Boston Edison

Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

Henry V. Oheim
General Manager - Technical Section

October 22, 1996
BECo 96-074

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

NPDES PERMIT MARINE ECOLOGY MONITORING REPORT

Dear Sirs:

In accordance with Part I, Paragraphs A.8.b. & e, and Attachment A, Paragraph I.F, of the Pilgrim Nuclear Power Station NPDES Permit No. MA0003557(Federal) and No. 359 (State), Semi-Annual Marine Ecology Report No. 48 is submitted. This covers the period from January through June, 1996.

H. V. Oheim

H. V. Oheim

Attachment: Semi-Annual Marine Ecology Report No. 48

HVO/RDA/nas/ECOLRPT

IE25 1/1

Boston Edison

Pilgrim Nuclear Power Station
Rocky Hill Road
Plymouth, Massachusetts 02360

Henry V. Oheim
General Manager - Technical Section

October 22, 1996
BECo 96-074

NPDES Programs (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. 48 is submitted. This covers the period from January through June, 1996.

H. V. Oheim

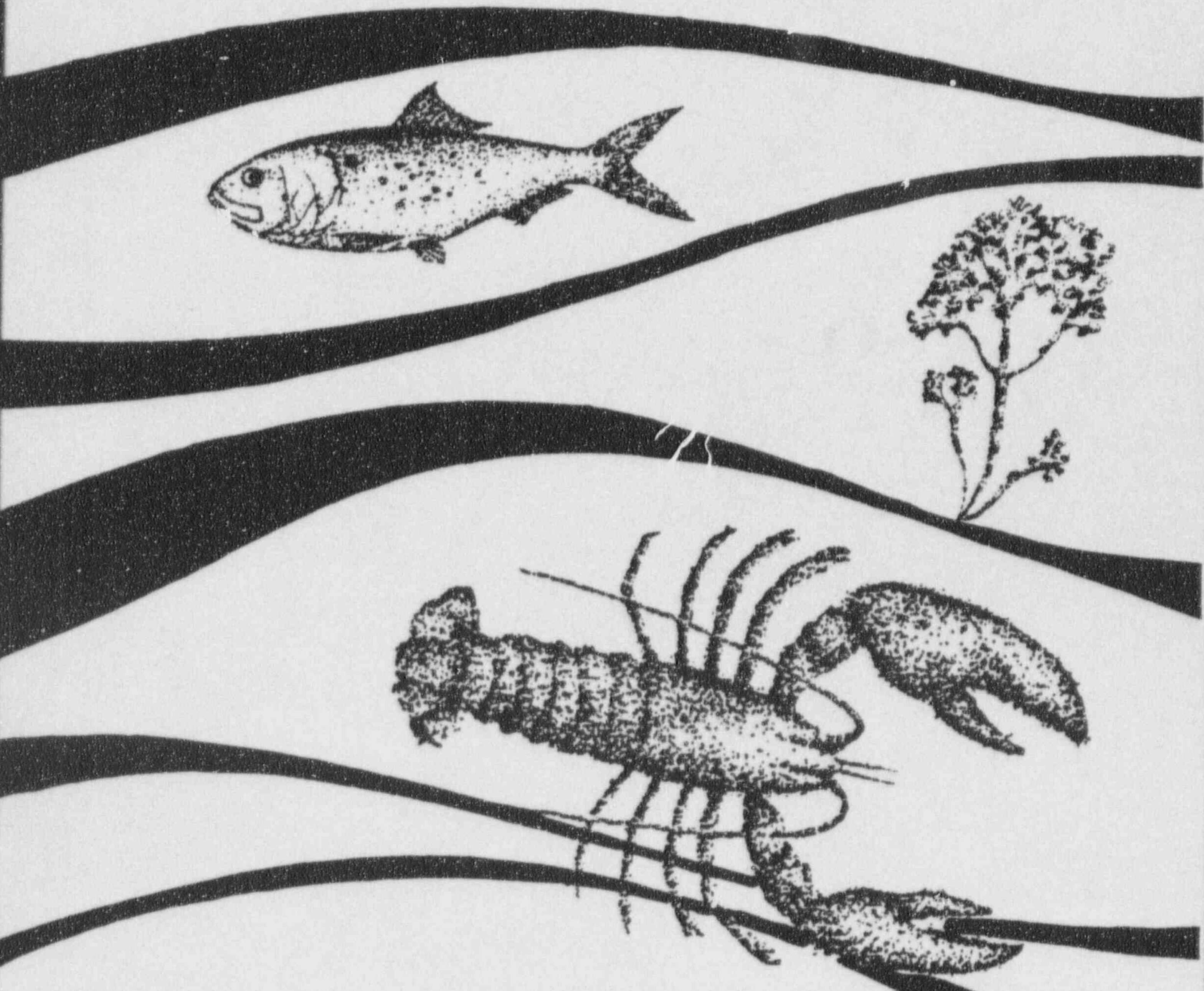
Attachment: Semi-Annual Marine Ecology Report No. 48

HVO/RDA/nas/ECOLRPT

marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 48
JANUARY 1996 - JUNE 1996



BOSTON EDISON COMPANY
REGULATORY AFFAIRS DEPARTMENT

Boston Edison

MARINE ECOLOGY STUDIES

RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 48

REPORT PERIOD: JANUARY 1996 THROUGH JUNE 1996

DATE OF ISSUE: OCTOBER 31, 1996

Compiled and Reviewed by: Robert D. Anderson

Robert D. Anderson
Principal Marine Biologist

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

TABLE OF CONTENTS

SUMMARY

Highlights of the environmental surveillance and monitoring program results obtained over this reporting period (January - June 1996) are presented below. (Note: PNPS was in high power operation during most of this period.)

Marine Fisheries Monitoring:

1. Yankee trawls during April 1996, in Plymouth Bay, for winter flounder stock assessment work were performed to determine population parameters with 4,997 fish marked. One hundred and eight recaptures have been recorded in 1996. Techniques for sampling young-of-the-year winter flounder for spawning success/year class strength studies were terminated due to lack of success with them.

2. In the April to June 1996, shorefront recreational fishery creel survey, 664 anglers caught 942 fish for a catch rate of 1.4 fish per angler. Striped bass (836) and bluefish (106) were the only species recorded.

3. Rainbow smelt spawning habitat enhancement of the Jones River (Kingston), to mitigate for the high PNPS smelt impingements in recent years, accounted for an increased egg set and ultimately hatching success to supplement the River's spawning population of this species. This effort also determined that the Jones River was the Plymouth Bay area's primary smelt spawning tributary in 1996.

4. The cunner trapping study concentrated on aging and mark/recapture for population estimation, as well as recruitment dynamics. No tagged cunner were released in June 1996, but 18 were recaptured from 1995.

Impingement Monitoring:

1. The mean January - June 1996 impingement collection rate was 3.32 fish/hr. The rate ranged from 0.22 fish/hr (June) to 11.15 fish/hr (April) with Atlantic silverside comprising 88.0% of the catch, followed by grubby, 3.9%, winter flounder, 3.0%, and rainbow smelt, 0.9%.

2. For April 1996, when the fish impingement rate was 11.15, Atlantic silverside accounted for 89% of the fishes collected. Fish impingement rate was notably higher in 1989-1996 than in 1988 (0.30), primarily because Pilgrim Station had much less circulating water pump capacity than normal that year.

3. The mean January - June 1996 invertebrate collection rate was 3.54/hr with sevenspine bay shrimp (92.2%) and sand worms (3.4%) dominating the catch. Three American lobsters were caught.

4. Impinged fish initial survival at the end of the Pilgrim Station intake sluiceway was approximately 77% for static washes and 82% for continuous washes.

Benthic Monitoring

April and June 1996 mappings of the discharge effluent, near-shore acute impact zones were performed. The largest total affected areas to date were evident for both April (2,436m^2) and June (>3,473m^2) indicating continuing impact since the 1986 - 1988 PNPS outage. In June a dense mat of juvenile blue mussels (5-20mm length) blanketed large portions of the Chondrus (Irish moss) sparse/stunted zones as was also apparent in June of 1990 and 1992-1995, possibly because of consistent thermal discharge during these periods.

Entrainment Monitoring:

1. A total of 34 species of fish eggs and/or larvae were found in the January - June 1996 entrainment collections: 16 eggs, 30 larvae.

2. Egg collections for January - April 1996 (winter-early spring spawning) were dominated by Atlantic cod, American plaice and winter flounder eggs. May and June (late spring - summer spawning) egg samples were most representative of Atlantic mackerel and labrids.

3. Larval collections for January - April 1996 were dominated by rock gunnel, grubby, sand lance, sculpin and Atlantic herring. For May and June larvae, sand lance, mackerel, winter flounder, radiated shanny and fourbeard rockling dominated.

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

5. On several occasions unusually high densities of ichthyoplankton were found, primarily involving sand lance larvae, and Atlantic mackerel eggs and larvae.

6. Labrid entrainment sampling, net mesh size efficiency comparisons were conducted (1994 - 1996) showing 0.202 mm mesh significantly more efficient in capturing eggs than 0.333 mm mesh. Larval cunner results were not significantly different.

radmisc/fishjob

INTRODUCTION

A. Scope and Objective

This is the forty-eigth semi-annual report on the status and results of the Environmental Surveillance and Monitoring Program related to the operation of Pilgrim Nuclear Power Station (PNPS). The monitoring programs discussed in this report relate specifically to the Western Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the thirty-sixth semi-annual report in accordance with the environmental monitoring and reporting requirements of the PNPS Unit 1 NPDES Permit from the U.S. Environmental Protection Agency (#MA0003557) and Massachusetts Division of Water Pollution Control (#359). A multi-year (1969-1977) report incorporating marine fisheries, benthic, plankton/entrainment and impingement studies was submitted to the NRC in July 1978, as required by the PNPS Appendix B Tech. Specs. Programs in these areas have been continued under the PNPS NPDES permit. Amendment #67 (1983) to the PNPS Tech. Specs. deleted Appendix B non-radiological water quality requirements as the NRC felt they are covered in the NPDES Permit.

The objectives of the Environmental Surveillance and Monitoring Program are to determine whether the operation of 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 populations' impacts, is being conducted by the Commonwealth of Massachusetts, Division of Marine Fisheries (DMF).

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

Smelt spawning habitat was enhanced in the Jones River (Kingston) in March/April 1996, to mitigate for the large impingement of 5,000+ rainbow smelt on Pilgrim Station intake screens in December 1994. Continuing smelt mitigation is being considered.

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

3. Plankton Monitoring

Marine Research, Inc. (MRI) of Falmouth, Massachusetts, has been monitoring entrainment in Pilgrim Station cooling water of fish eggs and larvae, and lobster larvae (from 1973-1975 phytoplankton and zooplankton were also studied). Information generated through these studies has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effect of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the Pilgrim A-T Committee on the basis of the program results. Plankton monitoring in 1996 emphasized consideration of ichthyoplankton entrainment and selected species adult equivalency analyses. Results of the ichthyoplankton entrainment monitoring for this reporting period are discussed in Section IIIC.

4. Impingement Monitoring

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

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

Results of the impingement monitoring and survival program for this reporting period are discussed in Section IIID.

C. Station Operation History

The daily average, reactor thermal power levels from January through June 1996 are shown in Figure 1. As can be seen, PNPS was in a high operating stage. Cumulative capacity factor from 1973 - 1995 is 52.0%. Capacity factors for the past 15 years are summarized in Table 1.

D. 1996 Environmental Programs

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

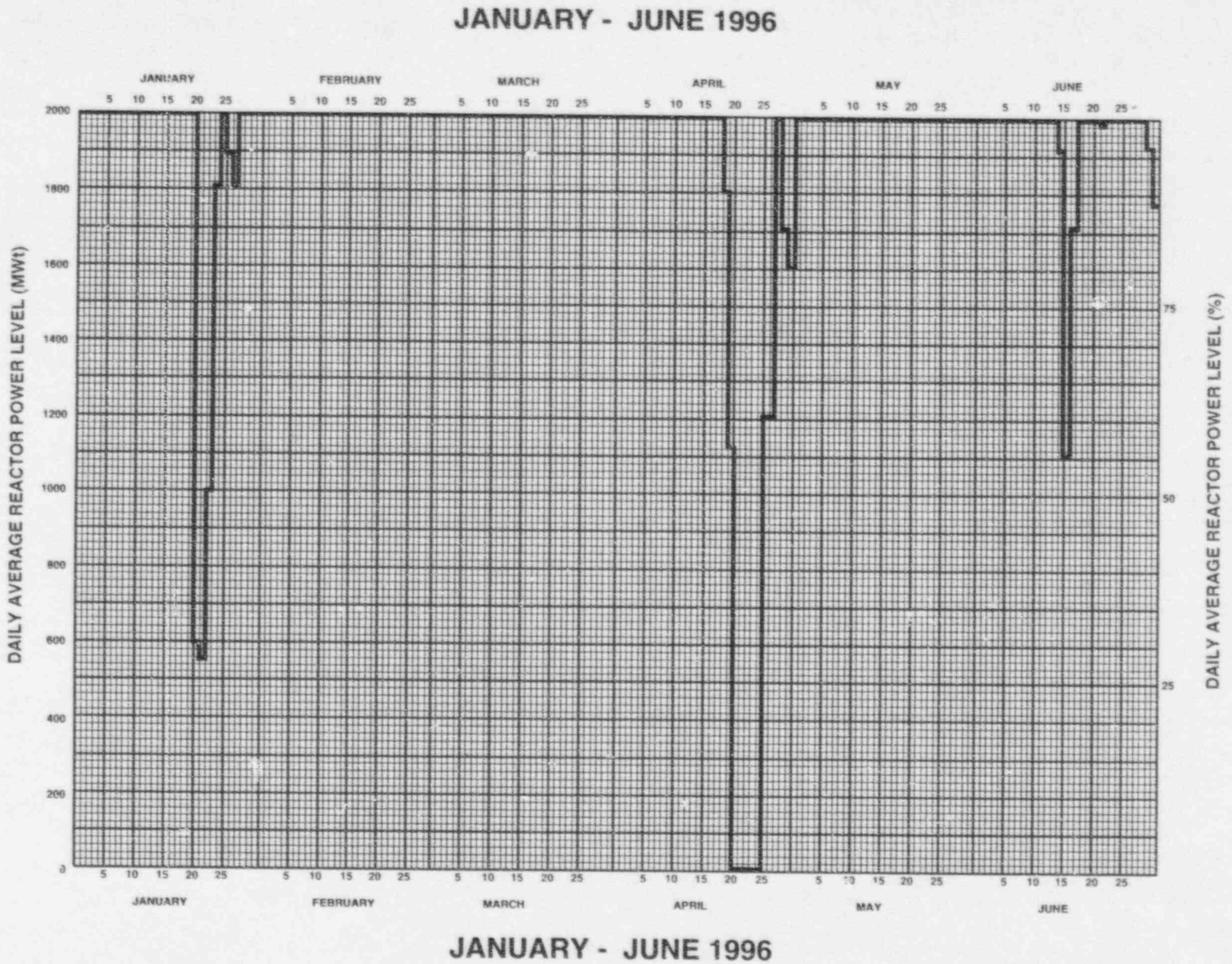


Figure 1. Daily Average Reactor Thermal Power Level (MWt and %) from January - June 1996 for Pilgrim Nuclear Power Station

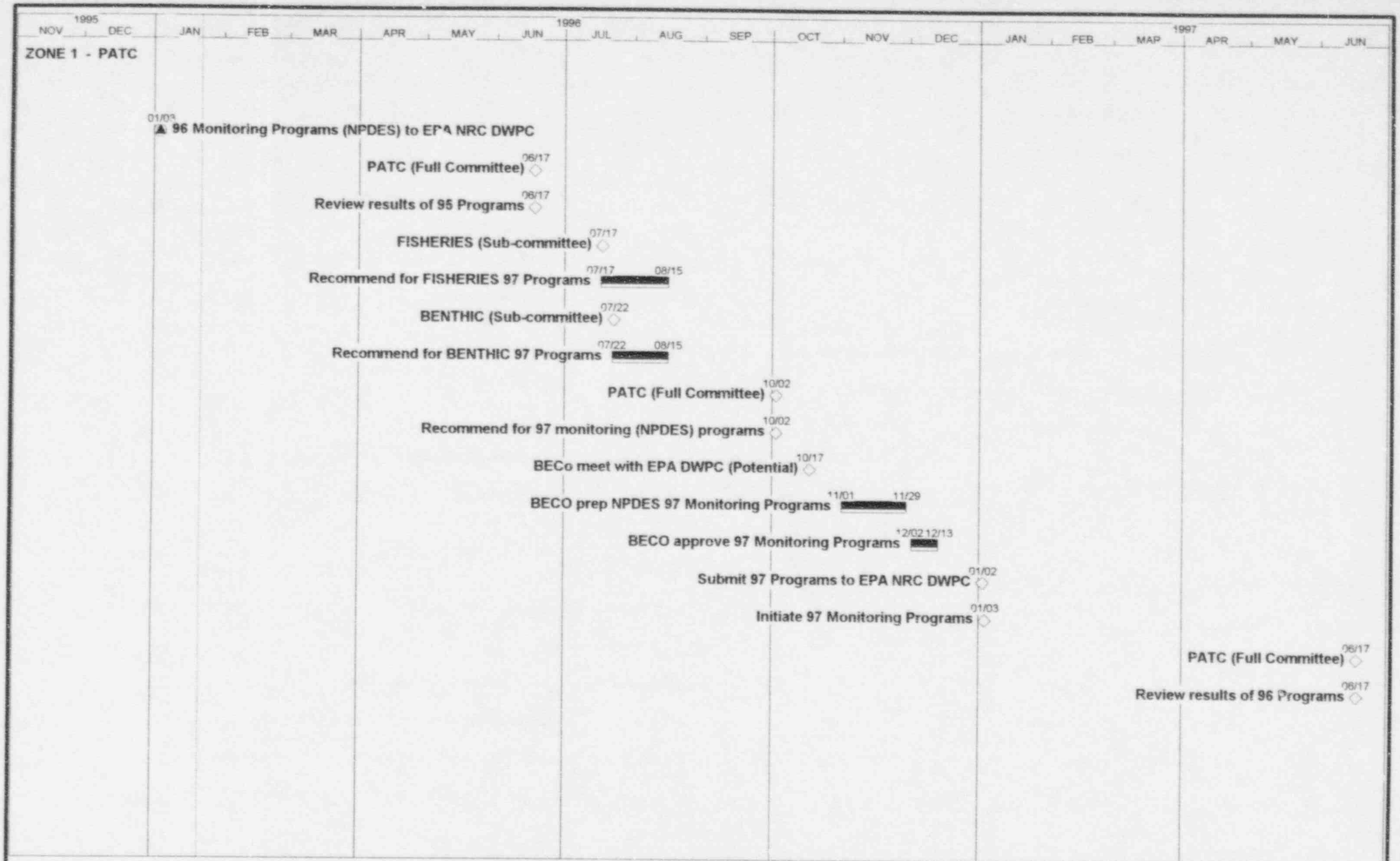
Table 1: PILGRIM NUCLEAR POWER STATION UNIT 1 CAPACITY FACTOR USING MDC NET%
(Roughly approximates thermal loading to the environment: 100%=32 Degrees F Δ T)

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

CUMULATIVE CAPACITY FACTOR (1973 - 1995) = 52.0%

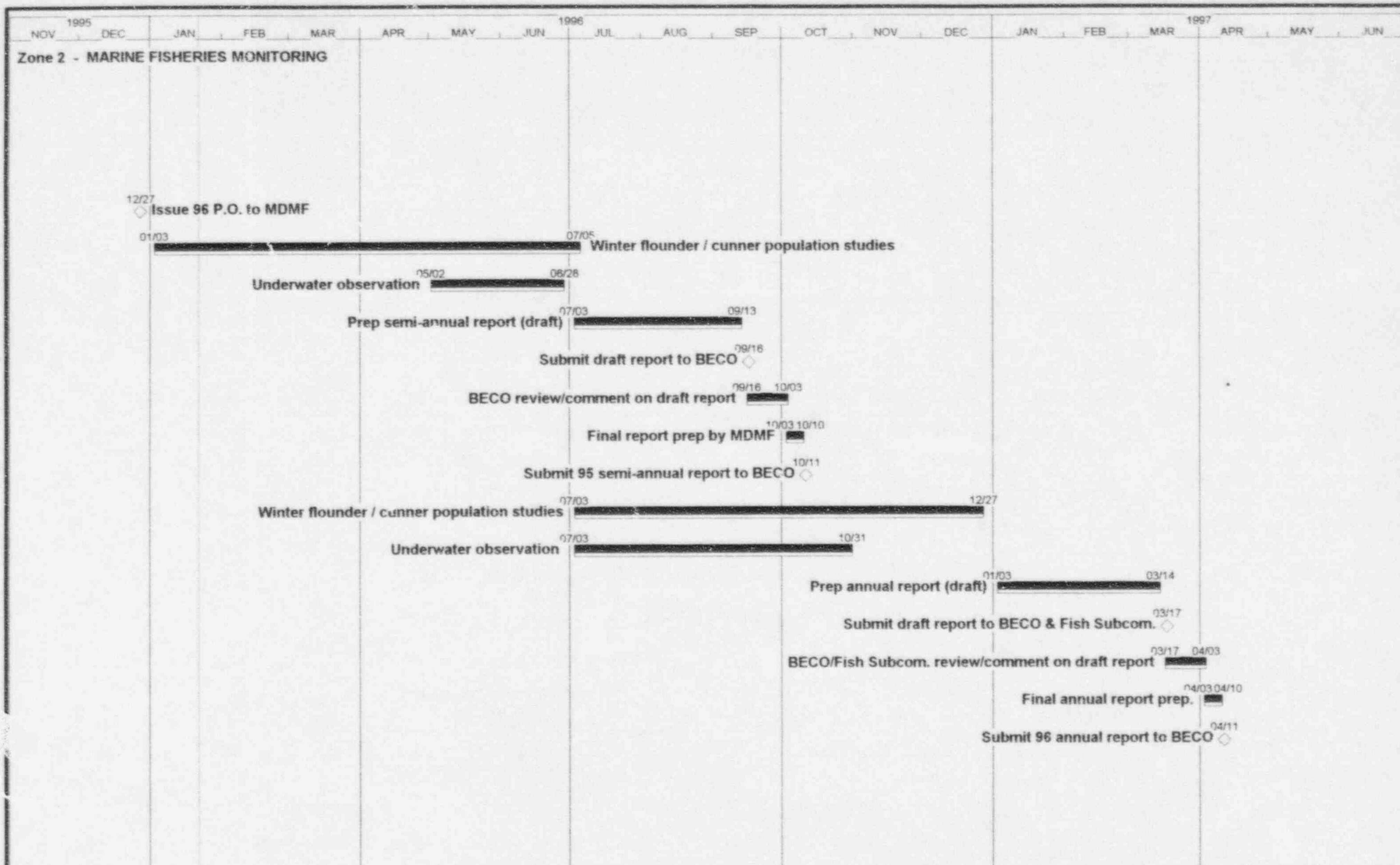
________________ = OUTAGES > 2 MONTHS

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



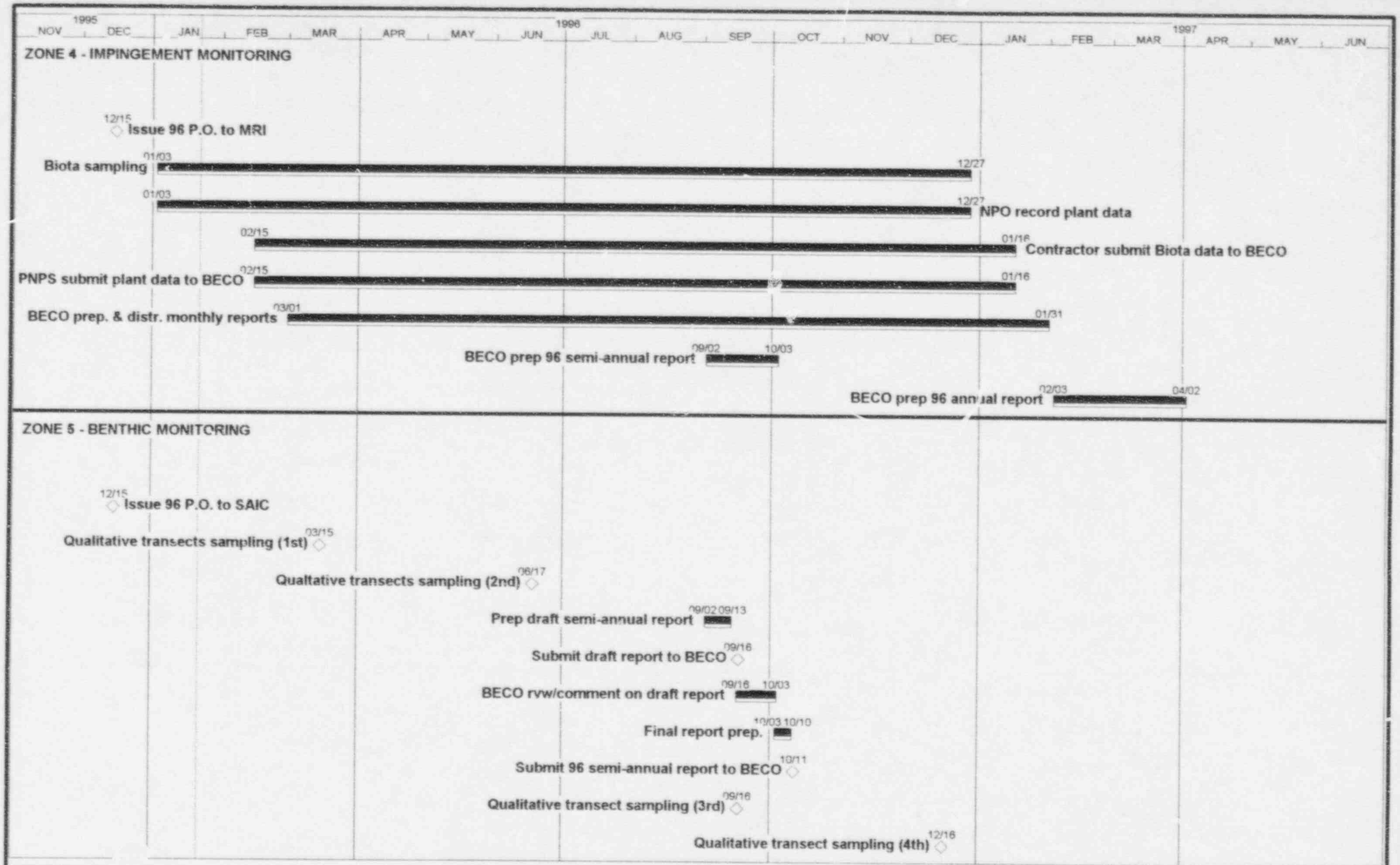
PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)

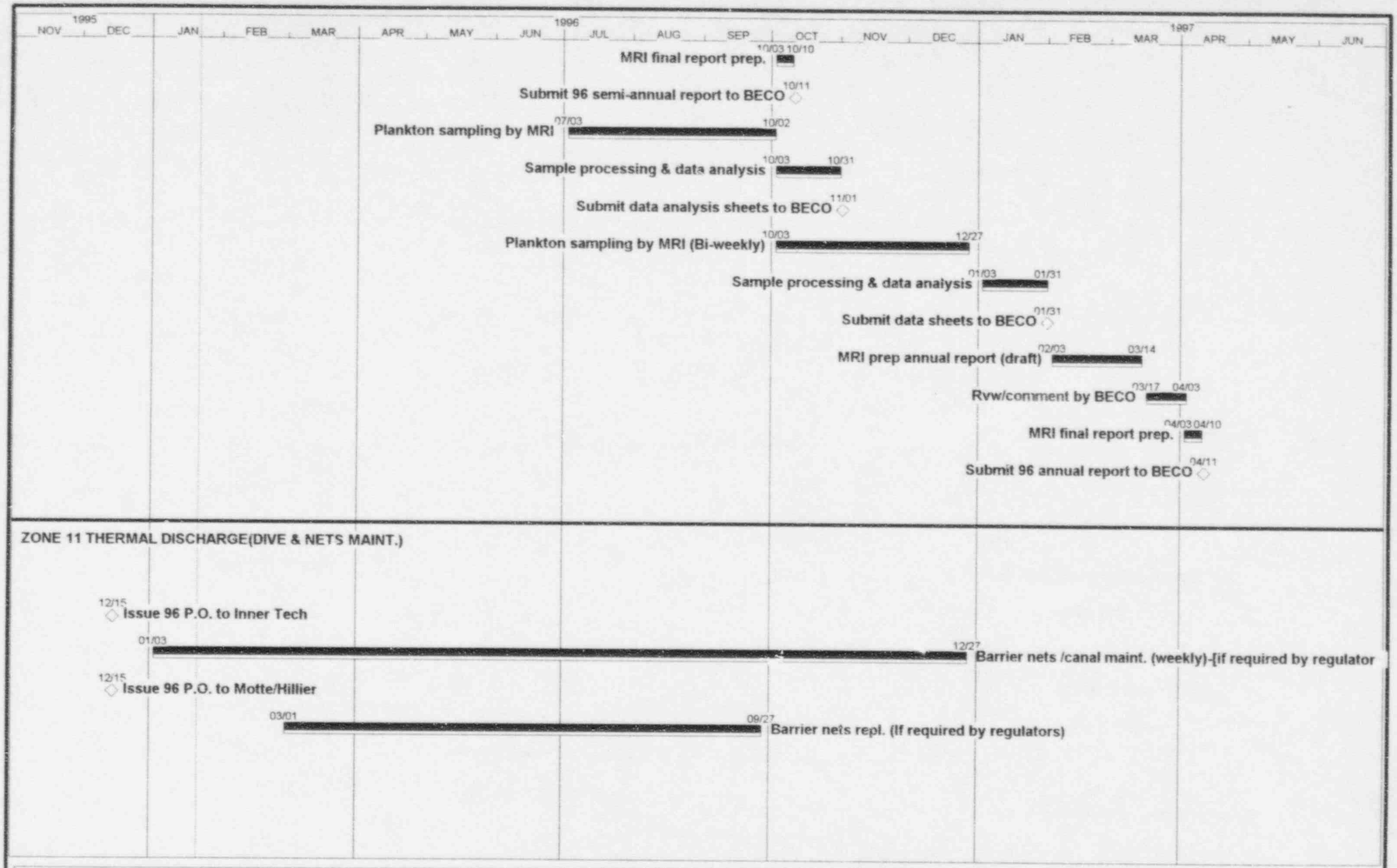
prep draft annual report	02/17	03/14
Submit draft report to BECO/Benthic Subcom.	03/17	
BECO/Benthic Subcom. rvw/comment on draft report	03/17	04/03
Final report prep.	04/03	04/10
Submit 96 annual report to BECO	04/11	

ZONE 6 - ENTRAINMENT MONITORING

Issue 96 P.O. to MRI	12/15	
Plankton sampling by MRI	01/02	03/29
Sample processing & data analysis	04/03	05/02
Submit data analysis sheets to BECO	05/02	
Plankton sampling by MRI	04/03	06/28
Sample processing & data analysis	07/03	08/01
Submit data analysis sheets to BECO	08/02	
MRI prep semi-annual draft	08/16	09/13
Rvw/comment by BECO	09/16	10/03

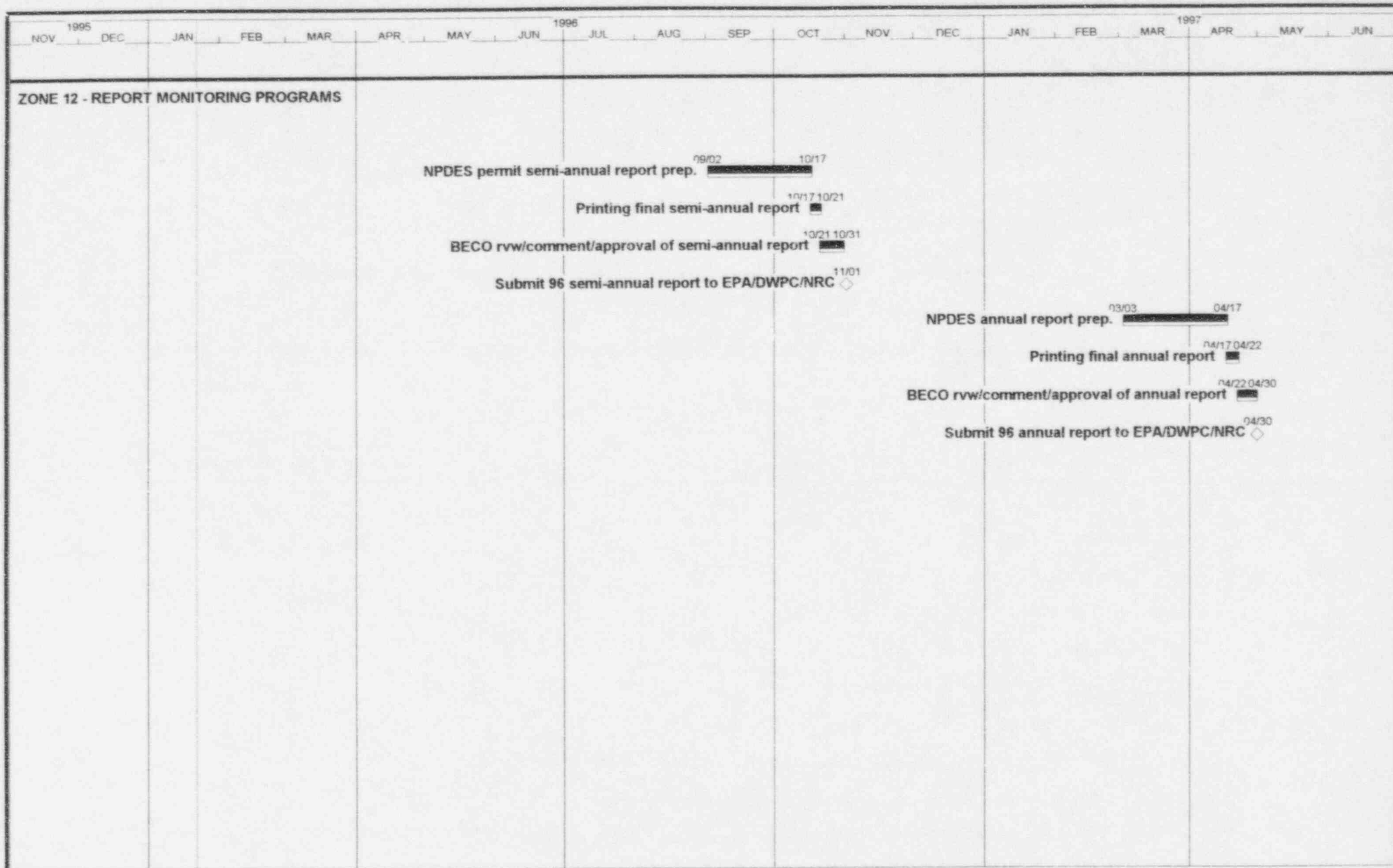
PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)



PNPS 1996 ENVIRONMENTAL PROGRAMS

(NPDES PERMIT #MA 0003557)

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

Project Report No. 61 (January to June 1996)

By

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

October 1, 1996

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

TABLE OF CONTENTS

LIST OF FIGURES

I. EXECUTIVE SUMMARY

Winter Flounder Population Studies

We continued studies to characterize the local winter flounder (*Pleuronectes americanus*) population. Our primary objectives are to define the discreteness (fidelity to natal waters) of the local spawning population and to estimate its absolute abundance.

Between 12 April and 3 May 1996, we completed 108 trawl tows with a commercial fishing vessel, the F/V Frances Elizabeth. A total of 6,708 winter flounder was captured, of which 4,997 were tagged. Of 108 tagged fish recaptured during sampling, 95 were tagged in 1996, 11 in 1995, and 2 from 1994.

Cunner Population Studies

We have studied the distribution and general movement patterns of adult cunner (*Tautogolabrus adspersus*) off Pilgrim Station and are now investigating their home range and recruitment dynamics. Fecundity by age, length, and weight was investigated last year for cunner in the Pilgrim Station area; findings appeared in the 1995 annual report. Cunner were caught in the immediate vicinity of the outer breakwater at Pilgrim Station by baited fish traps to generate catch per unit effort data, while individuals ≥ 90 mm in total length (TL) were marked with Floy T-bar anchor tags and released at the capture site. This June, 294 cunner were captured, of which 90 were kept for ageing. A total of 18 fish tagged in 1995 were recaptured. Demarcation and habitat characterization of the three recruitment study sites were completed, and diving observations revealed that cunner recruitment to the bottom had not begun yet by the end of June.

Smelt Restoration

To compensate for recent impingements of rainbow smelt (*Osmerus mordax*) at Pilgrim Station, the Massachusetts Division of Marine Fisheries has been funded for restoration work by Boston Edison Company. The objective was to enhance the quality of smelt spawning habitat in the Jones River, which hosts the major

smelt spawning run in the Pilgrim Station area. To improve spawning habitat and ultimate egg survival, we placed 130 egg collecting trays filled with sphagnum moss into the Jones River to collect eggs spawned there naturally. Smelt egg deposition is routinely higher on vegetation, while egg survival to hatching is up to ten times greater on plant material than on hard bottom.

Recreational Fishery

Creel data for 40 sampling days were collected at the Pilgrim Station Shorefront to determine sportfishing effort. Striped bass (*Morone saxatilis*) comprised 88.7 percent of the catch among anglers and bluefish (*Pomatomus saltatrix*) comprised the remaining 11.3 percent. The overall catch rate for the sampling period was 1.4 fish per angler or 23.6 fish per day.

II. INTRODUCTION

Ecological work in the marine environment off Pilgrim Nuclear Power Station is being conducted to assess and remunerate for impact of power plant operation. Investigations are conducted by the Power Plant Team of the Massachusetts Division of Marine Fisheries (MDMF), focusing on three key finfish species' populations (winter flounder, cunner, and rainbow smelt) in the inshore waters (coastal zone) of western Cape Cod Bay. Funded by Boston Edison Company under Purchase Order No. LSP005522 in 1996, this work is ongoing.

In this report, methodology and progress on investigative programs undertaken from January through June 1996 are discussed. Measurements, counts, indices, and visual observations are used in reporting preliminary results and accomplishments for the first half of 1996.

III. METHODS AND PRELIMINARY FINDINGS

1. WINTER FLOUNDER POPULATION STUDIES

To assess the magnitude of impact of larval winter flounder entrainment at Pilgrim Station, we continued studies to describe the local winter flounder population. Our primary objectives are to define the discreteness (fidelity to natal waters) of the local spawning population and to estimate its absolute abundance.

As in 1995 (Lawton et al. 1996), we contracted a commercial fishing vessel, the F/V *Frances Elizabeth*, to catch winter flounder, both for tagging and density extrapolation. The study area extended southeastward from High Pines Ledge to the Mary Ann buoy, and from the nearshore waters (9.2 m or 30 ft MLW) out to the 36.6 m (120 ft) (MLW) depth contour (Figure 1). The sampling gear used was a Yankee otter trawl (18.5-m sweep and 14.8-m headrope, with 15.2-cm stretch mesh and a 7.6-cm mesh liner). The net was fished with 12.9-m legs and 60.9-m ground cables. The trawl doors were steel, measuring 1.85 m X 1.1 m and weighing 990 kg each. Warp length varied with depth of water fished, ranging from 73.8 to 92.3 m.

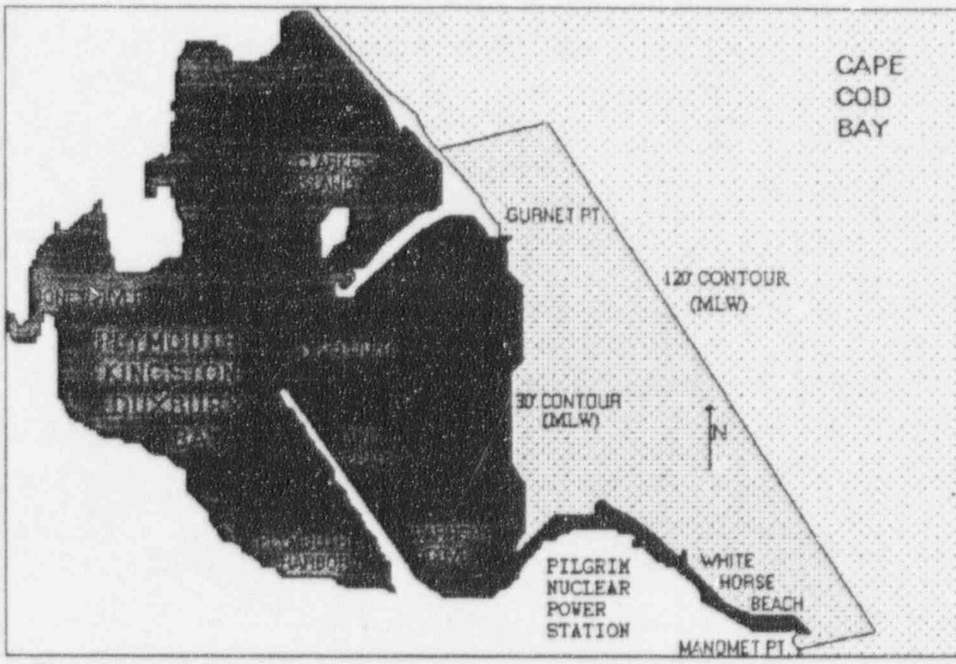


Figure 1. Study area (beyond 30' MLW) sampled by otter trawl for winter flounder in 1996 (not drawn to scale).

Winter flounder were measured (length) and assessed for reproductive state (sex and maturity). Those flounder ≥ 250 mm TL were tagged with red Petersen disc tags. All flounder were released. Additionally, data were collected from each tow on total number of flounder caught, net geometry, and the distance towed. These

data will be used to generate an independent estimate of population size via an area-swept approach (density extrapolation).

Between 12 April and 3 May 1996, we completed 108 trawl tows within the study area. Tow duration averaged 30 minutes, while tow length averaged 1.2 km. A total of 6,708 winter flounder was captured, of which 4,997 were tagged. Of the 108 tagged fish we recaptured during sampling, 95 were tagged in 1996, 11 in 1995, and 2 from 1994.

An analysis of tag returns will be undertaken when all data have been collected for 1996 and will appear in the next annual report, as will the population estimate derived from density extrapolation.

2. CUNNER POPULATION STUDIES

We formerly studied movement patterns, distribution and abundance of adult cunner in the vicinity of Pilgrim Station, via mark and recapture, with particular emphasis on their behavioral responses to the thermal discharge current. One of our objectives now is to estimate the cunner's home range. A Floy T-bar anchor tag is used in marking them. The numbered tag is embedded in the dorsal musculature via a tagging gun. To procure cunner, baited traps are fished overnight, in that cunner forage most actively at dusk and dawn. Fish are counted and measured for each trap, and all individuals ≥ 90 mm TL are tagged. Cunner are 100% mature by this size. All fish are released at the site of capture. We also are recording catch per unit effort data, i.e., catch per trap haul. Recovery information is obtained using baited fish traps. The outer breakwater was marked every 9.1 m to locate 15 sampling stations, which are being trapped to monitor movement of tagged cunner to address the question of home range.

Ageing of cunner from the Pilgrim area is ongoing. In addition, recruitment dynamics of cunner are being examined as part of a larger effort to assess entrainment impact of early life stages of cunner off Pilgrim Station. These data were needed for the Adult Equivalency model to equate eggs and larvae entrained to equivalent adults.

Our trapping efforts through June resulted in the capture of 294 cunner in the immediate Pilgrim area, of which 90 were kept for ageing analysis. Our tagging operations did not commence until July. A total of 18 recaptures of fish tagged last year (1995) was recorded in June. Work is ongoing through the fall to collect length/frequency and recapture data.

To address the recruit to adult relationship, post-settlement processes affecting recruitment are being investigated. A SCUBA census is again being undertaken this summer and fall to assess the impact of Pilgrim Station on cunner recruitment. In order to perform comparisons between years, we are using the same stations (Figure 2) as in 1995 (Lawton et al. 1996). Recruitment processes are affected by varying abiotic environmental conditions (density-independent factors, e.g., water temperature), and by demographics. However, we believe that several years of comprehensive data collection would reveal insights into local recruitment processes and possible power plant perturbation.

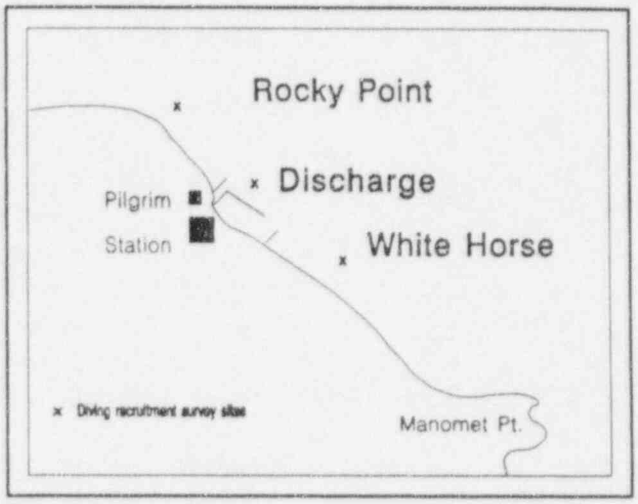


Figure 2. Site locations for cunner juvenile recruitment study, 1996.

Following the procedures established in 1995 (Lawton et al. 1996), we characterized the habitat at all three sampling stations prior to beginning our diver census in June. Habitat was quantified by visual estimation of percent composition of the dominant substrate, including algal types, in each square. Substrate categories were sand, cobble, filamentous macro-algae, fleshy macro-algae, and crustose macro-algae. Boulders were not considered as a category because all were covered with macro-algae. Algal type and rugosity, an index of substrate structural complexity, also were quantified along each transect.

Cunner recruits were visually enumerated while SCUBA diving along each transect. To delineate width and length of a transect, a one-meter wide t-bar sampling tool, with attached compass and line-reel (Figure 3), was pushed ahead of the swim path by a biologist-diver. A second diver (census taker) counts and records the number of cunner recruits while swimming above and slightly in front of the navigator. This position assured good visual coverage of the swath of the transect. All counts will be completed within a sampling day to limit temporal variability. At each station, bottom water temperature is taken with a hand-held thermometer, and underwater visibility measured using a Secchi disk.

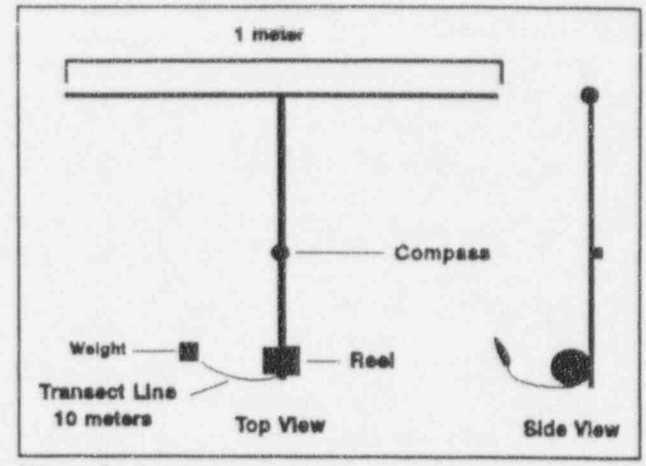


Figure 3. Survey tool used by divers to estimate abundance of juvenile cunner in the Pilgrim Station area.

We completed one day of sampling for recruits in late June just before the end of this reporting period (January to June '96). It was evident that settlement of cunner from the water column (larvae) to the bottom (recruits) had not yet begun, for all counts were zero.

3. <u>SMELT RESTORATION</u>

The goal for the 1996 rainbow smelt project was to enhance the quality of smelt spawning habitat in the Jones River, a tributary to Plymouth, Kingston, Duxbury Bay (PKDB). We placed 130 egg collecting trays in the smelt spawning area of the Jones River (Figure 4). The trays collect the naturally spawned, demersal, adhesive smelt eggs and provide an ideal habitat for egg protection and development. The sphagnum moss filling provides depositional surface and has spaces and crevices giving the material depth, thus providing a 3-dimensional surface. The interstices create a micro-environment which provides protection for the developing embryos, reducing 'egg turnover' (loss). The moss substrate allows water to seep into the trays carrying away metabolic wastes and providing a continuous supply of oxygen to the eggs.

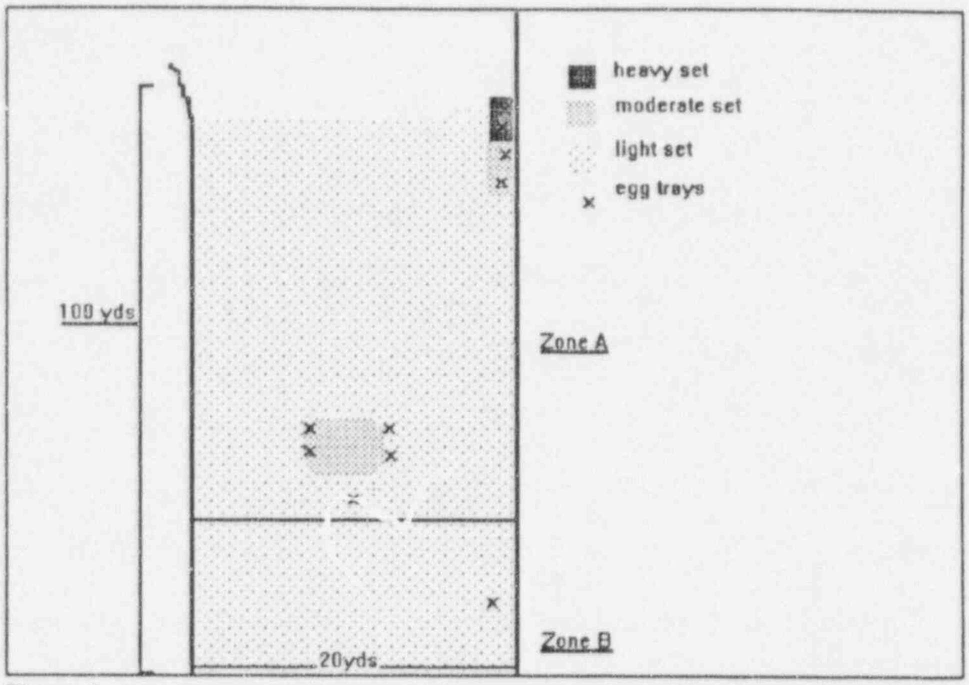


Figure 4. Smelt egg density within Zones A & B of the Jones River habitat enhancement area, 1996.

Sphagnum most often collects higher egg densities than natural hard bottom. The smelt spawning area in the Jones River is comprised largely of hard bottom (sand, gravel, and cobble). Natural aquatic vegetation also provides good substrate for egg development, but covers only ca. 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 covered ca. an additional five percent of the hard bottom in the upper spawning area (Figure 4).

There was a high level of variation in smelt egg densities on natural substrate and on the egg collecting trays throughout the Jones River spawning area in 1996. 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 of hard bottom in Zone A (Figure 4) had an average egg density of 15 eggs per square inch. Ten replicate counts on endemic plant material in the same area averaged 42 eggs per square inch. Egg densities were highest on the upper spawning ground, which is comprised of Zone A and part of Zone B (Figure 4). Unit area counts were obtained using square inch counting screens. Areas containing more than 50 eggs per square inch were identified as heavy sets, 20-50 per square inch, moderate, and less than 20, light (Figure 4).

The 1996 egg set in the Jones River appeared to be the best of the past three years. Approximately 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. Last year, egg sets were patchy and most of the traditional spawning ground was unutilized (Figure 5). Conditions in the Jones River spawning area were favorable in the spring of 1996 for smelt spawning, with good water flows and many riffles for dispersing the eggs and preventing them from aggregating in one area. When the density of eggs is too high, survival is usually poor. In many cases, a fungal infestation occurs on the dead eggs, which can be detrimental to extant egg development and survival. Furthermore, the abundance of macro- algae, which was a problem 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, thus hindering egg development.

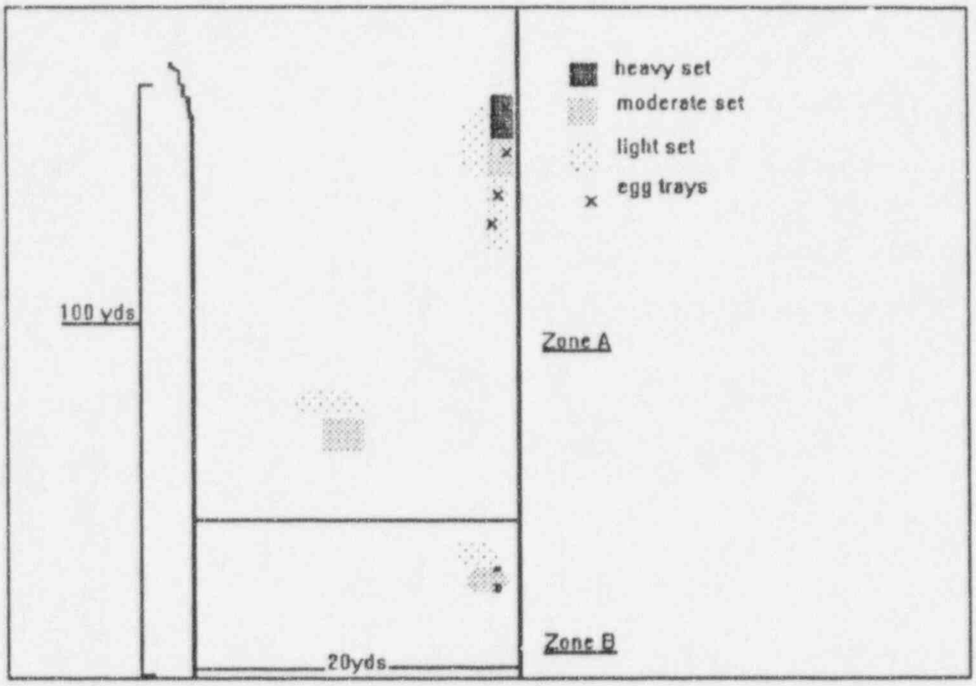


Figure 5. Smelt egg density in Zones A & B within the Jones River habitat enhancement area, 1995.

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. There was little production in the three systems this year. Egg densities averaged less than five eggs per square inch, with only small areas covered with eggs. 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 deploy about 200 egg collecting trays in areas of the river where plant material is limited and egg deposition has taken place in recent years. By employing this manipulative procedure, we hope to increase egg hatching. Saunders (1981) found that the most sensitive parameter driving future smelt population growth was egg survival.

4. RECREATIONAL FISHERY

Creel data were collected from April to June by seasonal public relations' personnel of Boston Edison Company at the Pilgrim Station Shorefront. Information was recorded in survey form for 40 sampling days to determine sportfishing effort, catch by species, and areas where fish were landed. In reference to fishing locations, the major concentration of anglers was situated on the north and south jetties bordering the thermal discharge canal. The change in fishing success at the Shorefront was depicted by plotting the mean catch per weekend of predominant species against the surveyed months (Figure 6). Also shown is the change in the number of anglers over time.

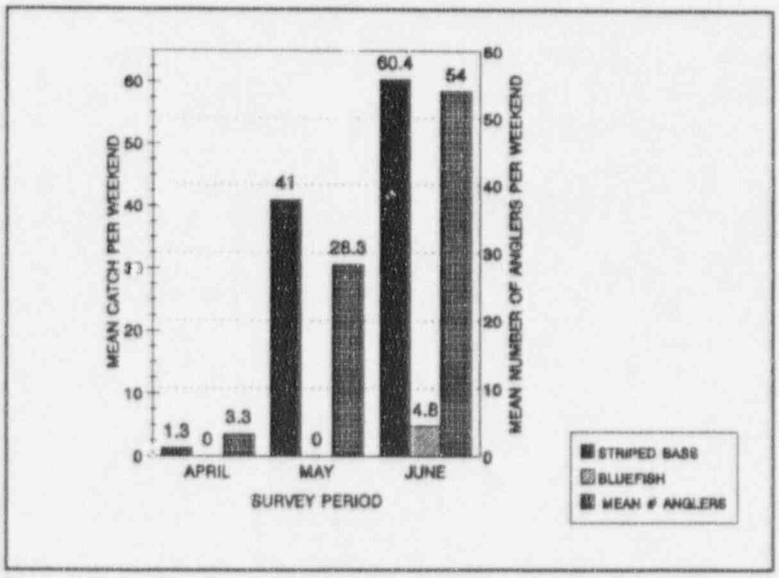


Figure 6. Mean catch per weekend of the predominant species and mean number of anglers per weekend for April, May, and June 1996.

Beginning April 13th and ending June 30th, 664 anglers reportedly fished at the Shorefront. The two predominant species caught were striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*). There were 942 recorded landings of these species during the survey - 836 were striped bass and the remaining 106 were bluefish. The overall catch rate for the sampling period was 1.4 fish per angler or 23.6 fish per day.

5. OBSERVATIONAL DIVES

No observational dives were made in the Pilgrim Station discharge canal during the study period.

IV. ACKNOWLEDGMENTS

We appreciate the guidance of Robert D. Anderson of Boston Edison Company, W. Leigh Bridges of the Division, and the Pilgrim Administrative-Technical Committee, specifically for their input on study programs.

VI. LITERATURE CITED

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 (Vol I). Project Report No. 58 (January to December 1994). *In*: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report No. 45. Boston Edison Company, Plymouth, MA.

Lawton, R.P., B.C. Kelly, V.J. Malkoski, J. Chisholm, P. Nitschke, and J. Boardman. 1996. Annual Report on Monitoring to Assess Impact of the Pilgrim Nuclear Power Station on Selected Finfish Populations in Western Cape Cod Bay (Vol I). Project Report No. 60 (January to December 1995). *In*: Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-Annual Report No. 47. Boston Edison Company, Plymouth, MA.

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. 19pp.

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

FINAL
SEMI-ANNUAL REPORT
Number 48

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

January-June 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 October 1996

TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

This report presents results of qualitative surveys of benthic algae in the thermal effluent of the Pilgrim Nuclear Power Station (PNPS) that were completed in April and June 1996. These investigations represent the most recent phase of long-term efforts to monitor effects of the thermal effluent on the benthic algal communities within and just offshore of the PNPS discharge canal. Field survey techniques were identical to those used in previous investigations.

The underwater profile of the jetties has changed somewhat over the years. Storms have moved some boulders away from the jetty to positions closer to the central transect line. For the sake of maintaining consistency in calculations of the area of the *Chondrus* denuded zone, the same base dimensions of the jetty that have been used in figures for this report for many years, are continued for the current surveys. However, as a reminder that the condition of the jetty is by no means static, those boulders encountered by the divers near the 30-m and 40-m marks are indicated in both the April and June figures.

The qualitative transect studies performed to evaluate the *Chondrus crispus* community in the thermal plume area indicated that in both late April and late June 1996 the areas of the denuded and total affected zones were dramatically larger than had been seen in previous surveys when the plant was in operation. The historical seasonal baseline dimensions set up at the beginning of the 1996 survey year were exceeded by more than 15% for both surveys. The denuded area (1860 m^2), in late April, was more than 40% larger than the historical baseline of 1321 m^2 (3/91), and by June had increased to 2194 m^2, 20% greater than the baseline of 1835 m^2 (6/90). The total affected area was also much larger than seen in earlier surveys and, indeed, was so large (>3473 m^2) in June (>63% larger than the June 1990 baseline of 2135 m^2) that it extended beyond the 30-m transect line surveyed by the divers. As in many prior summer surveys (1990, 1992, 1993, 1994, and 1995) a dense mat of juvenile blue mussels (*Mytilus edulis*) settled throughout the monitoring area. Mussels, already present in late April, had grown to 5-20 mm in length by June and increased in areal coverage to become one of the largest mussel mats ever seen by the divers off of the PNPS.

The very large *Chondrus* denuded and totally affected zones observed in April and June 1996 may have been due to a combination of the enormous numbers of juvenile mussels that had settled in the affected zone by late April, high water temperatures in Cape Cod Bay the previous August and September, and the high plant capacity in effect from July 1995 through March 1996. For the first time since qualitative transect surveys began in 1980, the plant operated at over 92% capacity for nine sequential months (mean = 97%). The increase in size of the *Chondrus* affected zones began to be noticeable even during the latest fall (1995) and winter (1996) surveys which showed the largest affected zones for fall and winter since 1983.

1.0 INTRODUCTION

This report represents a continuation of long-term (23 yr) benthic studies at Pilgrim Nuclear Power Station (PNPS) that are intended to monitor the effects of the thermal effluent. The 1996 qualitative monitoring program is identical to that performed since 1980 and consists of SCUBA surveys of algal cover in the thermal plume of the effluent within and beyond the discharge canal (Figure 1). Surveys are conducted quarterly during April, June, September, and December. This Semi-Annual Report includes qualitative observations recorded in late April and late June 1996. Work was performed under Boston Edison Co. (BECo) Purchase Order LSP005552 in accordance with requirements of the PNPS NPDES Permit No. MA 0003557.

2.0 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 present monitoring program began, approximately 15 years ago. The effluent area is surveyed by two or three SCUBA-equipped biologists operating from a small boat. To ameliorate the effect of the powerful outflowing current upon the divers it is critical that the survey occur near the time of high tide; the divers generally begin the survey at or within an hour of high tide and are finished an hour later. For the qualitative transect survey, observations are made along the axis of the discharge canal. A line is stretched across the mouth of the discharge canal (Figure 2). A weighted central transect line (CTL), marked at 10-m intervals, is then attached to the center of this line and deployed along the central axis of the canal to a distance of 100 m offshore. Using a compass, divers extend a 30-m measuring line, marked at 1-m intervals, perpendicular to the CTL at each 10-m mark. A diver swims along this third line, recording changes in algal cover from the CTL through the denuded and stunted *Chondrus* areas, until the algal cover looks normal.

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* grows 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 is fully developed and density reaches the ambient concentration.

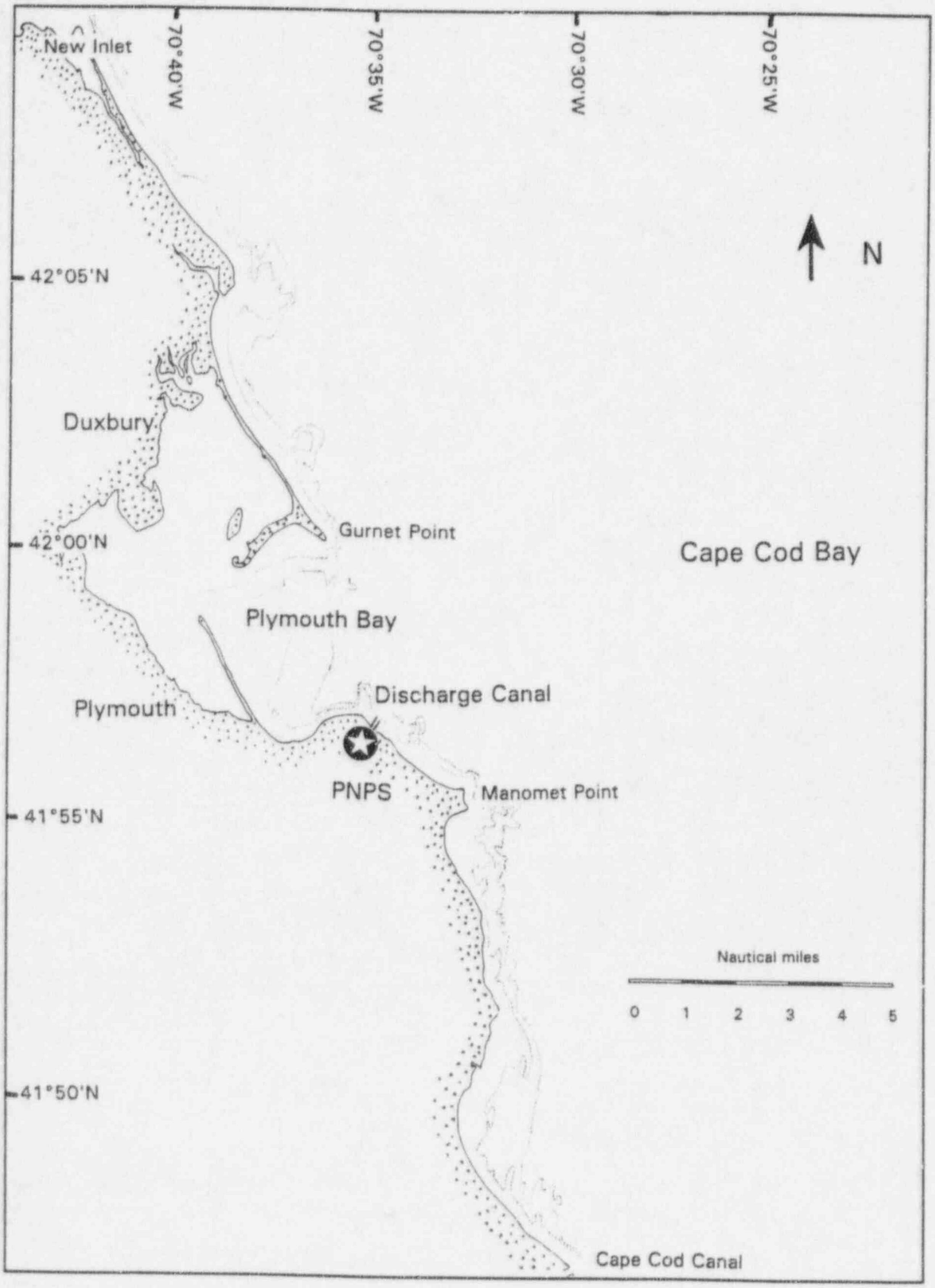


Figure 1. Location of Pilgrim Nuclear Power Station Discharge Canal.

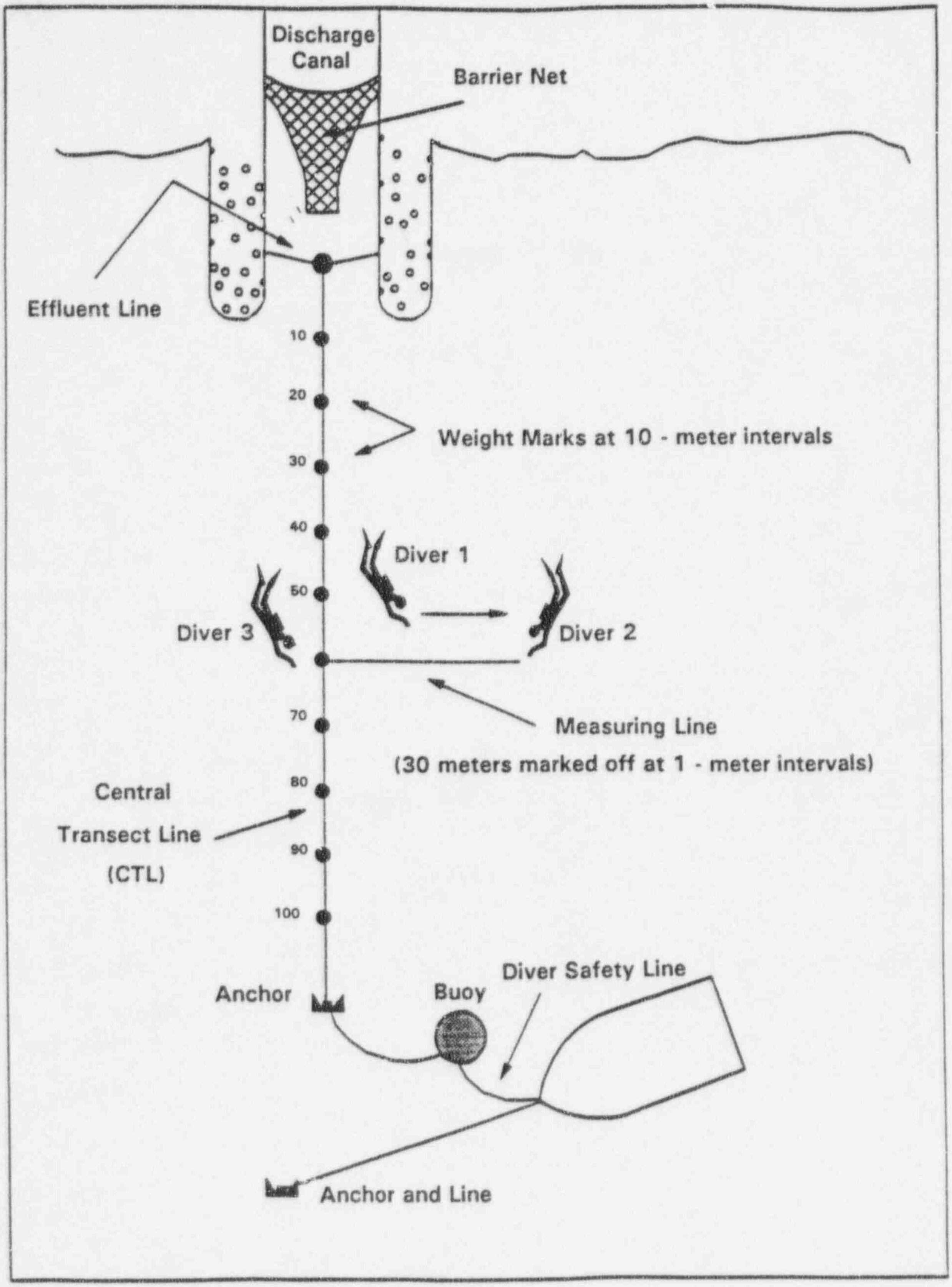


Figure 2. Design of the Qualitative Transect Survey.

The dive team must keep in mind while taking measurements that the shallow depths northwest of the discharge canal hamper normal *Chondrus* growth. In addition to evaluating algal cover, the divers record any unusual occurrences or events in the area, such as results of unusually strong storms, and note the location of any distinctive algal or faunal associations.

3.0 RESULTS

Qualitative transect surveys of acute nearfield impact zones began in January 1980 and have been conducted quarterly since 1982. Two surveys were performed (April 29 and June 27) during the current reporting period, bringing the total number of surveys conducted since 1980 to 60. Results of surveys conducted from January 1980 to June 1983 were reviewed in Semi-Annual Report 22 to BECo (BECo, 1983). A summary of surveys conducted between 1983 and 1995, including a review of the four surveys performed in 1995, was presented in Semi-Annual Report No. 47 (BECo, 1996). Detailed results of the mapping surveys conducted in April and June 1996 are presented in the next two sections.

3.1 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. A large boulder that is nearly exposed at mean low water, and that is used as a landmark by both the ENSR and Massachusetts Division of Marine Fisheries dive teams, is plotted in the figure. The denuded zone is essentially devoid of *Chondrus*, whereas sparse zones have normal-looking *Chondrus* that is thinly distributed.

In April 1996, the *Chondrus* denuded and totally affected zones were much larger than during past spring surveys. The *Chondrus* denuded area (1860 m^2) was 55% larger than in early May 1995 and 41% larger than the previous spring maximum of 1321 m^2 seen in March 1991. The typical asymmetrical distribution of the denuded zone around the central transect line was seen; 66% of the denuded *Chondrus* area was north of the transect line. At its furthest extent the denuded zone extended 25 m north of the line at the 50-m mark on the central transect line and to 105 m along the transect line. The sparse (including some stunted plants) *Chondrus* zone measured in April 1996 (575 m^2) was 28% larger than in May 1995, but still well within the range (90 - 901 m^2) encountered during prior spring surveys. The sparse zone occurred only in thin patches southeast of the denuded zone but was present as a solid band from the 50-m to the 115-m mark on the CTL. The total affected area (2436 m^2) was 5% larger than it had been in February 1996, 48% larger than in the 1995 spring survey, and 20% larger than measured in March 1983, the historical spring baseline for the total affected zone.

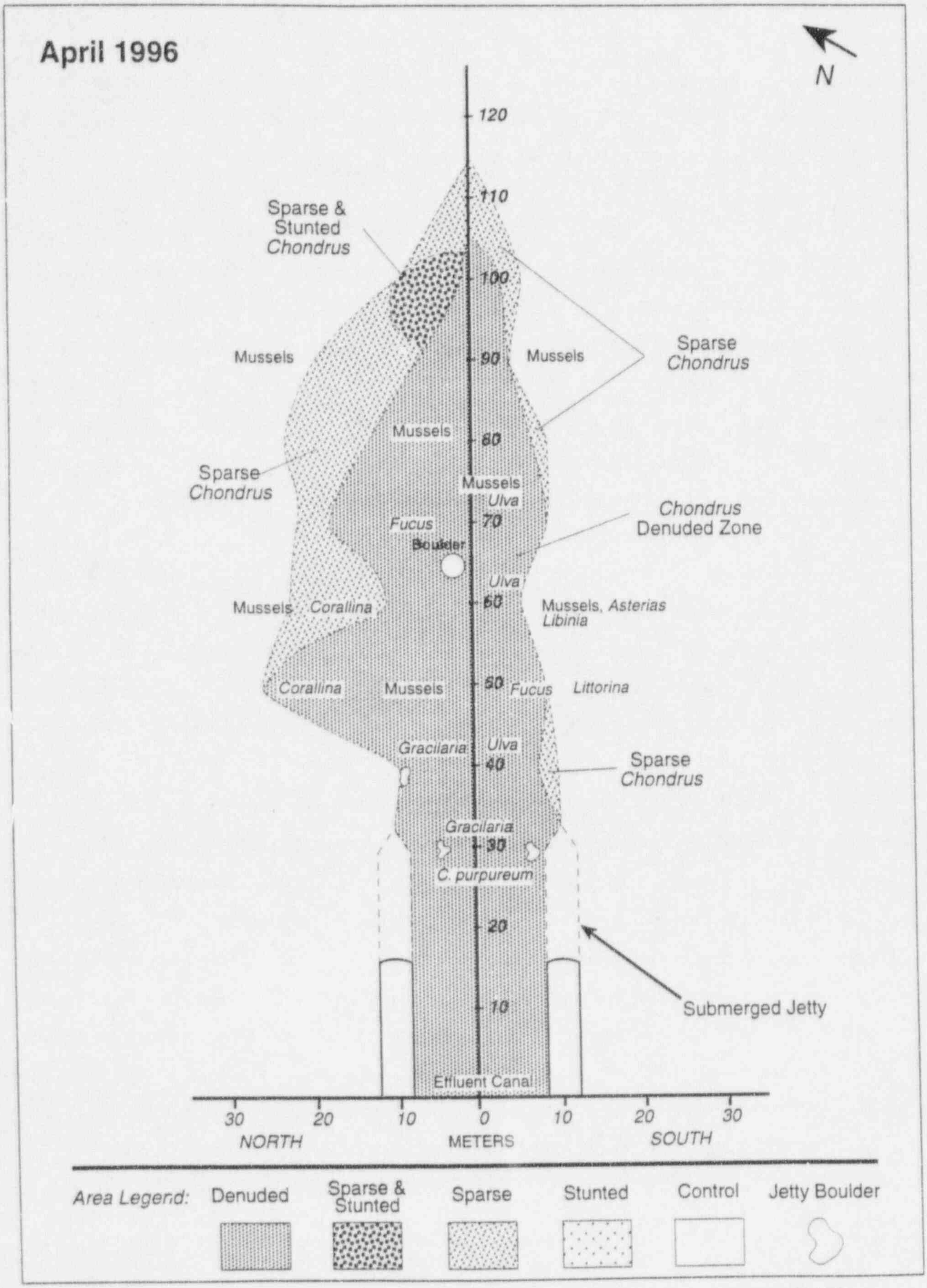


Figure 3. Denuded, Sparse, and Sparse & Stunted *Chondrus* Zones Observed in April 1996.

The *Chondrus* plants that occurred outside of the affected area were colorful and healthy. *Gracilaria*, an alga indicative of warmer water, was seen only within the discharge canal and extending along the transect line to the 40-m mark. Some specimens of the kelp, *Laminaria*, a cold water indicator, were seen, as were a few *Fucus* plants. An extensive set of juvenile blue mussels, *Mytilus edulis*, had already occurred by April 29, 1996. In May 1995, mussels were seen only occasionally; in contrast, by April 1996, 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 observed included: a few individuals of the starfish, *Asterias forbesii*, a mussel predator; swarms of mating ampeliscid amphipods; the periwinkle, *Littorina littorina;* and three species of crabs, the spider crab, *Libinia*, the common green crab, *Carcinus maenas*, and the rock crab, *Cancer irroratus*. No fish or lobsters were seen.

3.2 JUNE 1996 TRANSECT SURVEY

Results of the divers' survey for June 27, 1996 are mapped in Figure 4. The large set of juvenile blue mussels seen on the April 1996 dive and now grown to 5-20 mm in length, was still in place and covered an even larger area than before. Large mussels sets have been observed in many prior June surveys (e.g. every year since 1990 except for 1991) but the current crop of mussels was one of the heaviest observed in 25 years of monitoring. Mussels covered rocks, plants, and debris in a large denuded area from the 50-m mark on the CTL and beyond.

The *Chondrus* denuded and totally affected areas were much larger this summer than observed during past summer surveys. The area (2194 m^2) of the denuded zone was larger (18%) than that measured two months earlier, in April 1996, larger (56%) than that seen in June 1995, and 20% larger than the summer historical baseline of 1835 m^2 observed in June 1990.The asymmetrical distribution of the denuded zone around the transect line, with more area denuded of *Chondrus* north than south of the line, followed the pattern seen during most surveys for the past six years. The denuded zone extended furthest from the transect line at the 80-m mark to the northwest, reaching 25 m from the line, and at the 40-, 50-, and 90-m marks to the southeast, reaching 10.5 m from the line. Normal *Chondrus* was not observed by the divers anywhere along the routinely examined 30-m transect lines on the north side of the CTL from the 50-m to the 100-m mark. Consequently, the reported area covered by sparse and stunted *Chondrus* and the total affected zone are minimal measurements. The area occupied by sparsely distributed and stunted *Chondrus* plants (>1279 m^2) was more than twice as large (124%) than the sparse *Chondrus* area seen in late April 1996 (576 m^2) and had more than tripled in area since June 1995 (367 m^2). The sparse area, irregularly distributed on both sides of the denuded *Chondrus* zone with more than three-quarters of the zone to the

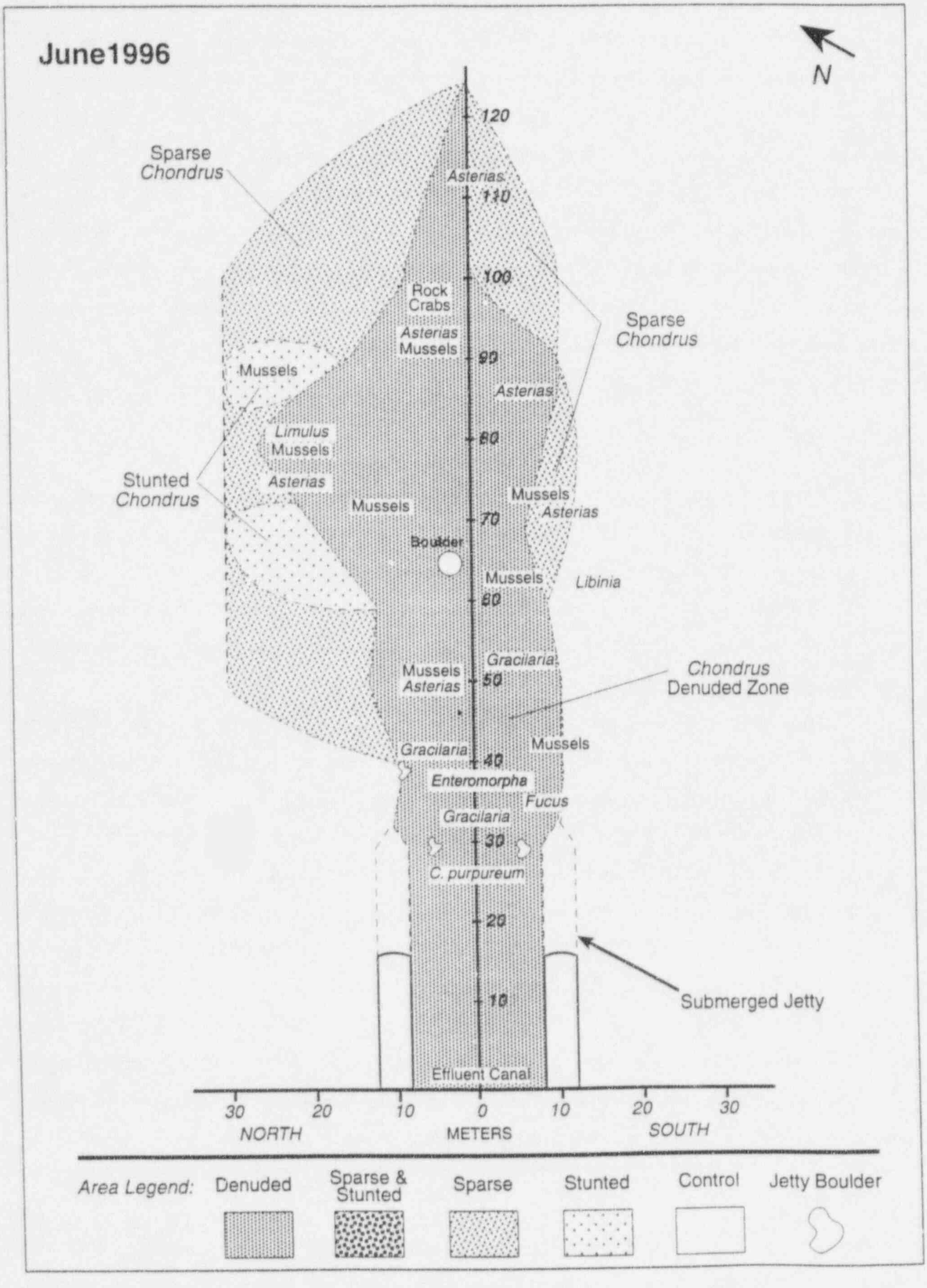


Figure 4. Denuded, Sparse, and Stunted *Chondrus* Zones Observed in June 1996.

the north, contributed to the asymmetrical pattern of the affected zone. The total affected area (>3473 m^2) was large, at least 43% larger than in April 1996 and more than 63% larger than the historical summer baseline of 2135 m^2 measured in June 1990.

Gracilaria, Enteromorpha, and *Chaetomorpha purpureum* dominated the flora at the head of the effluent canal. Rockweed, *Fucus*, was present but rare. The divers saw no specimens of *Laminaria*. Dense patches of the starfish, *Asterias forbesii*, a mussel predator, were seen. One horseshoe crab, *Limulus polyphemus*, was present north of the 80-m mark. Fish seen included: a small winter flounder (*Pleuronectes americanus*), tautog (*Tautoga onitis*), striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), and cunner (*Tautogolabrus adspersus*).

4.0 DISCUSSION

The configuration of the *Chondrus crispus* denuded zone that may extend as far as 100 m beyond the discharge canal is readily apparent to SCUBA divers and is easily mapped for the qualitative transect survey. The stunted and sparse zones are somewhat less obvious but in April and June 1996 were readily delineated. In contrast to previous surveys the areal dimensions of the *Chondrus* denuded and totally affected zones for both the spring and summer surveys were considerably larger than had been observed in earlier surveys when the power plant was in full or nearly full operation. The historical baseline dimensions set up at the beginning of the 1996 survey year were exceeded by more than the 15% for both 1996 surveys. As has often been observed in previous summer surveys (e.g.. every year since 1990 except for 1991), a dense mussel mat was present in June 1996; the juveniles settled early, by late April 1996, and increased in individual size and areal coverage by late June, to become one of the largest mussel mats ever seen by the divers off of the PNPS.

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. 1996. Marine Ecology Studies related to the operation of Pilgrim Station. Semi-Annual Report No. 47. Boston, MA.

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.

ICHTHYOPLANKTON ENTRAINMENT MONITORING

AT PILGRIM NUCLEAR POWER STATION

JANUARY - JUNE 1996

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

October 1, 1996

TABLE OF CONTENTS

*Available upon request.

LIST OF FIGURES

LIST OF TABLES

SECTION I

SUMMARY

Entrainment sampling at PNPS during the first half of 1996 was completed on six occasions per month during January and February, scheduled for three times per week from March through June. Standard netting was 0.333-mm mesh except during the larval flounder season when 0.202 mesh was used. On four dates in late June-early July 0.333/0.202 comparison samples were taken to study extrusion of cunner eggs and larvae by 0.333 mesh.

A total of 34 species were represented in the January-June 1996 samples. Winter-early spring collections (January-April) were dominated by winter flounder, American plaice, and Atlantic cod eggs along with sand lance, grubby, rock gunnel, sculpin, and Atlantic herring larvae. Collections in May and June, which together with July compose the late spring-summer spawning season, were dominated by eggs of Atlantic mackerel and tautog/cunner while larval sand lance, Atlantic mackerel, radiated shanny, fourbeard rockling, and winter flounder contributed the majority of larvae.

Comparison of January-June 1996 egg and larval densities with those recorded from 1985 through 1995 suggested that Atlantic mackerel eggs were taken in relatively low densities in June 1996. Larval sand lance were relatively abundant in March and April; radiated shanny and winter flounder were both relatively abundant in June.

Densities exceeding the unusually abundant notification level were recorded for mackerel eggs (May) and larvae (May and June), larval winter flounder (June), and larval sand lance (January, March, April, May).

No larval lobsters were encountered through the month of June, a total of five having been taken through that month dating back to 1974.

Paired sample collections completed in 1996 and pooled with those from 1994 and 1995 showed that tautog/cunner eggs were retained at significantly greater densities in 0.202-mesh compared with 0.333-mesh; a geometric mean ratio of 1.30:1 was obtained. Paired sample t-tests failed to detect a statistically significant difference between nets for the smallest (stage 1) larval cunner. Results were similar for somewhat larger stage 2 individuals.

SECTION II

INTRODUCTION

This progress report briefly summarizes results of ichthyoplankton entrainment sampling conducted at the Pilgrim Nuclear Power Station (PNPS) from January through June 1996 by Marine Research, Inc. (MRI) for Boston Edison Company (BECo) under Purchase Order No. LSP005524. As a result of studies completed in 1994, conversion from 0.333 to 0.202-mm mesh was initiated from late March through late May 1996 to improve retention of early-stage larval winter flounder. Extrusion of young larval cunner was also a concern at PNPS based on data gathered in 1994 and 1995. Additional 0.333 and 0.202-mm mesh samples were therefore taken in June and July 1996 to improve that data base. A more detailed annual report covering all 1996 data will be prepared following the July-December collection periods.

SECTION III

METHODS AND MATERIALS

Monitoring

Entrainment sampling at PNPS has historically been completed twice per month during January and February, weekly during March through June. Following a PNPS fisheries monitoring review workshop in early 1994, the sampling regime was modified beginning April 1994. In January and February during two alternate weeks each month single samples were taken on three separate occasions. Beginning with March single samples were taken three times every week. To minimize costs, sampling was linked to the impingement 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 30 minutes depending on tide, higher tide requiring a longer interval 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 collect this amount even with long sampling intervals. On two occasions (April 10, May 3) sampling was not possible since the net would not inflate in the

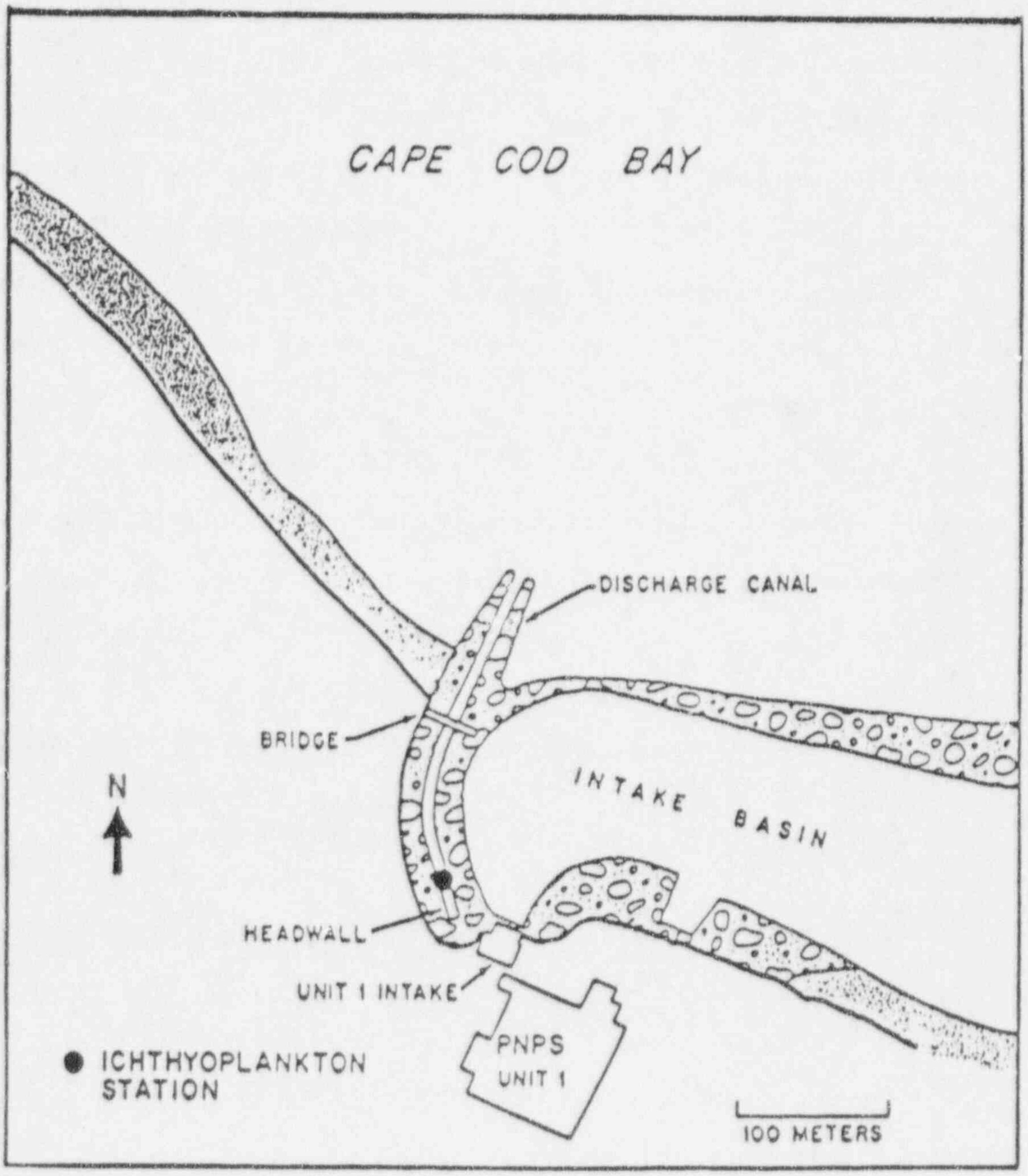


Figure 1. Entrainment sampling station in PNPS discharge canal.

low velocity near high tide. 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 the temporal extent of any unusual density can be more clearly discerned without additional sampling effort.

Until 1994 "unusually abundant" was defined as any mean density, calculated over three replicates, which was found to be 50% greater than the highest mean density observed during the same month from 1975 through to the current year. Restricting compari-

sons 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 over three replicates (1974-1993; to be updated each year) were examined and tested for normality following logarithmic transformation. Single sample densities obtained in 1994 and 1995 were added to the pool within each month. Where data sets (for example, mackerel eggs taken in June) fit the lognormal 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 lognormal distribution (generally months when a species was frequently but not always absent, i.e., many zeros occurred), the mean and standard deviation was computed using the delta-distribution (see for example Pennington 1983). The same mean plus standard deviation guideline was applied.

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

---

[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 above the mean + 2.58s.

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 m^3, the critical level is also quite small. This situation occurred during months when a given species was obviously uncommon and many zeros were present in the data set with an inherent small standard deviation. The external reference distribution methodology of Box et al. (1975) was also employed. This procedure relies on a dotplot of all previous densities for a species within month to produce a reference distribution. Densities exceeding either 97.5 or 99.5% of the reference set values were considered unusually high with this procedure.

Mesh Extrusion

To potentially improve enumeration of cunner eggs and larvae in PNPS entrainment samples, preliminary sampling was conducted in 1994 to see if eggs and young larvae are extruded through the standard 0.333-mm mesh netting. The smallest stage 1 larvae were not present in 1994 and slightly larger stage 2 larvae were

uncommon. Additional paired sampling was therefore completed in June 1995 to gather more data. Combining information from both seasons provided 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; 12 were analyzed, excluding 2 pairs 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 m³ of water:	Long-term Mean[1]	Mean + 2 std.dev.	Mean + 2.58 std.dev.
January			
LARVAE			
Atlantic herring[2]	0.2	1	
Sculpin			
Rock gunnel	0.8		1.4
Sand lance[2]	5	11	
February			
LARVAE			
Atlantic herring[2]	0.1	0.8	
Sculpin	2		65
Rock gunnel	3		99
Sand lance[2]	9	16	
March			
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	
April			
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	
May			
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	

[1]Geometric or Delta Mean.

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

SECTION IV

RESULTS

Monitoring

Population densities per 100 m^3 of water for each species listed by date, station, and replicate are presented for January-June 1996 in Appendix A (available upon request). The occurrence of eggs and larvae of each species by month appears in Table 2.

Ichthyoplankton entrained during January through April generally represent winter-early spring spawning fishes. Many of these 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 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, 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.

May and June collections (along with July) represent the late spring-summer ichthyoplankton period. Egg and larval densities, particularly among species with pelagic eggs, typically increase with expanding day length and rising water temperature. Considering both eggs and larvae, 22 species were represented in May, 24 were represented in June. The numerical dominant among eggs was the Atlantic mackerel in May followed by tautog/cunner in June. Mackerel accounted for 88% of all eggs in May with a monthly geometric mean of 134 per 100 m^3 of water. They ranked second in June while contributing 12% of total with a geometric mean of 18 eggs per 100 m^3. Tautog/cunner eggs represented 11% and 84% of the May and June totals with respective monthly means of 23 and 892 per 100 m^3. Based on a study completed at PNPS in 1975 and 1976 (MRI 1978), most tautog/cunner eggs are believed to be cunner.

Larval collections over the two-month period were numerically dominated by sand lance, Atlantic mackerel, radiated shanny (Ulvaria subbifurcata), fourbeard rockling (Enchelyopus cimbrius), and winter flounder. Sand lance, which normally decline sharply by early May from a peak in March or April, remained abundant to 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 then present through the end of that month. Overall they represented 4% of the May total with a monthly geometric mean of 1 per 100 m³ and 51% of the June total with a geometric mean of 14 per 100 m³. Radiated shanny, a small bottom fish found among rocks and seaweed, were taken throughout the two-month period. They accounted for 18% of the May larval catch with a geometric mean of 15 per 100 m³ and 14% of the June total with a geometric mean of 10 per 100 m³. Fourbeard rockling were taken at geometric mean densities of 1 per 100 m³ in May, 11 per 100 m³ in June; these values represented 2 and 12% of the two respective monthly totals. Lastly winter flounder contributed 8 and 10% to the May and June larval totals with geometric mean densities of 6 and 7 per 100 m³ of water, respectively.

Appendix B (available upon request) lists geometric mean monthly densities along with 95% confidence limits for each of the numerical dominants collected over the January-June period dating back to 1985. Geometric means are reported because they more accurately reflect the true population mean when the distribution of sample values are skewed to the right as is commonly the case with plankton data. Generally low values obtained for both eggs and larvae during April-June 1987 were shaded because low through-plant water volumes during those months probably affected densities of ichthyoplankton (MRI 1994); shaded values were omitted from the following discussion. Entrainment data collected from 1975-1984 remain in an outdated computer format requiring conversion before

geometric mean densities can be generated. These years were therefore excluded from comparison. Because densities of each ichthyoplankton species rise from and fall to zero over the course of each respective season, inter-year comparisons are most conveniently made within monthly periods. A general review of the data through the first six months of 1996 suggests the following:

- Only one notable density was apparent among eggs. Atlantic mackerel eggs were taken in relatively low densities in June 1996. The geometric mean density of 18 per 100 m^3 was just below the previous low of 19 per 100 m^3 recorded in 1993. Values among the nine remaining years ranged from 25 to 543 per 100 m^3.
- Larval sand lance were relatively abundant in March and April. In both cases geometric means ranked second behind 1994. The mean for March was 45 compared with 61 in 1994 and between 0.1 and 26 over the other years. For April a mean of 137 per 100 m^3 was recorded compared with 274 in 1994, 2.0 to 44 over the other years. Sand lance densities meeting the unusually abundant criterion were obtained in January, March, April, and May. One observation in January (337 per 100 m^3) and one in May (639 per 100 m^3) exceeded all previous values for those respective months by factors of 3 and 2 (Table 3).
- In June, radiated shanny larvae were relatively abundant. The 1996 geometric monthly mean of 10 per 100 m^3 exceeded 1994's value of 6, the previous high. Values over the remaining ten years ranged from only 0.1 to 3 per 100 m^3.

- Larval winter flounder were also relatively abundant in June 1996. The monthly geometric mean of 7 per 100 m^3 exceeded the previous June high of 4 noted in 1993; values ranged from 0.2 to 2 over the remaining ten years. On June 5, 8, and 10 observed larval flounder densities exceeded the unusually abundant level. The June 8 density (154 per 100 m^3) surpassed the previous June high of 110 per 100 m^3 recorded in 1974 (Table 3).

Although their respective monthly means were unremarkable, several collections of mackerel eggs and larvae exceeded the unusually abundant notification level (Table 3). These occurred in late May among the eggs, late May and early June among larvae. For mackerel eggs the last three observations of the month exceeded at least 95% of all previous observations. Similarly for mackerel larvae the last three May observations exceeded 96% of all previous May values. A density of 59 per 100 m^3 was recorded on the 31st which exceeded the previous high of 26 per 100 m^3 observed in 1991. Lastly, on June 3 a density of 1318 mackerel larvae per 100 m^3 was recorded, ranking third over all June observations.

No larval lobster (Homarus americanus) were encountered through the end of June, a total of five having been taken through that month dating back to 1974.

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 ($p < 0.001$; $n = 33$ pairs). Since densities were highly skewed by high values on June 28, 1995, geometric means were calculated over the 33 samples within each mesh category. The ratio of these (also the geometric mean of the ratios) was 1.30:1 with 95% confidence limits of 1.12 to 1.51:1. The arithmetic mean of the ratios was noted to be characteristically higher than the geometric mean at 1.45:1, 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 21 when pooled with 1994 and 1995 data sets. Again a paired sample t-test did not detect a significant difference between nets ($p = 0.25$; geometric mean ratio (0.202:0.333) = 1.27:1, 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 0.94:1 was obtained over nine pairs (paired t-test $p = 0.81$).

These results suggest that small cunner are not extruded through 0.333-mm mesh netting to any significant degree. While the ratio of 1.27:1 obtained for stage 2 larvae may appear important, the t-test indicated there was a 25% 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 ve / 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.

---

[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.

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

Species		Jan	Feb	Mar	Apr	May	June
American eel	*Anguilla rostrata*				L		L
Atlantic menhaden	*Brevoortia tyrannus*					E	E/L
Atlantic herring	*Clupea harengus*	L		L	L	L	
Rainbow smelt	*Osmerus mordax*					L	
Fourbeard rockling	*Enchelyopus cimbrius*	E			E	E/L	E/L
Atlantic cod	*Gadus morhua*		E	E/L	E/L	E/L	E/L
Haddock	*Melanogrammus aeglefinus*				E		
Silver hake	*Merluccius bilinearis*						E/L
Atlantic tomcod	*Microgadus tomcod*		L	L	L		
Hake	*Urophycis* spp.					E	E/L
Goosefish	*Lophius americanus*						E/L
Silversides	*Menidia* spp.					L	L
Northern pipefish	*Syngnathus fuscus*						L
Searobins	*Prionotus* spp.						E
Grubby	*Myoxocephalus aenaeus*		L	L	L	L	L
Longhorn sculpin	*M. octodecemspinosus*		L	L	L		
Shorthorn sculpin	*M. scorpius*		L	L	L		
Lumpfish	*Cyclopterus lumpus*						L
Seasnail	*Liparis atlanticus*				L	L	L
Wrasses	Labridae					E	E
Tautog	*Tautoga onitis*						L
Cunner	*Tautogolabrus adspersus*						L
Snakeblenny	*Lumpenus lumpretaeformis*				L		

Table 2 (continued).

Species		Jan	Feb	Mar	Apr	May	June
Radiated shanny	*Ulvaria subbifurcata*					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
Atlantic mackerel	*Scomber scombrus*					E/L	E/L
Smallmouth flounder	*Etropus microstomus*					E	E
Fourspot flounder	*Paralichthys oblongus*					L	
Windowpane	*Scophthalmus aquosus*					E	E/L
Witch flounder	*Glyptocephalus cynoglossus*			L		E/L	E/L
American plaice	*Hippoglossoides platessoides*			E/L	E/L	E/L	E/L
Winter flounder	*Pleuronectes americanus*			E	E/L	E/L	E/L
Yellowtail flounder	*P. ferrugineus*	E			E	E	E/L

Table 3. Ichthyoplankton densities (number per 100 m³) for each sampling occasion during months when notably high densities were recorded, January-June 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: 19203 (1995)
Notice level: 4031

Table 3 (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

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

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

Table 4. Densities per 100 m^3 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						
Cunner	1994					
Stage	May 4	All	0	0	-	
1	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	Mesh 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	6.9-10.4	0.53-1.68	

[1]p = paired t-test

SECTION V

LITERATURE CITED

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

Cohen, J. 1988. Statistical Power Analysis for the Behavioral Sciences. Academic Press, Inc., Orlando, Florida. 474p.

MRI (Marine Research, Inc.). 1978. Quarterly Progress Report Entrainment Investigations and Cape Cod Bay Ichthyoplankton Studies, September-November 1977. III.C.1. In Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-annual Report No. 11. Boston Edison Company.

____. 1988. Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1987. III.C.1. In Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-annual Report No. 31. Boston Edison Company.

____. 1994. Ichthyoplankton Entrainment Monitoring at Pilgrim Nuclear Power Station January-December 1993. III.C.1. In Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-annual Report No. 43. Boston Edison Company.

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. The Pennsylvania State University Statistics Department. 19p. Unpublished.

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

*Available upon request.

IMPINGEMENT OF ORGANISMS AT PILGRIM NUCLEAR POWER STATION

(January - June 1996)

Prepared by: Robert D. Anderson

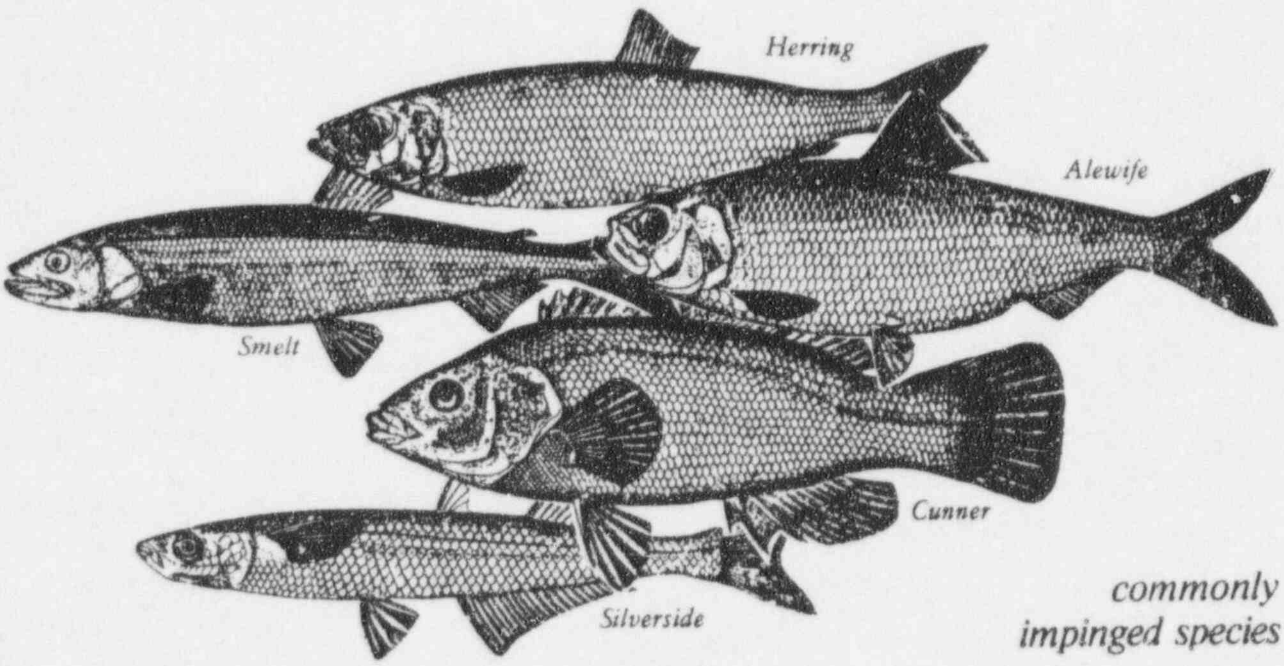
Robert D. Anderson

Principal Marine Biologist

Regulatory Affairs Department

Boston Edison Company

October 1996



commonly
impinged species

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

SUMMARY

Fish impingement averaged 3.32 fish/hour during the period January-June 1996. Atlantic silverside (Menidia menidia), grubby (Myoxocephalus aenaeus), winter flounder (Pleuronectes americanus), and rainbow smelt (Osmerus mordax) accounted for 96% of the fishes collected. Initial impingement survival for all fishes from static screen wash collections was approximately 77% and from continuous screen washes 82%.

The collection rate (no./hr.) for all invertebrates captured from January-June 1996 was 3.54. Sevenspine bay shrimp (Crangon septemspinosa) and sand worms (Nereis sp.) accounted for 96% of the invertebrates impinged. Mixed species of algae collected on intake screens amounted to 1,068 pounds.

The relatively high fish impingement rates from January-June 1993 (2.53), 1994 (3.34), 1995 (4.36) and 1996 (3.32) reflect circulating water pumps operating regularly during most of these periods, and high numbers of silversides impinged in early spring of each year. The invertebrate impingement was not as reflective of increased intake flow.

The Pilgrim Nuclear Power Station capacity factor was 93% from January - June 1996.

SECTION 2

INTRODUCTION

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

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

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

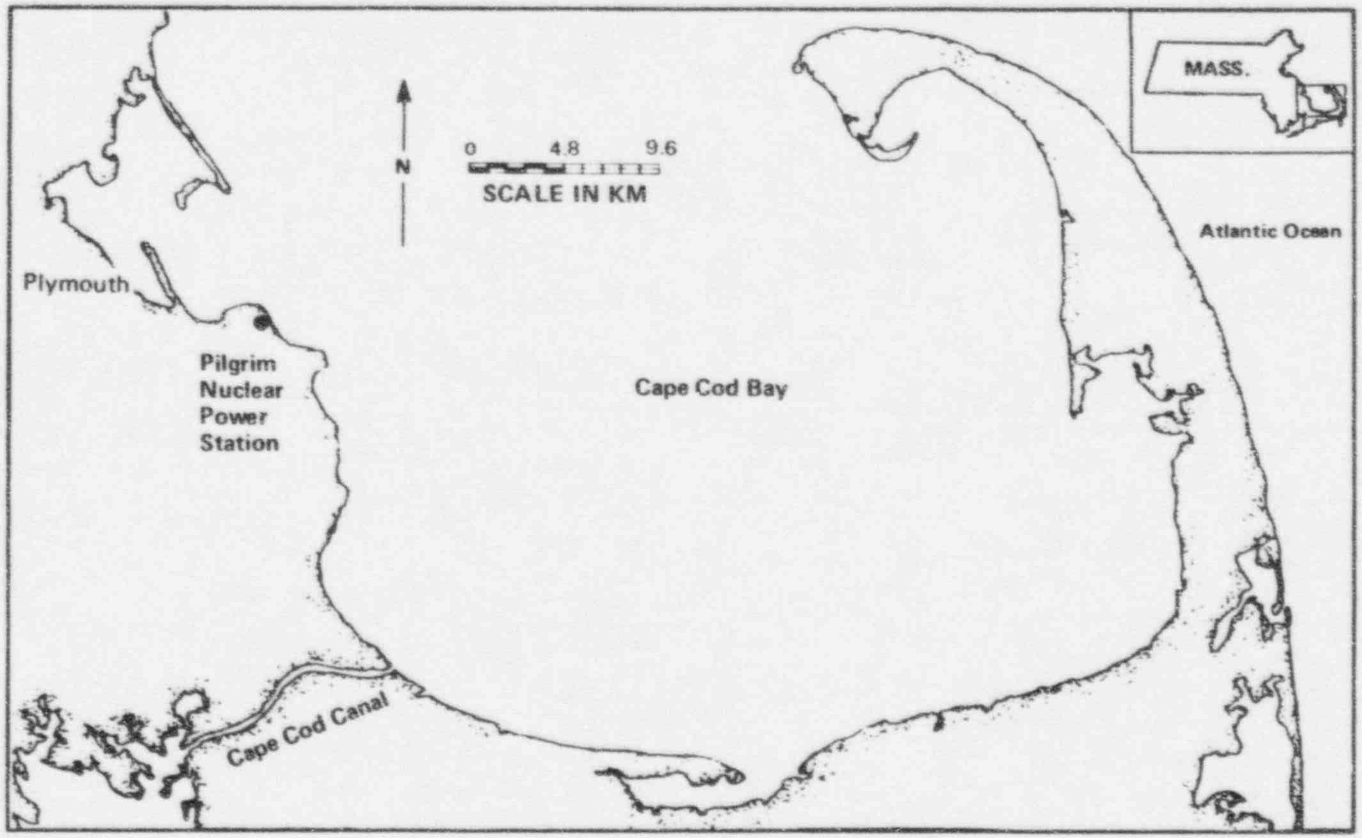


Figure 1. Location of Pilgrim Nuclear Power Station.

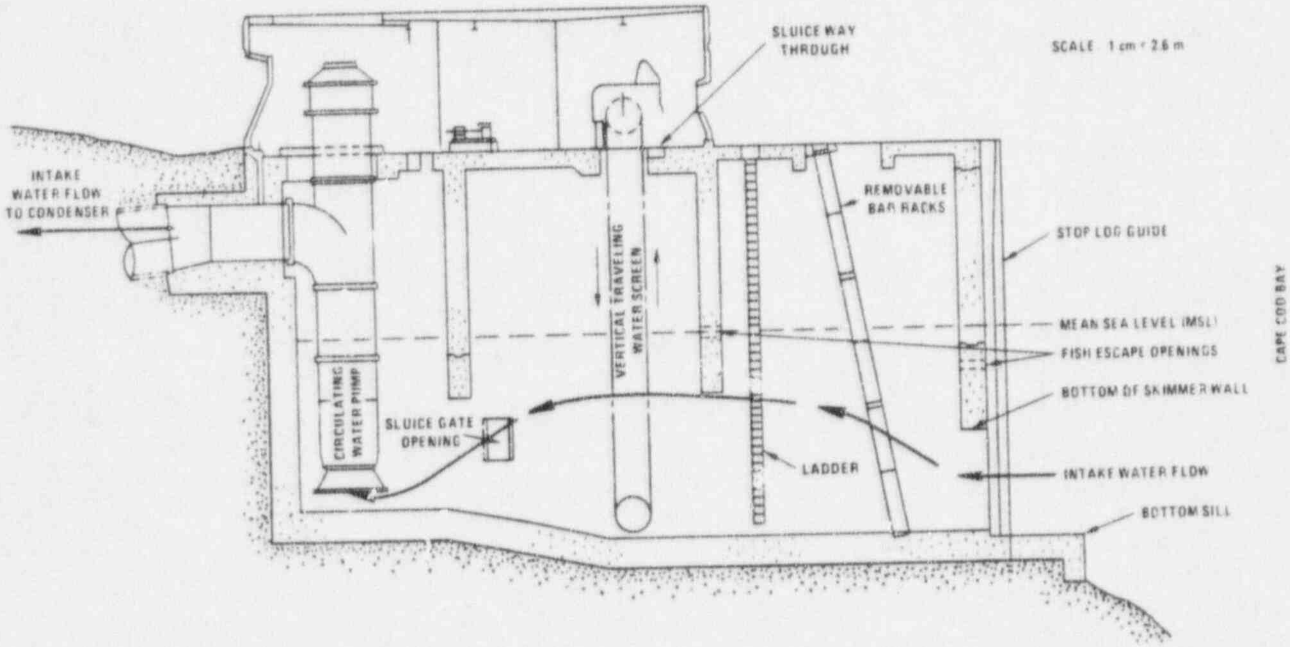


Figure 2: Cross-section of intake structure of Pilgrim Nuclear Power Station.

SECTION 3

METHODS AND MATERIALS

Three screen washings each week were performed from January-June 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 travelling screens were washed. Eight hours later, the screens were again washed (minimum of 30 minutes each) and all organisms collected. When screens were being washed continuously, one hour collections were made at the end of the regular sampling periods, and they represented two light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The trap was made of galvanized screen (3/8-inch mesh) attached to a removable steel frame and it collected impinged biota, 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. All common and scientific names in this report follow the American Fisheries Society (1988, 1989, 1991a and 1991b).

SECTION 4

RESULTS AND DISCUSSION

4.1 Fishes

In 222 collection hours, 736 fishes of sixteen species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January - June 1996. The collection rate was 3.32 fish/hour. Atlantic silverside (Menidia menidia) was the most abundant species accounting for 88.0% of all fishes collected (Table 2). Grubby (Myoxocephalus aenaeus), winter flounder (Pleuronectes americanus) and rainbow smelt (Osmerus mordax) accounted for 3.9, 3.0 and 0.9% of the total number of fishes collected. Atlantic silverside were impinged in highest numbers during March and April. These were primarily adult fish that averaged 99 mm total length. Grubby impingement was greatest in April, winter flounder and rainbow smelt were mostly impinged in January. The January-June 1996 fish impingement rate was within the range from the same period in 1989-1995, when rates varied from 0.52 (1990) to 4.36 (1995). Rates increased the past eight years compared to the 1988 rate (0.30), and this is possibly attributable to greater circulating water pump operating capacity from 1989-1996 and higher silverside impingement numbers, in general, in the springtime period.

4.2. Invertebrates

In 222 collection hours, 786 invertebrates of 13 species (Table 3) were collected from Pilgrim Station intake screens between January-June 1996. The collection rate was 3.54 invertebrates/hour. Sevenspine bay shrimp (Crangon septemspinosa) and sand worms (Nereis sp.) accounted for 92.2% and 3.4%, respectively, of the total number of invertebrates enumerated. Rock crabs (Cancer irroratus) were third in abundance and were impinged predominantly in April.

The collections of sevenspine bay shrimp occurred primarily during March, and sand worms in February. In 1989 from January - June, blue mussels and mussel predators dominated impingement, possibly due to the lack of effective macrofouling controls that year. Only three specimens of the commercially important

Table 1 - Monthly Impingement for All Fishes Collected from Pilgrim Station Intake Screens, January - June 1996

Species	Jan.	Feb.	March	April	May	June	Total
Atlantic silverside	8	30	226	269	114	1	648
Grubby	5	2	5	14	2	1	29
Winter flounder	8	3	5	5	1		22
Rainbow smelt	3		2	2			7
Rock gunnel			1	5			6
Northern pipefish			3	2			5
Windowpane	1		1	1		1	4
Cunner	1			1		1	3
White perch	3						3
Red hake				1	1		2
Threespine stickleback			1	1			2
Blueback herring			1				1
Little skate						1	1
Lumpfish						1	1
Radiated shanny	1						1
Striped killifish	1						1
Totals	31	35	245	301	118	6	736
Collection Time (hrs.)	26	60	35	27	47	27	222
Collection Rate (#/hr.)	1.19	0.58	7.00	11.15	2.51	0.22	3.32

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

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent Of Total Fish
Atlaintic silverside	648	77-150	99	1-17	5	88.0
Grubby	29	41-120	61	1-23	4	3.9
Winter flounder	22	52-321	121	-	-	3.0
Rainbow smelt	7	82-187	133	3-36	16	0.9
Rock gunnel	6	58-165	123	1-13	6	0.8
Northern pipefish	5	125-192	164	1-3	2	0.7
Windowpane	4	53-255	117	-	-	0.5
Cunner	3	46-157	116	1-89	45	0.4
White perch	3	115-127	120	16-22	18	0.4
Red hake	2	57-108	83	1-6	4	0.3
Threespine stickleback	2	64-72	68	2-3	3	0.3
Blueback herring	1	80	80	3	3	0.1
Little skate	1	492	492	-	-	0.1
Lumpfish	1	29	29	1	1	0.1
Radiated shanney	1	53	53	1	1	0.1
Striped killifish	1	83	83	6	6	0.1

Table 3 - Monthly Impingement for All Invertebrates Collected from Pilgrim Station Intake Screens January - June 1996

Species	Jan.	Feb.	March	April	May	June	Total
Sevenspine bay shrimp	124	109	329	161	2		725
Nereis sp.	7	15	3	1		1	27
Rock crab	1	1	2	3	1	2	10
Green crab	5		1	1			7
Horseshoe crab						4	4
American lobster	1					2	3
Common starfish					1	1	2
Longfin squid					1	1	2
Polychaete	1	1					2
Glycerid			1				1
Green sea urchin			1				1
Isopoda						1	1
Orbinid			1				1
Totals	139	126	338	166	5	12	786
Collection Time (hrs.)	26	60	35	27	47	27	222
Collection Rate (#/hr.)	5.35	2.10	9.66	6.15	0.11	0.44	3.54

American lobster were captured which is much lower than in recent years, and even as far back as 1990 and 1991 when 16 and 21 were recorded, respectively, for the same time frame.

Approximately 1,068 pounds of mixed algae species were recorded during impingement sampling, or 4.8 pounds/hour. Like the January-June, 1989 - 1996 fish impingement rates, the algal impingement rates for these years were notably higher than recorded for the same period in 1988 when lower circulating water pump operation was evident.

4.3 Fish Survival

Fish survival data collected while impingement monitoring are shown in Table 4. Static screen wash collections provided high numbers of fishes and revealed good impingement survival rates for some species, including Atlantic silversides. Continuous screen wash collections had relatively higher survival rates, although fewer fishes were sampled.

Table 4 - Survival Summary for the Fishes Collected During Pilgrim Station Impingement Sampling, January-June 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	523	125	400	101	99	77-150
Grubby	20	9	20	9	61	41-120
Winter flounder	17	5	16	4	121	52-321
Rainbow smelt	6	1	1	1	133	82-187
Rock gunnel	3	3	3	1	123	58-165
Nothern pipefish	2	3	2	3	164	125-192
Windowpane	3	1	2	0	117	53-255
Cunner	2	1	0	1	116	46-157
White perch	3	0	2	-	120	115-127
Red hake	2	0	1	-	83	57-108
Threespine stickleback	0	2	-	2	68	64-72
Blueback herring	1	0	0	-	80	80
Little skate	1	0	1	-	492	492
Lumpfish	1	0	1	-	29	29
Radiated shanny	0	1	-	1	53	53
Striped killifish	1	0	1	-	83	83
All Species:	585	151	450	123		
Number (% Surviving)			(76.9)	(81.5)		

SECTION 5

CONCLUSIONS

1. The average Pilgrim impingement rate for the period January-June 1996 was 3.32 fish/hour. The collection rate was notably lower in 1988, than in 1989 - 1996, possibly due to more circulating water pump capacity during the latter years.

2. Sixteen species of fish were recorded in 222 impingement collection hours.

3. The major species collected and their relative percentages of the total collections were Atlantic silverside, 88.0%; grubby, 3.9%; winter flounder, 3.0%; and rainbow smelt, 0.9%.

4. The hourly collection rate for invertebrates was 3.54 with sevenspine bay shrimp (92.2%) and sand worms (3.4%) dominating the catch. Three American lobsters were caught. Impingement rates for invertebrates were higher and algae lower for this period in 1988 (minimum circulating water pumps operating) then in 1989 - 1996.

5. Impinged fish survival was relatively high overall during static screen washes because of relatively high Atlantic silverside survival.

SECTION 6

LITERATURE CITED

American Fisheries Society. 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.

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

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

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

PHILIP G. COATES
DIRECTOR

(508) 888-1155

MEMORANDUM

TO: Members of the Administrative- Technical Committee, Pilgrim Power Plant Investigations
FROM: Erin Casey, Recording Secretary
SUBJECT: Minutes from the 85th meeting of the A-T Committee
DATE: July 17, 1996

This 85th meeting was called to order by Bob Maietta at 9:49, on June 25, 1996.

I. Minutes of the 84th meeting

Bob Maietta motioned to accept the minutes from the last meeting; Jack Paar seconded. The minutes were accepted unanimously with no changes.

II. Pilgrim Station 1995-1996 operational review

Bob Anderson Presented the latest Station operational status to the committee. Annual operation was at approximately 76% in 1995, despite a refueling outage in April and May. The plant operated at greater than 90% from July 1995 through March 1996; this was a record at the plant for high power production over a consecutive eight to nine month period. Bob informed the committee that the next refueling outage was scheduled for February 1997. Bob Lawton questioned the change from April to February. He explained that an outage in April would coincide with the peak spawning time for winter flounder. Bob Maietta suggested writing a letter to Boston Edison recommending timing the outage for April or May. Jack Paar motioned to write a letter to inform Boston Edison of the time best suited for reducing the entrainment of winter flounder larvae. It was seconded by Bob Lawton. The committee discussed the wording of the letter. The motion was accepted unanimously.

Dredging the Intake, according to Bob Anderson, will not take place this summer. Biological testing on Ampelisca, an amphipod, did not meet specifications. A discussion on bioassay techniques occurred. Boston Edison is exploring alternatives for land

disposal of the dredged sediment on their property. It may be possible to dredge part of the intake embayment, depending on the results of individual tests to be performed on four separate areas. Bob Maietta expressed concern about the ability of the testing to determine if the cause of contamination was more widescale. Bob Anderson explained to location of the control samples. Bob Anderson told the committee that the tests also showed approximately 1ppm mercury levels, despite there being no mercury source at the plant. It was suggested that a hazardous waste site near the North River may be a possible source. Bob Maietta suggested involving the Benthic Subcommittee for consultation involving the sediment removal.

III. 1995 Impingement Monitoring Results

Bob Anderson presented the impingement data. The overall impingement rate for 1995 was about 6 fish per hour. This is an increase over the 2 to 3 fish per hour the plant has averaged in the past. The increase is due to one significant incident in which an estimated 13,000 alewives were impinged on the 8th and 9th of September. The dominant species impinged in 1995 were: alewife (52%), Atlantic silversides (31%), rainbow smelt (4-5%), and winter flounder (3%). Bob Lawton pointed out that there was no isolated incident of impinged smelt. Jack Paar inquired as to how the average impingement rate was calculated. Bob Anderson and Bob Lawton explained that the calculations were based on assumptions of 100% operation and 100% mortality. Bob Anderson noted that the initial survival rate for continuous washes was 87%, while with static washes, it was 55%. Mike Scherer explained that a large number of impinged fish discharged into the intake was needed to begin a proposed tagging study to assess the recycling of impinged fish.

IV. 1995 Marine Fisheries Monitoring

Bob Lawton presented highlights of the Marine Fisheries monitoring. Bob explained that the smelt impact has been primarily from impingement. The estimated impingement for 1993 through 1995 was 22,500 smelt. As a result, both restoration and habitat enhancement efforts were introduced. In 1993, 0.6 million smelt eggs were stocked in the Jones River while in 1994, 1.2 million eggs were stocked. Habitat enhancement was also carried out to increase egg survival. In 1995, 75 trays with sphagnum substrate were placed in the principle spawning area, and in 1996, 130 trays were used. Bob explained that the key parameter influencing population growth is egg survival.

Next, Bob Lawton presented the winter flounder work. He explained that the impact on flounder is via both impingement and entrainment. Mike Scherer estimated that 16.4 million winter flounder larvae were entrained in 1995. Using the adult equivalency model, this is equal to 9,800 age-3 adult fish. Bob Lawton explained that to determine the discreteness of the population, DMF has been tagging winter flounder with Petersen disc

tags. Tagging efforts utilizing a contracted commercial fishing vessel resulted in 2,500 winter flounder being tagged in the spring of 1995 and 5,000 tagged in the spring of 1996. Bob explained that, according to Eric Adams' report, the geographical bounds of the study did not extend far enough north. A request was made to send Eric adams' report to each committee member. Bob explained that the report could be reworked due to Adams' assumption of spatially uniform larval production. Bob Anderson asked when the data from the flounder study would all come together. Bob Lawton stated that by next year, results would be forthcoming. Bob Lawton suggested that could modify the model to account for the spatial variability in larval production, for an additional cost. Bob agreed to contact him.

Next, Bob Lawton discussed the work with cunner. He explained that the impact is primarily via entrainment, with 4.6 billion labrid eggs and 40 million cunner larvae entrained in 1995. Bob also explained that funding of the graduate student developed from the need to know cunner fecundity. Bob then addressed cunner tagging. He explained that because the study area is so large, and cunner exhibit high fidelity, it is only possible to estimate size of subunits of the population. He noted that over six thousand fish have been tagged, with high recapture rates to date. Most fish are recaptured in the area where they were tagged. Bob Maietta suggested that there may be certain aspects of the cunner program that could be discontinued in the future. Bob Lawton explained that more aging was being done to generate better mortality figures for the adult equivalency model, which included trying to get better catch per unit effort data for Mike Scherer.

V. BECO-funded project on "Fecundity and Factors That Influence Reproduction and Recruitment in Cunner at Pilgrim"

Paul Nitschke presented his project entitled "Assessing the Factors of Cunner Recruitment in Cape Cod Bay". Paul presented his sampling and analysis protocol used to determine the length, weight, and age specific fecundity of cunner. Paul determined that the best model to use is one involving length. Paul also studied recruitment patterns under the influence of PNPS. Paul found that among the four sites sampled, the site at the discharge initially had the highest settlement. From his work, Paul concluded that the plant did not have a meaningful effect through entrainment in 1995. He also concluded that habitat is important in determining recruitment success, and that temperature influences fish counts. Bob Maietta suggested simplifying the conclusions for clarification. The committee discussed larval density and possible effects. Martha Mather suggested mapping out the hard substrate due to its effect on recruitment.

VI. 1995 Entrainment Monitoring Results

Mike Scherer began by reviewing the changes mad as a result of to fisheries workshop. The entrainment sampling is done on Monday, Wednesday, and Friday. From March to September sampling is done

weekly. The rest of the year, sampling is biweekly. Samples are collected with 333 mesh plankton net. However, from late March to late May, sampling was done using 202 mesh to limit extrusion of larvae. As for sampling in 1995, Mike reported that there were high Atlantic herring, Atlantic mackerel, and hake counts. He also noted that the number of tautog and cunner larvae increased. Mike reported that cod larvae were down and also noted that rockling and hake eggs were on a downward trend. The committee discussed predation and water temperature. Mike reviewed the notification plan which goes into effect if density exceeds the prescribed criteria. Mike also addressed the equivalent adult analysis on winter flounder, cunner, and Atlantic mackerel.

VII. <u>Benthic Monitoring Results</u>

Bob Anderson reviewed a letter sent from Don Miller to the Benthic Subcommittee. It described the notification program for benthic monitoring. After each quarterly sampling dive, a letter is sent with the basic results. If the affected area is 15% greater that the previous seasonal high, then the subcommittee is notified. The February and April dives exceeded previous parameters. Don Miller suggested explanations; the consistent operation of PNPS and/or a number of high mussel sets may have increased the affected area. Don Miller also suggested quantifying the area of the mussel sets in the outfall.

VIII. <u>1995 Marine Fish and Benthic Subcommittees</u>

In his letter, Don Miller stated that he was resigning from the benthic subcommittee within a year. He nominated Jack Paar as chairperson. Bob Maietta suggested that the subcommittee choose their own chairperson and suggested discussing it at the summer subcommittee meeting. The next fisheries subcommittee meeting and benthic subcommittee meeting were both scheduled for July 17th in Narragansett, RI.

A-T Committee Meeting Attendance
June 25, 1996

Robert Maietta	Mass. DEP, Grafton
Michael Scherer	MRI, Falmouth
W. Leigh Bridges	Mass. DMF, Boston
Carolyn Griswold	NMFS, Narragnsett
Robert Anderson	BECo, Plymouth
Robert Lawton	Mass. DMF, Sandwich
Martha Mather	Mass. Coop Fish & Wildlife
Paul Nitschke	UMass, Amherst
Rick Zeroka	Mass. CZM
Jack Paar	U.S. EPA, Lexington

Addendum to

ENTRAINMENT OF WINTER FLOUNDER LARVAE AND CUNNER EGGS AND LARVAE AT THE PILGRIM NUCLEAR POWER STATION

by

E. Eric Adams, PhD and Xue-Yong Zhang, PhD

MIT 48-325, Cambridge, MA 02139

prepared for

Massachusetts Division of Marine Fisheries
18 Route 6A, Sandwich, MA 02563
attn: Bob Lawton

March 15, 1996 (original report)

May 8, 1996 (addendum)

The following addendum provides additional discussion and calculations concerning the origin of winter flounder larvae and cunner eggs and larvae which are entrained by the Pilgrim Nuclear Power Station (PNPS). The addendum is based on recent information provided by Mr. Bob Lawton of Massachusetts Division of Marine Fisheries concerning 1) the survival rates of cunner eggs and larvae, 2) near bottom currents near PNPS and 3) the spatial distribution of egg production.

Cunner survival rates

Based on unpublished data collected by Marine Research Inc. near PNPS, the fraction of cunner eggs which survived to larval stage was found to be 0.0187 and the fraction of cunner larvae cunner which survived to adults was found to be 0.00767 (B. Lawton, personal communication, April, 1996). Each ratio can be used to compute a first order death rate, k, using

$$\text{ratio} = e^{-k\tau} \qquad 7^{*})$$

where τ is the appropriate lifetime. Following the original report we use $\tau = 2$ days along with a ratio of 0.0187 to compute a value of $k = 2.3 \times 10^{-5}\ \text{sec}^{-1}$ for cunner eggs, and $\tau = 21$ days along with a ratio of 0.00767 to compute a value of $k = 2.7 \times 10^{-6}\ \text{sec}^{-1}$ for cunner larvae. Note that these values of k are considerably larger (indicating lower survival) than the values of 10^{-6} and $3 \times 10^{-7}\ \text{sec}^{-1}$ which were used in the original report. Additional model runs presented below use the new values of k.

Near bottom currents

As reported by Bob Lawton (personal communication, April, 1996), Marine Research Inc. also released a series of seabed drifters near PNPS. The typical time reported for the drifters to travel 4 miles (6.4 km) was about 10 days, indicating an average near-bottom speed of about U = 0.007 m/s. This is about 50% of the lower mean speed (0.015 m/s) and about 20% of the higher mean speed (0.04 m/s) used in the original report. This is not inconsistent, however, since the seabed drifters measure near-bottom velocities while the mean speeds reported on earlier reflect velocities in the lower half of the water column (but generally well off the bottom). Because no information

---

* Equation numbers, figure numbers and table numbers continue from the orginal report.

is available concerning the variability of near bottom current speeds, Eq 6 is used to predict that the longshore and on-offshore dispersion coefficients (E_x and E_y, respectively) are proportional to U^2. In order to provide a lower bound on the spatial distribution of entrainment (feeling that previous estimates may give an upper bound) we estimate each dispersion coefficient as 25% of the corresponding dispersion coefficient associated with the mean current speed of 0.015 m/sec,= U yielding E_x = 12 m²/sec and E_y = 7 m²/sec. Additional model runs presented below use the lower values (U = 0.007 m/sec, E_x = 12 m²/sec and E_y = 7 m²/sec) as well as the original set.

Spatial variability of egg production

Our analysis provides predictions of the relative probability of entrainment of eggs and larvae which originate at various locations within the bay *under the assumption that egg and larval production is spatially uniform*. It is well known that this is not the case, but a detailed description of the spatial variability of the source is not available. In principle, our analysis could be modified to consider such data if they were available. Recall that the analysis seeks the probability density function p(x,y) describing the entrainment at the plant (located at the coordinate origin: 0,0) of passive organisms originating at location (x,y). p(x,y) is found by analogy with the corresponding two-dimensional contaminant transport problem as the concentration c(x,y) resulting from a continuous mass source emitting at (0,0), divided by the total contaminant mass in the system, M_T, where

$$M_T = \int c(x,y)dxdy \qquad 8)$$

Thus

$$p(x,y) = \frac{c(x,y)}{M_T} \qquad 9)$$

For a uniform source function, c(x,y) is given by Eq 2 and M_T is found by employing the decay rate k in Eq 4. If the actual production source function varies with space, call it f(x,y), then we should expect that c(x,y) will vary in proportion to f(x,y) and that Eq 2 would be replaced by

$$c = Af(x,y)\exp(xU/2E_x)W(\alpha,\beta/B) \qquad 10)$$

where A is a constant of proportionality. M_T would still be defined by Eq 8 so that p(x,y) would be

$$p(x,y) = \frac{f(x,y)\exp(xU/2E_x)W(\alpha,\beta/B)}{\int f(x,y)\exp(xU/2E_x)W(\alpha,\beta/B)dxdy} \quad 11)$$

The same approximations used in the orginal report could be used to evaluate $W(\alpha,\beta/B)$. In order to highlight particular regions of entrainment, it would perhaps be better to plot the discrete probability distribution p(x,y), rather than the cumulative probability distribution as reflected by the contours which have been produced to-date. In the absence of data, we have not made any calculations with this approach.

Additional calculations

In accordance with the above discussion, six additional runs were made. Parameters for these runs are summarized in Table 3 and results are presented in Figures 5 (Run 13 for winter flounder larvae), 6 (Runs 14-15 for cunner eggs) and 7 (Runs 16-18 for cunner larvae). As before, each plot presents a cumulative probability distribution, displaying contours within which a certain percentage of organisms is entrained. For each plot contours of 10, 50, 75, 90 and 95% are presented. In order to visually compare the runs, the contours plots have all been drawn to the same scale; however this makes it difficult to see the detail on some of them. To compensate, the distances north of the station to the 50 and 90% contours for each run are indicated in km in the right hand columns of Table 3.

Table 3
Summary of new run parameters

Run No	species/ stage	lifetime τ (days)	die-off rate k (s^{-1})	Current U (m/s)	Long disp E_x (m^2/s)	Lat disp E_y (m^2/s)	Dist to 50% (km)	Dist to 90% (km)
13	WF larvae	42	10^{-6}	0.007	12	7	7.5	18
14	Cunner eggs	2	2.3×10^{-5}	0.015	50	30	1.8	4.0
15	Cunner eggs	2	2.3×10^{-5}	0.04	400	100	5.0	12
16	Cunner larvae	21	2.7×10^{-6}	0.007	12	7	3.5	8.5
17	Cunner larvae	21	2.7×10^{-6}	0.015	50	30	7	17
18	Cunner larvae	21	2.7×10^{-6}	0.04	400	100	20	47

Discussion

For winter flounder larvae, Run 13 (Figure 5) differs from Run 1 (upper left panel of Figure 2) in the use of smaller values of mean current speed and dispersion coefficients. As expected, this results in small contours of entrainment. For example, in the earlier run the 90% contour extends approximately 35 km north of PNPS, while in the new run the distance is about half of this (18 km). To the extent that winter flounder larvae are found very near the bottom, the new run may be more realistic, while if the larvae are actually distributed within the water column, the former run may be more representative. It should be reemphasized that all of these runs assume that the organisms behave passively. Hence any larval behavior which could promote retention (e.g., vertical migration within the water column which is correlated with tidal current direction) has been ignored. Based on our earlier work at Millstone (Dimou and Adams, 1989, plus follow-on study), inclusion of such effects, if they could documented, could significantly limit migration distances.

For cunner eggs, the die-off rate for Runs 14 and 15 (Figure 6) is about 23 times greater than that for Runs 5 and 7 (upper left and lower left panels of Figure 3) and about 75 times greater than that for Runs 6 and 8 (upper right and lower right panels of Figure 3). Despite these large ratios, this does not have a significant effect on the contours because the short organism lifetime ($\tau = 2$ days) and relatively high dispersion already combine to limit the entrainment to regions relatively near the PNPS. For example, comparing runs with the lower combination of mean current speed and dispersion, and the smaller ratio of die-off rates, the distance to the 90% contour is about 4.5 km in Run 5 while it only dropts to about 4 km in Run 14. For the corresponding runs with the larger combination of mean current and dispersion, the distance to the 90% contour is about 13 km in Run 7 and about 12 km in Run 15.

For cunner larvae, the die-off rate for Runs 17 and 18 (upper right and lower left panels of Figure 7) is about 2.7 times greater than that for Runs 9 and 11 (upper left and lower left panels of Figure 4) and about 9 times greater than that for Runs 10 and 12 (upper right and lower right panels of Figure 4). Because of the longer lifetime of cunner larvae ($\tau = 21$ days), as opposed to cunner eggs ($\tau = 2$ days), there is a greater difference in the size of the contours. For example, comparing runs with the lower combination of mean current speed and dispersion, and the smaller ratio of die-off rates, the distance to the 90% contour is about 26 km in Run 9 and about 17 km in Run 17. For the corresponding runs with the larger combination of mean current and dispersion, the distance to the 90% contour is about 72 km in Run 11 and about 47 km in Run 18.

Finally, for cunner larvae, both the die-off rate and the combination of current speed/dispersion has been reduced in Run 16 (upper left panel of Figure 7) in comparison with Runs 9-12 (Figure 4).

As expected, the combined effect is a substantial reduction in the size of the contours; the distance to the 90% contour in Run 16 (8.5 km) compares with distances of 26 to 90 km in Runs 9-12.

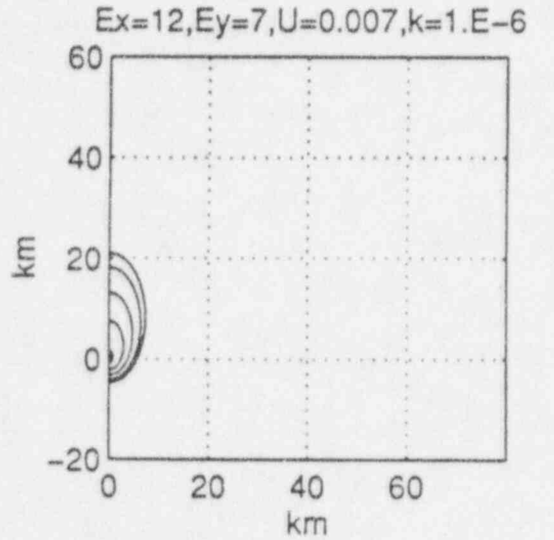


Figure 5 Cumulative probability distribution for the entrainment of winter flounder larvae at PNPS, showing contours (10, 50, 75, 90 and 95%) within which indicated percentage of organisms are entrained

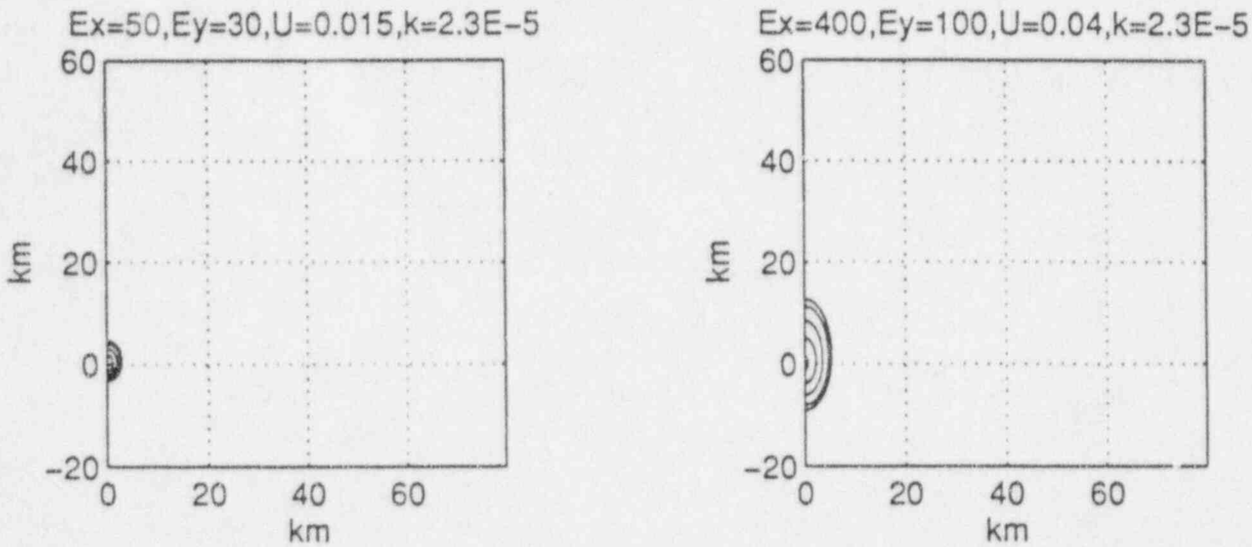


Figure 6 Cumulative probability distribution for the entrainment of cunner eggs at PNPS, showing contours (10, 50, 75, 90 and 95%) within which indicated percentage of organisms are entrained

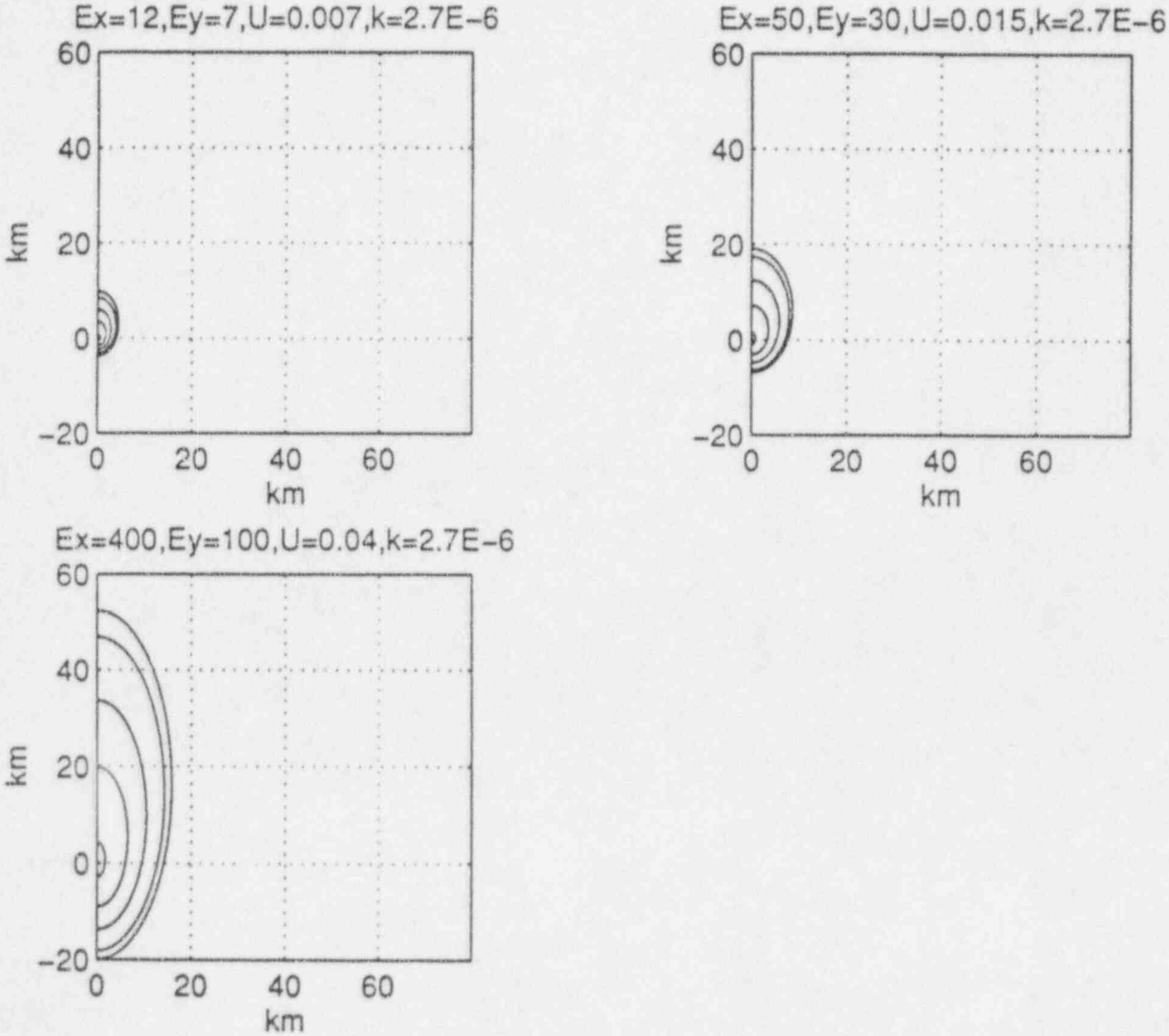


Figure 7 Cumulative probability distribution for the entrainment of cunner larvae at PNPS, showing contours (10, 50, 75, 90 and 95%) within which indicated percentage of organisms are entrained