Boston Edison

Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

Henry V. Oheim
General Manager - Technical Section

April 29, 1997
BECo Ltr. 5.97.037

Planning and Administration (SPA)
U. S. Environmental Protection Agency
P. O. Box 8127
Boston, MA 02114-8127

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. 49 is submitted. This covers the period from January through December 1997.

H. V. Oheim

HVO/RDA/avf/ecorpt97

Attachment: Semi-Annual Marine Ecology Report No. 49

Boston Edison

Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

Henry V. Oheim
General Manager - Technical Section

April 29, 1997
BECo Ltr. 5.97.037

State of Massachusetts
Department of Environmental Protection
20 Riverside Drive
Lakeville, MA 02347

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

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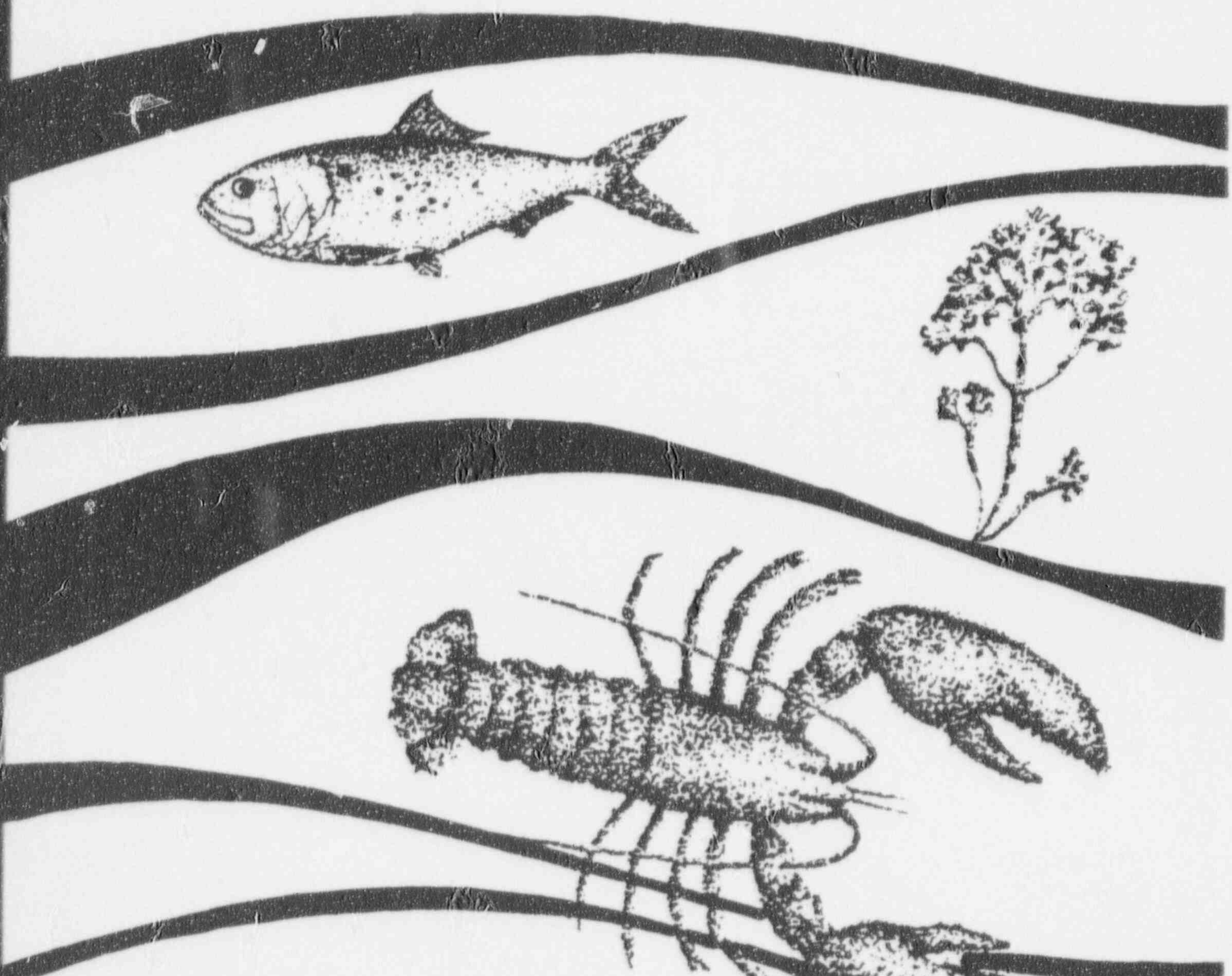
Attachment: Semi-Annual Marine Ecology Report No. 49

marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 49
JANUARY 1996 - DECEMBER 1996



BOSTON EDISON COMPANY
REGULATORY AFFAIRS DEPARTMENT

Boston Edison

MARINE ECOLOGY STUDIES

RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 49

REPORT PERIOD: JANUARY 1996 THROUGH DECEMBER 1996

DATE OF ISSUE: APRIL 30, 1997

Compiled and Reviewed by:

Robert D. Anderson
Principal Marine Biologist

Regulatory Affairs Department
Boston Edison Company
Pilgrim Nuclear Power Station
Plymouth, Massachusetts 02360

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Radmisc/Marine.doc

SUMMARY

Highlights of the Environmental Surveillance and Monitoring Program results obtained over this reporting period (January -December 1996) are presented below. (Note: PNPS was operating at high power level during January - December 1996).

Marine Fisheries Monitoring:

1. In the April - October 1996 shorefront sportfish survey at Pilgrim Station, 2,600 angler visits accounted for 3,854 fishes caught. Striped bass (48%) and bluefish (52%) comprised the sportfish catch. The presence of a strong thermal discharge component during most of 1990 - 1996 resulted in good sportfishery success compared with outage and low power years.

2. During late July - mid-October 1996 fish observational dive surveys, fish species were observed in the thermal effluent 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 while tautog were consistent throughout the summer.

   Mass. DMF recommendation - Data from the dive and sportfish surveys reveal that certain species are attracted to either the elevated water temperatures (spring and fall) or current. This places them at risk of impact from temperature aberrations, chemical releases, and potential gas bubble disease mortalities. As such, some form of direct visual monitoring should continue for as long as the plant is operational.

3. Several hundred cunner were tagged from 1990 - 1996. Many were recovered in the Pilgrim vicinity indicating that movement of this species is local consistant with its residential nature. Juvenile recruitment studies will be continued to assess Pilgrim impact on this species, which in 1995 was minimal and in 1996 were inconclusive because of adverse weather conditions (i.e., severe storms), which naturally impacted recruitment and influenced study results during the Fall.

Mass. DMF recommendation - A final evaluation of impact of Pilgrim Station on the local cunner population has not been rendered as yet. Minimal power plant impact was indicated from the recruitment study in 1995, while in 1996 recruitment results were inconclusive due to meteorological events. We recommend additional years of recruitment (juvenile) studies to ascertain whether recruitment is recruit limited, resource limited, or controlled by post-settlement predation and whether power plant impact is of consequence.

4. Winter flounder tagging in the Plymouth Bay vicinity to estimate adult population size and Pilgrim Station impact has accounted for 7,289 fish with 218 (3%) tag returns by the end of 1996. The 1996 population estimate based on an Area Swept Method in sampling for the Plymouth Bay area was 184,294 adult winter flounder (age 3+). This equates to roughly an 8.5% adult population impact from PNPS entrainment of 22,500,000 flounder larvae. When enough tag data is available, additional population size estimates will be generated using a more reliable tag return-population model approach for an expanded spawning area.

Mass. DMF recommendation - We are optimistic that expansion of the study area, and some modifications to the overall sampling regime in 1997, will yield a more accurate but probably no more precise estimate of population size. A few more years of study to define the impact of Pilgrim Station on this species would be helpful but, nevertheless, may not provide a definitive answer.

5. Rainbow smelt egg restocking of the Jones River (Kingston) to mitigate 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. Once hatched, these eggs will supplement those produced by 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. Both of these impingement incidents have the potential of impacting the local smelt population and were further mitigated in 1996 by improving the smelt spawning habitat in the Jones River to enhance egg survival, through the use of several dozen specially designed egg collecting trays.

   Mass. DMF recommendation - The Jones River smelt spawning habitat enhancement project should be considered for continuation for several more years or until Jones River spawning-run smelt numbers, which we monitor, substantially increase. From egg densities observed, it is evident that more adults entered the spawning gorunds in the Jones River in 1996 than in the recent past.

Impingement Monitoring:

1. The mean January - December 1996 impingement collection rate was 3.11 fish/hr. The rate ranged from 0.12 fish/hr (July) to 11.15 fish/hr (April) with Atlantic silverside comprising 59.2% of the catch, followed by rainbow smelt 13.5%, Atlantic menhaden 5.8%, and blueback herring 4.5%. Fish impingement rates in 1989 - 1996 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. The March/April 1996 Atlantic silverside impingement accounted for 65% of this species' annual collection.

3. The mean January - December 1996 invertebrate collection rate was 2.24/hr with sevenspine bay shrimp (78.7%) dominating. Green crabs and rock crabs accounted for 11% of the catch. Thirty-two American lobsters were sampled. The invertebrate impingement rates in 1989 - 1996 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.

4. Impinged fish initial survival in the Pilgrim Station intake sluiceway was approximately 61% during static screen washes and 67% 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, sparse, and stunted zone boundaries were indistinguishable during September 1987 - June 1989 discharge surveys as a result of the PNPS extended shutdown. However, these surveys did note impact zone boundaries in fall 1989 - 1996 primarily because two circulating water pumps were in operation most of the time resulting in maximum discharge current flow. The scouring impact area in 1996 varied from 1,671 m^2 (December) to 2,209 m^2 (September). Except for the December denuded zone, the 1996 denuded and total affected zones were the largest ever seen seasonally during this study (since 1983); in part, this was due to heavy mussel settlement on Irish moss and high PNPS operating capacity on a consistent basis.

Entrainment Monitoring:

1. A total of 41 species of fish eggs and/or larvae were found in the January - December 1996 entrainment collections: 17 eggs, 37 larvae.

2. Seasonal egg collections for 1996 were dominated by Atlantic cod, American plaice and winter flounder (winter - early spring); Atlantic mackerel and labrids (late spring - early summer); rockling/hake, windowpane, and labrids (late summer - autumn).

3. Seasonal larvae collections for 1996 were dominated by sculpin, Atlantic herring, rock gunnel, and sand lance (winter - early spring); sand lance, winter

flounder, Atlantic mackerel, fourbeard rockling, cunner, and radiated shanny (late spring - early summer); rockling, Atlantic menhaden, tautog, cunner, Atlantic herring, and hake (late summer - autumn).

4. No lobster larvae were collected in the entrainment samples for 1996.

5. In 1996, an estimated 5.443×10^9 fish eggs and 6.300×10^8 fish larvae were entrained at Pilgrim Station, assuming full flow capacity of all seawater pumps. On an annual basis, eggs were dominated by the labrid-Pleuronectes group and Atlantic mackerel, and larvae by sand lance sp. and sculpin spp.

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

7. On several occasions in 1996, "unusually abundant" ichthyoplankton densities were recorded including Atlantic menhaden, Atlantic herring, Atlantic mackerel, radiated shanny, winter flounder, hake and sand lance larvae for extended time periods. This possibly reflects 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 - 1996 were as follows: cunner 657,401; Atlantic mackerel 8,637; winter flounder 814 - 8,088. 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.

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INTRODUCTION

A. Scope and Objective

This is the forty-ninth 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-seventh 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 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 were 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 1996, 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 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 spawning habitat was enhanced in the Jones River (Kingston) in March/April 1996 to mitigate the large impingement of 5,000+ rainbow smelt on Pilgrim Station intake screens in December 1994. Continuing smelt mitigation will occur in 1997 as well as mitigation for the 13,000+ alewife impingment in September 1995.

A finfish observational dive program was initiated in June 1978. SCUBA gear is utilized on periodic dives from May-October 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.

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. 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 1996 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. 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.

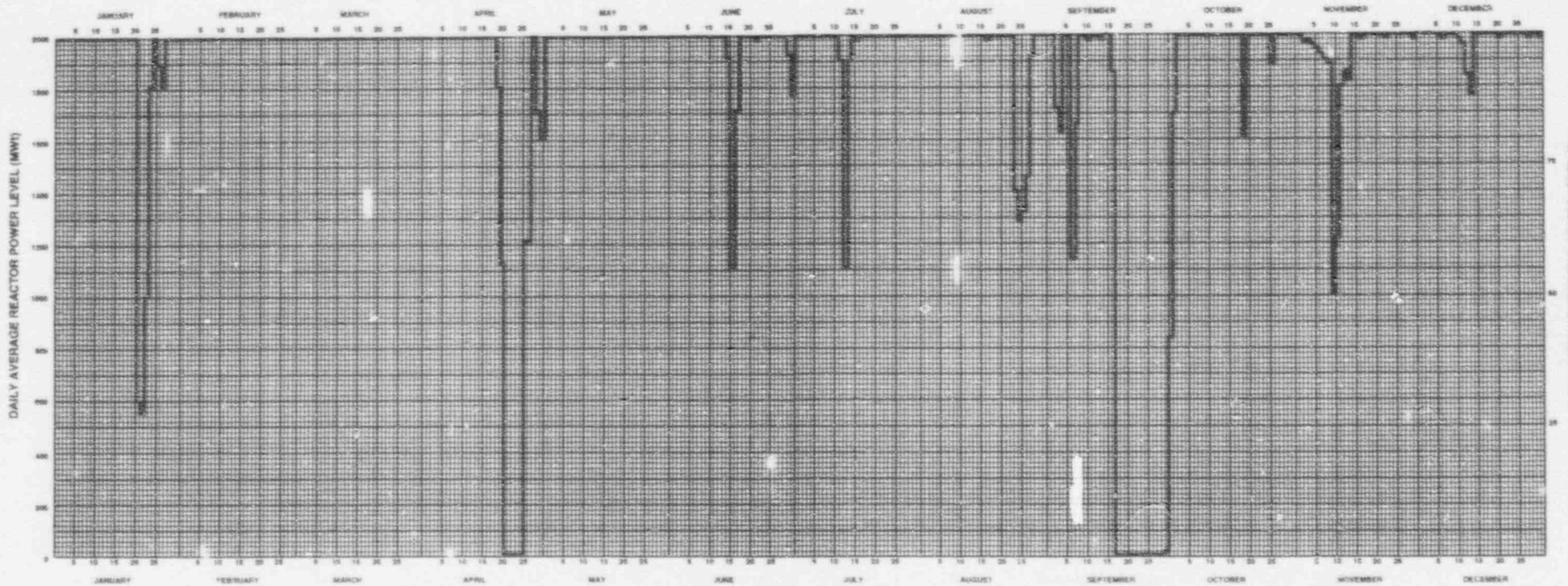
D. Station Operation History

The daily average reactor thermal power levels from January through December 1996 are shown in Figure 1. As can be seen, PNPS was in a high operating stage during this reporting period with a 1996 capacity factor (MDC) of 90.5%. Cumulative capacity factor from 1973-1996 is 53.6%. Capacity factors for the past 15 years are summarized in Table 1.

E. 1997 Environmental Programs

A planning schedule bar chart for 1997 environmental monitoring programs related to the operation of Pilgrim Station, showing task activities and milestones from December 1996 - June 1998, is included after Table 1.

JANUARY - DECEMBER 1996



JANUARY - DECEMBER 1996

Figure 1. Daily Average Reactor Thermal Power Level (MWt and %) from January - December 1996 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	1996	1995 *	1994 *	1993	1992	1991	1990	1989	1988 *	1987 *	1986	1985	1984 *	1983	1982
January	92.1	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
February	99.4	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
March	99.3	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
April	75.9	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
May	98.2	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
June	94.3	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
July	95.3	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
August	92.3	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
September	51.4	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
October	94.0	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
November	94.9	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
December	97.7	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
ANNUAL%	90.5	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

CUMULATIVE CAPACITY FACTOR (1973 - 1996) = 53.6%

________________ = 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

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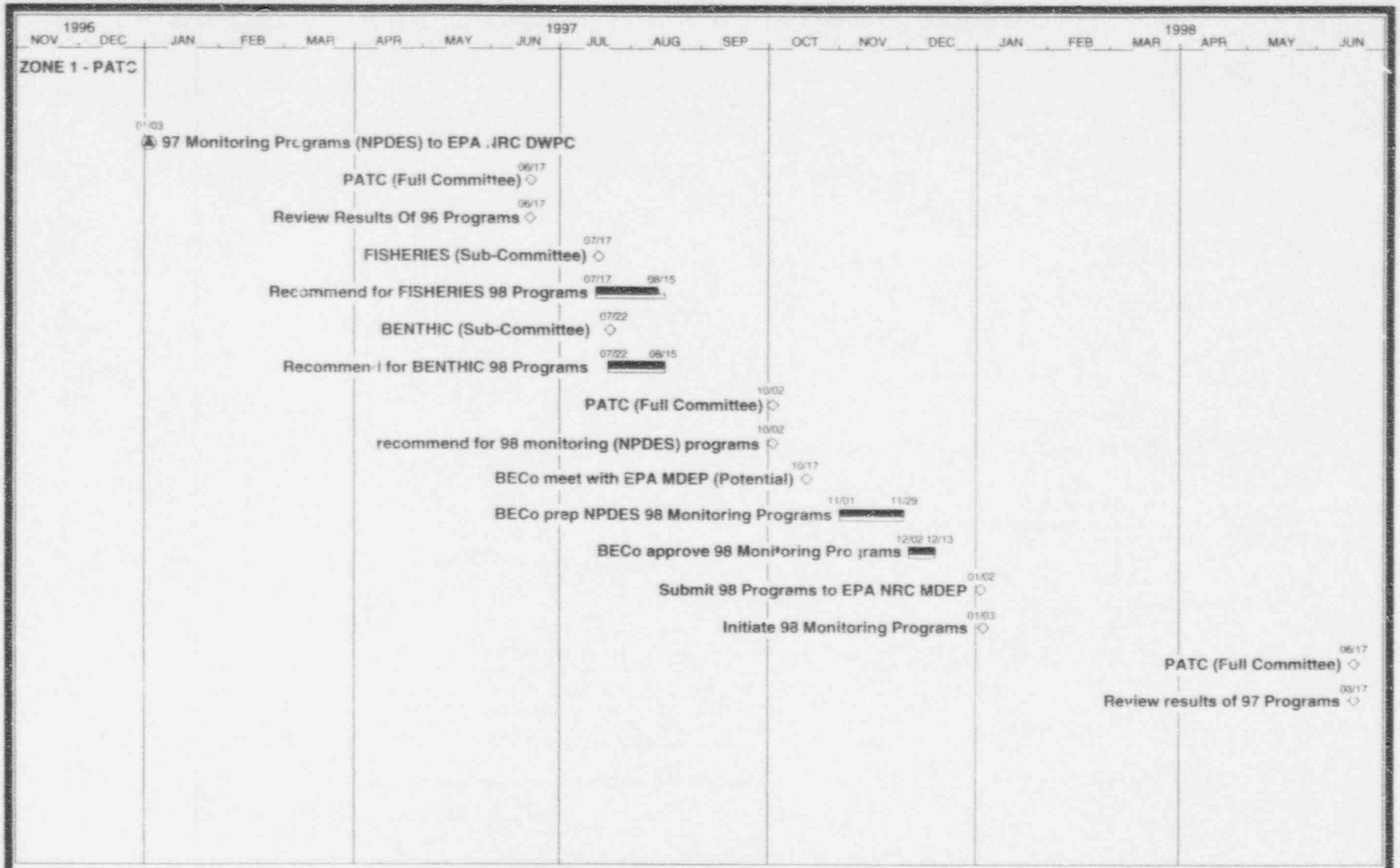
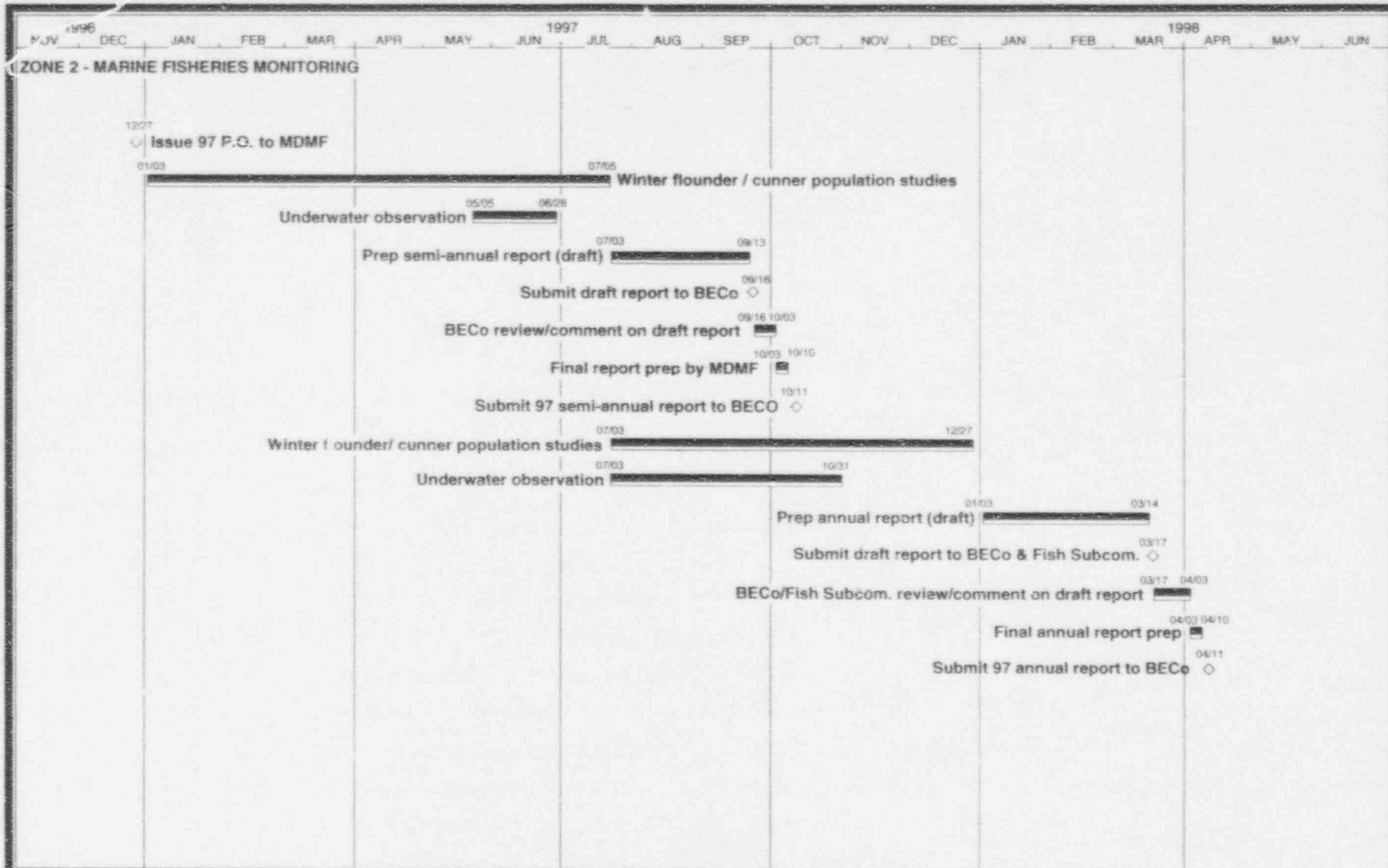


PNPS 1997 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



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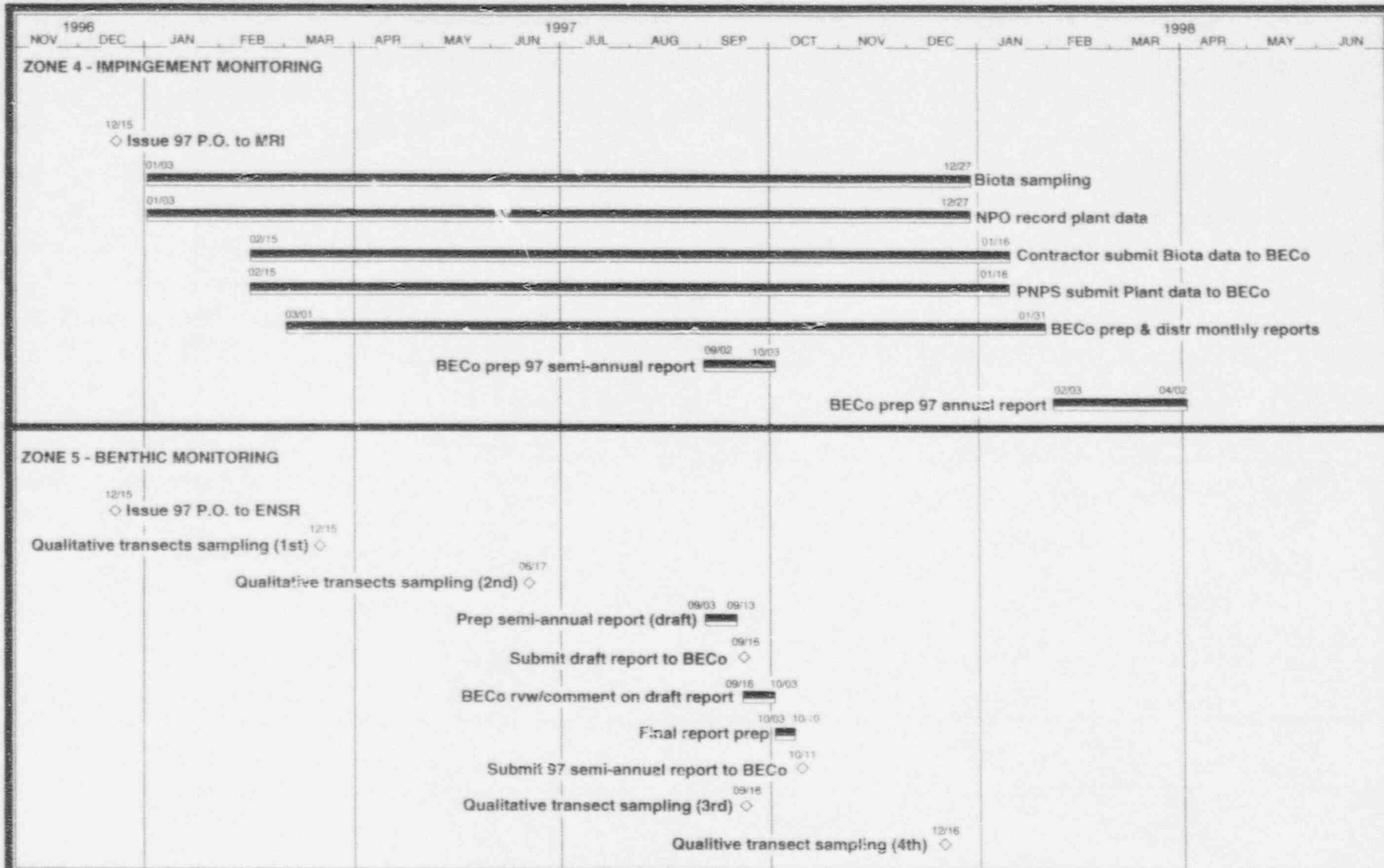

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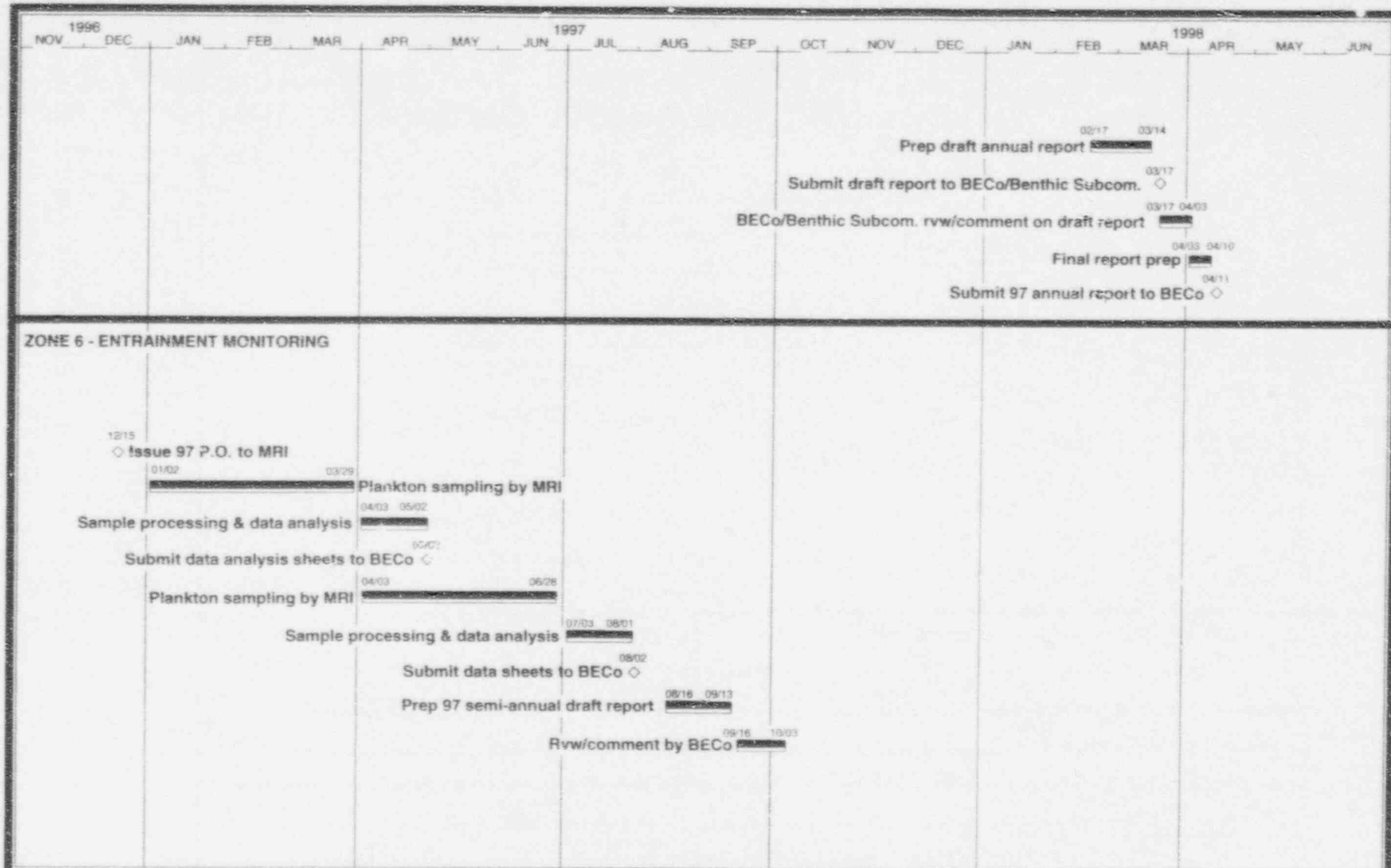

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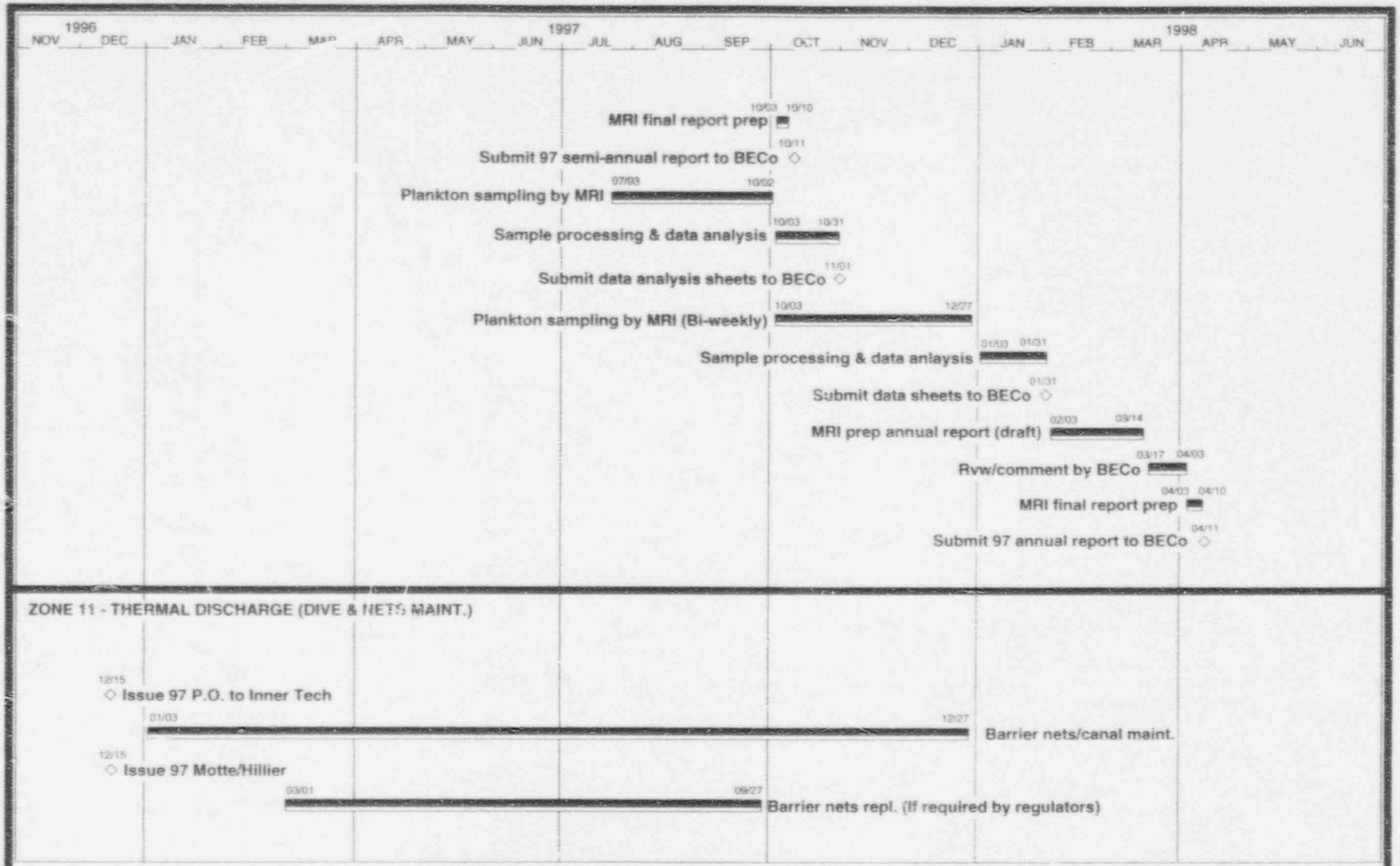

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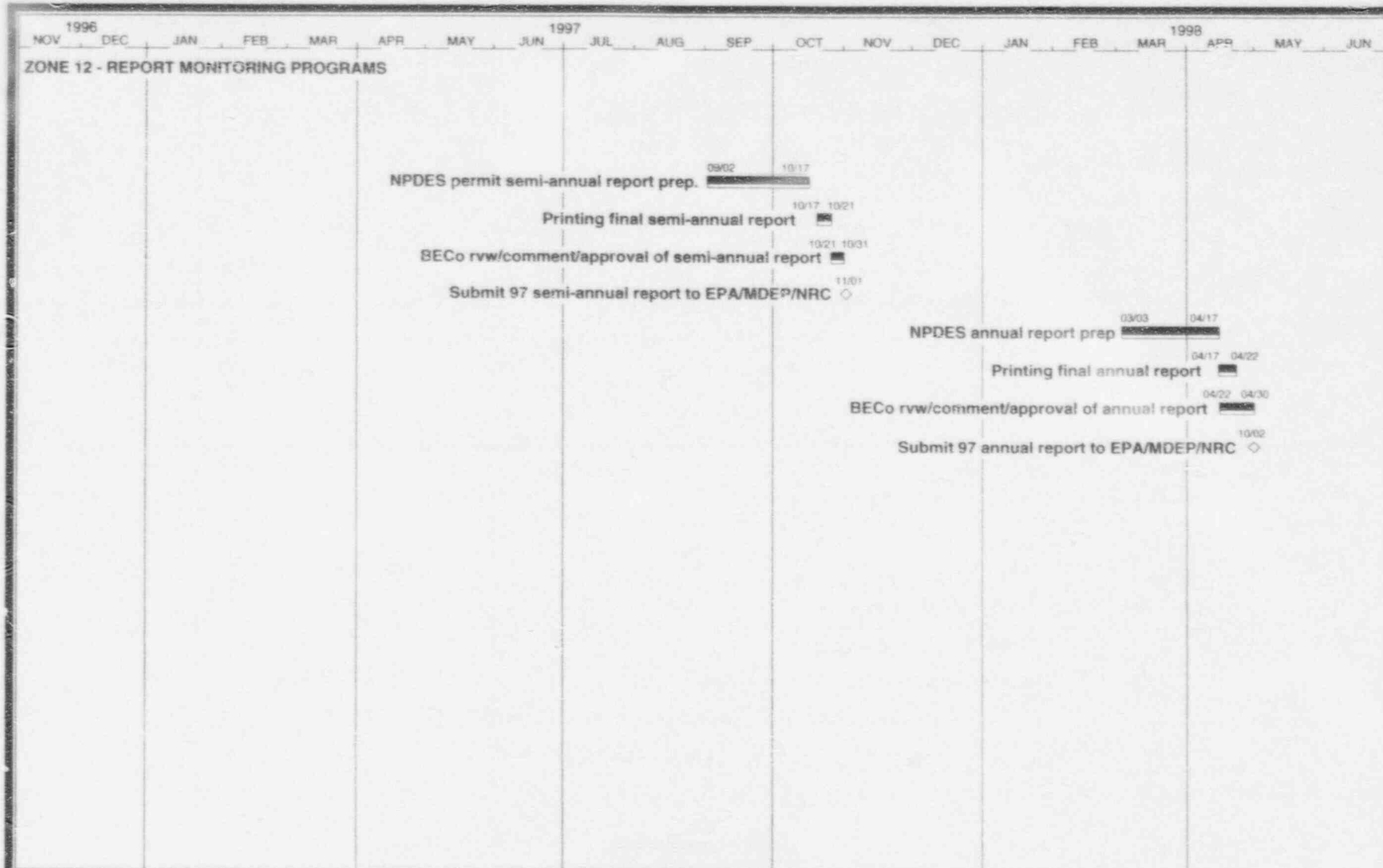

PNPS 1997 ENVIRONMENTAL PROGRAMS

(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. 62 (January to December 1996)

By
Robert Lawton, Brian Kelly, Vincent Malkoski,
John Boardman, and Greg Pintarelli

April 1997
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 1996 highlights of study findings for selected species. Additional information can be found in the Conclusions' section of this report.

Cunner

- Cunner (*Tautogolabrus adspersus*) larval abundance in the Pilgrim Station area appeared to be reduced in 1996, with larval entrainment down 63% from 1995.
- Length and age-specific fecundity relationships determined for cunner in the Pilgrim area were used to refine adult equivalency estimates.
- Impingement of cunner at Pilgrim Station was relatively light (211 fish) in 1996. However, the entrainment of cunner eggs and larvae was equivalent to the loss of 589,000 adults from the local population.
- A total of 385 adult cunner (≥ 90 mm total length) was tagged in 1996 at the outer breakwater in the Pilgrim Station area. Recapture information confirms that cunner have limited movements and demonstrate a high degree of site fidelity. No comprehensive estimate of the local cunner population has been generated because of logistics and financial constraints.
- A final evaluation of impact of Pilgrim Station on the local cunner population has not been rendered as yet. Minimal power plant impact was indicated from the recruitment study in 1995, while in 1996 recruitment results were inconclusive due to meteorological events. We recommend additional years of recruitment (juvenile) studies to ascertain whether recruitment is recruit limited, resource limited, or controlled by post-settlement predation and whether power plant impact is of consequence.

Rainbow Smelt

- To compensate for impingement mortality of rainbow smelt (*Osmerus mordax*) at Pilgrim Station, the Massachusetts Division of Marine Fisheries is conducting restoration work. Our objective in 1996 was to enhance the quality of spawning habitat in the Jones River, which hosts the majority of smelt spawning in the area.
- We selectively placed 130 sphagnum moss-filled egg collecting trays into the Jones River on the upper smelt spawning ground. The trays provide an ideal depositional surface for the demersal, adhesive rainbow smelt eggs.
- Rainbow smelt egg survival can be up to ten times higher on plant material than on hard bottom. Egg

survival is an important parameter to future stock size.

- The Jones River smelt spawning habitat enhancement project should be considered for continuation for several more years or until Jones River spawning-run smelt numbers, which we monitor, substantially increase. From egg densities observed, it is evident that more adults entered the spawning grounds in the Jones River in 1996 than in the recent past.

Winter Flounder

- Plymouth, Kingston, Duxbury Bay, and the surrounding coastal waters are important spawning areas for winter flounder (*Pleuronectes americanus*). In the Pilgrim study area, winter flounder exhibit fidelity (not 100%) to natal spawning grounds. They also undertake local seasonal movements which appear to be temperature-driven.
- In 1996, an estimated 22.5 million winter flounder larvae were entrained at Pilgrim Station, which equates to an equivalent loss of 15,727 adults from the local population.
- An estimated 866 winter flounder - mostly age-0 and age-1 - were impinged in Pilgrim Station in 1996.
- No winter flounder reportedly were angled at Pilgrim Shorefront in 1996.
- In 1996, we tagged 4,997 winter flounder with Petersen disc tags, bringing the study total to 7,289. As of the end of the year, 218 tagged flounder had been recaptured (recapture rate of 3%). Fifty percent of these were taken from the general area where they were tagged.
- Density extrapolation using the Area Swept Method provided an estimate of the 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 184,294 adults.
- Due to the low recapture rate of tagged flounder (3% to date), and the variability in our area-swept estimates, we, as yet, cannot confidently define the magnitude of entrainment impact on winter flounder of Pilgrim Station, where the equivalent adult loss because of entrainment mortality is preliminarily estimated to represent ~8.5% of the possible adults in the local population. We are optimistic that expansion of the study area, and some modifications to the overall sampling regime in 1997 will yield a more accurate but probably no more precise estimate of population size. A few more years of study to define the impact of Pilgrim Station on this species would be helpful but, nevertheless, may not provide a definitive answer.

Other Species

- Striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*) were the only species reported in the recreational catch at the Pilgrim Shorefront.
- Striped bass and tautog (*Tautoga onitis*) dominated the SCUBA finfish sightings off Pilgrim Station. Small aggregations of cunner also were observed.
- ✪● Data from the dive and sportfish surveys reveal that certain species are attracted to either the elevated water temperatures (spring and fall) or current. This places them at risk of impact from temperature aberrations, chemical releases, and potential gas bubble disease mortalities. As such, some form of direct visual monitoring should continue for as long as the plant is operational.

II. INTRODUCTION

The Massachusetts Division of Marine Fisheries (MDMF) power plant study team conducts field investigations to assess and mitigate negative environmental effects of Pilgrim Nuclear Power Station (PNPS). In 1996, we worked principally with three indicator finfish species that the power station impacts. This work was funded by Boston Edison Company (BECo) under Purchase Order No. LSP005522.

Focusing on cunner, winter flounder, and rainbow smelt, we employed a variety of gear types, techniques, and equipment to conduct sampling and undertake restorative efforts. Measurements, counts, percentages, and estimates of abundance were used in data quantification. Descriptive statistics were summarized in tables or displayed in figures. Statistical procedures were used when appropriate.

From extensive field monitoring off Pilgrim Station, it has become evident that mechanical impacts of station operations, i.e., entrainment of fish eggs and larvae followed by impingement of juvenile and adult fish, pose greater environmental threats than does the release of waste heat.

We primarily are working with three finfish species: cunner, winter flounder, and rainbow smelt (Table 1). In the environs of Pilgrim Station, cunner spawn, have nursery grounds, and reside as adults. This temperate reef fish is structure oriented, territorial, and basically sedentary in movements. Important in the local sportfishery at Pilgrim Shorefront in the past, cunner have a localized distribution and are good indicators for local stress. Cunner is primarily affected by early life stage entrainment at PNPS, and is the dominant fish entrained there. Winter flounder also spawn in the Pilgrim area, which likewise serves as nursery and feeding grounds. This flatfish is valued by commercial and recreational fishermen. Like cunner, its larvae are entrained in relatively high numbers. Rainbow smelt is a popular recreational species in the nearby Plymouth, Kingston, Duxbury estuary. Several incidents of relatively high smelt impingement have occurred at Pilgrim Station over the years.

Our objectives in 1996 were as follows: (1) to examine recruitment dynamics of cunner in relation to Pilgrim Station, study movement, and age fish to generate catch at-age data which is used to estimate natural

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 (June-Aug)
Rainbow Smelt	RIS	r, s	I, T/C	Impingement - large incidents in December of '78, '93, '94
Winter flounder	RIS	d, r, c, s	I, E, T/C	Entrainment - large number of larvae collected (April-May)

RIS - representative important 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.

mortality needed for the adult equivalent model calculations; (2) in the case of winter flounder, determine discreteness of the local population and estimate population size; and (3) to enhance the quality of spawning habitat for rainbow smelt in the Jones River, a tributary to the nearby Plymouth, Kingston, Duxbury Bay (PKDB) estuary, where the local population originates and increase the collection of eggs on good habitat to improve egg survival to hatching.

This annual report includes writeups on sampling design with methodology, together with findings and recommendations. Progress achieved in surveys and ongoing restorative projects was highlighted for the three indicator species populations in the Pilgrim Station area.

III. METHODS AND MATERIALS

The study area is bounded in Figure 1.

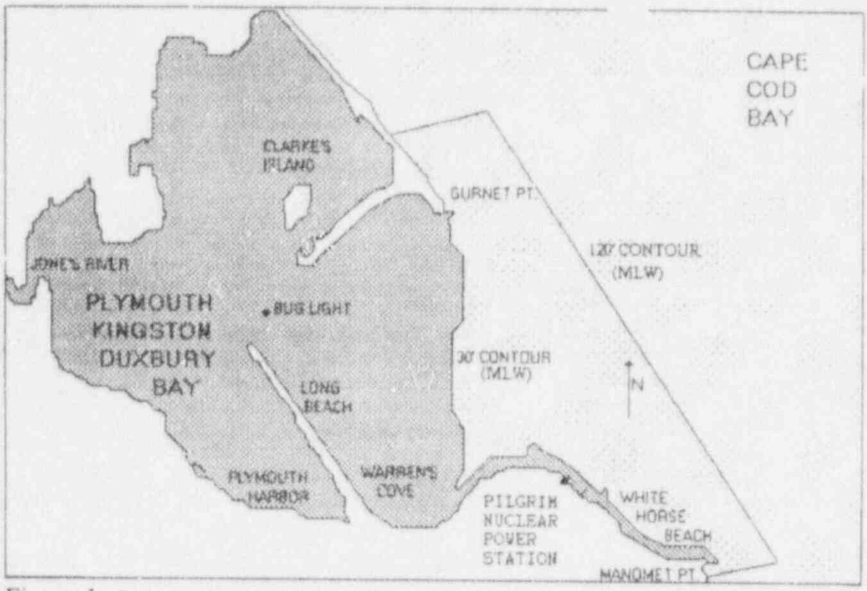

Figure 1. Investigative area inside and outside the estuary (shaded areas) for rainbow smelt, winter flounder, and cunner investigations, January to December 1996.

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 is used to equate entrained eggs and larvae to equivalent adults lost from the local population caused by power plant mortality.

Cunner fecundity by age, length, and weight has recently been investigated for fish collected off Pilgrim Station by Paul Nitschke, 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, including the residual and variance flow patterns that constitute circulation and which affect the resultant dispersion of ichthyofauna, was compiled by

Eric Adams of MIT, Cambridge. Area bounds for the origin of cunner eggs and larvae that are entrained at Pilgrim Station (primarily June through August) were identified by modeling. Cunner recruitment to the Pilgrim vicinity can be influenced, in part, by the status of spawning cunner located elsewhere; therefore, we needed to define the geographical limits 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 appears 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/post-settlement processes affecting recruitment were investigated. A second year of SCUBA surveys was undertaken as we continued to examine cunner recruitment in relation to Pilgrim Station operation. Locations with similar habitats again were sampled in 1996. We know that habitat type is important to recruitment success (Levin 1991; Tupper unpublished), and we did not want to mask possible power plant effects by sampling different habitats. Recruitment processes are affected by environmental conditions and demographics. We added a second year of comprehensive data collections to our existing database hoping to reveal important insights on local recruitment processes and possible power plant perturbation.

The density of juvenile recruits was quantified at a site just off Pilgrim Station and at two fixed locations away from the plant (Figure 2). The null hypothesis is that the power plant does not significantly affect recruitment. In that the plant "crops" young cunner (larvae and new recruits), recruitment at similar habitats may be higher with increasing distance from the power station. As part of our sampling design,

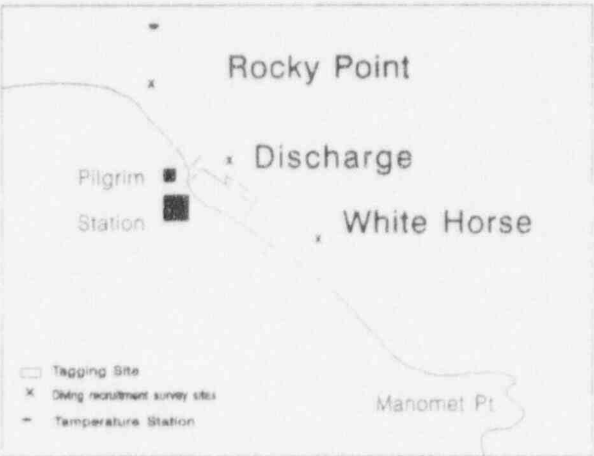

Figure 2. Station locations for cunner juvenile recruitment and tagging studies, and bottom temperature monitoring, 1996.

we collect information on post-settlement densities by observing recruits over time in comparable habitats but at spatially different sampling locations. If early settlement differs spatially, we can test the effects of density on recruitment at the end of the recruitment period. We also can examine an assumption of the adult equivalent model, viz., that there is a direct relationship between pelagic egg and benthic adult life stages. If this is fact, there should be a direct relationship between the number of recruits at the beginning of recruitment and those extant at the end. Stated as a hypothesis - initial settlement is correlated with net recruitment at the end of the recruitment period. Abiotic factors, including temperature and visibility, were measured during our sampling because of their importance to recruitment and our sampling of densities, respectively.

Three sites of similar substrate and depth were resampled in 1996. One site was located about 20 m southeast of the discharge canal. The other two locations were further from the power plant - one 0.5 km northwest at Rocky Point, and the other 1.5 km southeast at White Horse Beach (Figure 2). The center point of each fixed site location was marked with a mooring block and surface buoy. Painted red rocks were placed on the bottom beside each mooring to aid us in locating the site in case of buoy loss. At each sampling site, 10 transect starting points were established so as to radiate out from the center like spokes of a wheel. To insure that our diving would not bias counts along other line transects, the beginning of each was located 5 m out from the center block and was marked with a numbered, painted rock. Line transects were evenly metered at 36° intervals using an underwater compass, starting with a heading of 000° magnetic.

Prior to our diving recruitment surveys, and again at the end of the sampling program, the benthic habitat at each site was examined to establish similarity between sites and habitat stability over the course of the study. The post-survey habitat analysis could not be done at Rocky Point following loss of the mooring buoy after a major October coastal storm. 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 line marked in meters 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) without algal cover. Boulders were covered with algae and were not considered a category. We also recorded the algal types at the intersection point of adjacent sampling squares (16 squares rendered nine intersection points). Habitat characteristics were grouped into two functional groups: structure (filamentous and fleshy algae types) and non-structure (sand, gravel, and crustose algae), since habitat differences are important to recruitment of cunner (Levin 1991, 1993). The proportion of structure to non-structure among reefs for each time period was compared using chi-square analysis.

Rugosity (an index of structural complexity) was measured by laying a 10-m fine-linked brass chain on the substrate and allowing the chain to conform to the bottom contours. A straight-line measurement of the distance (m) covered by the chain was made, 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. Rugosity measurements were compared among reefs using analysis of variance (ANOVA).

Juvenile cunner (recruits) were visually counted while traversing each transect line using SCUBA. To delineate the width of a 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 the 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 was the enumerator throughout the survey.

Weather permitting, sampling was conducted on weekdays starting 27 June (prior to the beginning of the settlement period) until 8 October. Sampling was usually

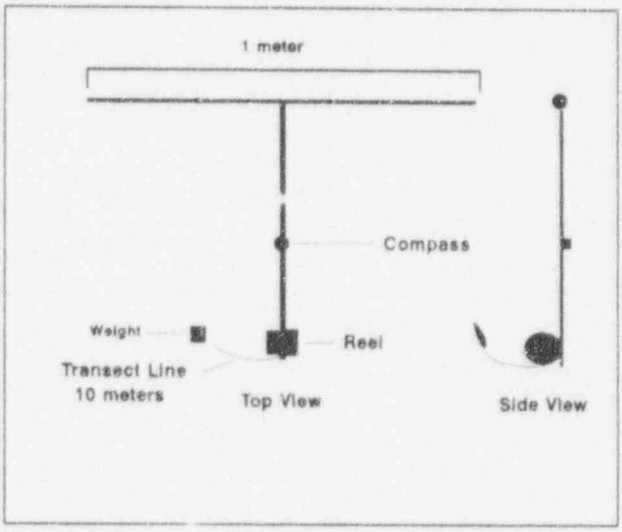

Figure 3. Survey tool used by divers to estimate abundance of juvenile cunner in the Pilgrim Station area.

conducted two to three times each week. Enumeration was completed at all sites within a sampling day to avoid temporal variation. Underwater visibility was measured using a Secchi disk after all counts were completed.

Adults. Mark and recapture studies have determined that cunner typically occupy a small area known as a home range (Green 1975). The objective of our cunner mark and recapture study in 1996 was to examine the home range of cunner in the Pilgrim Station area. Mature cunner (≥ 90 mm total length (TL)) were tagged with a Floy FD-94 Fine Fabric T-bar anchor tag, 40 mm long, 0.10 g in weight, in the dorsal musculature via a tagging gun during the summer and sampled for recaptures to determine lateral movement (Figure 4). The tag sleeves are printed with individual fish numbers and our agency telephone number. Fifteen trapping stations were selected along the seaward side of the southern end of the outer intake breakwater, with an arbitrarily chosen distance of 9 m between sites. Station locations were marked with paint along breakwater rocks to be visible from the trap-tending boat. Traps were individually numbered and set at the corresponding station number, enabling us to identify both individual tagged cunner movement and any trap displacement from a particular site. Traps were fished daily on weekdays, weather permitting, but were moved into the Intake on Fridays to prevent possible storm-related trap loss when untended over the weekends.

Cunner were captured in baited fish traps set overnight, and each was measured to the nearest millimeter (TL) and sexed, when possible, through ripeness and/or dichromatism. Fish were released at the station of capture. Lateral movements of individual fish between stations along the outer breakwater were determined and tabulated.

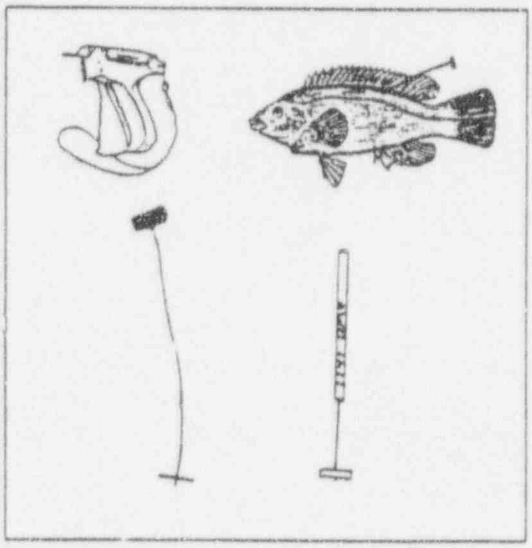

Figure 4. Tagging gun and styles of t-bar anchor tags used by DMF to mark cunner (shown above) off Pilgrim Nuclear Power Station.

The age structure of the local population (including age-1 and older) is being examined by aging otoliths taken selected specimens over the last several years. Aging information was incorporated into the fecundity analysis recently performed by the

UMass graduate student which, in turn, is used in entrainment modeling (Adult Equivalency) at Pilgrim Station (see 1995 annual report). Retained cunner were weighed to the nearest gram, measured for total length to the nearest millimeter, and sexed via internal examination of the gonads. Sagittal otoliths were removed, cleaned, 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 was validated by researchers in Newfoundland (John Green, personal communication)[1], so we are confident that the clear hyaline bands we read are 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 to dry at least two days. The mounted otolith was ground down with 320 grit sandpaper until the annular rings could be differentiated. Each otolith was aged independently by two readers. If concurrence occurred on their readings, that age was assigned to the fish. When disagreement occurred amongst the readers, the otolith was viewed again by the readers, and, if a consensus was not reached, that fish was excluded from the age analysis.

We will continue to collect catch/effort data (catch per trap haul) and to age selected cunner to generate catch-at-age data which will be used to estimate and fine-tune the natural mortality rate used in the adult equivalent model.

Rainbow Smelt

Eggs and Larvae. Each egg collecting unit (35.6 x 45.7 cm) was a weighted wooden frame, enclosed with chicken wire, and filled with unprocessed sphagnum moss as substrate for egg deposition. (Figure 5). Egg trays were placed into selected riffles in the upper Jones River smelt spawning ground. They were inspected, every few days, serviced, and monitored for egg deposition, development, and survival. Fouling macro-algae were removed from

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

the trays and discarded downstream of the spawning area. We endeavored to minimize egg disturbance and destruction on the river bed and on our trays during this process. Following egg hatchout, the larvae were expected to be carried downstream and out of the Jones River into the waters of Plymouth, Kingston, Duxbury Bay as they develop. As adults they should home back to this estuary, ascending the Jones River and possibly other tributaries to spawn.

Juveniles. There have been three unusually large rainbow smelt impingement incidents that occurred at Pilgrim Station, in December of 1978, '93, and '94. The majority of smelt impinged were age-0+. Impingement sampling data are collected by Marine Research, Inc. (see Impingement section, this report).

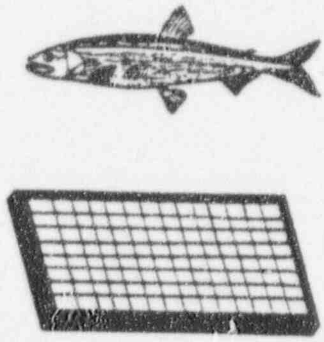

Figure 5. A collecting unit of the type used to collect and incubate smelt eggs (smelt shown above) in the Jones River.

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

Winter Flounder

Eggs and larvae. Data on these two life stages (primarily larvae, for winter flounder eggs are demersal)are collected by Marine Research, Inc. in their entrainment sampling program at Pilgrim Station (see Entrainment section, this report).

Juveniles. Juvenile winter flounder are impinged at Pilgrim Station. Monitoring data are collected by Marine Research, Inc. (see Impingement section, this report).

Adults. Our objectives are to determine the discreteness (delimit boundaries) of the local winter flounder population and then to estimate absolute population abundance. This information will be used to assess impact of flounder entrainment at Pilgrim Station.

During the winter flounder spawning season north of Cape Cod(ca mid-March to mid-June), some winter flounder may move in and/or out of PKDB (Figure 1), with evidence of spawning both inside and outside this estuary. Flounder 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.

In April 1996 we contracted a commercial fishing vessel, the F/V *Frances Elizabeth*, to trawl sample winter flounder, in order to collect catch data for density extrapolation and to capture winter flounder for tagging studies. The boundaries of our sampling area were extended to include the waters between High Pines Ledge, Duxbury and the Mary Ann buoy, Manomet from nearshore out to the 36.6 m (MLW) depth contour (Figure 1). The outer depth boundary was selected based on the distribution of winter flounder determined by the MDMF Resource Assessment Coastal Trawl Project. A Yankee otter trawl (18.5-m sweep, 14.8-m headrope, 15.2-cm stretch mesh, 7.6-cm mesh liner, 12.9-m legs, and 60.9-m ground cables) was used. Trawl doors were steel, measuring 1.8 m x 1.1 m and weighing 990 kg each. Warp length was varied with the depth fished and ranged from 73.8 to 92.3 m.

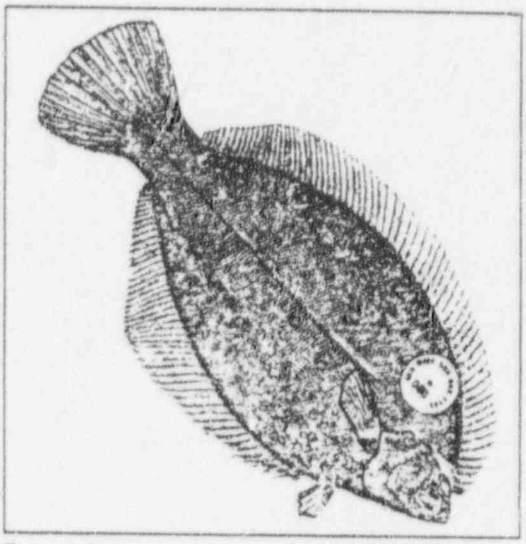

Figure 6. Winter flounder with Petersen disc tag attached (tag not to scale).

Catches were processed, winter flounder length (TL), sex, and evidence of maturity were recorded, and Petersen disc tags attached to fish ≥ 250 mm TL (Figure 6). Tow duration and length averaged 30 minutes and 1.6 km, respectively.

We generated an estimate of winter flounder population size (instantaneous abundance) from the 1996 contracted commercial vessel trawl catch data using an area-swept approach, based on density extrapolation. As trawl gear efficiency in our sampling is unknown, we estimated it to be 50%. To estimate density, the number of winter flounder by tow was divided by the area of bottom covered. Tow length was determined, and tow width was estimated from the trawl doors' spread on the bottom. Door spread is used as a measure of the width because of the "herding" action caused by the sediment cloud generated by the doors and legs while towing. Catch per area was calculated for individual tows. Estimates computed for adult winter flounder ≥ 280 mm TL and for all sizes pooled of winter flounder captured were doubled to reflect the assumed 50% catch efficiency.

Density estimates (number per m^2) were multiplied by the total bottom acreage in the study area to obtain estimates of population size. Bottom area was averaged using a dot grid and navigational charts. Acreage was converted to square meters.

Other Fish Species

Eggs and Larvae. Egg and larval information for all finfish species entrained at Pilgrim Station are obtained by Marine Research, Inc. (see Entrainment section, this report).

Juveniles. We collect data on juveniles of finfish species via SCUBA diving and fish potting. Impingement data are obtained from Marine Research, Inc. and BECo.

Adults. (Same as for juveniles)

IV. RESULTS AND DISCUSSION

A. PHYSICAL FACTORS

1. Power Output-Thermal Capacity

Pilgrim Nuclear Power Station's capacity factor (MDC net percent) is an index of operational status that approximates thermal loading into the receiving waters of the marine environment. This factor is relevant when assessing long-term thermal impact on marine organisms. By permit regulation, Pilgrim Station is allowed a maximum discharge temperature of 38.9°C and an effluent Δ T 18°C above ambient. For the 24-year history of plant operations, the long-term mean MDC at Pilgrim Station is 53.6%, with annual averages ranging from 0.0% (outage years) to 90.5% in 1996 (Figure 7). The annual power level has increased over the last three years - 65.2% in 1994, 76.4% in 1995, and 90.5% in 1996. Average monthly thermal capacity values in 1996 ranged from 51.4% in September to 99.4% in February.

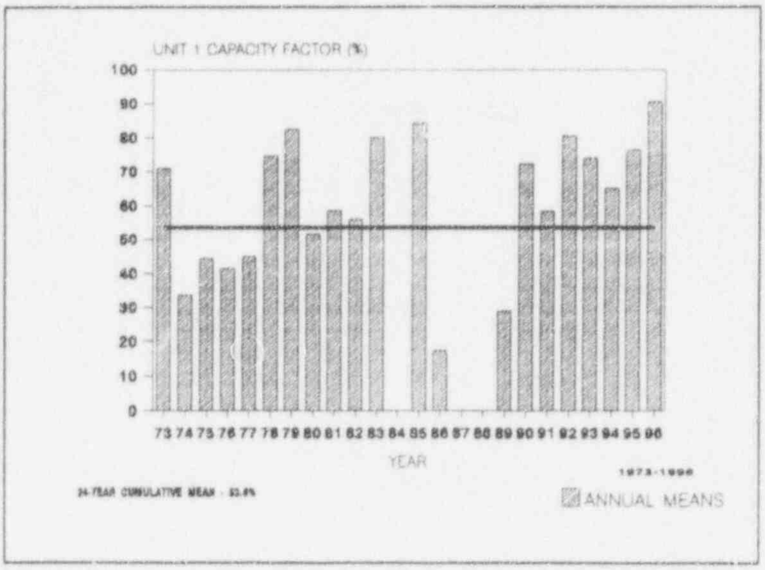

Figure 7. Annual means and 24-year cumulative Mean Capacity Factor (MDC Net %) for Pilgrim Nuclear Power Station, 1973 through 1996.

2. Pump Operations

Once-through, open-cycle cooling at Pilgrim Station induces a localized water current flow. Two circulating seawater pumps (586.7 kl/min each) withdraw water from the Intake embayment. The cooling water circulates through the plant condenser tubes before being discharged back into the waters of Cape Cod Bay laden with waste heat. At ebb tide, effluent velocities can exceed 2.1 m/sec at the egress 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 this power plant, there have been station outages, when one or both circulating seawater pumps were not operated (Figure 8). Such periods have occurred aperiodically and generally

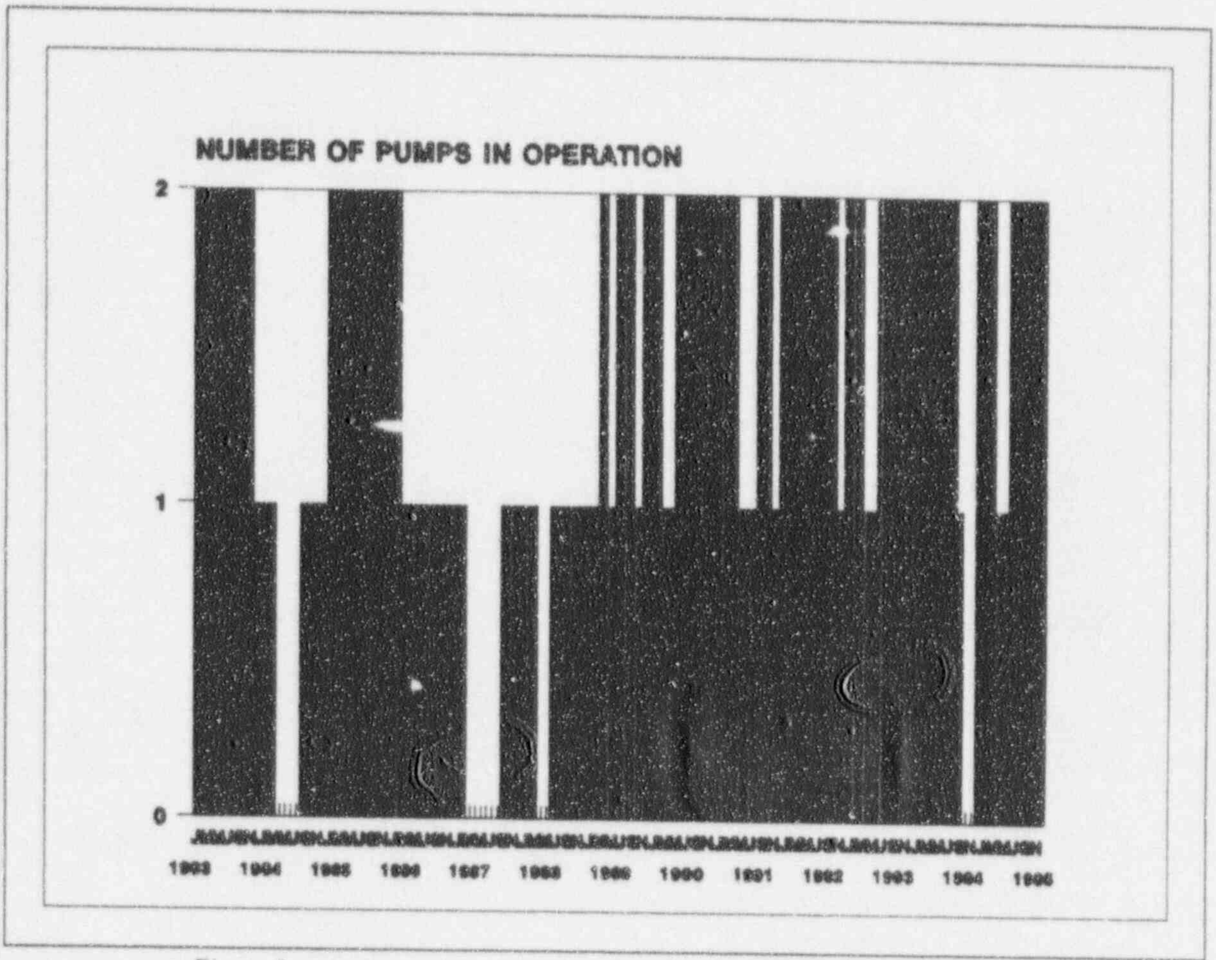

Figure 8. Operational history of the two circulating seawater pumps at Pilgrim Station by month for the years, 1983 through 1996.

are short-lived; however, prolonged outages occurred in 1984 and from 1986-1988 (Figure 8). During 1996, both circulating pumps essentially were in operation throughout the year.

3. Water Temperature

Bottom water temperature (°C) was recorded continuously throughout most of the year by a constantly recording thermistor (Ryan) secured on the seabed in a cement mooring located at Rocky Point, 0.8 km offshore and at 12-15 m of depth (MLW). Figure 9 displays temperature records for 1995 and 1996. It is evident from these records that winter, spring, and summer temperatures were generally higher in 1995, with fall temperatures more aligned. Overall, 1996 was a cooler year.

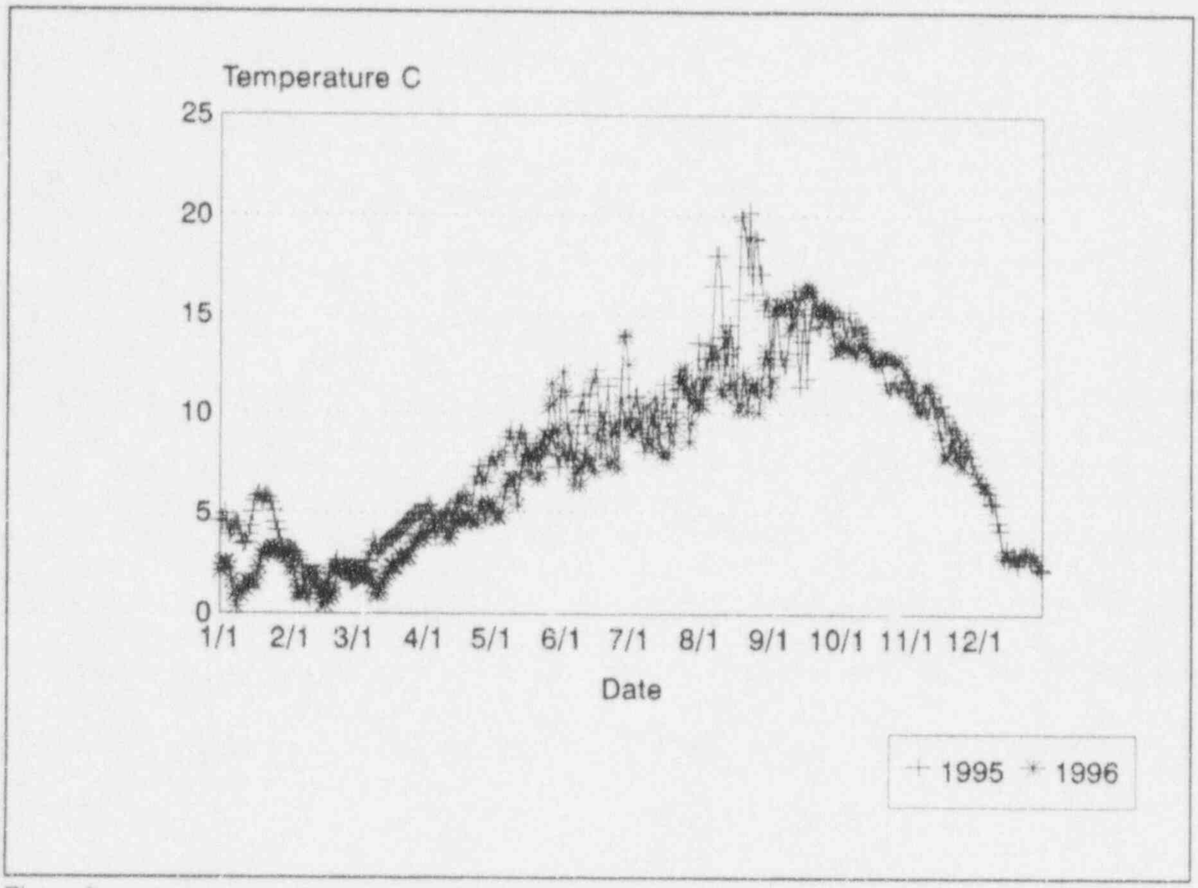

Figure 9. Mean daily bottom water temperatures (°C) recorded January to December of 1995 and 1996, off Rocky Point (0.8 km offshore in 12-15 m of water at MLW).

B. FINFISH SPECIES OF IMPORT

1. Cunner

Background

The cunner (*Tautogolabrus adspersus*) is a temperate reef fish that seeks the shelter of pilings, jetties, and rocky areas, distributed generally within 10 km of shore (Bigelow and Schroeder 1953). This species is abundant from Conception Bay, Newfoundland to New Jersey; Chesapeake Bay is the southern limit of their range. Massachusetts Bay, contiguous with Cape Cod Bay, is near the mid-point of the cunner's range. The cunner is a dominant component of many inshore marine benthic fish communities (Edwards et al. 1982).

Cunner do not undertake extensive migrations (Green and Farwell 1971; Olla et al. 1975) but may overwinter in their summer habitat in a dormant (non-feeding) state (Dew 1976). Olla et al. (1975) and Dew (1976) reported that as fall water temperatures drop to 7-8° C, cunner become inactive and then remain dormant until vernal waters warm above 6° C. Dew (1976) noted that large cunner in Connecticut waters become dormant first and remained so longer in the spring than small fish, resulting in a growing season for age-0 and age-1 fish that was a month longer than for older fish. There may be some systematic offshore movement of larger cunner (Olla et al. 1975; Dew 1976). Adult cunner are not known to stray far off the bottom or from night resting sites; they occupy relatively small home ranges (Green 1975), remaining near structure to which they recruited (Olla et al. 1975).

Cunner often are found in highly localized aggregates, where a population may be spatially separated into subunits, some of which occupy patch reefs. As such, they are vulnerable to local perturbations (e.g., point-source pollution, 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. Cunner appear to be a good indicator species to assess stress in inshore coastal regions (Olla et al. 1975; Dew 1976).

At Pilgrim Station, the intake breakwaters and discharge canal jetties augment naturally occurring structure, creating additional high-relief 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, and, in general, provide both protection from predators and 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 or even preclude their presence.

The cunner is a numerically dominant fish in the environs of Pilgrim Station. The density of cunner varies spatially in the Pilgrim area, with highest adult densities found on the seaward side of the outer intake breakwater. Our extensive tagging work shows they have high site fidelity.

Eggs and Larvae

Cunner are impacted by Pilgrim Station by entrainment of their pelagic eggs and larvae during late spring and summer, when the adults are known to spawn in western Cape Cod Bay. Having consistently captured numbers of running ripe male and female cunner off Pilgrim Station in May and June, we conclude that spawning does occur locally in the immediate vicinity of the power plant.

In 1996, cunner eggs were entrained at Pilgrim Station from May to September, while their larvae were entrained from June 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 the eggs collected. Substantially more cunner eggs than larvae are collected which is probably related, at least in part, to high egg mortality and the ability of the larvae to move in the water column.

Large numbers of cunner eggs and larvae have been entrained historically at Pilgrim Station (Figures 10 and 11). For analysis of impact, it is assumed they undergo 100% mortality and are thus lost to the local population (Marine Research, Inc. 1992). In 1996, Pilgrim Station entrained an estimated 3,176.482 X 10^6 eggs and 17.160 X 10^6 larvae, which equates to 588,997 future cunner adults lost to the local 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 4,282.479 X 10^6 cunner eggs and 46.484 X 10^6 cunner larvae were entrained, equating to 975,729 adults. The number of eggs entrained in 1996 was 26% lower than in 1995, while larval entrainment declined 63%. The resulting equivalent adult estimate concomitantly fell 40% in 1996. The SCUBA density observations from our cunner age-0 surveys indicated that recruits were noticeably less abundant in the Pilgrim Station vicinity in 1996 than in the previous year, which corroborates the larval entrainment values reported at the plant for these two years, indicating the pool of pre-settlement larvae was much reduced in 1996. Predation is implicated as potentially the greatest source of mortality to marine fish larvae. Even small changes in life stage durations can lead to substantial increases in mortality. Fast growth and rapid planktonic life stage transitions are important, as subtle declines in growth rates, e.g., via cooler temperatures, can increase predation mortality by an order of magnitude (Richards and Lindeman 1987). We know that ambient water temperatures in winter, spring, and summer were noticeably cooler in 1996 off PNPS.

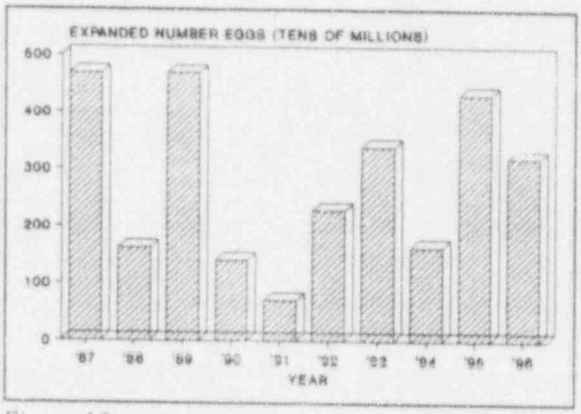

Figure 10. Expanded number of cunner eggs entrained at Pilgrim Station, 1987-1996.

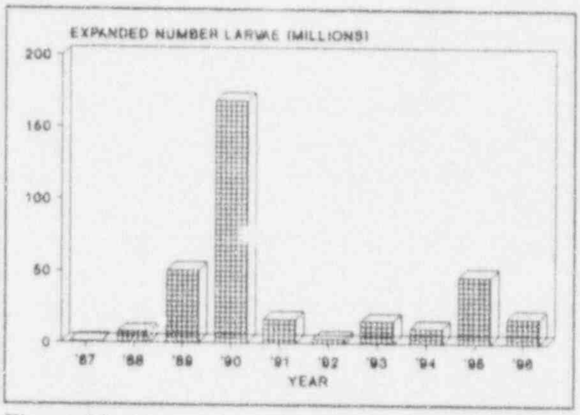

Figure 11. Expanded number of cunner larvae entrained at Pilgrim Station, 1987-1996.

While the magnitude of entrainment loss is substantial, its significance to the local cunner population is unknown. At 15.6°C, cunner eggs hatch in 2-3 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

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

portion of the larvae hatched from eggs produced in the immediate area of Pilgrim Station are advected from this area by prevailing currents.

We now have an estimate of the geographical bounds of this population based on recruitment sources, via hydrodynamic modeling of cunner egg and larval dispersion in the Pilgrim area conducted by Eric Adams of M.I.T.. The model predicted that 90% of the cunner eggs and larvae entrained at Pilgrim come from within approximately 8.8 km of Pilgrim Station to the north, from High Pines Ledge to White Horse Beach. The estimation of adult cunner population size, via tag and recapture, has proven unfeasible because of man-power constraints and logistics, so comparative juvenile recruitment success at various locations near Pilgrim Station is used to assess potential Station impact on this species.

Juveniles

Juvenile cunner are vulnerable to impingement on the traveling-screens at Pilgrim Station, typically during summer and fall (Lawton and Anderson et al. 1984). An estimated 211 fish were impinged in 1996. Impingement numbers from 1979 to 1996 have fluctuated but with an overall decline, with a low in 1992 and a high in 1980. Past survival studies of impinged cunner at Pilgrim Station revealed initial survival rates of between 24 and 100% (Anderson 1990, 1993). Influencing factors include number of pumps on line and the operational mode of the screen wash system (static vs. continuous). Impingement, when combined with sportfishing and entrainment mortality at Pilgrim Station, can impact the local population.

The Station's discharge, with its high velocity, waste heat, and periodic chlorine load, can influence all cunner life stages - particularly the distribution of juveniles in the receiving waters. In addition to thermal stress, the fast-flowing current can be limiting to cunner mobility and maneuverability. Small juveniles, e.g., 20-30 mm TL age-0, do not stray far from home shelter and ordinarily avoid the discharge current at Pilgrim Station, which, on an ebbing tide, can exceed 2.1 m/sec at the egress of the discharge canal. When the power station is operational, small cunner often are seen by our divers in a control area just outside the thermal discharge. Auster (1987) reported that adult cunner forage further from reef substrate and on current-exposed surfaces longer than do the juveniles. As the current velocity 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.

In 1996, habitat characteristics again were measured at each sampling site at the beginning (June) and end (October) of our continuation of the recruitment study to establish similarities amongst sites. We generally counted recruits three times per week, weather permitting, from 27 June through 8 October, when the study was terminated because of severe weather and loss of the marker buoy/mooring at the Rocky Point site. As in 1995, the recruit data set was separated into two time periods, settlement and post-settlement, with 16 September being the dividing date in 1996. Cunner larvae were rare in PNPS entrainment monitoring collections after that time (Mike Scherer, personal communication)[2]. Unfortunately, this mid-September period also included a two-week interval (16 September - 1 October) in which we could not sample due to severe weather conditions. Sampling counts after mid-September (four days in October) represent the post-settlement period.

Habitat characterization amongst the reefs was investigated to ascertain if habitat was similar at the sites sampled. No significant difference existed in the proportion of structure to non-structure amongst the three reefs at the beginning ($X^2 = 2.54$, $P = 0.28$) or between the two remaining sites (White Horse and Discharge) at the end ($X^2 = 1.81$, $P = 0.18$) of the study. Again in 1996, there was a noticeable decrease (ca. 12%) in the proportion of structure over the course of the survey at two sites (White Horse and Discharge), where pre- and post-study data were available. This probably is due to the loss of macroalgae from storms over the season. No significant difference amongst sites was observed in the substrate rugosity index, which reflects structural complexity, when measured at the start of the survey ($F = 1.90$, $P = 0.17$).

Recruitment - overall patterns. No recruits were observed until 15 July, and recruitment remained low until after 30 July, with increasing densities (no./10 m^2) occurring thereafter (Figure 12). Recruitment at the White Horse site was initially very low, and did not start to increase until 21 August. Bottom water temperatures (point estimates) at the three sites were similar during the period. Recruitment generally peaked in September

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

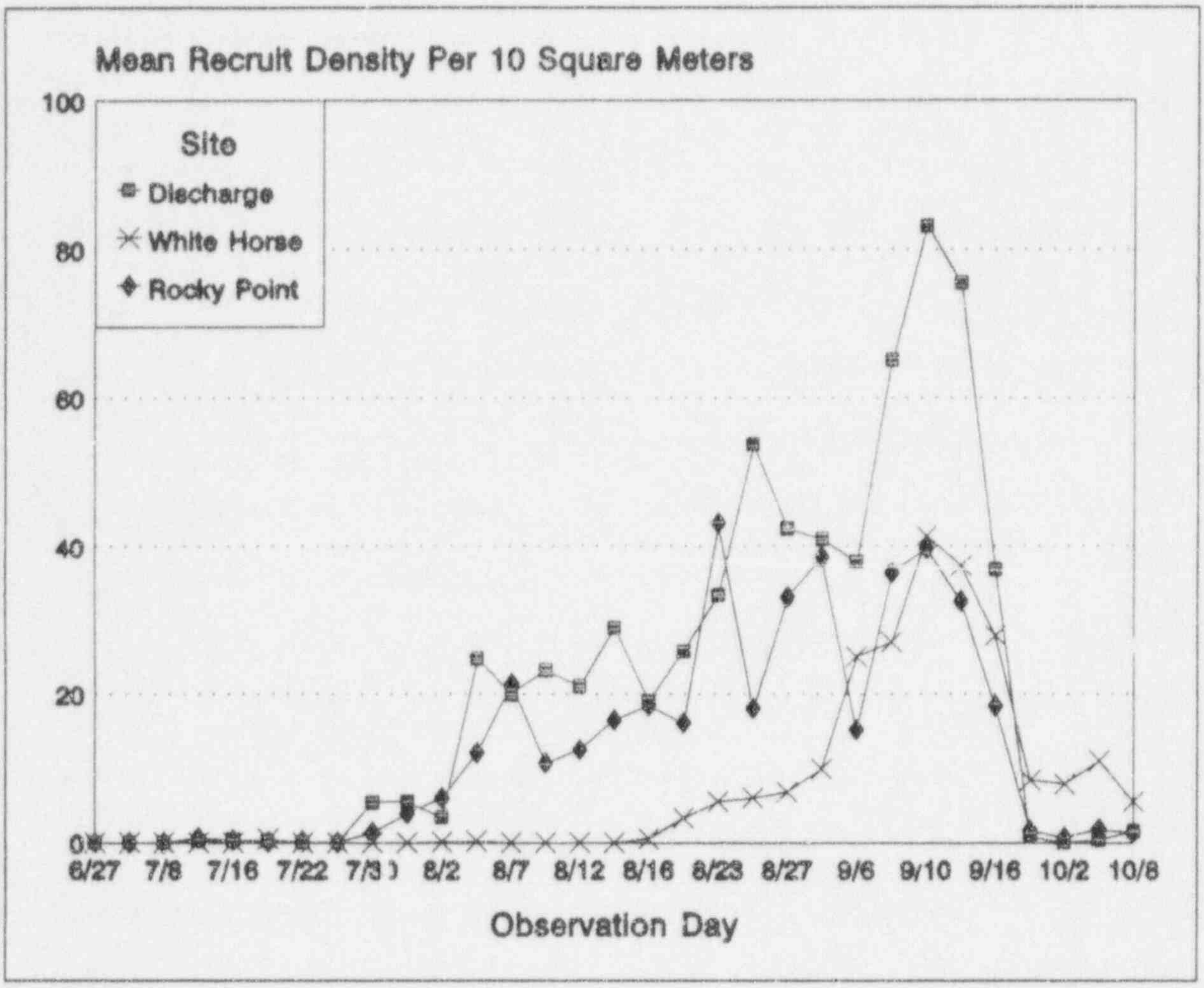

Figure 12. Mean cunner recruit densities (the average of 10 transects) per site per day for the recruitment study in the Pilgrim Station area, 27 June to 8 October 1996.

at all sites, with maximal densities at White Horse (41.4) and at the Discharge (83.2) on 10 September, and at Rocky Point (43.1) on 23 August. At all sites, recruitment densities fell precipitously after 16 September, the last day of counts before two weeks of severe weather. Over a great majority of the settlement period (15 July to 16 September), the Discharge site had higher recruit densities than at Rocky Point and substantially higher than at White Horse, indicating that, on average, settlement was greater there than at the other two sites. This also occurred in 1995. Multivariate repeated-measures ANOVA showed the discharge to have significantly greater recruit counts than the other sites for the overall settlement period in 1996 (Discharge vs. Rocky Point:

F = 24.81, P < 0.0001; Discharge vs. White Horse: F = 96.92, P < 0.0001), and Rocky Point had significantly greater cunner densities than did the White Horse site (F = 75.31, P < 0.0001).

The extremely limited post-settlement data collected in 1996 presented a problem regarding data analysis and interpretation of power plant impact. We could not perform the same analysis as in 1995. October recruit densities in 1996 were reduced at all sites but especially at Rocky Point and the Discharge (Figure 12). The 1995, recruit densities were not only higher in the settlement period, but also in the post-settlement period, with initial September values of 95-140 recruits per 10 m^2 at the three sites declining to the same level of approximately 55 per 10 m^2 for each sampling site at the end of the period in late October. In 1996, recruit densities at the termination of sampling in October were > 1/m^2 at all three sites. Such radical differences (an order of magnitude) between years in post-settlement densities make it impossible at this time to formulate any recruitment process generalizations for cunner in the Pilgrim area.

A repeated-measures ANOVA was used to test post-settlement recruit densities in 1996, for which we found White Horse values significantly greater than at both other sites for this period (vs. Rocky Point: F = 22.58, P < 0.0001; vs. Discharge: F = 28.21, P < 0.0001). However, due to extremely limited post-settlement data and because habitat characterization could not be done at Rocky Point in October, any conclusions regarding post-settlement processes as to implications of power plant impact for 1996 are speculative. The severe weather during the last half of September evidently resulted in the marked decline in recruit numbers at the sampling sites towards the end of the recruitment period. There likely was substrate scouring and habitat alteration with reduction of protective habitat (e.g., macroalgae), which may have caused displacement of recruits to new sites or more likely outright recruit mortality. It is possible the White Horse site was less impacted by the storm events, and therefore recruits there had better survival. Another possibility is there also may have been some late settlement at this site which would account for the higher recruit densities there in October.

This is the second year of cunner recruitment studies off Pilgrim Station. In both years, the amount of cunner eggs and larvae entrained at Pilgrim Station versus cunner recruit densities seen on our dives matched up well, with pre-settlement stages and recruits much greater in 1995. Levin (1996) reported a direct relationship between numbers of larger cunner larvae in the water column and subsequent settlement off the New Hampshire coast. Higher initial settlement overall occurred both years at the Discharge site. One could speculate the discharge current from Pilgrim Station produces an eddy which concentrates larvae there, allowing for higher settlement.

Recruitment success for marine fish is known to fluctuate greatly from year to year, due to a host of physical and biological factors (Sinclair 1988), which, in turn, has a major influence on structure of populations. It may well require several years of study to understand cunner recruitment processes near Pilgrim Station and the implications of power plant impact. We do believe that spawning was more successful in 1995, with substantially more eggs and larvae evident in entrainment sampling at PNPS. Delayed recruitment occurred at White Horse in 1996, which was not observed in 1995. Recruitment in 1995 apparently was more successful than in 1996 and was regulated during the post-settlement stage by compensatory processes, e.g., density-dependent mortality via predation. Storm events may well have overridden other mechanisms driving recruit success in 1996. Recruit survival is influenced by habitat structure/quality and how habitat quality (e.g., macroalgal cover) affects survival. A marked effect of power plant entrainment of pre-settlement cunner (larvae) on recruitment success is more likely to occur during a recruitment season where larval supply and subsequent settlement are low overall. Implicit in this is that there is a direct relationship between larval abundance and recruitment success.

Although recruitment is a demographic event of relatively short duration, the variation in recruitment, within and among years, has a major influence on population structure. Recruit levels should always be a major consideration when examining adult numbers in a population; however, other factors become increasingly important in high recruitment years. In good recruitment years, settlement is large enough for post-recruitment density-dependent effects on settled juveniles to be the major determinant of adult population size. Conversely, in poor recruitment years, recruit limitation, i.e., density-independent fluctuations in recruitment, is expected to be the major determinant of explaining patterns in adult numbers. At any other time, one may be more important than the other. Jones (1990) found with a coral reef, sedentary species that with recruitment densities below 1 recruit/m^2, adult numbers are recruit limited, but above 1 recruit/m^2, post-recruitment density-dependent processes become increasingly important. The long-term effects of recruitment on population structure and dynamics are likely to be known by studies continued over a time scale appropriate to the longevity of the species of concern (Jones 1990).

Adults

Adults also are impinged at Pilgrim Station, but the number has rarely been large. A review of temperature tolerance data on cunner (Kinne 1969) suggests the presence of an exclusion area within and just outside Pilgrim's discharge canal during summer and fall when the plant is fully operational. However, cunner kills have not been documented (Lawton et al. 1993). Our SCUBA observations in the thermal discharge area at flood tide from previous summers revealed the occurrence of far fewer cunner inside the mouth of the discharge canal than 60 m immediately seaward. We have measured bottom water temperatures exceeding 30°C at the mouth of the discharge, and it appears that cunner avoid the immediate area at this time of year.

Cunner are susceptible to acute, local sportfishing mortality, because of their apparent small home range (Green 1975) and nearshore distribution. In the past, cunner led the shore-based sportfish catch at Pilgrim Shorefront. None were reportedly landed the last several years, but this may be attributed to incomplete reporting during informal creel surveys conducted there.

Tag returns from our multi-year capture-recapture program clearly indicate that cunner are relatively stationary, at least during the warmer months off Pilgrim Station. Our objective of the 1996 tagging was to monitor local movement of adult cunner along the outer breakwater. From June through August 1996, 4,350 cunner (includes multiple recaptures) were captured in baited traps fished overnight at two locations. Of these, 2,971 came from the seaward side of the outer intake breakwater at Pilgrim Station. From this pool of fish, 385 adults (≥ 90 mm TL) were tagged and released over 10 sampling days between 2 and 23 July at marked (fixed) stations, in order to ascertain short-term lateral movement of cunner along the breakwater. The remaining 1,379 cunner captured came from the landward side of the outer breakwater in the Intake embayment.

During the past seven years, we have tagged 6,506 cunner in the Pilgrim area. This relatively large sample size has provided tag-recapture evidence of cunner's site fidelity within a year and for consecutive years. For example, in 1996, with recapture efforts continuing through 23 August at the outer breakwater, we had 161 recaptures of cunner tagged in that year, with all returns coming from the outer breakwater where the fish were tagged. No fish traveled around or through the breakwater to the Intake side.

Factors that must be considered when evaluating this year's tag returns include the spatial shifting of traps off station due to severe weather and the inadvertent movement of our traps by the daily fishing activities of lobstermen in the area. Fortunately, such problems were infrequent, and data from moved traps were tracked and excluded from the analysis. There were multiple recaptures, e.g., 35 cunner tagged in 1996 were recaptured more than once; one individual was retaken seven times and another eight. Lateral movement of tagged cunner along the outer breakwater during 1996 was minimal. Eighty-five percent of the recaptured fish had moved no further than 18.3 m or two trapping stations apart; of these, over half of all recaptures did not move from their original capture site. These data provide first-hand evidence that adult cunner in the Pilgrim area have a relatively small home range, a behavioral trait documented for Newfoundland fish (Green 1975). In our trapping efforts in 1996, we also recaptured two cunner tagged in 1992, 3 tagged in 1993, 36 in 1994, and 176 in 1995. All were recovered from the same side of the breakwater where they had been originally tagged and released.

Tag retention can be a problem when external tags are used. Cunner often take refuge under rocky outcrops and within crevices, so there is the potential for snagging and tag loss. In many finfish tagging programs, the percentage of recoveries typically ranges from 3 to 10% (Matthews and Reavis 1990). However, 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, 26% in 1995, and 25% in 1996 (includes multiple recaptures). By recapturing our own tagged fish, we limit unreported tag returns.

In a cooperative venture with UMass Amherst, a graduate student, with our assistance, investigated fecundity of cunner collected off Pilgrim Station in 1994; this parameter was needed for the Adult Equivalent Model. We continue to conduct cunner aging work and are developing a synoptic age-length key, which has been used to establish an age-specific fecundity relationship. We collected 145 cunner (67 to 222 mm TL) in our traps from the Pilgrim area for ageing in 1996; of these, 125 were successfully aged, using otoliths (Table 2). The oldest fish were age 10.

Most of the otoliths (N=100) were mounted on slides and hand-ground prior to analysis. Four individuals had crystallized, unreadable otoliths, while 17 could not be assigned an age according to our criteria (see Methods this section). Completion of annulus formation, which likely occurs in May in the Pilgrim area, was recently validated for the same time period for oxytetracycline-injected cunner kept in cages in the field under ambient temperatures by researchers in Newfoundland (John Green, personal communication)[3]. This correlates with annulus formation reported for late May-June for fish in Buzzards Bay south of Cape Cod by Serchuk and Cole (1974) and for May in cunner from Connecticut (Dew 1976). Both of these studies utilized scales for ageing.

Annuli for whole otoliths could only be read reliably for fish up to three or four years of age. The benefit of using ground otoliths to accurately age cunner is apparent for fish age-5 and older. There are larger cunner in the Pilgrim area, but they are excluded from entering our traps due to their size. Based on our project diving observations, these larger fish are not common. We have ground the otoliths from a few of these larger fish given to us by lobstermen from their traps and have estimated ages up to and over twelve years. Accurate ageing of these larger fish is difficult due to the crowding of the outermost annuli.

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

Table 2. Age-length key for cunner (sexes combined) in the Pilgrim Station area, 1996.

Length (mm)	Age										Total in this length category sampled for age
	1	2	3	4	5	6	7	8	9	10	
66-70	3										3
71-75	2	1									3
76-80		2									2
81-85		3									3
86-90		3									3
91-95		2									2
96-100		5	1								6
101-105		3	1								4
106-110		1	2								3
111-115			3	1							4
116-120			2	1							3
121-125			4	1							5
126-130			1	4							5
131-135				3	2						5
136-140				1	3	1					5
141-145				1	2	4					7
146-150				1	5	2					8
151-155					6		1				7
156-160				1	3	2					6
161-165					3	3	1				7
166-170					3	4					7
171-175					2	2	3	1			8
176-180						2	1				3
181-185						1	2				3
186-190					1		2				3
191-195							2			1	3
196-200								1			1
201-205							1				1
206-210								1			1
211-215									2		2
216-220							1				1
221-225										1	1
Total fish aged											125

2. **<u>Rainbow Smelt</u>**

Background

The start of the rainbow smelt (*Osmerus mordax*) spawning period in Massachusetts begins in late February south of Cape Cod to late-March in areas to the north. Reproduction takes place at night, and although there is no evidence of daylight spawning, small numbers (mostly males) remain on spawning grounds in the daytime. During the spawning runs at night, the overall sex ratio can be as high as nine males to one female, in that individual males use the spawning grounds for up to eight nights, while female spawning activity spans no more than four nights.

River spawning of smelt occurs in freshwater or low salinity water, with fertilization taking place externally. A female spawns up to 44,000 eggs, depending upon size and age. The eggs are demersal and adhere to gravel, rocks, and vegetation. Spawners prefer riffle areas, and egg deposition is not uniform on the bottom. After a night's spawning, most fish move downriver, and no parental care is rendered to the eggs. When spawning is entirely completed, adults vacate the spawning grounds and disperse in saltwater.

Our overall goals in working with smelt are to offset impingement mortalities at Pilgrim Station and to increase the size of the local smelt population.

Eggs and Larvae

The objective of for our 1996 smelt project was to enhance quality of smelt spawning habitat in the Jones River, the major smelt-spawning tributary to PKDB, the origin of the local population (Figure 1). We placed 130 egg collecting trays in a selected area of the smelt spawning ground on the Jones River to collect the naturally spawned smelt eggs and provide an ideal habitat for egg deposition and embryonic development. Sphagnum moss fills the trays and provides a depositional surface that has interstices, which in turn, give the depositional material depth. This 3-dimensional surface provides a micro-environment that offers protection for the developing embryos and thus reduces egg 'turnover' (loss). Water seeps into the moss, carrying away metabolic wastes and providing a continuous supply of oxygen to the eggs.

Sphagnum consistently collects higher egg sets than does natural hard bottom. The smelt spawning area in the Jones River is comprised largely of hard bottom (sand, gravel, and cobble). Endemic attached macroscopic aquatic vegetation provides ideal substrate for egg development, but comprises less than a quarter of the bottom area on the spawning ground. Sutter (1980) reported egg survival to hatching was about 10% on vegetation but only 1% on hard surfaces. Our egg trays provided ca. an additional five percent of plant material to the upper spawning area. They were placed in areas where smelt eggs are known to accumulate and where natural attached vegetation is sparse. The portable trays allow us to maximize egg survivorship in these areas by continually providing optimal habitat which would otherwise be in limited quantity.

There was extensive variation in smelt egg densities on natural substrate and on the egg collecting trays distributed throughout the Jones River smelt spawning area. However, the density of egg sets on the trays was more aligned with sets observed on endemic attached aquatic vegetation. In most areas, the various plant substrates had higher egg densities than the surrounding hard bottom. Ten replicate egg counts (obtained using square inch counting screens) of hard bottom in Zone A (Figure 13) had an average egg density of 15 eggs per square inch. Whereas ten replicate counts on endemic plant material in the same area averaged 42 eggs per square inch. Overall, egg densities were highest on the upper spawning ground, which is comprised of Zone A and part of Zone B (Figure 13). In areas containing more than 50 eggs per square inch, we identified the sets as heavy; 20-50 per square inch, moderate; and less than 20, light (Figure 13).

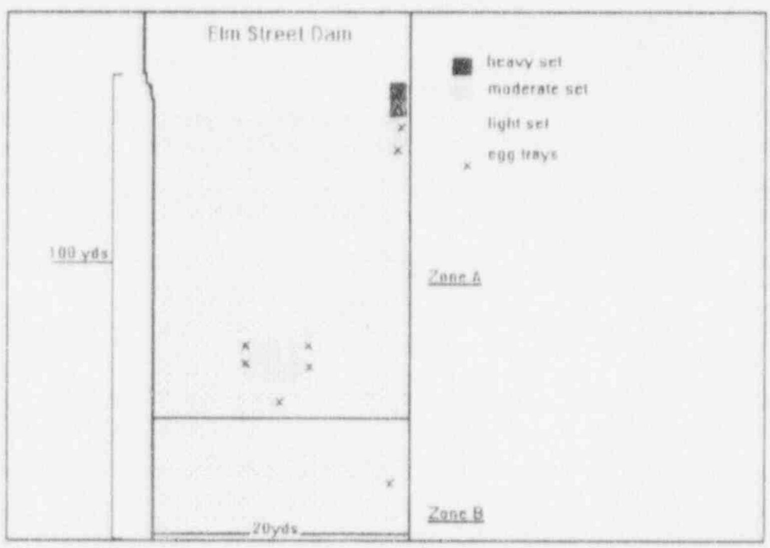

Figure 13. Smelt egg densities within Zones A & B of the Jones River habitat enhancement area, 1996.

The 1996 smelt egg set in the Jones River appeared to be the best of the past three years. About 95% of the substrate in Zone A was covered by eggs of varying densities. The upper one third of Zone B was also blanketed by a light egg set. In 1995, egg sets were patchy, and most of the traditional spawning ground was unutilized (Figure 14). Conditions in the Jones River were favorable in the spring of 1996 for successful smelt egg production, with good water flows, including many riffles for dispersing the eggs and preventing them from aggregating in one area. When the density of eggs per unit area is too high, i.e., more than one layer thick, survival is usually poor. In many cases, a fungal infestation will occur on the dead eggs, which can be detrimental to extant egg development and survival. The abundance of macro- algae, which was problematic last year in much of the spawning area, was not realized this year. Eggs can become entangled in the algae's long hair-like filaments, resulting in reduction of water flow which hinders egg development.

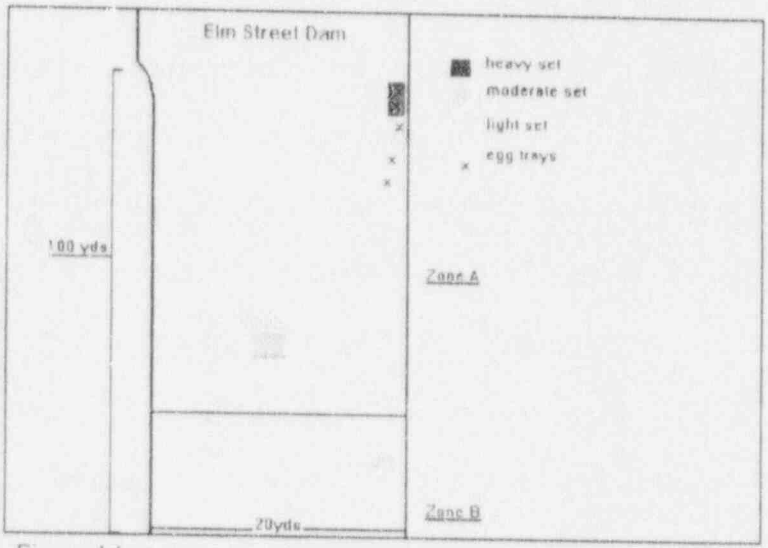

Figure 14. Smelt egg densities in Zones A & B within the Jones River habitat enhancement area, 1995.

During the 1996 smelt spawning season, Eel River, Town Brook and Smelt Brook (other tributaries to PKDB) were inspected weekly for egg production. We sampled areas in these tributaries of known spawning activity and found little production in these three systems. Egg densities in these tributaries averaged less than five eggs per square inch, with only small areas having egg sets. The Jones River, once again, hosted the majority of smelt spawning activity for the PKDB smelt population.

In 1997, our focus again will be on habitat enhancement of the smelt spawning area in the Jones River. We will increase the number of collecting trays to ca. 200, placed in areas of the river where attached plants are sparse and egg deposition has taken place in recent years. By employing this manipulative procedure, we opt to increase egg hatching. Saunders (1981) found that the most sensitive parameter driving future smelt population growth is egg survival to hatching.

Juveniles

Smelt impingement at PNPS in 1996 was estimated to be 3,674 fish. Impingement in 1993, '94, and '95 totaled 9,560, 10,644 and 2,335 smelt, respectively. A representative sample of impinged fish was measured each year. The lengths of these fish were compared to mean lengths of smelt by age-group from an earlier Jones River smelt study (Lawton et al. 1990). The majority of impinged smelt were apparently juveniles (ages 0+ and some 1+ fish). The Jones River smelt spawning run has been relatively small for well over a decade, and these power plant mortality incidents may have impacted existing and future population growth.

Adults

The number of spawning adults in the local population was especially depressed throughout the late 1980's and early '90s. It has been difficult to observe spawning-run smelt in the Jones River during many of our visits to this system even in recent years. The 1996 overall egg density in the Jones River indicated more smelt spawners and spawning activity than in the past few years. However, this increase in eggs and spawning-run smelt is still far below levels we observed in the early 1980's when we conducted comprehensive smelt studies in the Jones River (Lawton et al. 1990). From recent observations, it appears that the majority of local spawning has taken place over a relatively short time period of two to three weeks. This is further evidence of a reduced spawning smelt population, in that in the early 1980's, spawning took place over five to six weeks (Lawton et al. 1990). Any substantial continued reduction in the local parent stock via impingement will likely be adverse to future stock rebuilding efforts.

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). A hardy species, winter flounder can be found at temperatures between 0 and 24°C, and salinities ranging from 4 to 30‰. They can form discrete, resident populations, undertaking localized seasonal movements (Perlmutter 1947; Saila 1961, Howe and Coates 1975). Flounder movement appears to be temperature driven (Pearcy 1962; McCracken 1963; Scarlett 1988; Powell, unpublished data), with adults emigrating from shoal waters in spring when water temperatures rise above 15°C, and returning as waters cool below this level. Some groups of winter flounder are apparently nonmigratory. Although an avoidance temperature of 24.4°C was reported by Meldrim and Gift (1971), year-round occurrence has been documented in certain estuaries (Olla et al. 1969; Wilk et al. 1977) at water temperatures as high as 24°C. Additionally, Phelan (1992) found adult winter flounder year-round in an area offshore of New York and New Jersey.

Based on meristics, Pierce and Howe (1977) stated that estuarine groups of winter flounder do not necessarily constitute separate genetic or biological units. A group may be comprised of an assemblage of adjacent estuarine spawning units, of which some may be more geographically isolated than others. Homing patterns have been documented in some estuarine systems (NUSCO 1986; Black et al. 1988; Scarlett 1988; Phelan 1992; Powell, unpublished data), and several tagging studies (Lobell 1939; Perlmutter 1947; Saila 1961; Howe and Coates 1975) have provided evidence of fidelity to specific embayments for spawning following offshore migrations. At the same time, some winter flounder disperse to distant locations (Saila 1961; McCracken 1963; Howe and Coates 1975; Phelan 1992). There may be a random search for natal spawning grounds (Saila 1961) or random food searches (McCracken 1963). Phelan (1992) speculated that populations may be discrete only during spawning, and random temperature-related seasonal movements could result in intermixing at other times of the year. If the search for natal spawning grounds was also random, winter flounder might be found in non-natal locations during the spawning period. From mark-recapture work in the Inner New York Bight, Phelan (1992) concluded that winter flounder there formed a dynamic assemblage, consisting of three reproductively discrete spawning populations, one that "homes" to natal spawning grounds in the Navesink and Shrewsbury Rivers, (2) an aggregation found in Sandy Hook and Raritan Bays, and (3) a group found offshore, with all three capable of intermixing.

In Massachusetts waters, Lux et al. (1970), Howe and Coates (1975), and Pierce and Howe (1977) concluded from meristic and tagging work that, for management purposes, winter flounder consist of three stocks - one north of Cape Cod, another south and east of Cape Cod, and the third on Georges Bank. Extensive tagging of winter flounder (more than 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. Flounder dispersal was more extensive south of Cape Cod, where many areas are shoal (<18.3 m), and waters warm considerably during summer. Overall, returns from release sites north of Cape Cod showed more limited movement, with many marked fish recovered in respective subarea release sites, even years later.

Winter flounder spawning apparently occurs at night and when water temperatures are at or near the nadir for the year, occurring during late winter and early spring. Most spawning occurs below 6°C. Spawning and nursery areas are found in estuaries (bays, rivers, harbors), over shoals outside estuaries, and on offshore banks. The eggs are demersal and adhesive, while the pelagic larvae are relatively nonbuoyant and can move vertically in the water column, thus somewhat offsetting the effects of a diffusive pelagic environment. Age-0 fish (juveniles) are demersal and remain in nursery areas (Buckley 1982).

The PKDB estuary, not far from Pilgrim Station, is considered a primary local spawning ground for winter flounder, although spawning also occurs outside this estuary (Figure 1). The local population is exploited by a regulated otter trawl fishery that is open from 1 November to 31 January, with a minimum legal size of 305 mm TL. In past years, the fishery was open into the spring, but declining flounder abundance prompted a mandated reduction in effort.

Spawning success, recruitment, and population coherence is maintained where physiography and oceanographic circulation enhance larval retention in specific geographic areas. Size of spawning grounds and larval retention areas is a limiting factor to absolute abundance. Winter flounder population size is a function of the size of the physical system underlying larval retention. Large populations are often 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 (power plant related or otherwise) 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 typically subject to anthropogenic alterations and environmental degradation. The different flounder life stages can be greatly affected by the dredging and filling of wetlands, toxicants, disease infestation, and power plant-induced mortality. Direct mortality or the loss of reproductive and growth potential can result. Impingement and entrainment of winter flounder can substantially add to total mortality. Impingement losses may be especially problematic when power plant intakes are located in or near nursery grounds (Normandeau 1979), such as at Pilgrim Station. All life stages of winter flounder at least seasonally inhabit this artificial embayment, which simulates a cove.

Eggs and Larvae

The pelagic 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 to 22.5 million annually over the last 10 years (1987 to 1996); the 1996 estimate was the highest recorded during this period.

Larval mortality due to entrainment at Pilgrim Station in 1996, assuming no survival and using the Adult Equivalent Analysis, which assumes population equilibrium and no density-dependent compensation, equates to the highest loss (15,727 age-3 winter flounder) in the last 10 years. Gibson (1994) examined data for several 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.

Delimiting the geographic extent of the local population is important to establish the source of flounder larvae entrained at Pilgrim Station. Pilgrim Station entrains larval winter flounder produced in PKDB, but also from sites outside the estuary (Marine Research, Inc. 1988). Evidence of winter flounder spawning outside the estuary complicates our estimating adult stock size and assessing power plant impact.

Juveniles

In 1996, an estimated 866 winter flounder were impinged at Pilgrim Station. The majority were juveniles (age-0 and 1). Winter flounder generally are impinged throughout the year.

No further studies of age-1 winter flounder were conducted by the MDMF in 1996.

Adults

Direct mortality of winter flounder has been rare in the thermal plume off Pilgrim Station. 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 (McCracken 1963); Olla et al. 1969). Occasionally 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 less than 4,047 m^2.

No winter flounder were reported caught by anglers at Pilgrim Shorefront in 1996. In the 1970's and early '80's, this species ranked among the top five sportfish angled in the recreational fishery off the power plant.

As in 1995, we contracted the F/V *Frances Elizabeth*, to catch winter flounder, both for tagging and to estimate absolute abundance via density extrapolation. From 108 tows in the study area in 1996, we caught a total of 6,708 winter flounder, of which 4,997 (≥250 mm TL) were tagged. Overall, winter flounder length measurements from these catches ranged from 75 to 522 mm TL.

From 1994 to 1996, we tagged 7,289 winter flounder during the spring spawning period in Areas 1 and

2 of western Cape Cod Bay (Figure 15). The number of fish tagged by year is: 1994 - 226 fish (≥ 20 cm TL); 1995 - 2,066 fish (≥ 20 cm TL); 1996 - 4,997 fish (≥ 25 cm TL). All fish were released in the general vicinity of capture. Tag returns were obtained from commercial and recreational fishermen, and through our research efforts.

Through December 1996, 218 tagged winter flounder had been recaptured for an overall return rate of 3%. A similar recapture rate (2.8%) was reported by Phelan (1992) from 7,346 winter flounder (≥ 18 cm) tagged in the Inner New York Bight in the late 1980's. In many fish mark and recapture programs, the percentage of returns ranges from 3 to 10% (Matthews and Reavis 1990). By way of contrast, Howe and Coates (1975), working in Boston Harbor and Plymouth Outer Harbor, reported overall flounder tag return rates of 58% and 35.8%, respectively. It should be noted, however, that these return rates were compiled for longer periods of time after the flounder were tagged. Poor reporting of recaptures and spatio-temporal bans on commercial fishing in inshore waters likely contributed to our and Phelan's (1992) low return rates. The matter of poor reporting has been exacerbated by the small amount (MDMF) or absence (Phelan 1992) of a monetary reward for tag returns. In 1997, MDMF will offer a one-time prize of $500.00 for tag return information. The winner will be chosen by lottery from a pool of all returns.

Of the 218 tag returns (commercial, recreational, and research catches) from 1994 to 1996, we have recapture locations for 172 (79%). Of the later, the returns by recapture area (Figure 15) are found in Table 3. Highest returns (50%) came in the fall, especially in November. Spatially, 49% (107 fish) of the total recaptures came from Area 2, where they were tagged during spring spawning. Thirty of these flounder were tagged in 1995, while five were recaptured after two years at large (1994). Despite the overall low tag-return rate, there is evidence of "homing", or at least, partial fidelity to the local spawning area. Nonetheless, geographical isolation is not complete, as some fish were retaken during the spawning period in other zones.

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),

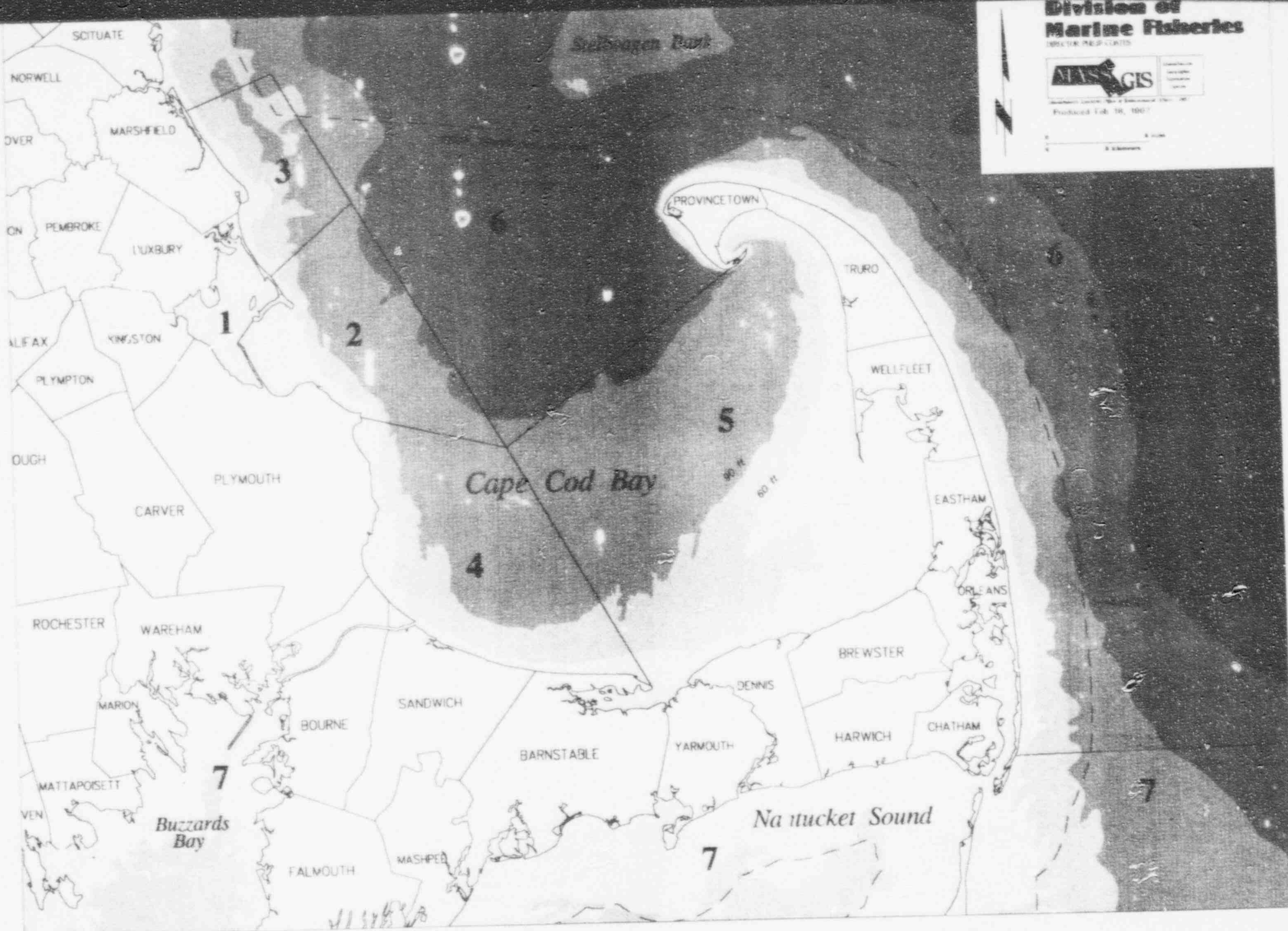

Figure 15. Recapture zones of winter flounder (Pleuronectes americanus) tagged in areas 1 – 3 by the MA Division of Marine Fisheries in the decade of the 1990's.

the other for winter flounder of all sizes (Table 4). The areal measurement was estimated for MLW.

Table 3. Tag returns by area from 7,289 winter flounder marked during the spawning season in Areas 1 and 2 from 1994-1996 off Cape Cod.

Area	Number of Recaptures	Percent of Total Recaptures
1	3	1.7
2	107	62.2
3	1	0.6
4	29	16.9
5	9	5.2
6	16	9.3
7	7	4.1
Total	172	

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, 12 April to 3 May 1996.

	Area (square meters)	Number of flounder	Upper 95% CI	Lower 95% CI
Flounder ≥ 280 mm T.L.	155,460,127	92,147	182,947	1,346
All Flounder	155,460,127	148,345	268,920	27,769

Our estimate of winter flounder numbers for the area sampled (see Methods section, this report) using this approach was 92,147 age-3+ (≥ 280 mm TL) fish and 148,345 total winter 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 184,294 adults and 296,690 total flounder. As might be expected, precision varied widely (Table 4), so that comparison with 1995 estimates has limited value. Some 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 also be noted that the adult estimate for the study area does not necessarily equal the total number of adults in the local population. Spatial variation of this species can be great, as demonstrated by Lawton et al. (1995). As we have primarily been seeking flounder for tagging purposes, we have not always evenly distributed sampling effort. Based on modeling predictions of the origins of eggs and larvae, we plan to expand the study area in 1997, and, after tagging, will allocate several days of trawling to a comprehensive sweep of the sampling area. During this time, we will attempt to ensure complete coverage of the area.

To calculate a percent loss of adult winter flounder, we used the estimate of equivalent adults (15,727) obtained from entrainment monitoring and our estimated number of adults (184,294) residing in the study area, as defined for 1996. The estimated adult loss because of entrainment corresponds to approximately 8.5% of the adults we projected to be found in the Pilgrim Station study area during the 1996 winter flounder spawning season. However, it must be remembered that it would have taken approximately three years for most of those entrained larvae to reach maturity. During that time, natural mortality rates could vary widely, greatly affecting survival. 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 then) were possible. Given that coast-wide winter flounder stocks have been 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 degree of fidelity to the spawning area, or sampled within the entire boundaries of the local population as defined by modeling. Based on the predictions of the output model created by Eric Adams of M.I.T., we now know that winter flounder larvae may be coming from up to 17.7 km away from Pilgrim Station. Accordingly, in 1997 we will expand our study area further to the north, off Humarock (Marshfield, MA), to ensure coverage of this potential source of larvae.

4. Other Species

Data on other species were obtained from a Pilgrim Shorefront creel survey. Additionally, several SCUBA dives were made in the Pilgrim Station discharge area during the summer to observe fish occurrence and for signs of distress or mortality to biota.

The 1996 creel survey of shore-based anglers at the Pilgrim Shorefront Recreational Area was conducted between 13 April and 13 October, with 2,599 anglers interviewed during 130 sampling days over 7 months. The intent was to obtain basic information on sportfishing activity - fishing effort and gamefish catch over time, including catch rates. There were two data collectors, who as seasonal public relations personnel for Boston Edison Company, conducted the survey in addition to other duties. The interviewers focused on surveying fishing activity in the discharge area. Only weekends were inventoried in April and May, while only four days in October were canvassed. The daily coverage from June through September was good for activity in the area of the discharge.

The overall monthly average number of angler trips per day was 20 and ranged from a low of 2 in April to 27 in July and August. The total recorded catch was 3,854 fish, comprising only two species - bluefish and striped bass. The overall mean catch rate (i.e., catch per angler trip) was 1.5, while the monthly average ranged from 0.4 (April) to 1.9 (July).

In 1996, the percent composition of the recreational gamefish catch overall was 52% bluefish and 48% striped bass. The highest monthly catch (pooled species) occurred in July (1,550 fish - 40% of total), followed by August (1,073 fish - 28% of total) and then June (21% of total).

Striped bass dominated monthly catches April through June and were caught all seven months of the creel survey. Of the 1,840 bass reportedly caught, most were sublegal (< 86.4 cm TL); only a dozen bass were legal ≥ 86.4 cm TL, with the largest being 114.3 cm TL and weighing 15.8 kg. The highest monthly catches were recorded in June (38% of total bass catch) and July (36% of total), followed distantly by August (12%) and May (7%). The overall catch rate, as catch per day, averaged 14.2 bass, with monthly rates high in June (24.5), July

(22.2), and May (20.5).

The seasonal catch of striped bass was the highest recorded at Pilgrim Shorefront since its opening to the public in the early 1970's. A much more plentiful supply of striped bass along the Atlantic coast in recent years ostensibly contributed to the elevated catches of this species at the Shorefront. Pilgrim Station's warm water discharge has consistently attracted feeding bass over the years when the plant is operating and with both circulating seawater pumps in use. Pilgrim Station operated at a station high in 1996 - 90.5% of thermal capacity. A few dozen overwintering striped bass were observed in the discharge canal during 1996, which makes them susceptible to mortality if PNPS were to experience an outage in the winter.

Bluefish were first angled in June of 1996 and led monthly catches July through September. A total of 2,000+ bluefish was caught at the Shorefront, with a variety of sizes landed, including 4.5+ kg individuals. Highest monthly totals were garnered in July (44% of seasonal total) and August (42% of catch). Catch rates (catch per day and catch per angler trip) matched up well with the total monthly catches: the former being 29.5 fish per day in July and 27.2 in August, with the latter at 1.1 fish per angler trip (July) and 1.0 (August), respectively.

The 1996 catch of bluefish closely parallels the bluefish catch in 1985 (2,200), which was the highest recorded to date. It is evident that when Pilgrim Station is operating, the warm-water discharge current concentrates bluefish at a point source within casting distance from shore and is advantageous to sportfishermen. Recreational catches at Pilgrim Shorefront have been notable as to the number and size of fish caught over the years when the station is operating. Power outages at the station markedly reduce sportfish catches of bluefish at the Shorefront (Table 5).

Our underwater finfish observations provided limited 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 temperatures), monthly SCUBA-dives were made within the mouth of the discharge canal and adjacent area. Striped bass and tautog were commonly observed, although small aggregations of cunner also were present.

Table 5. Recreational bluefish catches at the Pilgrim Station Shorefront in relation to plant operation and resultant discharge of a thermal plume

Year	Number of Bluefish	Reported Period	Plant Status
1973	500	September-October	On-line
1974	700	September-October	On-line
1975	14	September-October	Off-line
1983	1,200	June-November	On -line
1985	2,200	June-November	On-line
1984 & 1986	less then 100 fish for the two years combined	June-November	Off-line
1996	2,014	June/October	On -line

Striped bass were recorded on all dives. Abundance increased over the summer, peaking in late September/early October when divers commonly observed 75+ 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.

5. Impact Perspective

Cunner, winter flounder, and rainbow smelt were selected for investigative work, that involves assessing impact of Pilgrim Station (Table 6). The response of these species to perturbation may be illustrative of power plant-induced stresses on other marine finfish in the area.

In 1993 and 1994, rainbow smelt annual impingement at PNPS was relatively high - ca 9,500 and 10,600 fish, respectively. Impingements of that magnitude under a condition of low population numbers may have markedly impacted local rainbow smelt. As a remedial measure to offset power station impact, Boston Edison Co. funded our stocking of over 1.8 million smelt eggs into the nearby Jones River in 1994 and 1995. In 1995 and 1996, we also placed egg collecting trays into the stream to enhance spawning habitat for the purpose of

Table 6 A summary of mechanical impacts of Pilgrim Nuclear Power Station on selected finfish species and mitigation undertaken in the offsite 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, an estimated 20,000 smelt were impinged at the plant which could have serious local impact considering population numbers in recent years.**	**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, the prime smelt spawning ground.** **As a form of aquaculture, we have enhanced spawning habitat on the Jones River smelt run by adding artificial plant substrate for egg deposition to improve instream egg survival in 1995 and 1996. This helps compensate for the 1993 and 1994 impingement losses, and this effort is recommended to be continued until smelt spawning-run numbers substantially increase from the present level of abundance.**
Winter flounder	**In 1996, an estimated high of 22.6 million winter flounder larvae were entrained, which equates to the loss of 15,727 age-3 flounder from the local population.** **Entrainment losses, as related to adults, equaled 8.5% of the possible existing adults in the study area.** **An estimated 866 flounder were impinged in 1996; the majority were juveniles.** **Additional years of data would be desirable of population estimates for winter flounder to adequately assess impact.**	**Absolute abundance of adult winter flounder in the study area during the spring spawning period of 1996 was estimated to be 184,294 fish.** **In April and May 1995, there was a scheduled plant outage (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. Plant outages scheduled at this time of year are desirable and recommended to minimize impact on this species, as well as other springtime spawners.**
Cunner	**In 1996, an estimated 3,176.42 x 10^6 cunner eggs and 17,160 x 10^6 larvae were entrained, which equates to the loss of 588,997 adults from the local population.** **An estimated 211 cunner were impinged in 1996.** **Because of the diffuse nature of cunner on rocky reefs in the PNPS area, it is difficult to assess population levels, and a recruitment approach to impact can be undertaken the next few years.**	**Of the reef areas (natural and artificial) sampled in the study area for cunner mark and recapture, the largest sub-unit of the local population per unit area occurs off the outer intake 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 structurally complex habitat critical to cunner survival. As such, construction of this structure may have allowed local cunner abundance to flourish beyond what could be supported naturally.**
Alewife	**In September 1995, about 13,100 juvenile alewives were impinged and presumed to have died. The potential for this or other species to be impinged in large numbers make future impingement monitoring advisable, so mitigative measures can be undertaken as necessary.**	**Natural reproduction was the exclusive means relied on to replace the lost alewives, and no restocking was recommended. However, we did recommend a measure of habitat rehabilitation. To improve the passage of spawning-run alewives in local streams, we obtained a sum of money from BECo to help fund the repair of a fish ladder in the Pilgrim Station area.**
Atlantic silverside	**An estimated 11,900 Atlantic silversides were impinged in 2 separate incidents at PNPS, occurring in late November and late December 1994. This species is typically dominant and is impinged in high numbers, estimated at several thousand individuals annually during many of the past years at PNPS.**	**No compensatory action was taken at this time because the Atlantic silverside is short-lived, and prolific.**

optimizing egg survival. This latter effort should be considered whenever PNPS impacts large numbers of rainbow smelt and until smelt spawning-run numbers substantially increase.

Entrainment of cunner eggs and larvae in 1996 at PNPS equated by the Equivalent Adult Analysis model to the loss of an estimated 589,000 adults from the local population. Entrainment of this magnitude appears to be substantial, but the importance of this loss to the local cunner population is unknown. We now have geographical bounds on the local population, which include the area of major recruitment sources. We have recent estimates of abundance for local (PNPS near-field) sub-units of this population only, using mark and capture-recapture techniques. Absolute population estimates may be impossible to obtain because of logistics and financial constraints, so recruitment, considering the large number of equivalent adults lost because of entrainment, trended over a number of years can be used to analyze for power plant effects.

The 1995 cunner recruitment study revealed that recruit success that year was regulated primarily at the post-settlement stage by compensatory processes, which implies that the plant's impact via entrainment of cunner larvae was probably inconsequential. The 1996 recruitment study was inconclusive as to plant impact. Storm events prematurely terminated the study and were the cause for altering the patterns of recruitment at the termination of sampling.

Larval winter flounder entrainment in 1996 would have resulted in about 15,927 equivalent adults (age-3) lost to the population. We estimated population size in 1995 (184,294 adults) by an area swept approach (density extrapolation) using a bottom trawl. We now know we probably did not sample the entire spatial range of the local population and, thus, likely underestimated total abundance. Consequently, the impact of the power plant would be overestimated. Again in 1996, we calculated population abundance by expanding the average fish density obtained by trawl over the sampled area. This equated to an entrainment loss of 8.5% of the possible existing adults in this area. Mark-recapture data of several years are necessary to address the question of population discreteness and to generate an independent estimate of population size, because of the low number of winter flounder tag returns obtained through the present.

In 1994, there were two incidents of high impingement of Atlantic silversides (*Menidia menidia*) at Pilgrim Station: 28-29 November - 5,800 fish and 26-28 December - 6,100 fish. In 1996, it was the dominant species impinged and typically has led all other species, with an estimated several thousand impinged each year. No renumeration action was taken because the silverside is a prolific annual species and has no commercial and only limited recreational value. However, the silverside is an important forage species and should be monitored for impingement.

A relatively high impingement of alewives (*Alosa pseudoharengus*) occurred at Pilgrim Station 8-9 September 1995, when an estimated 13,100 individuals died. The alewife is important as bait for the lobster and recreational fisheries, 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 this fish kill to be about $5,000.00. The Division of Marine Fisheries negotiated with Boston Edison Co. for this sum of money, which was granted to the Division to be used for habitat rehabilitation (i.e., the money will go toward rebuilding or repairing a river herring fish ladder in the local area). Large impingements of alewives have been uncommon in recent years at PNPS. Nevertheless, impingement monitoring should be continued for species susceptible to high impingements on intake screens, so appropriate mitigation measures can be undertaken when warranted.

V. CONCLUSIONS

Cunner

1. Impingement of cunner at PNPS is not normally a major problem. Annual impingement has been relatively low since 1980, when an estimated 1,683 cunner were affected. Impingement in 1996 totaled only about 211 fish.

2. Large numbers of cunner eggs and larvae are entrained routinely at Pilgrim Station each year. In 1996 alone, the number entrained equated to the loss of ~589,000 adult fish from the local population.

3. The settlement phase of cunner recruitment in 1996 differed from that in 1995, as overall recruit densities were lower from the start, and the White Horse site experienced a substantial delay in onset of recruitment in 1996.

4. The 1996 recruit survey post-settlement data collections were prematurely terminated in 1996 due to adverse weather conditions (storm events), thus complicating data analyses. Recruitment was not as successful as in 1995, with recruit densities at the termination of sampling in 1996 being an order of magnitude lower.

5. Analyses of the 1995 recruit data indicated that density-dependent compensatory processes (differential mortality via predation) in the post-settlement period likely drove recruitment success, with power plant impact (through larval entrainment) probably of minimal consequence.

6. Several more recruitment surveys should be conducted to help us understand recruitment processes near Pilgrim Station and potential power plant impact.

7. Stressful high water temperatures likely cause an avoidance response of cunner to the discharge canal and near-thermal plume during late summer/early fall.

8. 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 seen residing in the path of the discharge current at flood tide.

9. No cunner were reported caught by anglers at the Pilgrim Station Shorefront in 1996; however, this is

likely due in, part, to incomplete surveying and reporting in the informal creel census.

10. The tagging of 385 cunner this year and subsequent recapture information help confirm that this species has limited seasonal movements and shows high reef fidelity.

11. A total of 125 cunner (selected specimens) from the Pilgrim area was aged; fish range up to age-10.

Rainbow Smelt

1. High impingement incidents of rainbow smelt occurred at Pilgrim Station in December of 1978, '93, and '94. For the last four years (1993-1996), smelt impingement at the power plant was estimated to total 24,835 fish, which would appear to be is a substantial loss to the local population.

2. For the past two years, we have enhanced the quality of spawning habitat on the Jones River by placing specially-designed egg collection/incubation trays, filled with sphagnum moss, on the Jones River spawning grounds.

3. The Jones River smelt spawning habitat enhancement project should be considered for continuation for several more years or until spawning-run smelt numbers substantially increase. The run will be monitored visually for adults and for egg densities. Highest quality spawning habitat is limited in this river system. The presence of egg collecting trays resulted in an increased number of their demersal, adhesive eggs being spawned on ideal habitat, thus optimizing 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 geographic bounds of the local population make this species 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 avoidance temperature (24 °C) for winter flounder and exclude them from this relatively small (~ 4,047 m^2) area of stress.

3. In 1996, an estimated 22.5 million winter flounder larvae were entrained at Pilgrim Station, which equates to the equivalent loss of 15,727 winter flounder from the local population. This is the largest entrainment of the last 10 years.

4. In 1996, an estimated 866 winter flounder were impinged at Pilgrim Station; the majority were juveniles (age 0+). Impingement is a source of mortality, but is not as major a factor as entrainment.

5. We tagged 4,997 winter flounder in 1996, bringing the total tagged to 7,289 fish.. By the end of 1996, 218 tags have been recovered from commercial and recreational fishermen, and our research catches. Our recovery rate (3%) is low, being hampered by the relative number of tagged fish for the size of the area, the sporadic reporting of tagged fish, and the seasonal closure of the area to commercial fishing. In 1997, we will expand the study area (based on modeling) and the active time of tagging and field sampling, again contracting a fishing vessel to tag, as well as recapture tagged winter flounder.

6. We estimated by density extrapolation that in the Pilgrim study area (Figure 1) in spring 1996, winter flounder numbered 184,294 adults (≥ 280 mm TL). It is noted, however, that precision of the estimate is not high.

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VII. LITERATURE CITED

American Fisheries Society. 1992. Investigation and Valuation of Fish Kills. Special Publication 24: 96 pp.

Anderson, R.D. 1990. Impingement of organisms at Pilgrim Nuclear Power Station. *In*: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 35. Boston Edison Company, Braintree, MA.

Anderson, R.D. 1993. Impingement of organisms at Pilgrim Nuclear Power Station. *In*: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 41. Boston Edison Company, Braintree, MA.

Auster, P.J. 1987. The effects of current speed on the small scale spatial distribution of fishes. NOAA Symp. Ser. for Undersea Res. 2(2):7-16.

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U.S. Fish and Wildlife Service Fishery Bulletin. 53:577 pp.

Black, D.E., D.K. Phelps, and R.L. Lapan. 1988. The effect of inherited contamination on egg and larval winter flounder, *Pseudopleuronectes americanus*. Marine Environmental Research 25:45-62.

Bridges, W.L., and R.D. Anderson. 1984. A brief survey of Pilgrim Nuclear Power Plant effects upon the marine aquatic environment, pp. 263-271. *In*: J.D. Davis and D. Merriman (editors), Observations on the Ecology and Biology of Western Cape Cod Bay, Massachusetts. Springer-Verlag, Berlin, F.R.G. 289 pp.

Buckley, L.J. 1982. Effects of temperature on growth and biochemical composition of larval winter flounder, *Pseudopleuronectes americanus*. Mar. Ecol. Prog. Ser. 8:181-186.

Dew, C.B. 1976. A contribution to the life history of the cunner, *Tautogolabrus adspersus*, in Fishers Island Sound, Connecticut. Chesapeake Science 17:101-113.

Edwards, D.C., D.O. Conover, and F. Sutter III. 1982. Mobile predators and the structure of marine intertidal communities. Ecology 63 (4): 1175-1180.

Gibson, M.R. 1994. Population dynamics of winter flounder in Mount Hope Bay in relation to operations at the Brayton Point Electric Plant. R.I. Division of Fisheries and Wildlife. Kingston, R.I.

Green, J.M., and M. Farwell. 1971. Winter habits of the cunner, *Tautogolabrus adspersus* (Walbaum 1792), in Newfoundland. Can. J. Zool. 49:1497-1499.

Green, J.M. 1975. Restricted movements and homing of the cunner *Tautogolabrus adspersus*. Can. J. Zool. 53:1427-1431.

Howe, A., and P. Coates. 1975. Winter flounder movements, growth, and mortality off Massachusetts. Trans. Amer. Fish. Soc. 104:13-29.

Howell, P., A. Howe, M. Gibson, and S. Ayvazian. 1992. Fishery Management Plan for Inshore Stocks of Winter Flounder (*Pleuronectes americanus*). Fisheries Management Report No. 21 of the Atlantic States Marine Fisheries Commission. 138 pp.

Iwanowicz, H.R., R.D. Anderson, and B.A. Ketschke. 1974. A study of the marine resources of Plymouth, Kingston, and Duxbury Bay. Monograph Series No. 17. Mass. Div. Mar. Fish. 37 pp.

Jones, G.P. 1990. The importance of recruitment to the dynamics of a coral reef fish population. Ecology 71(5):1691-1698.

Kinne, O., (Ed.) 1969. Marine Ecology, "A Comprehensive Integrated Treatise on Life in Oceans and Coastal Waters". Wily-Interscience, London. 681 pp.

Lawton, R.P., R.D. Anderson, P. Brady, C. Sheehan, W. Sides, E. Kouloheras, M. Borgatti, and V. Malkoski. 1984. Fishes of western inshore Cape Cod Bay: studies in the vicinity of the Rocky Point shoreline, p. 191-230. *In*: J. D. Davis and D. Merriman (editors), Observations on the Ecology and Biology of Western Cape Cod Bay, Massachusetts. Springer-Verlag, Berlin, F.R.G.. 289 pp.

Lawton, R.P., P. Brady, C. Sheehan, S. Correia, and M. Borgatti. 1990. Final Report on Spawning Sea-Run Rainbow Smelt (*Osmerus Mordax*) in the Jones River and Impact Assessment of Pilgrim Station on the Population, 1979-1981. Pilgrim Nuclear Power Station Marine Environmental Monitoring Program Series - Number 4: 33-43.

Lawton, R.P., B.C. Kelly, V.J. Malkoski, J. Chisholm, and P.Nitschke. 1993. Annual Report on Environmental Impact Monitoring of Pilgrim Nuclear Power Station (Vol 2). Project Report No. 54 (Jan.-Dec. 1991). *In*: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 41. Boston Edison Company, Braintree, MA.

Lawton, R.P., B.C. Kelly, V.J. Malkoski, and J. Chisholm. 1995. Final Report on Bottom Trawl Survey (1970-1982) and Impact Assessment of the Thermal Discharge from Pilgrim Station on Groundfish. Pilgrim Nuclear Power Station Marine Environmental Monitoring Program Report Series - Number 7. 56 pp.

Levin, P.S. 1991. Effects of microhabitat on recruitment variation in a Gulf of Maine reef fish. Marine Ecology Progress Series 75:183-189.

Levin, P.S. 1993. Habitat structure, conspecific presence, and spatial variation in the recruitment of a temperate reef fish. Oecologia 94:176-185.

Levin, P.S. 1996. Recruitment in a temperate demersal fish: Does larval supply matter. Limnology and Oceanography. 41:672-679.

Lobell, M.J. 1939. A biological survey of the salt waters of Long Island, 1938. Report on certain fishes. Winter flounder, *Pseudopleuronectes americanus*, New York Conservation Department, Albany, 28th Annual Report, Part 1, Supplement 14:63-96.

Lux, F., A. Peterson, Jr., and R. Hutton. 1970. Geographic variation in fin ray number in winter flounder, *Pseudopleuronectes americanus* (Walbaum), off Massachusetts. Trans. Amer. Fish. Soc. 99:483-512.

Marine Research, Inc. 1986. Winter flounder early life history studies related to operation of Pilgrim Station - A review 1975-1984. Pilgrim Nuclear Power Station Marine Environmental Monitoring Program Report Series No. 2. Boston Edison Company, Braintree, MA.

Marine Research, Inc. 1988. Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station, Jan.-Dec. 1988 (Vol 2). *In*: Marine Ecology Studies Related to Operation of Pilgrim Station. Final Report. Boston Edison Company.

Matthews, K.R., and R.H. Reavis. 1990. Underwater tagging and visual recaptures as a technique for studying movement patterns of rockfish. American Fisheries Society Symposium 7:168-172.

McCracken, F.D. 1963. Seasonal movements of the winter flounder, *Pseudopleuronectes americanus* (Walbaum) on the Atlantic coast. J. Fish. Res. Bd. Can. 20:551-586.

Meldrim, J.W. and J.J. Gift. 1971. Temperature preference, avoidance, and shock experiments with estuarine fishes. Ichthyological Associates, Inc. Bulletin 7. 75 pp.

Normandeau Associates, Inc. 1979. New Haven Harbor Ecological Studies, Summary Report 1970-77 (prepared for United Illuminating Co.), New Haven, CT. 720 pp.

NUSCo (Northeast Utilities Service Company). 1986. Winter flounder population studies, Section 7. *In*: Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station, Waterford, Connecticut. NUSCo, Annual Report, 1985, Waterford, Connecticut.

Olla, B.L., R. Wicklund, and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Trans. Amer. Fish. Soc. 4:719-720.

Olla, B.L., A.J. Bejda, and A.D. Martin. 1975. Activity, movements, and feeding behavior of the cunner, *Tautogolabrus adspersus*, and comparison of food habits with young tautog, *Tautoga onitis*, off Long Island, New York. Fish. Bull. 73(4):895-900.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder. Bull. Bingham. Oceanogr. Collect., Yale Univ. 18(1):78 pp.

Perlmutter, A. 1947. The blackback flounder and its fishery in New England and New York. Bulletin of the Bingham Oceanographic Collection, Yale Univ. 18(1):1-78.

Phelan, B.A. 1992. Winter flounder movements in the Inner New York Bight. Trans. Amer. Fish Soc. 121:777-784.

Pierce, D., and A. Howe. 1977. A further study on winter flounder group identification off Massachusetts. Trans. Amer. Fish. Soc. 106(2):131-139.

Richards, W.J., and K.C. Lindeman. 1987. Recruitment dynamics of reef fishes: planktonic processes, settlement, and fishery analysis. Bull. of Marine Sci. 41(2):392-410.

Saila, S.B. 1961. A study of winter flounder movements. Limnol. Oceanogr. 6:292-298.

Saunders, W.P. 1981. Final report: sensitivity analysis of a rainbow smelt population dynamics model. *In*: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report No. 17. Boston Edison Company, Boston, MA. 19 pp.

Scarlett, P.G. 1988. Life history investigations of marine fish: occurrence, movements, food habits and age structure of winter flounder from selected New Jersey estuaries. New Jersey Department of Environmental Protection, Technical Series 88-20, Trenton, N.J.

Serchuk, F.M. and C.F. Cole. 1974. Age and growth of the cunner, *Tautogolabrus adspersus* (Walbaum) in the Weweantic River estuary, Massachusetts. Chesapeake Science 15:205-213.

Sinclair, M.S. 1988. *Marine Populations: An Essay on Population Regulation and Speciation*. Washington Press, Seattle, 252 pp.

Stone and Webster Engineering Corporation. 1977. Supplemental Assessment in Support of the 316 Demonstration, Pilgrim Nuclear Power Station, Units 1 and 2. Boston, MA.

Sutter, F.C. 1980. Reproductive biology of anadromous rainbow smelt, *Osmerus mordax*, in the Ipswich Bay area, Massachusetts. M.S. Thesis, Univ. Mass., Amherst. 49 pp.

Wilk, S.J., W.W. Morse, D.E. Ralph, and T.R. Azarovitz. 1977. Fishes and associated environmental data collected in New York Bight, June 1974-June 1975. NOAA (National Oceanic and Atmospheric Administration) Technical Report NMFS (National Marine Fisheries Service) SSRF (Special Scientific Report Fisheries) 716.

FINAL
SEMI-ANNUAL REPORT
Number 49

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

January-December 1996

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 1997

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EXECUTIVE SUMMARY

This report presents results of qualitative surveys of benthic algae performed in 1996 in the area affected by thermal effluent from the Pilgrim Nuclear Power Station (PNPS). The report summarizes the impact of the PNPS on algal distributions near the discharge canal. Field studies for 1996 were conducted in April, June, September, and December 1996 and included transect surveys designed to map algal cover in the area of water outflow. 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 were identical to those used in prior years. Starting in 1996, data from each quarterly survey were compared to the historical baseline (maximum measurements recorded prior to the 1996 survey year) for that season. Measurements greater than 15% above the historical baseline triggers a report to the (PATC) Benthic Subcommittee for review.

The qualitative transect studies performed to evaluate the *Chondrus crispus* (Irish moss) community indicate that from October 1995 through September 1996 the sizes of the denuded and totally affected areas in the thermal plume were consistently larger for each season surveyed than had been measured in earlier surveys when the power plant was in full or nearly full operation (1983, 1985, 1989-1995). For all four 1996 surveys, at least two parameters exceeded the 15% trigger level. *Chondrus* denuded areas were larger than historical maxima in April, June, and September; in December, although the denuded zone was smaller than the historical baseline it was still the second largest ever measured for a winter survey. Totally affected *Chondrus* zones were larger than historical maxima in all four 1996 surveys. In June, the sparse *Chondrus* zone extended laterally farther than 30 m from the central transect line (CTL) for the first time; the divers failed to extend their survey line to the normal *Chondrus* zone, so that the size recorded for the total affected area is conservative. This was rectified in September when it was necessary to extend the survey line 42 m north of the CTL. A dense population of newly settled blue mussels (*Mytilus edulis*), even thicker than seen in previous June surveys, was observed in June 1996. Damage to *Chondrus* plants from extensive mussel settlement appears to be correlated to the increase in area of denuded and total affected *Chondrus* zones between the spring and summer surveys.

For the first time since qualitative transect surveys began in 1980 the plant operated at over 92% (mean = 97%) capacity for nine months in a row (July 1995 through March 1996); plant capacity for seven of the remaining nine months of 1996 stayed above 92% (mean = 95%). The large *Chondrus* denuded and totally affected zones seen in each survey since October 1995 may be due to a combination of high plant capacity in effect since July 1995 (mean = 92.5%), high summer water temperatures, and extremely dense settlement by mussel larvae in late spring that totally covered and damaged the algal plants.

1.0 INTRODUCTION

The presence of hundreds of square meters of seafloor where the regionally abundant red alga species *Chondrus crispus* (Irish Moss) is unnaturally absent, even in the presence of suitable substrata, provides evidence that the nearfield discharge area is intensely affected by bottom scouring produced by the PNPS 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 (23 yr) benthic studies at Pilgrim Nuclear Power Station (PNPS) designed to monitor the effects of the thermal effluent. The 1996 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 made. Starting in 1996, quarterly reports were prepared that compared data collected during each survey with an historical baseline that tabulated, for each parameter, the maximal sizes measured prior to the 1996 survey season (1983 through February 1996). This Semi-Annual Report includes qualitative observations recorded in April, June, September, and December 1996, comparison of these data with the historical baseline, and a summary of the potential impact on algal distributions caused by PNPS. Work was performed under Boston Edison Co. (BECo) Purchase Order LSP005525 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 ($\Delta T = 32°$ F), 2) through chemical discharge (mainly Cl_2), and, 3) by scouring of the seabed by the rapid (~ 7 fps at low tide) 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 inhibiting settlement and recolonization; where there is intense bottom scouring, rock surfaces may support fewer and smaller macroscopic organisms than would be normally present.

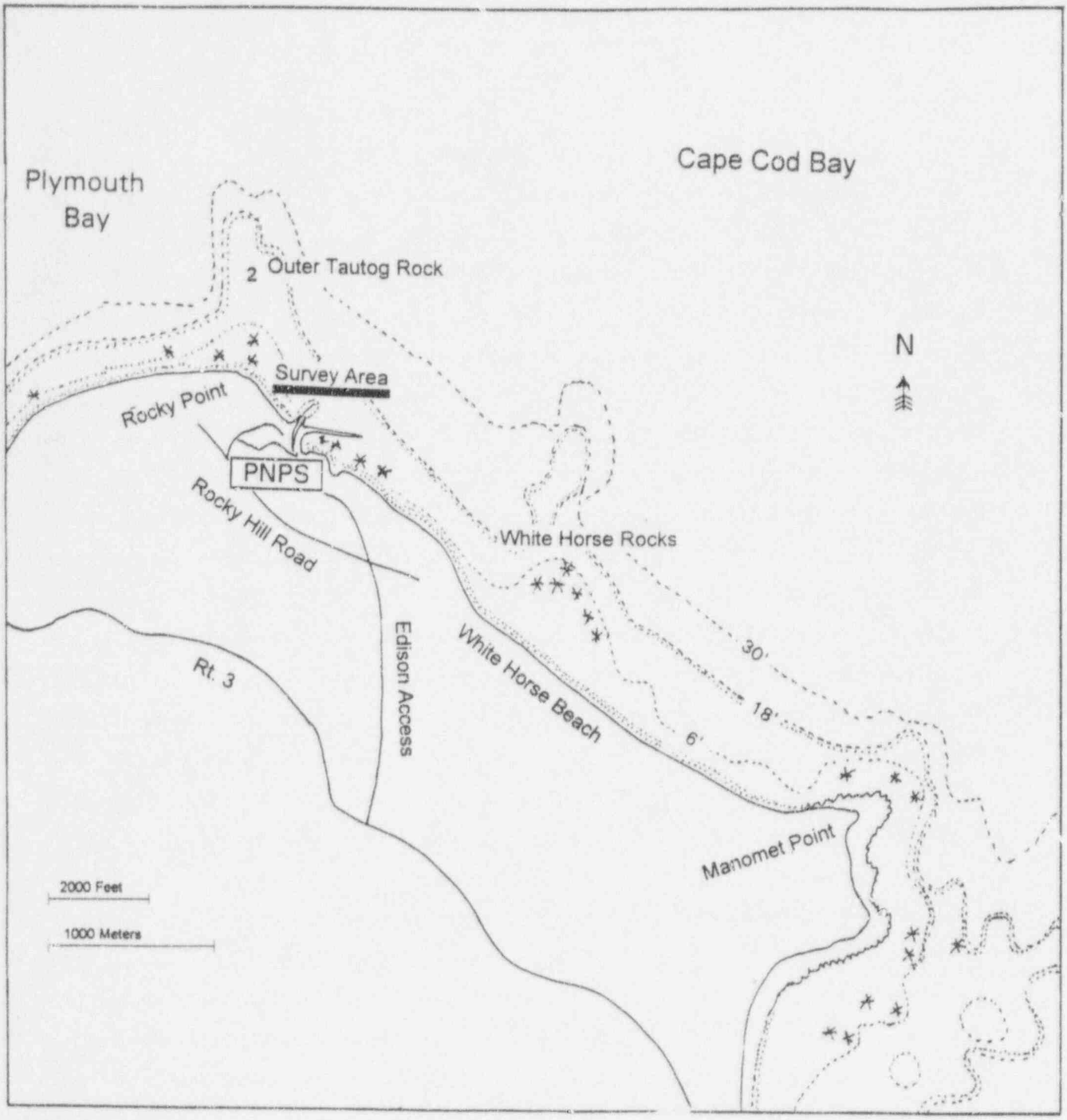

Figure 1. Location of Pilgrim Nuclear Power Station Qualitative Algal Survey Area.

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 15 years ago. The effluent area is surveyed by two or three SCUBA-equipped biologists operating from a small boat. For all 1996 surveys the divers were able to launch their boat from the regular fishermen's launching site within the PNPS facility, although in December this was only possible because fishermen had cleared a path through a field of large exposed boulders left from scouring by winter storms. 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. Starting in September 1996, a second 30-m measuring line was included in the dive gear to ensure that the perpendicular transect would extend beyond the affected *Chondrus* zone. 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 line 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

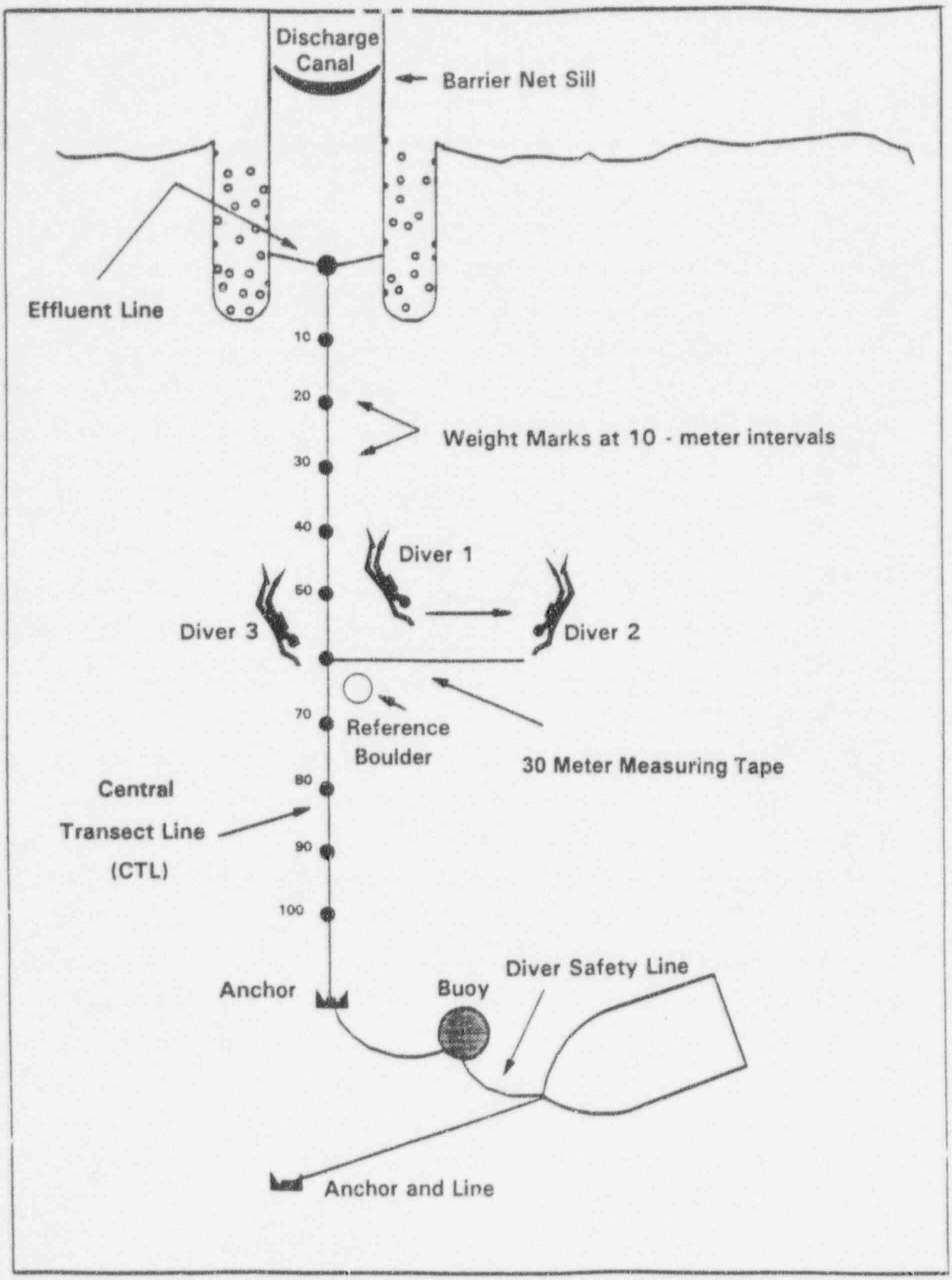

Figure 2. Design of the Qualitative Transect Survey.

discharge canal hamper normal *Chondrus* growth. In addition to evaluating extent and condition of algal cover, the divers record any unusual events in the area, such as the occurrence of unusually strong storms, and note the location of any distinctive algal or faunal associations.

Beginning in 1996, Quarterly Progress reports were submitted to Boston Edison Company. These reports tabulate areal results of each SCUBA survey and compare them to previously measured maximal sizes of *Chondrus* denuded and totally affected zones, as well as other parameters, for that season. Particular attention is paid to changes in the sizes of impacted regions that exceed earlier results (prior to 1996) by more than 15%, which requires reports to be submitted to the PATC Benthic Subcommittee. Table 1 summarizes these comparisons for 1996. The quality control (QC) protocol for the benthic algal monitoring program is attached as Appendix A.

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 (April 29, June 27, September 26, and December 24, 1996) during the current reporting period, bringing the total number of surveys conducted since 1980 to 64. 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 1995, including a review of the four performed in 1995, was presented in Semi-Annual Report No. 47 (BECo, 1996). The present report summarizes the April and June 1996 surveys, presents detailed results of the September and December 1996 surveys, and discusses long-term trends.

Figures 3 to 7 show the results of the 1996 transect surveys performed by SCUBA divers. The denuded zone is essentially devoid of *Chondrus crispus;* sparse zones are those in which normal looking *Chondrus* is sparsely distributed; stunted zones contain smaller than normal *Chondrus* plants. In April 1996, the divers delineated one region that contained plants that were both thinly distributed and stunted in growth. In September, the dense mussel area within the denuded zone was mapped. Dislodged jetty boulders encountered by the divers along their transects are indicated. The landmark boulder (at 65-m) is plotted in all figures as are positions of the most common algal and faunal species observed by the divers.

2.2.1 APRIL 1996 TRANSECT SURVEY

The denuded and sparse *Chondrus crispus* areas mapped on April 29, 1996, immediately offshore of the PNPS, are shown in Figure 3. In April 1996, the denuded and totally affected zones were much larger than during prior spring surveys. The *Chondrus* denuded area (1859 m²) in April was 55% larger

Table 1. Qualitative Algal Survey Data for 1996 Compared to Historical Baseline Data.

	Spring			Summer			Fall			Winter		
Measurement	April 1996	Historical Baseline (Date)	Percent Change from Baseline	June 1996	Historical Baseline (Date)	Percent Change from Baseline	September 1996	Historical Baseline (Date)	Percent Change from Baseline	December 1996	Historical Baseline (Date)	Percent Change from Baseline
Total Denuded Area (m^2)	1859	1321 (3/91)	+41%	2194	1835 (6/90)	+20%	2209	2043 (10/95)	+8%	1671	1961 (2/96)	-15%
Total Affected Area (m^2)	2436	2029 (4/83)	+20%	>3473	2135 (6/90)	>+63%	2845	2348 (10/95)	+21%	3111	2328 (2/96)	+34%
Maximal Distance of Affected Area from Discharge Canal (m)	115	94 (3/91)	+22%	125	105 (6/92)	+19%	101	100 (9/90; 10/95	+1%	100	100 (12/93; 2/96)	+0%
Maximal Width of Affected Area (m)	34	40 (4/83; 3/84)	-18%	>43	39 (6/84)	+10%	60	42 (10/94)	+43%	52	42 (12/83)	+24%

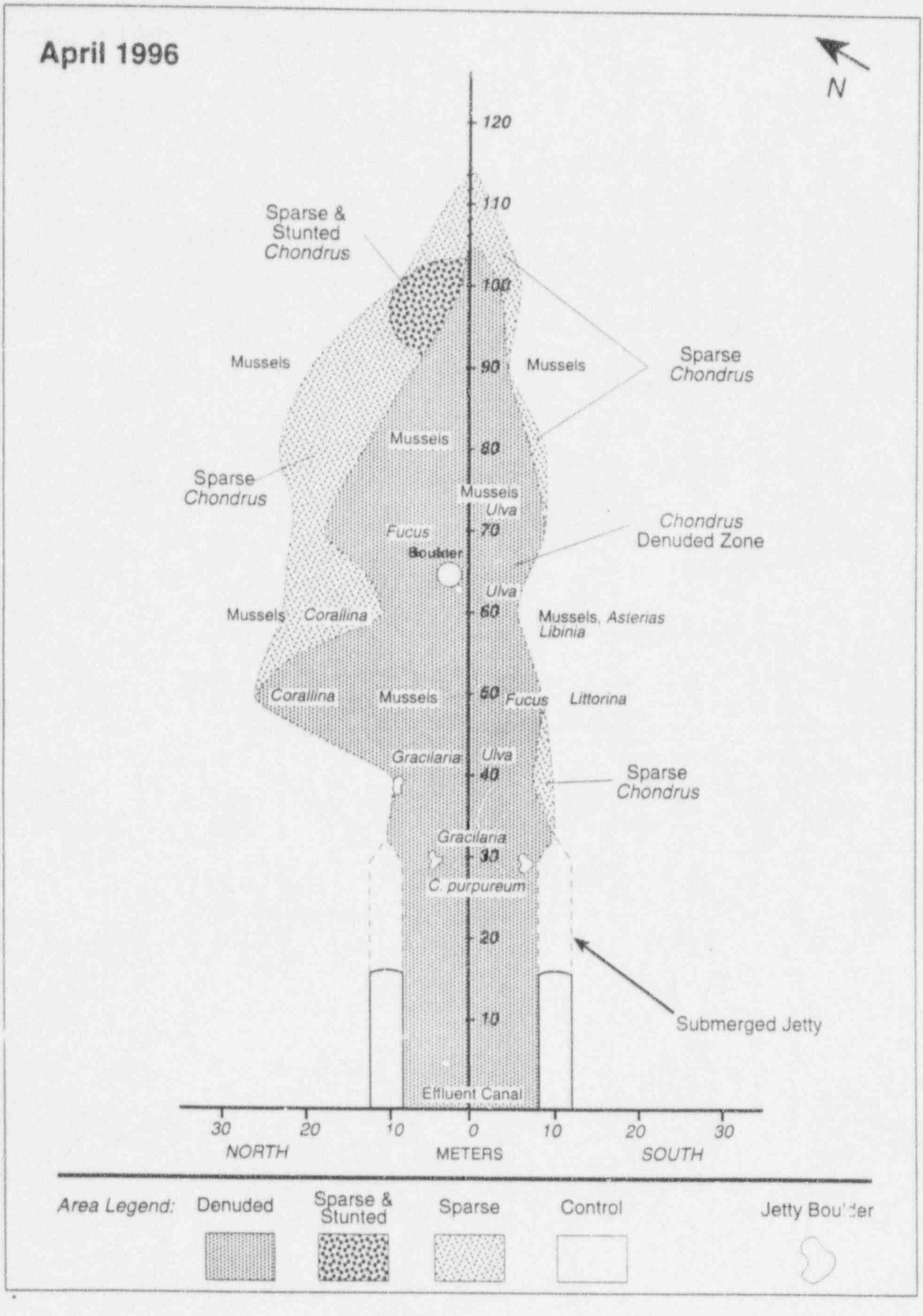

Figure 3. **Denuded, Sparse, and Sparse & Stunted *Chondrus* Zones Observed in April 1996.**

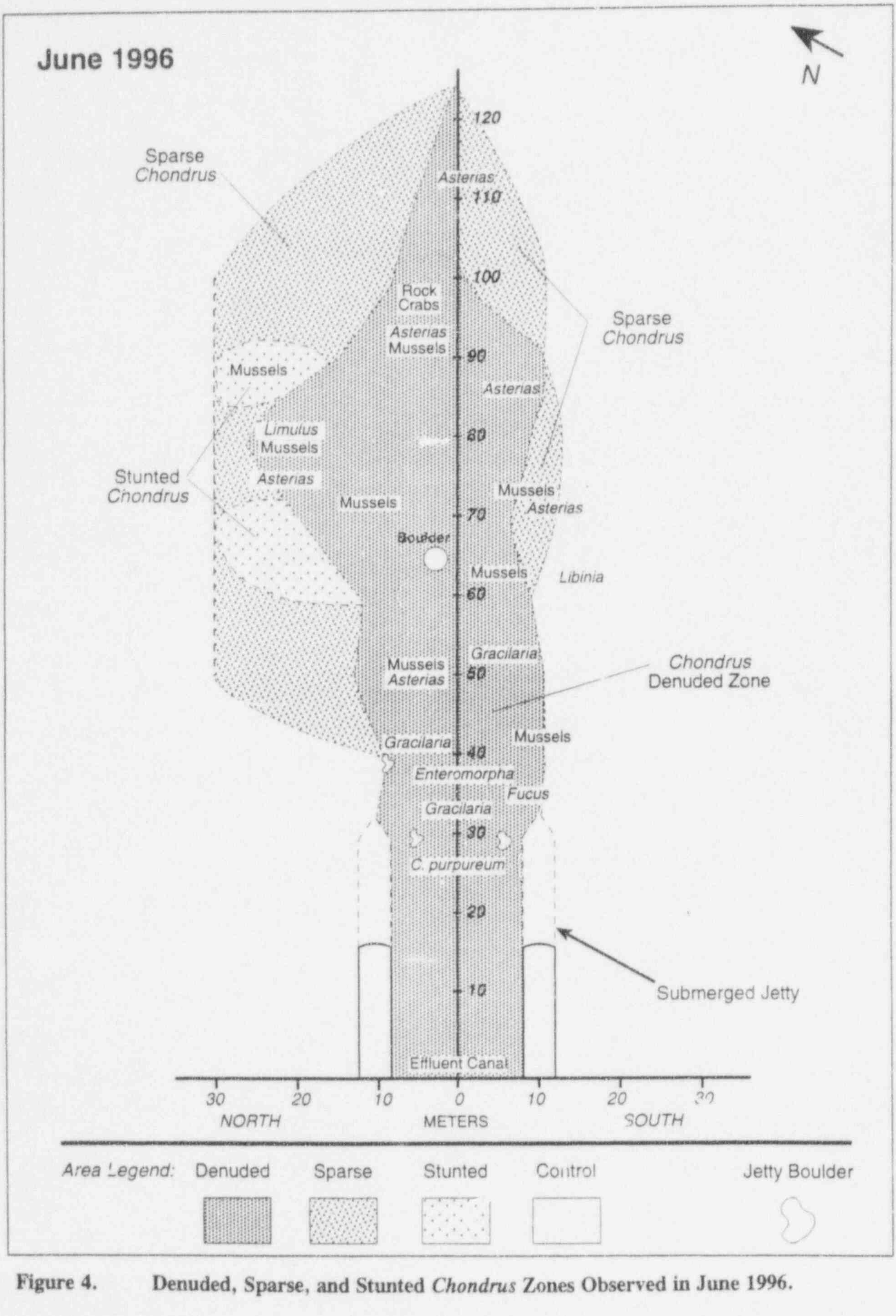

Figure 4. **Denuded, Sparse, and Stunted *Chondrus* Zones Observed in June 1996.**

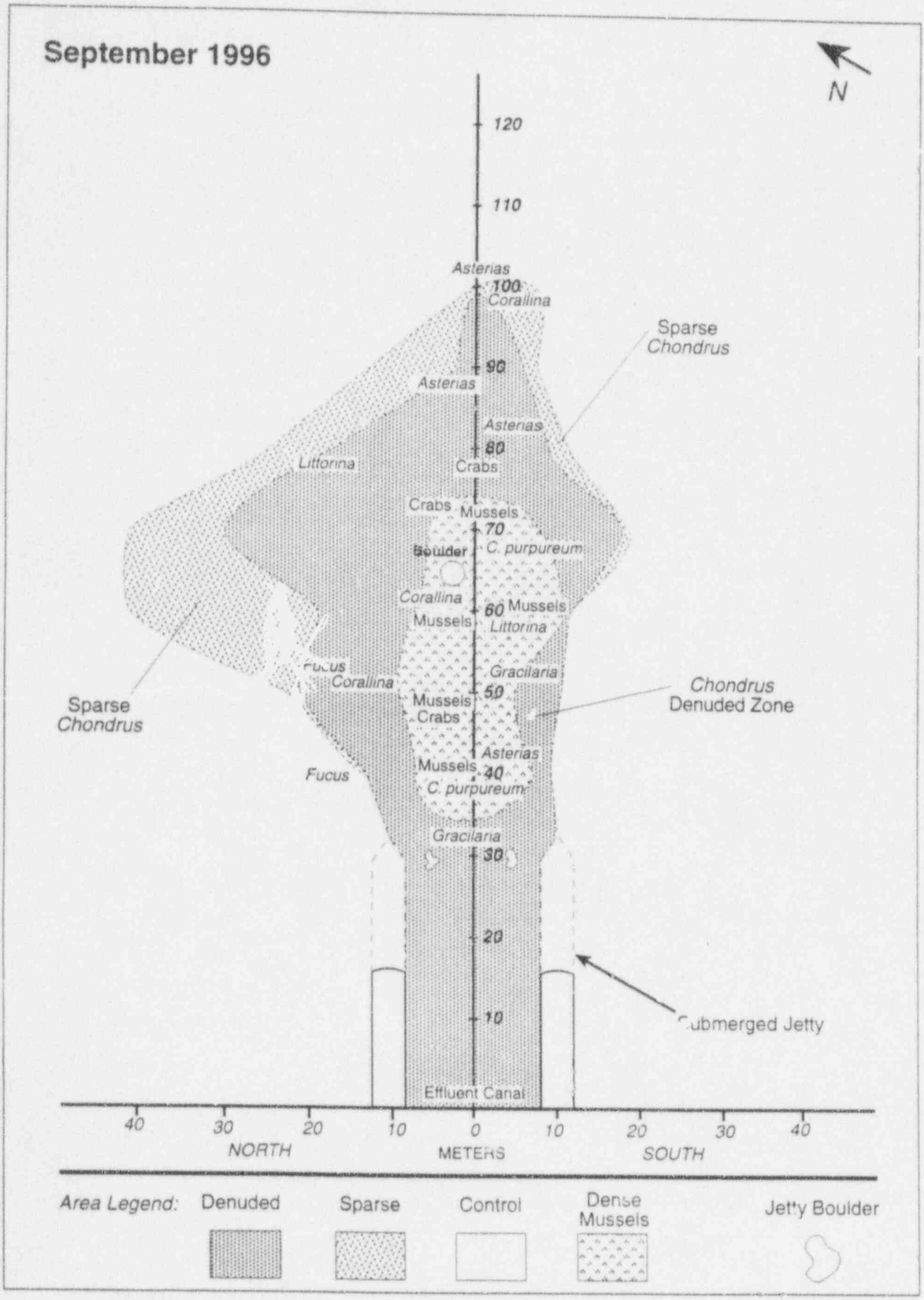

Figure 5. **Denuded and Sparse *Chondrus* Zones, and Dense Mussel Area, Observed in September 1996.**

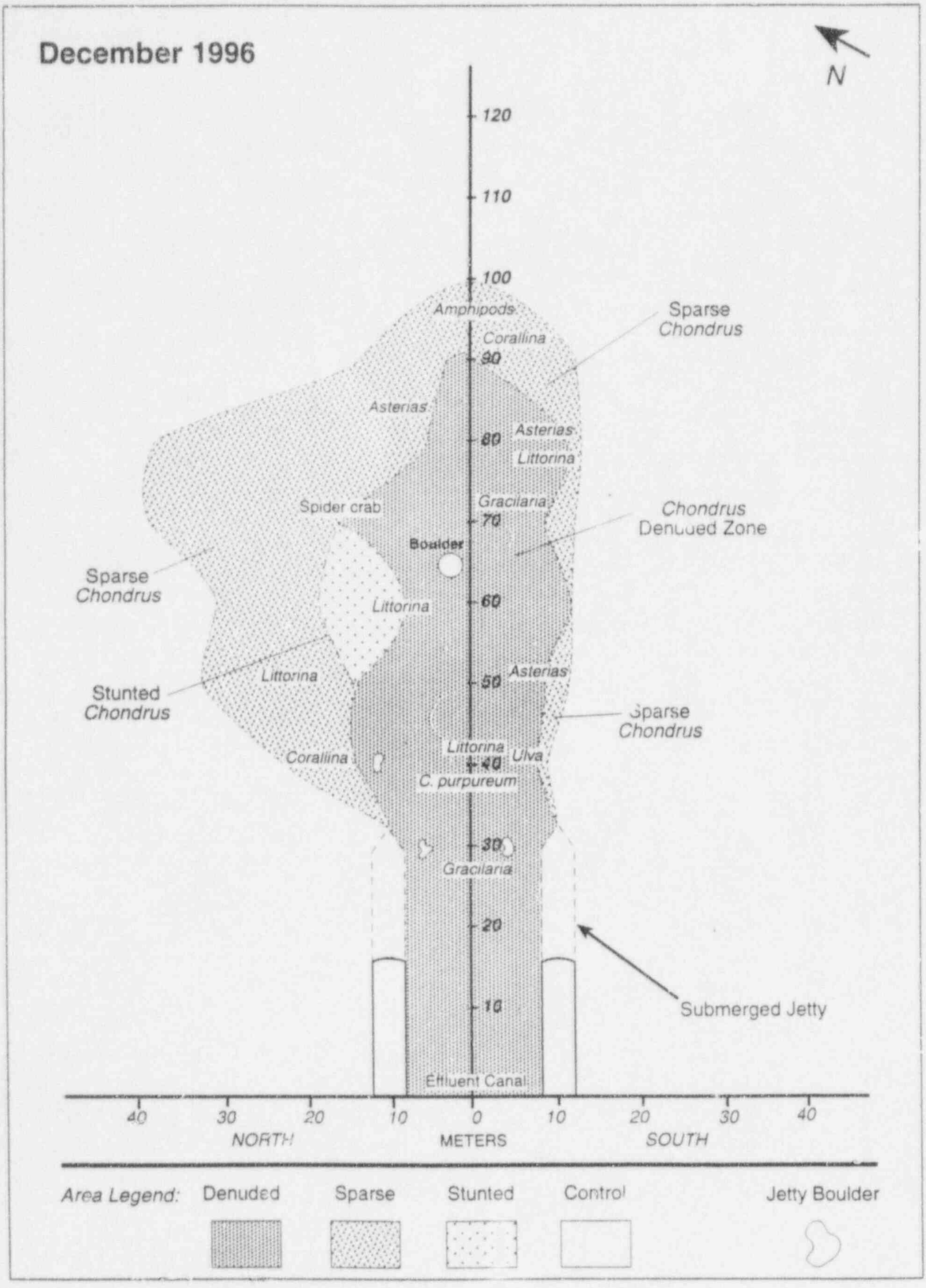

Figure 6. Denuded, Sparse, and Stunted *Chondrus* Zones Observed in December 1996.

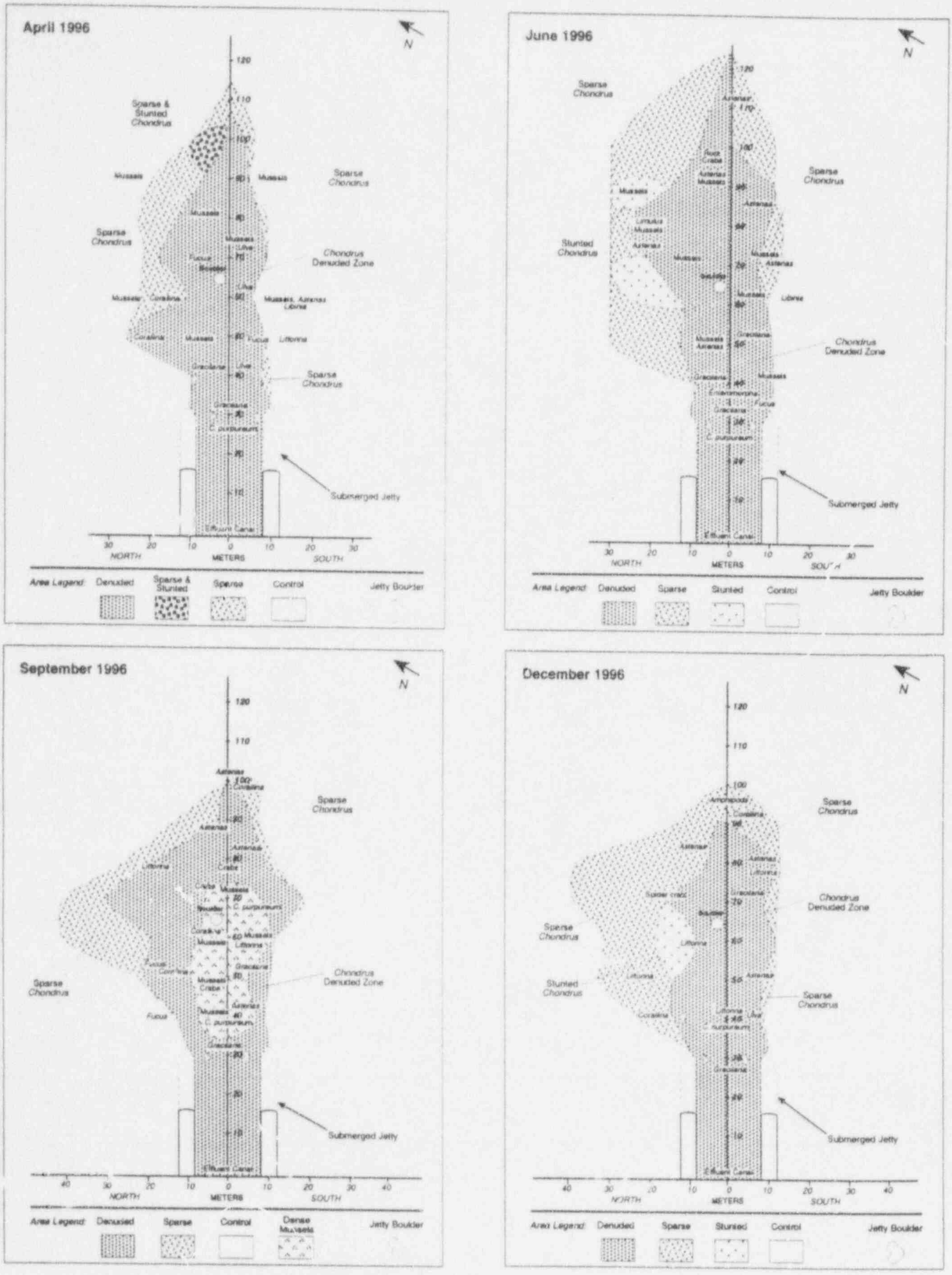

Figure 7. **Results of the 1996 Qualitative Transect Surveys of the PNPS Acute Impact Zone off the Discharge Canal taken in April, June, September, and December 1996.**

than in the spring 1995 survey and 41% larger than the previous spring maximum of 1321 m² seen in March 1991 (Table 1). The total affected area (2436 m²) was only slightly larger (5%) than in the previous survey, February 1996 (2328 m²), but was much larger (48%) than in the 1995 spring survey, and 20% larger than the historical spring baseline measured in April 1983. The denuded region extended approximately 115 m (10 m farther than ever observed before) along the transect line and, as often seen before, was asymmetrically distributed with 66% of the denuded area north of the line. Other algae present included the warm water indicator, *Gracilaria*, near the discharge canal and a cold water indicator, the kelp *Laminaria*, further offshore. *Phyllophora* spp. was not noted by the divers. An extensive set of juvenile blue mussels, *Mytilus edulis*, had already occurred; mussels from 1 - 10 mm in length covered rocks, plants, and other substrata from the 50-m mark to beyond the 100-m mark on the CTL and laterally out to a distance of 25 meters. Other invertebrates included: a few starfish, *Asterias forbesi;* periwinkle snails, *Littorina littoria;* and three species of crab, rock crab, *Cancer irroratus,* green crab, *Carcinus maenas,* and a spider crab, *Libinia* sp. No fish or lobsters were seen.

2.2.2 JUNE 1996 TRANSECT SURVEY

Results of the divers' survey for June 27, 1996 are mapped in Figure 4. The *Chondrus* denuded and totally affected areas were much larger than observed in prior summer surveys. The *Chondrus* denuded zone (2194 m²) extended 125 m (10 m farther than in April) along the central transect line, was 18% larger than two months earlier, in April 1996, 56% larger than in June 1995, and 20% larger than the June 1990 summer historical baseline of 1835 m² (Table 1). The sparse *Chondrus* area extended laterally beyond the 30-m distance normally surveyed by the divers; consequently, the sizes of the sparse *Chondrus* (>1279 m²) and the totally affected zones (>3473 m²) were larger than reported. The sparse *Chondrus* zone (>1279 m²) was more than twice as large as in April 1996 and had more than tripled in area since June 1995. The total affected area (>3473 m²) was at least 43% larger than in April 1996 and more than 63% larger than the June 1990 historical summer baseline (2135 m²). Both the denuded and sparse *Chondrus* zones contributed to the asymmetrical distribution of the affected area. *Gracilaria*, *Enteromorpha*, and *Chaetomorpha purpureum* dominated the flora at the head of the effluent canal. Rockweed, *Fucus* sp., was seen; neither kelp, *Laminaria,* nor *Phyllophora* spp. were noted. A dense array (thickest seen in 25 years of monitoring) of juvenile blue mussels (*Mytilus edulis*), now 5-20 mm in length, similar to that seen in prior June surveys, was present from the 50-m mark seaward. Dense aggregations of the starfish, *Asterias forbesi*, a mussel predator, were seen. Tautog (*Tautoga onitis*), striped bass (*Morone saxatilis)*, cunner (*Tautogolabrus adspersus*), bluefish (*Pomatomus saltatrix*), and small winter flounder (*Pleuronectes americanus*) were seen.

2.2.3 SEPTEMBER 1996 TRANSECT SURVEY

Figure 5 shows the results of the transect survey conducted on September 26, 1996. The area (2209 m^2) of the denuded zone was slightly larger than in June 1996, a not unusual event, and 8% larger than the historical baseline (2043 m^2) measured in October 1995 (Table 1). The denuded zone extended just beyond the 100-m mark on the transect line. The greatest lateral extent of the denuded zone was 30 m to the north of the transect line at the 70-m mark. As has been seen often in the past, the denuded zone was asymmetrical around the transect line, with more of the area north (65%) of the line than south (35%) of the line.

The area of the sparse *Chondrus* zone was 636 m^2 in September, more than double that seen in the previous fall survey (305 m^2). The sparse *Chondrus* area extended 42 m north of the CTL both at the 60-m and 70-m marks on the CTL, a distance farther away from the CTL than had ever been mapped previously. The total affected area in September was 2843 m^2 which was smaller than measured in the June 1996 survey but 21% larger than the historical baseline (2348 m^2) established in the previous fall survey.

Most of the algal plants that had been covered with mussels in June were beginning to recover, but *Chondrus* appeared colorful and healthy only beyond the impact zone. As usual, the algal species seen within the discharge canal were *Gracilaria* spp., and *C. purpureum*. The warm water alga, *Gracilaria* spp., was the dominant macroalga species occurring close to the CTL out to the 50-m mark. Rockweed (*Fucus* sp.)and the encrusting red alga, *Corallina*, were seen occasionally between the 40 m and 60-m marks, 10 to 20 m north of the transect. *Phyllophora* spp. again was not noted.

Mussels, averaging 1.5 cm in length, did not occur over as large an area as they had in June but were still abundant within the denuded zone within 10 m of the CTL between the 35-m mark to about the 75-m mark along the CTL. A few starfish (*Asterias forbesi*) were seen, as were snails (*Littorina littorea*), rock crabs (*Cancer irroratus*), and green crabs (*Carcinus maenus*). Only one demersal fish, a winter flounder (*Pleuronectes americanus*), was observed during the survey.

2.2.4 DECEMBER 1996 TRANSECT SURVEY

The results of the 1996 winter dive, performed on December 24, 1996, are mapped in Figure 6. The area (1671 m^2) of the denuded zone was 24% smaller than it had been in September and was well under (-15%) the historical baseline established during the previous winter survey (Table 1) but was still the second largest denuded zone measured in winter while the power plant was in full operation. The denuded zone extended seaward just beyond the 90-m mark on the transect line. The shape of the denuded zone was highly asymmetrical around the transect line with 67% of the area north of the line and 33% south of the line. The greatest lateral extent of the denuded zone observed by the divers was at the 70-m mark where it projected 15 m north of the transect line.

The area inhabited by sparse and stunted *Chondrus* (1440 m^2) was more than double that measured in September 1996 (636 m^2) and like the denuded zone was arranged asymmetrically around the central transect line with most (84%) of the area north of the line, especially in a northward bulge from the 70-m to 80-m marks on the CTL. The total affected area (3111 m^2) in December 1996 was 9% larger than measured in September 1996 (2845 m^2) and much larger (34%) than the historical baseline measured in February 1996 (Table 1). The maximal extent of the totally affected area out along the CTL was equal to the historical baseline, that is, near the 100-m mark on the CTL. The maximal width of the affected zone (52 m) was greater than seen in earlier winter surveys (24% over the historical baseline of 42 m) but less than in September.

During this survey, *Chondrus* was repopulating the region near the CTL but appeared colorful and healthy only outside the totally affected area. The red alga, *Phyllophora* spp., was not observed by the divers. *Gracilaria* and *C. purpureum* were present at the head of the effluent canal. *Fucus* sp. was seen only occasionally. Snails, *Littorina littorea*, were extremely abundant throughout the entire area surveyed. Very few blue mussels, *Mytilus edulis*, were seen and consequently the starfish, *Asterias forbesi*, that often feed on the mussels were reduced in number from the concentrations seen in June. As for fish, only one winter flounder (*Pleuronectes americanus*) was seen.

2.3 DISCUSSION

The configuration of the *Chondrus crispus* denuded zone that may extend even farther than 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 1996 were delineated with no difficulty. For April, June, and September 1996, the areas of the denuded and total affected zones were much larger than those seen previously (1983, 1985, 1989-1995) when the power plant was in full or nearly full operation. In June 1996, an extremely dense mussel mat, similar to those seen every June since 1990, with the exception of 1991, was present. 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 December 1996, the area of the *Chondrus* denuded zone was exceeded only by that measured during the previous winter survey which at the time was the largest recorded since the quarterly surveys began in 1983. For the first time since qualitative transect surveys began in 1980, the plant operated at over 92% (mean = 97%) capacity for nine months in a row (July 1995 through March 1996). In addition, for seven of the remaining nine months of 1996, plant capacity stayed above 92% (mean = 95%).

The large *Chondrus* denuded and totally affected zones seen in each quarterly survey since October 1995 may be due to a combination of the high plant capacity that has been in effect for the 18 months since July 1995 (mean = 92.6%), high summer water temperatures, and extremely dense settlement by mussel larvae in late spring that totally covered and damaged algal plants.

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 1996, the monitoring program consisted of seasonal qualitative surveys of the discharge area.

PNPS operated at very high capacity in 1996. 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°CΔT). In 1996, the monthly maximum dependable capacity factor was greater than

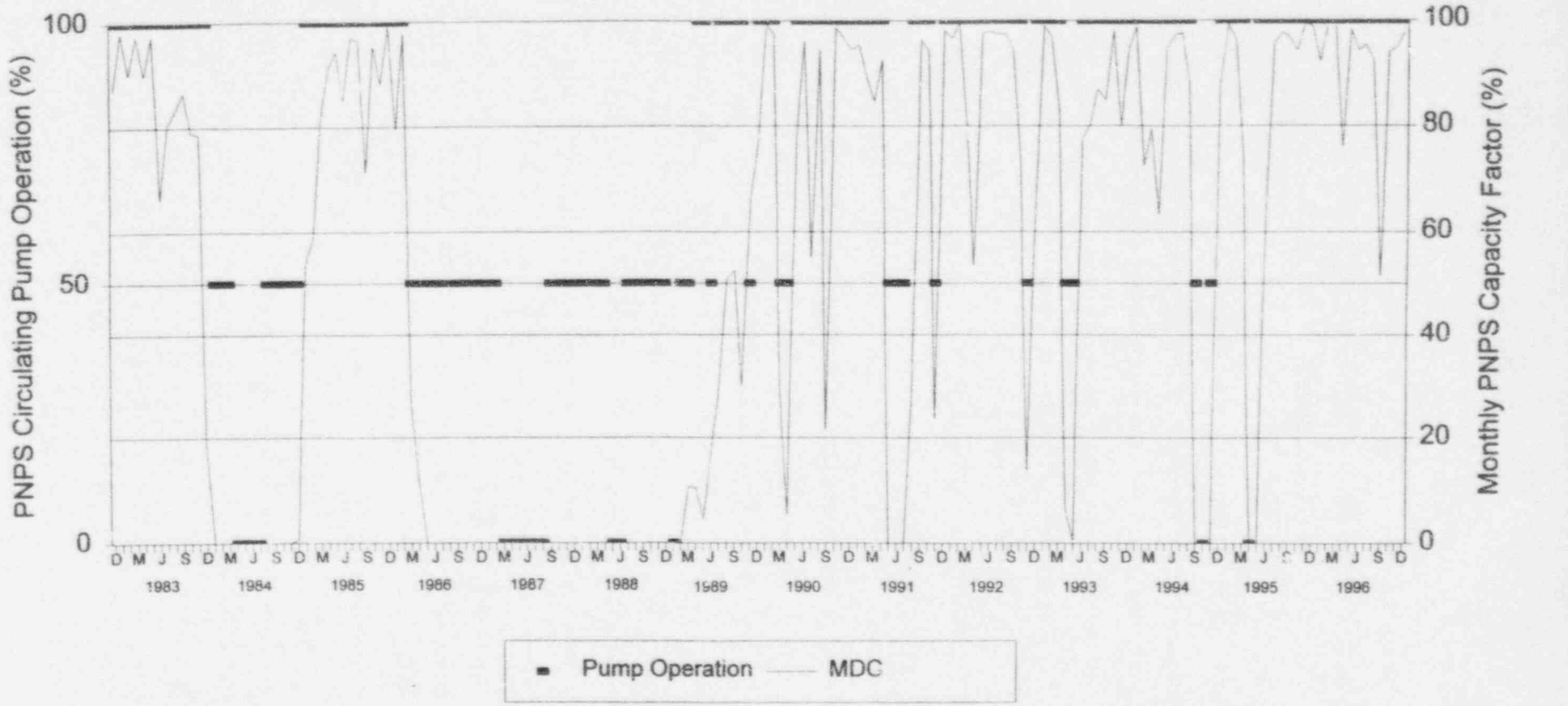

Figure 8. Monthly PNPS Capacity Factor (solid lines) and Circulating Pump Activity (black bars at 100% = 2 pumps; at 50% = 1 pump; at 0% = 0 pumps) Plotted for the Period 1983 Through 1996.

92% for 10 months and between 51% and 76% for 2 months. These monthly capacity factors resulted in an annual capacity factor of 90.5% for 1996, much higher than in any previous year (second highest annual capacity factor was 84.4% in 1985). In addition, both pumps were operating virtually all year.

3.2 QUALITATIVE TRANSECT SURVEYS: 1983-1996

Results of the qualitative transect surveys from 1983 through 1996 are summarized in Figure 9. A detailed enlargement showing the most recent 8 years (1989 - 1996) is presented in Figure 10. The total acute impacted area (denuded, sparse, and stunted), the area of the denuded zone only, and the monthly PNPS capacity factor (MDC) are plotted. The difference between the denuded and total acute impact zones represents the area of the sparse and stunted zones.

A lag in recovery time in the acute impact zone during and 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 1986-1989 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 into the summer (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

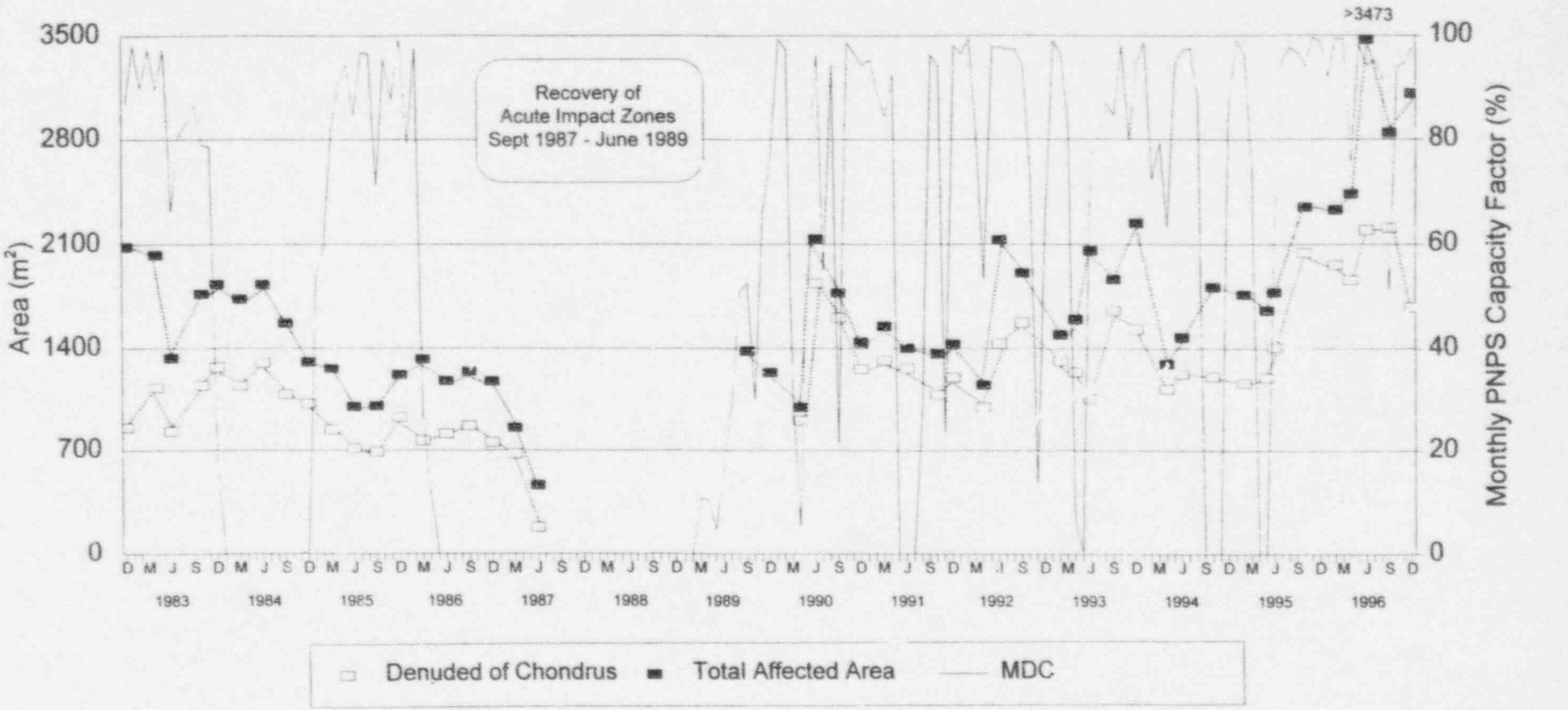

Figure 9. **Area of the Denuded and Totally Affected Zones in the Vicinity of the PNPS Effluent Canal Plotted with the Monthly PNPS Capacity Factor (MDC) for the Period 1983 Through 1996. No area measurements were made from September 1987 through June 1989 because definitive demarcations of denuded and stunted zones were absent.**

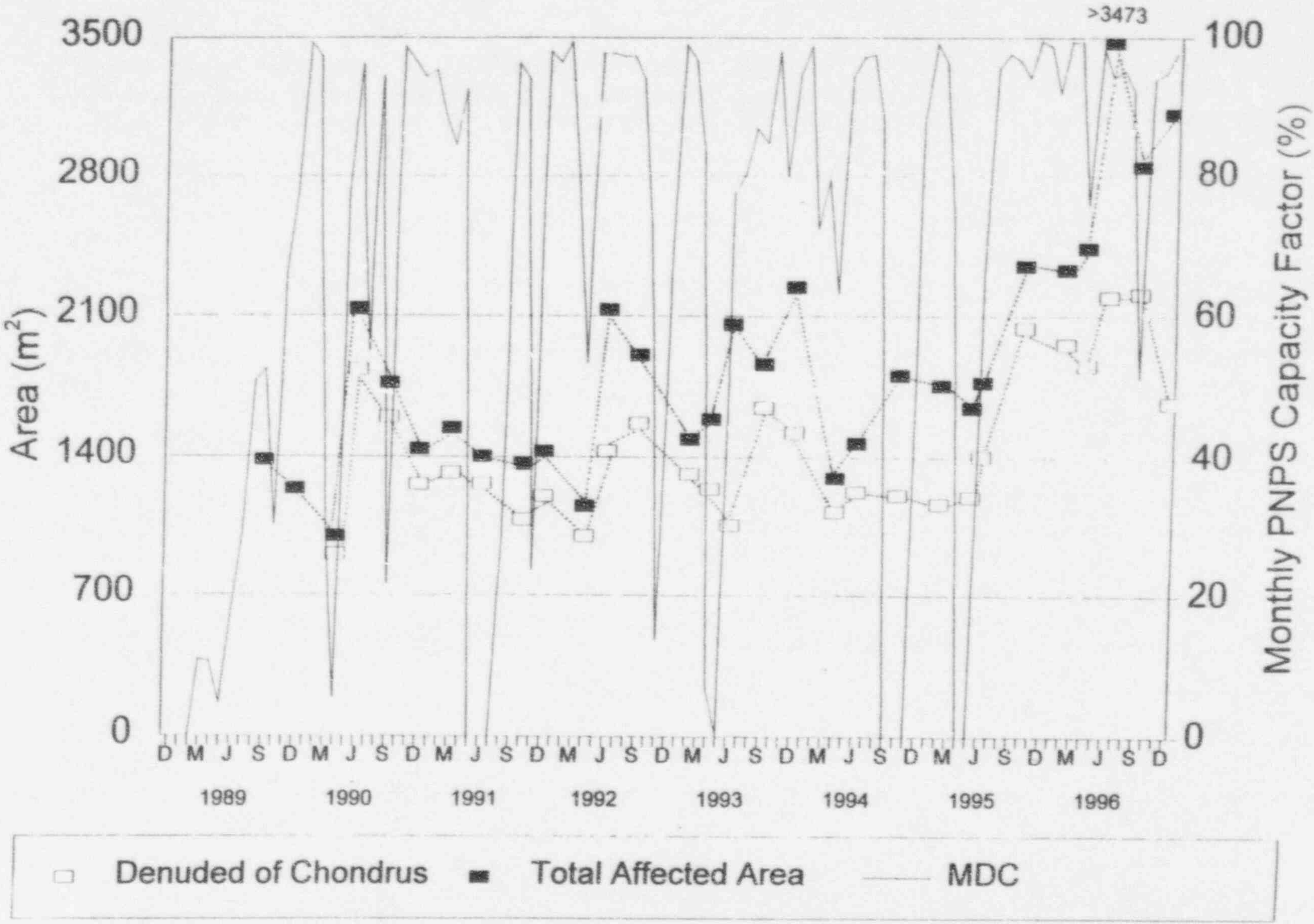

Figure 10. **Area of the Denuded and Totally Affected Zones in the Vicinity of the PNPS Effluent Canal Plotted with the Monthly PNPS Capacity Factor (MDC) for the Period 1989 Through 1996.**

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 power plant outage from May into August. 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 can no longer be considered anomalous but may be related to oceanographic conditions that lead to a large settlement of mussel larvae and consequent damage to *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 (BECo, 1995). 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 surveys. 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* zones.

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 (BECo, 1996). 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.

In 1996, the sizes of the denuded and totally affected *Chondrus* areas continued to increase over the historical baseline measurements (1983 through the 1995 survey season, i.e. February 1996) except that in December 1996 the denuded zone decreased to less than the winter historical baseline measurement although it was still the second largest winter denuded zone observed. The large *Chondrus* denuded and totally affected zones seen in each survey since October 1995 may be due to a combination of the high plant capacity that has been in effect for the 18 months since July 1995 (mean = 92.6%), high summer water temperatures, and extremely dense settlement by mussel larvae in late spring that totally covered and damaged the algal plants.

4.0 CONCLUSIONS

- The sizes of the denuded and totally affected *Chondrus* areas of the acutely impacted region for April, June, and September 1996 were larger than had been observed during prior surveys at times of full power plant operation.

- By December 1996 the area of the *Chondrus* denuded zone had decreased in size to less than that measured in February 1996 (1995 winter survey) but was still the second largest winter denuded zone observed since 1983.

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

- The high power plant capacity in effect from July 1995 through December 1996, in combination with an extremely dense mussel settlement in June, and high summer water temperatures, may have contributed to the generation of the largest denuded and totally affected *Chondrus* zones measured since the present monitoring program began in 1983.

5.0 LITERATURE CITED

Boston Edison Co. 1983. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 22. Boston, MA.

Boston Edison Co. 1986. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 27. Boston, MA.

Boston Edison Co. 1988. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 31. Boston, MA.

Boston Edison Co. 1990. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 35. Boston, MA.

Boston Edison Co. 1991. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 37. Boston, MA.

Boston Edison Co. 1992. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 39. Boston, MA.

Boston Edison Co. 1993. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 41. Boston, MA.

Boston Edison Co. 1994. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 43. Boston, MA.

Boston Edison Co. 1995. Marine ecology studies related to the operation of Pilgrim Station. Semi-Annual Report No. 45. Boston, MA.

Boston Edison Co. 1996. Marine ecology studies related to the operation of Pilgrim station. Semi-Annual Report No. 47. Boston, MA.

Bridges, W.L. and R.D. Anderson. 1984. A brief survey of Pilgrim Nuclear Power Plant effects upon the marine aquatic environment, p. 263-271. *In*: J. D. Davis and D. Merriman (eds.) Observations on the ecology and biology of western Cape Cod Bay, Massachusetts, 289 pp. Springer-Verlag. (Lecture Notes on Coastal and Estuarine Studies, Vol. 11).

Taxon. 1982. Benthic studies in the vicinity of Pilgrim Station. In: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report No. 19.

APPENDIX A

Quality Control (QC) Protocol for Qualitative Transect Surveys at PNPS Outfall Area

1 Field Operation Planning

Field equipment is organized by the scientist in charge of dive operations; for 1997, the chief diver will be Mr. George Hampson, or his designate, of the Woods Hole Oceanographic Institution. Mr. Hampson has been a diver or chief diver on every quarterly survey at the PNPS outfall site since April 1990. The survey equipment includes a boat and associated safety equipment; anchor and line; buoy and diver safety line; SCUBA gear, including a collecting bag; 100-ft kevlar line to be deployed across the mouth of the discharge canal; the weighted 100-m central transect line (CTL), marked at 10-m intervals; two 30-m measuring tapes; compass; clipboard; data sheets on plasticized paper; two #1 pencils.

Every attempt will be made to perform the dives as scheduled for March, June, September, and December. Windows of opportunity, considering times of high tide (less current for the divers to contend with) and other commitments for both boats and personnel, will be blocked out in advance of each scheduled month. Enough leeway will be planned to allow some flexibility for bad weather days. A trainee diver will be included for each field operation to decrease the possibilities for postponements caused by illness or conflicting schedules during the appropriate months.

2 Pre- and Post-dive Briefings

The chief diver and ENSR data manager, Isabelle Williams, will hold pre- and post-dive briefings. The pre-dive briefing (may be made by telephone) will be the opportunity for determining the dive schedule, for reviewing data collection, and for informing the dive team whether or not any additional observations are requested. At this time, emphasis will be placed on the importance of the divers exploring the limits, and defining them, of the entire affected area so that a comprehensive survey map can be produced. The post-dive briefing (in person) will give the chief diver the opportunity to tell the data manager his immediate impressions about the region surveyed and whether any problems were encountered that need to be corrected before the next dive.

3 Data Collection

A diver swimming perpendicularly away from the CTL, along the measuring line, records the distance away from the CTL line that changes in algal cover occur, from denuded to sparse and/or stunted

Chondrus areas, and from sparse and/or stunted *Chondrus* to normal-looking *Chondrus*. Positions of other algal species, especially *Gracilaria*, a warm-water indicator, and kelp (*Laminaria*), a cold water indicator, are noted. Positions of animals, including mussels, starfish, crabs, and fish, and any unusual activities are also indicated.

For 1997 and beyond, detailed observations will be made of *Chondrus*, including notes on robustness, color, occurrence of epiphytes, and qualitative descriptions of density and height. The divers will look for the presence of *Phyllophora*, the second dominant algal species in this community, throughout the survey area; if necessary, they will collect an algal sample from the normal *Chondrus* zone for examination in the laboratory. Particular attention will be paid to the boundaries of the high-density mussel set that appears to often occur in late spring or early summer.

A sample blank data sheet is shown. A separate sheet is used for the north and south sides of the CTL. As the diver swims away from the CTL, distances and notes are recorded on the data sheet from left to right. For ease in working in an underwater environment algal cover is coded as indicated on the data sheet: 1 - denuded; 2 - stunted; 3 - sparse; 4 - normal. Codes for mussel cover are M1 - very dense; M2 - separated clumps; M3 - absent.

4 Data validation

The diver recording data during the field survey is responsible for reviewing his work at the end of the survey to ensure that the data are complete and accurate. The chief diver will submit to the data manager the original field notes and a survey report, previously reviewed for accuracy and completeness by other members of the dive team, that includes the data on the total extent of the denuded and stunted *Chondrus* zones as well as a general description of the area surveyed, including notes on flora and fauna observed. The data manager is responsible for reconciling data in the submitted field report to those recorded on the original data sheets. The data manager will discuss any questions that may arise with the chief diver. The data manager is responsible for constructing maps based on the survey data and for calculating the total areal extent of the denuded and totally affected *Chondrus* regions. All calculations performed by hand are checked for accuracy. The data manager is responsible for proof-reading the final computer-generated maps against the original maps for accuracy. All reports generated by the data manager will be reviewed by the ENSR Project Manager, Dr. James Blake.

5 Observation

The data manager will plan to accompany the divers on several of their field trips in 1997. She will tend the boat and be on hand to accept any samples collected during those dives and to hear immediately the impressions of all divers about the conditions of the outfall area, as well as ensure that the entire affected area has been surveyed.

6 Meetings

The project and/or data manager will attend full Administrative-Technical Committee and Benthic Subcommittee meetings when appropriate. This will help ensure communication between ENSR and the A-T Committee so that the quality of the benthic survey will be maintained as guided by the Committee.

Date:
Wind:
Visibility:

Divers Down @:
Divers Up @:

CTL (m)	NORTH/SOUTH
30	CHONDRUS 1 DENUDED 2 STUNTED
40	3 SPARSE 4 NORMAL
50	MUSSELS M1 V. DENSE M2 CLUMPS
60	M3 ABSENT
70	
80	
90	
100	NORMAL CHONDRUS ROBUSTNESS________ COLOR______________
>100	EPIPHYTES_________ HEIGHT____________ COLOR______________

Qualitative Transect Survey Field Data Sheet.

ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY-DECEMBER 1996

Volume 1 of 2

(Monitoring)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 1, 1997

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*Available upon request.

SECTION I

EXECUTIVE SUMMARY

Sampling of entrained ichthyoplankton at PNPS followed the revised protocol initiated 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.

A total of 41 species were represented in the 1996 collections, three more than the 21-year mean of 38 species. Numerical dominants included American plaice, sand lance, rock gunnel, and sculpin during winter-early spring; cunner, Atlantic mackerel, sand lance, radiated shanny, winter flounder, and rockling during late spring-early summer; and windowpane, cunner, hake, and rockling during late summer-autumn.

Comparisons of densities over the 1975-1996 time series suggested that the decline in cod-witch flounder eggs has ended but densities remain very low. Eggs of fourbeard rockling, hake, and cunner demonstrated long-term declines in abundance which appear to have reversed for cunner over the past two years. Abundance estimates based on entrained densities were relatively high in 1996 for Atlantic mackerel and windowpane eggs, which is consistent with high stock biomass for mackerel. In contrast, windowpane biomass is relatively low. Among larval species Atlantic herring, radiated shanny, sand lance, and Atlantic mackerel densities were relatively high in 1996. In the case of herring high larval densities are consistent with recent increases in stock biomass on Georges Bank and Nantucket Shoals. Larval abundance for winter flounder was relatively high in 1996 in spite of region-wide low stock abundance.

Mesh comparison studies using 0.202 and 0.333-mm mesh nets showed that cunner eggs were retained at significantly higher densities in the finer mesh with a catch ratio of 1.29:1. A significant difference was not detected for stage 1 or 2 cunner larvae where ratios of 1.10:1 and 1.28:1 were noted, respectively.

No lobster larvae were found in 1996 entrainment samples, the total dating back to 1974 remaining at 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 1996. Work was carried out by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. LSP005524 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 continued in 1996 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 collected in 1994 and 1995 (MRI 1996).

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 begun in 1974 was historically completed twice per month during January, February, October-December; weekly during March through September in triplicate at low tide. 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

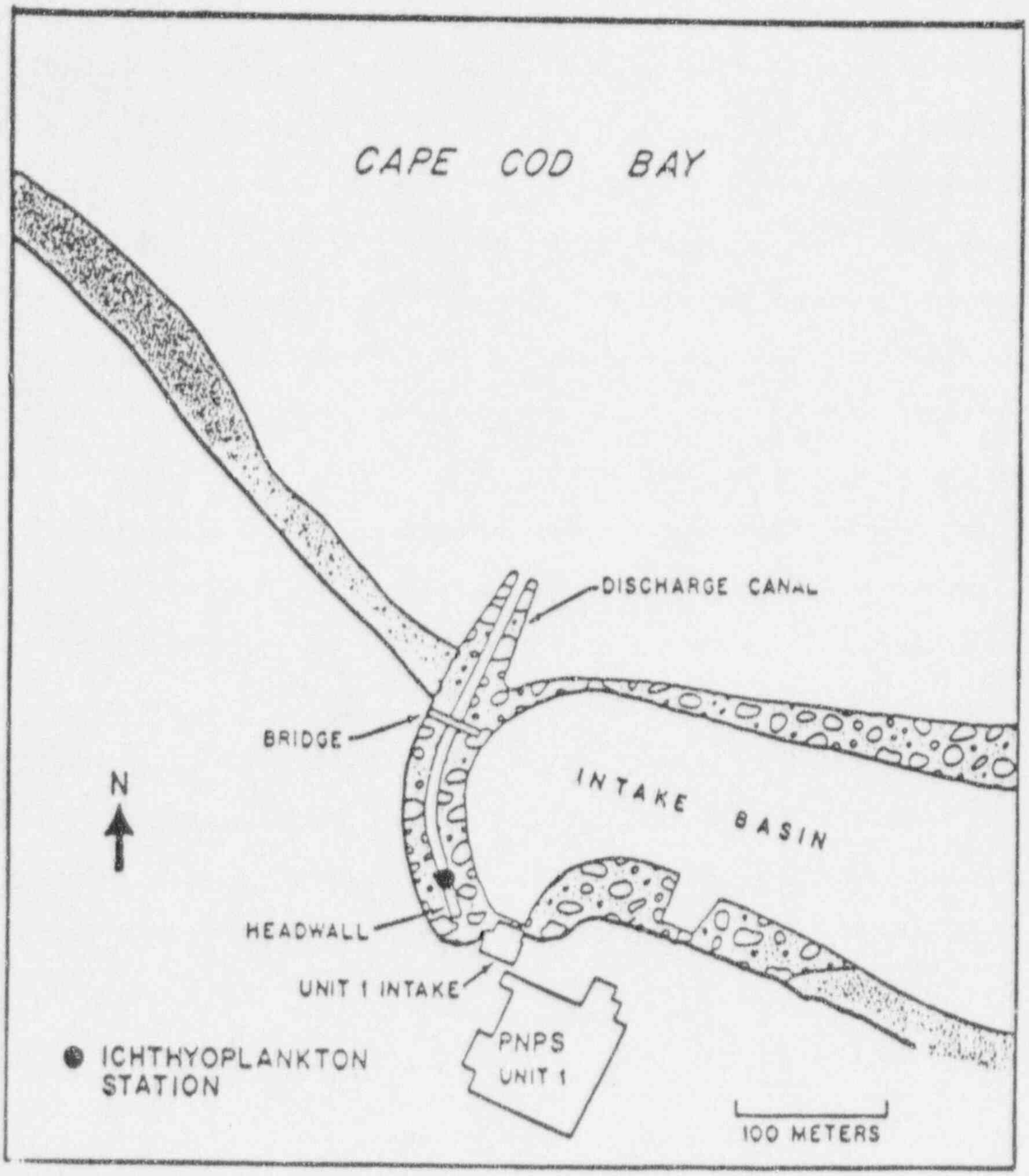

Figure 1. Entrainment sampling station in PNPS discharge canal.

due to lower discharge stream velocities. In most cases, a minimum quantity of 100 m^3 of water was sampled although at astronomical high tides it proved difficult to filter this amount even with long sampling intervals. On rare occasions no sample was obtained because flow velocity was too low to inflate the net. 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.

With the exception of a brief maintenance outage in April, all entrainment sampling was completed with both circulating water pumps in operation. On April 19 and 22 samples were taken with one pump out of service.

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 it has been possible to discern more clearly the temporal extent of any unusual density 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.[1] 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.

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[1]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 below the mean + 2.58s.

The decision to rely on 2 standard deviations or 2.58 standard deviations was based on the relative importance of each species. 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 1996 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 m³, 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 dual-mesh 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 uncommon that year. Additional paired sampling was therefore completed in June 1995 to gat' - more data. Combining information from both seasons pro..ded variable results, suggesting that consistent extrusion may not occur. One source of variability was believed to result from the inability to collect paired 0.333/0.202 samples concurrently. The existing sample rig only permitted samples to be taken alternately. In 1996 the rig was improved to allow two nets to be streamed concurrently Paired samples were taken on four occasions in late June-early July, three or four replicates per occasion, for a total of 14 pairs; 13 were analyzed, excluding one pair with low larval cunner densities. 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. Since flow rates in the canal visibly vary across its width, the position of the nets was reversed between replicates to compensate for sampling position. Methodology followed that described for the routine sampling.

Table 1. PNPS ichthyoplankton entrainment notification levels for 1996 by species category and month. See text for details.

Densities per 100 m^3 of water:	Long-term Mean[1]	Mean + 2 std.dev.	Mean + 2.58 std.dev.
<u>January</u>			
LARVAE			
Atlantic herring[2]	0.2	1	
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]	18	4031	
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[2]	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]	91	155	
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	5	9	
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	6		10
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
Hake	1		2
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

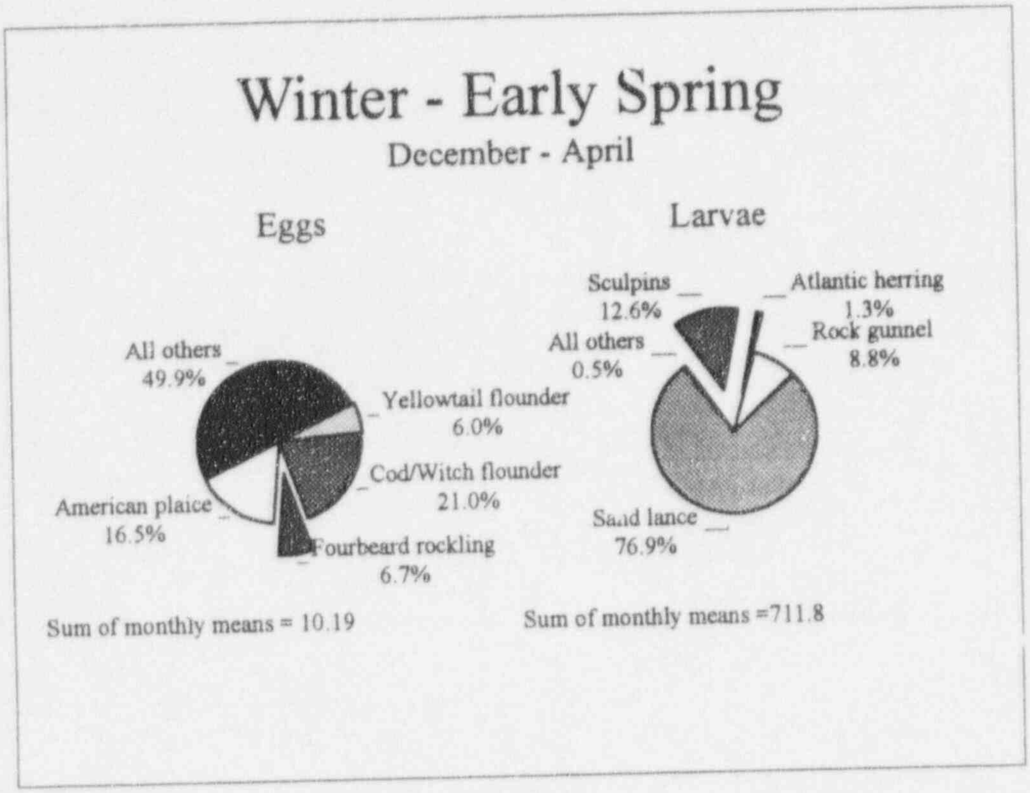
A. Ichthyoplankton Entrained - 1996

Population densities per 100 m^3 of water for each species by sampling date in 1996 are presented in Appendix A (available upon request). Table 2 lists all species represented in the 1996 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 1996.

Winter-early spring spawners (December-April)

This spawning season is split between the beginning and end of the calendar year. Many species spawning during this season 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 both life stages 4 species were represented in the January collections, 7 were represented in February, 12 in March, and 16 in April. Egg collections over the season as a whole contained six species; winter flounder, American plaice, and Atlantic cod accounted for the majority. Winter flounder eggs were present in March and April



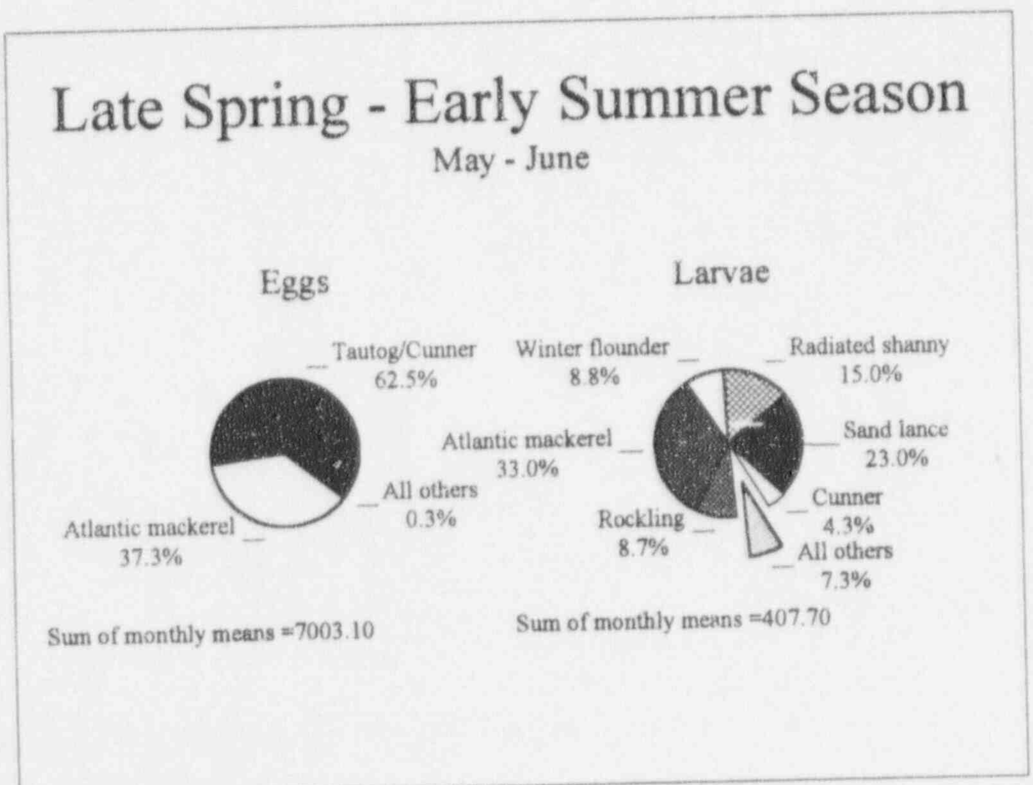


Figure 2. Dominant species of fish eggs and larvae found in PNPS ichthyoplankton samples by season for 1996. Percent of total and summed monthly means for all species are also shown.

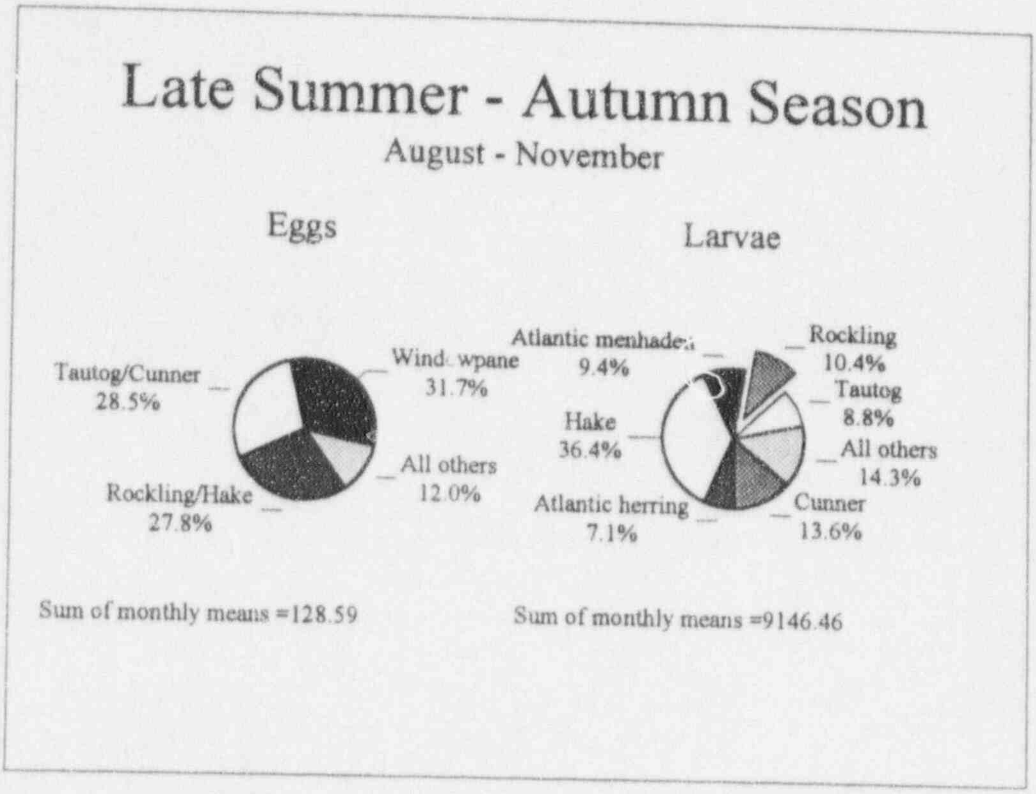


Figure 2 (continued).

when they accounted for 53 and 69% of the eggs taken with monthly geometric means of 0.4 and 1.1 per 100 m^3 of water. American plaice eggs were also taken in March and April with monthly geometric means of 0.1 and 0.7 per 100 m^3 accounting for an additional 6 and 15% of total. Atlantic cod eggs were present in February, March, and April with monthly geometric means of 0.5 per 100 m^3 or less. They accounted for all eggs taken in February, 23% of total in March, and 6% in April.

Since they are demersal and adhesive, winter flounder eggs are not often entrained by water intake systems. Their densities in PNPS samples are therefore not considered representative of numbers present in the surrounding area. Those entrained were probably dislodged from the bottom by currents and perhaps the activities of other fish and benthic invertebrates.

Larval collections during the winter-early spring season contained 15 species - sand lance, rock gunnel (*Pholis gunnellus*), sculpin (*Myxocephalus* spp.) and Atlantic herring were numerically dominant. Sand lance larvae first appeared in late January, were taken on most sampling occasions in February, then every date from mid-March through April. They accounted for 99, 27, 52, and 87% of all larvae during the four respective months of the season. Larval rock gunnel first appeared at the end of January, then occurred on all but four dates through April. Monthly geometric mean densities amounted to 0.1, 4, 16, and 9 per 100 m^3, respectively, values which represented 0.2, 33, 21, and 4% of each monthly larval total. As in past years three species of sculpin were represented in the winter-early spring collections. As a group they first appeared in February and were taken throughout the month of April. Pooled geometric mean densities amounted to 3 in February, 20 in both March and April. Shorthorn sculpin (Myoxocephalus scorpius) dominated among the three species in February but gave way to the grubby (M. aenaeus) by mid-March; the latter ranked first over the remainder of the season. Atlantic herring larvae were taken in small numbers occasionally in January and February, regularly at greater densities in March and April. Monthly geometric mean densities were 0.4 in January, 0.1 in February, 0.4 in March, and 3 in April. These values accounted for 0.9, 0.6, 0.3, and 1.4 of each respective monthly total.

Late Spring-Early Summer (May-July)

This clearly is an active season for reproduction of fishes. Egg and larval densities, especially among species spawning pelagic eggs, typically increase with expanding day length and rising water temperatures. Considering both life stages, 22 species were represented in the May collections, 24 were represented in the June collections, and 23 were taken in July. Numerical dominants included Atlantic mackerel in May followed by tautog/cunner in June and July. Mackerel accounted for 88% of all eggs in May with a monthly geometric mean of 134 per 100 m^3 of water. Tautog/cunner eggs represented 11, 84, and 97% of all eggs taken during the three respective months. Corresponding monthly geometric means amounted to 23, 892, and 745 per 100 m^3. Based on a study completed at PNPS in 1975 and 1976 (MRI 1978), most (>90%) tautog/cunner eggs are believed to be cunner.

Larval collections over the three-month period were numerically dominated by sand lance, Atlantic mackerel, radiated shanny (Ulvaria subbifurcata), fourbeard rockling (Enchelyopus cimbrius), winter flounder and cunner. Sand lance, which typically decline sharply by early May from a peak in March or April, remained abundant until mid-May being present throughout the month; a single individual was also taken in June. Over May as a whole they accounted for 61% of the larval total with a geometric mean of 15 per 100 m^3. Atlantic mackerel larvae first appeared late in May, were most abundant early in June, and continued to appear in entrainment samples through July 10. They accounted for 4% of the May total with a monthly geometric mean of 1 per 100 m^3, 51% of the June total with a monthly mean of 14 per 100 m^3, and 19% of the July total with a mean density of 2 per 100 m^3. Radiated shanny, a small bottom fish found among rocks and seaweed, were taken throughout the months of May and June as well as the early half of July. They represented 18, 14, and 5% of the three respective monthly larval totals with geometric monthly means of 15, 10, and 0.5 per 100 m^3. Fourbeard rockling, a small bottom species similar in appearance to the hakes, accounted for 2% of the May catch, 12% of the June catch, and 5% of the July total with respective monthly geometric means of 1, 11, and 0.8 per 100 m^3 of water. Winter flounder occurred at geometric mean densities of 6 in May, 7 in June, and 0.1 in July, these values accounting for 8, 10, and 1% of each respective month's total. Lastly, larval cunner first appeared in mid-June, ultimately contributing 2% to the June total with a geometric mean density of 2 per 100 m^3. They occurred on each sampling occasion in July, accounting for 44% of the month's total larval catch with a monthly geometric mean of 7 larvae per 100 m^3.

The occurrence of larval winter flounder on three dates in July was uncommon for PNPS samples. They appeared as late as July during nine of 21 other years dating back to 1975. Based on intake water temperature records for the PNPS intake basin, July 1996 was relatively cool which may have resulted in protracted larval development rates or perhaps an extended spawning season. The average for July 1996 was 56.1 F or 2.5 F below the long term mean of 58.6 F (1976-1995; Anderson 1986, 1996).

Late Summer - Autumn Spawners (August-November)

This season is typically one showing marked decline in both overall ichthyoplankton density and number of species. Over both egg and larval life stages number of species declined from 16 in August to 11 in September, 7 in October, and 6 in November. Numerical dominants included windowpane, tautog/cunner, and rockling/hake among the eggs; and hake, cunner, rockling, Atlantic menhaden, tautog, and Atlantic herring among larvae.

Windowpane were assumed to predominate among the Paralichthys-Scophthalmus egg group because, consistent with past years, larval windowpane were far more abundant than fourspot flounder larvae. During 1996 a ratio of 4:1 windowpane to fourspot larvae was recorded. These eggs accounted for 30% of all eggs in August, 57%

in September, and 8% in November; none were taken in October. Monthly geometric mean densities reached a high of 32 per 100 m^3 in September. Tautog/cunner eggs contributed an additional 32, 9, 0, and 4% to the four respective monthly totals with geometric mean densities reaching a high of 19 per 100 m^3 in August. Rockling and hake eggs were taken in August and September, hake eggs likely predominating among the grouped eggs based on the ratio of late-stage eggs. Together they represented 30% of the August egg catch with a geometric mean of 22 per 100 m^3 and 29% of the September catch with a mean of 2 per 100 m^3.

Larval hake were taken during the months of August (41% of total), September (3% of total), and October (16%), August showing the greatest densities with a monthly geometric mean of 3 per 100 m^3. Cunner larvae were present in August and September collections with monthly geometric mean densities of 4 and 1 per 100 m^3, accounting for 19 and 13% of the two respective totals. Rockling were collected regularly during the season until mid-November. With monthly geometric mean densities of 3, 0.5, 0.6, and 0.2 they contributed between 4 and 15% of each month's total larval catch. Larval Atlantic menhaden were entrained from August through October, accounting for less than 1% of the August total to 47% of the October total. Monthly geometric means were 0.1, 0.6, and 2 per 100 m^3 during the three respective months. Tautog occurred from August to the beginning of October contributing 9, 13, and 3% of total; monthly geometric means amounted to [illegible], 1, and 0.2 per 100 m^3 respectively. Atlantic herring occurred only in November with a geometric mean density of 3 per 100 m^3 representing 91% of that month's total.

B. Multi-year Ichthyoplankton Comparisons

A master species list for ichthyoplankton collected from the discharge canal at PNPS appears in Table 3; the years during which each species was represented is indicated for 1975 through 1996. A total of 41 species was represented in the 1996 collections, three more than the 21-year mean of 38. The only noteworthy entry was the collection of three prejuenile alewives in July. This represented the first occurrence of Alosa spp. since 1990 and only the seventh appearance dating back to 1975. Since the alewife is an anadromous species, they apparently drifted a considerable distance from spawning tributaries in Plymouth Harbor, Kingston, Duxbury Bay, or locations farther to the north such as the Green Harbor River.

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 1996 egg total, along with total eggs (all species combined) for each year dating back to 1984. 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-August 1984 and April-August 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 1975-1983 remain in an outdated computer format requiring conversion before geometric mean densities can be generated. Those years were therefore excluded from Appendix B but are discussed in the multi-year comparisons if noteworthy.

To help compare values over the 13-year period, egg data were plotted in Figure 3. For this figure cod and pollock eggs were combined with the Enchelyopus-Urophycis-Peprilus group, and labrids and yellowtail flounder were combined with the labrid-Pleuronectes group. For each category shown, the highest monthly geometric means obtained from 1984 through 1995 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 1996 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 (1984-1996) and the other, longer time series, on arithmetic monthly means (1975-1996). Appendix B and Figure 4 contain corresponding data for the 13 numerically dominant species of fish larvae, those accounting for 99% of the 1996 catch, as well as total larvae (all species combined). As mentioned for eggs, low values obtained for both eggs and larvae during April through August 1984 and 1987 were flagged in these figures and omitted from the following discussion.

In many cases densities of fish eggs and larvae vary considerably from year to year. For example, over the 13-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 pronounced variation, no consistent upward or downward trend was apparent for many species such as menhaden and windowpane eggs, menhaden, sculpin, seasnail (Liparis atlanticus), tautog, and rock gunnel larvae. Following are noteworthy 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 for example) at PNPS during winter months from 1975-1987. Following 1987 they became uncommon particularly during January and February. None were taken either month in 1993 or 1994 and only one was taken in 1995. In 1996 collections rose to three eggs, all in February. The gadidae-Glyptocephalus group in general showed a significant decline from 1975 to 1993 ($p<0.001$) based on a nonparametric sign test which is consistent with the downward trend reported for Atlantic cod and witch flounder stocks apparently resulting, at least in part, to overexploitation (NOAA 1995, NEFSC 1996). Annual geometric mean indices suggest the decline has ended since values for 1994, 1995, and 1996 appear stable at about three times the low value recorded in 1993.
2. Eggs of the fourbeard rockling and closely related hake (grouped in the early developmental stages with far less common butterfish as Enchelyopus-Urophycis-Peprilus) have been

uncommon in recent years. Trend analysis using the longer-term arithmetic time series indicated that a significant downward trend occurred from 1978 through 1996 ($p = 0.05$) in spite of a moderate catch in 1995. Any suggestion of a reversal in 1995 was erased by the 1996 value which was similar to values observed from 1992 to 1994. Fourbeard rockling dominate within this grouping based on late-stage egg as well as larval collections. Since this a small bottom fish with little or no commercial value, stock size data are not available with which to compare trends. 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 grouped 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 failed to confirm it using the conventional 95% significance level ($p = 0.055$). The arithmetic and geometric indices both showed an increase in density in 1995; the geometric index continued to rise in 1996 as well. The 1995 arithmetic index appeared exceptional and disproportionate to the geometric values due to a single high density in June (37,282 per 100 m^3 of water) which greatly biased the arithmetic mean for that month. The downward trend

through 1994 is consistent with finfish observations in the PNPS area (Lawton et al. 1995). Changes in sampling protocols at PNPS have eliminated the ability to monitor general cunner population trends which in the past were sampled by gill net and trawl. Numbers impinged appeared to systematically decline from 1980 through 1992 then increased slightly in 1993 and 1994, more sharply in 1995 consistent with the egg data.

4. The arithmetic indices for Atlantic mackerel eggs clearly indicates that greater numbers were entrained from 1988 through 1996 compared with the 1975 through 1987 period. A sign test confirmed this upward trend ($p = 0.001$). Mackerel eggs typically display a sharp peak in their abundance curve often with one or two very high densities. For example in May 1995 a single density of 19,203 eggs per 100 m^3 was obtained on May 26 while the next highest density was 4,754 per 100 m^3 on June 9 ; as a result arithmetic and geometric indices are usually quite far apart (Figure 3). Greater entrainment of mackerel eggs over the past decade 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. Windowpane eggs, assuming, based on larval collections, that they predominate within this egg group, appear to have been increasing in number over the past three years. The geometric mean index for 1996 ranked third among the 13 years for which that index is available. The arithmetic index ranked sixth

over the entire 22-year series. In general these eggs have not shown wide variations in number, at least not compared with other species regularly entrained. Current indices for windowpane in the Gulf Of Maine and in southern New England are among the lowest of a time series dating back to the 1960's (NEFSC 1996).

6. Following the arithmetic mean index over the entire 22-year time series suggests that American plaice eggs dropped in number from the late 1970's to a low point in 1986. Following 1986 densities appear to have gradually increased through 1995. Both the arithmetic and geometric indices declined somewhat in 1996 although they remained well above the 1986 low point. According to NOAA survey results, a strong year-class of plaice was produced in 1987, the stock slowly rebuilding since that time, at least through 1993 (NOAA 1995).
7. Larval Atlantic herring were exceptionally abundant in 1994 and 1995, both arithmetic and geometric indices greatly exceeding all previous annual values. In 1996 numbers declined from the preceding two years but remained relatively high, both indices ranking third overall (the geometric index actually tied with 1990). Herring stocks on Georges Bank and Nantucket Shoals have increased markedly in recent years as have larval abundance estimates (NOAA 1995, NEFSC 1996), the increases noted at PNPS being consistent with that trend.
8. Larval radiated shanny have been relatively abundant since 1989, 1995 and 1996 densities being particularly high. Among

the 12 years for which geometric indices are available, 1995 (927) and 1996 (776) rank first and second, respectively. Dating back to 1975, 1995 (1727) and 1996 (1865) ranked third and second, respectively, behind 1975 (2178) based on the arithmetic index. Since this is a small rather inconspicuous botttom fish, relatively little is known of its habits and no data are available concerning population trends.

9. Over the course of the last three years larval sand lance have been very abundant. The geometric mean index for 1996 (6,156) is the second highest of the shorter time series, exceeding all previous geometric values but that recorded in 1994 (12,490). Over the complete time series, 1996 (arithmetic index = 19,512) also ranked second behind 1994 (26,276). The three most recent annual abundance indices appear biased by the fact that sand lance larvae may be more susceptible to entrainment at night, regular sampling during those hours beginning in 1994. For example, among six samples which exceeded all previous densities for the month at the time during 1994, 1995, and 1996 (see Table 1, Vol. 2), all but one (83%) were night samples.

10. Following an exceptionally high-density year in 1995 (arithmetic index = 12,086), larval mackerel densities declined in 1996 (arithmetic index = 4,104) although they remained abundant relative to past seasons, ranking fifth out of 22 years. Like their eggs, mackerel larvae densities are typically skewed by a small number of high densities. As a

result, arithmetic and geometric indices are often wide apart. Within the shorter 1984-1996 time series the current year ranked fourth.

11. Winter flounder larvae remain a species of great concern throughout the New England region since stocks are near historically low levels (NEFSC 1996). Larval densities in 1996 were relatively high by both indices. The long-term arithmetic index ranked fourth out of 22 years, the shorter geometric index second out of 13 years.

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 1994-1996 appear in Table 4.

Eggs

Paired sample t-tests on log-transformed data for all three years combined indicated tautog/cunner eggs were significantly more abundant in the 0.202-mesh samples ($p < 0.001$; $n = 34$ pairs). Since densities were highly skewed by high values on June 28, 1995, geometric means were calculated over the 34 samples within each mesh category. The ratio of these (also the geometric mean of the ratios) was 1.29:1 with 95% confidence limits of 1.12 to 1.50:1. The arithmetic mean of the ratios was noted to be characteristically higher than the geometric mean at 1.44:1, raising the question of which value provides the better conversion factor. The ratios were not found to be normally distributed (following Ryan and

Joiner 1976) indicating the geometric mean provided a less biased estimate.

Geometric mean ratios were higher in 1994 (1.58:1) than in 1995 (1.20:1) and 1996 (1.14:1) suggesting variability in extrusion can be expected between years. The similarity between 1995 and 1996 at least suggests that great error was not introduced by alternately collecting samples (1995) rather than streaming both nets simultaneously (1996).

Larvae

Recently hatched larval cunner were common in the 1996 mesh comparison samples, all but two pairs containing individuals in both nets. Combined with 1995 data, 15 pairs were available (stage 1 cunner were absent in 1994). A paired sample t-test failed to detect a statistically significant difference between nets ($p = 0.75$; geometric mean ratio (0.202:0.333) = 1.10:1 (Table 4).

Similar results were obtained for stage 2 cunner. They were taken in all samples in 1996, bringing the number of pairs to 22 when pooled with 1994 and 1995 data sets. Again a paired sample t-test did not detect a significant difference between nets ($p = 0.22$; geometric mean ratio (0.202:0.333) = 1.28:1, Table 4).

As expected, larger stage 3 larval cunner were taken in similar densities in both nets. A geometric mean ratio (0.202: 0.333) of 1.00:1 was obtained over ten pairs (paired t-test $p = 0.99$).

These results suggest that small cunner are not extruded through 0.333-mm mesh netting to any significant degree. While the ratio of 1.28:1 obtained for stage 2 larvae may appear important, the t-test indicated there was a 22% chance of obtaining such a difference by chance alone. Power analysis indicated that 140 pairs of samples would be required to detect a ratio of that magnitude with a probability of Type I[2] error of 5% and probability of Type II error of 10% (Cohen 1988). One very conservative approach in assessing impact at PNPS would be to multiply the observed ratios times the respective stage 1 and 2 larval cunner densities, realizing that resulting estimates are likely to be overestimates.

D. Lobster Larvae Entrained

No lobster larvae were found in the 1996 entrainment samples, the total, dating back to 1974, remaining at 13. Following is a tabulation of previous collections:

1995: 1 larva - stage 4-5, July 28.
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.

[2]Type I error occurs when a difference between means is indicated by a statistical test but in fact the observed difference occurred by chance alone. This is commonly set at p = 0.05, the value reported with most statistical tests. Type II error occurs when a test results in failure to reject the null hypothesis when it is in fact false. Type II error may typically occur when sample size is small and/or variability within samples is high. It is clearly most common when trying to detect small differences between samples.

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 (MRI 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 1996 included American plaice, cunner, mackerel, fourbeard rockling, hake, and windowpane among the eggs; sand lance, sculpin, rock gunnel, mackerel, radiated shanny, winter flounder, hake, cunner, and rockling among the larvae.
2) A statistically significant downward trend in abundance was apparent over the 1978-1996 period for rockling and hake eggs in spite of a moderate catch in 1995.
3) Numbers of Atlantic mackerel eggs have clearly increased during the 1988-1996 period compared with 1975 through 1987. This is consistent with a dramatic rise in stock biomass attributable to reductions in foreign fishery and underexploitation by U.S. fisheries.
4) Larval Atlantic herring were exceptionally abundant in 1994 and 1995. Densities in 1996 declined from those two years but remained relatively high. These collections are consistent with marked increases in adult stock in recent years on Georges Bank and Nantucket Shoals.
5) The long-term arithmetic index for larval winter flounder ranked fourth out of 22 years in 1996, a bright sign in light of low stock biomass throughout the New England region.
6) Mesh comparison studies completed for cunner eggs and larvae indicated that eggs were retained at significantly higher

densities in 0.202-mm mesh samples compared with 0.333 mesh. An average ratio of 1.29:1 was recorded. No significant difference was detected for stage 1 or 2 larval cunner although respective mean ratios of 1.10:1 and 1.28:1 were recorded.

7) No lobster larvae were found in the 1996 entrainment samples, the total remaining at 13 dating back to 1974.

Figure 3. Geometric mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the eight numerically dominant egg species and total eggs, 1996 (bold line). Solid lines encompassing shaded area show high and low values over the 1984-1995 period.

Brevoortia tyrannus

Gadidae-Glyptocephalus

Enchelyopus-Urophycis
Peprilus

Prionotus spp.

Labridae-Pleuronectes

Scomber scombrus

Paralichthys-Scophthalmus

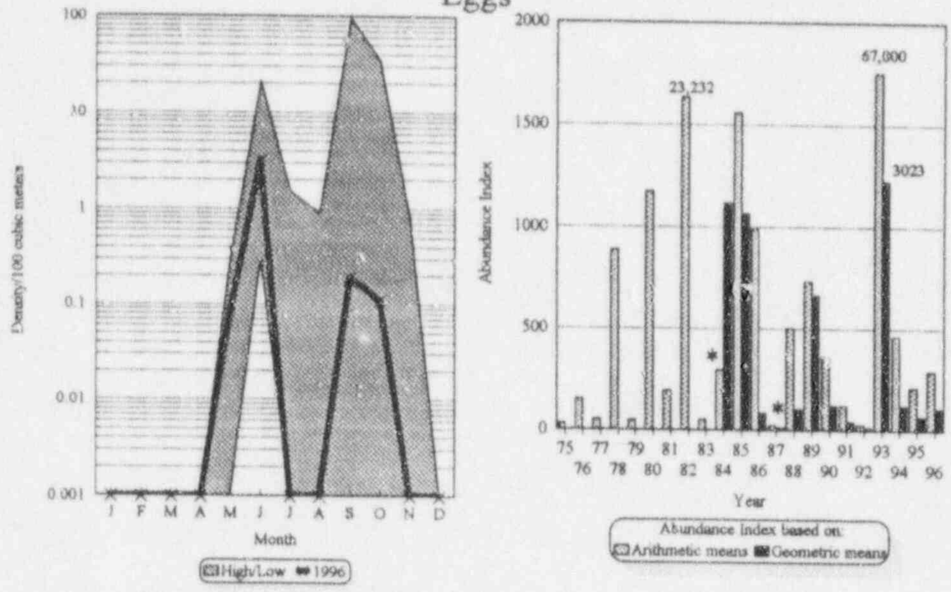
Hippoglossoides platessoides

Total eggs

To the right are plotted integrated areas under the annual entrainment abundance curves for 1975-1996. 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 (1984-1996) indices based on monthly geometric means.

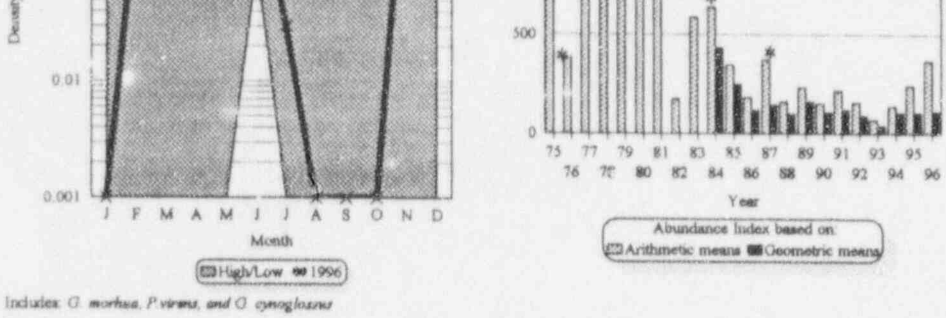
Brevoortia tyrannus

Eggs



Gadidae - *Glyptocephalus*

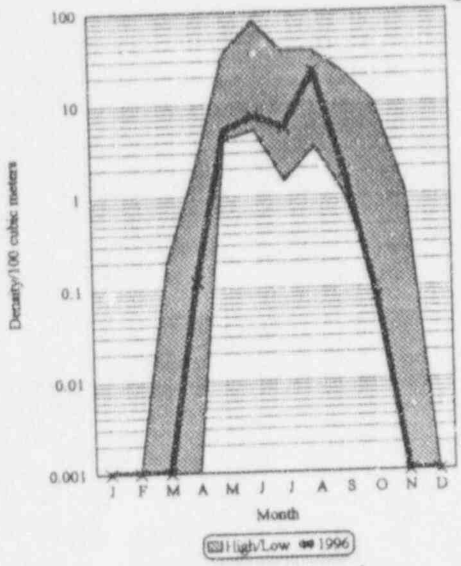
Eggs

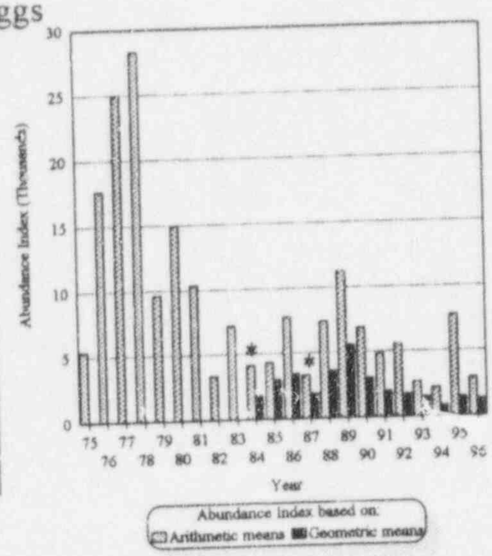


Includes: *G. morhua, P. virens, and G. cynoglossus*

Enchelyopus - Urophycis - Peprilus

Eggs

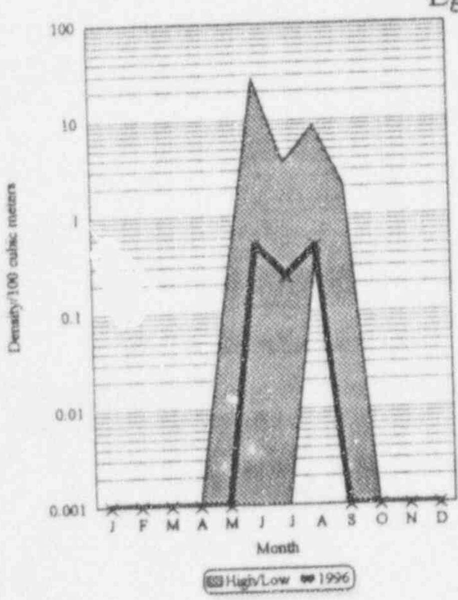


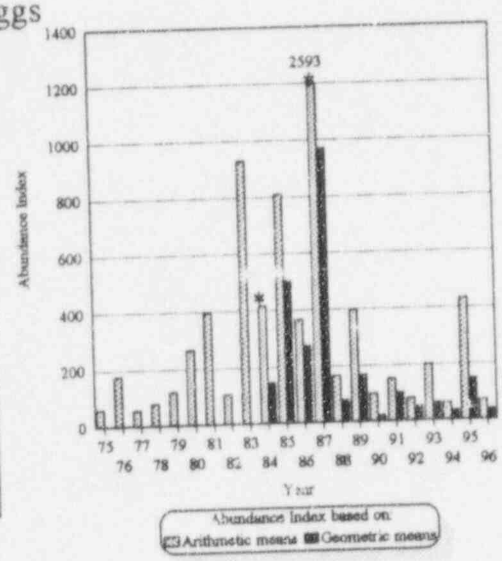


Includes: *B. cimbrius*, *Urophycis spp.*, and *P. triacanthus*

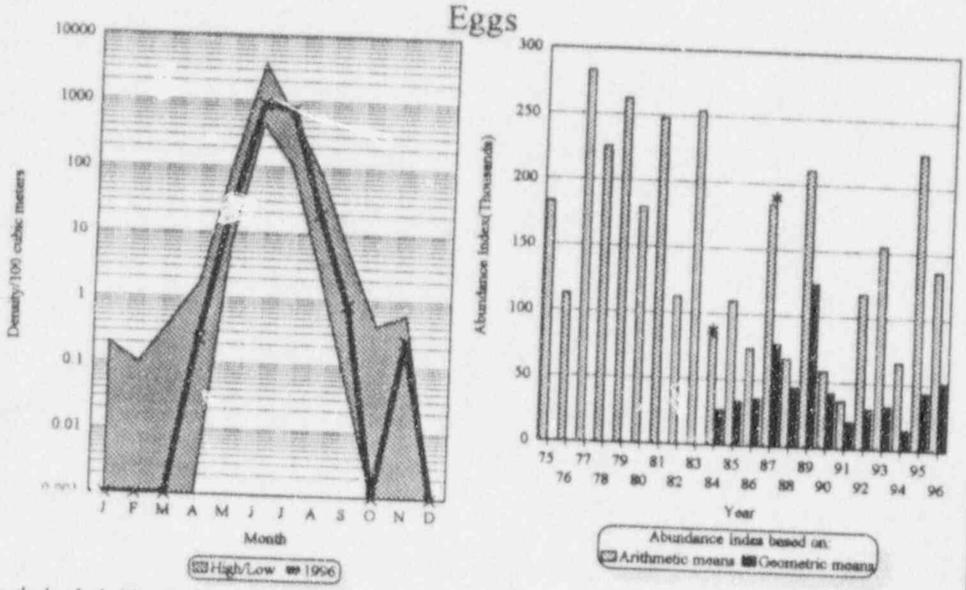
Prionotus spp.

Eggs



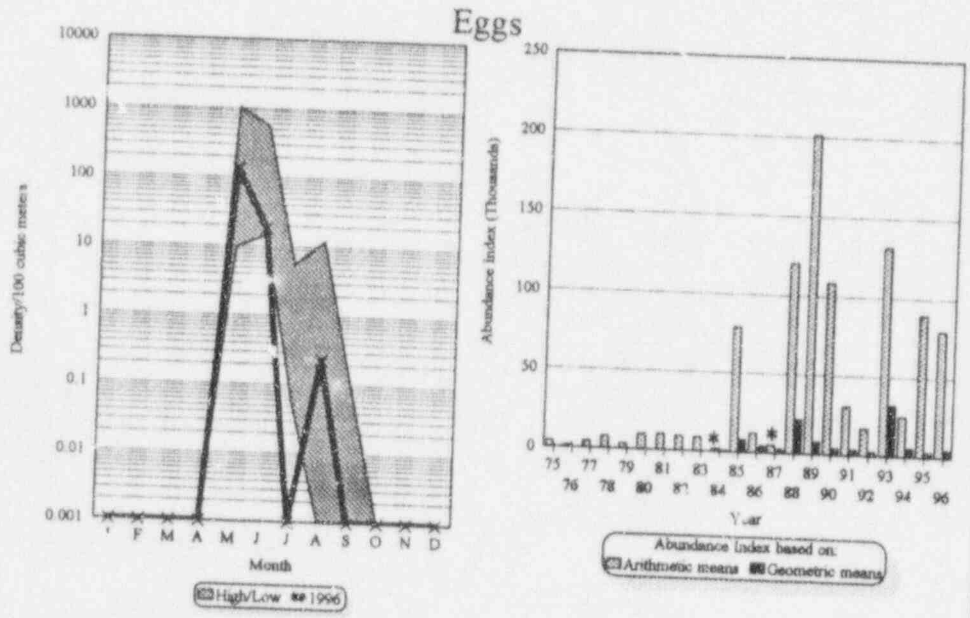


Labridae - *Pleuronectes*



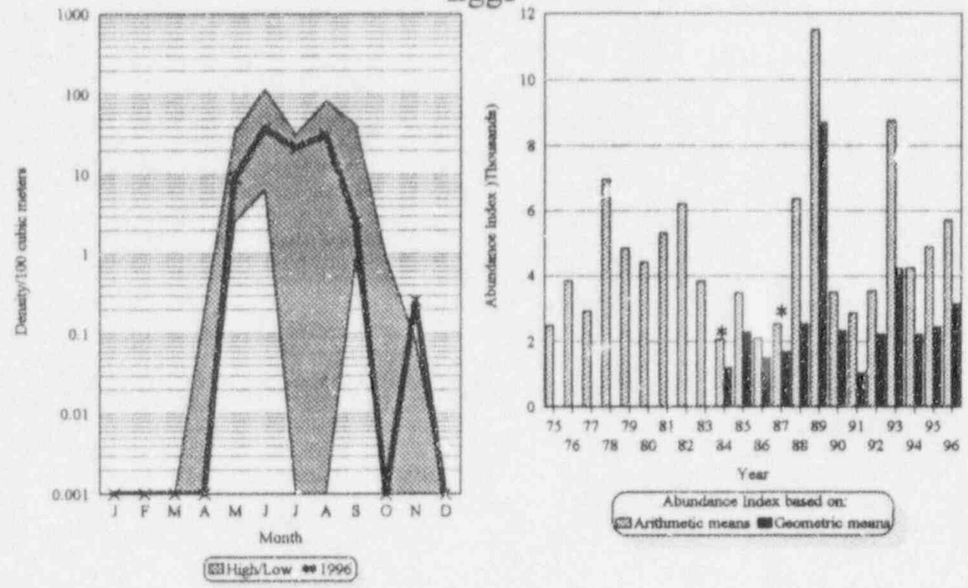
Includes Labridae and *P. ferrugineus*

Scomber scombrus



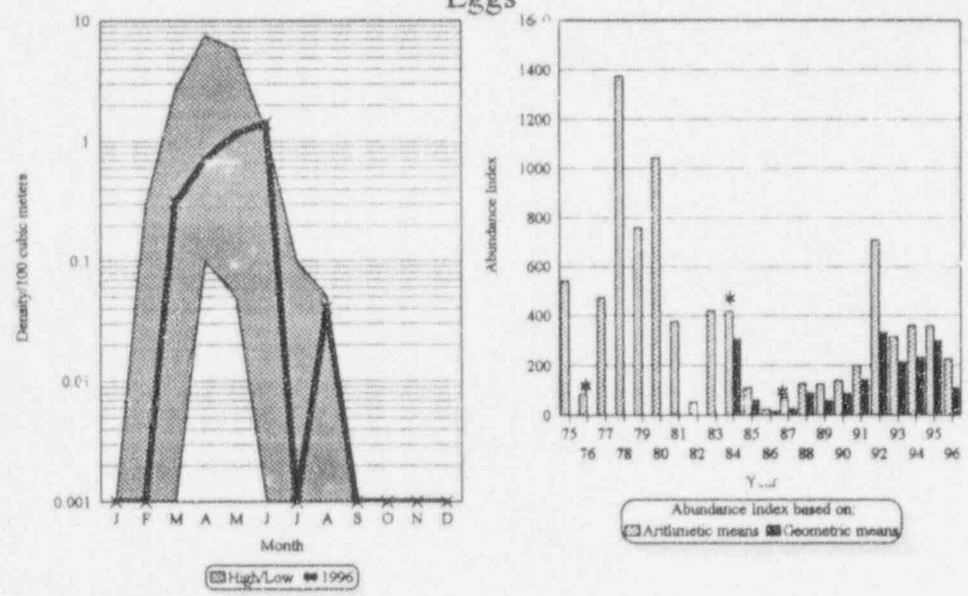
Paralichthys - Scophthalmus

Eggs



Hippoglossoides platessoides

Eggs



Total Eggs

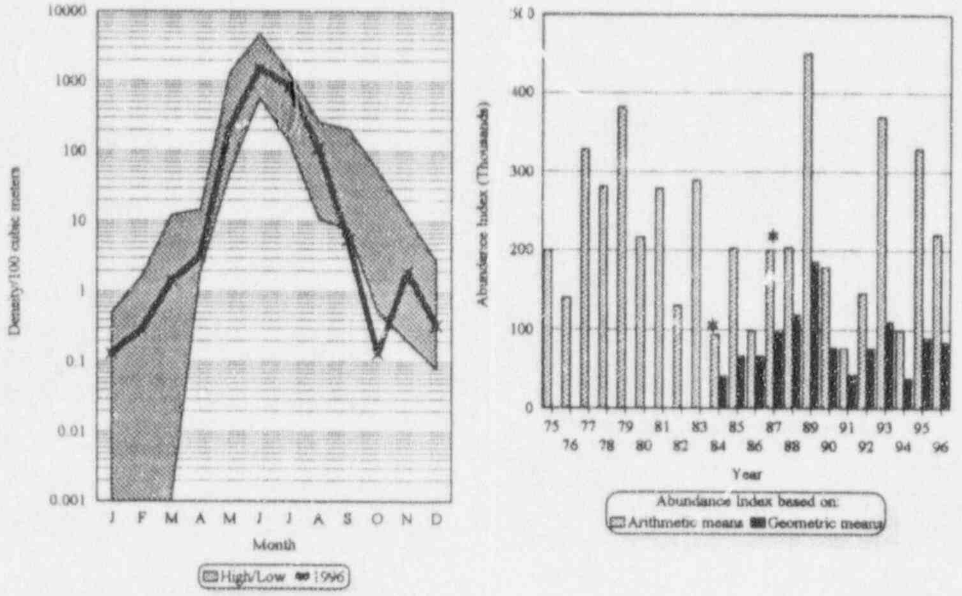

Density/100 cubic meters
10000
1000
100
10
1
0.1
0.01
0.001
J F M A M J J A S O N D
Month
High/Low 1996
Abundance Index (Thousands)
400
300
200
100
0
75 77 79 81 83 85 87 89 91 93 95
76 78 80 82 84 86 88 90 92 94 96
Year
Abundance Index based on:
Arithmetic means Geometric means

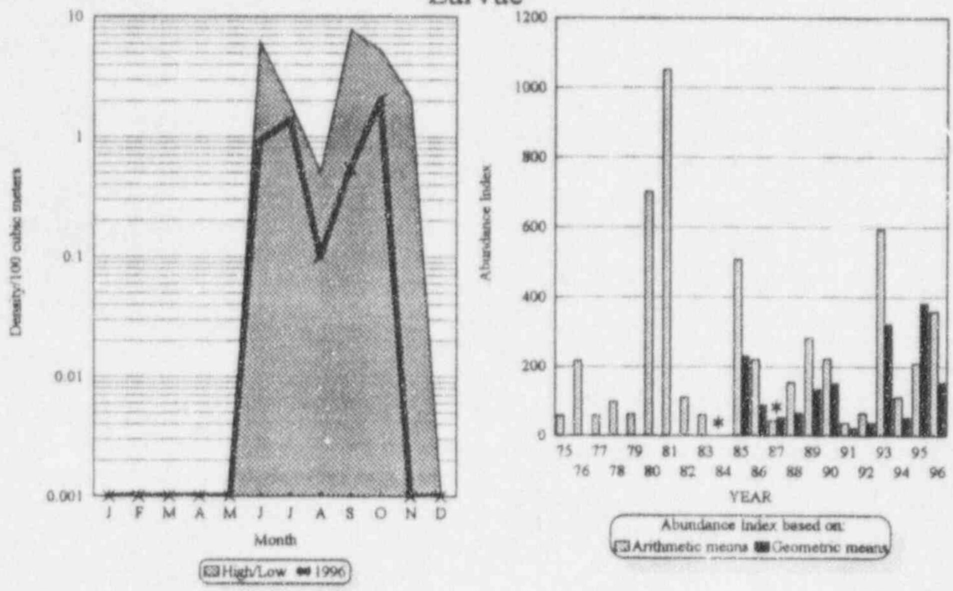
Figure 4. Geometric mean monthly densities per 100 m^3 of water in the PNPS discharge canal for the thirteen numerically dominant larval species and total larvae, 1996 (bold line). Solid lines encompassing shaded area show high and low values over the 1984-1995 period.

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 1975-1996. 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 (1984-1996) indices based on monthly geometric means.

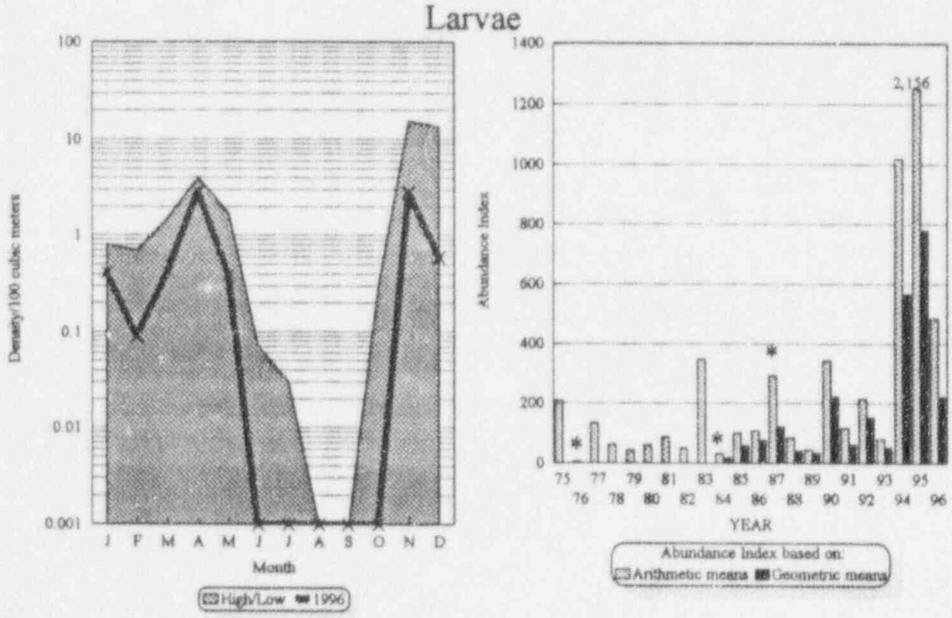
Brevoortia tyrannus

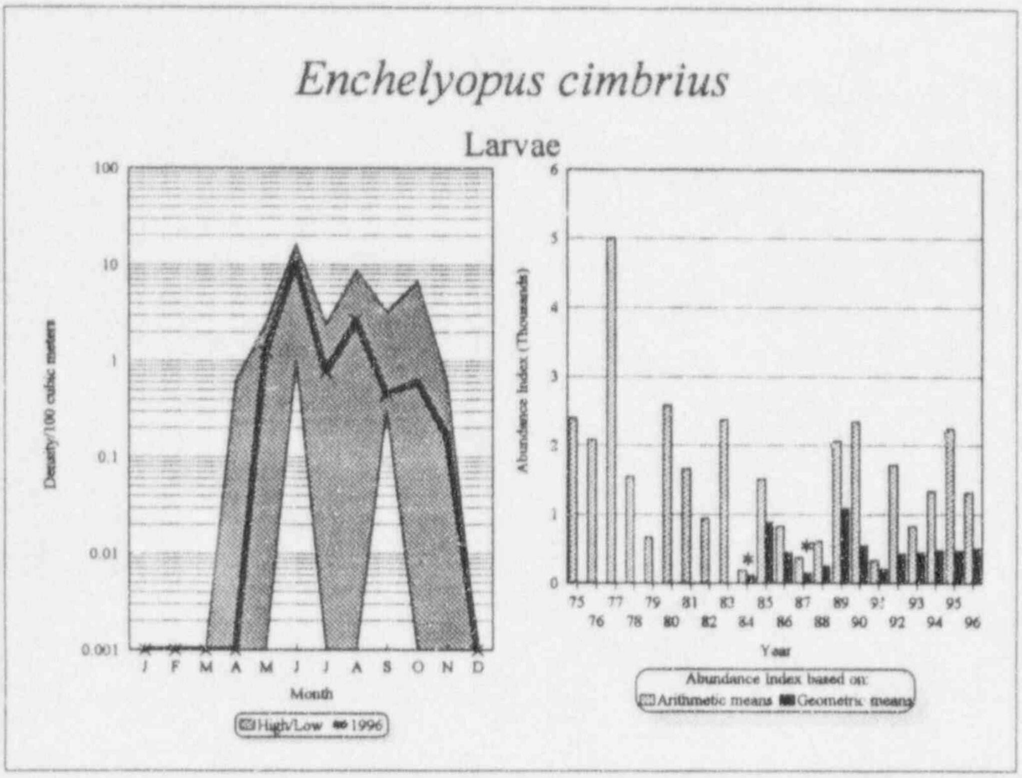
Larvae

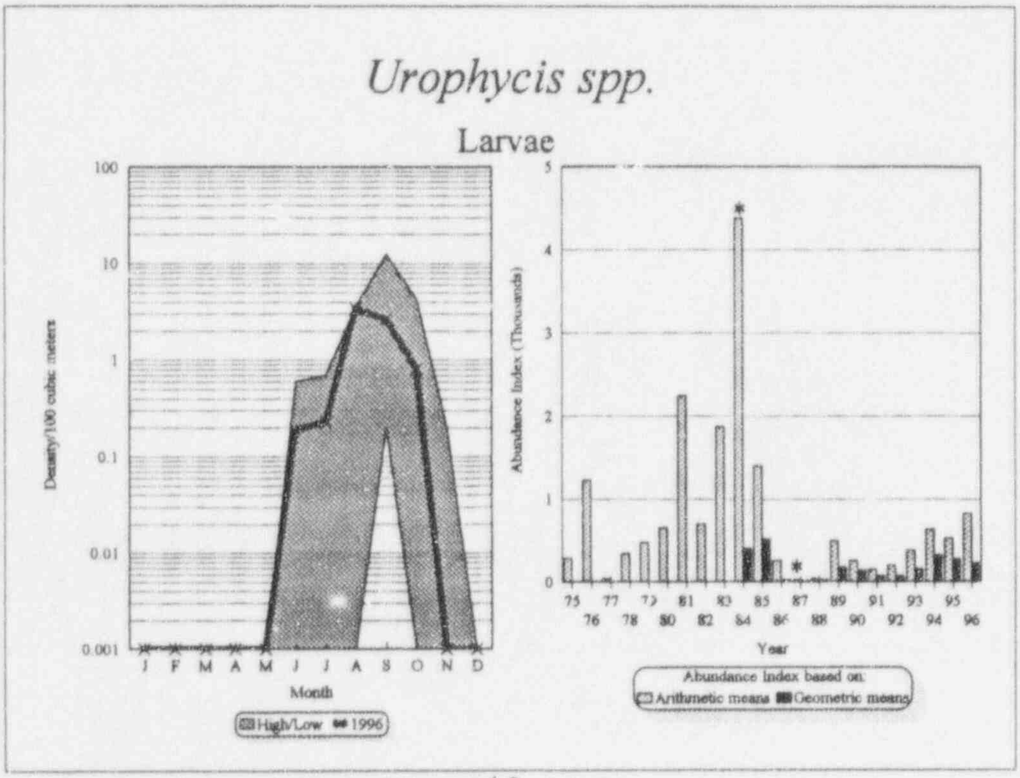


Clupea harengus

Larvae

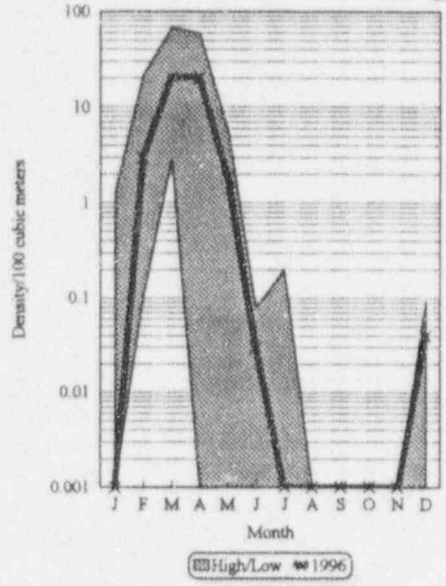


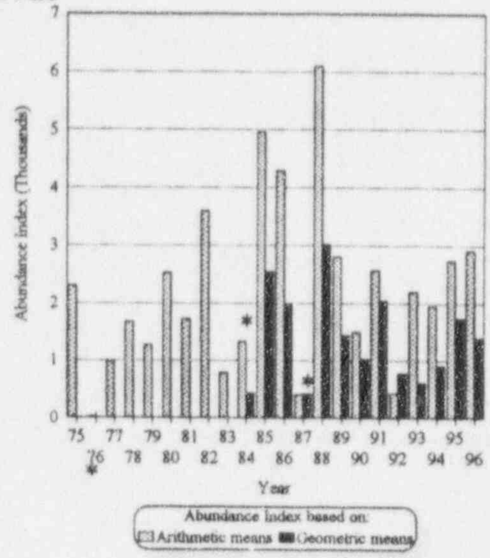

Enchelyopus cimbrius
Larvae
Density/100 cubic meters
Month
High/Low
1996
Abundance Index (Thousands)
Year
Abundance Index based on:
Arithmetic means
Geometric means


Urophycis spp.
Larvae
Density/100 cubic meters
Month
High/Low
1996
Abundance Index (Thousands)
Year
Abundance Index based on:
Arithmetic means
Geometric means

Myoxocephalus spp.

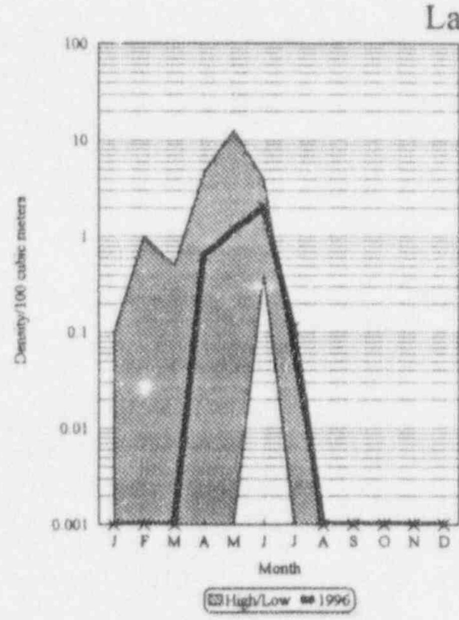
Larvae

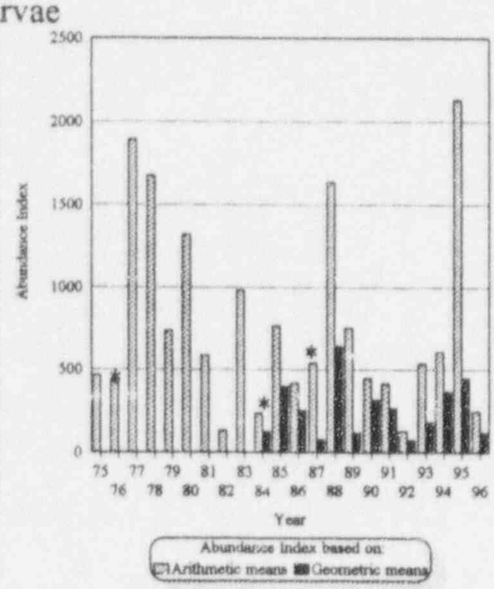




Liparis spp.

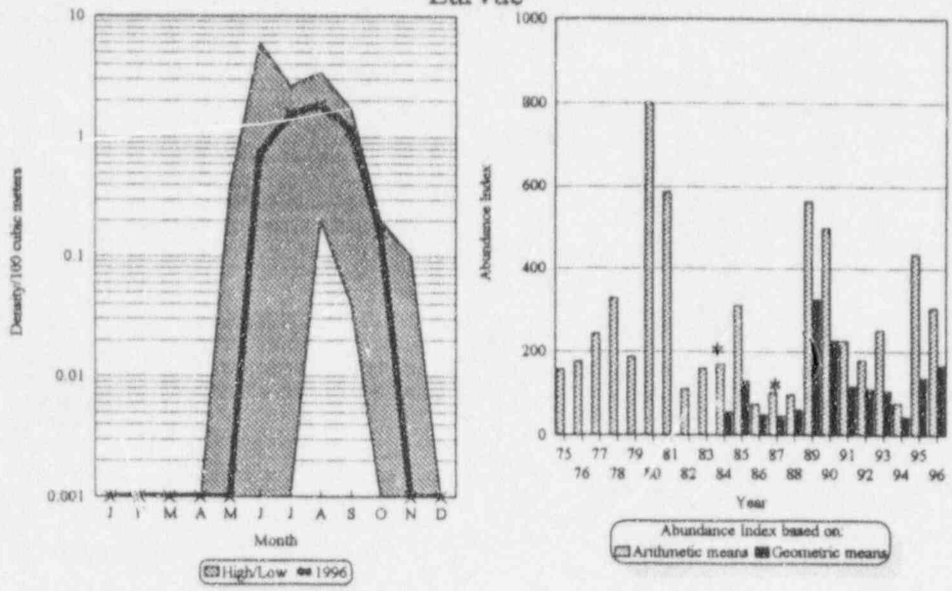
Larvae





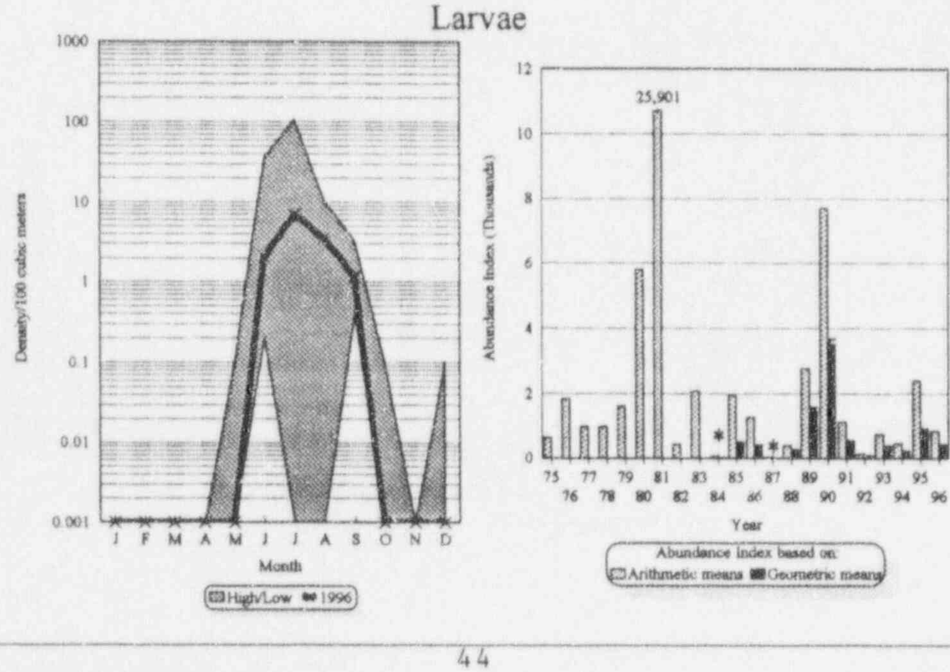
Tautoga onitis

Larvae



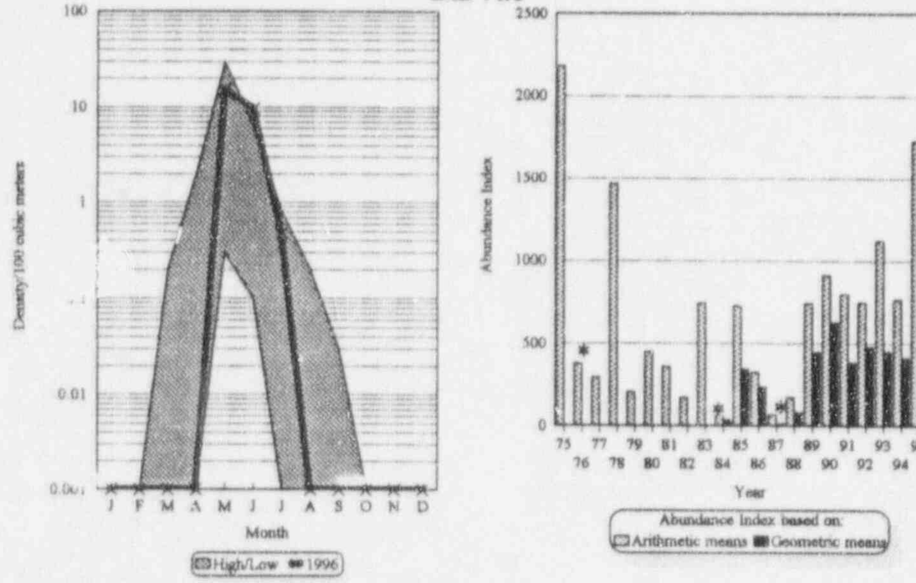
Tautogolabrus adspersus

Larvae



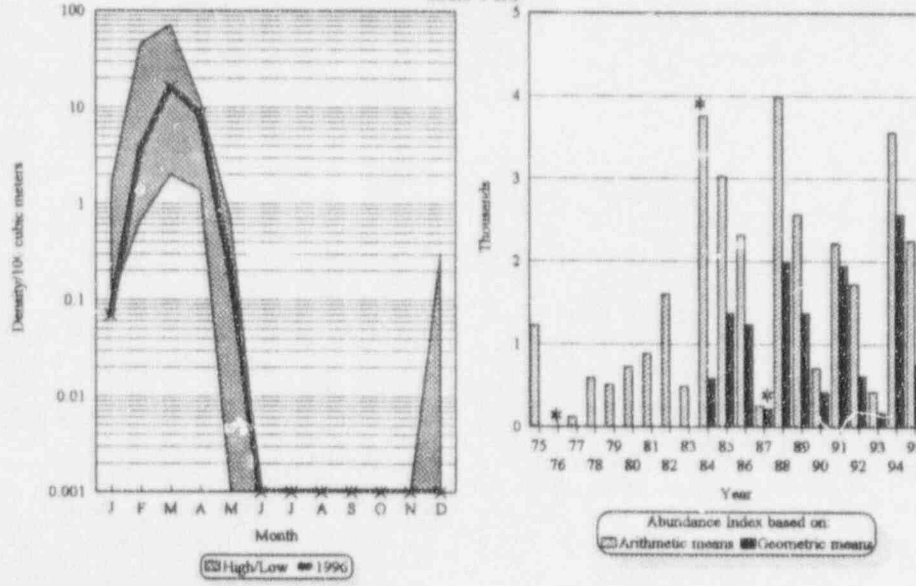
Ulvaria subbifurcata

Larvae



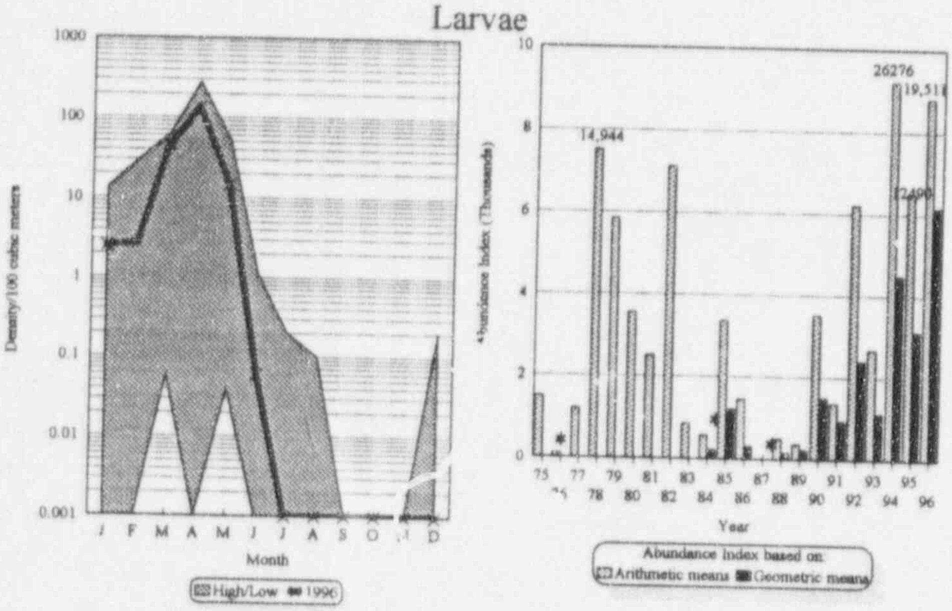
Pholis gunnellus

Larvae



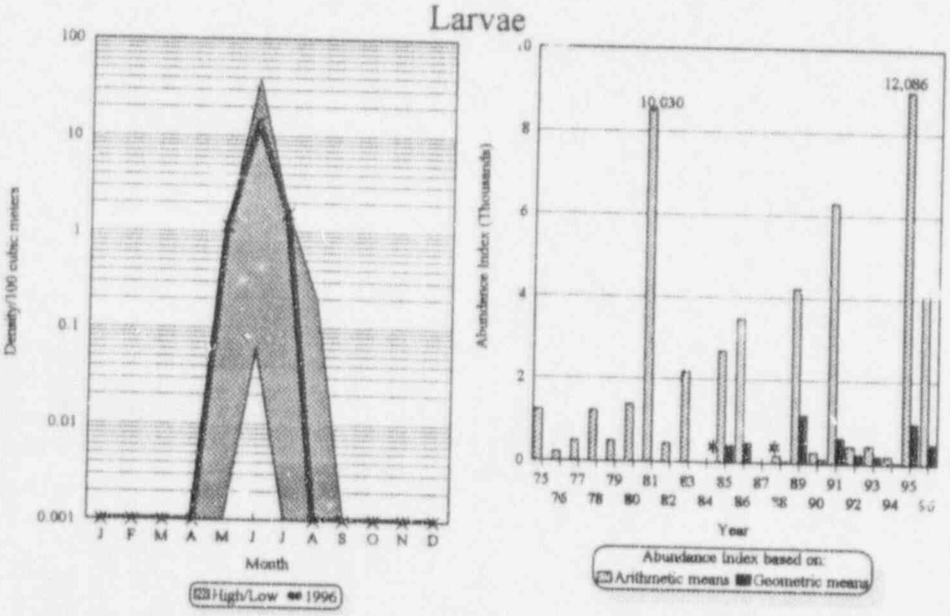
Ammodytes spp.

Larvae



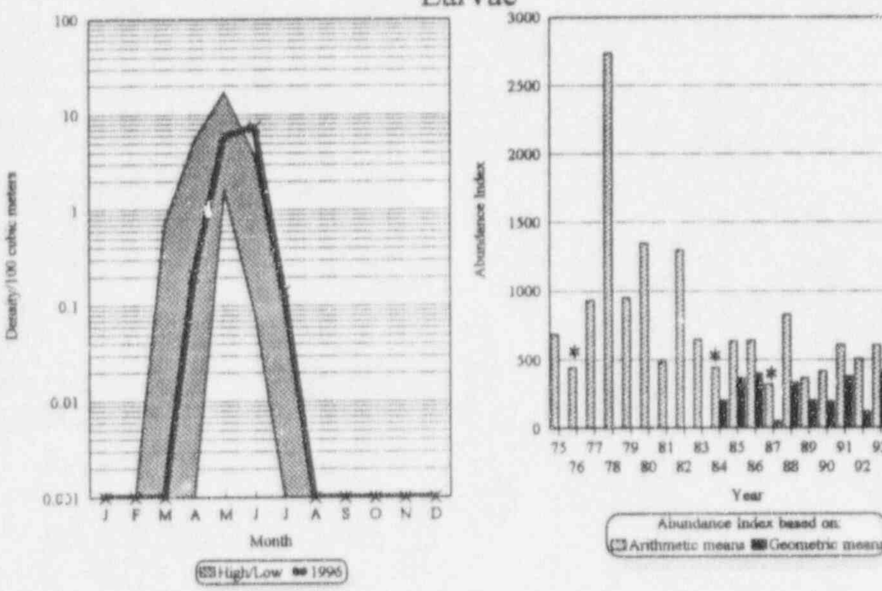
Scomber scombrus

Larvae



Pleuronectes americanus

Larvae



Total Larvae

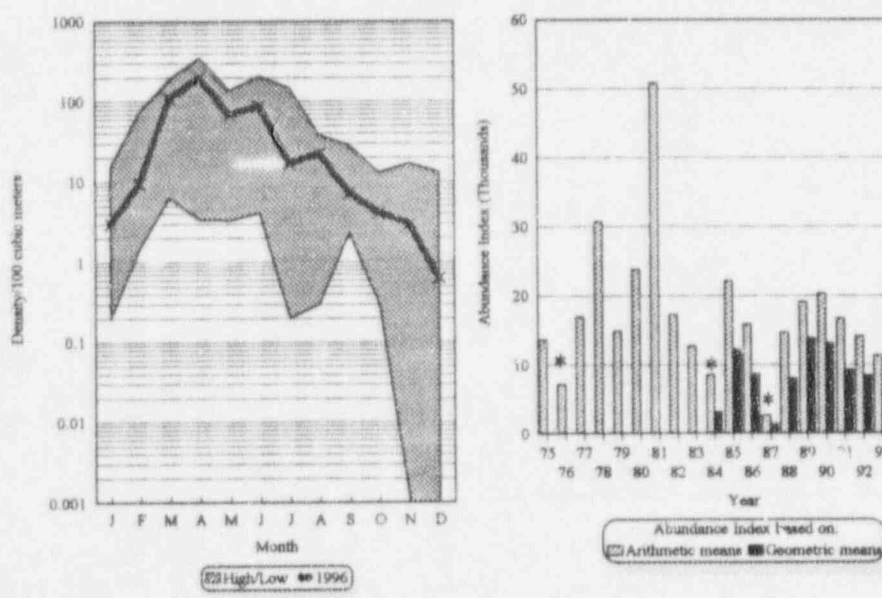


Table 2. Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-December 1996.

Species		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
American eel	*Anguilla rostrata*				L		L						
Alewife	*Alosa pseudoharengus*							L					
Atlantic menhaden	*Brevoortia tyrannus*					E	E/L	L	L	E/L	L		
Atlantic herring	*Clupea harengus*	L		L	L	L						L	L
Bay anchovy	*Anchoa mitchilli*							L		L			
Rainbow smelt	*Osmerus mordax*					L							
Fourbeard rockling	*Enchelyopus cimbrius*	E			E	E/L	E/L	E/L	E/L	E/L	E/L	L	
Atlantic cod	*Gadus morhua*		E	E/L	E/L	E/L	E/L	E/L					
Haddock	*Melanogrammus aeglefinus*				E								
Silver hake	*Merluccius bilinearis*						E/L	L	E/L	E/L	E/L		
Atlantic tomcod	*Microgadus tomcod*		L	L	L								
Hake	*Urophycis* spp.					E	E/L	E/L	E/L	L			
Goosefish	*Lophius americanus*						E/L	L					
Silversides	*Menidia* spp.					L	L	L	L				
Northern pipefish	*Syngnathus fuscus*						L	L	L			L	
Searobins	*Prionotus* spp.						E	E	E				
Grubby	*Myoxocephalus aenaeus*		L	L	L	L	L	L					
Longhorn sculpin	*M. octodecemspinosus*		L	L	L								L
Shorthorn sculpin	*M. scorpius*		L	L	L								
Lumpfish	*Cyclopterus lumpus*						L						
Seasnail	*Liparis atlanticus*				L	L	L	L					
Weakfish	*Cynoscion regalis*								L				
Wrasses	Labridae					E	E	E	E	E		E	

Table 2 (continued).

Species		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Tautog	*Tautoga onitis*						L	L	L	L	L		
Cunner	*Tautogolabrus adspersus*						L	L	L	L			
Snakeblenny	*Lumpenus lumpretaeformis*				L								
Radiated shanny	*Ulvaria subbifurcata*					L	L	L					
Rock gunnel	*Pholis gunnellus*	L	L	L	L	L							
Wrymouth	*Cryptacanthodes maculatus*			L		L							
Sand lance	*Ammodytes* sp.	L	L	L	L	L	L						L
Atlantic mackerel	*Scomber scombrus*					E/L	E/L	L	E				
Butterfish	*Peprilus triacanthus*								L	L			
Smallmouth flounder	*Etropus microstomus*					E	E	E	E	L			
Summer flounder	*Paralichthys dentatus*										L		
Fourspot flounder	*P. oblongus*					L			E/L	L			
Windowpane	*Scophthalmus aquosus*					E	E/L	E/L	E/L	E	L	E/L	
Witch flounder	*Glyptocephalus cynoglossus*			L		E/L	E/L	L					
American plaice	*Hippoglossoides platessoides*			E/L	E/L	E/L	E/L	L	E/L				
Winter flounder	*Pleuronectes americanus*			E	E/L	E/L	E/L	L					
Yellowtail flounder	*P. ferrugineus*	E			E	E	E/L	E/L					

Table 3. Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal, 1975-1996. 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	1996	Period of Occurrence
Anguilla rostrata	J[1]	J	J		J	J								J		J				J	J	J	Feb - Jun
Alosa spp.		L	L	J	L						L					J						L	May - Jul
Brevoortia tyrannus	E/L	E/L	L/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	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	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	L	Jun - Sep
A. mitchilli			E	E	E		E	E/L			E	E			E	E	E	E	E			L	Jun - Sep
Osmerus mordax	L	L	L	L	L		E/L	L	L		L	L	L	L	E/L			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	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	E/L	Jan(Nov) - (Dec)Dec
Melanogrammus aeglefinus	L	E/L	E/L	E/L	L				L		E			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	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	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	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	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	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	1996	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	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	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	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	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	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	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	L	Jan(Apr) - (Jun)Jul
L. atlanticus							L	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	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	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	L	May(Jun) - (Aug)Oct
Lumpenus lumpretaeformis	L						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	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	L	Jan(Feb) - (Apr)Jun
Cryptacanthodes maculatus				L	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	1996	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	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	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	L	May - Oct
Etropus microstomus	L								L		E	E/L	E		E		E	E	E		E/L	E/L	Jul - Oct
Paralichthys dentatus	E/L								E/L		L		E/L	E		L			E/L	E	E/L	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	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	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	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	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	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	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	41	

[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, three 1995 dates, and four 1996 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	570	1.11	
	June 28	1	17447	17658	1.01	
		2	16432	24925	1.52	
		3	21671	26357	1.22	
	1996					
	June 19	1	1959	2150	1.22	
		2	1739	2128	1.22	
		3	1382	1351	0.98	
	June 24	1	3637	4123	1.13	
		2	2572	3413	1.33	
		3	3865	2782	0.72	
		4	2893	3637	1.26	
	July 1	1	871	1092	1.25	
		2	495	850	1.72	
		3	959	794	0.83	
	July 5	1	4168	4388	1.05	
		2	3118	3963	1.27	
Geometric mean			465	605	1.30	0.001
95% confidence limits			175-1229	245-1506	1.12-1.51	
LARVAE						
	1994					
Stage 1	May 4	All	0	0	-	
	May 9	All	0	0	-	
	July 21	All	0	0	-	
	August 8	All	0	0	-	

Table 4 (continued).

	Date	Replicate	Mesh 0.333	0.202	Ratio	p[1]
	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	-	
	1996					
	June 19	1	8.4	2.2	0.26	
		2	10.2	26.8	2.63	
		3	5.4	12.7	2.35	
	June 24	1	3.0	5.8	1.93	
		2	3.0	2.1	0.70	
		3	4.1	3.1	0.76	
		4	5.0	9.7	1.94	
	July 1	1	20.8	5.0	0.24	
		2	13.0	15.9	1.22	
		3	14.6	5.1	0.35	
	July 5	1	0	0	-	
		2	0	1.4	-	
Geometric mean			7.7	8.5	1.10	>0.05
95% confidence limits			3.6-16.5	5.1-14.0	0.58-2.09	
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	-	
	1995					
	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	36.3	0.42	
	June 28	1	1.5	10.4	6.75	
		2	4.5	14.0	3.13	
		3	14.4	0	-	
	1996					
	June 19	1	1.8	2.2	1.22	
		2	1.7	6.7	3.94	
		3	2.7	3.3	1.22	

Table 4 (continued).

	Date	Replicate	Mesh 0.333	0.202	Ratio	p[1]
	1996					
	June 24	1	3.0	2.9	0.97	
		2	6.7	2.1	0.31	
		3	4.1	1.8	0.44	
		4	2.8	6.8	2.43	
	July 1	1	35.4	24.9	0.70	
		2	39.8	39.3	0.99	
		3	40.2	41.1	1.02	
	July 5	1	1.3	4.3	3.31	
		2	10.9	11.6	1.27	
Geometric mean			9.1	11.6	1.27	>0.05
95% confidence limits			4.5-18.2	6.6-20.4	0.83-1.95	
	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	-	
	1996					
	June 19	All	0	0	-	
	June 24	All	0	0	-	
	July 1	1	0	1.3	-	
		2	0	2.8	-	
		3	0	1.7	-	
	July 5	1	10.1	13.8	1.37	
		2	14.8	10.8	0.73	
Geometric mean			9.0	9.5	0.94	>0.052
95% confidence limits			6.6-12.3	6.9-10.[illegible]	0.53-1.68	

[1]p = paired t-test

SECTION VI

LITERATURE CITED

Anderson, R.D. 1986. Impingement of organisms at Pilgrim Nuclear Power Station (January-December 1985). In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 27. Boston Edison Company.

______. 1996. Impingement of organisms at Pilgrim Nuclear Power Station (January-December 1995). In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 47. Boston Edison Company.

Box, G.E.P., W.G. Hunter, and J.. Hunter. 1975. Statistics for Experimenters. John Wiley & Sons, New York.

Cohen, D.M. and J.G. Nielsen. 1978 Guide to the Identification of Genera of the Fish Order Ophidiiformes with a Tentative Classification of the Order. NOAA Technical Report NMFS Circular 417. 72p.

Lawton, R.P., B.C. Kelly, V.J. Malkoski, and J. Chisholm. 1995. Annual report on monitoring to assess impact of the Pilgrim Nuclear Power Station on selected finfish populations in western Cape Cod Bay. Project Report No. 58 (January-December 1994). IIIA.i-77. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual report No.45. Boston Edison Company.

MRI (Marine Research, Inc.). 1977. Entrainment investigations and Cape Cod Bay Ichthyoplankton Studies, July-September 1976. III.C 1-1-71. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 9. Boston Edison Company.

______ 1978. Entrainment investigations and Cape Cod Bay Ichthyoplankton Studies, March-December 1977. III.C.2-34-38. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 11. Boston Edison Company.

______ 1994. Ichthyoplankton entrainment monitoring at Pilgrim Nuclear Power Station January-December 1993. Volume 2 (Impact Perspective). IIIC.2.i-33. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 41. Boston Edison Company.

_____ 1996. Ichthyoplankton entrainment monitoring at Pilgrim Nuclear Power Station January-December 1995. Volume 1 (Monitoring). IIIC 1-67. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 47. Boston Edison Company.

Matthiessen, G.C. and M.D. Scherer. 1983. Observations on the seasonal occurrence, abundance, and distribution of larval lobsters (Homarus americanus) in Cape Cod Bay. p41-46 In: M.J. Fogarty (ed.). Distribution and relative abundance of American lobster, Homarus americanus, larvae: New England investigations during 1974-79. NOAA Technical Report NMFS SSRF-775.

NEFSC (Northeast Fisheries Science Center). 1996. Report of the 21st Northeast Regional Stock Assessment Workshop (21st SAW). Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fisheries Science Center Reference Document 96-05d. 200p.

NOAA (National Oceanic and Atmospheric Administration). 1995. Status of the Fishery Resources off the Northeastern United States for 1994. NOAA Technical Memorandum NMFS-NE-108. 140p.

Overholtz, W.J. 1993. Harvesting strategies and fishing mortality reference point comparisons for the Northwest Atlantic stock of Atlantic mackerel (Scomber scombrus). Canadian Journal of Fisheries and Aquatic Science 50:1749-1756.

Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. Biometrics 39:281-286.

Ryan, T.A., Jr. and B.L. Joiner. 1976. Normal probability plots and tests for normality. Minitab, Inc., State College, PA. 19p.

Scherer, M.D. 1984. The ichthyoplankton of Cape Cod Bay. In: J.D. Davis and D. Merriman (editors). Observations on the Ecology and Biology of Western Cape Cod Bay, Massachusetts. Lecture Notes on Coastal and Estuarine Studies. Volume II. Springer-Verlag, New York. 289p.

APPENDIX A*. Densities of fish eggs and larvae per 100 m^3 of water recorded ir the PNPS discharge canal by species, date, i replicate, January-December 1996.

*Available upon request.

APPENDIX B*. Geometric mean monthly densities and 95% confidence limits per 100 m³ of water for the dominant species of fish eggs and larvae entrained at PNPS, January-December 1984-1996.

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 1984 and 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 1996

Volume 2 of 2

(Impact Perspective)

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

April 1, 1997

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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 in 1996 involving Atlantic mackerel eggs and larvae, larval Atlantic menhaden, larval Atlantic herring, larval hake, larval sand lance, larval radiated shanny, and larval winter flounder. High densities occurred at least three times for each species, being particularly prolonged for larval sand lance, suggesting that production, survival, and/or retention were relatively high in the PNPS area during each respective season.

Total estimated egg entrainment at PNPS in 1996 ranged from 1,213,000 for searobins to 3,176,483,000 for the labrids, amounting to 5,442,814,000 for all eggs combined. Corresponding values for larvae ranged from 4,305,000 for seasnail to 340,701,000 for sand lance amounting to 630,010,000 for all larvae combined.

Equivalent adult analyses were completed for winter flounder, cunner, and Atlantic mackerel adding to analyses dating back to 1987. Estimates for 1996 were 1,392 or 15,727 age 3 winter flounder following two sets of survival parameters. These values were compared with available commercial and recreational landings as well as local population size determined by trawl; in each case losses were less than 9%. Respective EA estimates of 588,997 adult cunner and 10,593 age 1 mackerel or 6,822 age 3 mackerel potentially lost due to entrainment effects were also obtained. As for winter flounder, these estimates were compared with commercial, recreational, and local stock size estimates where available. For both species equivalent adult losses represented less than 1% of landing or stock size estimates.

No larval lobster were collected in 1996 bringing the 22-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 1996", Volume 1 - Monitoring. Work was conducted by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. LSP005524 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.

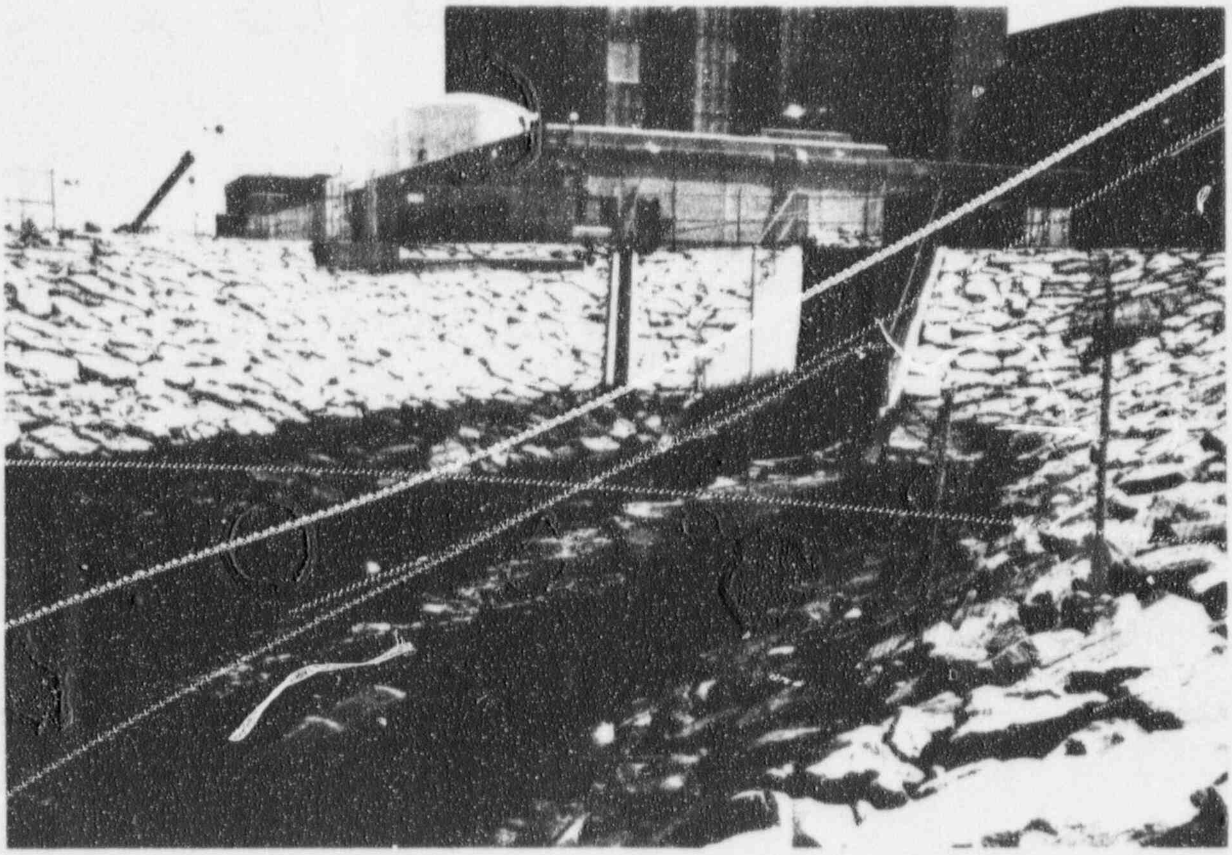

Plate 1. Plankton net streaming in the discharge canal at Pilgrim Station for the collection of fish eggs and larvae (lobster larvae are also recorded). A single, six-minute collection can contain several thousand eggs and larvae representing 20 or more species.

SECTION III

IMPACT PERSPECTIVE

A. Notification Plan

Ichthyoplankton densities reaching the unusually high level during 1996 occurred on a number of occasions. These involved Atlantic mackerel eggs and larvae, larval Atlantic menhaden, larval Atlantic herring, larval hake, larval sand lance, larval radiated shanny, and larval winter flounder (Table 1). Larval sand lance were found to be abundant on a number of occasions from January to mid-May. In January (337 larvae per 100 m^3) and May (639 per 100 m^3) single densities exceeded all previous values for those respective months. The protracted nature of the high sand lance densities suggests that larvae were abundant in the PNPS area in 1996 also indicating perhaps that spawning stock was high. For each of the remaining species high densities occurred at least three times during their period of occurrence suggesting that production, survival, and/or retention was relatively high for these species as well in 1996 in the PNPS area. In the case of mackerel larvae in May (59 per 100 m^3) and winter flounder larvae in June (154 per 100 m^3) densities exceeded all previous values for those respective months.

Table 1. Ichthyoplankton densities (number per 100 m³) for each sampling occasion during months when notably high densities were recorded, January-December 1996. 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

Jan	12	0
	15	0
	17	0
	22	0
	24	0.4
	26	337.0 + (100)

Previous high: 104 (1985)
Notice level: 11

March	4	38.3
	6	13.1
	8	0
	11	47.7
	13	74.2
	15	179.8 + (96)
	18	64.9
	20	8.4
	22	106.5
	25	388.5 + (98)
	27	178.6 + (96)
	29	52.0

Previous high: 511 (1994)
Notice level: 164

April	1	492.7
	3	1663.9 + (99)
	5	1360.7 + (98)
	8	1.5
	10	n.s.[1]
	12	490.0
	15	12.4
	17	130.8
	19	76.8
	22	14.6
	24	209.1
	26	443.3
	29	134.9

Previous high: 2591 (1994)
Notice level: 998

Sand lance larvae (continued)

May	1	639.1 + (100)
	3	n.s.
	6	137.7 + (95)
	8	96.4 + (95)
	10	187.3 + (97)
	13	48.7
	15	42.5
	17	8.6
	20	11.3
	22	24.0
	24	5.6
	27	3.9
	29	0
	31	1.7

Previous high: 368 (1978)
Notice level: 32

Atlantic mackerel eggs

May	1	0
	3	n.s.
	6	0
	8	4.0
	10	2.4
	13	13.8
	15	2932.0
	17	165.8
	20	36.8
	22	950.2
	24	2755.2
	27	5765.0 + (95)
	29	9745.8 + (97)
	31	6944.9 + (96)

Previous high: 192[illegible] (1995)
Notice level: 4031

Table 1 (continued).

Atlantic mackerel larvae

May	1	0
	3	n.s.
	6	0
	8	0
	10	0
	13	0
	15	0
	17	0
	20	0
	22	0
	24	0.8
	27	6.9 + (96)
	29	22.1 + (98)
	31	59.0 + (100)

Previous high: 26 (1991)
Notice level: 2

June	3	1318.2 + (98)
	5	46.8
	8	2.4
	10	6.5
	12	9.5
	14	14.0
	17	41.1
	19	4.8
	21	14.5
	24	8.9
	26	3.9
	28	1.3

Previous high: 2700 (1981)
Notice level: 155

Radiated shanny larvae

June	3	39.9 + (99)
	5	28.7 + (98)
	8	262.2 + (100)
	10	6.5
	12	4.0
	14	3.5
	17	8.8
	19	17.9 + (97)
	21	15.3 + (94)
	24	0
	26	7.3
	28	0.6

Previous high: 42 (1994)
Notice level: 15

Winter flounder larvae

June	3	5.2
	5	31.7 + (98)
	8	153.8 + (100)
	10	51.9 + (99)
	12	7.1
	14	16.3
	17	1.1
	19	0
	21	4.6
	24	11.1
	26	0
	28	0

Previous high: 110 (1974)
Notice level: 20

Table 1 (continued).

Hake larvae

Aug	2	2.6
	5	8.1
	7	0
	9	1.4
	12	0
	14	0
	16	19.0 + (95)
	19	2.0
	21	4.0
	23	0
	26	16.0 + (93)
	28	2.6
	30	130.7 + (98)

Previous high: 196 (1995)
Notice level: 9

Sept	2	n.s.
	4	7.0
	6	0
	9	5.0
	11	12.3 + (87)
	13	0
	16	2.3
	18	n.s.
	20	17.6 + (91)
	23	n.s.
	25	4.7
	27	30.6 + (97)
	30	75.2 + (99)

Previous high: 122 (1985)
Notice level: 10

Hake larvae

Oct	7	7.0 + (96)
	9	n.s.
	11	2.1
	17	1.7
	21	0
	23	0.8
	25	0

Previous high: 14 (1985)
Notice level: 2

Atlantic menhaden larvae

Oct	7	7.0 (93)
	9	n.s.
	11	6.2 + (91)
	17	10.3 + (95)
	21	0
	23	0
	25	10.2 + (95)

Previous high: 12 (1980)
Notice level: 1

Atlantic herring larvae

Nov	4	12.1 + (84)
	6	n.s.
	8	11.2 + (82)
	11	3.6
	18	6.2
	20	11.0 + (82)
	22	1.8

Previous high: 125 (1995)
Notice level: 8

[1]n.s. = No sample taken due to storm or high water.

Beginning in 1994 when the sampling protocol at PNPS was revised, sampling included regular collection of night-time entrainment samples. As covered under methods in Volume 1, these were taken on Friday typically between 2230 and 2330 hours. Depending upon time of sunset, Wednesday samples may also have been taken during darkness. It is possible that some of the unusually high densities noted in recent years can be attributed to time of day rather then an actual unusual occurrence. For example, from 1994 through 1996 unusually high densities have been recorded for larval sand lance on 27 occasions. Nine of those samples were taken on a Friday night, representing 33% of the high occurrences, exactly equal to what would be expected by chance alone. However, each of the samples exceeding all previous observations (n = 4) was taken on Friday nights. Dalley and Winters (1987) offer data suggesting that larval sand lance move upward in the water column at night which might make them more susceptible to entrainment. Entrainment densities have been shown to be significantly higher for some species at night at other locations also (see for example, MRI 1997).

B. Ichthyoplankton Entrainment - General

Ichthyoplankton entrainment at PNPS represents a direct negative environmental impact since fish eggs and larvae passing through the station are subjected to elevated water temperatures, shear forces, and periodic chlorination. In effect PNPS operates as a predator increasing overall mortality rates in western Cape Cod Bay. When PNPS is not on line, elevated temperature is not a factor but fish eggs and larvae 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%; MRI 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 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. 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). For cunner, mackerel, and winter flounder, egg and larval totals were calculated using individual densities and mesh adjustment where appropriate (see next section). Among the eight numerically dominant groups, numbers of eggs entrained ranged from 1,213,000 for searobins (Prionotus spp) to 3,176,483,000 for the labrids. Corresponding values among the thirteen dominant larval species varied from a low of 4,305,000 for seasnail (Liparis spp.) to a high of 340,701,000 for sand lance (Ammodytes spp.). For all eggs and larvae combined, values amounted to 3,844,456,000 and 630,010,0070 respectively. These totals state the extent to which large quantities of eggs and larvae can be entrained by the circulating seawater system at PNPS during a single year; all are presumably lost to the local population.

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 procedure (EA, see Horst 1976, Goodyear 1978, for example). Somewhat arbitrarily this review dates back to 1987 so that with the addition of 1996 ten years are included. The adult equivalent methodology applies estimated survival rates to numbers of eggs and larvae lost to entrainment to obtain a number

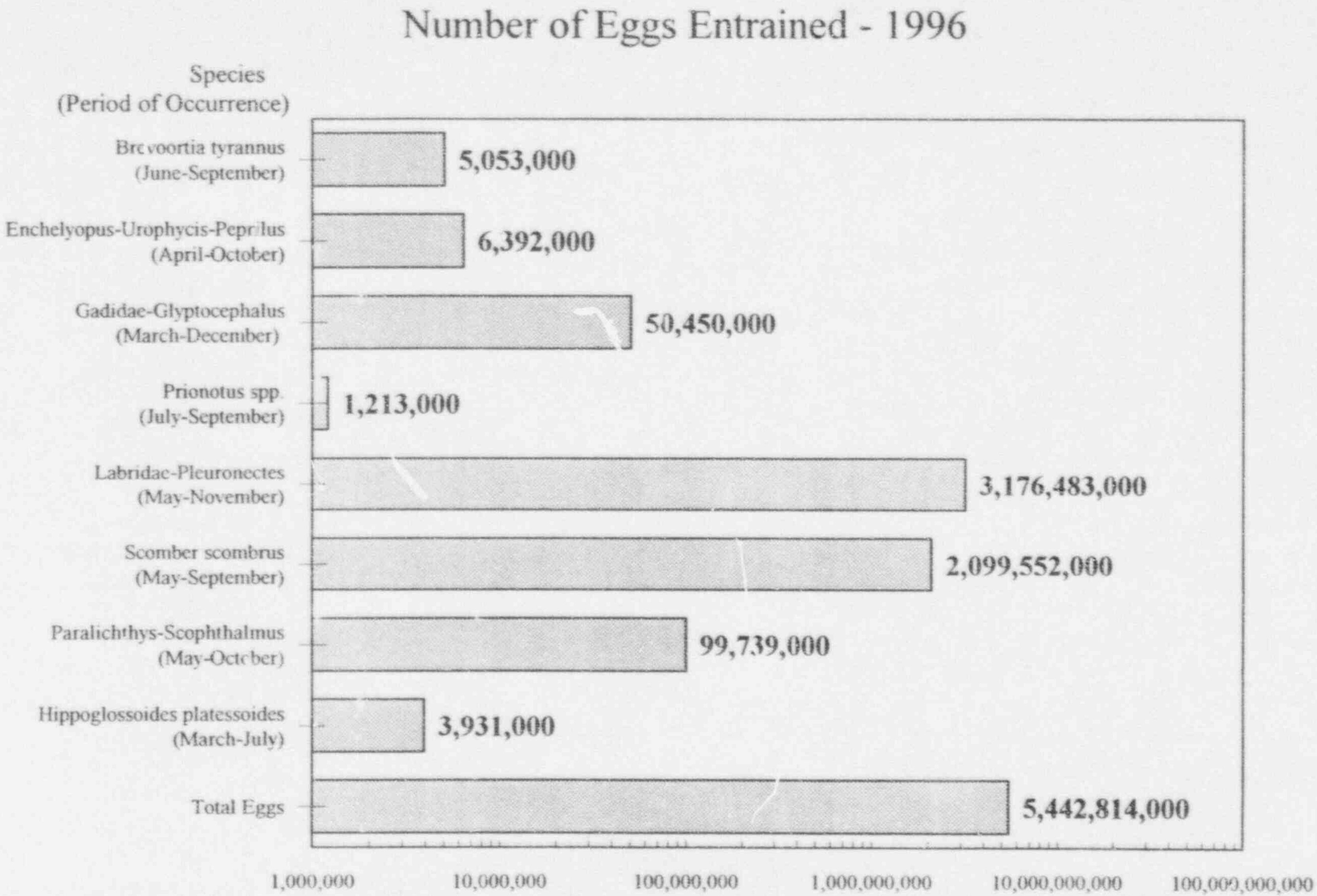

Figure 1. Number of eggs estimated to have been entrained by PNPS in 1996 had it operated at full pump flow by species or species groups (dominants only) including all egg species combined. The period of occurrence observed in 1996 is also indicated.

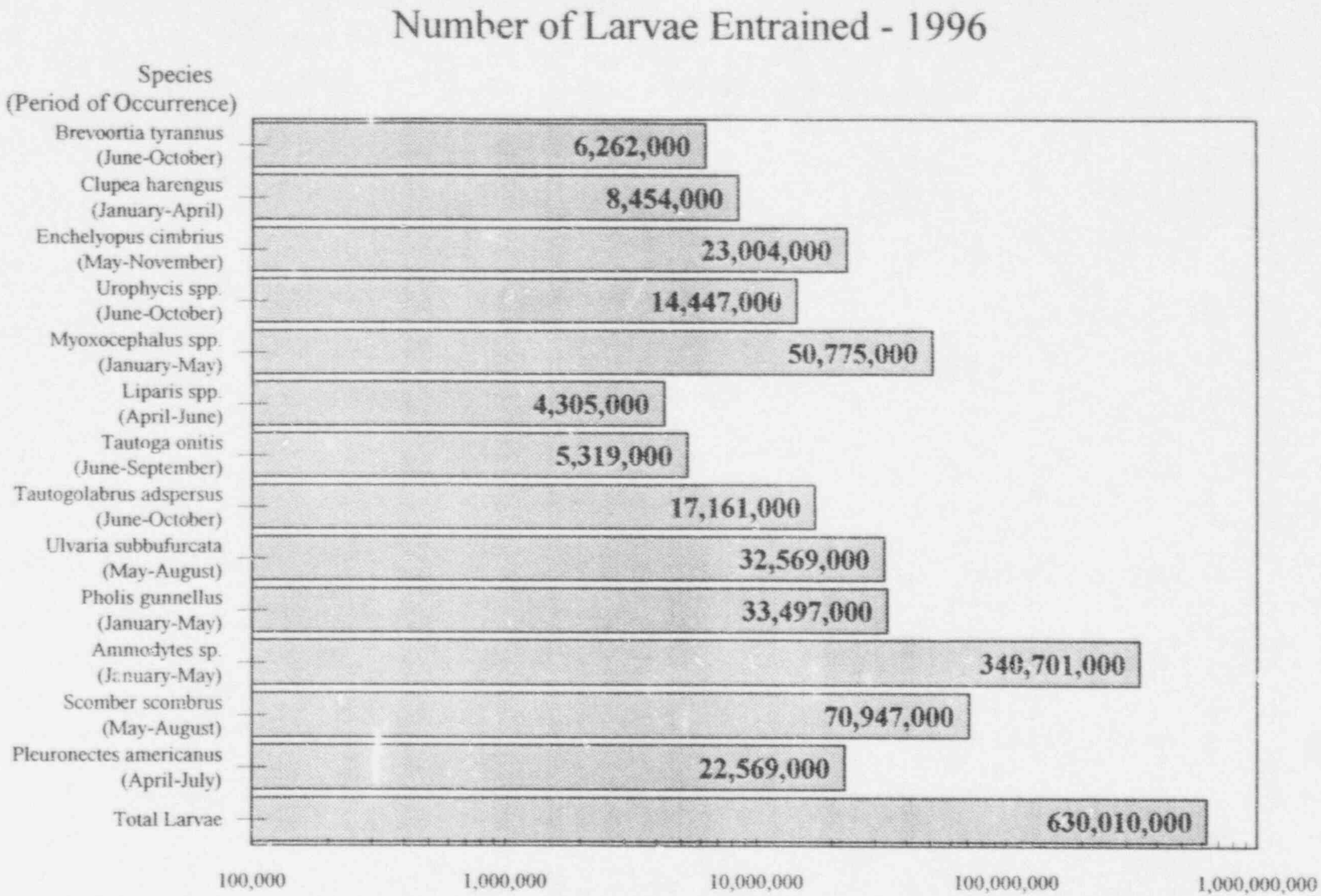

Figure 2. Numbers of larvae estimated to have been entrained by PNPS in 1996 had it operated at full pump flow for each dominant species including all larvae combined. The period of occurrence in 1996 is also indicated.

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 EA procedure. 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 (See Volume 1, Figures 3 and 4). 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. Beginning with April 1994 each individual sample density was utilized so that no averaging was necessary.

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 was assumed to occur.
3) PNPS was 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, cunner and Atlantic mackerel. 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 entrainment samples and in the local area and PNPS finfish studies have been focusing on that species which appeared to be in a declining trend from 1980 to 1994 (Lawton et al. 1995). Mackerel were included because they are abundant among the ichthyoplankton entrained, both eggs and larvae being removed from the local 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 1995). 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. However a comparison of samples from both studies showed stages to be quite comparable until larvae approach metamorphosis, a size not often collected. Although small numbers are entrained each year, flounder eggs were ignored because they are demersal and adhesive and not generally impacted by entrainment.

Recently Rose et al. (1996) presented information on a population dynamics model for winter flounder consisting of separate young-of-the-year and adult components. The young-of-the-year model includes survival rates for eggs, larvae, early and late juveniles stages. Since the model is designed to mathematically represent numbers of individuals as they develop from one stage to another, it is difficult to apply their survival rates to the mixed age pool of larvae entrained at PNPS. All individuals would need to be converted to hatched eggs as is done with the unstaged approach. By using a value of 0.09 to step back from mixed-up larvae to hatched eggs, the rates utilized by Rose et al. produce approximately twice as many fish as the staged survival values provided above. Since the staged survival values were adjusted by Gibson (1993a) to provide an equilibrium population this approach is believed to overestimate EA values.

The general, unstaged larval survival values produced an adult equivalent value of 1,392 age 3 fish for 1996 (Table 2). The stage-specific values produced an EA total over eleven times higher at 15,727 age 3 individuals. Based on a weight of 0.6 pounds per fish (Gibson 1993b), these values convert to 835 and 9,436 pounds, respectively. Comparable values for 1988-1995 ranged from 533 to 1,272 fish (mean = 814 fish, 488 pounds) for the general approach and 2,618 to 15,556 (mean = 8,088, 4,853 pounds) for the staged approach; 1987 was omitted here because sampling was not conducted during April that year during an outage period. Values for 1996 exceeded the previous high by 9% within the general, unstaged column, and by 1% within the staged larval column. The relatively high EA values are directly attributable to the relatively high number of larvae entrained in 1996 (see Volume 1). 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).

Table 2. Numbers of larval winter flounder entrained at PNPS annually by stage, 1987-1996. 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
1996	0.818	9.426	11.330	0.995	22.569	1392	15727
Mean	1.461	3.747	7.761	0.228	13.206	814	8088
S.E.	0.323	0.907	1.350	0.101	1.958	121	1577
w/o 1987	1.623	4.115	8.281	0.253	14.282	880	8695
S.E.	0.312	0.927	1.393	0.109	1.829	113	1627

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

[2]No April sampling, estimates therefore biased.

Over the 1988 through 1994[1] 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 pounds per fish, the average estimated loss of 528 or 5,217 pounds of equivalent adults represents 0.04 or 0.4% of those landings. Area 514 landings for 1994, the most recent year available, dropped sharply from those recorded in 1993 (328,706 vs 1,057,211 pounds) due to increased fishing restrictions and stock declines. EA values for that year alone amounted to 0.4% of the landings for the unstaged approach or 3.8% for the staged approach.

Winter flounder also have considerable value as a recreational species. Based on NOAA records[2] an annual average of 679,259 fish (s.e. = 271,439) weighing an average of about 1.3 pounds each were landed in Massachusetts from 1988-1995. More recently (1991-1995) recreational landings have been well below earlier years because of stock declines and area closures; an annual average of 272,995 fish (s.e. = 36,779) were reported landed in the state during that more recent period. Unfortunately these landings are compiled by state

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[1] Area 514 landings were not yet available for 1995 or 1996 at the time this report was prepared because NOAA was involved in a change in data methodology (Joan Palmer, NOAA, Woods Hole, MA personal communication).

[2] Recreational landings data were obtained via the internet at http://remora.ssp.nmfs.gov/mrfss.

and the number of fish taken from a more appropriate area such as Cape Cod Bay are not available. Arbitrarily adding 50,000 pounds of recreationally caught flounder to the 1994 commercial 514 landings would bring that total to 378,706 pounds and the EA values for that year to 0.3 for the general approach and 3.5% for the staged approach.

Massachusetts Division of Marine Fisheries personnel made estimates of the number of adult winter flounder (>280 mm TL - age 3+) in the vicinity of PNPS using area swept by a commercial trawl in 1995 and 1996 (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. These estimates equalled 61,915 in 1995, 92,147 in 1996 based on gear efficiency of 100%. These numbers would double if gear efficiency were closer to 50% as suggested by MDMF. EA estimates for 1995 and 1996 using the unstaged survival values and 50% efficiency amount to 0.8 and 0.8% of those respective values. EA estimates with the staged values amount to 8.0 and 8.5%, respectively.

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 (1.29 for eggs, none required for larvae) were first applied. From 1988 to 1995 the ratio averaged 0.0184; 1987 was excluded because of extended circulating seawater 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^ (-0.164 (t + 0.869))] 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 588,667 cunner potentially lost to entrainment effects in 1996. Comparable values for 1987-1995 ranged from 228,449 to 1,508,080 adults averaging 657,401 (s.e. = 130,539) over the 10-year period (Table 3).

Cunner have no commercial value and little recreational importance (although many may be taken unintentionally by shore fishermen) so that current landing records are not available. To shed some light on their abundance in the PNPS area, calculations were performed to estimate the number of adult cunner which would be necessary to produce the number of eggs found there. The PNPS area was defined by Cape Cod Bay sampling stations 2,3,4,7,8 (MRI 1978), the half-tide volume of which was estimated by planimetry from NOAA chart 1208 at 22,541,000 100 m^3 units. Labrid egg densities were obtained at those stations on a weekly basis in 1975; they were integrated over time (April-December) using the mean density of the five stations. The integrated values were multiplied by 1.40 to account for extrusion through the 0.505-mm

Table 3. Numbers of cunner eggs and larvae entrained at PNPS annually, 1987-1996. Numbers of equivalent adults are also shown.

	Total Number Entrained ($x10^6$)					Equivalent Year
		Larvae				
	Eggs[1]	Stage 1[2]	Stage 2[2]	Stage 3	Total	Adults
1987	4645.627	0.288	0.310	0.244	0.843	672,710
1988	1601.149	2.170	2.595	2.462	7.227	285,821
1989	4649.634	32.346	15.102	2.864	50.311	1,058,146
1990	1389.921	62.309	61.893	44.020	168.223	1,508,080
1991	702.218	5.493	3.681	7.246	16.421	228,449
1992	2262.349	0	1.175	1.606	2.782	346,048
1993	3365.774	0.077	7.119	7.927	15.123	600,285
1994	1621.086	0	5.500	4.435	9.935	309,746
1995	4282.479	7.550	29.677	9.258	46.485	975,729
1996	3176.483	3.571	8.031	5.559	17.161	588,997
Mean	2769.672	11.380	13.508	8.562	33.451	657,401
S.E.	459.263	6.445	6.039	4.046	15.900	130,539

[1]Mesh adjustment = 1.40

[2]Mesh adjustment = 1.00

mesh used in that survey (MRI unpublished), then by the sector volume. Based on the 0.333/0.202-mm 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 annual mean loss of 657,401 fish due to PNPS operation represents 0.19% of that value.

Massachusetts Division of Marine Fisheries personnel have chosen cunner as an indicator species for PNPS impact investigations. Tagging studies were conducted during the 1994-1996 seasons to estimate the size of the cunner population in the immediate PNPS area. Minimum tagging size and therefore the minimum size fish enumerated was 90 mm TL. Estimates were highly localized since individual cunner have a very small home range measured on the order of 100 m^2 or less (Pottle and Green 1979). Estimated population size for the outer breakwater and intake areas combined were 7,408 and 9,300 for the two respective years. Combining upper 95% confidence limits produced totals of 10,037 and 11,696 fish, respectively. Since the upper confidence limit total is only 0.003% of the egg based population estimate, it is clear that eggs must arrive at PNPS from areas removed from the immediate vicinity of the Station. A hydrodynamic modeling study completed by Eric Adams (see section III.A) predicted that 90% of the cunner eggs and larvae entrained at PNPS come from within about 5.5 miles of PNPS to the north to White Horse Beach, about one mile to the south. This area extends further to the north than the area 2,3,4,7,8 used in the above egg estimates. The number of eggs entrained indicate that cunner must be abundant in these waters.

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. 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 0.02763 (1988-1995) provided a larva-to-age 1 survival rate of 8.21462E-5. A mesh adjustment factor of 1.56 was applied to the egg data based on 1994 mesh comparison collections (MRI 1995). 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 fishing mortality rate of F = 0.02 (NOAA 1995). These values provide an annual survival rate of S = 0.8025.

Equivalent adult estimates for 1996 amounted to 10,593 age 1 fish or 6,822 age 3 fish. These compare with an annual average of 9,436 (s.e. = 2,678) and 6,077 (s.e. = 1,724) age 1 and 3 individuals, respectively, over the 1988-1995 period. Data from 1987 were omitted here because sampling was not conducted during April of that year during an outage period. Converting numbers of fish to weight using 0.2 and 0.7 pounds per individual (Clayton et al. 1978) resulted in an estimated average annual loss of 1,887 or 4,254 pounds, respectively (1987 excluded). Weight values for 1996 alone were 2,119 pounds of age 1 fish ,4,775 pounds of age 3 fish.

Table 4. Numbers of Atlantic mackerel eggs and larvae entrained at PNPS annually, 1987-1996. Numbers of equivalent age 1 and 3 fish are also shown.

Year	Total Entrained ($x10^6$) Eggs[1]	Larvae	Equivalent Adults Age 1	Age 3
1987[2]	117.146	0.281	289	186
1988	3710.026	3.401	8700	5603
1989	6510.097	65.562	20162	12984
1990	3222.258	4.627	7694	4955
1991	668.240	66.009	6939	4469
1992	525.958	8.086	1858	1197
1993	2509.062	8.326	6379	4108
1994	725.563	3.419	1928	1241
1995	2462.027	197.690	21828	14057
1996	2099.552	70.947	10593	6822
Mean	2254.993	42.835	8637	5562
S.E.	611.983	19.608	2310	1488
Mean w/o 1987	2492.532	47.563	9564	6160
S.E.	630.574.83121.275		2365	1523

[1]Mesh adjustment = 1.56 for eggs.

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 1,887 pounds of age 1 fish (1987-1996) amounts to 0.6% of those landings and the loss of 4,254 pounds of age 3 fish, 1.3%. In addition to commerical landings, mackerel have considerable recreational value. For example, over the years 1987-1995 an average of 1,616,720 fish (s.e. = 285,820) were landed in Massachusetts with an average weight of about one pound. Unfortunately these landings are available only by state and therefore the portion attributable to Cape Cod Bay is not known. Arbitrarily adding 500,000 one-pound fish to the commercial landings brings the harvest total to 834,806 pounds and the EA total to 0.2 and 0.5%, respectively.

SECTION IV

LITERATURE CITED

Clayton, G., C. Cole, S. Murawski and J. Parrish. 1978. Common marine fishes of coastal Massachusetts. Massachusetts Cooperative Extension Service, Amherst, Massachusetts. 231p.

Dalley, E.L. and G.H. Winters. 1987. Early life history of sand lance (Ammodytes) with evidence for spawning A. dubius in Fortune Bay, Newfoundland. Fishery Bulletin U.S. 85(3):631-641.

Ecological Analysts, Inc. 1981. Entrainment survival studies. Research Report EP 9-11. Submitted to Empire State Electric Energy Research Corporation, New York.

Gibson, M.R. 1993a. Population dynamics of winter flounder in Mt. Hope Bay in relation to operations at the Brayton Point electric plant. Rhode Island Division Fish and Wildlife, West Kingston, R.I.

————. 1993b. Stock assessment of winter flounder in Rhode Island, 1992: A report to the RI Marine Fisheries Council. Rhode Island Division Fish and Wildlife. Res. Ref. Doc. 93/1.

Goodyear, C.P. 1978. Entrainment impact estimates using the equivalent adult approach. U.S. Fish and Wildlife Service, Biological Service Project. FWS/OBS-78/65. 14p.

Griswold, C.A. and M.J. Silverman. 1992. Fecundity of the Atlantic mackerel (Scomber scombrus) in the Northwest Atlantic in 1987. Journal of Northwest Atlantic Fisheries Science 12:35-40.

Horst, T.J. 1975. The assessment of impact due to entrainment of ichthyoplankton. In: Fisheries and Energy Production: A Symposium. S.B. Saila, ed. D.C. Heath and Company, Lexington, Mass. p107-118.

Johansen, F. 1925. Natural history of the cunner (Tautogolabrus adspersus Walbaum). Contribution to Canadian Biology new series 2:423-467.

Lawton, R.P., B.C. Kelly, V.J. Malkoski, and J. Chisholm. 1995. Annual report on monitoring to assess impact of the Pilgrim Nuclear Power Station on selected finfish populations in western Cape Cod Bay. Project Report No. 58 (January-December 1994). IIIA.i-77. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual report No.45. Boston Edison Company.

Marine Research, Inc. 1978. Entrainment investigations and Cape Cod Bay ichthyoplankton studies, March 1970-June 1972 and March 1974-July 1977. Volume 2, V.1-44. In: Marine Ecology Studies Related to Operation of Pilgrim Station. Final Report. July 1969-December 1977. Boston Edison Company.

______. 1982. Supplementary winter flounder egg studies conducted at Pilgrim Nuclear Power Station, March-May 1982. Submitted to Boston Edison Company. 4p.

______. 1995. Ichthyoplankton entrainment monitoring at Pilgrim Nuclear Power Station January-December 1994. Volume 1 (Monitoring) IIIC.i-57. In: Marine Ecology Studies Related to Operation of Pilgrim Station, Semi-annual Report No. 45. Boston Edison Company.

______. 1997. Ichthyoplankton entrainment monitoring at Manchester Street Station, Providence, Rhode Island, 1996. Prepared for New England Power Company, Westborough, Mass.

Neja, Z. 1992. Maturation and fecundity of mackerel, (Scomber scombrus L.) in Northwest Atlantic. Acta Ichthyol. Piscatoria 22(1):125-140.

NEP (New England Power Company). 1978. Environmental report NEP 1 and 2. Volume 4, Appendix G. Charlestown site study (unpublished).

NOAA (National Oceanic and Atmospheric Administration). 1995. Status of Fishery Resources off the Northeastern United States for 1993. NOAA Technical Memorandum NMFS-NE-108. 140p.

NUSCO (Northeast Utilities Service Company. 1993. Monitoring the marine environment of Long Island Sound at Millstone Nuclear Power Station, Waterford CT. Annual Report.

Overholtz, W.J., S.A. Muraski, W.L. Michaels, and L.M. Dery. 1988. The effects of density dependent population mechanisms on assessment advice for the northwest Atlantic mackerel stock. Woods Hole, MA: NMFS, NEFC. NOAA Technical Memorandum NMFS-F/NED-62. 49p.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder *Pseudopleuronectes americanus*. Bulletin of Bingham Oceanographic Collection 18:1-78.

Pottle, R.A. and J.M. Green. 1979. Territorial behaviour of the north temperate labrid, *Tautogolabrus adspersus*. Canadian Journal of Zoology 57(12):2337-2347.

Rose, K.A., J.A. Tyler, R.C. Chambers, G. Klein-MacPhee, and D.J. Danila. 1996. Simulating winter flounder population dynamics using coupled individual-based young-of-the-year and age-structured adult models. Canadian Journal of Fisheries and Aquatic Sciences 53(5):1071-1091.

Saila, S.B. 1976. Effects of power plant entrainment on winter flounder populations near Millstone Point. URI-NUSCO Report No. 5.

Scherer, M.D. 1984. The ichthyoplankton of Cape Cod Bay. In: J.D. Davis and D. Merriman (eds.). Observations on the Ecology and Biology of Western Cape Cod Bay, Massachusetts. Lecture Notes on Coastal and Estuarine Studies. Volume II. Springer-Verlag, New York. 289p.

Serchuk, F.M. and C.F. Cole. 1974. Age and growth of the cunner, *Tautogolabrus adspersus*, in the Weweantic River estuary, Mass. Chesapeake Science 15(4):205-213.

Vaughan,D.S. and S.B. Saila. 1976. A method for determining mortality rates using the Leslie matrix. Transactions of the American Fisheries Society 3:380-383.

Witherell, D.B. and J. Burnett. 1993. Growth and maturation of winter flounder, *Pleuronectes americanus*, in Massachusetts. Fishery Bulletin U.S. 91(4):816-820.

IMPINGEMENT OF ORGANISMS AT

PILGRIM NUCLEAR POWER STATION

(January - December 1996)

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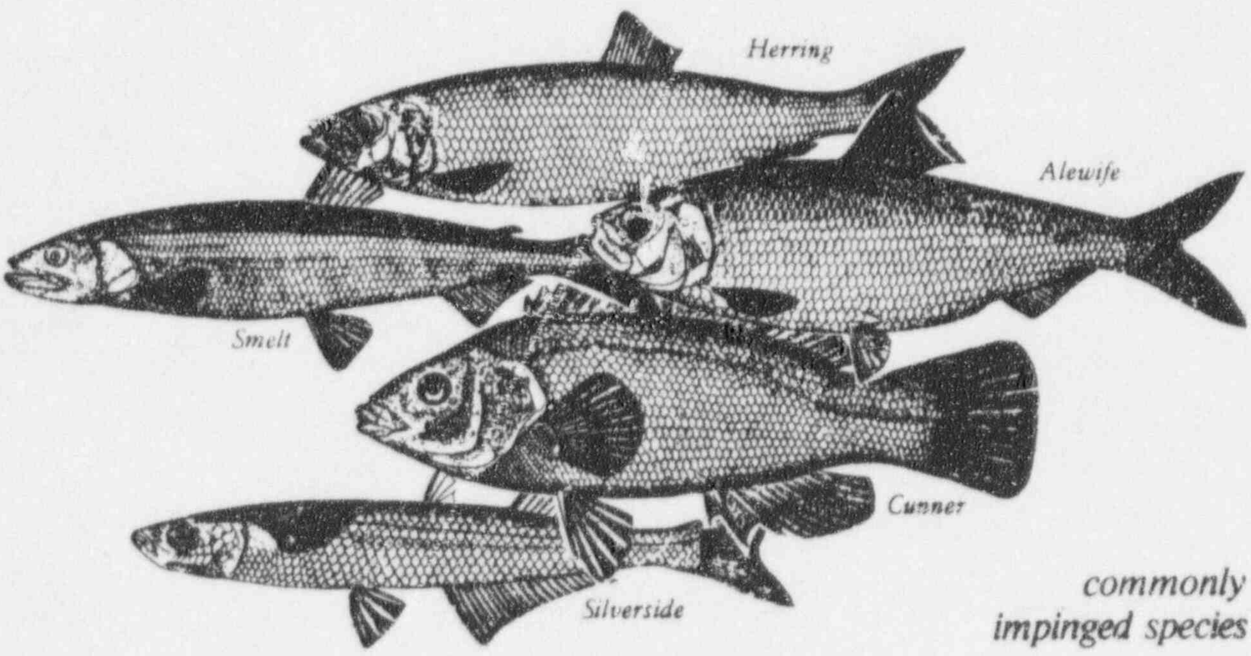
April 1997



commonly impinged species

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SECTION I

SUMMARY

Fish impingement rate averaged 3.11 fish/hour during the period January-December 1996, which is considerably lower than the past couple of years partially because of no large impingement incidents. Atlantic silverside (Menidia menidia) accounted for 59.2% of the fishes collected followed by rainbow smelt (Osmerus mordax) at 13.5%. Atlantic menhaden (Brevoortia tyrannus) and blueback herring (Alosa aestivalis) represented 5.8 and 4.5%, respectively, of the fishes impinged. The peak period was March/April when fish impingement was dominated by Atlantic silversides. This time period is typical for high silverside impingement. Initial impingement survival for all fishes from static screen wash collections was approximately 61% and from continuous screen washes 67%.

At 100% yearly (January-December) operation of Pilgrim Nuclear Power Station (PNPS) the estimated annual impingement was 27,318 fishes. The PNPS capacity factor was 90.5% during 1996.

The collection rate (no./hr.) for all invertebrates captured from January-December 1996 was 2.24. Sevenspine bay shrimp (Crangon septemspinosa) were most numerous. Green crab (Carcinus maenus) and rock crab (Cancer irroratus) accounted for 6.1 and 5.3%, respectively, of the invertebrates impinged and enumerated. Mixed species of algae collected on intake screens amounted to 2,718 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 traveling water screens of 3/8 inch wire mesh (Figure 2). There are two traveling 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, Unit I. The report describes impingement of organisms and survival of fishes carried onto the vertical traveling water screens at Unit I. It presents analysis of the relationships among impingement, environmental factors, and plant operational variables.

This report is based on data collected from screen wash samples during January-December 1996.

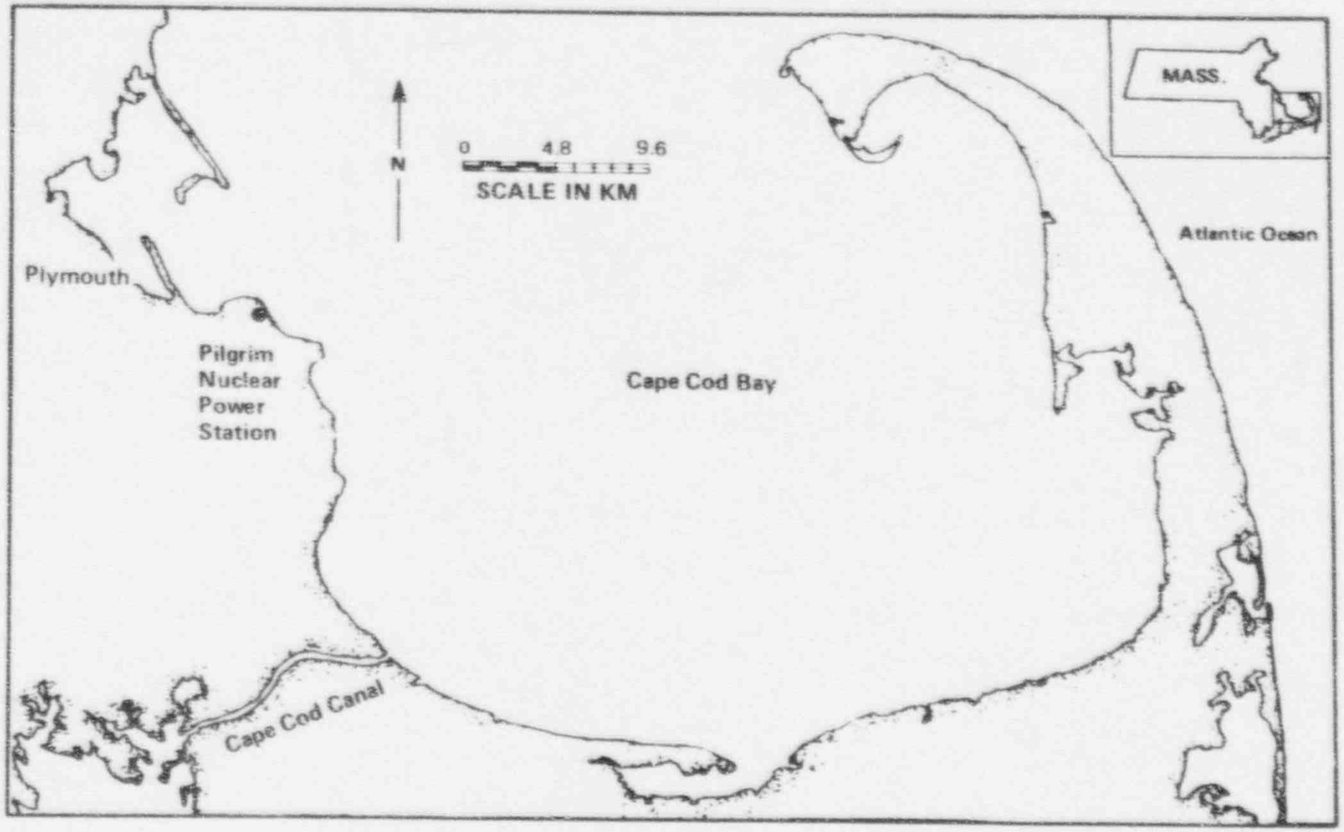

Figure 1. Location of Pilgrim Nuclear Power Station.

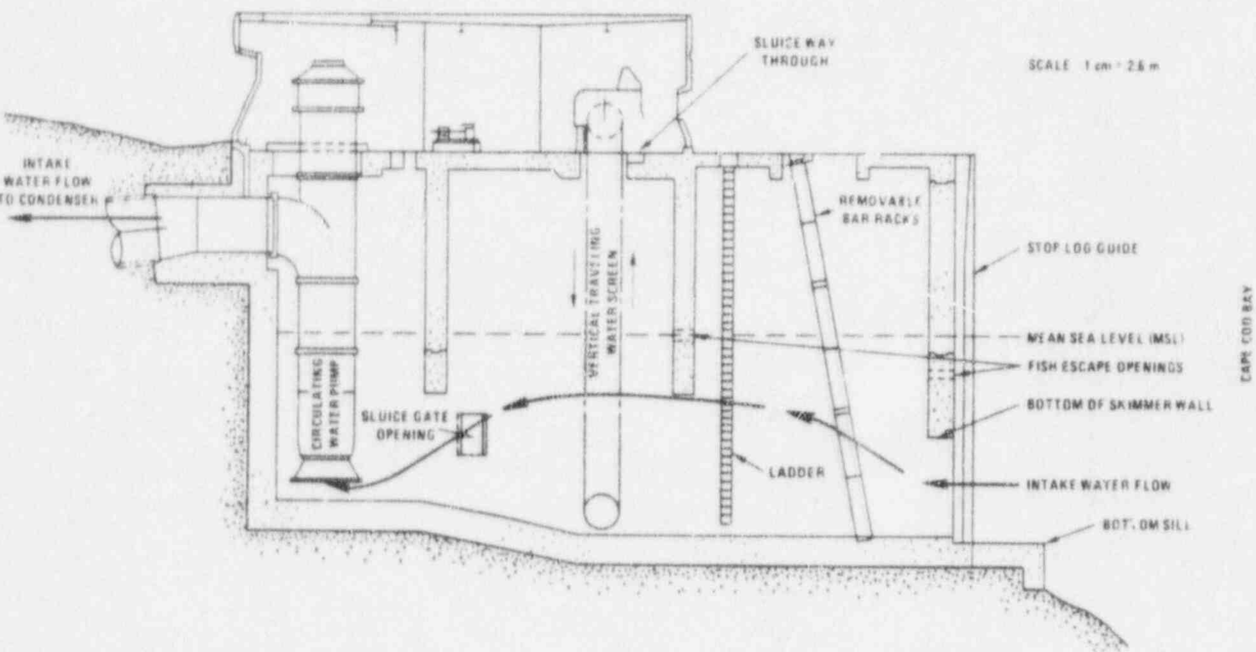

Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-December 1996 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 traveling 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, in the screenhouse, 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 416 collection hours, 1,292 fishes of 25 species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January - December 1996. The collection rate was 3.11 fish/hour. This annual impingement rate was relatively low compared to the last two years, 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. Atlantic silverside was the most abundant species in 1996 accounting for 59.2% of all fishes collected, followed by rainbow smelt at 13.5% (Table 2). Atlantic menhaden (Brevoortia tyrannus) and blueback herring (Alosa aestivalis) accounted for 5.8 and 4.5% of the total number of fishes collected and identified to lowest taxon.

Atlantic silverside occurred most predominately in monthly samples from March and April. Hourly collection rates per month for them ranged from 0 to 9.96. Silverside impinged in March/April accounted for 65% of all this species captured in impingement collections from January-December 1996. They averaged 97 mm total length and 5 grams in weight. Their impingement indicated no relationship to tidal stage or diel factors. They are usually the dominant fish in the annual impingement catch, being the most abundant species caught in six of the last ten years. Impingement histories of abundant species impinged at Pilgrim Station in 1996, over the past 10 years, are documented in Table 3.

Rainbow smelt were very abundant in November and December 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.

Table 1. Monthly Impingment for All Fishes Collected from Pilgrim Station Intake Screens, January - December 1996

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Atlantic silverside	8	30	226	269	114	1			5	7	75	30	765
Rainbow smelt	3		2	2				1	5	5	69	87	174
Atlantic menhaden								1	35	10	28	1	75
Blueback herring			1				2		2	53			58
Grubby	5	2	5	14	2	1		1	1	4	12	10	57
Winter flounder	8	3	5	5	1			3			10	6	41
Tautog											12	13	25
Atlantic tomcod										8	3	3	14
Windowpane	1		1	1		1					3	6	13
Alewife								2	2		6	1	11
Cunner	1			1		1		1		5	1		10
Lumpfish						1						7	8
White perch	3								1	1	1	1	7
Northern pipefish			3	2								1	6
Rock gunnel			1	5									6
Red hake				1	1		2					1	5
Threespine stickleback			1	1								2	4
Atlantic moonfish								1	2				3
Striped bass												3	3
Silver hake											2		2
Butterfish										1			1
Little skate						1							1
Longhorn sculpin											1		1
Radiated shanny	1												1
Striped killifish	1												1
Totals	31	35	245	301	118	6	4	10	53	94	223	172	1,292
Collection Time (hrs.)	26	60	35	27	47	27	33	40	19	17	56	29	416
Collection Rate (#/hr.)	1.19	0.58	7.00	11.15	2.51	0.22	0.12	0.25	2.79	5.53	3.98	5.93	3.11

Table 2 - Species, Number, Total Length (mm), Weight (gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January - December 1996

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent Of Total Fish
Atlantic silverside	765	63-150	97	1-17	5	59.2
Rainbow smelt	174	71-199	114	2-43	9	13.5
Atlantic menhaden	75	58-106	79	2-10	5	5.8
Blueback herring	58	49-94	69	1-7	3	4.5
Grubby	57	41-141	70	1-34	5	4.4
Winter flounder	41	51-321	100	-	-	3.2
Tautog	25	49-86	59	2-10	4	1.9
Atlantic tomcod	14	114-179	146	14-47	25	1.1
Windowpane	13	36-255	108	-	-	1.0
Alewife	11	66-110	81	2-9	4	0.9
Cunner	10	46-175	107	1-104	33	0.8
Lumpfish	8	29-66	43	1-14	5	0.6
White perch	7	103-152	127	10-41	24	0.5
Northern pipefish	6	125-192	165	1-3	2	0.5
Rock gunnel	6	58-165	123	1-13	6	0.5
Red hake	5	57-108	82	1-6	4	0.4
Threespine stickleback	4	42-72	60	1-3	3	0.3
Atlantic moonfish	3	55-60	57	2-3	2	0.2
Striped bass	3	300	300	-	-	0.2
Silver hake	2	199-242	221	49-72	61	0.2
Butterfish	1	28	28	-	-	0.1
Little skate	1	492	492	-	-	0.1
Longhorn sculpin	1	100	100	11	11	0.1
Radiated shanny	1	53	53	1	1	0.1
Striped killifish	1	83	83	6	6	0.1

Table 3. Annual Impingement collections (1987 - 1996) for the 10 Most Abundant Fishes From Pilgrim Station Intake Screens During January - December 1996

Number of Impinged fishes Collected From January - December

Species	1987*	1988**	1989	1990	1991	1992	1993	1994+	1995++	1996	Totals
Atlantic silverside	27	35	120	457	275	232	720	3,112	1,100	765	6,843
Rainbow smelt	41	11	39	38	41	2[illegible]	735	896	162	174	2,162
Atlantic menhaden	0	4	82	345	113	2	4	14	73	75	712
Blueback herring	1	2	15	103	31	11	25	24	87	58	357
Grubby	5	5	29	59	46	43	51	98	45	57	438
Winter flounder	10	11	42	31	67	72	90	90	92	41	546
Tautog	5	2	12	6	18	9	23	4	5	25	109
Atlantic tomcod	5	31	17	26	16	11	26	14	15	14	175
Windowpane	2	0	6	15	11	3	10	14	10	13	84
Alewife	4	8	8	131	24	22	52	11	1,871	11	2,142
Totals	100	109	370	1,211	642	430	1,736	4,277	3,460	1,233	13,568
Collection Time (hrs.)	527	525	618	919.50	930.25+	774	673.5	737.39	607.67	416	6,599.91+
Collection Rate (#/hr.)	0.19	0.21	0.60	1.32	0.69	0.55	2.58	5.80	5.69	2.96	2.06

* 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.

Atlantic menhaden were relatively prevalent in September-November samples and have been most prevalent in the fall period, ranking third in 1986/1991 and second in 1989/1990. Generally, it has been one of the less abundantly impinged fish over the years.

Blueback herring impingement occurred predominately in October accounting for 91% of the total. 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 1996 are illustrated in Figure 3.

There were several small fish impingement incidents (20 fish or greater/hr.) at Pilgrim Station in 1996 (March, October, November and December) when mostly Atlantic silversides were recorded, but impingement rates rapidly decreased upon subsequent samplings indicating minimal impact. There were no large fish impingement incidents (1,000 fish or greater) in 1996 on intake screens. Most large fish impingement mortalities have occurred while both circulating water pumps were operating.

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.

Fish impingement rate at Pilgrim Station has been shown to be related to the number of circulating water pumps operating, in general (Lawton, Anderson et al,1984b). Reduced pump operation has lowered total impingement, particularly during the April to mid-August 1984 and portions of the mid-February to August 1987 periods when no circulating water pumps were operating for extended time frames.

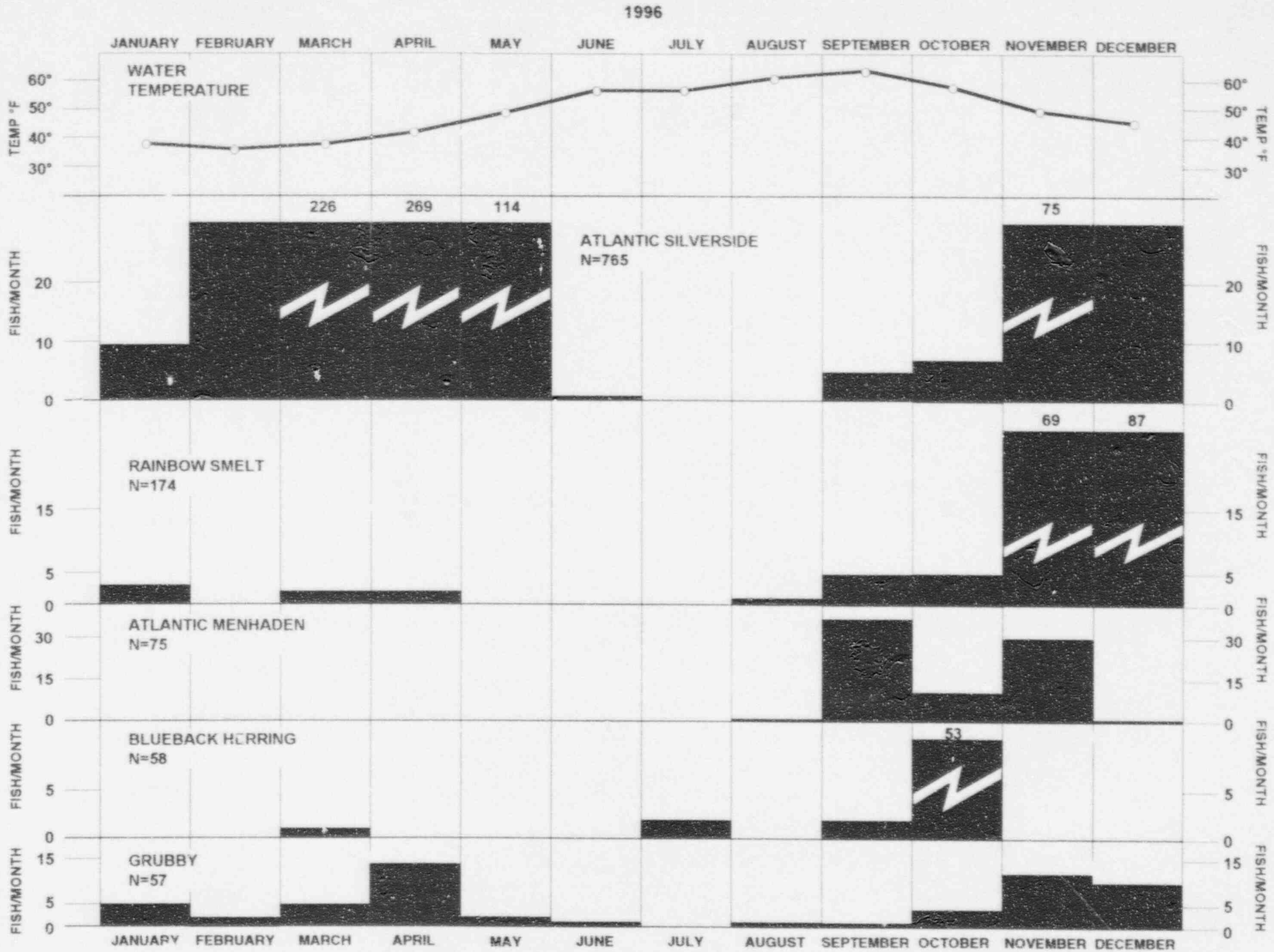

Figure 3. Trends Of Intake Water Temperature, And Number Of Fish Captured By Month From Pilgrim Station Intake Screens For The Five Most Abundant Species Collected, January - December 1996.

Table 4. Approximate Number and Cause for Dominant Species of Most Notable Fish Mortalities at Pilgrim Nuclear Power Station, 1973-1996

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

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 operation years) than in 1989 - 1996, 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 1989-1996 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 1996. 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 3.11, 74.64 and 27,318. The yearly rate of 27,318 is fairly normal and only 130% of the last 20-years' (1977-1996) mean annual projection of 20,954 fishes (Table 6). This was considerably lower than the 1994 and 1995 rates which were the highest yearly fish impingement rates since 1981 and greatly exceeded 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.

Over the past 20-year period (1977-1996), Pilgrim Station has had a mean impingement rate of 2.39 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

Table 5. Impingement Rates Per Hour, Day and Year For All Fishes Collected From Pilgrim Station Intake Screens During January - December 1996. Assuming 100% Operation of Pilgrim Unit 1*

Species	Rate/Hr.	Rate/Day	Rate/January-December 1996	Dominant Months Of Occurrence
Atlantic silverside	1.84	44.13	16,153	March/April
Rainbow smelt	0.42	10.04	3,674	December
Atlantic menhaden	0.18	4.33	1,584	September
Blueback herring	0.14	3.35	1,225	October
Grubby	0.14	3.29	1,204	April/November
Winter Flounder	0.10	2.37	866	November
Tautog	0.06	1.44	528	November/December
Atlantic tomcod	0.03	0.81	296	October
Windowpane	0.03	0.75	275	December
Alewife	0.03	0.63	232	November
Cunner	0.02	0.58	211	October
Lumpfish	0.02	0.46	169	December
White perch	0.02	0.40	148	January
Northern pipefish	0.01	0.35	127	March
Rock gunnel	0.01	0.35	127	April
Red hake	0.01	0.29	106	July
Threespine stickleback	0.01	0.23	84	December
Atlantic moonfish	0.07	0.17	63	September
Striped bass	0.07	0.17	63	December
Silver hake	0.005	0.12	42	November
Butterfish	0.002	0.06	21	June
Little skate	0.002	0.06	21	June
Longhorn sculpin	0.002	0.06	21	November
Radiated shanny	0.002	0.06	21	January
Striped killifish	0.002	0.06	21	January
Totals	3.11	74.64	27,318	

*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 1977-1996, Assuming 100% Operation of Pilgrim Unit 1*

Year	Rate/Hr.	Rate/Day	Rate/Year	Dominant Species (Rate/Year)
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)
1996	3.11	74.64	27,318	Atlantic silverside (16,153)
Means	2.39	57.41	20,954	

*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.

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. Recently, Normandeau Associates (1996) compared fish impingement at several marine power plant intakes which demonstrated Pilgrim rates to be among the lowest with the exception of incidents that involve one or two species occasionally. However, in terms of the number of fish species impinged, Pilgrim Station displays a greater variety than most 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 normal during most of 1996 compared to the mean monthly temperatures for the 10-year interval 1987-1996 (Table 7). During the fall of 1996, water temperatures were generally higher than this 10-year period, particularly during September and December whose monthly means were the highest recorded in that period.

Overall, 1990/1995 displayed relatively warm water temperatures, 1987/1989/1991/1994/1996 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 1996, with the warmer water species Atlantic menhaden and blueback herring also being well represented.

4.2. Invertebrates

In 416 collection hours, 933 invertebrates of 16 species (Table 8) were recorded from Pilgrim Station intake screens between January-December 1996. The annual collection rate was 2.24 invertebrates/hour. Sevenspine bay shrimp (Crangon septemspinosa) dominated, being

Table 7. Monthly Means of Intake Temperature (°F) Recorded During Impingement Collections at Pilgrim Nuclear Power Station, 1987 - 1996

Month	1996	1995	1994	1993	1992	1991	1990	1989	1988	1987	($\bar{X}$) 1987-1996
January	37.15	41.13	28.21	37.36	36.24	37.56	36.45	38.42	36.80	38.42	36.89
February	35.82	36.61	29.18	32.21	34.32	36.70	38.15	42.97	36.00	38.71	35.84
March	37.38	39.51	30.91	35.24	36.53	39.72	37.87	38.43	36.20	40.70	37.36
April	41.83	41.67	37.95	41.16	43.42	44.46	46.63	41.37	41.30	*	42.72
May	48.56	48.77	44.26	48.33	51.56	53.79	50.86	48.70	48.79	*	49.40
June	56.03	56.43	45.21	52.70	54.21	60.09	53.63	57.38	50.21	56.68	54.46
July	56.08	58.14	56.85	56.78	55.94	61.67	61.24	61.57	52.83	63.00	58.41
August	60.78	67.31	59.34	53.66	60.40	58.49	64.71	59.80	58.75	*	60.55
September	62.92	62.37	60.45	50.55	57.42	58.63	63.35	58.62	56.86	58.21	59.46
October	57.50	57.93	63.33	43.96	53.83	52.00	55.13	53.92	52.31	52.73	54.61
November	49.63	50.61	55.78	39.97	50.85	47.88	47.88	45.60	47.17	47.49	48.61
December	45.18	40.33	44.88	34.53	43.06	41.74	42.86	35.58	38.90	41.30	40.98
Mean											48.27

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

radmisc/chart

Table 8. Monthly Impingment for All Invertebrates Collected from Pilgrim Station Intake Screens January - December 1996

Species	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Sevenspine bay shrimp	124	109	329	161	2					1	3	5	734
Green crab	5		1	1				5	5	7	21	12	57
Rock crab	1	1	2	3	1	2	3	9	7	10	7	3	49
American lobster	1					2		6	4	12	5	2	32
Nereis sp.	7	15	3	1		1		1					28
Longfin squid					1	1	1	2	2	3			10
Horseshoe crab						4	2		1				7
Common starfish					1	1	2					1	5
Green sea urchin			1								1	1	3
Polychaete	1	1											2
Actinaria								1					1
Glycerid			1										1
Isopoda						1							1
Lady crab										1			1
Orbinid			1										1
Stomatopoda											1		1
Totals	139	126	338	166	5	12	8	24	19	34	38	24	933
Collection Time (hrs.)	26	60	35	27	47	27	33	40	19	17	56	29	416
Collection Rate (#/hr.)	5.35	2.10	9.66	6.15	0.11	0.44	0.24	0.60	1.00	2.00	0.68	0.83	2.24

captured in greatest numbers from January - April. Green crab (Carcinus maenus) and rock crab (Cancer irroratus) represented 6.1 and 5.3%, respectively, of the total invertebrates enumerated. Unlike the fishes, the 1987 and 1988 invertebrate impingement rates were comparable to 1989 - 1996 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 - 1996 several thermal backwashes were performed and blue mussel impingement was minor for those years. During 1996 aggressive biofouling control activities included three effective thermal backwashes during the months of April, June and September.

Green crabs were the second most abundant invertebrate impinged, peaking in November. Rock crabs were third, being most represented in October. Thirty-two specimens of the commercially important American lobster were captured in 1996 ranking them fourth. This equals 676 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 20-70 mm carapace length and were impinged mostly in October.

Approximately 2,718 pounds of mixed algae species were recorded during impingement sampling, for a rate of 6.53 pounds/hr. This equates to 29 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, 1994, and 1995, and lower than 1993 which experienced very adverse meterological conditions of high winds and coastal storms (particularly in December).

4.3 Fish Survival

Fish survival data collected in 1996 while impingement monitoring are shown in Table 9. Continuous screenwash collections provided the fewest numbers of fishes and revealed an overall survival rate of approximately 67%. Fishes collected during static screen washes fared worse showing a survival rate of 61%. The relatively high initial survival rate for static screen washes, compared with most years previous to 1991, was influenced by the high initial survival of Atlantic silverside which were impinged in abundant numbers. As illustrated in 1993-1996, 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 1996, six demonstrated initial survival rates of 50% or greater. Grubby showed 100% survival, winter flounder 93%, alewife18%, Atlantic silverside 72%, tautog 100%, rainbow smelt 11%, Atlantic tomcod 43%, Atlantic menhaden 37%, windowpane 69%, and blueback herring 66%. 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 small fish impingement incidents in March and the fall of 1996.

Table 9. Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January - December 1996. Initial Survival Numbers are Shown Under Static (8-Hour) and Continuous Wash Cycles

Species	Number Collected		Number Surviving		Total Length (mm)	
	Static Washes	Cont. Washes	Static	Cont.	Mean	Range
Atlantic silverside	566	199	404	144	97	63-150
Rainbow smelt	135	39	10	10	114	71-199
Atlantic menhaden	53	22	18	10	79	58-106
Blueback herring	4	54	0	38	69	49-94
Grubby	42	15	42	15	70	41-141
Winter flounder	30	11	28	10	100	51-321
Tautog	8	17	8	17	59	49-86
Atlantic tomcod	5	9	4	2	146	114-179
Windowpane	6	7	5	4	108	36-255
Alewife	6	5	0	2	81	66-110
Cunner	3	7	0	4	107	46-175
Lumpfish	1	7	1	6	43	29-66
White perch	4	3	3	2	127	103-152
Northern pipefish	2	4	2	4	165	125-192
Rock gunnel	3	3	3	1	123	58-165
Red hake	5	0	1	-	82	57-108
Threespine stickleback	0	4	-	3	60	42-72
Atlantic moonfish	2	1	2	1	57	55-60
Striped bass	2	1	0	1	300	300
Silver hake	2	0	1	-	221	199-242
Butterfish	0	1	-	1	28	28
Little skate	1	0	1	-	492	492
Longhorn sculpin	1	0	1	-	100	100
Radiated shanny	0	1	-	1	53	53
Striped killifish	1	0	1	-	83	83
All Species:	882	410	535	276		
Number (% Surviving)			(60.7)	(67.3)		

SECTION 5

CONCLUSIONS

1. The average Pilgrim impingement rate for the period January-December 1996 was 3.11 fish/hour. The impingement rates for fish in 1984, 1987, and 1988 were several times lower than in 1989-1996 because of much reduced circulating water pump capacity during the former years..

2. Twenty-five species of fish were recorded in 416 impingement collection hours during 1996. In 1989-1996 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 1996 impingement rate was 27,318 fishes. This projected annual fish impingement rate was much lower than 1994 and 1995 rates 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 Atlantic silverside, 59.2%; rainbow smelt, 13.5%, Atlantic menhaden, 5.8%; and blueback herring, 4.5%.

5. The peak in impingement collections occurred during March/April when 65% of the annual catch of Atlantic silverside occurred.

6. Monthly intake water temperatures, which generally reflect ambient water temperatures, were typical for most of 1996 of the ten-year monthly averages for the period 1987-1996, with the fall period being warmer than normal.

7. The hourly collection rate for invertebrates was 2.24. Sevenspine bay shrimp dominated because of large winter collections. Green crab and rock crab were 6.1 and 5.3% of the enumerated catch. Thirty-two American lobsters were collected which equates to a potential 1996 impingement of 676 lobsters.

8. Impinged fish initial survival was approximately 61% during static screen washes and 67% during continuous washes for pooled species. Of the ten f..nes impinged in greatest numbers during 1996, six showed initial survival rates of 50% or greater.

SECTION 6

LITERATURE CITED

American Fisheries Society. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. Spec. Pub. No. 16: 277 pp.

_____. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada. decapod crustaceans. Spec. Pub. No. 17:77 pp.

_____. 1991a. A list of common and scientific names of fishes from the United States and Canada. Spec. Pub. No. 20: 183 pp.

_____. 1991b. Common and scientific names of aquatic invertebrates from the United States and Canada: cnidaria and ctenophora. Spec. Pub. No. 22: 75pp.

Anderson, C.O., Jr., D.J. Brown, B.A. Ketschke, E. M. Elliott and P. L. Rule. 1975. The effects of the addition of a fourth generating unit at the Salem Harbor Electric Generating Station on the marine ecosystem of Salem Harbor. Mass. Div. Mar. Fish., Boston: 47 pp.

Briges, W.L. and R. D. Anderson. 1984a. A brief survey of Pilgrim Nuclear Power Plant effects upon the marine aquatic environment, p. 263-271. In: J. D. Davis and D. Merriman (editors), Observations on the ecology and biology of western Cape Cod Bay, Massachusetts, 289 pp. Springer - Verlag. (Lecture Notes on Coastal and Esturaine Studies, Vol. 11).

Lawton, R. P., R. D. Anderson, P. Brady, C. Sheehan, W. Sides, E. Koulokeras, M. Borgatti, and V. Malkoski. 1984b. Fishes of western inshore Cape Cod Bay: studies in the vicinity of the Rocky Point shoreline, P. 191-230. In: J. D. Davis and D. Merriman (editors), Observations on the ecology and biology of western Cape Cod Bay, Massachusetts, 289 pp. Springer-Verlag. (Lecture Notes on Coastal and Esuarine Studies, Vol. 11).

Normandeau Associates. 1996. Seabrook Station 1995 environmental studies in the Hampton - Seabrook area: a characterization of environmental conditions during the operation of Seabrook Station. Section 5.0 - Fish. Northeast Utilities Service Company: 103 pp.

Stupka, R. C. and R. K. Sharma. 1977. Survey of fish impingement at power plants in the United States Vol. III. Estuaries and Coastal waters. Argonne National Lab.: 310 pp.

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The Commonwealth of Massachusetts

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TO: Members of the Administrative-Technical Committee, Pilgrim Power Plant Investigations
From: John Boardman, Recording Secretary
Subject: Minutes from the 86th meeting of the A-T Committee
Date: September 17, 1996

The 86th meeting of the A-T Committee was called to order by Gerry Szal at 10:15.

I. Minutes of 85th meeting

Bob Maietta motioned to accept the minutes; Bob Anderson seconded. The minutes were accepted unanimously with no changes.

II. Pilgrim Station 1995-1996 operational review

Bob Anderson presented the current Pilgrim Nuclear Power Station (PNPS) operational status to the Committee. The plant operated at approximately 93% capacity from January to August 1996. This was the best production over an eight month period since operation commenced. Bob told the committee the Semi-annual Marine Ecology report should be out by the end of October. He reported that PNPS has had no significant impingements in 1996. Bob informed the Committee a planned refueling outage will take place in February. The outage will not take place in April or May, as the Committee suggested, because of a low supply of fuel at the plant. Bob explained that high operating levels in 1995/1996 have depleted the nuclear fuel supply more quickly than anticipated. However, future outages will be scheduled in April or May (on a two year basis) whenever possible. Bob also confirmed that Boston Edison Co. will grant the Massachusetts Division of Marine Fisheries (DMF) $5000 as mitigation for an alewife impingement last September at the plant. The money will be used in repairing a local fish ladder.

III. Benthic Monitoring Program

Bob Anderson and Bob Lawton summarized a letter from Don Miller to the A-T Committee. The protocol for QAQC and the benthic sampling proposal for 1997 will be sent to the Benthic Subcommittee for review. The A-T Committee voiced their concerns about the insufficient data collected by the benthic divers regarding the outfall area size and mussel sets in 1996. These recent sampling problems were discussed. Bob Anderson confirmed that the sampling problems will be addressed before the next quarterly dive. The committee agreed that the consistent high operating level at PNPS was probably a primary factor effecting the increased size of the outfall area. Cost ≈ $32,000 for 1997.

IV. **Marine Fisheries Monitoring**

Bob Lawton presented to the Committee the proposed smelt work for 1997, which will again focus on spawning habitat enhancement in the Jones River. Egg trays (n = ca. 200 trays) will be deployed in the Jones River to collect the smelt's demersal, adhesive eggs. Bob stated that egg survival on plant material is much higher than on hard bottom. He also explained that egg survival is the most sensitive parameter driving future smelt population growth.

Bob then discussed the winter flounder work. DMF has been tagging winter flounder with Petersen disc tags to determine the discreetness of the local winter flounder population. In the spring of 1995, ca. 2,500 winter flounder were tagged. This spring, 5,000 flounder were tagged. He also mentioned the 1997 flounder study area will be expanded further north, following a modelling analysis completed by Eric Adams of M.I.T..

Next, Bob addressed the cunner work. He told the Committee that estimating cunner absolute abundance would have to be done ledge by ledge throughout the study area. The size, heterogeneous composition of the study area, and limited personnel make estimating abundance of the local population infeasible.

Bob told the Committee his project would continue to collect trap catch/effort data and to age selected cunner to generate catch at age data which will be used to estimate natural mortality needed for the adult equivalent model.

To address PNPS impact on cunner, DMF will continue Paul Nitschke's work on recruitment. Bob described the sampling protocol at the three fixed sampling stations to the Committee.

He noted that the creel data from the Pilgrim shorefront will continue to be collected and reported. Underwater visual observations of fish and other biota will be made using SCUBA off the discharge canal in the plume area during the summer and early fall. Two dives also will be made during the winter to look for overwintering striped bass or other species.

The committee approved and endorsed by unanimous vote Bob's proposal for 1997. Cost ≈ $275,000 for 1997.

V. **Impingement Monitoring**

Bob Anderson reported that the impingement rate for the first six months of 1996 has averaged 3 fish per hour. There have been no significant impingement incidents during this time period. The Atlantic silverside was the most abundant species impinged. Bob informed the Committee that the plant installed a differential alarm system. This system allows more continuous wash samples to be taken. The Committee was somewhat concerned about this system. Bob assured the Committee that the intake screens would be monitored for any significant numbers of impinged fish. Bob also mentioned that Mike Scherer, to date, has not collected the large number of fish needed to begin the proposed tagging study of the recycling of impinged fish. Bob Maietta motioned to continue the impingement monitoring program. The motion was accepted unanimously. Cost ≈ $30,000 for 1997.

VI. **Entrainment Monitoring**

The Committee reviewed Mike Scherer's letter on cunner egg and larval entrainment. The Committee accepted Mike's suggestion to use a .333 mesh plankton net instead of a .202 mesh to collect cunner larvae. However, the Committee was unclear about Mike's recommendation regarding mesh size for egg entrainment collections. The Committee concluded that Carolyn Griswold would ask Mike for clarification on this matter. The Committee agreed to accept the other facets of the entrainment monitoring program including the sampling schedule. Cost ≈ $70,000 for 1997.

VII. **Barrier Net**

The Committee concurred on keeping the barrier net out of the discharge canal again in 1997.

VIII. **Other Business**

Bob Lawton nominated Jack Parr as chairperson of the Benthic Subcommittee. Bob Maietta seconded the motion. The committee endorsed Jack Parr as chairperson for 1997.

Bob Anderson asked Gerry Szal to send a letter to members of the A-T Committee regarding the importance of attending meetings.

Gerry agreed to contact Leigh Bridges and discuss plans to initiate a new monograph for publication.

Bob Anderson informed the committee that the dredging of the intake embayment would take place this winter. Public notice would be given in about two weeks. Approximately 45,000 to 50,000 square yards of material will be removed from the area closest to the intake. The material will be deposited at an offshore disposal site. The outer half of the intake embayment, also scheduled for dredging, did not completely pass the biological testing requirements. Dredging plans for this area are not yet finalized.

IX. The meeting adjourned at 14:55.

X. Attendees at the 86th meeting of the A-T Committee:

DEP -	Gerry Szal Bob Maietta
DMF -	Bob Lawton John Boardman
PNPS -	Bob Anderson
NMFS -	Carolyn Griswold

PILGRIM NUCLEAR POWER PLANT

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