, although not clearly detectable in the flowmeter data, greater back pressure may reduce collection of some larvae.

D. Lobster Larvae Entrained

A single larval lobster (Homarus americanus, stage 4-5) was taken in 1995 (July 28), the first individual taken since 1993. This brings the total to 13 dating back to 1974, distributed over time as follows:

1994: none found.
1993: 1 larva - stage 4-5, July 21.
1991-1992: none found.
1990: 2 larvae - 1 stage 1, June 26; 1 stage 4 August 23.
1983-1989: none found.
1982: 1 larva - stage 1 on June 14.
1981: 1 larva - stage 4 on June 29.
1980: none found.
1979: 1 larva - stage 1 on July 14.
1978: none found.
1977: 3 larvae - 1 stage 1, June 10; 2 stage 1, June 17.
1976: 2 larvae - 1 stage 1, July 22; 1 stage 4-5, August 5.
1975: 1 larva - stage 1, 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.

During the three-season Cape Cod Bay neuston study for larval lobster begun in 1974, larvae were found from May through September at monthly mean densities ranging from 0.2 (September) to 3.8 per 100 $m^3$ (July) (Matthiessen and Scherer 1983). Considering that a minimum of roughly 10,500 $m^3$ of water were sampled during these months each year, larval lobster must indeed be rare in the PNPS circulating water system.

## SECTION V

## HIGHLIGHTS

1) Numerical dominants among the ichthyoplankton entrained in 1995 included tautog/cunner, mackerel, fourbeard rockling, and windowpane among the eggs; mackerel, sand lance, Atlantic herring, cunner, grubby, and rockling among the larvae.
2) Cod and witch flounder eggs have shown a significant downward trend in abundance from 1975 to 1995 consistent with the downward trend reported for Atlantic cod and witch flounder stocks.
3) Cunner eggs appear to have been in a downward trend at least through 1994 consistent with finfish observations in the PNPS area. In 1995 an increase in abundance was noted.
4) Mackerel eggs have shown marked greater abundance from 1988-1995 compared with the 1975-1987 period. This is consistent with a dramatic rise in stock biomass attributable to reductions in foreign fishing and underexploitation by U.S. fishermen.
5) Larval Atlantic herring were exceptionally abundant in 1994 and surpassed even that level in 1995. Like Atlantic mackerel this observation is consistent with recent increases in herring stock biomass on Georges Bank and Nantucket Shoals.
6) Winter flounder remain a species of great concern since adult stock size estimates are at historical low levels. In 1995

larval production, based on PNPS entrainment samples, was strong ranking highest over the 1985-1995 period.

7) Mesh comparison collections completed for cunner eggs and larvae in 1994 and 1995 indicated that 0.202-mm mesh retained significantly more cunner eggs than 0.333-mm mesh, a ratio of 1.41:1 being recorded. Stage 1 and 2 larval cunner were retained in equal numbers by both meshes although variability was high.

8) A single lobster larva was taken in 1995, the first since 1993. Dating back to 1974 a total of only 13 have been collected.

Figure 3. Mean monthly densities per 100 $m^3$ of water in the PNPS discharge canal for the eight numerically dominant egg species and total eggs, 1995 (bold line). Solid lines encompassing shaded area show high and low values over the 1975-1994 period.

Brevoortia tyrannus

Gadidae-Glyptocephalus

Enchelyopus-Urophycis Peprilus

Prionotus spp.

Labridae-Pleuronectes

Scomber scombrus

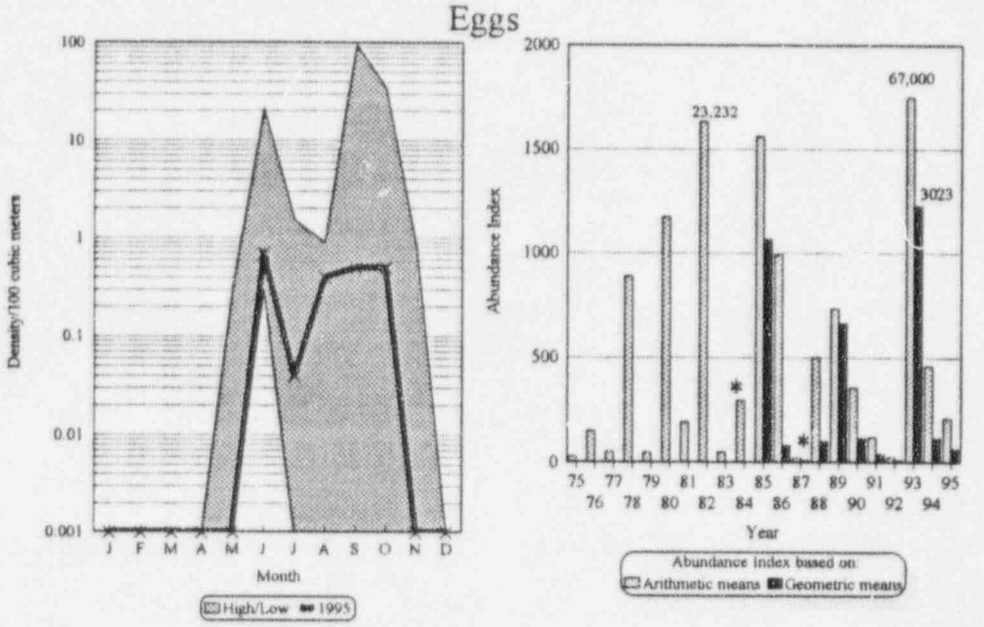
Paralichthys-Scophthalmus

Hippoglossoides platessoides

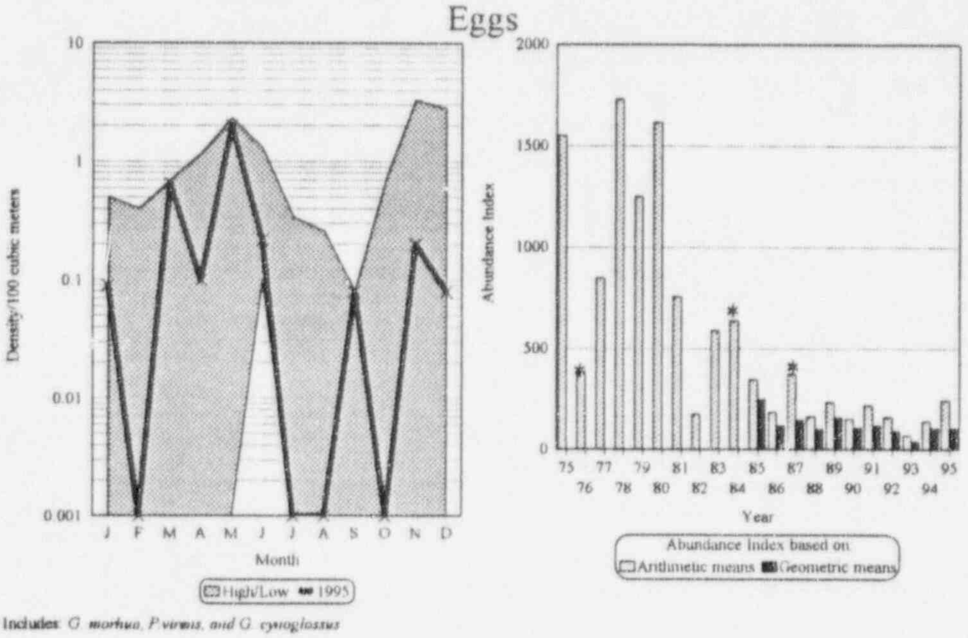
Total eggs

To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1995. 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. An asterisk above 1976 indicates abundance value may be low due to absence of sampling during January-late April; see text for clarification. Light bars represent indices based on monthly arithmetic means, solid bars (1985-1995) indices based on monthly geometric means.

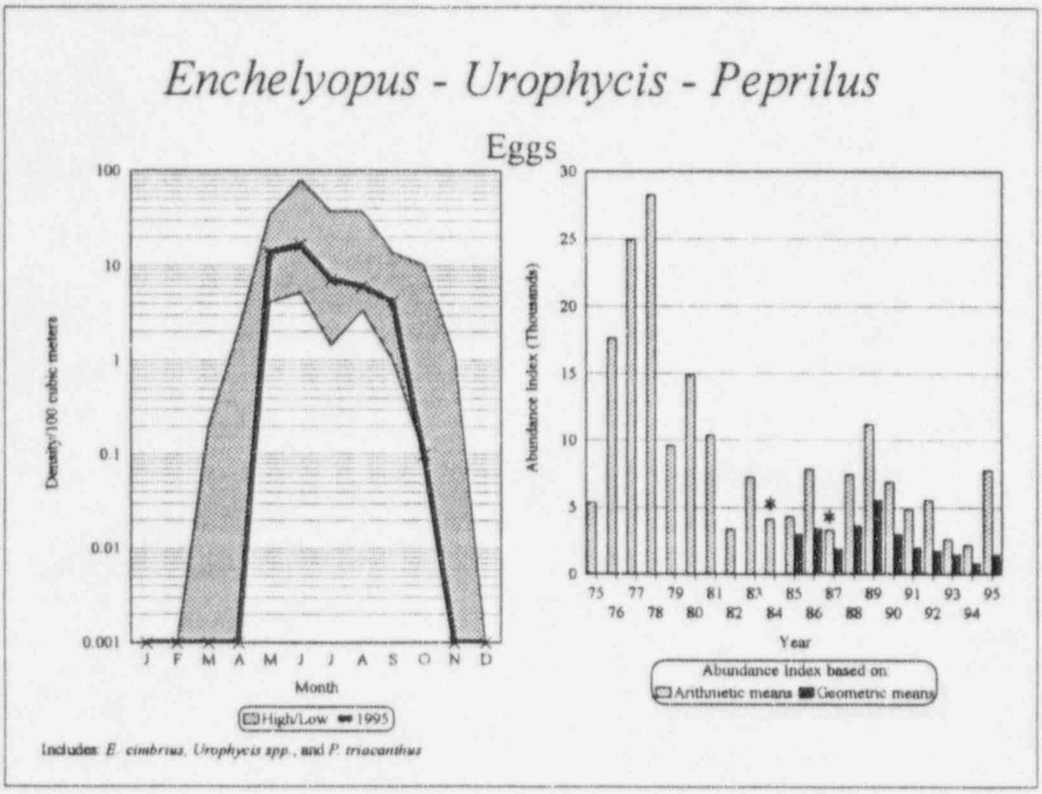
# *Brevoortia tyrannus*

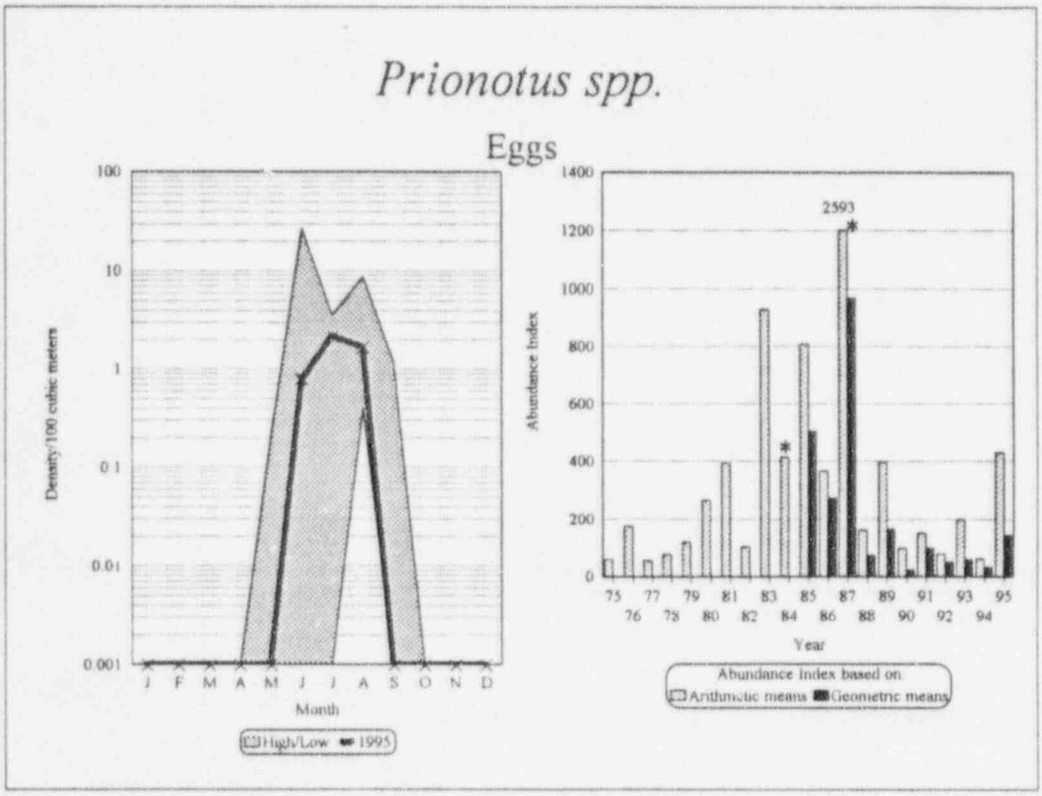



# Gadidae - *Glyptocephalus*



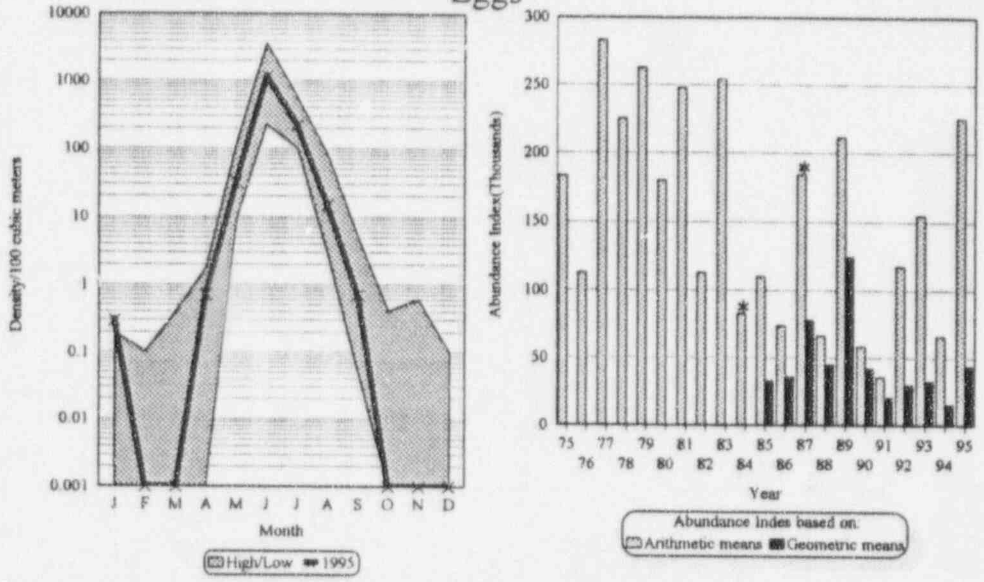

Includes: *G. morhua, P. virens,* and *G. cynoglossus*


Enchelyopus - Urophycis - Peprilus
Eggs
Density/100 cubic meters
Month
High/Low 1995
Abundance Index (Thousands)
Year
Abundance Index based on:
Arithmetic means Geometric means
Includes: E. cimbrius, Urophycis spp., and P. triacanthus


Prionotus spp.
Eggs
Density/100 cubic meters
Month
High/Low 1995
2593
Abundance Index
Year
Abundance Index based on:
Arithmetic means Geometric means

# Labridae - *Pleuronectes*

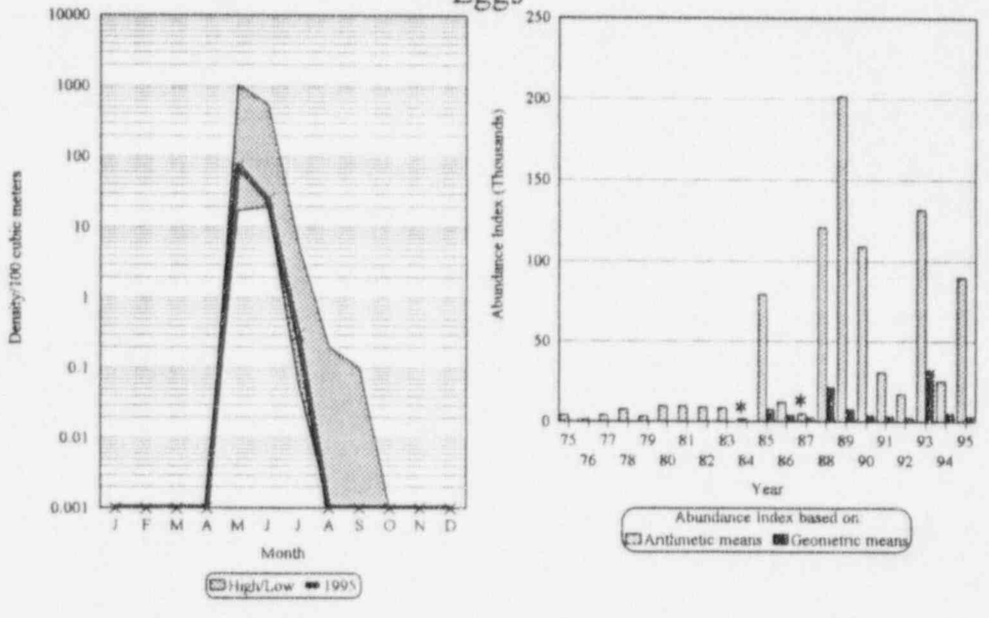
Eggs

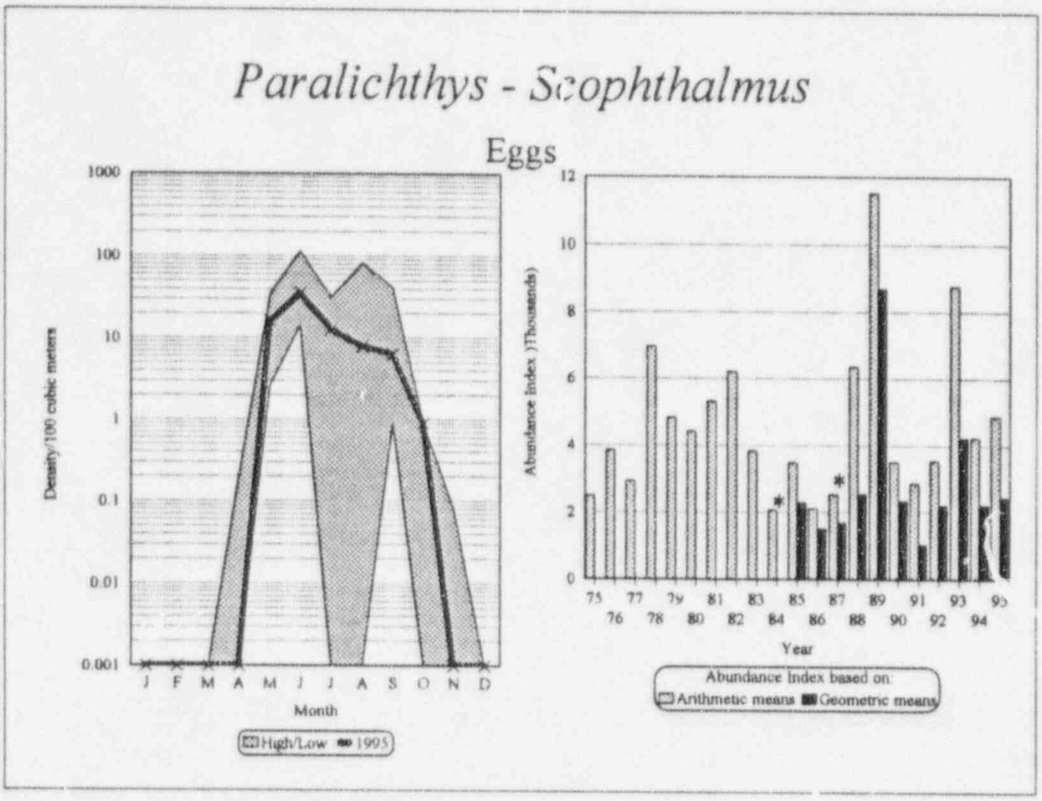



Includes Labridae and *P. ferrugineus*

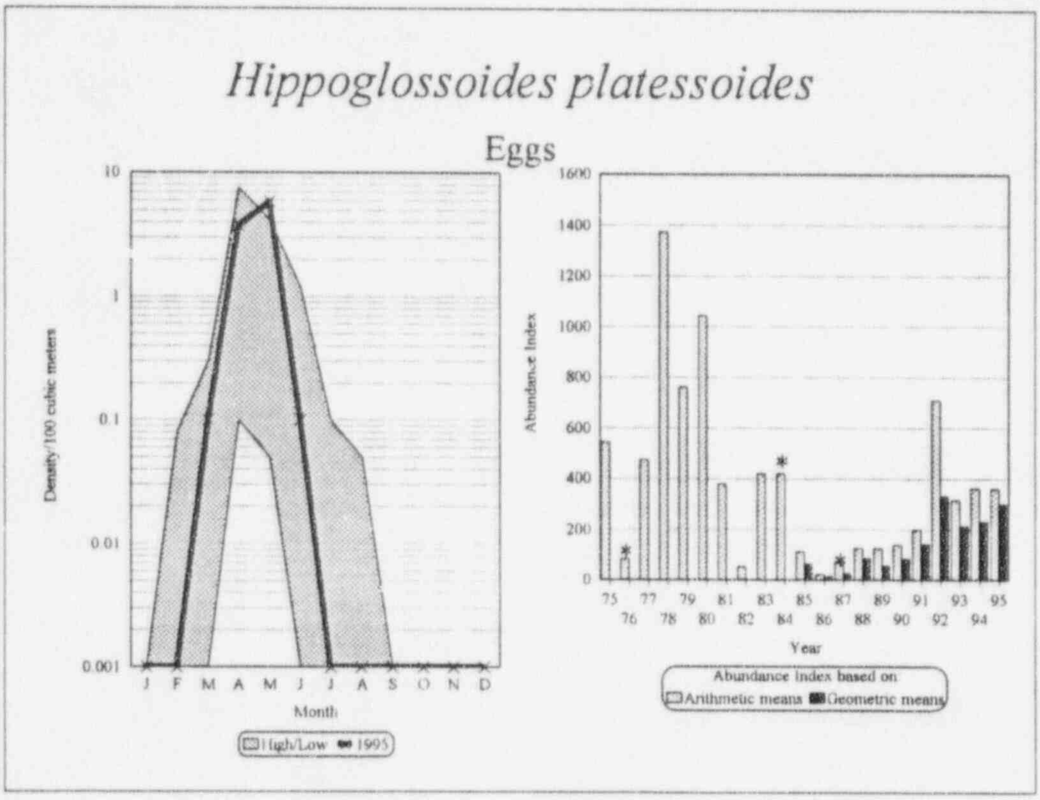
# *Scomber scombrus*

Eggs



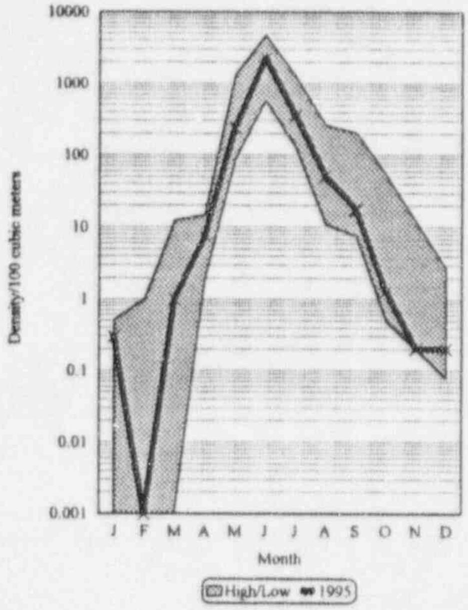


Paralichthys - Scophthalmus
Eggs
Density/100 cubic meters
Month
High/Low 1995
Abundance Index )Thousands)
Year
Abundance Index based on:
Arithmetic means Geometric means

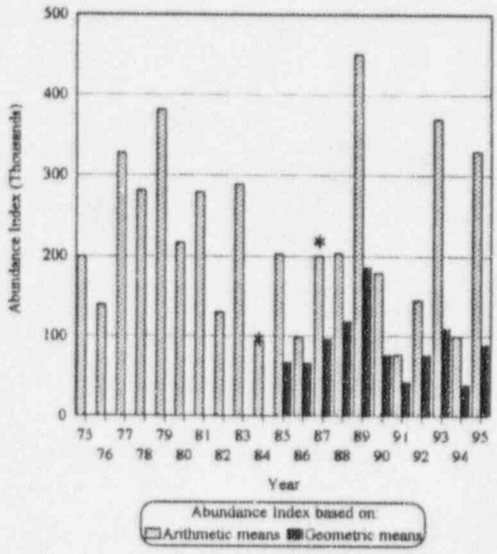



Hippoglossoides platessoides
Eggs
Density/100 cubic meters
Month
High/Low 1995
Abundance Index
Year
Abundance Index based on:
Arithmetic means Geometric means

# Total Eggs



10000
1000
100
10
1
0.1
0.01
0.001
Density/100 cubic meters
J F M A M J J A S O N D
Month
High/Low 1995

500
400
300
200
100
0
Abundance Index (Thousands)
75 77 79 81 83 85 87 89 91 93 95
76 78 80 82 84 86 88 90 92 94
Year
Abundance Index based on:
Arithmetic means Geometric means

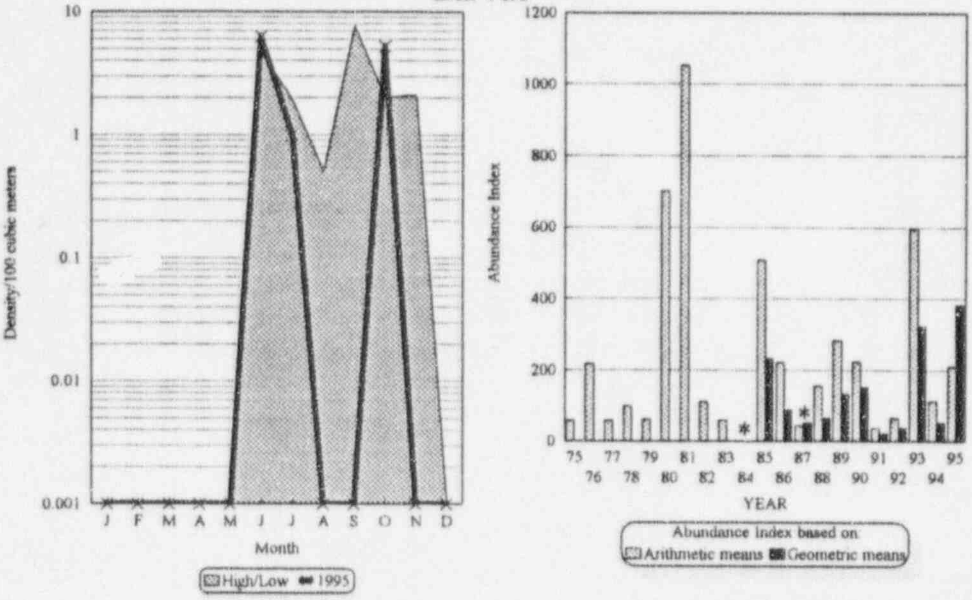
Figure 4. Mean monthly densities per 100 $m^3$ of water in the PNPS discharge canal for the thirteen numerically dominant larval species and total larvae, 1995 (bold line). Solid lines encompassing shaded area show high and low values over the 1975-1994 period.

| | |
|---|---|
| Brevoortia tyrannus | Tautogolabrus adspersus |
| Clupea harengus | Ulvaria subbifurcata |
| Enchelyopus cimbrius | Pholis gunnellus |
| Urophycis spp. | Ammodytes sp. |
| Myoxocephalus spp. | Scomber scombrus |
| Liparis spp. | Pleuronectes americanus |
| Tautoga onitis | Total larvae |

To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1995. 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. An asterisk above 1976 indicates abundance value may be low due to absence of sampling during January-late April; see text for clarification. Light bars represent indices based on monthly arithmetic means, solid bars (1985-1995) indices based on monthly geometric means.

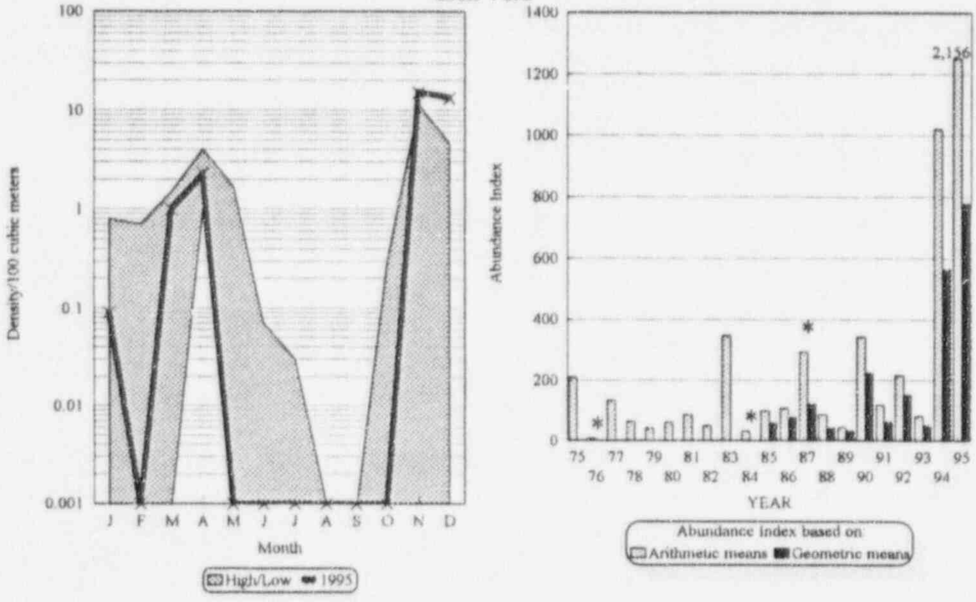
# *Brevoortia tyrannus*

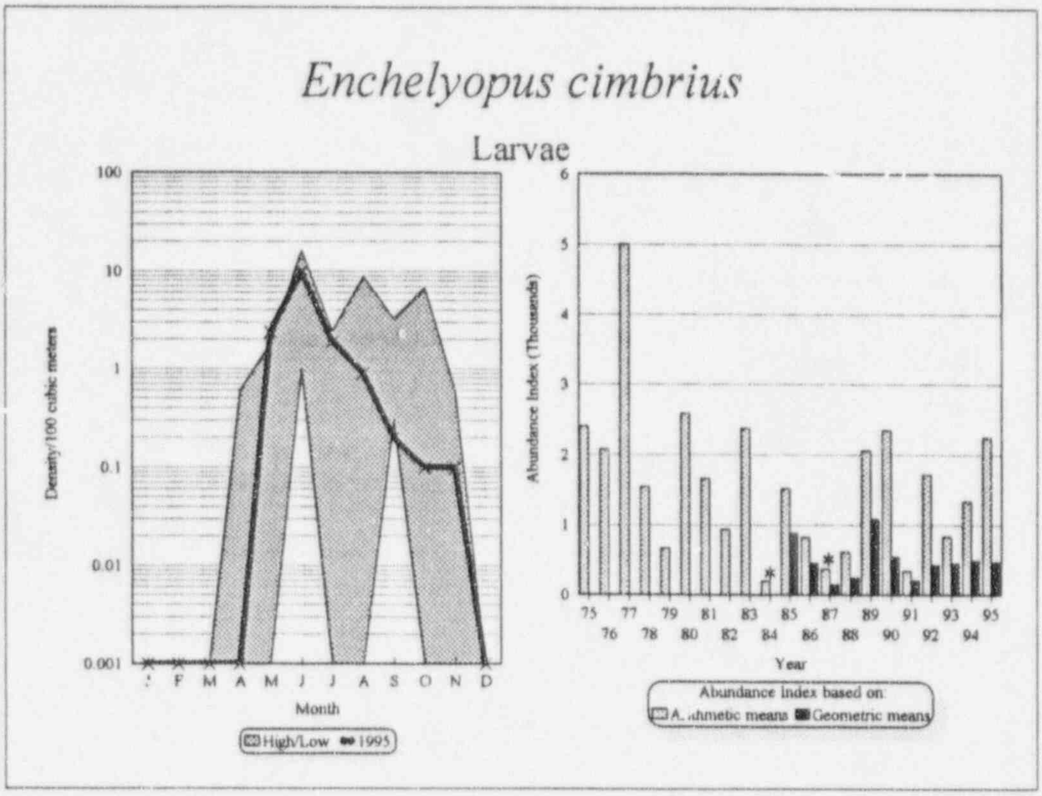
Larvae

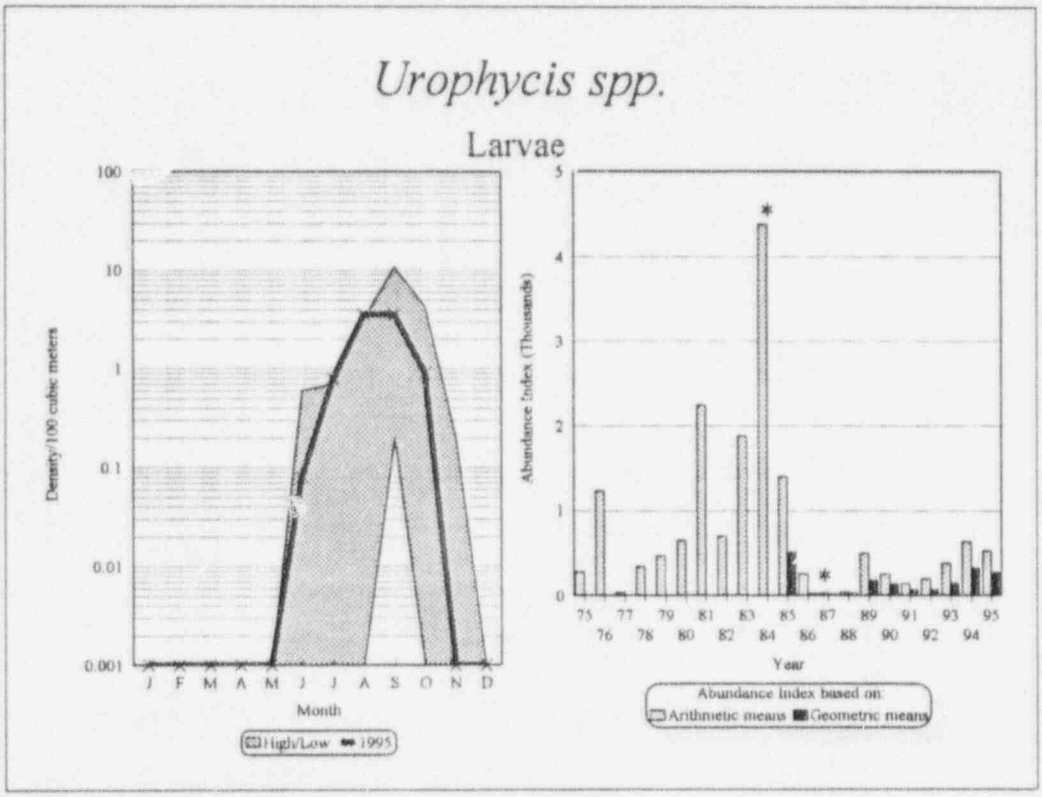


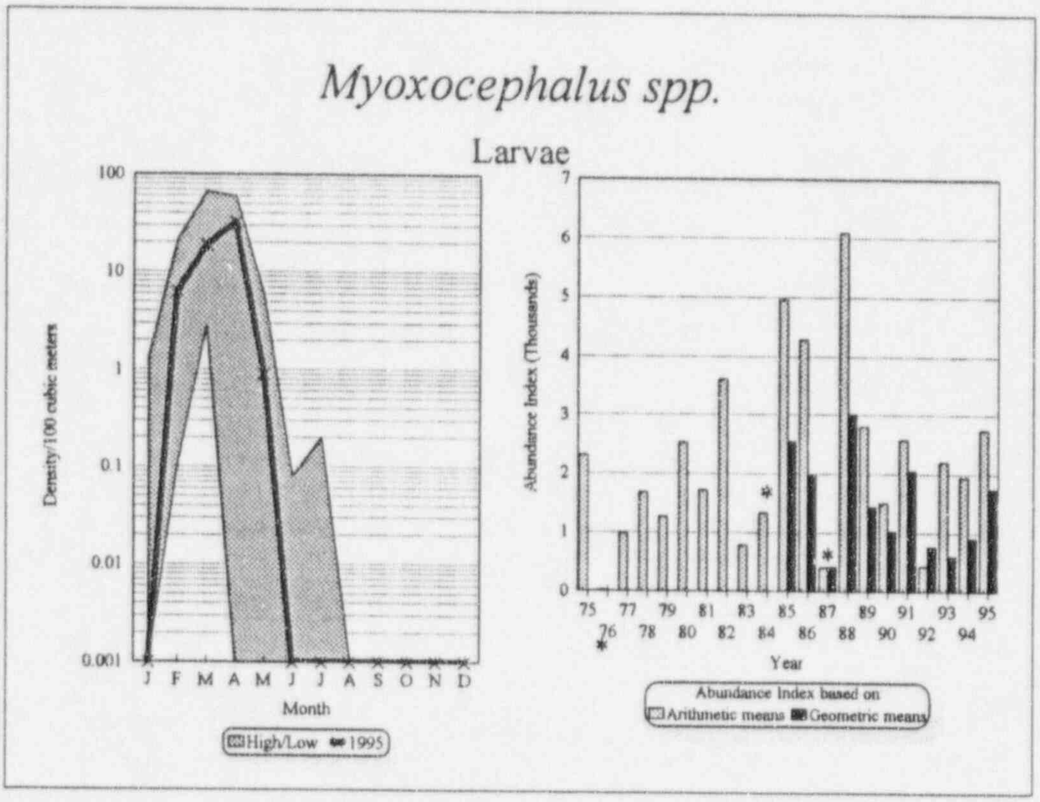

# *Clupea harengus*

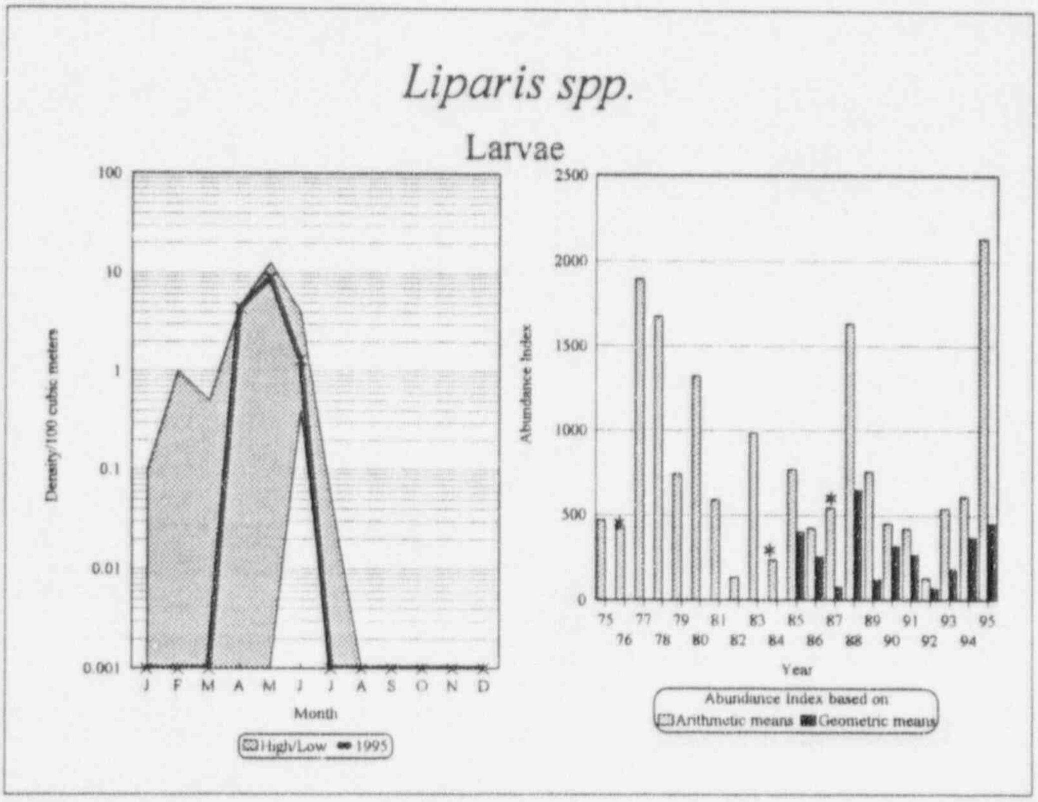
Larvae

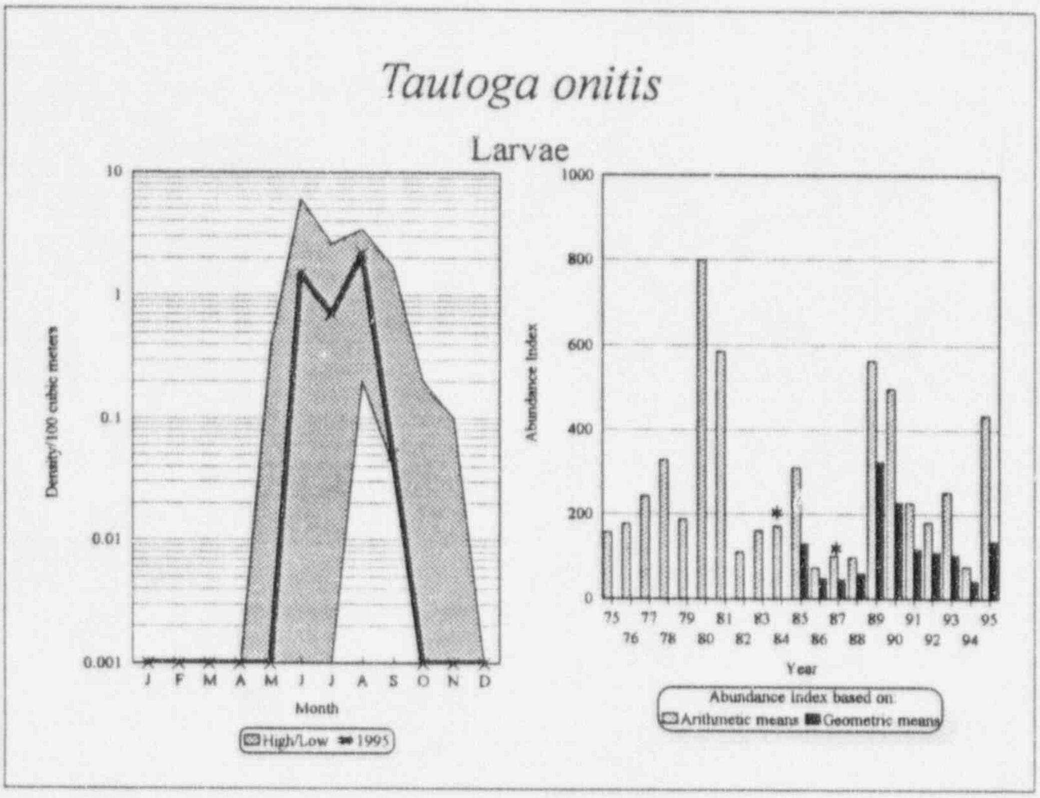



Enchelyopus cimbrius
Larvae
Density/100 cubic meters
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
Month
High/Low 1995
Abundance Index (Thousands)
6
5
4
3
2
1
0
75 77 79 81 83 85 87 89 91 93 95
76 78 80 82 84 86 88 90 92 94
Year
Abundance Index based on:
Arithmetic means Geometric means

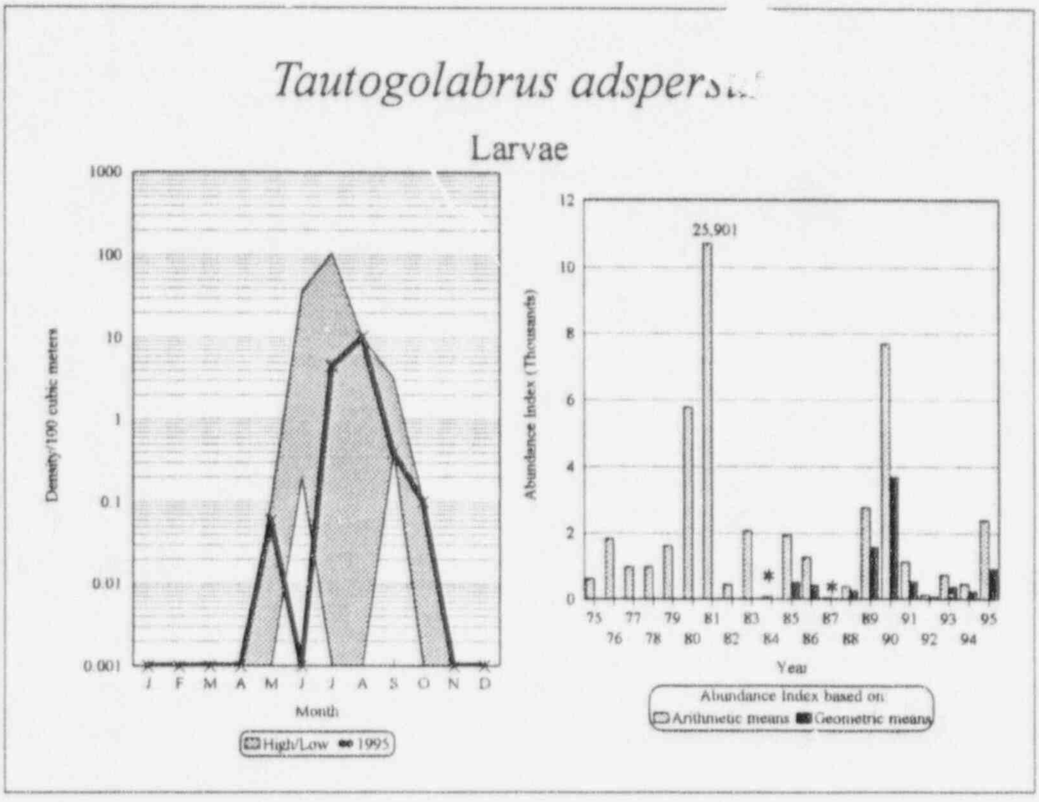

Urophycis spp.
Larvae
Density/100 cubic meters
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
Month
High/Low 1995
Abundance Index (Thousands)
5
4
3
2
1
0
75 77 79 81 83 85 87 89 91 93 95
76 78 80 82 84 86 88 90 92 94
Year
Abundance Index based on:
Arithmetic means Geometric means


Myoxocephalus spp.
Larvae
Density/100 cubic meters
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
Month
High/Low
1995
Abundance Index (Thousands)
7
6
5
4
3
2
1
0
75 77 79 81 83 85 87 89 91 93 95
76 78 80 82 84 86 88 90 92 94
Year
Abundance Index based on
Arithmetic means
Geometric means


Liparis spp.
Larvae
Density/100 cubic meters
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
Month
High/Low
1995
Abundance Index
2500
2000
1500
1000
500
0
75 77 79 81 83 85 87 89 91 93 95
76 78 80 82 84 86 88 90 92 94
Year
Abundance Index based on
Arithmetic means
Geometric means

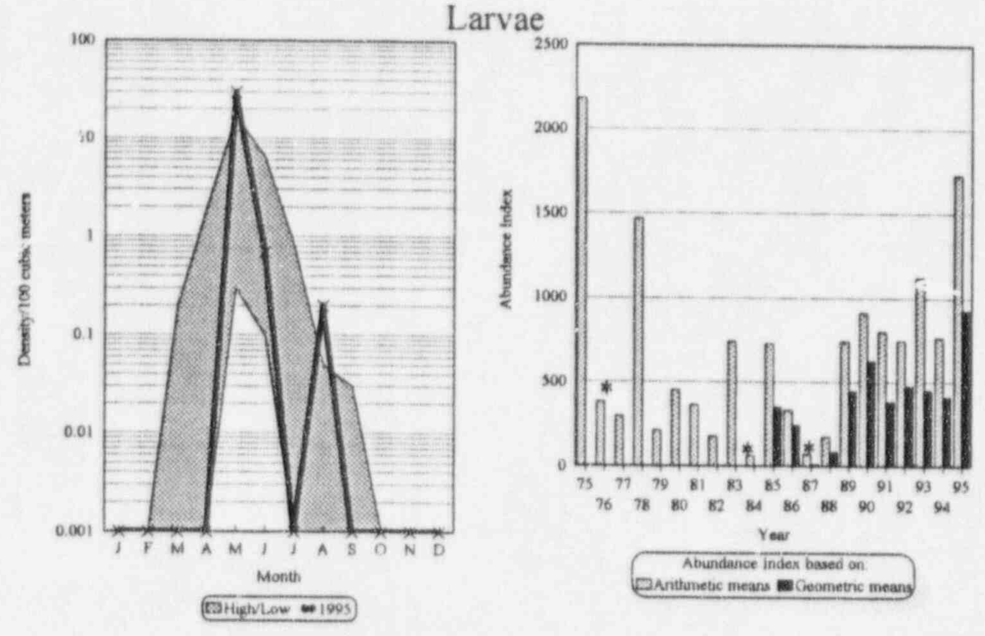


Tautoga onitis
Larvae
Density/100 cubic meters
Month
High/Low
1995
Abundance Index
Year
Abundance Index based on:
Arithmetic means
Geometric means

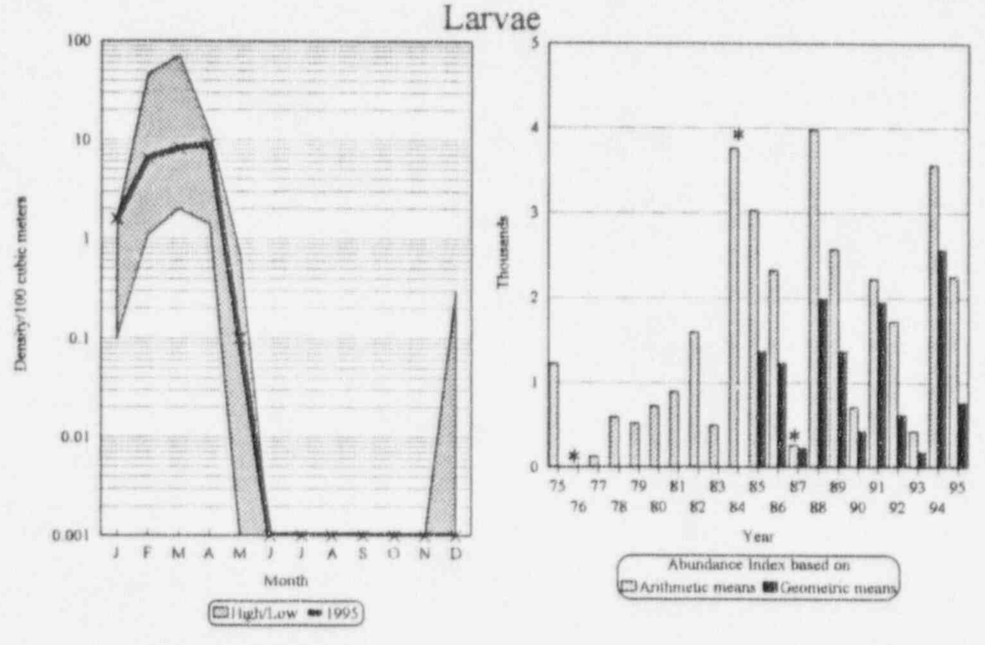



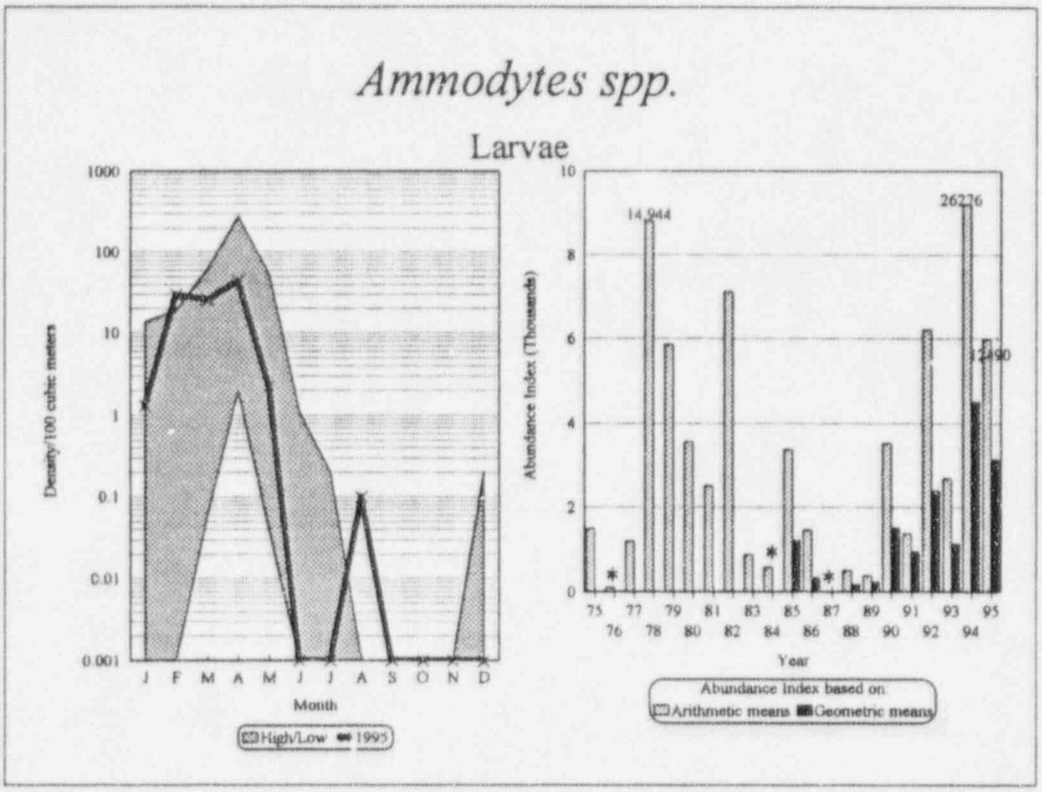
Tautogolabrus adspersus
Larvae
Density/100 cubic meters
Month
High/Low
1995
25,901
Abundance Index (Thousands)
Year
Abundance Index based on:
Arithmetic means
Geometric means

# *Ulvaria subbifurcata*

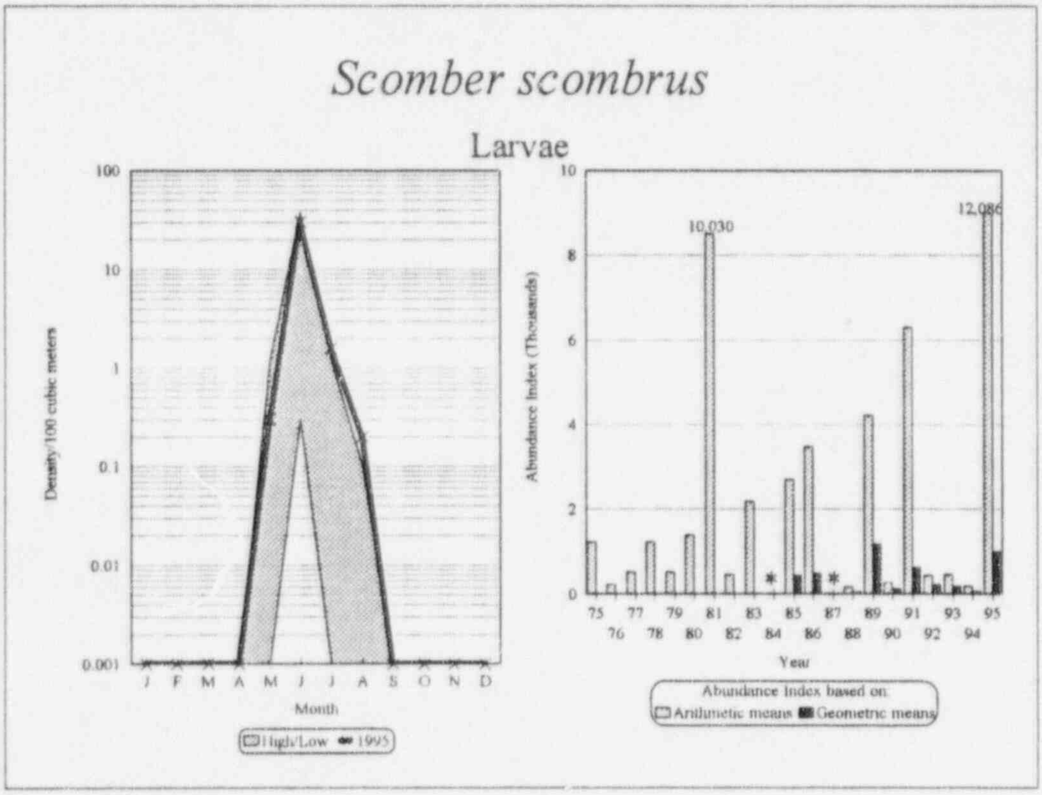



# *Pholis gunnellus*





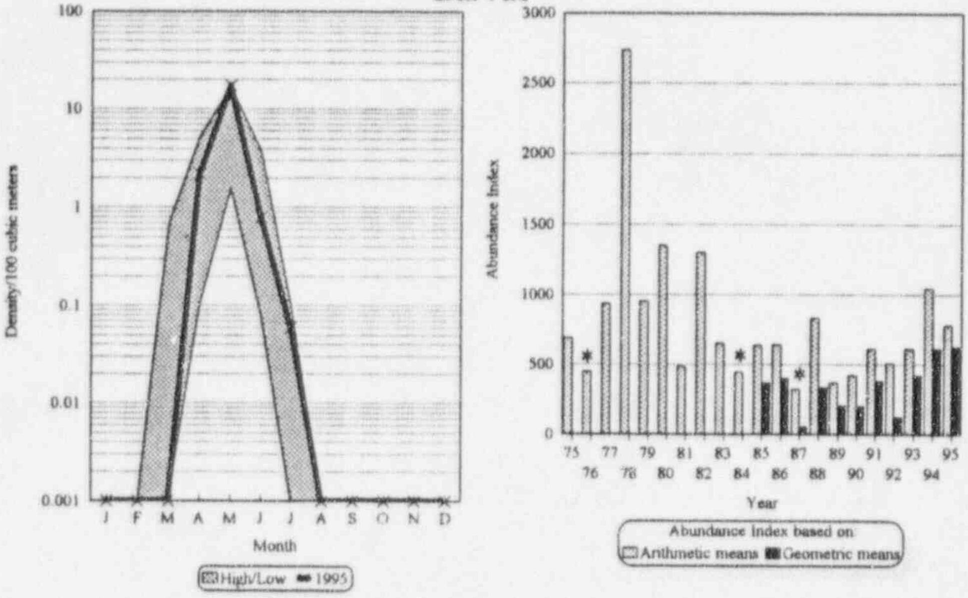
Ammodytes spp.
Larvae
Density/100 cubic meters
Month
High/Low 1995
Abundance Index (Thousands)
14,944
26,276
12,490
Year
Abundance Index based on:
Arithmetic means Geometric means

Scomber scombrus
Larvae
Density/100 cubic meters
Month
High/Low 1995
Abundance Index (Thousands)
10,030
12,086
Year
Abundance Index based on:
Arithmetic means Geometric means

# *Pleuronectes americanus*

## Larvae




# Total Larvae

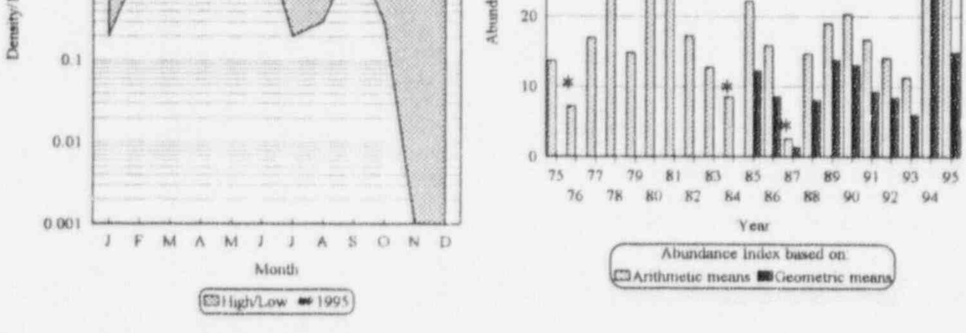


Table 2. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-December 1995.

| Species | | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American eel | Anguilla rostrata | | | | L | | | | | | | | |
| Atlantic menhaden | Brevoortia tyrannus | | | | | | E/L | E/L | E/L | E | E/L | | |
| Atlantic herring | Clupea harengus | L | | L | L | L | | | | | | L | L |
| Anchovy | Anchoa spp. | | | | | | | L | L | L | 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 | L | | E | | E | E |
| Haddock | Melanogrammus aeglefinus | | | E | | | | | | | | | |
| Silver hake | Merluccius bilinearis | | | | | | E/L | L | E/L | E/L | L | | |
| Atlantic tomcod | Microgadus tomcod | L | L | | | | | | | | | | |
| Hake | Urophycis spp. | | | | | | E/L | E/L | E/L | E/L | L | | |
| Cusk-eel | Ophidion marginatum | | | | | | | | L | L | | | |
| Goosefish | Lophius americanus | | | | | | E | E/L | | E | L | | |
| Northern pipefish | Syngnathus fuscus | | | | | | | L | L | L | | L | |
| Silversides | Menidia spp. | | | | | | L | L | | | | | |
| Searobins | Prionotus spp. | | | | | | E | E | E | | | | |
| Sea raven | Hemitripterus americanus | | | L | | | | | | | | | |
| Grubby | Myoxocephalus aenaeus | | L | L | L | L | L | | | | | | |
| Longhorn sculpin | M. octodecemspinosus | | L | L | L | | | | | | | | |
| Shorthorn sculpin | M. scorpius | | L | L | L | L | | | | | | | |
| Lumpfish | Cyclopterus lumpus | | | | L | | | | | | | | |
| Seasnail | Liparis atlanticus | | | | L | L | L | | | | | | |
| Black sea bass | Centropristis striata | | | | | | | | L | L | | | |

Table 2 (continued).

| Species | | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scup | Stenotomus crysops | | | | | | | L | | | | | |
| Wrasses | Labridae | | | | | 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 | | | | |
| Rock gunnel | Pholis gunnellus | L | L | L | L | L | | | | | | | |
| Wrymouth | Cryptacanthodes maculatus | L | L | | L | L | | | | | | | |
| Sand lance | Ammodytes sp. | L | L | L | L | L | | | L | | | | |
| Seaboard goby | Gobiosoma ginsburgi | | | | | | | | L | L | | | |
| Atlantic mackerel | Scomber scombrus | | | | | E/L | E/L | E/L | L | | | | |
| Butterfish | Peprilus triacanthus | | | | | | | L | E/L | L | L | | |
| Smallmouth flounder | Etropus microstomus | | | | | | | | E | E/L | L | | |
| Summer flounder | Paralichthys dentatus | | | | | | | | | E | L | L | |
| Fourspot flounder | P. oblongus | | | | | | | L | L | L | | | |
| Windowpane | Scophthalmus aquosus | | | | | E | E/L | E/L | E/L | E/L | E/L | | |
| Witch flounder | Glyptocephalus cynoglossus | | | | | | | L | | | | | |
| American plaice | Hippoglossoides platessoides | | | E | E | E/L | E/L | | | | | | |
| Winter flounder | Pleuronectes americanus | | | E | E/L | E/L | L | L | | | | | |
| Yellowtail flounder | P. ferrugineus | E | | | E | E | E/L | E/L | | | | | E |
| Smooth flounder | P. putnami | | | | | | | | | | | L | |

Table 3. Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal, 1975-1995. General periods of occurrence for eggs and larvae combined are shown along the right side; for the dominant species, periods of peak abundance are also shown in parentheses.

| Species | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | Period of Occurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Anguilla rostrata | J[1] | J | 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 | 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 | L | L | Jan - Dec[2] |
| Anchoa spp. | L | | L | 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 | 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 | 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 | E/L | E/L | Jan(Nov) - (Dec)Dec |
| Melanogrammus aeglefinus | L | E/L | E/L | E/L | L | | | | L | | E | | | 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 | 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 | 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 | 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 | E/L | E/L | Apr(Aug) - (Sep)Nov |
| Ophidion marginatum | L | | | | | | | | | | | | | | | | | | | | L | Aug - 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 | 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 | L | L | May - Sep |
| M. menidia | E/L | E/L | E | | | | | | L | | | | | | | | E | | E | | | May - Sep |

Table 3 (continued).

| Species | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | Period of Occurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Syngnathus fuscus | L | L | 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 | E | E | May(Jun) - (Aug)Sep |
| Hemitripterus americanus | | | | | | | | | | | | | | | | | | | | L | L | Feb - Mar |
| 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 | L | L | Dec(Mar) - (Apr)Jul |
| M. aenaeus | | | | | L | L | L | L | L | L | L | L | L | L | L | L | E/L | L | L | L | L | Jan(Mar) - (Apr)Jul |
| M. octodecemspinosus | | | | | | L | L | L | L | L | L | L | L | L | E/L | L | L | L | L | L | L | Jan(Mar) - (Apr)May |
| M. scorpius | | | | | | L | L | 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 | 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 | L | L | Jan(Apr) - (Jun)Jul |
| L. atlanticus | | | | | | | L | L | 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 | L | | Jan(Feb) - (Mar)Apr |
| Centropristis striata | L | | | | | 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 | | 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 | 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 | 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 | L | L | May(Jun) - (Aug)Oct |
| Lumpenus lumpretaeformis | L | | | | | | 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 | 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 | L | L | Jan(Feb) - (Apr)Jun |
| Cryptacanthodes maculatus | | | | L | L | | L | L | L | L | L | L | | | L | L | L | L | L | L | L | Feb - Apr |

Table 3 (continued).

| Species | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | Period of Occurrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammodytes sp. | L | L | L | L | E/L | L | 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 | | | | | | L | L | Jul - Sep |
| 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 | 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 | L | E/L | May - Oct |
| Etropus microstomus | L | | | | | | | | L | | E | E/L | E | | E | | E | E | E | | E/L | Jul - Oct |
| Paralichthys dentatus | E/L | | | | | | | | E/L | | L | | E/L | E | | L | | | E/L | E | E/L | Sep - Nov |
| P. oblongus[3] | | 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 - Oct |
| Scophthalmus aquosus[3] | 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 | 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 | 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 | 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 | 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 | E/L | E/L | Feb(Apr) - (May)Nov |
| P. putnami | | | | | | | L | E/L | | | | | | | | | | | | | 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[4] | 41 | 36 | 43 | 35 | 37 | 35 | 40 | 38 | 37 | 34 | 42 | 37 | 36 | 41 | 40 | 42 | 34 | 36 | 38 | 40 | 42 | |

[1]J = juvenile.

[2]Absent August and September; peaks = March-May and November-December.

[3]Although these eggs were not identified specifically, they were assumed to have occurred as shown based on the occurrence of larvae.

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

Table 4. Densities per 100 m³ of water for tautog/cunner eggs and cunner larvae taken with 0.333 and 0.202-mm mesh netting on four 1994 dates and three 1995 dates.

| | Date | Replicate | Mesh 0.333 | Mesh 0.202 | Ratio | p[1] |
|---|---|---|---|---|---|---|
| EGGS | 1994 | | | | | |
| | May 4 | 1 | 2.9 | 16.1 | 5.55 | |
| | | 2 | 3.2 | 9.0 | 2.81 | |
| | | 3 | 5.3 | 4.4 | 0.83 | |
| | May 9 | 1 | 1.1 | 3.9 | 3.55 | |
| | | 2 | 4.7 | 4.9 | 1.04 | |
| | | 3 | 1.8 | 2.9 | 1.61 | |
| | July 21 | 1 | 1194 | 1330 | 1.11 | |
| | | 2 | 1028 | 1462 | 1.42 | |
| | | 3 | 1377 | 2259 | 1.64 | |
| | August 8 | 1 | 134 | 110 | 0.82 | |
| | | 2 | 134 | 172 | 1.28 | |
| | | 3 | 134 | 152 | 1.13 | |
| | 1995 | | | | | |
| | June 16 | 1 | 1364 | 1959 | 1.44 | |
| | | 2 | 1405 | 1514 | 1.08 | |
| | | 3 | 1609 | 1299 | 0.81 | |
| | June 26 | 1 | 386 | 675 | 1.75 | |
| | | 2 | 631 | 675 | 1.07 | |
| | | 3 | 515 | 622 | 1.21 | |
| | June 28 | 1 | 17447 | 17658 | 1.01 | |
| | | 2 | 16432 | 24925 | 1.52 | |
| | | 3 | 21671 | 26357 | 1.22 | |
| Geometric mean | | | 207 | 290 | 1.41 | 0.005 |
| 95% confidence limits | | | 50-859 | 76-1101 | 1.20-1.64 | |
| LARVAE | | | | | | |
| Cunner | 1994 | | | | | |
| Stage 1 | May 4 | All | 0 | 0 | - | |
| | May 9 | All | 0 | 0 | - | |
| | July 21 | All | 0 | 0 | - | |
| | August 8 | All | 0 | 0 | - | |
| | 1995 | | | | | |
| | June 16 | 1 | 59.7 | 25.0 | 0.42 | |
| | | 2 | 30.7 | 18.4 | 0.60 | |
| | | 3 | 69.3 | 39.7 | 0.57 | |
| | June 26 | 1 | 0.6 | 5.4 | 9.82 | |
| | | 2 | 0.8 | 7.3 | 8.80 | |
| | | 3 | 0 | 0 | - | |
| | June 28 | All | 0 | 0 | - | |
| Geometric mean | | | 9.1 | 14.8 | 1.64 | >0.05 |
| 95% confidence limits | | | 0.6-138 | 6-39 | 0.3-10 | |

Table 4 (continued).

| | Date | Replicate | Mesh 0.333 | Mesh 0.202 | Ratio | p[1] |
|---|---|---|---|---|---|---|
| | <u>1994</u> | | | | | |
| Stage 2 | May 4 | All | 0 | 0 | - | |
| | May 9 | All | 0 | 0 | - | |
| | July 21 | 1 | 0 | 2.5 | - | |
| | | 2 | 1.1 | 7.8 | 7.09 | |
| | | 3 | 2.1 | 0 | - | |
| | August 8 | 1 | 0.7 | 0 | - | |
| | | 2 | 0 | 0 | - | |
| | | 3 | 0 | 0 | - | |
| | <u>1995</u> | | | | | |
| | June 16 | 1 | 56.8 | 60.0 | 1.06 | |
| | | 2 | 36.3 | 12.3 | 0.34 | |
| | | 3 | 72.2 | 34.0 | 0.47 | |
| | June 26 | 1 | 16.6 | 43.5 | 2.62 | |
| | | 2 | 56.2 | 90.7 | 1.61 | |
| | | 3 | 85.9 | 54.4 | 0.63 | |
| | June 28 | 1 | 1.5 | 10.4 | 6.75 | |
| | | 2 | 4.5 | 14.0 | 3.13 | |
| | | 3 | 14.4 | 0 | - | |
| Geometric mean | | | 10.0 | 10.0 | 1.00 | >0.05 |
| 95% confidence limits | | | 3-28 | 3-28 | | |
| | <u>1994</u> | | | | | |
| Stage 1 & 2 | May 4 | All | 0 | 0 | - | |
| | May 9 | All | 0 | 0 | - | |
| | July 21 | 1 | 0 | 2.5 | - | |
| | | 2 | 1.1 | 7.8 | 7.09 | |
| | | 3 | 2.1 | 0 | - | |
| | August 8 | 1 | 0.7 | 0 | - | |
| | | 2 | 0 | 0 | - | |
| | | 3 | 0 | 0 | - | |
| | <u>1995</u> | | | | | |
| | June 16 | 1 | 116.5 | 85.0 | 0.73 | |
| | | 2 | 67.1 | 30.7 | 0.46 | |
| | | 3 | 141.5 | 73.7 | 0.52 | |
| | June 26 | 1 | 17.2 | 48.9 | 2.85 | |
| | | 2 | 56.2 | 98.0 | 1.74 | |
| | | 3 | 85.9 | 54.4 | 0.63 | |
| | June 28 | 1 | 1.5 | 10.4 | 6.75 | |
| | | 2 | 4.5 | 14.0 | 3.13 | |
| | | 3 | 14.4 | 0 | 0 | |
| Geometric mean | | | 11.6 | 12.0 | 1.02 | >0.05 |
| 95% confidence limits | | | 3-36 | 3-36 | | |

Table 4 (continued).

| | Date | Replicate | Mesh 0.333 | Mesh 0.202 | Ratio | p[1] |
|---|---|---|---|---|---|---|
| | 1994 | | | | | |
| Stage 3 | May 4 | All | 0 | 0 | - | |
| | May 9 | All | 0 | 0 | - | |
| | July 21 | 1 | 0 | 0 | - | |
| | | 2 | 1.1 | 0 | - | |
| | | 3 | 2.1 | 2.3 | 1.10 | |
| | August 8 | 1 | 12.2 | 13.4 | 1.10 | |
| | | 2 | 13.5 | 7.3 | 0.54 | |
| | | 3 | 2.9 | 5.1 | 1.76 | |
| | 1995 | | | | | |
| | June 16 | All | 0 | 0 | - | |
| | June 26 | 1 | 3.9 | 14.5 | 3.74 | |
| | | 2 | 24.8 | 7.3 | 0.29 | |
| | | 3 | 28.1 | 12.7 | 0.45 | |
| | June 28 | All | 0 | 0 | - | |
| Geometric mean | | | 7.1 | 5.7 | 0.80 | >0.05 |
| 95% confidence limits | | | 3-17 | 2-13 | | |

[1]p = paired t-test

SECTION VI

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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 1995.

*Available upon request.

APPENDIX B*. Geometric mean monthly densities and 95% confidence limits per 100 $m^3$ of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December 1985-1995.

Note the following:

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

Shaded columns for certain months in 1987 delineate periods when sampling was conducted with only salt service water pumps in operation. Densities recorded at those times were probably biased low due to low through-plant water flow (MRI 1994).

*Available upon request.

ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1995

Volume 2 of 2

(Impact Perspective)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 1, 1996

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## SECTION I

## EXECUTIVE SUMMARY

Unusually high entrainment densities as defined under PNPS's notification plan were identified on a number of occasions involving larval sand lance, Atlantic herring, Atlantic mackerel, Atlantic menhaden, hake, and cunner. High densities of tautog/cunner and Atlantic mackerel eggs were also noted. In the case of herring, menhaden, hake, and mackerel, high densities occurred for periods of ten days or more suggesting that survival and/or retention in the PNPS area were relatively high.

Total estimated entrainment losses at PNPS amounted to 1,564,727,621 eggs and 260,082,910 larvae. Equivalent adult analyses were completed for winter flounder, cunner, and Atlantic mackerel. Estimates for 1995 were 1012 or 9879 age 3 winter flounder (depending on methodology), 969,667 cunner, and 14,356 age 3 mackerel. Estimates of equivalent adult cunner potentially lost to entrainment increased sharply (approximately seven-fold) following revised estimates of average lifetime fecundity. These were obtained from studies of the PNPS area population completed in 1995. For flounder and mackerel equivalent adult estimates amounted to less than 1% of commercial and recreational landings. For cunner equivalent adult estimates represented about 0.2% of an estimate of local stock biomass.

A single larval lobster was collected in 1995,raising the 21-year total for PNPS entrainment sampling to 13 individuals.

# SECTION II

## INTRODUCTION

This report focuses on the potential impact of ichthyoplankton entrainment at PNPS. Discussions are based on results presented in "Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1995", Volume 1 - Monitoring. Work was conducted by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. LPS001616 in compliance with environmental monitoring and reporting requirements of the PNPS NPDES Permit (U.S. Environmental Protection Agency and Massachusetts Department of Environmental Protection). 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. Notification Plan

Ichthyoplankton densities reaching the unusually high level during 1995 occurred on a number of occasions. These involved larval sand lance, larval Atlantic herring, larval Atlantic menhaden, larval hake, and both eggs and larvae of cunner and mackerel (Table 1). In the case of Atlantic herring high densities occurred during both spring and fall sampling seasons, over several weeks in each case, suggesting that larval production was strong. This is consistent with the overall 1995 abundance indices and with trends in adult biomass as discussed in Volume 1. Larval hake, mackerel, and menhaden also remained at high densities for periods of ten days, in each case suggesting that survival and/or retention in the PNPS area was relatively high during the period.

Under the revised sampling protocol initiated in 1994 sampling was completed Monday morning, Wednesday afternoon, and Friday night (see Volume 1 Methods and Materials). Depending upon time of sunset, Wednesday samples may also have been taken in darkness. It is interesting to compare uncommonly high densities observed in 1995 with available information on spawning times and diel activity patterns. In some cases high densities observed under the new protocol can be attributed to sampling time rather than an occurrence of exceptional entrainment. Under the previous sampling regime such events likely occurred but remained unidentified.

Table 1. Ichthyoplankton densities (number per 100 m³) for each sampling occasion during months when notably high densities were recorded, January-December 1995. Densities marked by + were unusually high based on values in Table 1. Number in parentheses indicates percent of all previous values during that month which were lower.

**Sand lance larvae**

| | | | |
|---|---|---|---|
| Feb. | 6 | 11.7 | |
| | 8 | 4.6 | |
| | 10 | 14.5 | |
| | 20 | 31.3 + | (97) |
| | 22 | 49.7 + | (97) |
| | 24 | 372.9 + | (100) |

Previous high: 95.8 (1985)
Notice level: 16

**Atlantic herring larvae**

| | | | |
|---|---|---|---|
| March | 6 | 0.8 | |
| | 8 | 0 | |
| | 10 | 0.6 | |
| | 13 | 0 | |
| | 15 | 0 | |
| | 17 | | |
| | 20 | 0 | |
| | 22 | 0 | |
| | 24 | 12.6 + | (100) |
| | 27 | 8.0 | |
| | 29 | 1.3 | |
| | 31 | n.s.[1] | |

Previous high: 9.1 (1983)
Notice level: 1

| | | | |
|---|---|---|---|
| April | 3 | n.s. | |
| | 5 | 4.5 + | (90) |
| | 7 | 0 | |
| | 10 | n.s. | |
| | 13 | 5.5 + | (90) |
| | 15 | 5.6 + | (90) |
| | 17 | 0.8 | |
| | 19 | n.s. | |
| | 21 | n.s. | |
| | 24 | n.s. | |
| | 26 | n.s. | |
| | 28 | n.s. | |

Previous high: 13.8 (1994)
Notice level: 2

**Atlantic herring larvae** (continued)

| | | | |
|---|---|---|---|
| Nov | 6 | 46.9 + | (98) |
| | 8 | 1.8 | |
| | 10 | 124.8 + | (100) |
| | 22 | 20.7 + | (100) |
| | 24 | 51.5 + | (98) |
| | 29 | 0 | |

Previous high: 54.8 (1994)
Notice level: 8

| | | | |
|---|---|---|---|
| Dec | 4 | 20.9 + | (100) |
| | 6 | 216.7 + | (100) |
| | 8 | 71.1 + | (100) |
| | 13 | 15.6 + | (100) |
| | 18 | 6.3 + | (92) |
| | 22 | 0 | |
| | 26 | 2.0 | |

Previous high: 12.3 (1987,1994)
Notice level: 3

**Tautog/Cunner eggs**

| | | | |
|---|---|---|---|
| June | 2 | 225.9 | |
| | 5 | 242.9 | |
| | 7 | 406.1 | |
| | 9 | 1710.8 | |
| | 12 | 281.4 | |
| | 14 | 10510.5 | |
| | 16 | 1363.9 | |
| | 19 | 107.2 | |
| | 21 | 37282.5 + | (100) |
| | 23 | 2787.7 | |
| | 26 | 385.7 | |
| | 28 | 17446.7 | |
| | 30 | 639.9 | |

Previous high: 31833 (1974)
Notice level: 21599

Table 1 (continued)

**Atlantic mackerel**

| | | Eggs | Larvae |
|---|---|---|---|
| May | 1 | n.s. | n.s. |
| | 3 | n.s. | n.s. |
| | 5 | 0 | 0 |
| | 8 | n.s. | n.s. |
| | 10 | n.s. | n.s. |
| | 12 | 1.9 | 0 |
| | 15 | n.s. | n.s. |
| | 17 | 134.7 | 0 |
| | 19 | 12.2 | 0 |
| | 22 | 24.7 | 0 |
| | 24 | n.s. | n.s. |
| | 26 | 19203 + (100) | 4.0 |
| | 29 | 557.0 | 0 |
| | 31 | 139.0 | 0 |
| Previous high: | | 14967 (1989) | 26.4 (1991) |
| Notice level: | | 3405 | -- |
| June | 2 | 337.7 | 1.5 |
| | 5 | 346.0 | 0.7 |
| | 7 | 480.6 | 0.8 |
| | 9 | 4754.0 + (98) | 15.3 |
| | 12 | 2242.7 | 1965.4 + (99) |
| | 14 | 20.5 | 601.1 + (99) |
| | 16 | 144.9 | 1034.3 + (99) |
| | 19 | 12.9 | 207.3 + (93) |
| | 21 | 0 | 535.3 + (99) |
| | 23 | 0 | 141.6 + (93) |
| | 26 | 0 | 62.1 |
| | 28 | 0 | 35.5 |
| | 30 | 0 | 21.2 |
| Previous high: | | 8193 (1990) | 2700 (1981) |
| Notice level: | | 3515 | 83 |
| July | 3 | 0 | 43.2 + (100) |
| | 5 | 0 | 60.1 + (100) |
| | 7 | 0 | 35.4 + (99) |
| | 10 | 0 | 0 |
| | 12 | 0 | 1.2 |
| | 14 | 0 | 0 |
| | 17 | 0 | 0 |
| | 19 | 0 | 0 |
| | 21 | 0 | 0 |
| | 24 | 0 | 0 |
| | 26 | 0 | 0 |
| | 28 | 0 | 1.6 |
| Previous high: | | | 37.1 (1981) |
| Notice level: | | | 3 |

**Atlantic menhaden larvae**

| | | |
|---|---|---|
| June | 2 | 0 |
| | 5 | 0 |
| | 7 | 0 |
| | 9 | 1.5 |
| | 12 | 8.2 |
| | 14 | 0 |
| | 16 | 19.9 + (92) |
| | 19 | 58.6 + (98) |
| | 21 | 38.0 + (96) |
| | 23 | 25.5 + (92) |
| | 26 | 10.0 + (89) |
| | 28 | 7.7 |
| | 30 | 8.0 |
| Previous high: | | 495.9 (1981) |
| Notice level: | | 10 |
| July | 3 | 1.4 |
| | 5 | 2.0 |
| | 7 | 0 |
| | 10 | 1.0 |
| | 12 | 4.2 + (88) |
| | 14 | 2.8 |
| | 17 | 1.4 |
| | 19 | 0.8 |
| | 21 | 0 |
| | 24 | 0.7 |
| | 26 | 0 |
| | 28 | 6.3 + (95) |
| | 31 | 0 |
| Previous high: | | 124 (1974) |
| Notice level | | 3 |
| Oct | 9 | 0 |
| | 11 | 3.9 + (98) |
| | 13 | 0.7 |
| | 23 | 9.6 + (98) |
| | 25 | 40.7 + (100) |
| | 27 | 14.8 + (100) |
| Previous high: | | 11 (1980) |
| Notice level: | | 1 |

Table 1 (continued)

**Hake larvae**

| | | | |
|---|---|---|---|
| Aug | 2 | 31.9 + | (99) |
| | 4 | 131.3 + | (100) |
| | 7 | 62.0 + | (100) |
| | 9 | 196.1 + | (100) |
| | 11 | [2] | |
| | 14 | 47.1 + | (99) |
| | 16 | 0 | |
| | 18 | 0 | |
| | 21 | 0 | |
| | 23 | 0 | |
| | 25 | 1.9 | |
| | 28 | 5.2 + | (88) |
| | 30 | 0.9 | |

Previous high: 49 (1989)
Notice level: 4

| | | | |
|---|---|---|---|
| Sept | 1 | 0 | |
| | 4 | 0 | |
| | 6 | 0 | |
| | 8 | 7.6 | |
| | 11 | 9.8 + | (88) |
| | 13 | 18.7 + | (95) |
| | 15 | 28.4 + | (98) |
| | 18 | 0 | |
| | 20 | 1.7 | |
| | 22 | 0 | |
| | 25 | 33.3 + | (98) |
| | 27 | 2.9 | |
| | 29 | 4.0 | |

Previous high: 122 (1985)
Notice level: 9

**Cunner larvae**

| | | | |
|---|---|---|---|
| Aug | 2 | 2.7 | |
| | 4 | 8.3 | |
| | 7 | 8.6 | |
| | 9 | 92.8 + | (97) |
| | 11 | n.s. | |
| | 14 | 51.4 + | (95) |
| | 16 | 24.7 + | (88) |
| | 18 | 22.5 + | (88) |
| | 21 | 4.8 | |
| | 23 | 0.8 | |
| | 25 | 13.1 | |
| | 28 | 9.1 | |
| | 30 | 2.6 | |

Previous high: 165 (1974)
Notice level: 15

[1]n.s. = No sample taken due to circulating water pump shutdown.
[2]No sample due to storm.

In 1994 record high densities of larval sand lance were taken on two occasions; both were night samples. Similarly in February 1995 one night sample density exceeded the previous 20-year high for that month by a factor of nearly four. Dalley and Winters (1987) offer some data suggesting that larval sand lance move upward in the water column at night; they, and perhaps others, may be more susceptible to entrainment at night as a result of such behavior (see MRI 1995a for example).

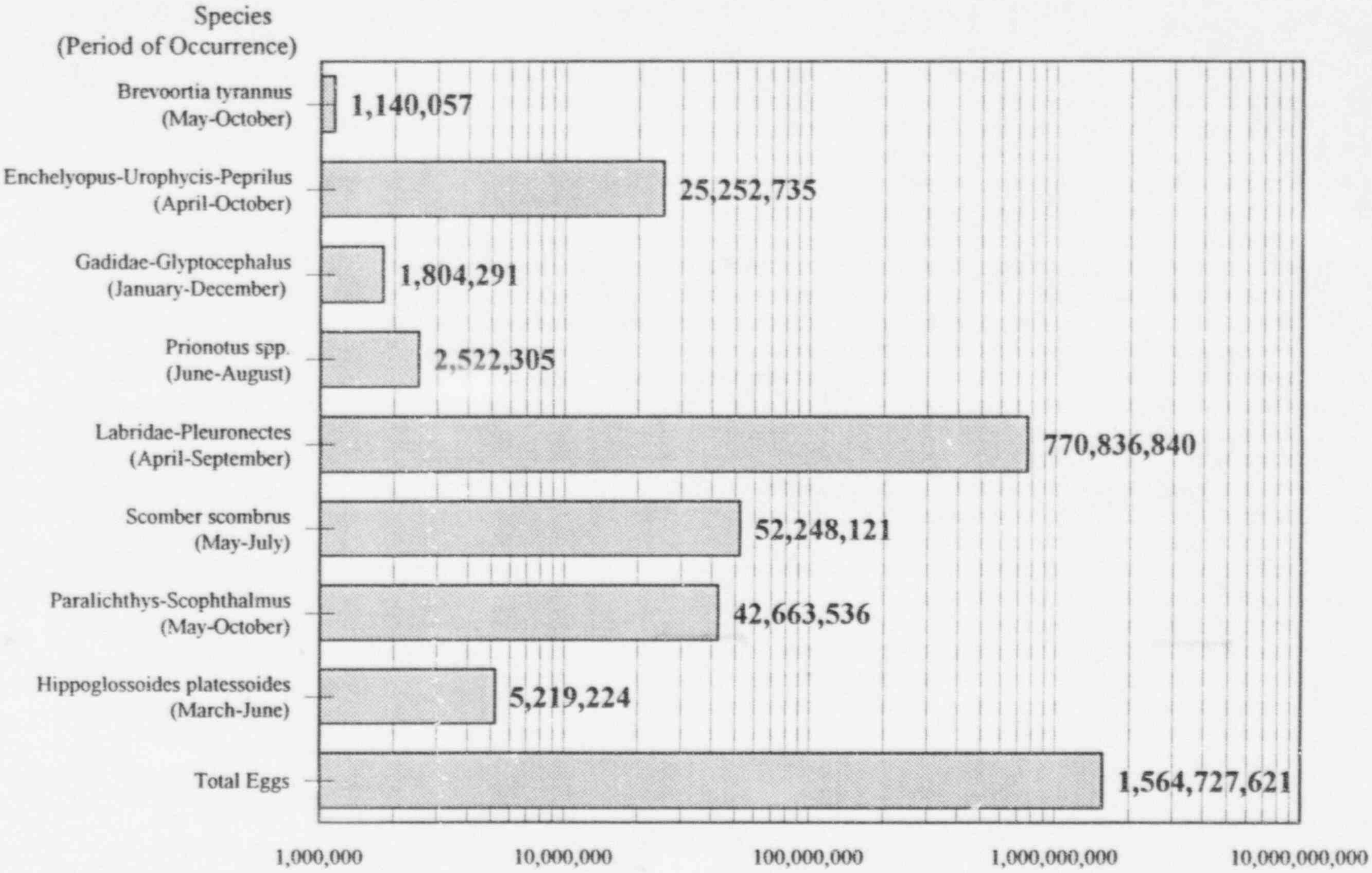
Atlantic mackerel eggs were exceptionally abundant on the night of May 26. However for this species spawning can occur at any time of day or night (Walsh and Johnstone 1992) so the high density in that case was more likely to have been a random occurrence. Cunner are reported to spawn most heavily during late afternoon and evening hours (Ferraro 1980). This is consistent with egg density observations made during June 1995 at PNPS (Table 3). The three highest densities over the course of the month, each exceeding 10,000 eggs per 100 $m^3$, occurred in Wednesday afternoon samples.

B. <u>Ichthyoplankton Entrainment - General</u>

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. In effect the power plant acts as a predator increasing overall mortality rates. When PNPS is not on line, increased temperature is not a potential mortality 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) and winter flounder (MRI 1982) and among larvae at other power plants (0-100% initial survival depending on species and size; Ecological Analysts 1981), entrainment mortality is conservatively assumed to be 100% in all PNPS impact assessments.

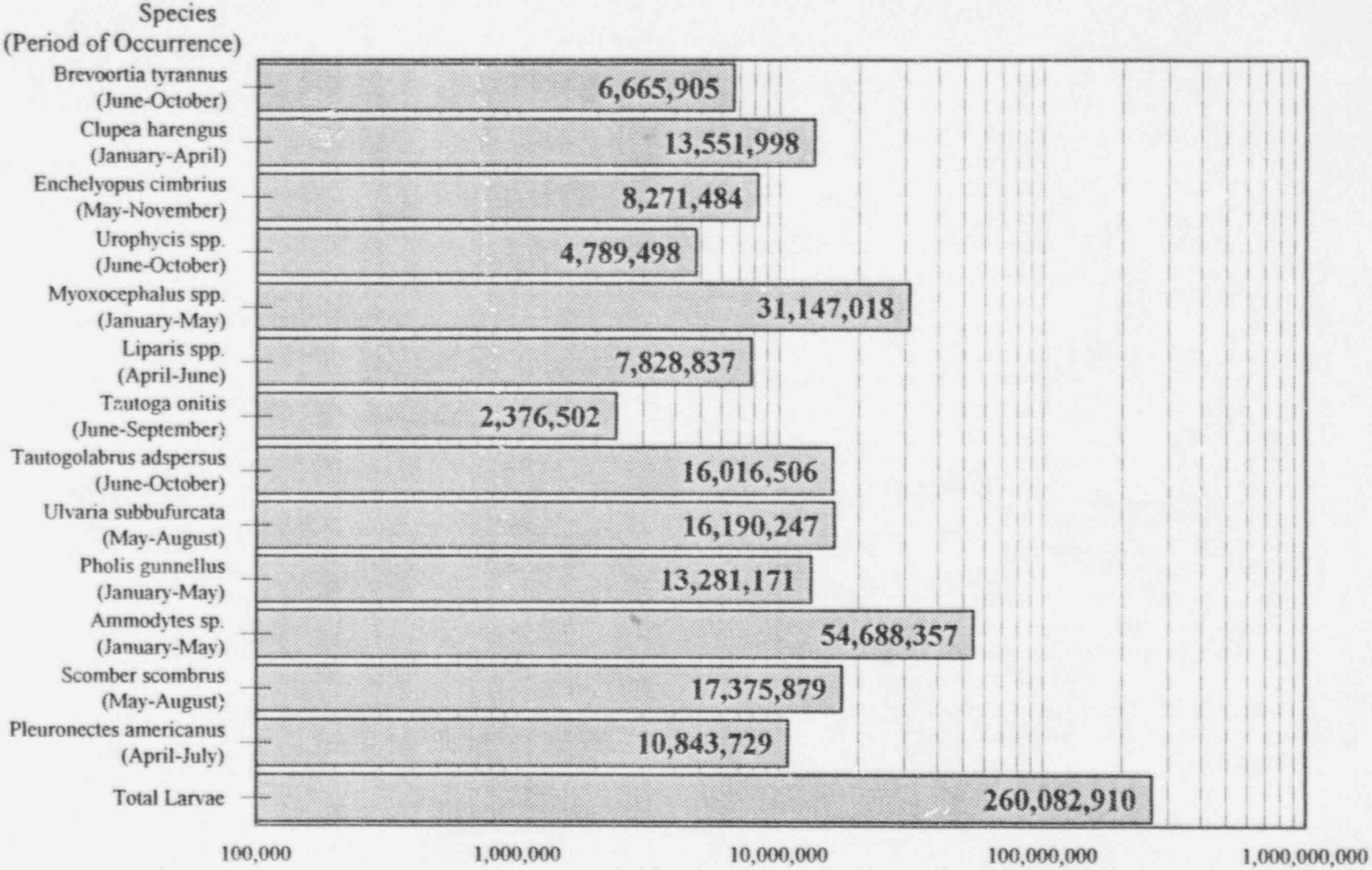
To place fish egg and larval densities entrained at PNPS, expressed as numbers per 100 $m^3$ of water, in some perspective in relation to amounts of water utilized by PNPS, they were multiplied by maximum plant flow rates over each respective period of occurrence. This was completed for each of the numerically dominant species as well as total eggs and total larvae. Geometric 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 1,140,057 for the Atlantic menhaden (Brevoortia tyrannus) to 770,836,840 for the labrid-yellowtail group (tautog, Tautoga onitis, cunner, Tautogolabrus adspersus, yellowtail flounder, Pleuronectes ferrugineus). Corresponding values among the thirteen dominant larval species varied from a low of 2,376,502 for tautog to a high of 54,688,357

# Number of Eggs Entrained - 1995




C:\JFB\PNPS\ENTNUM95.PRS

# Number of Larvae Entrained - 1995




C:\JFB\PNPS\ENTNUM95.PRS

for sand lance (Ammodytes sp). For all eggs and larvae combined, values amounted to 1,564,727,621 and 260,082,910, respectively. These totals clarify the extent to which vast quantities of eggs and larvae can be entrained by the circulating seawater system at PNPS during a single year and are presumably lost.

C. Ichthyoplankton Entrainment - Specific

Estimated numbers of eggs and larvae entrained annually at PNPS were examined in greater detail for three species of fish using the equivalent adult approach (EAA, see Horst 1976, Goodyear 1978, for example). Somewhat arbitrarily this review dates back to 1987 so that with the addition of 1995 nine years are included. The adult equivalent methodology applies estimated survival rates to numbers of eggs and larvae lost to entrainment to obtain a number of adult fish which might have entered the local population had entrainment not occurred. The consequences, if any, of the loss can then be considered if the size of the extant population is known or numbers can be compared with commercial or recreational landings.

Many assumptions are associated with the EAA. 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 non-entrained 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 calculated over three replicates typically varied by 10% or less. In calculating total entrainment values for the adult equivalent methodology we chose to use the larger arithmetic mean for all sampling dates preceding April 1994 when replicate samples were taken to lend additional conservatism to the assessments.

In summary, four opportunities were chosen to overestimate the impact of PNPS:

1) All eggs and larvae were assumed killed by plant passage.
2) No density-dependent survival compensation is assumed to occur.
3) PNPS is assumed to operate at full-flow capacity year round.
4) Mean entrainment densities were overestimated by the arithmetic mean for sampling dates when three replicates were taken.

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. 1995). Mackerel were included because they are abundant among the ichthyoplankton entrained, both eggs and larvae being removed from the population, and they are commercially and recreationally 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 (Witherell and Burnett 1993, NOAA 1995). Numbers of stage 1 and 2 larvae were scaled upward by 1.62 to correct for mesh extrusion (MRI 1995b). 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 during the 1996 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 1012 age 3 fish for 1995 (Table 2). The stage-specific values produced an EA total nearly ten times higher at 9879 age 3 individuals. Based on a weight of 0.6 pounds per fish (Gibson 1993b), these values convert to 607 and 5927 pounds, respectively. Comparable values for 1988-1994 ranged from 533 to 1272 fish (mean = 788 fish, 473 pounds) for the general approach and 2618 to 15,556 (mean = 7522 fish, 4513 pounds) for the staged approach; 1987 was omitted here because sampling did not occur in April that year. 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 1,431,651 pounds (S.E. = 186,709) 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 average 1988-1995 loss of 490 or 4690 pounds of equivalent adults represents 0.03 or 0.3% of those landings. Winter flounder also have considerable value as a recreational species. For example, in 1989 and 1991, 2,990,000 and 199,000 flounder, respectively, were landed in Massachusetts by recreational anglers (Van Voorhees et al. 1992). The estimated loss of an average of 816 or 7817 flounder equates to 0.05 or 0.5% of the average of the above two values.

Massachusetts Division of Marine Fisheries personnel made a preliminary estimate of the number of adult winter flounder (≤280 mm TL - age 3+) in the PNPS area using area swept by a commercial trawl (see Section IIIA, this report). While reliable estimates of local population size are difficult to make, they often provide more realistic numbers with which to compare EA values since landings data typically represent numbers caught over a very large area. Numbers of fish equalled about 62,000 with 95% confidence limits of 12,000 to 112,000. If, as they point out, gear efficiency is assumed to be 50% (perhaps less), these values would double. The 1995 adult equivalent loss of 9879 age 3 fish from the staged approach equates to 16% of the straight estimate, 8% of the efficiency-adjusted value.

Table 2. Numbers of larval winter flounder entrained at PNPS annually by stage, 1987-1995. Number of equivalent age 3 adults calculated by two methods is also shown.

| | Number of Larvae Entrained ($x10^6$) | | | | | Equivalent Age 3 Adults | |
|---|---|---|---|---|---|---|---|
| Stage: | 1[1] | 2[1] | 3 | 4 | Total | General | Staged |
| 1987[2] | 0 | 0.432 | 3.088 | 0 | 3.520 | 217[1] | 2618[1] |
| 1988 | 1.971 | 1.635 | 15.080 | 0.511 | 19.197 | 1184 | 15556 |
| 1989 | 1.648 | 5.685 | 2.225 | 0.039 | 9.597 | 592 | 2618 |
| 1990 | 0.635 | 1.141 | 6.847 | 0.033 | 8.656 | 533 | 6014 |
| 1991 | 3.429 | 3.861 | 5.188 | 0.038 | 12.516 | 772 | 4960 |
| 1992 | 0.862 | 0.866 | 7.035 | 0.026 | 8.789 | 542 | 6113 |
| 1993 | 1.576 | 3.498 | 4.935 | 0.089 | 10.098 | 623 | 4953 |
| 1994 | 1.022 | 6.354 | 13.060 | 0.172 | 20.608 | 1272 | 12439 |
| 1995 | 2.645 | 4.568 | 8.826 | 0.376 | 16.416 | 1012 | 9879 |
| Mean | 1.532 | 3.116 | 7.365 | 0.143 | 12.165 | 750 | 7239 |
| S.E. | 0.352 | 0.729 | 1.443 | 0.060 | 1.855 | 115 | 1486 |
| w/o 1987 | 1.724 | 3.451 | 7.900 | 0.161 | 13.246 | 816 | 7817 |
| S.E. | 0.334 | 0.734 | 1.519 | 0.065 | 1.709 | 106 | 1553 |

[1]Mesh factor = 1.62 applied to Stages 1 and 2.

[2]No April sampling, estimates therefore biased.

Cunner. Goodyear's (1978) basic procedures were used to estimate equivalent adult values. This method converts numbers of eggs and larvae to numbers of fish at age of sexual maturity which occurs for approximately half the population at age 1 (P. Nitschke, University of Massachusetts, Amherst, 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. Mesh correction values presented earlier (1.40 for eggs, none required for larvae) were first applied. From 1988 to 1995 the ratio averaged 0.0187; 1987 was excluded because of extended pump shutdown. Average lifetime fecundity was calculated from fish in the PNPS area provided by P. Nitschke (personal communication). He provided numbers of eggs produced at age in the second order form:

$$\text{Log } F = [4.46 \log A] - [2.49 \log A^2] + 2.61 \text{ where}$$

$F$ = fecundity at age A

Age-specific instantaneous mortality was calculated from pot collections (P. Nitschke, personal communication). Pot collections were converted from length to age using a von Bertalanffy growth equation for sexes combined developed by Massachusetts Division of Marine Fisheries personnel working in conjunction with P. Nitschke (B. Kelly, personal communication).

$$L_t = 235.9\ [1 - e\verb|^|\ (-0.164\ (t + 0.869))] \text{ where}$$

$L_t$ = length at age t in mm

This growth model was solved for age t providing

$$t = -0.869 - \frac{1}{0.164} \ln \left(1 - \frac{L_t}{235.9}\right)$$

The PNPS area collections provided an annual instantaneous mortality rate of Z = 0.6958 equivalent to an annual survival rate of 0.499 for ages 2 through 10. Utilizing data from Serchuk and Cole (1974) for age 1 through 5 cunner collected with assorted gear, a survival rate of 0.605 was obtained (Z = 0.5025). Since their study was completed in the more temperate, protected waters of the Weweantic River estuary, greater survival there seemed reasonable. Age 1 fish appeared less abundant in the PNPS collections than age 2 fish, suggesting they were not fully recruited to the pot collections, perhaps due to their small size or behavior. In the absence of additional information the age 2 through 10 value was applied to that age class as well.

Based on the PNPS area fecundity study, 50% of age 1 females were assumed to be mature; complete recruitment was assumed by age 2. Following Goodyear (1978), an average lifetime fecundity of 13,946 eggs per female was calculated. Utilizing the survival estimate for eggs to larvae and average lifetime fecundity, a survival estimate for larvae to adult of 7.67E-3 was calculated. Converting numbers of eggs to larvae utilizing the larvae:egg ratio and then converting numbers of larvae to adult produced an estimate of 969,667 cunner potentially lost to entrainment effects in 1995.

Comparable values for 1987-1994 ranged from 225,386 to 1,362,297 adults averaging 663,135 (S.E. = 133,065) over the nine-year period (Table 3).

Numbers of equivalent adult cunner potentially lost to entrainment increased sharply in the analysis presented here compared with previous years (see MRI 1995c for example). The annual average for 1987-1994 increased from 89,495 (S.E. = 19,327) to 624,819 (S.E. = 144,490) fish, nearly a seven-fold change. The increase in EA values resulted from a seven-fold decrease in average lifetime fecundity. Prior to empirical data being available, a value of 100,000 was somewhat arbitrarily selected (MRI 1995), clearly too high for the PNPS area population. Since the EA procedure assumes a stable population, when fewer eggs are produced, survival rates by definition must increase to maintain the population.

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 multiplied by 1.40 to account for extrusion through the 0.505-mm mesh used in that survey (MRI unpublished), then by the sector volume. Based on the 0.333/0.202 mesh data collected from the PNPS discharge stream in 1994 and 1995, additional upward scaling might be appropriate. No specific data for towed samples are available and an estimated value was not applied to provide additional conservatism to the comparison. The resulting value was divided by 2.2, the estimated incubation time in days for cunner eggs (Johansen 1925), then divided by 17,882, an estimate of mean annual fecundity per female derived from P. Nitschke (personal communication). Lastly the resulting value was multiplied by 2 assuming an even sex ratio. These calculations resulted in an estimated production of 6.899E12 eggs by an estimated 350,739,000 adult fish. The mean loss of 663,135 fish represents 0.19% of that value.

Massachusetts Division of Marine Fisheries personnel have chosen cunner as an indicator species for PNPS impact investigations. Studies are underway to develop population estimates for the PNPS area. An important and difficult phase of this study is setting bounds to the population potentially impacted by PNPS.

Atlantic mackerel. Procedures outlined by Vaughan and Saila (1976) were used to derive a survival rate for mackerel eggs to age 1 fish. This procedure utilizes the Leslie matrix algorithm to estimate early survival from proportion mature, fecundity, and survival within each age class assuming a stable population. If

Table 3. Numbers of cunner eggs and larvae entrained at PNPS annually, 1987-1995. Numbers of equivalent adults are also shown.

| | Total Number Entrained ($x10^6$) | | | | | |
|---|---|---|---|---|---|---|
| | | Larvae | | | | |
| Year | Eggs[1] | Stage 1[2] | Stage 2[2] | Stage 3 | Total | Equivalent Adults |
| 1987 | 5041.766 | 0.268 | 0.246 | 0.249 | 0.748 | 729068 |
| 1988 | 1737.681 | 1.975 | 2.050 | 2.461 | 6.521 | 299316 |
| 1989 | 5046.115 | 29.397 | 11.894 | 2.864 | 44.178 | 1062880 |
| 1990 | 1508.441 | 56.643 | 48.733 | 44.015 | 149.398 | 1362297 |
| 1991 | 762.097 | 4.992 | 2.892 | 7.244 | 15.130 | 225386 |
| 1992 | 2455.263 | 0 | 0.927 | 1.605 | 2.565 | 371924 |
| 1993 | 3652.777 | 0.073 | 5.608 | 7.923 | 13.561 | 628064 |
| 1994 | 1759.319 | 0 | 4.333 | 4.440 | 8.773 | 319694 |
| 1995 | 4647.652 | 6.864 | 23.368 | 9.258 | 39.489 | 969667 |
| Mean | 2956.790 | 11.135 | 11.024 | 8.895 | 31.151 | 663135 |
| S.E. | 554.551 | 6.490 | 5.312 | 4.507 | 15.651 | 133065 |

[1]Mesh adjustment = 1.40

[2]Mesh adjustment = 1.00

the same parameters are used, the Vaughan and Saila, and Goodyear (1978) procedures yield equal numbers of equivalent adults. Fecundity for Atlantic mackerel was obtained from Griswold and Silverman (1992) and Neja (1992). Age-specific instantaneous mortality was obtained from Overholtz et al. (1988) and NOAA (1995). Since two fecundity profiles provide two egg to age 1 survival values: 2.2231E-6 for Griswold and Silverman, 2.3162E-6 for Neja, values were averaged (2.2697E-6). The observed average ratio of eggs to larvae for PNPS of 0.026863 (1988-1995) provided a larva-to-age 1 survival rate of 8.4492E-5. A mesh adjustment factor of 1.56 was applied to the egg data based on 1994 mesh comparison collections (MRI 1995b). According to NOAA (1995) 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). Age 3 individuals were estimated using an instantaneous natural mortality rate of M = 0.20 together with an instantaneous fishing mortality rate of F = 0.02 (NOAA 1995). These values provide an annual survival rate of S = 0.8025.

Equivalent adult estimates for 1995 were 22,291 age 1 individuals, 14,356 age 3 fish. These compare with an average of 6790 (S.E. = 2227) and 4373 (S.E. = 1434) age 1 and 3, respectively, over the 1987-1994 period. Converting these numbers to weight using 0.2 and 0.7 pounds per individual (Clayton et al. 1978) resulted in an average estimated annual loss of 1358 pounds of age

Table 4. Numbers of Atlantic mackerel eggs and larvae entrained at PNPS annually, 1987-1994. Numbers of equivalent age 1 and 3 fish are also shown.

| Year | Total Entrained ($x10^6$) | | Equivalent Adults | |
|---|---|---|---|---|
| | Eggs[1] | Larvae | Age 1 | Age 3 |
| 1987[2] | 117.146 | 0.281 | 290 | 187 |
| 1988 | 3710.026 | 3.401 | 8708 | 5608 |
| 1989 | 6510.097 | 65.562 | 20315 | 13083 |
| 1990 | 3222.258 | 4.627 | 7705 | 4962 |
| 1991 | 668.240 | 66.009 | 7094 | 4569 |
| 1992 | 525.958 | 8.086 | 1877 | 1209 |
| 1993 | 2509.062 | 8.326 | 6398 | 4121 |
| 1994 | 725.563 | 3.419 | 1936 | 1247 |
| 1995 | 2462.027 | 197.690 | 22291 | 14356 |
| Mean | 2272.654 | 39.711 | 8513 | 5482 |
| S.E. | 683.945 | 21.642 | 2612 | 1682 |
| Mean w/o 1987 | 2541.264 | 44.64 | 9541 | 6144 |
| S.E. | 712.831 | 23.895 | 2723 | 1754 |

[1]Mesh adjustment = 1.56 for eggs.

[2]Only SSWS pumps running during much of summer, densities likely biased (MRI 1994).

1 or 3061 pounds of age 3 fish over the eight-year period, 4458 and 10,049 pounds respectively in 1995.

According to NOAA statistical records, an annual average of 334,806 pounds (S.E. = 120,177) of mackerel were taken commercially from statistical area 514 over the years 1987-1994. The loss of an average of 1703 pounds of age 1 fish (1987-1995) amounts to 0.5% of those landings and the loss of 3837 pounds of age 3 fish, 1.1%. In addition to commercial landings, mackerel have considerable recreational value. For example, in 1989 and 1991, 1,999,000 and 2,333,000 mackerel, respectively, were landed in Massachusetts by recreational anglers (Van Voorhees et al. 1992). The estimated loss of an average of 8513 age 1 fish equates to 0.4% of the average of the above two values.

Finfish collections in western Cape Cod Bay might be expected to show declines if the annual loss of eggs and larvae to entrainment by PNPS were a serious impact. This appears to be the case for cunner based on diver surveys off PNPS (Lawton et al. 1995). Numerous trawl surveys suggest that winter flounder are at historically low levels regionwide (see NEP and MRI 1995, for example). At least in the case of winter flounder, overfishing has been identified as a major contributor to their low levels. Sampling of finfish populations in the PNPS area has evolved from a general monitoring approach to an indicator-species approach focusing on cunner, flounder, and smelt. Program changes associated with this focus make it less appropriate for tracking long-term trends in abundance for other species. In general, however, data suggest that groundfish stocks are at low levels (Lawton et al. 1995). These general declines in finfish stocks, particularly among cunner which have little or no commercial value, have stimulated renewed examinations of the role that PNPS entrainment might play both in the decline of these stocks and the rate at which they can rebuild with reductions in exploitation.

D. Lobster Larvae

With only 13 individuals being taken in 21 years of entrainment sampling, the scarcity of larval lobsters (Homarus americanus) 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 1352 tons annually (S.E. = 30 tons) from 1985-1994 (see McCarron and Hoopes 1995 for example). Landings in 1995 were the highest of the time series. 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. The revised sampling regime begun in 1994 might produce some larval lobster if they are more susceptible to entrainment at night. The 1994 and 1995 results (only one lobster larva taken) at least suggest this is not the case.

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# IMPINGEMENT OF ORGANISMS AT
# PILGRIM NUCLEAR POWER STATION
(January - December 1995)

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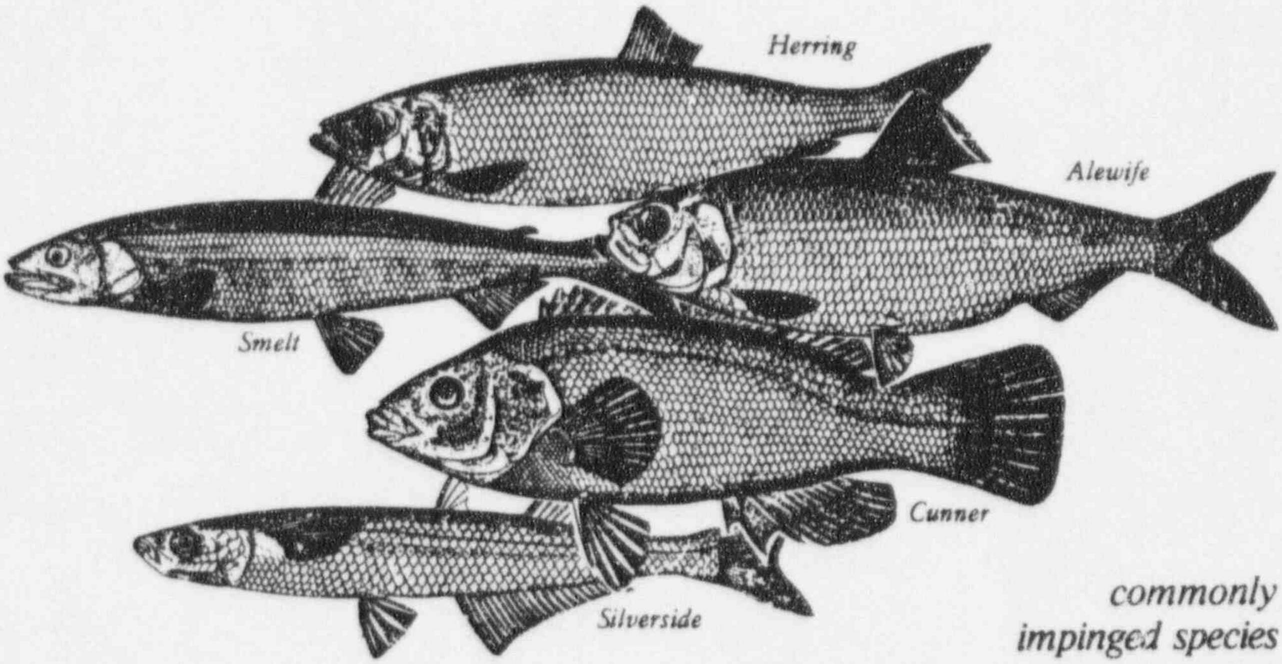


commonly
impinged species

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## SECTION I

## SUMMARY

Fish impingement rate averaged 5.87 fish/hour during the period January-December 1995, which is with 1994 (5.97) the highest rate since 1981 because of large impingement incidents. Alewife (Alosa pseudoharengus) accounted for 52.4% of the fishes collected followed by Atlantic silverside (Menidia menidia) at 30.8%. Rainbow smelt (Osmerus mordax) and winter flounder (Pleuronectes americanus) represented 4.5 and 2.6%, respectively, of the fishes impinged. The peak period was September 8-9 when a large fish impingement incident was dominated by an estimated 13,100 alewife. This was the first large impingement for alewives since 1976. Initial impingement survival for all fishes from static screen wash collections was approximately 55%, and from continuous screen washes 87%.

At 100% yearly (January-December) operation of Pilgrim Nuclear Power Station (PNPS) the estimated annual impingement was 51,464 fishes (1,017 lbs.). The PNPS capacity factor was 76.4% during 1995.

The collection rate (no./hr.) for all invertebrates captured from January-December 1995 was 1.52+. Ctenophores and jellyfish were most numerous. Sevenspine bay shrimp (Crangon septemspinosa), longfin squid (Loligo pealeii) and worms (Nereis sp.) accounted for 45.8, 14.5 and 13.5%, respectively, of the invertebrates impinged and enumerated. Mixed species of algae collected on intake screens amounted to 5,381 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. DEP) for Pilgrim Nuclear Power Station. The report describes impingement of organisms and survival of fishes carried onto the vertical travelling water screens at Pilgrim Station. It presents analysis of the relationships among impingement, environmental factors, and plant operational variables.

This report is based on [illegible] collected from screen wash samples during January-December 1995.

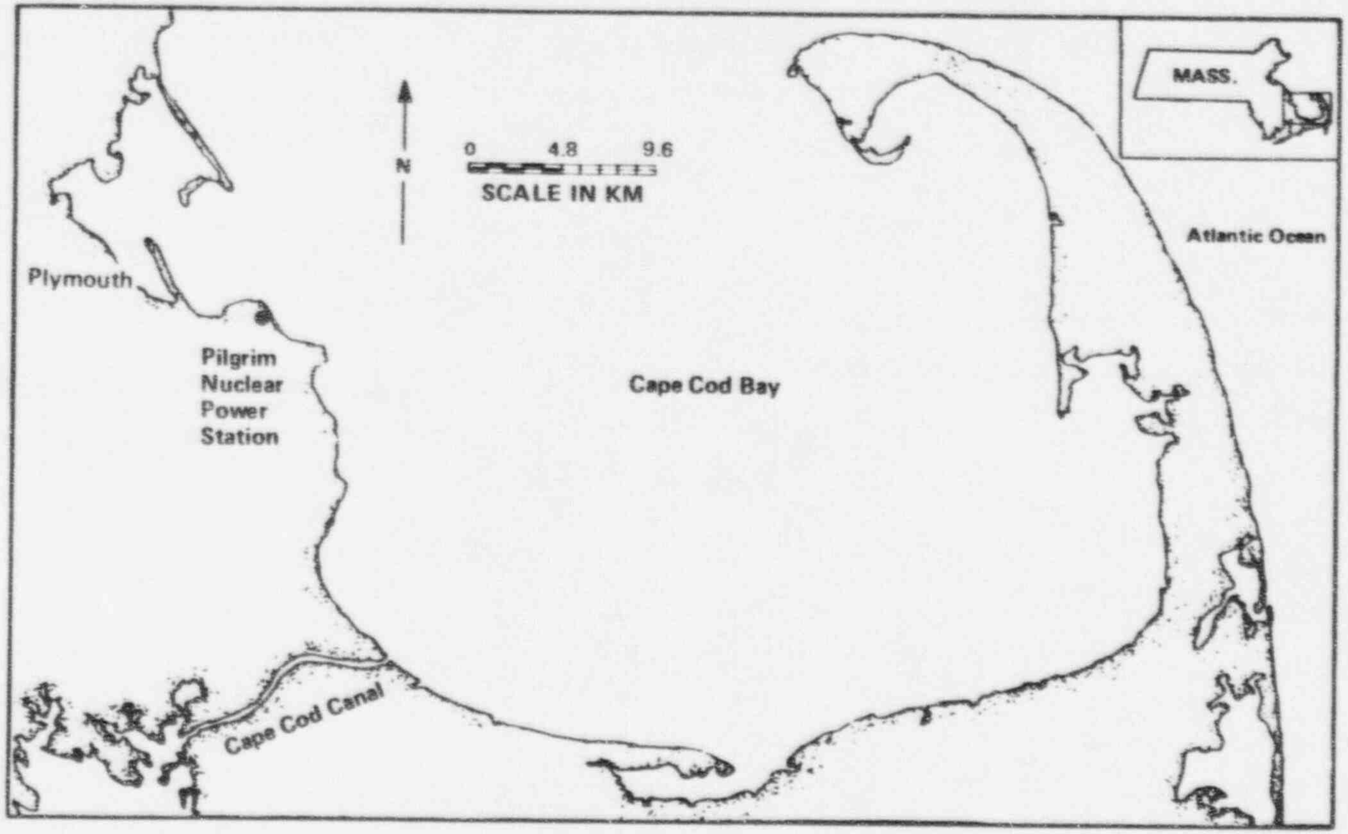


Figure 1. Location of Pilgrim Nuclear Power Station.

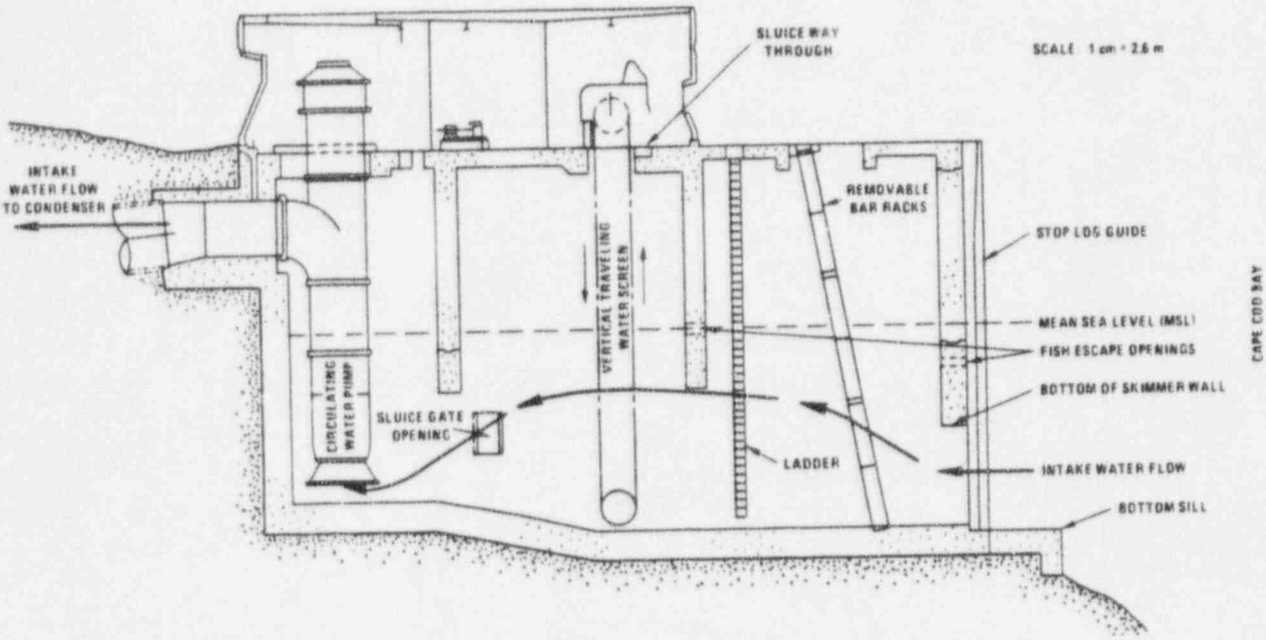


Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

## SECTION 3

## METHODS AND MATERIALS

Three screen washings each week were performed from January-December 1995 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 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. Initial fish survival was determined for static (8-hour) and continuous screenwash cycles.

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

Intake seawater temperature, power level output, tidal stage, number of circulating water pumps in operation, time of day and date were recorded at 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 607.67 collection hours, 3,570 fishes of 35 species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January - December 1995. The collection rate was 5.87 fish/hour. This annual impingement rate and the 1994 rate (5.97) were the highest since 1981, primarily because of large impingement incidents of Atlantic silverside (Menidia menidia) and/or rainbow smelt (Osmerus mordax) in 1994, and alewife (Alosa pseudoharengus) in September 1995. Alewife was the most abundant species in 1995, accounting for 52.4% of all fishes collected, followed by Atlantic silverside at 30.8% (Table 2). Rainbow smelt and winter flounder (Pleuronectes americanus) accounted for 4.5 and 2.6% of the total number of fishes collected and identified to lowest taxon.

Alewife occurred most predominantly in monthly samples from September. Hourly collection rates per month for them ranged from 0 to 54.65. Alewife impinged in September accounted for 98% of all this species captured in impingement collections from January-December 1995. They averaged 117 mm total length and 11 grams in weight. Their impingement indicated no relationship to tidal stage or diel factors. This is the first time for them to be the dominant fish in the annual impingement catch, although herrings (clupeids) as a general category dominated impingement in 1973 and 1974. Impingement histories of abundant species impinged at Pilgrim Station in 1995, over the past 10 years, are documented in Table 3.

Atlantic silverside were very abundant in January and March impingement collections and have been most prevalent in the early spring period in the past, ranking first in 10 out of the last 15 years in total numbers impinged. In 1994 there were two large impingements of silversides, one in November and another in December.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January-December 1995

| Species | Jan | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alewife | 4 | | 1 | | 1 | 4 | | 13 | 1,840 | | 2 | 6 | 1,871 |
| Atlantic silverside | 288 | 39 | 680 | 20 | 1 | | | | 1 | | 31 | 40 | 1,100 |
| Rainbow smelt | 138 | 2 | 2 | 3 | | | | | | | 3 | 14 | 162 |
| Winter flounder | 17 | 6 | 3 | 8 | 4 | 1 | 6 | 24 | 1 | | 4 | 18 | 92 |
| Blueback herring | 1 | | 2 | | 38 | 6 | 8 | | | | 3 | 29 | 87 |
| Atlantic menhaden | | | | | | | | | 70 | | 3 | | 73 |
| Grubby | 20 | 1 | 2 | 1 | 3 | 4 | 1 | | 1 | 1 | 3 | 8 | 45 |
| Cunner | | | | | 1 | 7 | | | | | 11 | 1 | 20 |
| Atlantic tomcod | 8 | | 1 | 2 | | | | | | | 2 | 2 | 15 |
| Threespine stickleback | 4 | 1 | 6 | | | | | | | | | | 11 |
| Atlantic herring | | | 6 | | | 4 | | | | | | | 10 |
| Windowpane | | | | 3 | | 1 | | | 1 | | 2 | 3 | 10 |
| Lumpfish | 6 | | 1 | | | | 1 | | 1 | | | | 9 |
| Northern pipefish | | | 1 | | | | | | 1 | | 7 | | 9 |
| Red hake | | | | 3 | | 1 | | | 1 | | | 1 | 6 |
| Atlantic cod | | 1 | | | | 4 | | | | | | | 5 |
| Radiated shanny | 1 | | 2 | 1 | | | | | | | | 1 | 5 |
| Rock gunnel | | 1 | 2 | 2 | | | | | | | | | 5 |
| Tautog | 1 | | 1 | | | | | | | | 1 | 2 | 5 |
| Black sea bass | | | | | | | | | | | 4 | | 4 |
| Northern searobin | | | | | 3 | | | | | 1 | | | 4 |
| Little skate | | | | | 1 | 1 | 1 | | | | | | 3 |
| Pollock | | | | | 1 | 2 | | | | | | | 3 |
| Butterfish | | | | | | | | | 1 | 1 | | | 2 |
| Mummichog | | | 2 | | | | | | | | | | 2 |
| Northern puffer | | | | | | | | | 2 | | | | 2 |
| Striped killifish | | | | 1 | | | | | | | | 1 | 2 |
| Atlantic moonfish | | | | | | | | | 1 | | | | 1 |
| Atlantic seasnail | | 1 | | | | | | | | | | | 1 |
| Flying gurnard | | | | | | | | 1 | | | | | 1 |
| Fourspot flounder | | | | | | | | | 1 | | | | 1 |
| Hake spp. | | | | | | | | | | | 1 | | 1 |
| Silver hake | | 1 | | | | | | | | | | | 1 |
| Striped searobin | | | | | | 1 | | | | | | | 1 |
| White perch | | | | | | | | | | | 1 | | 1 |
| TOTALS | 488 | 53 | 712 | 44 | 53 | 36 | 17 | 38 | 1,922 | 3 | 78 | 126 | 3,570 |
| Collection Time (hrs.) | 58 | 60 | 73 | 19 | 47 | 61 | 100 | 34 | 33.67 | 36 | 34 | 52 | 607.67 |
| Collection Rate (#/hr.) | 8.41 | 0.88 | 9.75 | 2.32 | 1.13 | 0.59 | 0.17 | 1.12 | 57.08 | 0.08 | 2.29 | 2.42 | 5.87 |

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January- December 1995

| Species | Number | Length Range | Mean Length | Weight Range | Mean Weight | Percent of Total Fish |
|---|---|---|---|---|---|---|
| Alewife | 1,871 | 70-260 | 117 | 3-114 | 11 | 52.4 |
| Atlantic silverside | 1,100 | 67-141 | 97 | 1-15 | 5 | 30.8 |
| Rainbow smelt | 162 | 81-215 | 123 | 3-61 | 11 | 4.5 |
| Winter flounder | 92 | 30-347 | 90 | - | - | 2.6 |
| Blueback herring | 87 | 72-134 | 89 | 2-17 | 5 | 2.4 |
| Atlantic menhaden | 73 | 62-118 | 95 | 2-14 | 8 | 2.0 |
| Grubby | 45 | 39-110 | 70 | 1-17 | 6 | 1.3 |
| Cunner | 20 | 41-196 | 80 | 1-114 | 19 | 0.6 |
| Atlantic tomcod | 15 | 96-198 | 135 | 8-63 | 21 | 0.4 |
| Threespine stickleback | 11 | 61-70 | 66 | 2-3 | 3 | 0.3 |
| Atlantic herring | 10 | 45-62 | 50 | 0.4-2 | 1 | 0.3 |
| Windowpane | 10 | 32-210 | 91 | 1-94 | 17 | 0.3 |
| Lumpfish | 9 | 39-65 | 50 | 2-11 | 5 | 0.3 |
| Northern pipefish | 9 | 107-135 | 119 | 1 | 1 | 0.3 |
| Red hake | 6 | 86-210 | 129 | 4-53 | 16 | 0.2 |
| Atlantic cod | 5 | 61-166 | 89 | 2-29 | 8 | 0.1 |
| Radiated shanny | 5 | 62-90 | 78 | 2-6 | 4 | 0.1 |
| Rock gunnel | 5 | 87-153 | 129 | 5-10 | 7 | 0.1 |
| Tautog | 5 | 42-86 | 67 | 1-12 | 6 | 0.1 |
| Black sea bass | 4 | 58-91 | 69 | 2-9 | 4 | 0.1 |
| Northern searobin | 4 | 113-255 | 205 | 13-184 | 102 | 0.1 |
| Little skate | 3 | 315-382 | 358 | - | - | 0.1 |
| Pollock | 3 | 75-93 | 82 | 3-8 | 5 | 0.1 |
| Butterfish | 2 | 35-43 | 39 | 1 | 1 | 0.1 |
| Mummichog | 2 | 55-57 | 56 | 2 | 2 | 0.1 |
| Northern puffer | 2 | 36-76 | 56 | 5-10 | 7 | 0.1 |
| Striped killifish | 2 | - | - | - | - | 0.1 |
| Atlantic moonfish | 1 | 46 | 46 | 2 | 2 | 0.03 |
| Atlantic seasnail | 1 | 75 | 75 | 6 | 6 | 0.03 |
| Flying gurnard | 1 | 58 | 58 | 3 | 3 | 0.03 |
| Fourspot flounder | 1 | 78 | 78 | 4 | 4 | 0.03 |
| Hake spp. | 1 | 80 | 80 | 3 | 3 | 0.03 |
| Silver hake | 1 | 125 | 125 | 14 | 14 | 0.03 |
| Striped searobin | 1 | 266 | 266 | - | - | 0.03 |
| White perch | 1 | 113 | 113 | 17 | 17 | 0.03 |

Table 3. Annual Impingement collections (1986 -1995) For the 10 Most Abundant Fishes From Pilgrim Station Intake Screens During January - December 1995

Number of Impinged Fishes Collected From January - December

| Species | 1986 | 1987* | 1988** | 1989 | 1990 | 1991 | 1992 | 1993 | 1994+ | 1995++ | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alewife | 25 | 4 | 8 | 8 | 131 | 24 | 22 | 52 | 11 | 1,871 | 2,156 |
| Atlantic silverside | 44 | 27 | 35 | 120 | 457 | 275 | 232 | 720 | 3,112 | 1,100 | 6,122 |
| Rainbow smelt | 278 | 41 | 11 | 39 | 38 | 41 | 25 | 735 | 896 | 162 | 2,266 |
| Winter flounder | 76 | 10 | 11 | 42 | 31 | 67 | 72 | 90 | 90 | 92 | 581 |
| Blueback herring | 5 | 1 | 2 | 15 | 103 | 31 | 11 | 25 | 24 | 87 | 304 |
| Atlantic menhaden | 113 | 0 | 4 | 82 | 345 | 113 | 2 | 4 | 14 | 73 | 750 |
| Grubby | 30 | 5 | 5 | 29 | 59 | 46 | 43 | 51 | 98 | 45 | 411 |
| Cunner | 26 | 14 | 2 | 17 | 22 | 23 | 3 | 8 | 16 | 20 | 151 |
| Atlantic tomcod | 16 | 5 | 31 | 17 | 26 | 16 | 11 | 26 | 14 | 15 | 177 |
| Threespine stickleback | 0 | 1 | 3 | 2 | 3 | 2 | 2 | 4 | 23 | 11 | 51 |
| Totals | 613 | 108 | 112 | 371 | 1,215 | 638 | 423 | 1,715 | 4,298 | 3,476 | 12,969 |
| Collection Time (hrs) | 806 | 527 | 525 | 618 | 919.50 | 930.25+ | 774 | 673.5 | 737.39 | 607.67 | 6,989.91+ |
| Collection Rate (#/hr) | 0.76 | 0.20 | 0.21 | 0.60 | 1.32 | 0.69 | 0.55 | 2.55 | 5.83 | 5.72 | 1.86 |

*No CWS pumps were in operation 18 February - 8 September 1987.
**No CWS pumps were in operation 14 April - 5 June 1988.
+No CWS pumps were in operation 9 October - 16 November 1994.
++No CWS pumps were in operation 30 March - 15 May 1995

Rainbow smelt were very abundant in January impingement collections and have been most prevalent in the late Fall/early Winter period in the past, ranking first in 1978, 1987 and 1993 in total numbers impinged. In 1978, 1993 and 1994, large impingement incidents involving smelt occurred during December.

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

Blueback herring (Alosa aestivalis, 2.4% of the catch) occurred predominantly in May and December when 77% of them were sampled. It has been one of the most impinged fish, although not dominating the annual catch. Monthly intake water temperatures and impingement rates for the five dominant species in 1995 are illustrated in Figure 3.

There was one small, fish impingement incident (20 fish or greater/hr.) at Pilgrim Station in 1995 (March 4) when mostly Atlantic silversides were recorded, but their impingement rate rapidly decreased upon subsequent sampling, indicating minimal impact. There was one large fish impingement incident (1,000 fish or greater) in 1995 during September 8 and 9 when 13,100 alewife (318/hour) were impinged on intake screens. The alewives were mostly juveniles averaging ~115 mm in total length. Most large fish impingement mortalities have occurred while both circulating water pumps were operating, as in this case. According to the Mass. Division of Marine Fisheries, 1995 was a strong year for river herring spawning stocks in the State.

Fifteen large fish incidents have been documented since Pilgrim operation commenced in 1973, and most (11) 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.

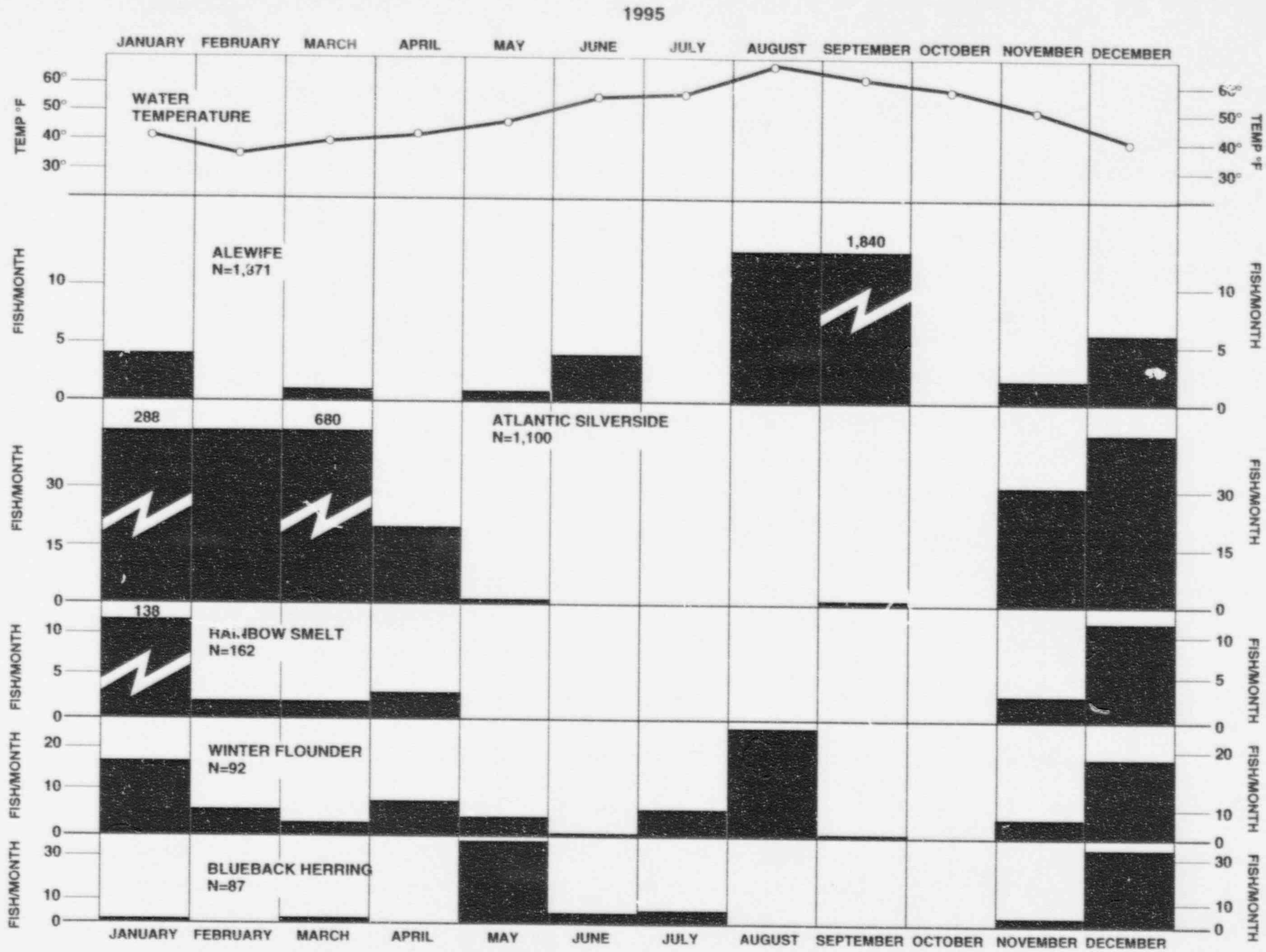


Figure 3. Trends Of Intake Water Temperature, And Number Of Fish Captured By Month From Pilgrim Station Intake Screens For The Five Most Abundant Species Collected, January - December 1995.

Table 4. Approximate Number and Cause for Dominant Species of Most Notable Fish Mortalities at Pilgrim Nuclear Power Station, 1973-1995

| Date | Species | Number | Cause |
|---|---|---|---|
| April 9-19, 1973 | Atlantic menhaden | 43,000 | Gas Bubble Disease |
| August/September, 1973 | Clupeids | 1,600 | Impingement |
| April 2-15, 1975 | Atlantic menhaden | 5,000 | Gas Bubble Disease |
| August 2, 1975 | Atlantic menhaden | 3,000 | Thermal Stress |
| August 5, 1976 | Alewife | 1,900 | Impingement |
| November 23-28, 1976 | Atlantic herring | 10,200 | Impingement |
| August 21-25, 1978 | Clupeids | 2,300 | Thermal Stress |
| December 11-29, 1978 | Rainbow smelt | 6,200 | Impingement |
| March/April, 1979 | Atlantic silverside | 1,100 | Impingement |
| September 23-24, 1981 | Atlantic silverside | 6,000 | Impingement |
| July 22-25, 1991 | Atlantic herring | 4,200 | Impingement |
| December 15-28, 1993 | Rainbow smelt | 5,100 | Impingement |
| November 28-29, 1994 | Atlantic silverside | 5,800 | Impingement |
| December 26-28, 1994 | Atlantic silverside | 6,100 | Impingement |
| | Rainbow smelt | 5,300 | Impingement |
| September 8-9, 1995 | Alewife | 13,100 | Impingement |

Fish impingement rate at Pilgrim Station has been shown to be significantly related to the number of circulating water pumps operating, in general (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 - 1993, despite a greater number of collecting hours in 1984 and an average number of hours in 1988. In 1987, far fewer collecting hours were possible when both circulating pumps were off than in these other years which limits comparisons to them. However, total fish impingement rates in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1995 when at least one circulating pump was more consistently in operation. Although there were brief periods in 1994 and 1995 when no circulating water pumps were operational, mixed results were noted regarding the effect on impingement of pump operation, possibly influenced by conditions causing large impingement incidents each of these years.

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 1995. 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 5.87, 141.00 and 51,464. The yearly rate of 51,464 fishes impinged is 228% of the last 20-years' (1976-1995) mean annual projection of 22,548 fishes (Table 6). This and the comparable 1994 rate (52,259 fishes) were the highest, yearly fish impingement rates since 1981, and greatly exceed 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 or operational conditions influencing species' behavior and vulnerability.

Table 5. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During January - December 1995. Assuming 100% Operation of Pilgrim Unit 1*

| Species | Rate/Hr. | Rate/Day | Rate/January-December 1995* | Dominant Months Of Occurrence |
|---|---|---|---|---|
| Alewife | 3.08 | 73.90 | 26,972 | September |
| Atlantic silverside | 1.81 | 43.44 | 15,857 | March |
| Rainbow smelt | 0.27 | 6.40 | 2,335 | January |
| Winter flounder | 0.15 | 3.63 | 1,326 | August |
| Blueback herring | 0.14 | 3.44 | 1,254 | May |
| Atlantic menhaden | 0.12 | 2.88 | 1,052 | September |
| Grubby | 0.07 | 1.78 | 649 | January |
| Cunner | 0.03 | 0.79 | 288 | November |
| Atlantic tomcod | 0.02 | 0.59 | 216 | January |
| Threespine stickleback | 0.02 | 0.43 | 159 | March |
| Atlantic herring | 0.02 | 0.39 | 144 | March |
| Windowpane | 0.02 | 0.39 | 144 | April/December |
| Lumpfish | 0.01 | 0.36 | 130 | January |
| Northern pipefish | 0.01 | 0.36 | 130 | November |
| Red hake | 0.01 | 0.24 | 86 | April |
| Atlantic cod | 0.01 | 0.20 | 72 | June |
| Radiated shanny | 0.01 | 0.20 | 72 | March |
| Rock gunnel | 0.01 | 0.20 | 72 | March/April |
| Tautog | 0.01 | 0.20 | 72 | December |
| Balck sea bass | 0.01 | 0.16 | 58 | November |
| Northern searobin | 0.01 | 0.16 | 58 | May |
| Little skate | 0.005 | 0.12 | 43 | May-July |
| Pollock | 0.005 | 0.12 | 43 | June |
| Butterfish | 0.003 | 0.08 | 29 | Sept./October |
| Mummichog | 0.003 | 0.08 | 29 | March |
| Northern puffer | 0.003 | 0.08 | 29 | September |
| Striped killifish | 0.003 | 0.08 | 29 | April/December |
| Atlantic moonfish | 0.002 | 0.04 | 14 | September |
| Atlantic seasnail | 0.002 | 0.04 | 14 | February |
| Flying gurnard | 0.002 | 0.04 | 14 | August |
| Fourspot flounder | 0.002 | 0.04 | 14 | September |
| Hake spp. | 0.002 | 0.04 | 14 | November |
| Silver hake | 0.002 | 0.04 | 14 | February |
| Striped searobin | 0.002 | 0.04 | 14 | June |
| White perch | 0.002 | 0.04 | 14 | November |
| Totals | 5.87 | 141.00 | 51,464 | |

* 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 1976-1995, Assuming 100% Operation of Pilgrim Unit 1*

| Year | Rate/Hr. | Rate/Day | Rate/Year | Dominant Species (Rate/Year) |
|---|---|---|---|---|
| 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 | 3.38 | 81.14 | 29,616 | Atlantic herring (22,318) |
| 1992 | 0.63 | 15.22 | 5,572 | Atlantic silverside (2,633) |
| 1993 | 2.78 | 66.78 | 24,375 | Rainbow smelt (9,560) |
| 1994+ | 5.97 | 143.18 | 52,259 | Atlantic silverside (36,970) |
| 1995+ | 5.87 | 141.00 | 51,464 | Alewife (26,972) |
| Means | 2.57 | 61.78 | 22,548 | |

*Rates have been rounded to significant figures.

+No CWS pumps were in operation 29 March - 13 August 1984, 18 February - 8 September 1987, 14 April - 5 June 1988, 9 October - 16 November 1994 and 30 March - 15 May 1995.

Over the past 20-year period (1976-1995), Pilgrim Station has had a mean impingement rate of 2.57 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. 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 boundary presented to marine biota by Cape Cod.

Monthly intake water temperatures recorded during impingement collections at Pilgrim Station were warmer during most of 1995 compared to the mean monthly temperatures for the 10-year interval 1986-1995 (Table 7). During the last half of summer 1995, water temperatures were notably higher than this 10-year period, particularly during August whose monthly mean was a very high 67.31°F.

Overall, 1983/1985/1986/1990/1995 displayed relatively warm water temperatures, 1984/1987/1989/1991/1994 were average years, and 1988/1992/1993 were cold water years. Pilgrim Station intake temperatures approximate ambient water temperatures. However, a dominance of colder water species (i.e., Atlantic silverside, winter flounder, grubby and rainbow smelt) appeared in impingement collections during 1995, with the alewife dominating in number impinged and being more partial to warmer water.

4.2 Invertebrates

In 607.67 collection hours, 926+ invertebrates of 15 species (Table 8) were recorded from Pilgrim Station intake screens during January-December 1995. The annual collection rate was 1.52+ invertebrates/hour. Ctenophores and jellyfish dominated, being captured in greatest numbers from August-September. Sevenspine bay shrimp (Crangon septemspinosa), longfin

Table 7. Monthly Means of Intake Temperature ($^{o}F$) Recorded During Impingement Collections at Pilgrim Nuclear Power Station, 1986-1995

| | Year | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | 1995 | 1994 | 1993 | 1992 | 1991 | 1990 | 1989 | 1988 | 1987 | 1986 | ($\bar{X}$) 1986-1995 |
| January | 41.13 | 28.21 | 37.36 | 36.34 | 37.56 | 38.45 | 38.42 | 36.80 | 38.42 | 35.97 | 36.77 |
| February | 36.61 | 29.18 | 32.21 | 34.32 | 36.70 | 38.15 | 42.97 | 36.00 | 38.71 | 34.98 | 35.76 |
| March | 39.51 | 30.91 | 35.24 | 36.53 | 39.72 | 37.87 | 38.43 | 36.20 | 40.70 | 37.18 | 37.34 |
| April | 41.67 | 37.95 | 41.16 | 43.42 | 44.46 | 46.63 | 41.37 | 41.30 | * | 44.98 | 43.11 |
| May | 48.77 | 44.26 | 48.33 | 51.56 | 53.79 | 50.86 | 48.70 | 48.79 | * | 48.84 | 49.43 |
| June | 56.43 | 45.21 | 52.70 | 54.21 | 60.09 | 53.63 | 57.38 | 50.21 | 56.68 | 56.11 | 54.47 |
| July | 58.14 | 56.85 | 56.78 | 55.94 | 61.67 | 61.24 | 61.57 | 52.83 | 63.00 | 61.51 | 58.95 |
| August | 67.31 | 59.34 | 53.66 | 60.40 | 58.49 | 64.71 | 59.80 | 58.75 | * | 63.29 | 60.83 |
| September | 62.37 | 60.45 | 50.55 | 57.42 | 58.63 | 63.35 | 58.62 | 56.86 | 58.21 | 58.26 | 58.99 |
| October | 57.93 | 63.33 | 43.96 | 53.83 | 52.00 | 55.13 | 53.92 | 52.31 | 52.73 | 58.58 | 54.72 |
| November | 50.61 | 55.78 | 39.97 | 50.85 | 47.88 | 47.88 | 45.60 | 47.17 | 47.49 | 52.23 | 48.87 |
| December | 40.33 | 44.88 | 34.53 | 43.06 | 41.74 | 42.86 | 35.58 | 38.90 | 41.30 | 44.00 | 40.86 |
| Mean | | | | | | | | | | | 48.34 |

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

squid (Loligo pealeii) and worms (Nereis sp.) represented 45.8, 14.5 and 13.5%, respectively, of the total invertebrates enumerated. Unlike the fishes, the 1987 and 1988 invertebrate impingement rates were comparable to 1985, 1986, and 1989 - 1995 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 abilities of mussels. In 1990 - 1995 several thermal backwashes were performed and blue mussel impingement was minor for those years. During 1995 aggressive biofouling control activities included three effective thermal backwashes during the months of June, September and December.

Sevenspine bay shrimp were the third most abundant invertebrate impinged, peaking in January and March. Longfin squid were fourth, being most represented in September. Forty-one specimens of the commercially important American lobster were captured in 1995, ranking them seventh. This equals 591 lobsters impinged on an annual basis at 100% operation of Pilgrim Station, under conditions at the times of impingement. This is considerably less than in 1991-1994, and is more comparable to the number of lobsters impinged in most previous years. The lobsters ranged in size from 28-71 mm carapace length.

Approximately 5,381 pounds of mixed algae species were collected during 1995 impingement sampling for a rate of 8.86 pounds/hr. This equates to 39 tons of algae annually on Pilgrim intake screens. This rate is considerably higher than the low flow 1984, 1987 and 1988 outage years, comparable to 1989-1992 and 1994, and lower than 1993 which experienced very adverse meterological conditions of high winds and coastal storms (particularly in December).

Table 8. Monthly Impingement For All Invertebrates Collected From Pilgrim Station Intake Screens, January-December 1995

| Species | Jan. | Feb. | March | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jellyfish/Ctenophores | | | | | | * | | * | * | | | | * |
| Sevenspine bay shrimp | 171 | 53 | 149 | 24 | 1 | | | | | | 20 | 6 | 424 |
| Longfin squid | | | | | 1 | 22 | 27 | 5 | 72 | 7 | | | 134 |
| Nereis sp. | 4 | 119 | | | | 1 | | | 1 | | | | 125 |
| Green crab | 12 | | 3 | 2 | 14 | 5 | 8 | 5 | 4 | 4 | 19 | 8 | 84 |
| Rock crab | 4 | 4 | 1 | 4 | 3 | 1 | 1 | 21 | 29 | 5 | 4 | 1 | 78 |
| American lobster | 4 | 1 | | | 7 | 3 | 10 | 3 | 9 | | 3 | 1 | 41 |
| Horseshoe crab | | | | | 2 | 6 | 5 | 1 | 1 | | | | 15 |
| Common starfish | 1 | | | | | 3 | 2 | | | 1 | 3 | | 10 |
| Green seaurchin | | 1 | | | 1 | 1 | | 1 | | | | | 4 |
| Lady crab | | | | | | 1 | 1 | | | 1 | 1 | | 4 |
| Nemertea | | | | | | | | | | | 3 | | 3 |
| Isopoda | | | | 2 | | | | | | | | | 2 |
| Glycera sp. | | | 1 | | | | | | | | | | 1 |
| Squilla empusa | | | | | | | | | | | 1 | | 1 |
| TOTALS | 196 | 178 | 154 | 32 | 29 | 43+ | 54 | 36+ | 116+ | 18 | 54 | 16 | 926+ |
| Collection Time (hrs.) | 58 | 60 | 73 | 19 | 47 | 61 | 100 | 34 | 33.67 | 36 | 34 | 52 | 607.67 |
| Collection Rate (#/hr.) | 3.38 | 2.97 | 2.11 | 1.68 | 0.62 | 0.70+ | 0.54 | 1.06+ | 3.45+ | 0.50 | 1.59 | 0.31 | 1.52+ |

* Undetermined numbers

## 4.3 Fish Survival

Fish survival data collected in 1995 while impingement monitoring was conducted are shown in Table 9. Continuous screenwash collections provided the fewest numbers of fishes and revealed an overall survival rate of approximately 87%. Fishes collected during static screen washes fared worse showing a survival rate of 55%. 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 alewife and Atlantic silverside which were impinged in abundant numbers. As illustrated in 1993 - 1995, 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 1995, six demonstrated initial survival rates of 50% or greater. Grubby showed 27% survival, winter flounder 90%, alewife 57%, Atlantic silverside 63%, cunner 50%, rainbow smelt 4%, Atlantic tomcod 20% Atlantic menhaden 78%, threespine stickleback 55%, and blueback herring 6%. Some of these relatively high survival percentages may be explained by the large proportion of fish that were sampled during continuous screenwashes at the times of fish impingement incidents in March and September.

Table 9. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-December 1995. Initial Survival Numbers Are Shown Under Static (8-Hour) and Continuous Wash Cycles

| Species | Number Collected Static Washes | Number Collected Cont. Washes | Number Surviving (Initial) Static | Number Surviving (Initial) Cont. | Total Length (mm) Mean | Total Length (mm) Range |
|---|---|---|---|---|---|---|
| Alewife | 1,869 | 2 | 1,068 | 2 | 117 | 70-260 |
| Atlantic silverside | 1,068 | 32 | 664 | 25 | 97 | 67-141 |
| Rainbow smelt | 159 | 3 | 5 | 2 | 123 | 81-215 |
| Winter flounder | 78 | 14 | 70 | 13 | 90 | 30-347 |
| Blueback herring | 86 | 1 | 5 | 0 | 89 | 72-134 |
| Atlantic menhaden | 72 | 1 | 56 | 1 | 95 | 62-118 |
| Grubby | 40 | 5 | 7 | 5 | 70 | 39-110 |
| Cunner | 9 | 11 | 0 | 10 | 80 | 41-196 |
| Atlantic tomcod | 14 | 1 | 2 | 1 | 135 | 96-198 |
| Threespine stickleback | 11 | 0 | 6 | - | 66 | 61-70 |
| Atlantic herring | 10 | 0 | 0 | - | 50 | 45-62 |
| Windowpane | 5 | 5 | 1 | 5 | 91 | 32-210 |
| Lumpfish | 9 | 0 | 6 | - | 50 | 39-65 |
| Northern pipefish | 2 | 7 | 2 | 7 | 119 | 107-135 |
| Red hake | 6 | 0 | 3 | - | 129 | 86-210 |
| Atlantic cod | 5 | 0 | 0 | - | 89 | 61-166 |
| Radiated shanny | 4 | 1 | 4 | 1 | 78 | 62-90 |
| Rock gunnel | 5 | 0 | 5 | - | 129 | 87-153 |
| Tautog | 3 | 2 | 3 | 2 | 67 | 42-86 |
| Black sea bass | 4 | 0 | 4 | - | 69 | 58-91 |
| Northern searobin | 4 | 0 | 1 | - | 205 | 113-255 |
| Little skate | 2 | 1 | 2 | 0 | 358 | 315-382 |
| Pollock | 3 | 0 | 0 | - | 82 | 75-93 |
| Butterfish | 2 | 0 | 1 | - | 39 | 35-43 |
| Mummichog | 2 | 0 | 2 | - | 56 | 55-57 |
| Northern puffer | 2 | 0 | 2 | - | 56 | 36-76 |
| Striped killifish | 1 | 1 | 1 | 1 | - | - |
| Atlantic moonfish | 1 | 0 | 1 | - | 46 | 46 |
| Atlantic seasnail | 1 | 0 | 1 | - | 75 | 75 |
| Flying gurnard | 0 | 1 | - | 1 | 58 | 58 |
| Fourspot flounder | 1 | 0 | 0 | - | 78 | 78 |
| Hake spp. | 0 | 1 | - | 1 | 80 | 80 |
| Silver hake | 1 | 0 | 0 | - | 125 | 125 |
| Striped searobin | 1 | 0 | 1 | - | 266 | 266 |
| White perch | 1 | 0 | 1 | - | 113 | 113 |
| All Species: Number (% Surviving) | 3,481 | 89 | 1,924 (55.3) | 77 (86.5) | | |

## SECTION 5

## CONCLUSIONS

1. The average Pilgrim collection rate for the period January-December 1995 was 5.87 fish/hour. The impingement rates for fish in 1984, 1987 and 1988 were several times lower than in 1985, 1986 and 1989 - 1995 because of much reduced circulating water pump capacity during the former years.

2. Thirty-five species of fish were recorded in 607.67 impingement collection hours during 1995. In 1985, 1986 and 1989 - 1995 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 1995 impingement rate was 51,464 fishes (1,017 lbs.). This projected annual fish impingement rate and 1994's (52,259 fishes) were the highest since 1981 at Pilgrim Station because of three large impingement incidents involving Atlantic silverside and rainbow smelt in 1994, and alewife in 1995.

4. The major species collected and their relative percentages of the total collections were alewife, 52.4%; Atlantic silverside, 30.8%; rainbow smelt, 4.5%; and winter flounder, 2.6%.

5. The peak in impingement collections occurred during the September 8-9 fish impingement incident when an estimated 13,100 alewife were impinged.

6. Monthly intake water temperatures, which generally reflect ambient water temperatures, were warmer for most of 1995 than the ten-year monthly averages for the period 1986-1995, with August being very warm.

7. The hourly collection rate for invertebrates was 1.52+. Ctenophores and jellyfish dominated because of large late summer collections. Sevenspine bay shrimp, longfin squid and worms (Nereis sp.) were 45.8, 14.5 and 13.5% of the enumerated catch. Forty-one American lobsters were collected which equates to a potential 1995 impingement of 591 lobsters.

8. Impinged fish initial survival was approximately 55% during static screen washes and 87% during continuous washes for pooled species. Of the ten fishes impinged in greatest numbers during 1995, six showed initial survival rates of 50% or greater.

<u>SECTION 6</u>

<u>LITERATURE CITED</u>

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**Pilgrim Nuclear Power Station TAC Meeting**
**9/27/95**

The meeting was called to order by Chairman Szal at 10:20 AM. Those present were Bob Lawton (MDMF), Leigh Bridges (MDMF), Bob Maietta (MDEP), Gerry Szal (MDEP), Bob Anderson (PNPS), and Carolyn Griswold (NMFS). Bob Maietta volunteered to take the minutes in the absence of the recording secretary.

Carolyn Griswold made a motion to accept the minutes of the previous meeting as presented. Bob Anderson second, and the motion passed unanimously.

Gerry Szal queried about the state and electric utilities apparently working on a rate-restructuring plan. Bob Anderson gave a brief presentation on de-regulation of the utility industry. The actual process seems vague at this time.

OPERATIONS

Bob Anderson presented an overview of the operating status of Pilgrim Station since January of this year. The plant has operated at about 69% capacity over that period and was in a re-fueling outage during April and May. The next planned outage is for the spring of 1997. Dredging is planned for July and August of 1996.

A large alewife impingement occured on September 8 and 9, with an estimated 13,000 juvenile alewives (4-5 inches) impinged. The question of remuneration resulted in a motion by Gerry Szal that the Fisheries Subcommittee meet, discuss, and report to the full committee their recommendations. Bob Maietta second, and the motion passed unanimously. The subject of possible fish ladder work in the area of Plymouth was discussed, and Leigh Bridges asked Bob Lawton to look into this matter.

BENTHIC

Bob Lawton presented a report of the Benthic Subcommittee with regard to recommended benthic monitoring for 1996 off Pilgrim Station. Their recommendation included provisions to continue quantiative quarterly dives to document the denuded and stunted zones in the vicinity of the discharge. In addition, it was recommended that a >15% increase in the area, length, or width of the bottom impacted (denuded and stunted) zone would trigger additional work to include documentation of operating conditions at the Station prior to the benthic dive. The comparison condition is defined as the worse case documented from 1982 - 1994. Bob Maietta made a motion to concur with the Benthic Sub-Committee's recommendation to continue the quarterly observational dives during 1996, with the condition that if the impact area (defined as the stunted and denuded zones) off the discharge canal exceeds 15% in the width, length or total area over the seasonal high values from 1982 - 1994, BECO would notify the TAC for possible mitigative actions or analysis. Carolyn Griswold second, and the motion passed unanimously.

No quantitative benthic thermal plume monitoring is recommended for 1996; however, the Benthic Subcommittee has asked EG&G to go back and re-calibrate the thermal plume map based on the scale of the existing dive survey map.

FISHERIES

The Fisheries Subcommittee report was summarized by Bob Lawton. Bob reported that rainbow smelt eggs will not be moved into the Jones River in 1996; however habitat enhancement in the form of artificial egg substrate (egg trays) will be employed as mitigation for the December 1994 impingement of smelt at PNPS.

Cunner population dynamics work will be completed in 1996. The ability to bound the population is thought to be critical with regard to the continuance of cunner work and the ability to assess plant impact on the local population. Cunner work beyond 1996 will hinge on this.

Winter flounder work through the present time has revealed that there are not a large number of adult winter flounder residing in the Plymouth, Kingston, Duxbury Bay (PKDB) estuary. It appears that adults spawn inside and outside this estuary. A fishing vessel will be contracted in 1996 to expand sampling and tagging outside PKDB out to 120m in depth.

Bob Lawton informed the Committee that a large trawl (1970-1982) final report has been drafted, and the final commercial lobster project report should be completed by spring.

The winter flounder recruitment work (seining) will be discontinued for 1996. Bob Maietta made a motion to accept the Fisheries Sub-Committee's recommendation for the 1996 fish sampling with the exception of recruitment seining which will be dropped in 1996. Carolyn Griswold second, and the motion passed unanimously.

It was noted that the most recent Fisheries Subcommittee minutes should be corrected to read "The Subcommittee recommends that the **1996** Marine Fisheries Plan be approved as submitted."

IMPINGEMENT

Bob Anderson made a brief presentation on Impingement Monitoring. Discussions on this Monitoring program resulted in Carolyn Griswold making a motion that 1996 Impingement monitoring be continued under the same provisions as those adhered to in 1995. Gerry Szal second, and the motion passed unanimously.

ENTRAINMENT

Bob Anderson presented the 1995 entrainment monitoring schedule. Bob Lawton reviewed results of the .333mm vs. 202mm mesh size comparison data for cunner. There was a lengthy discussion involving this matter. Carolyn Griswold made a motion that the 1996 Entrainment Program should continue under the same frequency and schedule as 1995; however, the question of plankton net mesh for cunner ichthyoplankton sampling again will be discussed at the next Fisheries Subcommittee meeting in October. Leigh Bridges second, the motion passed unanimously.

OTHER BUSINESS

Bob Lawton brought up the subject of again activating the Monograph Committee to begin thinking about publishing results of many of the more recent scientific investigations involving the Plant. Leigh was asked to chair the Committee but said that he would consider the matter and could not make a commitment at this time.

A Fisheries Subcommittee meeting then was scheduled for October 31st, in Narragansett at 10:00 am.

Bob Anderson touched upon the subject of the barrier net. The barrier net was removed from the Pilgrim Station discharge canal in 1995. While striped bass were observed in the discharge canal, no abnormal behavior or mortality has been observed to date. Carolyn motioned to allow BECO to operate without a barrier net in place again in 1996, provided that a net in good repair is available for deployment if needed. Leigh Bridges second the motion, which passed unanimously.

Bob Maietta motioned to adjourn the meeting. This motion recieved a second from Leigh, and the meeting was adjourned at about 2:15 PM.
The Division of Marine Fisheries and the Pilgrim A-T Committee thank Bob Maietta for stepping in and doing a fine job on the minutes of this meeting.

PILGRIM NUCLEAR POWER PLANT

ADMINISTRATIVE-TECHNICAL COMMITTEE

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