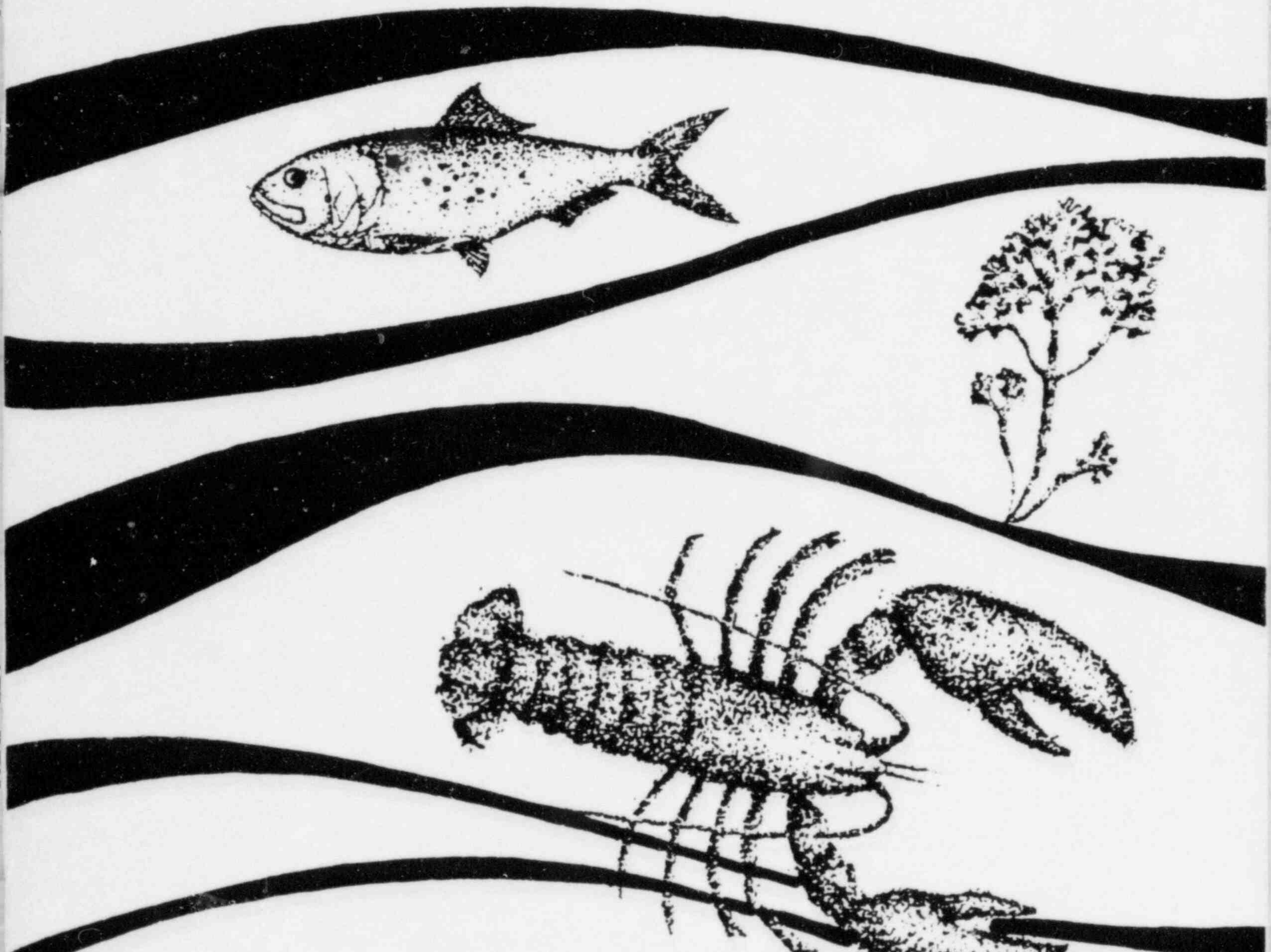
marine ecology studies

Related to Operation of Pilgrim Station

SEMI-ANNUAL REPORT NUMBER 22
JANUARY 1983 — JUNE 1983



BOSTON EDISON COMPANY
NUCLEAR MANAGEMENT SERVICES DEPARTMENT

BOSTON EDISON

NUC149-C1

MARINE ECOLOGY STUDIES
RELATED TO OPERATION OF PILGRIM STATION

SEMI-ANNUAL REPORT NO. 22

REPORT PERIOD: JANUARY 1983 THROUGH JUNE 1983

DATE OF ISSUE: OCTOBER 31, 1983

Compiled and Reviewed by: Robert D. Anderson
Robert D. Anderson
Senior Marine Fisheries Biologist

Lewis N. Scotton
Lewis N. Scotton
Senior Marine Fisheries Biologist

Nuclear Management Services Department
Boston Edison Company
25 Braintree Hill Office Park
Braintree, Massachusetts 02184

TABLE OF CONTENTS

SUMMARY

Highlights of the environmental surveillance and study program results obtained over this reporting period (January - June 1983) are presented below:

Marine Fisheries Studies:

1. The May/June 1983 shorefront sportfish survey at Pilgrim Station revealed a catch rate of 0.24 and 0.35 fish per hour, respectively. In 219 fishing trips in May, 87 fish were caught and for 624 trips in June, 480 fish were taken. The economic value of the Pilgrim Station shorefront sportfishery was estimated at $1,250 in May and $8,100 in June.

2. Pelagic fish mean catch from January - June 1983 at the gill net station (227.2 fishes/set) increased from 1982 when 151.3 fishes/set were taken. Pollock (57.8%), cunner (16.3%) and alewife (8.8%) accounted for 82.9% of the total catch. Pollock accounted mostly for the increase in overall pelagic fish catch as its own catch rate was 42% greater than in 1982.

3. Shrimp trawl catch from January - June 1983 recorded fifteen benthic fish species with winter flounder (40.1%), little skate (28.9%), windowpane (15.7%), yellowtail flounder (5.7%), ocean pout (2.4%) and longhorn sculpin (2.1%) composing 94.9% of the total. Mean CPUE for all species was 37.8 at the surveillance station and 30.8 for all stations pooled in 1983. Individual species CPUEs from January - June 1983 were winter flounder at 12.3, little skate 8.9, windowpane 4.8, yellowtail 1.8, and longhorn sculpin 0.6.

4. Adult lobster mean monthly catch rate per pot haul in May and June 1983 was 0.20 lobsters (0.45 in 1982). This is the lowest value since sampling commenced in 1970. The surveillance area (thermal plume) catch rate was 0.36 while the reference area (control) was 0.21.

5. In May - June 1983 fish observational dive surveys six species were observed in the thermal plume area. Cunner (53.2%), pollock (36.6%), tautog (5.1%) and striped bass (4.7%) were the most numerous species seen. No fish showed abnormal behavior and no gas bubble disease symptoms were observed on routine observational dives. Most species were in greatest concentrations at stations in the direct path of the thermal plume, indicating attraction to the Pilgrim Station thermal effluent.

6. Atlantic silverside accounted for 88.8% of the April - June 1983 haul seine (shore zone) fish catch with a total of eighteen species collected. Shrimp (Crangon spp.) dominated the invertebrate catch. Fish captured in the PNPS intake embayment were Atlantic silverside, sand lance spp., windowpane, northern kingfish, and Americal eel.

7. During April 7 (low tide) and April 26 (high tide), nitrogen plus argon gas saturations were measured in the thermal plume area. Surface saturations were higher at high tide, generally decreasing seaward. Nitrogen saturations did not exceed 115% at greater than 31m from the mouth of the discharge canal.

Impingement Studies:

1. The mean January - June 1983 impingement collection rate was 0.42 fish/hr. The rate ranged from 0.15 fish/hr (June) to 0.71 fish/hr (March and April) with Atlantic silverside comprising 33.5% of the catch, followed by grubby 15.9%, rainbow smelt 6.5%, winter flounder 6.5%, and Atlantic tomcod 5.3%.

2. In March 1983, when the fish impingement rate was 0.71, Atlantic silverside accounted for 78.4% of the fishes collected. This is historically the maximum impingement period for Atlantic silverside.

3. The mean January - June 1983 invertebrate collection rate was 2.94/hr with the horseshoe crab accounting for 56.6%, Crangon sp. 26.0% and sand shrimp 12.7% of the catch. No American lobsters were caught.

4. The impingement collection rates for horseshoe crabs in May (3.34) and June (6.97) were the highest recorded during these months since 24-hour weekly sampling began in 1979.

5. Impinged fish survival (pooled for static and continuous washes) at the end of the new Pilgrim Station sluiceway was 31.9% (short-term) and 26.4% (long-term). Fish introduced in front of operating traveling screens showed initial survival of 94.5% for mummichog (N=110), 17.7% for winter flounder (N=52) and 16.3% for Atlantic silverside (N=129). Long-term survival percentages were 40.0, 9.6 and 0 respectively.

Benthic Studies:

1. Several minor changes in faunal taxonomy may be due to these species being overlooked by previous taxonomists rather than the species being new to the area.

2. In September, 1982 the Effluent station had significantly fewer species than the Manomet Point and Rocky Point reference sites. This pattern appears to be related to reduced habitat stability due to hydrodynamic forces and not due to thermal effects. In April, however, species richness at the Effluent was indistinguishable from that at Rocky Point.

3. Faunal densities in September were higher at the Effluent than at the two reference sites. Densities of Mytilus throughout the area were somewhat lower than in previous years, particularly at Effluent where the community was dominated by an amphipod, Jassa falcata. This pattern was not repeated in April, 1983.

4. Patterns of dominant species were generally similar at all three sites in September; however, at Effluent Mytilus was only the fourth most abundant species at 6.6% of the total fauna. Mussels are known to vary greatly from year to year in reproductive success.

5. Similarity in dominance patterns was evident in the April, 1983 collections. Three species, including Mytilus were among the top four dominants at each station. Mytilus assumed its more typical dominant position in the community, comprising approximately 30% of the total fauna at Effluent and Manomet Point and 12% at Rock Point.

6. Algal biomass was greatest at Effluent, with Rocky Point supporting considerably less biomass than the other two sites, both fall and spring.

7. Results of the four most recent mappings of the extent and configuration of near-field acute impact zones indicate a trend toward diminished size of the impacted area. Previous data available indicated a seasonal variation in impacted area. Because of an extremely small area recorded in June, 1983, it now appears that the seasonal relationship may not be as straightforward as had originally been proposed and that a hypothesis of a steadily decreasing area (probably indicative of a longer cycle) may be more tenable.

8. A preliminary examination of the relationship between changes in the configuration of the near-field impact zones and certain environmental variables was conducted by means of a correlation analysis. Significant correlations were found between near-field impacts and two environmental factors: mean discharge temperature one month prior to mapping and amount of southeast winds during the quarter preceding mapping.

Plankton Studies:

1. Entrainment

   a. A total of 33 species of fish eggs and/or larvae were found in the January - June 1983 entrainment collections.

   b. Egg collections for January - June 1983 were dominated by American plaice (February - March), winter flounder (March - April), labridae - Limanda group (May - June), Atlantic mackerel, windowpane and rockling (May - June).

   c. Larval collections for January - June 1983 were dominated by rock gunnel, longhorn sculpin, and sand lance (January - March), winter flounder (April - June), grubby (February - April), cunner (June), rockling (May), and Atlantic mackerel (June).

   d. No lobster larvae were collected in the entrainment samples for January - June 1983.

   e. Several rainbow smelt larvae were collected in May 1983.

2. Winter Flounder Drift and Egg Viability Studies

a. Sea-bed drifters were released on three dates near the mouth of PHKDB. These drifters provided information on time it takes to drift from PHKDB to PNPS.

b. Results from 2 out of 3 sets do not indicate that drift rates less than seven days can occur.

c. Egg samples were taken from both the intake bay and the discharge canal in order to document age of these eggs.

d. 56% of the live eggs sampled were younger than 7 days. 25% were 1-2 days old and 19% were 3-4 days old.

e. The data suggest that spawing occurs outside the estuary nearer to PNPS.

INTRODUCTION

A. Scope and Objective

This is the twenty-second semi-annual report on the status and results of the environmental surveillance and study programs related to the operation of Pilgrim Nuclear Power Station (PNPS). The study programs discussed in this report relate specifically to the Cape Cod Bay ecosystem with particular emphasis on the Rocky Point area. This is the tenth semi-annual report in accordance with the environmental monitoring and reporting requirements of the PNPS Unit 1 NPDES permit (#MA0003557) from the U.S. Environmental Protection Agency and Massachusetts Division of Water Pollution Control. 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.

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

These studies are guided by an Administrative-Technical Committee which is chaired by a member of the U.S. Environmental Protection Agency and whose membership includes representatives from the University of Massachusetts, the Mass. Division of Water Pollution Control, the Mass. Division of Marine Fisheries, the National Marine Fisheries Service (NOAA), the U.S. Bureau of Sport Fisheries and Wildlife, 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 VI.

B. Marine Biota Studies

1. Marine Fisheries Studies

A modified version of the marine fisheries study initiated in 1969 is being conducted by the Commonwealth of Massachusetts, Division of Marine Fisheries (DMF).

The occurrence and distribution of fish around Rocky Point and at sites outside the area of temperature increase are being studied. Pelagic species are sampled using gill net (1 station) collections (Figure 1) made at biweekly intervals. In 1981, shrimp trawling and haul seining were initiated which provide more PNPS impact-related sampling of benthic fish and shore zone fish, respectively. Shrimp trawling is done twice/month at 5 stations (Figure 2) and haul seining once/week during April - September at 4 stations (Figure 1).

Studies have been conducted since early 1970 of local lobster stock catch statistics for areas off Rocky and Manomet Points (Figure 3). Catch statistics continue to be collected approximately weekly throughout the fishing season (May-November).

A sportfishing creel census was initiated in 1983 to determine the fishing effort, catch and economic value of this activity at the PNPS shorefront recreation area. The census was conducted during randomly selected time segments from May-October.

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

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

2. Benthic Studies

The studies described in this report were conducted by Battelle New England Marine Labs, Duxbury, Massachusetts.

The benthic flora and fauna were sampled at three locations at depths of 10 feet (MLW) (Figure 1). Quantitative

(rock substratum) samples were collected, and the dominant flora and fauna in each plot were recorded. Sampling was conducted two times per year to determine biotic changes, if any. Transet sampling off the discharge canal to determine the extent of the denuded and stunted zones is conducted four times a year. Results of the benthic surveys reported during this period are discussed in Section IIIB.

3. Plankton Studies

Since August 1973, Marine Research, Inc. (MRI) of Falmouth, Massachusetts has been studying entrainment in Pilgrim Station cooling water of fish eggs and larvae, and lobster larvae (from 1973-1975 phytoplankton and zooplankton were also studied). Figure 4 shows the entrainment contingency sampling station locations. Information generated through these studies has been utilized to make periodic modifications in the sampling program to more efficiently address the question of the effect of entrainment. These modifications have been developed by the contractor, and reviewed and approved by the Pilgrim A-T Committee on the basis of the program results. Plankton studies in 1983 emphasized consideration of ichthyoplankton entrainment. The 1983 entrainment report was prepared by Boston Edison Company. Data were collected by Marine Research, Inc. Results of the ichthyoplankton entrainment studies for this reporting period are discussed in Section IIIC.1.

The 1983 winter flounder larvae study focused on drift time between the PH-DB estuary and the power plant using sea-bed drifters. In addition, winter flounder larvae eggs from the intake and discharge were aged as in 1982 and the results compared with the drift rates. Results from the winter flounder larvae studies are shown in Section IIIC.2.

4. Impingement Studies

The Pilgrim 1 impingement program commenced in November 1972 to speciate and quantify the organisms carried onto the four intake traveling screens. Through June 1976, the Mass. Division of Marine Fisheries reported on collection by private contractors. In January 1976, Marine Research Institute began both collecting and reporting on results of this program. 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 1 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. Fish survival studies were conducted in 1983 to determine its effectiveness in protecting marine life.

Results of the impingement monitoring and survival programs for this reporting period are discussed in Sections IIID.1 and IIID.2, respectively.

C. Fish Surveillance Studies

In Spring 1976, regular fish spotting overflights were commenced as part of a continuing effort to monitor the times when large concentrations of fish might be expected in the Pilgrim vicinity. Since September 1976, and regularly from May-October since 1978, dive inspections have been conducted of the Pilgrim discharge canal in order to evaluate fish barrier net durability, and effectiveness in excluding fishes from the discharge canal.

Annual summary reports for these efforts for 1983 will be presented in Semi-Annual Report No. 23.

D. Station Operation History

The daily average, reactor thermal power levels from January through June 1983 are shown in Figure 5.

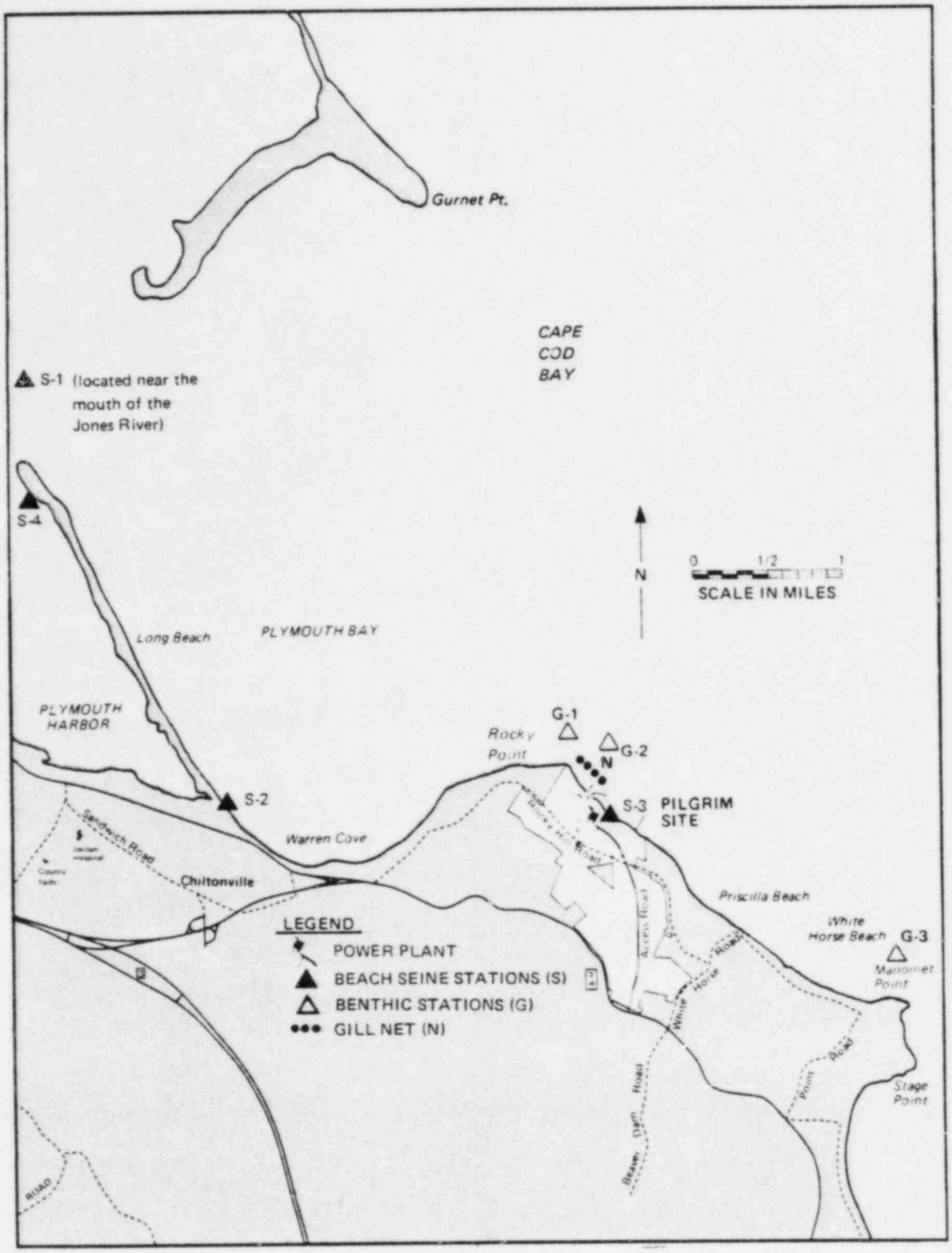


Figure 1. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations

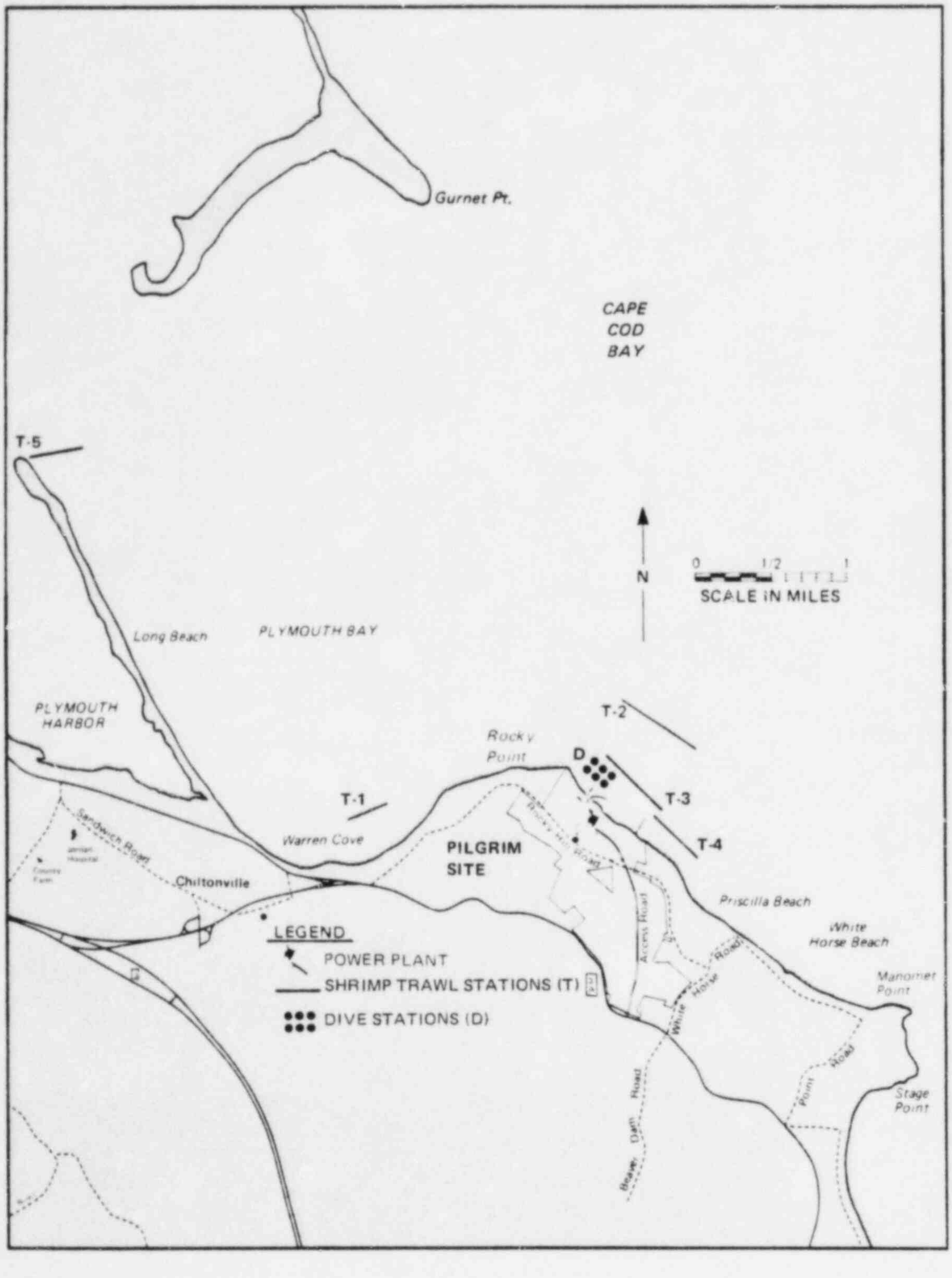


Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies

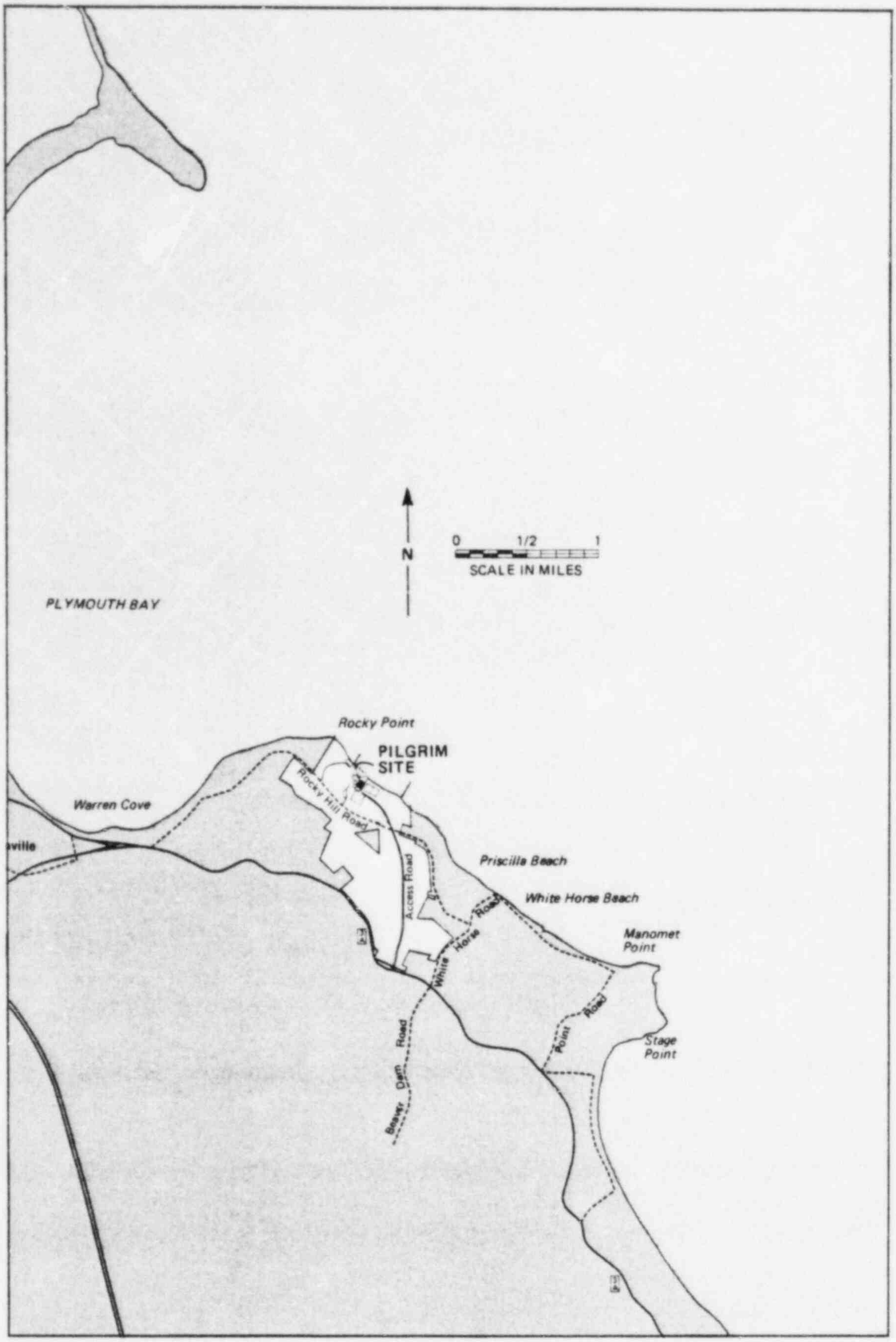


Figure 3. Lobster Pot Sampling Grid for Marine Fisheries Studies.

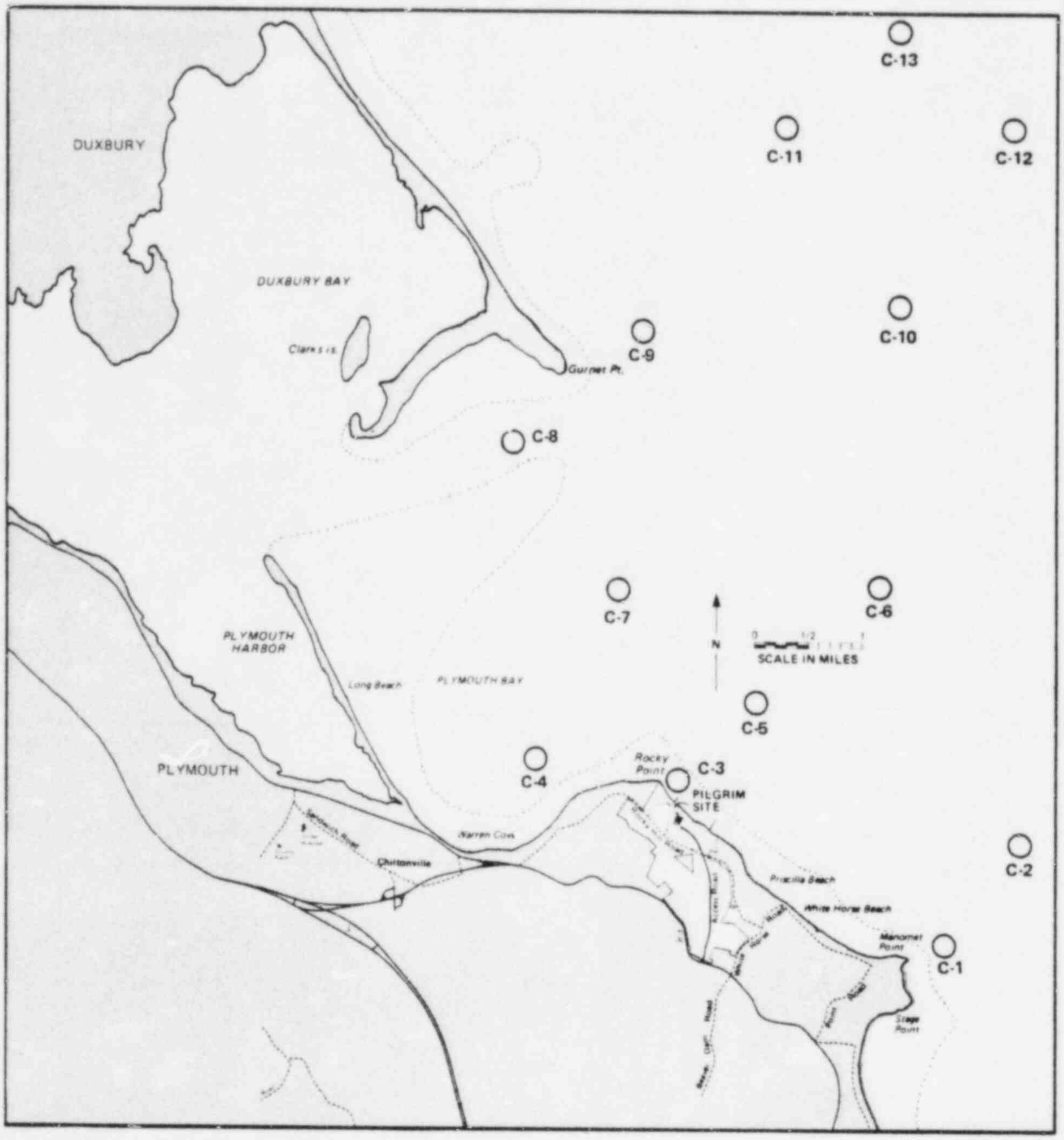


Figure 4. Location of Entrainment Contingency Plan Sampling Stations, C.

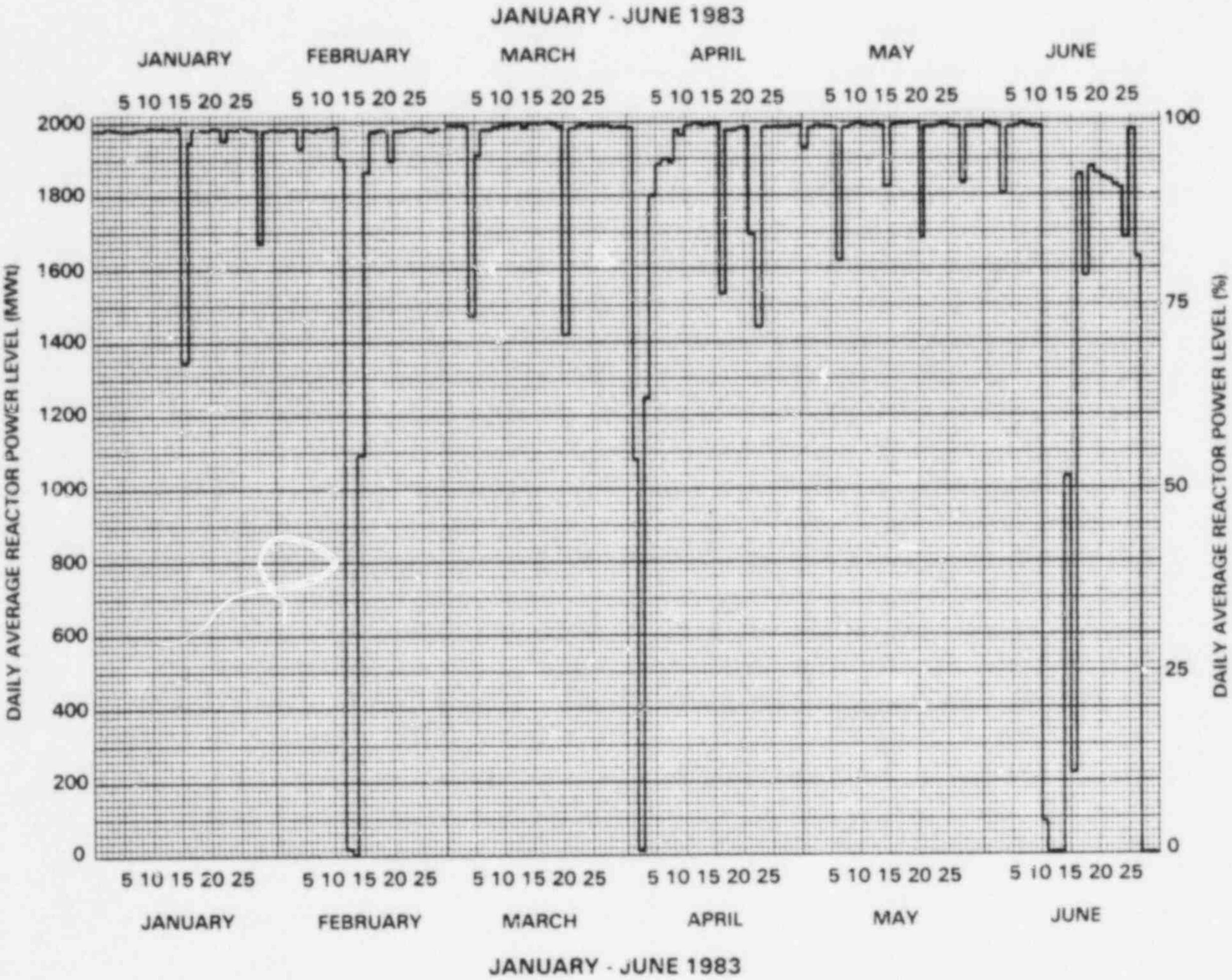


Figure 5. Daily Average Reactor Thermal Power Level (MW_t and %) from January-June 1983 for Pilgrim Nuclear Power Station.

SEMI-ANNUAL REPORT
ON
STUDIES TO EVALUATE POSSIBLE EFFECTS
OF
PILGRIM NUCLEAR POWER STATION
ON MARINE FISHERIES RESOURCES
OF WESTERN CAPE COD BAY

Project Report No. 35 (January-June, 1983)

By
Robert P. Lawton, Phillips Brady, Christine Sheehan,
Mando Borgatti, and Vincent Malkoski

August 30, 1983
Massachusetts Department of Fisheries,
Wildlife and Recreational Vehicles
Division of Marine Fisheries
100 Cambridge Street
Boston, Massachusetts 02202

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. SUMMARY

Lobster catches declined markedly throughout the study area. A total of 1,205 lobster pots was sampled in May and June rendering data on 1,017 lobsters. May's legal catch rate (catch per pot haul) was the lowest of the study, while June's was 50% below that of last year. The mean rate for the surveillance area was slightly higher (0.36) than for a reference area (0.21). Mean catch of lobsters per trawl tow declined 50% from last year.

Although 15 finfish species were taken in our nearshore bottom trawl survey during the January-June sampling period, winter flounder, little skate, and windowpane accounted for 85% of the total catch in number. The greatest number of species (12) and fish were captured at the discharge site (Station 3). Densities of little skate and windowpane were highest there, while abundance of winter flounder was greatest in Warren Cove (Station 1).

Twice as many species of fish (30) were captured by gill net in the vicinity of the discharge during the same sampling period. Catch-per-unit-effort for all species combined increased 67% from last year, primarily due to increased pollock catches. In addition to the latter species, cunner, Atlantic cod, Atlantic menhaden, alewife, and tautog were numerically dominant.

We seined 18 species of fish in the shore zone. The numerical dominance of the Atlantic silverside in the nearshore community in the environs of Pilgrim Station was evident considering that this species comprised 88.8% of the total seine catch in the spring. Of the taxa captured in the intake embayment since 1981, only the silverside and sand lance were taken all three years of the seine survey. Diversity was greatest at Long Point, located at the mouth of Plymouth, Kingston, Duxbury Bay.

Six species of fish were observed during observational SCUBA dives con-

ducted in May and June in the vicinity of Pilgrim's discharge plume. Cunner and pollock were most often sighted. The majority of fish displayed an apparent attraction to the effluent current. No fish exhibited an abnormal appearance or behavior, and no overt symptoms of gas bubble disease were evident.

A creel census conducted at Pilgrim's Shorefront recreational area revealed that an estimated 219 and 624 angler-trips were made in May and June, respectively. During May, an estimated 370 hours of effort were expended by anglers and 87 fish caught comprising 8 species. The mean catch rate for pooled species in May was 0.24 fish per angler hour. In June, all parameters increased; an estimated 1,363 hours of effort resulted in a catch of 480 fish constituting 10 species. The average pooled catch rate for June increased slightly to 0.35 fish per hour angled. The economic value of the recreational fishery at Pilgrim Shorefront (based on cost to go fishing) was appraised to be $1,250 in May and $8,100 in June.

Gas saturations were measured in the thermal discharge on two dates this spring - one at low tide and the other at high, to ascertain the distal extent of nitrogen saturations in the plume. Nitrogen plus argon saturations at the surface were highest at the closest station to the mouth of the discharge canal. Percent saturations generally decreased going seaward of the discharge canal. Surface nitrogen saturations were higher at all stations at high tide. Levels did not exceed 115% at distances greater than 31 m from the mouth of the discharge canal.

II. INTRODUCTION

Ecological studies conducted by the Massachusetts Division of Marine Fisheries since 1969 to assess non-radiological impact of Pilgrim Nuclear Power Station on fisheries resources were continued in 1983 under Purchase Order No. 69886 to Boston Edison Company. Data from January-June, 1983 are summarized and discussed in this report and compared with past findings. Measurements, counts, percentages, and indices of abundance are compared spatio-temporally to identify trends and relationships between stations and over time and to examine causation for observed ecological phenomena.

III. METHODS AND MATERIALS

With the large number of lobstermen fishing in the vicinity of Pilgrim Nuclear Power Station and the many landing sites along the coast, it was impractical to monitor the entire lobster fishery. Therefore, an index of harvest has been obtained by sampling the catch of two cooperating commercial lobstermen, who fish a large number of pots in the study area. Because of cost and manpower restraints, controlled research fishing was not undertaken. Sampling was conducted weekly during the inshore lobster season by alternating lobstermen. To facilitate data treatment, the study area was partitioned into 0.8 km^2 quadrats, with catch records kept separately for each quadrat (Fig. 1) so that reference and surveillance areas could be compared. Information collected included: catch of lobsters per pot-haul; pot location; and for each lobster: carapace length (CL) in mm, sex, reproductive state, and molting condition. Data were verbally reported on tapes in the field and later transcribed to written records and analyzed.

To assess power plant impact on the nearshore demersal fish community, we continued small vessel (7 m) trawling to representatively sample the inshore coastal area (3-10 m in depth MLW) in the environs of Pilgrim Station. Five stations were sampled on a bi-weekly basis (Fig. 2). Trawling in the impact area was conducted approximately 30-200 m seaward of the intake breakwater and discharge outlet, respectively. Fifteen minute tows were made utilizing a 9.8 m Wilcox trawl (9.8 m sweep; 7.0 m head rope; with wings of 11.4 cm stretch measure; and fitted with a 6.4 mm stretch mesh cod-end liner. A duplicate sample was taken at one randomly selected station each sampling day. Catch (no. of fish) per 15 minute tow (CPUE) was used as a measure of relative abundance. Data for replicate tows were averaged. When uncontrollable factors

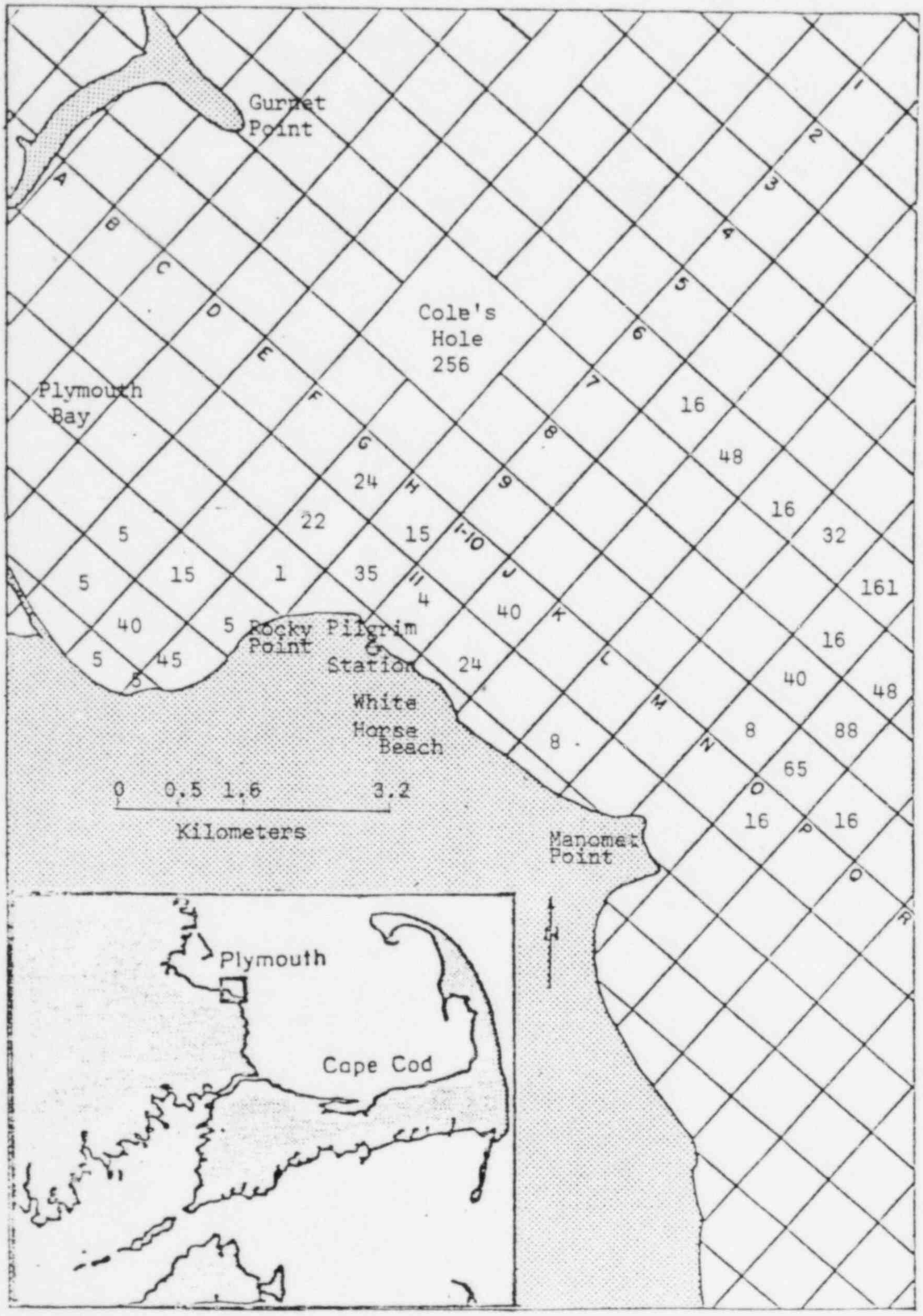


Figure 1. Distribution of lobster pots sampled, May-June, 1983.

[An additional 81 pots in quadrats N-4 (16), and O-6 (65) were sampled, but do not appear on the grid map.]

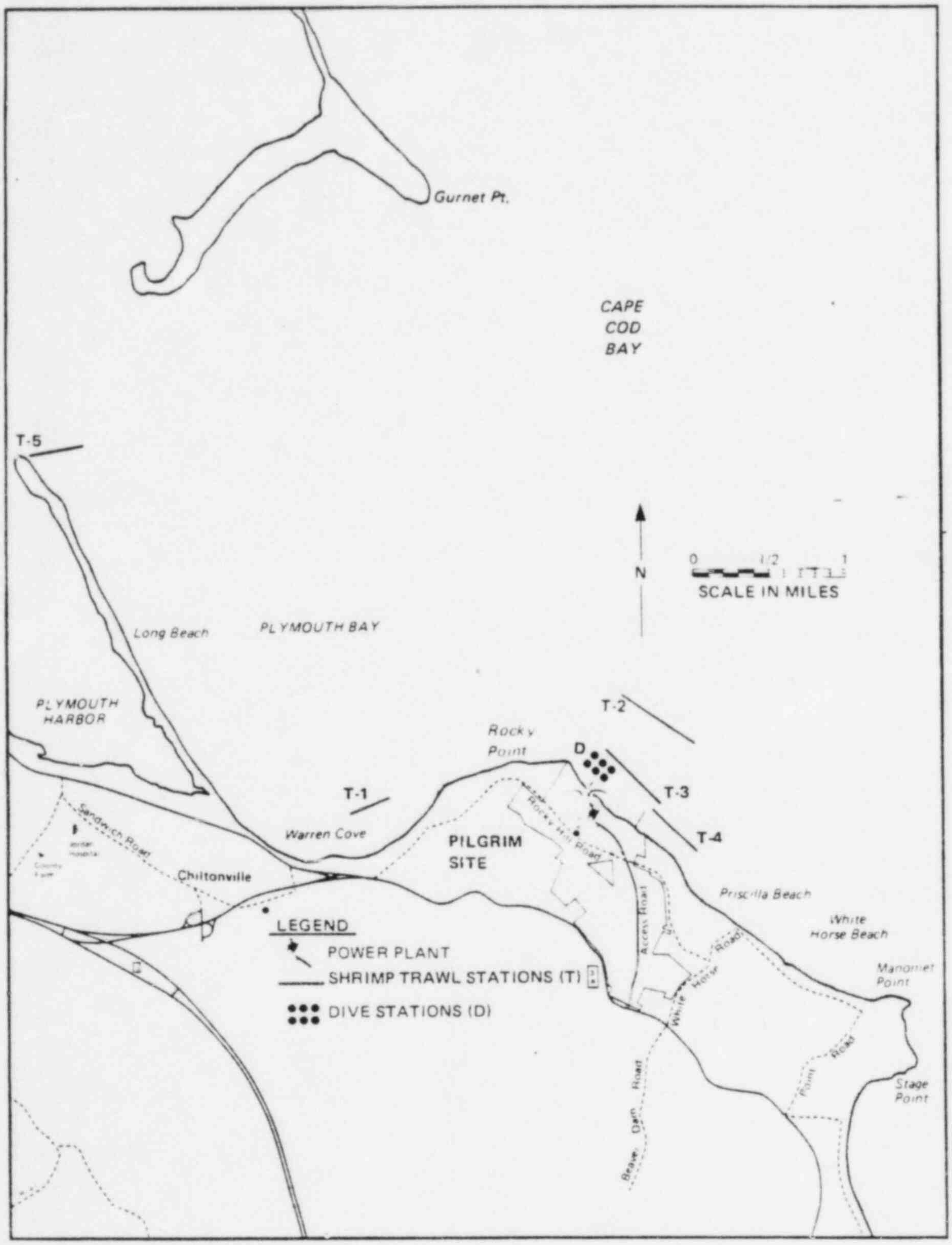


Figure 2. Location of Shrimp Trawl and Dive Sampling Stations for Marine Fisheries Studies.

prevented us from completing a 15-minute tow, catch figures were adjusted accordingly.

Pelagic and demersal fish frequenting the ledges that bracket the plant site were sampled with a sinking monofilament gillnet: 3.0 m deep and 213.4 m long consisting of a "gang" of seven 30.5 m panels of the following mesh sizes: 3.8, 5.1, 6.4, 7.6, 6.9, 11.4, 15.2 cm - stretch measure. Data records were kept by mesh size and also pooled for inter-year comparisons. Biweekly overnight sets were made at one station located northwest of the terminus of the discharge jetties with the net set parallel to shore along the 3 m depth contour (MLW) (Fig. 3). This site is subject to limited thermal elevation from waste heat. To minimize bias, the end of the net positioned nearest to the discharge plume was reversed on alternate sets.

Haul seining, initiated in 1981, was continued to sample shore-zone finfish in the vicinity of Pilgrim Nuclear Power Station. This sampling technique complements other sampling methods and provides representative data on forage species and the juvenile stages of sport and commercial fishes which inhabit the intertidal and shallow subtidal zones. Species occurring in the nearshore area are important components of community structure. As an effective means of sampling shallow water habitats, haul seining countervails gear selectivity of trawl and gill nets.

Five stations (Fig. 3), representing typical shore-zone habitats in the study area, were systematically sampled weekly beginning in April. The temporal selection of field sampling coincided with the traditional period of highest numbers of fish found inshore. Gray's Beach (Station 1) in Plymouth, Kingston, Duxbury Bay complex, an estuarine location, is a sandy beach bordered by salt marsh grass (Spartina alterniflora) with exposed mud flats at low tide. Warren

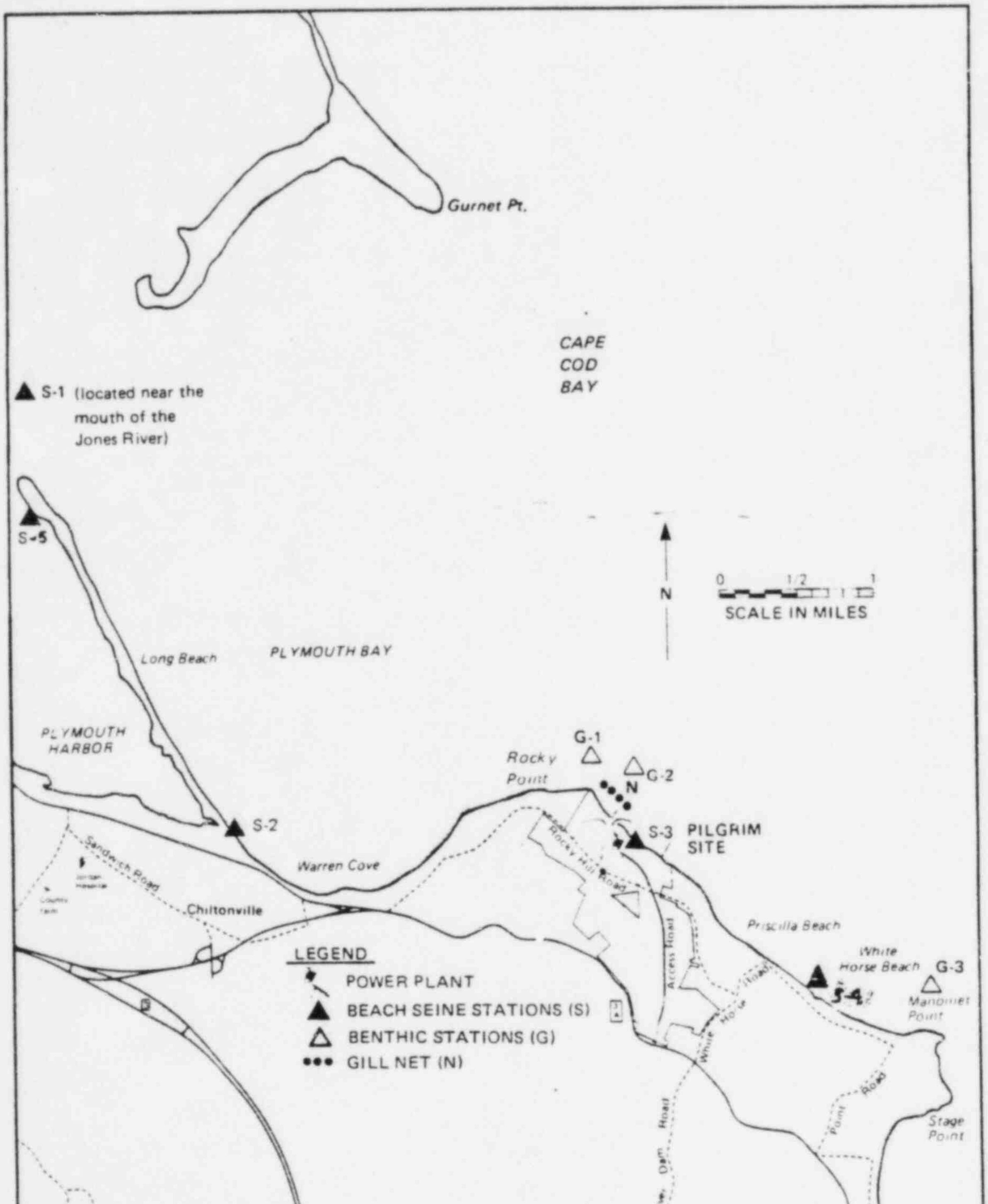


Figure 3. Location of Beach Seine and Gill Net Sampling Stations for Marine Fisheries Studies, and Benthic Studies Sampling Stations

Cove (Station 2) and White Horse Beach (Station 4), both in Plymouth, are open coastal sand beaches. White Horse Beach was sampled on a supplemental basis. Pilgrim Station Intake embayment (Station 3) is a man-made enclosure bordered by breakwaters and rip-rap. Seining at the latter site was conducted at the head of the embayment, proximal to the power plant's intake screens. Station 5 was added this year and is located just inside the mouth of Plymouth Harbor at Long Beach, a barrier beach.

We adopted a standardized quantitative seining technique, modified after Conover and Ross (1982), requiring 3-4 people and employing a 45.7 x 1.8 m haul seine with a 1.8 x 1.8 x 1.8 m pocket of 0.48 cm square mesh (twine #63). The net was set as follows: 13.7 m of net were drawn together at one end and walked out perpendicular from shore to a depth of approximately 1.1 m with the rest of the net trailing behind. The central 18.3 m section, containing the bag, was then stretched parallel to the shoreline while the other end was secured ashore. At this point, an attached lead weight and float was dropped at the newly formed corner, and this end of the net was quickly brought to shore thus enclosing a rectangular area completed by the shoreline. Replicate hauls were made at each station to address data variability, and mean catches were calculated. Seining was conducted at different tidal stages. Water temperature and salinity of the nearshore water column (≈ 1 m deep) were measured using a YSI (Model 33) SCT meter at the time of sampling.

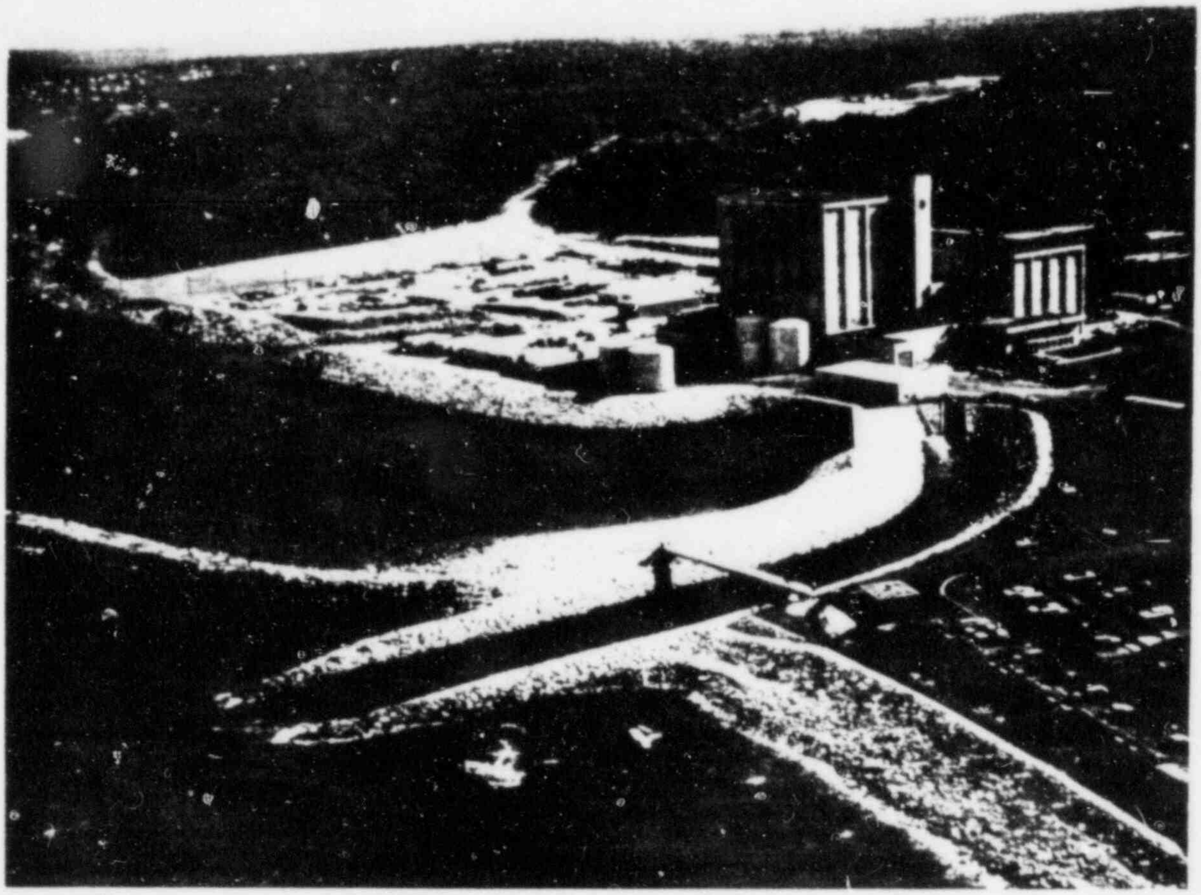
The surface area (m^2) of water seined each haul was estimated considering the linear distance of the net from shore at inception of a set. Fish were identified, enumerated, and measured. If catches were unusually large, all fish were counted, but length data were obtained from a subsample of at least 100 individuals of each species caught. Density estimates (no. per m^2 surface

area) will later be calculated by dividing species catch by the surface area seined.

The underwater finfish observational study continued in 1983. Standardized inspection at six selected station's (Fig. 2) was systematically accomplished bi-weekly by biologist divers, utilizing SCUBA, beginning in May. Diving was restricted to a two-hour period before and after high tide. Two divers descend to the bottom and occupy each station for about 8 minutes while they record their observations on marine biota, placing the major emphasis on finfish. Dive stations designated as 'S', 'D', and 'C' were located in the 'stunted', 'denuded', and 'control' zones (Boston Edison Company 1980). This endeavor provides first-hand observations with which to biomonitor plysical impact seaward of the discharge canal barrier net.

An on-site intercept creel census was begun in May to evaluate the recreational fishery at PNPS Shorefront Area. Only shore anglers were interviewed by the census-taker in that manpower and cost constraints precluded interviewing boat fishermen off the plant. Accuracy of the data was improved by surveying anglers while they were actively engaged in fishing rather than relying on their recall. Complete and incomplete fishing-trip interviews were obtained, and catch statistics were expanded to obtain estimated totals. Shore fishing is conducted from two effluent canal jetties, an intake breakwater, and off the sandy beach at the head of the intake embayment (Fig. 4).

The study's principal objectives were to describe and evaluate the recreational fishery at the Shorefront, specifically assessing angling effort and returns to fishermen, including catch information. We obtained data on catch, effort, species preference, catch rates, size and weight measurements, and trip expenditures.



(Boston Edison Co.)

Figure 4. Aerial view of Pilgrim Shorefront; pictured in the foreground from left to right: intake breakwater, two effluent canal jetties, and parking area.

The census in May and June consisted of four randomly selected half-day segments during weekdays, one randonly chosen morning or afternoon segment each weekend with the other weekend day receiving all-day coverage, and all day on holidays. Estimates of the number of fishermen, effort expended, and total catch for each species were calculated separately for half-day segments on weekdays and weekends by extrapolating respective sample data. Results were combined with any holiday and weekend totals to provide monthly and yearly sums.

We undertook a short-term project this year relative to regulatory concerns as to the extent of lethal gas saturations in the thermal plume because of the potential of future fish kills induced by gas bubble disease. Our objective was to define the 115% nitrogen isopleth emanating from the discharge canal. Our work was conducted bracketing the plume from outside the discharge jetties seaward to about 183 m offshore. Field measurements, were collected in April and will again be obtained in September on flood and ebb tides when the plant is operating at or near full capacity. We sampled at 11 stations (Figs. 5 and 6) on days of offshore winds in order to measure maximum distal effect of the plume on nitrogen saturations at the water's surface. Two Weiss saturometers were used to measure total gas pressure. Dissolved oxygen samples were collected, fixed, and returned to the laboratory for titration analyses. Temperature, salinity, and barometric pressure were also recorded.

Figure 5. Nitrogen + Argon percent gas saturations at 11 stations in PNPS discharge plume, 7 April, 1983 - low tide.

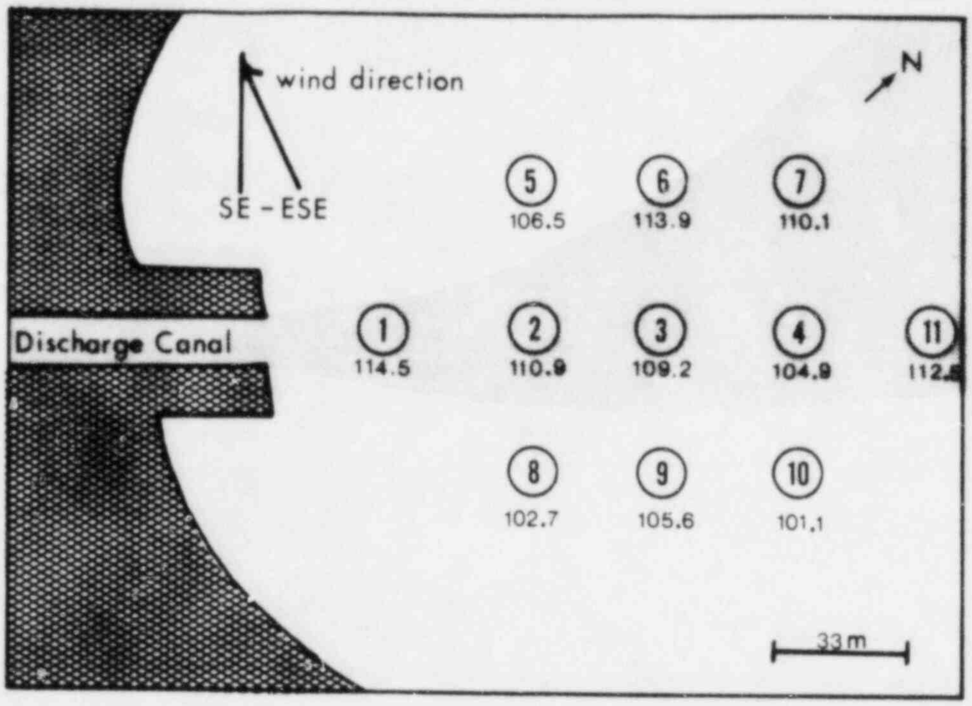
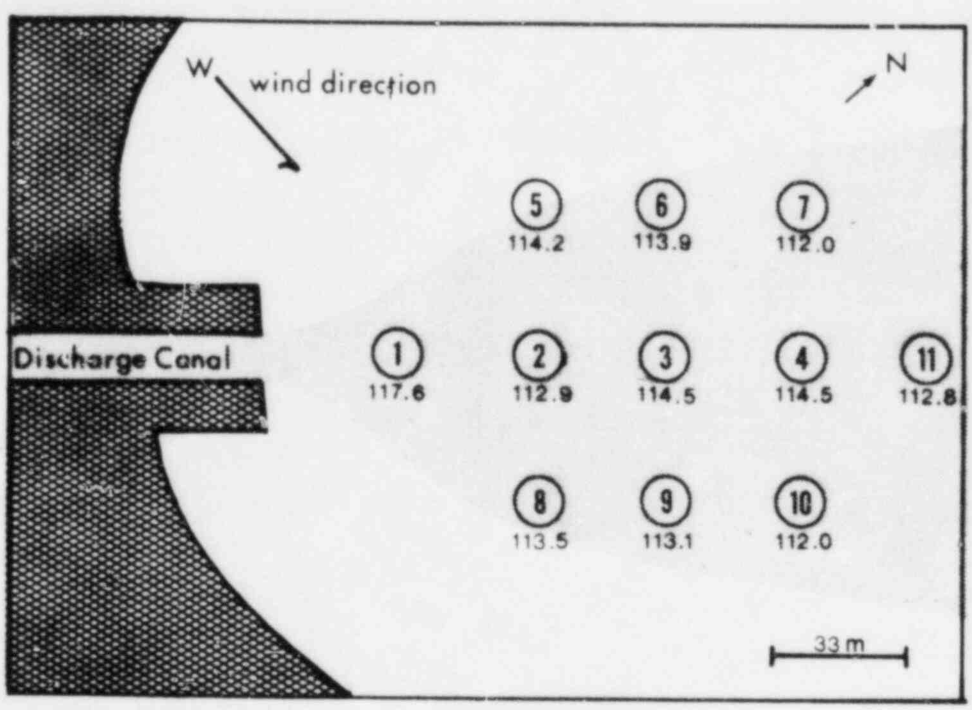


Figure 6. Nitrogen + Argon percent gas saturations at 11 stations in PNPS discharge plume, 26 April, 1983 - high tide.



IV. RESULTS AND DISCUSSION

A. COMMERCIAL LOBSTER CATCH STATISTICS

A total of 1,205 lobster pots, containing 1,017 lobsters, was sampled during this reporting period with data collections commencing on 6 May. Spatial distribution of sampled pots is presented in Figure 1. Average legal lobster catch per pot haul per month for all quadrats combined together with monthly rates from past years are presented in Appendix A.

The project biologist sampled 241 legal lobsters this spring. Mean monthly catch rates (catch per pot haul) of legal lobsters ($\geq$ 81 mm carapace length) for May and June were 0.18 and 0.23, respectively. May's catch rate was the lowest monthly value recorded for all years of the study, while June's rate, the second lowest obtained for that month, was 50% below last year. The overall average for all quadrats combined for May and June was 0.20 legal lobsters per pot haul; this value is the lowest obtained since sampling commenced. The mean rate for surveillance quadrats H-11 and I-11 was slightly higher (0.36). A catch rate of 0.21 for two selected comparable nonthermal quadrats, G-11, and J-11, mirrored closely the rate for all quadrats combined.

Reduced commercial catches were also reported this spring from northern portions of Massachusetts' waters (e.g., Cape Ann and Beverly-Salem) whereas areas south of Cape Cod were more productive[1].

Since 1978, commercial lobstermen have expanded their fishing operations on sand substrate. Data from project trawl studies have corroborated an increase in abundance of lobsters on sand bottom over the last few years. Catch

---

[1]B. Estrella, Marine Fisheries Biologist, Coastal Lobster Investigations, Mass. Division of Marine Fisheries, Sandwich, Mass.

per standard trawl tow, utilizing a half-Yankee trawl and a half-Wilcox trawl averaged 16.4 lobsters per tow from 1979-1980 and increased to 22.4 per tow in 1981. The 1982 catch per tow averaged 20.2 but was 26.9 for the January-June period, traditionally a time of reduced lobster activity. Catch per bottom trawl for the first half of 1983 declined by more than 50% to 13.1 lobsters. We can only speculate as to cause of the reduced catches in the vicinity of Pilgrim Station. One possible factor is the mild winter of 1983, which may have allowed an increased exploitation of last fall's recruits, thus reducing the stock of legal lobsters available in the spring fishery. A review of monthly lobster landings from Plymouth County will be conducted when 1983 landings are available to verify this contention.

B. NEARSHORE BENTHIC FINFISH

Nearshore trawling commenced on 31 January and continued through June. Sampling trips were monthly from January-March due to inclement weather, but increased to biweekly from April through June.

A total of 1,226 fish representing 15 species was collected in 40 tows (Table 1). Six species: winter flounder, little skate, windowpane, yellow-tail flounder, ocean pout and longhorn sculpin comprised 94.9% of the total catch. Station 3 (surveillance station) yielded the greatest combined catch per standard tow (CPUE) of 37.8; while the average catch for all stations for all species combined was 30.7 fish/tow.

Winter flounder was dominant comprising 40.1% of the total catch. This species comprised 42.4 and 42.0% of the catches in 1981 and 1982, respectively. Abundance was greatest at Station 1 where we obtained a mean annual CPUE of 14.6 (Table 2). The average catch at other locations sampled ranged from 9.8-14.5, with a mean CPUE for pooled stations of 12.3.

Little skate ranked second in total catch at 28.9%. In 1982, skate spp. ranked fourth at 20.8% of the total catch and in 1981 ranked second at 14.2%. Mean CPUE ranged from 5.0 - 14.4, with the largest concentrations occurring at the surveillance location (Station 3). Pooled CPUE was 8.9 (Table 2).

The largest catches of windowpane also occurred at the discharge station, where we obtained a mean CPUE of 7.0 (Table 2). Windowpane comprised 15.7% of the total catch in 1983, as compared to 15.8% and 11.4% in 1981 and 1982, respectively. Overall mean catch per tow was 4.8.

Yellowtail flounder was fourth in abundance, constituting 5.7% of all fish captured. This species ranked third in 1981 and 1982, comprising 15.8 and 16.2% of the trawl totals. Catch per tow ranged from 0 at Station 5 to

Table 1. Species numbers and percent composition of finfish captured by near-shore trawling at Stations 1-5, January-June, 1983.

	Sta. 1	Sta. 2	Sta. 3[a]	Sta. 4	Sta. 5	Totals	Percent of total catch
No. of Tows	10	6	11	7	6	40	
Winter flounder	146	58.5	109.3*	101.2*	77*	492*	40.1
Little skate	54	37.3*	158.9*	74.7*	30*	354.9*	28.9
Windowpane	48	17.3*	76.8*	28.1*	22.5*	192.7*	15.7
Yellowtail flounder	1	26*	24.7*	18.3*	-	70*	5.7
Ocean pout	12	5	6	6.3		29.3*	2.4
Longhorn sculpin	2	4	10.2*	6.5*	3	25.7*	2.1
Winter skate	3	2	7	5.8*	1	18.8*	1.5
Fourspot flounder		6	9	2.5*		17.5*	1.4
Sea raven		1	3		1.5*	5.5*	0.4
Rainbow smelt	1		4.3			5.3*	0.4
Atlantic silverside			5.3			5.3	0.4
Atlantic tomcod				1.2	3*	4.2*	0.3
Northern searobin	2		1			3.0	0.2
Grubby				1.2		1.2*	0.1
Sand lance				1		1.0	0.1
Total species	9	9	12	11	7	15	
Total number of fish	269.0	157.1	415.5	246.8	138.0	1226.4	
Pooled species catch/tow	26.9	26.2	37.8	35.3	23.0	30.7	

* Represents expanded value.
a Surveillance station.

Table 2 . Near-shore trawl catch data for selected demersal community species occurring in the vicinity of Pilgrim Station, January-June, 1983.

	Pseudopleuronectes americanus	Limanda ferruginea	Raja erinacea	Scopthalmus aquosus	Myoxocephalus octodecemspinosus
Station 1					
Size range (mm)	105-407	158	240-506	126-321	243-321
Mean size (mm)	292.9	158.0	374.0	253.5	282
Mean catch/tow	14.6	0.1	5.4	4.8	0.2
Station 2					
Size range (mm)	126-389	45-373	137-485	116-330	270-293
Mean size (mm)	280.0	204.7	308	261.8	280
Mean catch/tow	9.8	4.0	6.2	2.9	0.7
Station 3*					
Size range (mm)	88-372	135-392	185-495	148-356	272-318
Mean size (mm)	254.6	252.9	276.6	235.7	286.6
Mean catch/tow	9.9	2.2	14.4	7.0	0.9
Station 4					
Size range (mm)	90-381	120-410	260-462	87-333	294-324
Mean size (mm)	253.3	250.5	339.9	256.3	307.4
Mean catch/tow	14.5	2.6	10.7	4.0	0.9
Station 5					
Size range (mm)	68-371	-	241-528	120-243	311-324
Mean size (mm)	261.2	-	409.2	203.2	317.5
Mean catch/tow	12.8	0	5.0	3.8	0.5
Pooled catch/tow	12.3	1.8	8.9	4.8	0.6

* Surveillance station.

4.0 at Station 2 (Table 2); pooled CPUE averaged 1.8.

Ocean pout and longhorn sculpin each comprised approximately 2% of the total catch (Table 1). Longhorn sculpin were most abundant at Stations 3 and 4 and ocean pout, at Station 1. Pooled CPUE was 0.6 for longhorn sculpin and 0.7 for ocean pout.

The greatest number of species (12) was captured at the surveillance site (Station 3), with the second largest diversity occurring at Station 4 (Table 1). However, Station 3 had more species in common with Stations 1 and 2 than with Station 4. Little skate, windowpane, and longhorn sculpin were most abundant at the surveillance station (Table 1). Little skate abundance indices exceeded CPUE values for winter flounder at this location, while winter flounder ranked first at other sites. Pooled CPUE for all species combined (37.8) was greatest at the surveillance station (Table 1).

C. PELAGIC AND BENTHI-PELAGIC FISHES

A total of 2,045 fish (pooled 7 panels) representing 30 species (Tables 3 - 4) was captured during 9 sets of the net. By-catch of crabs (Cancer irroratus and C. borealis) and lobsters was low.

Mean catch per overnight set (catch per unit effort - CPUE) was 227.2 (pooled species) for the 7 panels. Although sampling was conducted at two stations in 1982, we feel that Station 1 data was representative and comparable for both years. This year's overall catch estimate represents a 67% increase over last year's mean CPUE of 151.3. Primarily responsible for this was an increase of 42% in catch per set of pollock (Pollachius virens). Further comparison between these years indicated that trends in occurrence, numbers of species and individuals were quite similar.

Pooled data from the five original panels (3.8-8.9 cm mesh) revealed that pollock was most abundant, comprising 60% of the total catch. Mean catch per set was 130.4. Comprising 17% of the pooled catch, cunner (Tautogolabrus adspersus) was second in abundance. A mean CPUE of 37.0 was obtained for the sample period.

Other common species were Atlantic cod (Gadus morhua), Atlantic menhaden (Brevoortia tyrannus), and alewife (Alosa pseudoharengus). None, however, represented more than 10% of the total catch.

Tautog (Tautoga onitis) was dominant in catches of the larger two panels (11.4 and 15.2 cm mesh). This species comprised 28.1% of the total, with a mean CPUE of 2.8. Atlantic cod and winter flounder (Pseudopleuronectes americanus) comprised 18% and 12.4% of the total catch, respectively.

Among the uncommon species captured was a lumpfish (Cyclopterus lumpus) taken in March; this individual was a ripe female. We also caught a shorthorn sculpin (Myoxocephalus scorpius) in June, measuring 136.0 mm.

Table 3 . Gill net catch data (5 panels of 3.8-8.9 cm mesh) from the vicinity of PNPS, from January-June, 1983.

Species	Number	Percent of total catch	Size range (mm)
pollock	1,174	60.0	120-488
cunner	333	17.0	115-273
alewife	176	9.0	184-357
Atlantic cod	78	4.0	146-683
tautog	32	1.6	169-399
northern searobin	26	1.3	182-361
silver hake	23	1.2	185-531
Atlantic menhaden	22	1.1	225-312
longhorn sculpin	17	0.9	239-407
sea raven	17	0.9	198-392
Atlantic herring	13	0.7	228-253
winter flounder	10	0.5	165-375
Atlantic mackerel	8	0.4	251-375
striped bass	5	0.3	298-418
blueback herring	3	0.2	170-188
rainbow smelt	3	0.2	230-249
Atlantic tomcod	2	0.1	210-212
little skate	2	0.1	432
smooth dogfish	2	0.1	770-962
American shad	1	0.1	349
black sea bass	1	0.1	285
coho salmon	1	0.1	484
four-spot flounder	1	0.1	272
grubby	1	0.1	185
northern kingfish	1	0.1	333
shorthorn sculpin	1	0.1	136
weakfish	1	0.1	365
white perch	1	0.1	249
winter skate	1	0.1	517
Total	1,956		

Table 4. Gill net catch data (2 panels of 11.4-15.2 cm mesh) from the vicinity of PNPS, from January-June, 1983.

Species	Number	Percent of total catch	Size range (mm)
tautog	25	28.1	200-482
Atlantic cod	16	18.0	412-603
winter flounder	11	12.4	215-368
pollock	8	9.0	187-485
smooth dogfish	8	9.0	678-956
sea raven	6	6.7	277-366
alewife	4	4.5	262-345
longhorn sculpin	3	3.4	311-332
little skate	2	2.2	444-483
winter skate	2	2.2	540-560
lumpfish	1	1.1	542
silver hake	1	1.1	500
striped bass	1	1.1	462
summer flounder	1	1.1	535
Total	89		

D. SHORE-ZONE FISHES

During 11 sampling days, we made 70 sets of the haul seine and captured 1,292 fish comprising 18 species (Table 5). Several invertebrates were also collected, with the common shrimp (Crangon spp.) being most abundant. Water temperatures at the time of sampling ranged from 5.0 to 22.8 C, and salinities were from 24-33 ‰ .

The Atlantic silverside (Menidia menidia) was dominant at three stations (Table 5) and comprised 88.8% of the total catch. As was noted in 1981, the greatest numbers of this species were taken at Gray's Beach (Station 1).

Winter flounder (Pseudopleuronectes americanus) was the second most abundant species and was taken at four of the five stations.

Of the taxa captured in the intake since 1981, only Atlantic silverside and sand lance spp. (Ammodytes spp.) have been taken all three years of the study. Other species seined at this site were windowpane (Scophthalmus aquosus), northern kingfish (Menticirrhus saxatilis), and the American eel (Anguilla rostrata).

Finfish diversity was greatest at Long Point (Station 5), where 14 species were caught. The location of this station at the mouth of Plymouth, Kingston, Duxbury Bay, probably was a major contributing factor to its productivity. Bottom type may also have been a factor as the site is replete with small rocks and clumps of algae. The open coastal sites (Stations 2 and 4) were characterized by low diversity. Here again, bottom topography may be of import as both are areas of smooth, hard-packed sand with little cover.

Of the total number of taxa, no one species was captured at all five stations this spring. This finding is possibly the result of the limited time-frame of sampling. Past work has indicated that a major contributing

Table 5. Catch and percent composition of shore-zone fishes captured by haul seine at five stations in the environs of PNPS, from April-June, 1983.

Species	Station 1	2	3[a]	4	5	Total	Percent of total catch
Atlantic silverside	912		94	6	135	1,147	88.8
winter flounder	11	6		5	38	60	4.6
longhorn sculpin					27	27	2.1
windowpane		5	2	13		20	1.5
sand lance spp.*		7	1		1	9	0.7
mummichog	5				1	6	0.5
threespine stickleback				1	4	5	0.4
northern kingfish		2	1		1	4	0.3
bay anchovy	2				1	3	0.2
hake spp.*					2	2	0.2
spotted hake					2	2	0.2
American eel			1			1	0.1
Atlantic cod					1	1	0.1
Atlantic tomcod	1					1	0.1
grubby					1	1	0.1
northern pipefish					1	1	0.1
rainbow smelt	1					1	0.1
rock gunnel					1	1	0.1
Total numbers of fish	932	20	99	25	216	1,292	
Total number of species	6	4	5	4	14	18	
Number of sets	16	16	9	7	22	70	

* Not separated by species

a Intake station

factor to fish occurrence is the seasonal component of fish movements influenced by changes in water temperature. Some species, such as Atlantic silverside, have been taken from all sites in the past.

E. UNDERWATER FINFISH OBSERVATIONS

The underwater finfish observational study began on 5 May, with results being reported through 20 June. Stations S_1 and S_2 were located in areas of stunted algal growth, D_1 and D_2 in the direct path of the thermal discharge, and C_1 and C_2 were control stations (Fig. 7).

Six finfish species (cunner, pollock, tautog, striped bass, winter flounder, and longhorn sculpin) were observed during four dives (Table 6). All species have been previously recorded. Again this year, no fish were observed in the study area during the first dive (5 May). Bottom water temperatures were 8C at all stations at the time.

Within the observational area, surface and bottom temperatures ranged from 13-27C and 6.5-18.0C, respectively (Table 7). Ambient temperatures recorded from Pilgrim's intake embayment were between 6.2 and 14.5C (surface) and 6.5 to 13.0C (bottom) for the same period. Average surface and bottom water temperatures for the three observational zones and ambient (intake) waters from the vicinity of Pilgrim station are presented in Table 8. The average surface and bottom temperatures were highest in the discharge zone, while temperatures in the stunted and control zones were similar to each other. All temperatures in the observational zones were higher than ambient levels in June. In May, surface temperatures were higher, but bottom temperatures at the stunted and control zones were the same. Due to high discharge velocities at low tide, temperatures were taken within approximately two hours of slack high tide. The largest temperature differentials between ambient and discharge conditions were found at station D_2 where a ΔT of 13.0C (surface) and 11.5C (bottom) were recorded on 9 May and 6 June, respectively (Table 7).

Cunner was the most abundant fish observed, appearing at all stations.

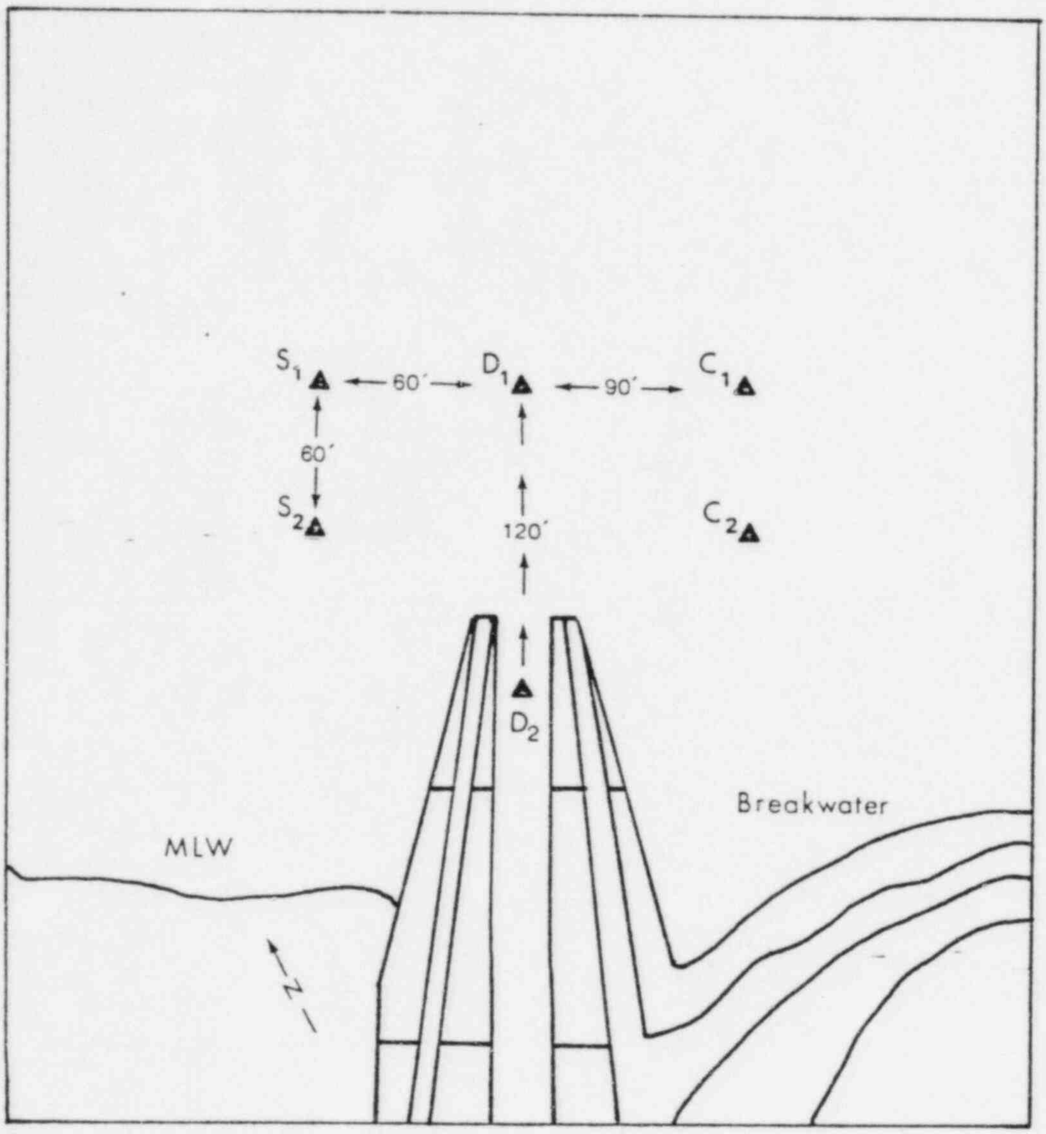


Figure 7. Finfish observational diving stations at PNPS.

Table 6 . Abundance, size ranges and temperatures associated with the occurrence of all species observed during underwater finfish observations, May-June, 1983.

Species	Station where most abundant	Number observed by divers	% of all fish	Size range (cm)	Bottom Temperature Range (C)
Cunner	D_1	269	53.2	~ 3-25	8.0-15.0
Pollock	S_1	185	36.6	~15-46	8.0-15.0
Tautog	D_2	26	5.1	~15-50	12.0-15.0
Striped bass	D_2	24	4.7	~25-50	12.0-15.0
Winter flounder	D_2	1	0.2	~15	15.0
Longhorn sculpin	S_1	1	0.2	~28	6.5

Table 7. Surface (S) and Bottom (B) water temperatures (C) at each observational station, and ΔT (C) between observational stations and ambient, May-June, 1983.

Stations	5 May S	5 May B	9 May S	9 May B	6 June S	6 June B	20 June S	20 June B
S_1	-	8.0	16.5	6.5	19.0	12.0	22.0	14.0
S_2	-	8.0	-	6.5	18.0	12.0	18.0	12.5
D_1	-	8.0	-	9.0	25.5	12.0	21.0	14.5
D_2	-	8.0	-	18.0	27.0	13.0	25.0	15.0
C_1	-	8.0	-	6.5	22.0	12.0	22.0	15.0
C_2	-	8.0	-	6.5	13.0	12.0	23.0	14.0
Ambient	9.0	8.0	6.2	6.5	14.0	11.5	14.5	13.0

ΔT (C)

Observation stations and Ambient

Stations	5 May S	5 May B	9 May S	9 May B	6 June S	6 June B	20 June S	20 June B
S_1	-	0.0	10.3	0.0	5.0	0.5	7.5	1.5
S_2	-	0.0	-	0.0	4.0	0.5	3.5	-0.5
D_1	-	0.0	-	2.5	11.5	0.5	6.5	1.5
D_2	-	0.0	-	11.5	13.0	1.5	10.5	2.0
C_1	-	0.0	-	0.0	8.0	0.5	7.5	2.0
C_2	-	0.0	-	0.0	-1.0	0.5	8.5	1.0

Table 8 . Surface and bottom water temperatures (C)* at observational zones in vicinity of Pilgrim Station, May-June, 1983.

Month	Surface temperature				Bottom temperature			
	A	S	D	C	A	S	D	C
May	7.6	16.5	-	-	7.2	7.2	10.8	7.2
June	14.2	19.2	24.6	20.0	12.2	12.6	13.6	13.2

* Averaged temperature for sampling days and stations within study zones.

A = intake (ambient)

S = stunted zone

D = denuded zone

C = control zone

Table 9. Percent occurrence of finfish at observational zones in the vicinity of Pilgrim Station, 5 May through 20 June, 1983.

Species	Percent Occurrence		
	S	D	C
Tautogolabrus adspersus (cunner)	15.2	56.2	28.6
Pollachius virens (pollock)	67.1	11.3	21.6
Tautoga onitis (tautog)	-	76.9	23.1
Morone saxatilus (striped bass)	-	58.3	41.7
Pseudopleuronectes americanus (winter flounder)	-	100.0	-
Myoxocephalus octodecemspinosus (longhorn sculpin)	100.0	-	-

S = stunted zone

D = discharge zone

C = control zone

This species comprised 53% of all fish sighted (Table 6). Fish ranged in size from approximately 3-25 cm (total length). Greatest concentrations (≈ 56%) were found in the discharge zone (Table 9).

Pollock, the second most abundant species constituted 37% of the sightings. Found at all stations, individuals ranged in size from 15-46 cm in total length.

Numbers decreased substantially among the four other species sighted with tautog, striped bass, winter flounder, and longhorn sculpin comprising 5.1%, 4.7%, 0.2% and 0.2%, respectively.

The majority of tautog (≈ 77%) were noted adjacent to large rocks located in the warm discharge current. The remaining 23% were sighted on the outside edge of the control zone. Fish ranged in size from 15-50 cm, and all were active within 0.5-1.0 meters of the bottom.

Aggregations of striped bass (25-50 cm) were seen in early June at two locations. The larger number (≈ 58%) were crisscrossing the inner discharge station, feeding at midwater (2 m). A slightly smaller group (42%) was noted circling Station C_1. These fish were active and moved from the area as divers approached.

Of the two additional species sighted, only single individuals were recorded. A longhorn sculpin was noted in early May at the outer station of the stunted zone. Bottom temperature was 6.5C, and this fish's activity appeared reduced. A single winter flounder was observed in late June at the innermost discharge station. Bottom temperature was 15.0C among the rocks but 22C approximately half a meter above the substrate. McCracken (1963) reported that winter flounder move from areas where water temperatures rise above 14-15C.

Only two of the six species sighted were pelagic in habit and occupied

an elevated position in the water column. Striped bass and pollock were generally noted cruising at or above midwater. The other four species were noted on or directly above the rubble substrate.

During June's observations, divers noted large numbers of horseshoe crabs (Limulus polyphemus) and broken crab shells throughout the study area. Greatest concentrations appeared in the discharge zone.

Many fish displayed an apparent attraction to the thermal effluent but none exhibited an abnormal appearance, and, except for the longhorn sculpin, no altered behavior patterns. No external symptoms of gas bubble disease were evident.

F. SHOREFRONT SPORTFISH SURVEY

Pilgrim Shorefront, a specially constructed recreational area, has provided shore-based marine sportfishing opportunities for the public since 1973. Accessibility, seasonal abundance of sportfish, scenic view, and ample parking have popularized this site in a locale that has limited shore fishing possibilities. From April-November, anglers are allowed to fish from the two effluent canal jetties, the intake breakwater, and off the sandy beach at the head of the intake embayment (Fig. 4).

A creel census is being conducted this year to assess the current status of the recreational fishery at Pilgrim Shorefront. No data were collected in April because of funding constraints; however, watchmen at the Shorefront report that fishing activity was relatively light throughout the month. Much of the data collected this spring is still being processed, but we will report on the findings to date.

During the May and June creel census, 133 and 220 anglers, respectively, were interviewed. The total number of angler-trips to Pilgrim Shorefront was estimated to be 219 in May and 624 in June. During May an estimated 370 hours of effort were expended and 87 fish caught comprising 8 species. The average pooled catch rate for May was 0.24 fish per angler hour. In June, it is estimated that 1,363 hours of effort resulted in a catch of 480 fish comprising 10 species. The average pooled catch rate for June increased to 0.35 fish per hour angled. Cunner (Tautogolabrus adspersus) and striped bass (Morone saxatilis) constituted 68% and 22%, respectively, of the total catch in June. Cunner were taken primarily from the intake breakwater while all striped bass were caught fishing from the discharge jetties.

Striped bass, winter flounder (Pseudopleuronectes americanus), and long-

horn sculpin (Myoxocephalus octodecemspinosus) led all catches in May, comprising 60% of the total monthly catch. All bass were caught from the discharge jetties by anglers fishing in the thermal effluent and were released because of their sub-legal (< 61 cm) size. All winter flounder and longhorn sculpin were angled from the intake breakwater. Although flounder were retained, sculpin were not considered a desirable species and were released by fishermen.

As to species preference, the most sought after species in May was the winter flounder. Thirty-seven percent of the anglers interviewed were bottom fishing for flounder using natural bait primarily from the intake breakwater and to a lesser extent from the head of the intake embayment. Twenty-eight percent of the anglers had no preference for what they caught; all bottom fished from off the intake breakwater using natural bait. The second most popular target species was the striped bass; 26% of those questioned were bass fishermen, who casted artificial lures from off the discharge jetties.

Polling all the shore-based anglers interviewed in May, we found that 62% fished from the breakwater, 30% from the discharge jetties, and 8% from the head of the intake embayment. Twice as many anglers employed still-fishing (bottom) techniques using natural bait as opposed to spin-casting artificial lures.

We also examined sex and age composition and residence of anglers visiting Pilgrim Shorefront in May. Eighty-nine percent were male. Ages ranged from 6-76 years old. The oldest female angler was 68 years of age. Fifty-six percent of the recreational fishermen were between the ages of 25 and 44. All visiting fishermen were from Massachusetts, with the majority from four counties on the South Shore (Bristol, Plymouth, Norfolk, and Middlesex Counties).

Thirty-eight percent were from the towns of Plymouth and nearby Manomet (Plymouth County); most of these were seeking striped bass. It is clear that travel distance to the recreational site was a principal factor affecting visitation of Pilgrim Shorefront, at least in May.

In June, there were more anglers traveling greater distances to fish at the Shorefront. Some came from the North Shore and the western part of the state. Out-of-state participants from Rhode Island, Connecticut, Maine, New York, New Jersey, and Pennsylvania fished at Pilgrim Station this month. Residents from Plymouth, Kingston, and Manomet comprised only 28% of the fishermen.

The travel-cost method was used to estimate the economic value of the recreational fishery at Pilgrim Shorefront. The actual expenditures incurred to travel to, to fish, and return home from the recreational site, included costs for fuel, bait, food, incidental costs, and lodging. The expenditures per angler-day for May were estimated by anglers to range from $2 to $20 with a mean of $5.70. Using the latter figure as representing a reasonable estimate of cost per angler-day, the economic value of the sport fishery at Pilgrim Shorefront for May was appraised to be $1,250.

Estimated expenditures for June ranged from $1 to $100 per angler-day, with a mean of $13.00. These figures reflect increased travel and lodging expenses incurred during this month. We estimate the value of the fishery in June was $8,100.

G. SATURATED DISSOLVED GAS PLUME MAPPING

Two dates (7 and 26 April) were chosen and sampled on the basis of wind conditions. Days of offshore winds were selected to insure maximum distal effect of nitrogen gas saturation in the discharge plume. Sampling bracketed the period of low tide on 7 April and high tide on 26 April.

On 7 April, slightly less than ideal wind conditions were encountered. Although the sea state was calm when we began operations, with a light offshore (SE) breeze prevailing, the wind eventually increased in speed and shifted to the east while we were sampling stations 4-7. The sea condition changed quickly from calm to choppy. A definable bend in the discharge plume toward the north was evident (Fig. 5). The plume direction was discerned from $N_2 + A_r$ saturations, O_2 saturations, and temperature data. No measurements obtained on 7 April reached 115% $N_2 + A_r$ saturation. Station 1 (nearest to the mouth of the discharge canal) had the highest $N_2 + A_r$ saturation (114.5%).

On 26 April, wind direction and speed remained constant (westerly at approximately five knots) and sea state remained calm. No bend in the plume was apparent from the data (Fig. 6); intuitively this was not expected given the prevailing wind condition. Saturations of $N_2 + A_r$ exceeded 115% at Station 1 and approached 115% at Stations 3, 4, and 5.

As anticipated, $N_2 + A_r$ gas saturations at the surface were highest near the mouth of the discharge canal. Percent saturations decreased with increased distance into Cape Cod Bay. Nitrogen saturations were higher at all stations during high water sampling. This may be due to differences in plume dynamics at flood and ebb tides. At high water, it appears that colder Cape Cod Bay water forms a wedge beneath the thermal plume, causing it to lift up and over the colder, denser ambient water with minimal initial mixing. This was evident

from our temperature data. Conversely, at low tide, the plume intrudes into Cape Cod Bay along the bottom for an extended distance before it detaches from the sea floor. This probably enhances mixing action resulting in lowered nitrogen saturations and plume temperatures at the surface.

Overall, $N_2 + A_r$ saturations were not excessive (> 115%) at distances greater than 30.5-61.0 m from the mouth of the discharge canal. This information aids in defining the 'impact zone' where fish are likely to contract gas bubble disease from prolonged exposure to high levels of nitrogen saturation.

ACKNOWLEDGEMENTS

We especially acknowledge the contributions of Neil Churchill for phases of field sampling and data compilation. We extend thanks to the numerous staff members of the Massachusetts Division of Marine Fisheries who also assisted in field collections; and to W. Leigh Bridges for editing the manuscript. Also greatly appreciated is the work of Eleanor Bois and Marie Callahan in typing this report.

LITERATURE CITED

Boston Edison Company. 1980. Benthic map overlays and assessment of benthic monitoring programs, Vol. 2. Nuclear Engineering Dept., Environmental Sciences Group. Boston Edison Company, Boston, MA. 25 p.

Conover, D. O., and M. R. Ross. 1982. Patterns in seasonal abundance, growth, and biomass of the Atlantic silverside, Menidia menidia, in a New England estuary. Estuaries. 5(4):275-286.

McCracken, F. D. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum) on the Atlantic coast. Journal of the Fisheries Research Board of Canada. 20(2):551-586.

APPENDIX A.

Average legal lobster catch per pot haul per month for all quadrats combined.

	March	April	May	June	July	Aug	Sept	Oct	Nov	Seasonal mean
1970	-	-	0.41 (330)	0.30 (351)	0.54 (627)	0.75 (667)	0.61 (571)	0.68 (691)	0.80 (72)	0.58
1971	0.68 (95)	0.46 (331)	0.62 (681)	0.32 (591)	0.68 (723)	0.86 (730)	0.77 (668)	0.70 (668)	-	0.64
1972	-	0.59 (428)	0.55 (248)	0.31 (519)	0.66 (718)	0.80 (707)	1.30 (477)	0.88 (352)	-	0.73
1973	-	0.46 (135)	0.39 (646)	0.41 (634)	0.74 (625)	0.60 (295)	0.56 (279)	0.82 (151)	-	0.57
1974	-	-	0.38 (309)	0.33 (341)	1.00 (544)	0.51 (595)	1.09 (499)	0.64 (455)	-	0.66
1975	-	0.32 (322)	0.23 (525)	0.26 (555)	0.64 (314)	0.58 (299)	0.81 (278)	0.70 (269)	0.65 (233)	0.52
1976	-	-	0.27 (438)	0.21 (541)	0.69 (641)	0.59 (554)	0.34 (570)	1.11 (37)	0.63 (178)	0.55
1977	-	0.48 (379)	0.46 (417)	0.29 (203)	0.55 (555)	0.47 (663)	0.72 (604)	0.86 (664)	-	0.55
1978	-	-	0.41 (374)	0.30 (571)	0.63 (441)	0.62 (775)	1.09 (279)	0.71 (162)	-	0.63
1979	-	-	0.31 (130)	0.29 (659)	0.54 (797)	0.59 (491)	0.50 (200)	0.42 (272)	0.58 (271)	0.46
1980	-	-	0.21 (107)	0.25 (477)	0.63 (983)	0.64 (849)	0.58 (476)	0.84 (520)	0.63 (255)	0.54
1981	-	-	0.58 (318)	0.26 (798)	0.62 (744)	0.64 (352)	0.96 (696)	0.73 (482)	0.67 (377)	0.64
1982	-	-	0.45 (410)	0.46 (271)	0.46 (780)	0.73 (877)	1.11 (475)	0.66 (454)	0.58 (107)	0.64
1983	-	-	0.18 (719)	0.23 (486)						

(Number of pots hauled)

SEMI-ANNUAL REPORT

Number 22

to

BOSTON EDISON COMPANY

on

BENTHIC ALGAL AND FAUNAL STUDIES AT THE PILGRIM NUCLEAR POWER STATION
September, 1982 - August, 1983

James A. Blake
Richard A. McGrath
Judith A. Scanlon
John W. Williams

BATTELLE
New England Marine Research Laboratory
397 Washington Street
Duxbury, Massachusetts 02332

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF APPENDICES

EXECUTIVE SUMMARY

This report presents the results of benthic algal and faunal studies conducted from August, 1982 to August, 1983 in conjunction with the operation of Pilgrim Nuclear Power Station (PNPS) in Plymouth, Massachusetts. Quantitative samples were collected on September 24, 1982 and April 12, 1983; qualitative observations and mappings of nearfield impact zones were conducted on September 24 and December 1, 1982 and April 13 and June 23, 1983.

These investigations represent the most recent phase of an extensive long-term effort by Boston Edison to assess the impact of PNPS on the inshore benthic community of Cape Cod Bay.

The benthic monitoring program has been refined in scope during the past several years by the Pilgrim Administrative - Technical Committee in conjunction with Boston Edison Company and presently comprises the following components:

- semi-annual quantitative sampling at the Effluent, and at the Rocky Point and Manomet Point control sites, and
- quarterly mapping of the near-field acute impact zones via diver observation.

A variety of analytical techniques were employed to assess community structure. Specific data on algal biomass, dominant fauna and density of selected species were also investigated. Both spatial (with control sites) and temporal (with previous samplings) comparisons were used to examine the data for any evidence of PNPS effects.

Field collection and laboratory analysis techniques were in most cases identical with techniques used by former contractors. Comparability of methodology was insured by the continuation of some personnel who have had a long history with the program and by the use of previous investigators as consultants. Every effort was made to ensure that the long-term comparability of the data base would not be compromised due to a change in contractors. We have carefully noted any changes in techniques which were deemed advisable.

As in previous samplings, five replicate 33 cm^2 benthic samples were collected with SCUBA at three sites: Effluent, Manomet Point and Rocky Point. Samples were

preserved in the field and returned to the laboratory where the faunal and algal fractions were separated and analyzed. Data analysis was conducted at Woods Hole Oceanographic Institution using software which had previously been used to analyze PNPS data.

The diver-transect study was conducted with particular care to ensure comparability with previous work. Previous contractors participated in the initial survey and were consulted regularly on particular technical points. Methods were therefore identical with previous years, involving a fixed line stretched offshore along the discharge centerline and a moveable line perpendicular to this which was traversed by divers who noted the boundaries of the stunted and denuded algal zones.

There have been some minor changes in faunal taxonomy as a result of this year's work, most of which are as a result of analysis of the September, 1982 samples. This was the first set of samples analyzed by Battelle after several years of the study being conducted by a different contractor and these types of changes were anticipated. We are not presently sure which of the newly-identified species are in fact new to the area and which were perhaps overlooked by previous taxonomists. This will become clearer with subsequent samplings, examination of previous voucher specimens, and consultation with systematists. In any event, none of the major species are involved, and those taxonomic discrepancies are not of sufficient importance to change any of the previous conclusions.

In September, 1982 the Effluent station had significantly fewer species than the Manomet Point and Rocky Point reference sites. This pattern has been typical in recent years and appears to be related to reduced habitat stability due to hydrodynamic rather than thermal effects of the PNPS discharge. In April, however, species richness at the Effluent was indistinguishable from that at Rocky Point. Manomet Point had significantly greater numbers of species than these two sites.

For the sampling year (i.e. the September and April collections) both the effects of time and location and the time x location interaction were significant. These results indicate that, for the year, there were significantly fewer species at the Effluent and, considering all stations, there was greater richness in September than in April. The significance of the interaction indicates the change in Effluent between September, 1982 and April, 1983.

Faunal densities in September were higher at the Effluent than at the two reference sites. Densities of Mytilus throughout the area were somewhat lower than in

previous years, particularly at Effluent where the community was dominated by an amphipod, Jassa falcata. This pattern was not repeated in April, 1983. All stations had different faunal densities with greatest densities occurring at Manomet Point and lowest densities at Rocky Point. April densities at Effluent and Rocky Point were considerably lower than the previous September. Mytilus was more common throughout the area in April, particularly at the Effluent station, when it comprised over 70% of the total fauna.

Patterns of dominant species were generally similar at all three sites in September, though some differences were noted. Chief among those was the depressed dominance of mussels mentioned above, especially at Effluent where Mytilus was only the fourth most abundant species at 6.6% of the total fauna. Mussels have been known to vary greatly from year to year in reproductive success and this variance may account for the observed distribution pattern.

Similarity in dominance patterns was even more evident in the April, 1983 collections. Three species, including Mytilus were among the top four dominants at each station. Mytilus assumed its more typical dominant position in the community, comprising approximately 30% of the total fauna at Effluent and Manomet Point and 12% at Rocky Point.

Shannon-Wiener diversities were markedly lower at the Effluent station in September. Examination of the data indicated that this was most likely due to the combined effects of depressed species richness and strong dominance by Jassa falcata. Depressed diversity values are not uncommon at this site and appear to be related to this station's position near the periphery of the nearfield acute impact zone.

In April, 1983 diversities were generally lower throughout the study area. This was evidently caused by lowered species richness and increased dominance, particularly by Mytilus, at all stations. Because of less strong dominance at Effluent, the decrease in diversity between September and April was not as apparent at this site.

Classification (cluster) analysis was used to identify broad patterns of similarity in the data. In September, all stations were distinct from each other and the replicates from each station tended to cluster together. Rocky Point and Manomet Point were clearly more closely related to each other than to the Effluent station. The differences seen at the Effluent in September were unquestionably due to the integrated effects of the PNPS discharge at this site.

Analysis of the April, 1983 data indicated generally greater similarity among the stations. Rocky Point samples are separable from the other two sites, but this difference is not obvious, particularly when the analysis is performed using NESS. Effluent and Manomet Point samples were indistinguishable from the April data. These results indicate that the Effluent station was not within the nearfield impact zone in April.

No additional algal species were identified from the September, 1982 and April, 1983 samplings. Gracilaria foliifera has been referred to its senior synonym G. tikvahiae (McLachlan, 1979). Other algal systematics were identical with those in previous years. Abundant species throughout the sampling area continued to be Chondrus crispus and Phyllophora spp., with Chondrus being more dense at two of the three sites for the present sampling period.

Gracilaria tikvahiae and Codium fragile tomentosoides, two warm-water algae, were found in the discharge canal and immediately beyond the ends of the discharge jetties during both sampling periods. these species do not normally occur in open coastal situations north of Cape Cod, and their occurrence is partly due to the presence of heated effluent from PNPS.

Algal community overlap values were similar at all three sampling sites during September and April samplings and indicated comparable habitat homogeneity.

Algal biomass was determined separately for six different algal catagories. Although there was considerable variability, greatest biomass was found at the Effluent, with Rocky Point supporting considerably less biomass than the other two sites, both fall and spring. A two-way ANOVA showed significant differences between the two sampling periods and among stations for total algal biomass. Chondrus/Phyllophora biomass ratios were similar in September 1982, but dissimilar for April 1983 due to low Chondrus and high Phyllophora biomass at the Effluent station, probably a result of scouring at the PNPS discharge.

Comparison of present algal biomass data with September, 1982 indicated significant differences for the effect of time for Chondrus crispus and Chondrus epiphytes. Results of a two-way ANOVA for differences in Phyllophora spp. biomass were highly significant for the effects of site and time and site x time interaction. The same analysis for epiphytes of Phyllophora showed effects of time and site x time interaction

significant. No significant differences were found for variations in biomass of remaining benthic species between samplings and among stations.

The Chondrus/Phyllophora condition index study indicated that Phyllophora was more heavily colonized, presumably due to its ability to tolerate epiphyte-induced stress. Condition Index values were highest at the Manomet Point station in September and at the Effluent in April. For all stations and all years, colonization and condition index values showed similar seasonal fluctuations and appeared unrelated to the PNPS discharge.

Results of the four most recent mappings of the extent and configuration of near-field acute impact zones appeared to indicate a trend toward diminished size of the impacted area. We had hypothesized in the previous report that data available at that time appeared to indicate a seasonal variation in impacted area. Because of an extremely small area recorded in June, 1983, it now appears that this seasonal relationship may not be as straightforward as had originally been proposed and that a hypothesis of a steadily decreasing area (probably indicative of a longer cycle) may be more tenable.

A preliminary examination of the relationship between changes in the configuration of the near-field impact zones and certain environmental variables was conducted by means of a correlation analysis. Significant correlations were found between near-field impacts and two environmental factors: mean discharge temperature one month prior to mapping and amount of southeast winds during the quarter preceding mapping. Additional analyses will be conducted to clarify these observed relationships.

SEMI-ANNUAL REPORT
Number 22

to

BOSTON EDISON COMPANY

on

BENTHIC ALGAL AND FAUNAL STUDIES AT THE PILGRIM NUCLEAR POWER STATION September, 1982-August, 1983

James A. Blake
Richard A. McGrath
Judith A. Scanlon
John W. Williams

INTRODUCTION

This report presents the results of the most recent series of benthic monitoring surveys performed at the Pilgrim Nuclear Power Station (PNPS). The monitoring surveys are part of a long-term effort by Boston Edison Company to assess the impact of the thermal effluent from the 655 MW^e nuclear steam-electric generating station on the inshore benthic community. PNPS is located on the northwest shore of Cape Cod Bay, five miles southeast of Plymouth Harbor, Massachusetts. The quantitative algal and faunal data presented and analyzed in this report were derived from field collections conducted in September, 1982 and April, 1983. Qualitative transect data were collected on September 24, and December 1, 1982 and April 13 and June 23, 1983. A detailed report of the September, 1982 quantitative collections and the transect dives of September and December, 1982 are presented in Semi-Annual Report Number 21 (BECo., 1983).

The specifications for times of sampling and procedures follow guidelines established by the Pilgrim Administrative Technical Committee (PATC) and adopted by the Boston Edison Company. The program was modified in the summer of 1981 to include: 1) Semi-annual (August, March) benthic sampling (quarterly samples were taken from September, 1974 to June 11, 1981); 2) Three quantitative sampling sites (Manomet Point, Rocky Point and Effluent Station); 3) Five replicate samples (0.33m^2) from each of the 3 stations (three replicates were taken from September, 1974 through June, 1980; six replicates were taken from September, 1980 through June, 1981); and 4) Diver-conducted

transect surveys to be performed quarterly (August, December, March, June) from December, 1981 to assess localized effects of PNPS cooling water discharge on near-field benthic communities.

A variety of analytical techniques were employed in this program to assess community structure. In addition, specific data on algal biomass, dominant fauna and densities of selected species were also investigated. Where appropriate, biological interpretation of observed results are incorporated. All data were analyzed and compared with data from previous samplings and with control station results.

Field collections were supervised by Mr. John Williams. Sorting and identification of algal and faunal samples was supervised by the Project Manager, Dr. James A. Blake. Data analysis was supervised by Mr. Richard McGrath. Algal taxonomy and analysis were performed by Ms. Judy Scanlon, with the consultation of Mr. Walter Grocki. Other key personnel included: Ms. Maggie Dutch, Mr. Dale Davis, Mr. Mark Curran, Mr. Jim Cammarata, Ms. Sandra Weiss, Mr. Bill Johnson, Ms. Elizabeth Garlo, Mr. Phillip Nimeskern and Mr. Paul Banas.

METHODS

QUANTITATIVE ALGAL AND FAUNAL SAMPLING

The field procedures basically follow techniques initiated by Battelle in 1972 and adhere closely to the most recent modifications initiated by Taxon, Inc. in subsequent years, especially since 1974.

Benthic Sampling Stations

Quantitative benthic samples were collected on September 24, 1982 and April 12, 1983 at three stations: Manomet Point, Rocky Point and Effluent (Figure 1). The first two stations served as southern and northern reference sites, respectively, while the Effluent Station represented the area of most immediate potential impact. All stations were located at a depth of 10 feet (MLW). The Effluent Station is located directly seaward of the center line of the discharge canal. The Rocky Point control station is located approximately 0.25 nautical miles (nm) northeast of the Effluent site. The Manomet Point Station is located approximately 2 nm southeast of the Effluent Station.

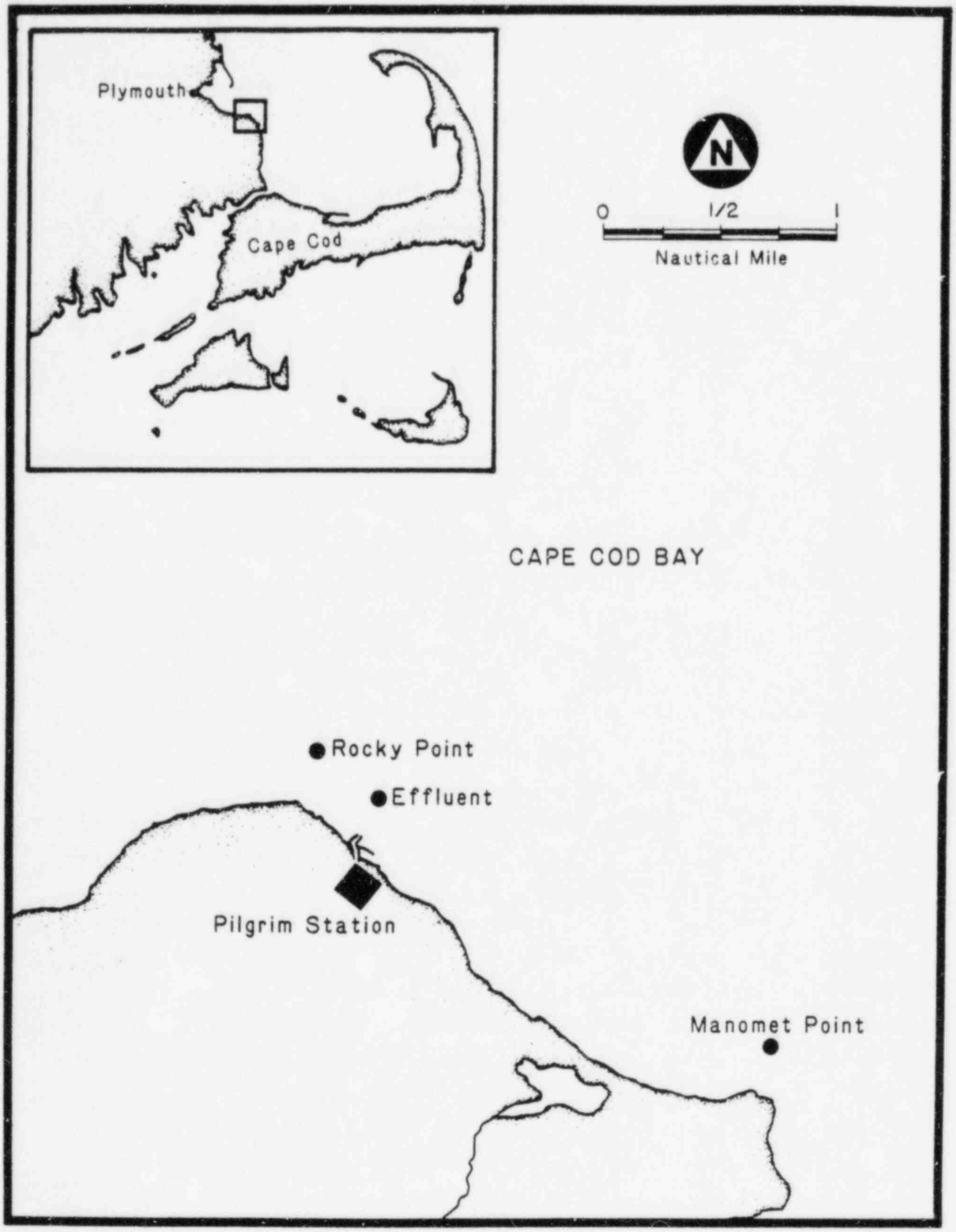


Figure 1. Location of the Rocky Point, Effluent, and Manomet Point Rock-Substratum Subtidal (10' MLW) Stations.

Precise station locations depend upon line-of-sight techniques, with highly visible structures located on the shore. These reference points are coordinated with fathometer readings to provide precise station location. The Rocky Point Station was located by lining up the microwave relay tower with the off-gas stack. The Effluent Station was identified as the center line between the two discharge jetties. The Manomet Point Station was located by lining up the two southernmost telephone poles on top of Manomet Point. Station relocation techniques are sufficiently reliable to insure that all sampling occurs within a radius of 20-50 m of the originally established station locations.

Collection Techniques

All sampling was performed by a team of SCUBA divers. Sampling equipment consisted of an airlift sampling device and a 0.33 cm^2 metal pipe-frame quadrate (Figure 2). The pipe-frame insured that a uniform surface area of 1089 cm was consistently sampled from each rock. A standard SCUBA tank supplied the suction necessary for the operation of the airlift device. The Battelle research vessel, R/V Mya was used as a base. At Manomet Point, a small boat was required to assist the divers, due to large rocks in the area which forced the Mya to anchor slightly seaward of the station.

Upon arriving at the sampling location, divers descended to the bottom with the sampling equipment and randomly chose large, flat-surfaced rocks or boulders for sampling. Small rocks with less than half the surface area of the quadrate were eliminated from sampling consideration due to their increased susceptibility to movement or dislodging during stormy weather. Such rocks were considered to have a less stable resident community. The quadrate was placed on the surface of a rock and the airlift device was positioned a few inches above the quadrate by one diver, while a second diver began scraping the quadrate with a sharp bladed tool (Red Devil Paint Scraper). The algae and resident fauna were carried by suction up the airlift into a bag (Nitex, 0.5 mm mesh) at the opposite end. When the quadrate had been scraped clean, the bag was removed and sealed. A new bag was then attached while a third diver took the filled sample bag and placed it into a longer catch bag. Five replicate samples were taken at each station, placed into the catch bag, and delivered to the boat.

On board the Mya, each sealed bag was placed in a wet box containing fresh seawater. While underway to the next station, the contents of each bag were transferred to a one-gallon plastic jar, labelled and preserved with 10% formalin. Approximately 100 g of Borax were added as a buffering agent to prevent softening of mollu[illegible] shells.

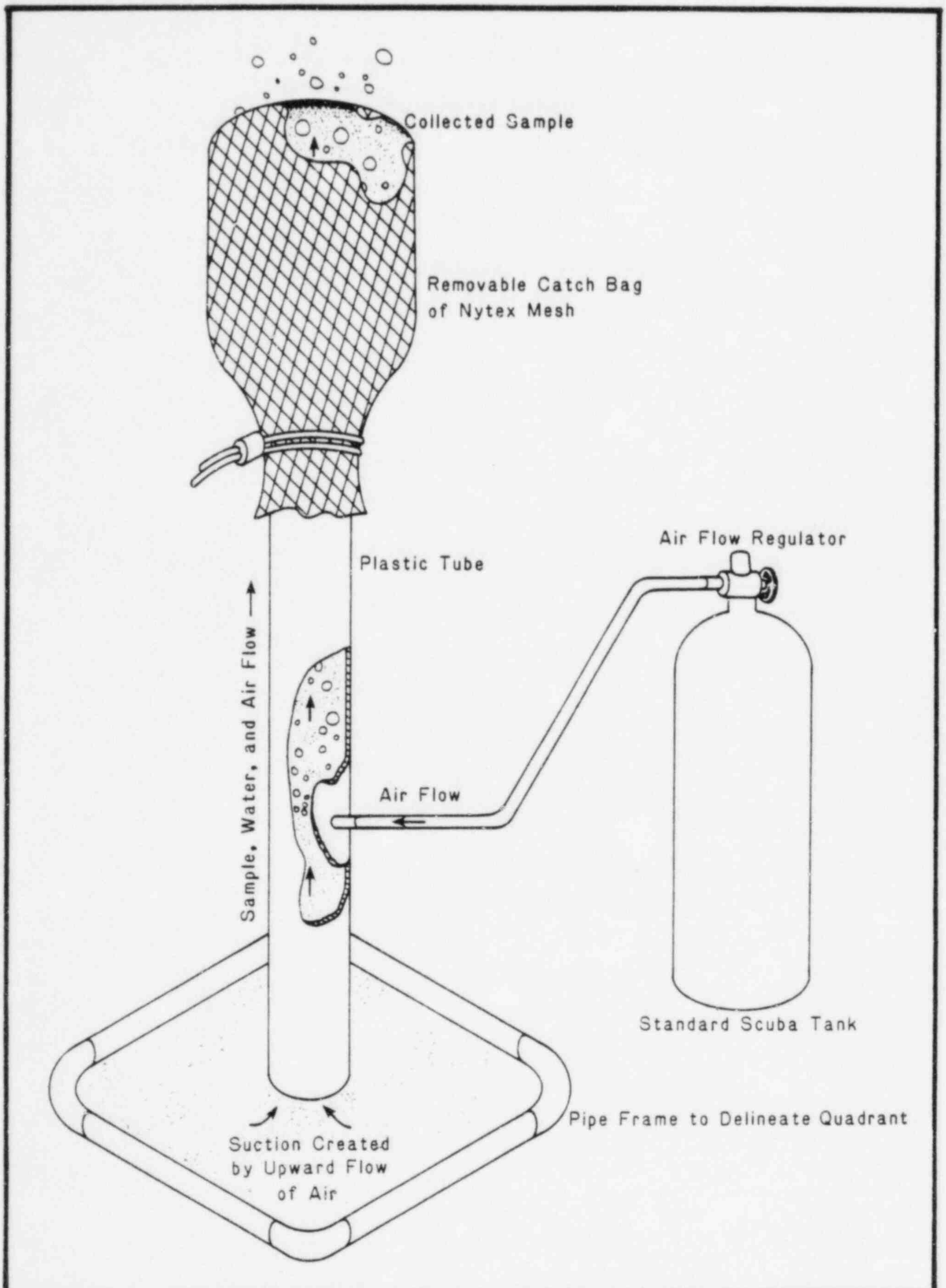


Figure 2. Rock Substratum Airlift Sampling Device.

QUALITATIVE TRANSECT SURVEY

SCUBA observations along the axis of the discharge canal were conducted on September 24, 1982 and December 1, 1982 and on April 13 and June 23, 1983. The purpose of this phase of the investigation is to map the lateral and offshore extent of denuded and stunted algal zones directly in front of the PNPS discharge.

The distinction between "denuded" and "stunted" is based on distribution of Chondrus crispus. The denuded zone is defined as that area where Chondrus occurs only as stunted plants restricted to the sides and crevices of rocks. No Chondrus is found on the upper surfaces of rocks in this area except where the microtopography of the rock surfaces creates small protected areas. In the stunted zone, Chondrus is found on the upper surfaces of the rocks but is noticeably inferior to normal specimens in height, density, and frond development. The normal zone is considered to begin at that point where these factors are "typical" for the depth and substratum in question. To ensure that Battelle divers made the same judgements as to changes in algal cover, as previously made by Taxon, Inc. biologists, Mr. Walter Grocki demonstrated the procedure to Battelle divers during a preliminary sampling trip on September 17, 1982.

Qualitative Transect Study

Because of the complexity of this procedure, we have presented the methods and procedures followed during the qualitative transect study in sequential order of events:

A. Laying Out Transect Line.

1. R/V Mya & crew approach sampling area. Battelle's 18' Boston Whaler is used to transport transect equipment to shore. Transect equipment inventory includes:

    - 3/4" nylon Base Line, approximately 35 m length.
    - 100 m Transect Line - 3/8" nylon with 2 lb lead weights and distance marks every 10 m.
    - Anchor (Danforth, 10 lb) for seaward end of Transect Line.
    - Marking buoy plus line attached to end of Transect Line.
    - Diver-safety line - attaches from buoy to R/V Mya.

2. Two crew members transport equipment to effluent area aboard the Whaler. The Whaler is secured outside the effluent canal and the Base Line is fastened to an eye bolt on the north jetty. The free end is carried across the effluent canal via the top of the barrier net or the canal bridge. This end is attached to an eye bolt on the south jetty. The Base Line is drawn tight and tied-off, crossing perpendicular to the effluent canal. This line provides a point of attachment for the Transect Line from the center of the effluent canal.

3. The Whaler is then maneuvered into the effluent canal and an approach is made to the Base Line. The Transect Line is attached by snaphook to the center point of the Base Line. The Whaler is maneuvered seaward parallel to the effluent canal while a crew member feeds out the Transect Line. Sufficient tension is maintained to keep the Transect Line straight and on center to the effluent canal. The Transect Line is fed out until the end anchor and attached buoy line is reached. The buoy line is cleated off and engine power is used to stretch the Transect Line taut and align along the centerline of the effluent canal. When the Transect Line is straight and centered it is lowered to the bottom with the buoy line, and the marking buoy is released.

4. The R/V Mya is then maneuvered into position near the seaward end of the Transect Line and anchored. A diver Safety Line is rigged from the marking buoy to the R/V Mya to facilitate diver access to the Transect Line. The safety line is kept sufficiently slack to avoid the potential of lifting the Transect Line.

B. The Transect Survey (Fig. 3)

1. Divers don scuba gear. Three divers are required for the survey and each has specific responsibilities:

- **Diver No.1** - Serves as the dive leader carries writing tablets, measures algal transition zones, makes general observations and signals for transfer of the Measuring Line.

- **Diver No. 2** - Reels out Measuring Line perpendicular to the Transect Line then remains stationed just beyond stunted zone with reel in hand. On signal, transfers Measuring Line to successive 10 m marks with Diver No. 3.

- **Diver No.3** - Remains stationed at 10 m marks of the Transect Line. Attaches Measuring Line by snap hook to the Transect Line and holds securely to prevent movement of the Transect Line. On signal, transfers Measuring Line to successive 10 m marks with Diver No.2.

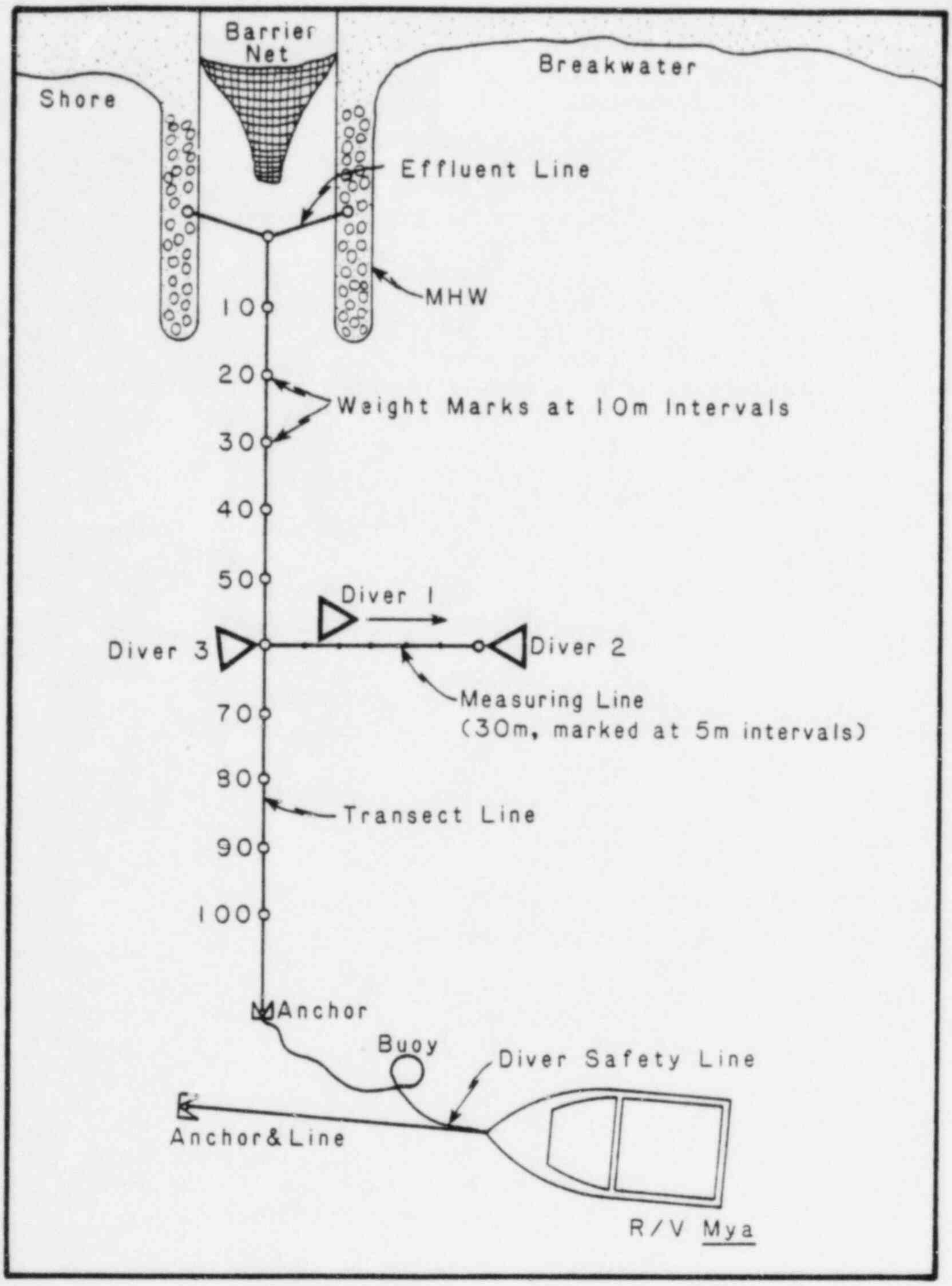


Figure 3. Diagram of Qualitative Transect Survey.

2. Equipment specific to the transect study includes:

   - Two white plastic writing tablets & pencils. Separate tablets are used for the NW and SE areas of the Transect Zone. The tablets provide space for recording measurements and observations for each 10 m interval (Fig. 4). The compass course (310° for the NW zone and 130° for the SE zone) for each measurement angle is written on the tablet.

   - Measuring Line & reel - 1/4" dacron line of 30 m length, wound on plastic reel. Line distances are marked with orange fluorescent paint and duct tape for each 5 m interval.

   - Catch bag

   - Magnetic diving compass (2) used by Divers No. 1 & 2.

3. Divers No. 1, 2, & 3 descend the buoy line to the seaward end of the Transect Line. Divers swim along Transect Line toward effluent canal and note changes in Chondrus density and condition. Several passes are made by Diver No. 1 to identify the transition zones from normal growth, to stunted growth, to denuded. These zones are defined as:

   - **Normal Zone** - Chondrus density, height, and frond development lush and/or apparently characteristic of the local natural environment.

   - **Stunted Zone** - Chondrus is found on the upper surfaces of the rocks but it is noticeably inferior in height, density, and frond development.

   - **Denuded Zone** - Chondrus occurs only as stunted plants restricted to the sides and crevices of rocks. No Chondrus is found on the upper surfaces of rocks in this area except where the microtopography of the rock surfaces creates small protected areas.

4. Diver No. 1 records the distance from the Base Line that the denuded and stunted zones intersect the Transect Line. Measurement is made by interpolation between the 10 m marks to the nearest meter.

5. Diver No. 3 takes position at the first mark shoreward of a transition zone and attaches the Measuring Line to the Transect Line. Diver No. 2 swims from that point on a course of 310° and unwinds the Measuring Line. This establishes a line of measurement perpendicular to the Transect Line. Diver No. 2 stops just beyond the Stunted/Normal transition zone.

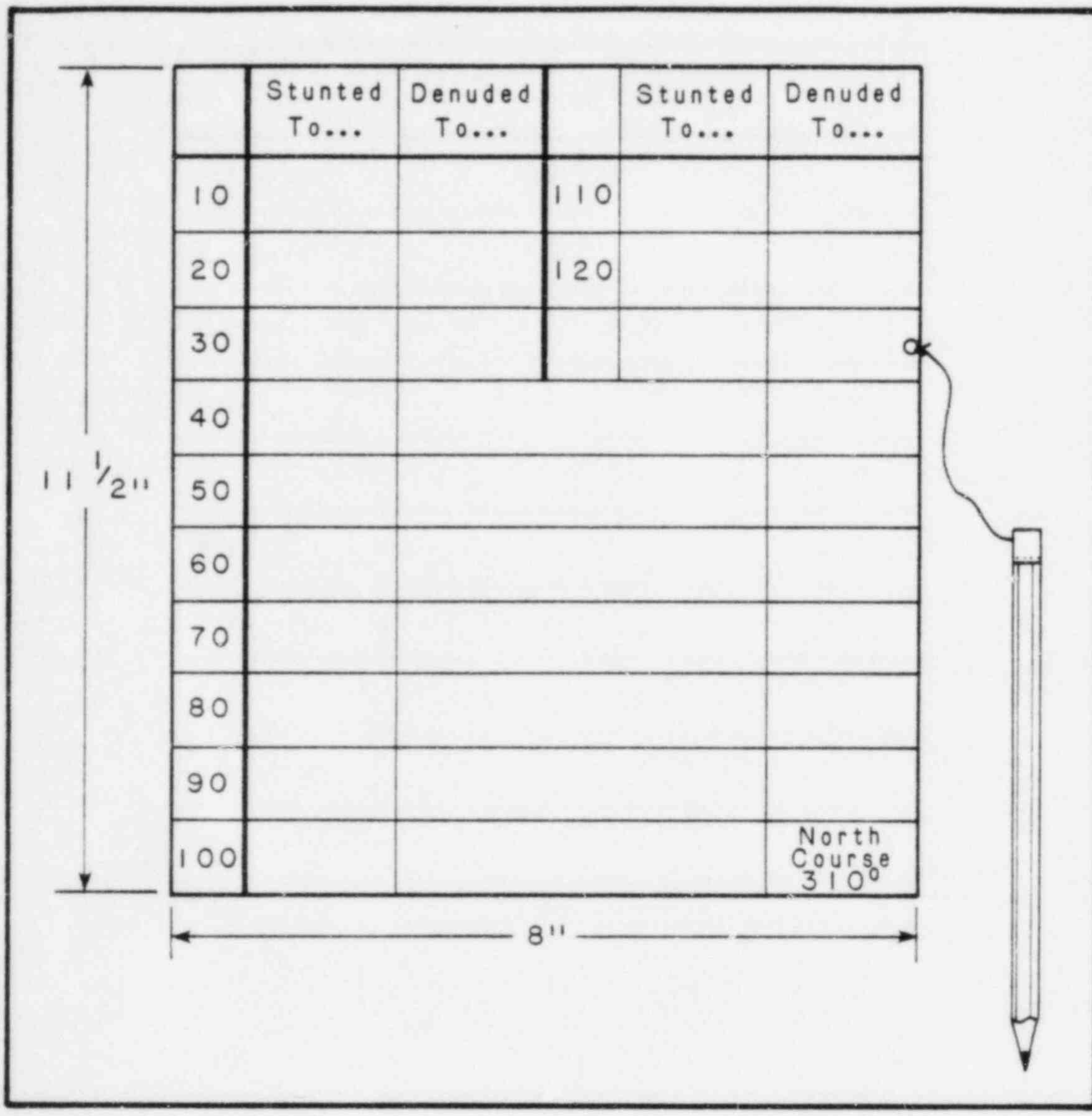


Figure 4. Writing tablet used by divers for Qualitative Transect Survey.

6. Diver No. 1 checks the compass bearing of the Measuring Line and corrects the position if required. The diver then swims along the Measuring Line from the Transect Line point of attachment to the distal end. Several passes are made back and forth in order to clearly define transition zones. Once the transition zone has been defined, the distance (to the nearest meter) is measured and recorded on the tablet.

7. Diver No. 1 swims beyond the measurement zone of normal growth, to ensure that normal growth is characteristic beyond the measurement area. Diver No. 1 also communicates to Diver No. 2 his perception of the Stunted/Normal transition zone to gain a second opinion. If there is a discrepancy, additional observations are made to clearly delineate the transition zone.

8. Diver No. 1 swims back along the Measuring Line toward the Transect Line and records general observations regarding the floral/faunal assemblage.

9. Diver No. 1 signals for transfer of the Measuring Line by tugging on the line. The line is then transferred by Divers No. 2 & 3 to the next 10 m mark shoreward. This procedure is continued until each 10 m distance from the Base Line is measured and surveyed.

10. Upon reaching the north jetty, Diver No. 1 records the distance of the submerged jetty ends from the Base Line by comparison with the Transect Line. This data serves to calibrate the Transect Line position for mean highwater.

11. Diver No. 1 swims toward the Base Line inside the effluent canal and records algal growth characteristics in this area.

12. Divers No. 2 & 3 take position to measure Transition Zones on the SE side of the Transect Line. Measurements and observations are taken by Diver No. 1. Procedures follow those described above along successive 10 m marks seaward. Diver No. 2 swims a magnetic course of 130° to position the Measuring Line at each interval.

13. When all measurements and observations have been completed, the divers ascend and return to the R/V Mya.

14. The Transect Line and the Base Line are retrieved using the Whaler and stowed on the R/V Mya.

15. Upon return to the laboratory, the field notes are incorporated into a field report and submitted to the Project Manager.

LABORATORY ANALYSIS

Faunal Processing

In the laboratory, algal and faunal components were separated by washing the animals from the algae onto a 0.5 mm mesh screen. The fauna was then preserved in 70% ethanol. The algae were returned to 5% formalin.

Each faunal sample was divided in one-quarter aliquots prior to sorting. One aliquot from each replicate was processed, and the others were archived. A solution of Rose Bengal stain was added to each faunal aliquot prior to sorting. Animals were sorted into major groups or to the lowest possible taxon depending upon the individual sorter. Major groups were then assigned to identifiers as follows: polychaetes, echinoderms, cnidarians, nemerteans and turbellarians to J. Blake, arthropods to J. Cammarata, S. Weiss and E. Garlo; molluscs to M. Curran and P. Nimeskern. J. Blake, E. Garlo and P. Nimeskern are senior level taxonomists and certify that all identifications follow the latest nomenclature. Research quality stereomicroscopes and compound microscopes were used by all personnel during the identification process.

Species counts did not include bryozoa, colonial hydroids and spirorbid worms because they are attached epifauna on the algae and their presence in the faunal fraction is an underestimate of their abundance. These epifauna were noted during the algal processing (see below).

Species exhibiting very high densities, such as juvenile Mytilus edulis, were subsampled.

Algal Processing

The algal component of each replicate sample was examined, using both dissection and compound microscopes, to determine the presence or absence of 38 indicator species (See Appendix 1). Relative abundance of each indicator species was also noted for each sample. The indicator species currently under observation were originally chosen in September 1978, and were carefully selected from a listing of the several hundred algal species recorded from the Pilgrim I study sites in the 1974 - 1978 period. They include members of each major algal family, and representatives of a variety of habitat types; the group includes all of the dominant species within the study area, the majority of the macrophytic species, and the most common epiphytic species. Although

the indicator species constitute only a small fraction of the total number of species inhabiting the study area, they comprise by far the most substantial part of the algal community as measured by both percent cover and biomass. Reproductive states of various algal species encountered, algal species present in addition to the 38 indicator species, and similarities and differences between each replicate sample were also recorded. Two voucher collections were established, one preserved in 5% formalin and another as a set of permanent slide mounts. The slides include reproductive structures and other characteristics useful for identification.

The Chondrus crispus and Phyllophora spp. fractions of each replicate sample were examined to assess the degree of algal and faunal colonization of the host species. The algal colonizers included epiphytic species such as Spermothamnion repens, Ceramium rubrum, Cystoclonium purpureum and Polysiphonia spp.; the faunal colonizers were primarily the encrusting hydrozoans, bryozoans, spirorbid worms and mussel spat (Mytilus edulis). Each Chondrus and Phyllophora replicate fraction was compared with a set of five reference samples which were ranked in order of increasing levels of algal and faunal infestation. Each fraction was then assigned the numerical value of the reference sample with which it most closely compared. Separate algal and faunal colonization indices were then determined for the Chondrus and Phyllophora populations of each station by summing the values assigned to the three replicate samples.

Dry weight biomass of each sample was determined for five separate algal fractions: Chondrus crispus, Phyllophora spp., epiphytes of Chondrus, epiphytes of Phyllophora, and the remaining benthic species. Total algal biomass was also determined. Each fraction was weighed on a Mettler balance after drying for 72 hours in a standard drying oven set at 80°C.

Sediment Grain Size

Because of large volumes of sand encountered in the Effluent samples in September, 1982, a sample of sediment was taken from each of the Effluent Station replicates for that collection only. The sample was dried and passed through a 10 nested series of Standard Sieves on a Roto-Tap Shaking Device. The contents of each sieve were weighed and tabulated.

DATA ANALYSIS

Data analysis was performed on the VAX - 11/780 computer at Woods Hole Oceanographic Institution (WHOI). All data were coded onto specially-designed project coding sheets as the samples were processed. Data were entered onto diskettes on a VT-180 microcomputer located at BNEMRL and subsequently transmitted to magnetic disk at WHOI.

Following transmittal, a hard copy of the raw data was generated at BNEMRL's remote terminal and verified against the original coding sheets. All keypunching errors were corrected at this point. Auditing software was then employed to further examine the data for errors.

Analytical software comprised a suite of programs developed at WHOI specifically for the analysis of benthic data. In addition to a variety of data management and modification utilities, these include primarily the programs PRARE1 and SPSTCL. PRARE1 summarizes the data for each sample, calculates a variety of diversity-related indices, and generates a rarefaction curve. SPSTCL is a multivariate classification package which allows a wide variety of user-specified options for similarity indices and clustering strategies.

Analytical Techniques

Rank Order of Abundance. The individual species comprising the fauna at each station are rank ordered by abundance for each replicate. The most dominant species are listed first, followed in order by less dominant forms. The contribution of each species to the overall total percent of the fauna is denoted by an increasing cumulative percentage starting with the most dominant species and ending with the most rare. Basic statistical analyses including calculation of means, standard deviations, standard error and extrapolation to an abundance per m^2 are performed on each replicate sample in order to obtain the rank order for each station.

Diversity Measures (Community Parameters). At least two measures of diversity are calculated for each sample and station, including the Shannon-Wiener information index, H', as well as evenness (Pielou's J) and species richness. In addition, rarefaction curves according to the method of Hurlbert (1971) are calculated. It can be

shown that Shannon's H' is a biased estimator, and for small samples will underestimate the true population information (Smith and Grassle, 1977). Hurlbert's expected species index of diversity has an unbiased estimator and is thus particularly useful when small and unequal sample size must be compared.

Similarity Measures. The most direct measure of faunal similarity between field samples is the number of species in common. The concept of species shared is biologically meaningful and can be readily visualized in terms of species distribution. We used the measure of similarity developed by Grassle and Smith (1976), the Normalized Expected Species Shared (NESS). This measure is based on the expected number of species shared between random samples of size, m, drawn from a population. The NESS is sensitive to the less common species in the populations to be compared. Confidence intervals can be calculated for this index using the two sample jackknife estimator (Smith, Grassle and Kravitz, 1979).

The classic Bray-Curtis similarity measure, the most widely used clustering technique, was also used (Boesch, 1977). These values can be calculated for Stations (Q Type) and by species (R Type). For the present report, only the Q Type analysis was conducted.

In developing similarity values for station pairs (Effluent station with Rocky Point; Effluent Station with Manomet Point; Rocky Point with Manomet Point), clustering algorithms, such as flexible sorting and group averaging are applied to the similarity matrix, and a cluster diagram or dendrogram is generated. This provides a graphical means of visualizing station relationships based on similarity. The significance of differences between stations and sampling periods is also tested using standard parametric and non-parametric methods.

Time-Series Analysis. New results were compared with important components of the 8-year data base to observe long-term effects of thermal discharge on the benthic community. The simplest manner in which to compare long-term data of this sort is to compare changes in species composition over time. Changes in rank of dominants may indicate that perturbation of the community has occurred, or may be merely indicative of natural population cycles. In the August, 1981 samples for example, Mytilus edulis and Caprella penantis were the most dominant faunal species at all three stations. In the same samples, however, two other highly placed dominants at Rocky Point and Manomet

Point, Hiatella arctica and Margarites umbilicus, were greatly reduced in numbers at the Effluent site. The past data base is valuable to determine whether this relationship and others has always existed or if it is related to operation of PNPS, as suspected.

RESULTS

FAUNAL STUDIES

Systematics

Following the change in contractors from Taxon, Inc. to Battelle, there were changes in the names applied to some taxa. With two exceptions, however, none of the common indicator or dominant faunal components are affected. We have decided that Nicolea venustula, a terebellid polychaete, should properly be called N. zostericola since it has 15 instead of 17 thoracic setigerous segments. The caprellid amphipod, Aeginina longicornis found in previous years was not identified by our crustacean taxonomist Elizabeth Garlo. Instead, Caprella linearis, a superficially similar species was identified. We are currently unsure whether A. longicornis has been replaced, or whether there is a disagreement among amphipod taxonomists, although the latter appears unlikely due to differences in morphology. Dr. Les Watling of the University of Maine will soon examine our specimens and the reference specimens from Taxon to resolve the issue.

Among the Mollusca, several species have been identified which appear to be newly reported for the program. These include the bivalves Mysella planulata and Spisula solidissima and the gastropods Facelina bostoniensis, Doto coronata, Anachis avara, Odostomia gibbosa and Nassarius vibex. Cingula aculea is the same as Taxon's Onoba aculea and Turbonilla sumneri is possibly the same as T. interrupta. Our Anomia squamula is a senior synonym of A. aculeata.

Several very interesting species of Polychaeta have been identified. Caulleriella bioculata occurred at both the Rocky Point and Manomet stations and represents the first record of the species from North America. Previously known from European waters, C. bioculata is the type-species of its genus. Representative specimens will be archived in the National Museum of Natural History, Smithsonian Institution. A new species of Cirratulidae has been discovered, which is possibly referrable to the genus Chaetozone. Two species of Polydora have been identified including P. socialis and P.

giardi. The latter species resolves a long standing taxonomic problem. Blake (1971) suggested that P. anoculata Moore, 1909 from Woods Hole, might be a junior synonym of P. giardi Mesnil, 1897 known from widely distributed areas. Little material was available at the time to resolve the issue. The new specimens clearly indicate that the characters of the widespread P. giardi are present and that P. anoculata must be sunk into synonymy.

Two species, Harmothoe extenuata and H. imbricata, have been separated from what was previously called H. imbricata. The two forms may be readily distinguished by the lateral placement of the anterior eyes in the former and their forward location in the latter (Pettibone, 1963).

Five species of Amphipoda and one of the Isopoda appeared in the April collections which have not previously been reported from the study area: Corophium insidiosum (Rocky Point and Effluent Stations, all replicates, see also Table 4), Eudorella pusilla (Manomet, one replicate), Metopella carinata (Rocky Point, Manomet and Effluent, 5 replicates in total), Marinogammarus sp. A (Effluent, 2 replicates), Caprella unica (Effluent, 1 replicate), Limnoria ligorum (Manomet, 1 replicate). According to Bousfield (1973) C. insidiosum females are ovigerous from April to August and tend to migrate from deeper waters inshore in late spring. The species is normally an estuarine species, however, and its presence among the 15 dominant species at Rocky Point and Manomet is unusual (Table 4).

Species Richness

Species richness for the September, 1982 and April, 1983 samplings is presented in Tables 1 and 2, respectively and is plotted in Figure 5. Data are presented as total species for each replicate, with a mean value over all replicates and a cumulative total for each station.

In September, the Manomet Point and Rocky Point reference stations had both greater mean species per replicate and greater total species per station than the Effluent station. The two reference sites were similar to each other for these parameters, with mean species per replicate of 55 and 54.6 for Manomet Point and Rocky Point, respectively, and cumulative species totals of 89 and 83.

The observed pattern for these parameters in September was not repeated in April, 1983. The Effluent station and the Rocky Point reference site were similar for both parameters with 30 and 30.4 mean species per replicate and 51 and 54 total species

TABLE 1. FAUNAL SPECIES RICHNESS, FAUNAL DENSITY WITH AND WITHOUT *MYTILUS EDULIS*, SEPTEMBER, 1982.

Station/ Replicate No.	Species Richness (No.of Species)	Density	Density w/o *Mytilus*
Effluent			
1	40	39,376	36,220
2	42	12,852	11,288
3	48	7,716	7,464
4	41	10,616	10,276
5	37	39,364	37,392
x	41.6	21,985	20,528
m^2	--	197,865	184,752
Total No. Species	75	--	--
Manomet Point			
1	52	6,944	5,660
2	53	8,232	6,844
3	58	14,240	11,804
4	56	16,192	12,916
5	56	8,068	6,584
x	55	10,735	8,762
m^2	--	96,616	78,845
Total No. Species	89	--	--
Rocky Point			
1	56	8,844	7,364
2	54	14,244	12,476
3	56	9,712	8,040
4	53	7,472	6,512
5	54	9,476	8,304
x	54.6	9,950	8,539
m^2	--	89,546	76,853
Total No. Species	83	--	--

TABLE 2. FAUNAL SPECIES RICHNESS, FAUNAL DENSITY WITH AND WITHOUT MYTILUS EDULIS, APRIL, 1983.

Station/ Replicate No.	Species Richness (No.of Species)	Density	Density w/o Mytilus
Effluent			
1	27	13,236	10,004
2	27	9,860	8,964
3	29	12,160	7,332
4	33	10,064	8,232
5	34	8,192	6,628
$\bar{x}$	30	9,242	8,232
m^2	--	83,181	24,088
Total No. Species	51	—	—
Manomet Point			
1	49	23,548	13,248
2	41	13,944	10,644
3	42	12,948	8,172
4	40	13,248	10,252
5	39	14,676	11,848
$\bar{x}$	42.2	15,673	108,128
m^2	--	141,055	97,315
Total No. Species	65	—	—
Rocky Point			
1	36	4,648	4,108
2	38	5,828	5,212
3	29	5,008	4,384
4	21	3,572	3,140
5	28	5,308	4,524
$\bar{x}$	30.4	4,873	4,274
m^2	--	43,855	38,462
Total No. Species	54	—	—

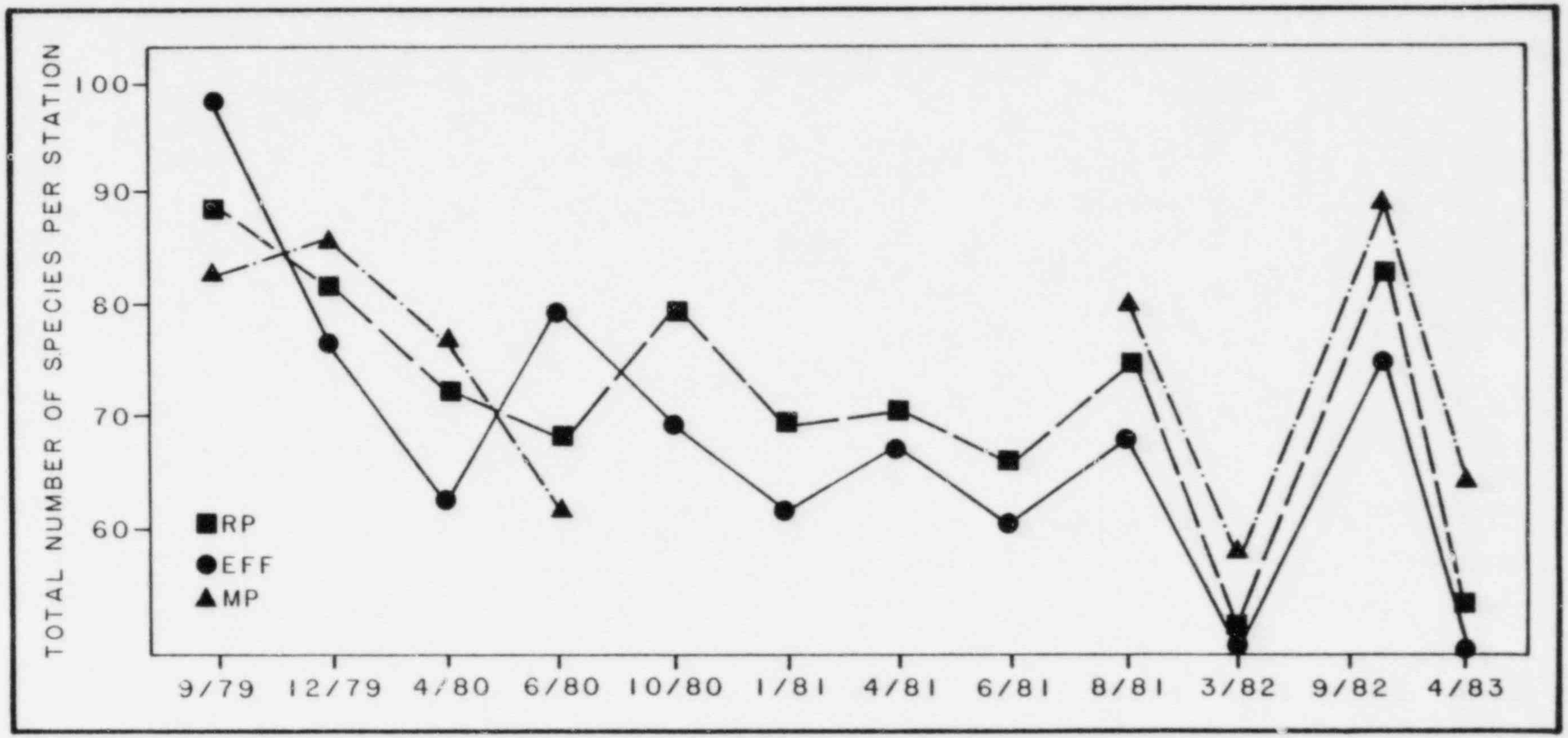


Figure 5. Species richness for the period September, 1979 through April, 1983.

per station, respectively. Manomet Point had considerably greater values for both parameters: 42.2 mean species per replicate and 65 total species.

Differences in these parameters were examined further via a two-way ANOVA (sites vs. times) using subprogram ANOVA of the Statistical Package for the Social Sciences (SPSS) (Nie, et al., 1975). Both main effects (time and site) were very highly significant, indicating that there was significantly greater species richness over all sites in September than in April and significantly fewer species at Effluent for the year. The site x time interaction effect was also significant, reflecting the differences in patterns of species richness discussed above.

Faunal Density

Benthic macrofaunal densities per replicate and per square meter are presented in Tables 1 and 2 for the September, 1982 and April, 1983 samplings, respectively. Because of the tendency for large numbers of mussels (Mytilus edulis) to obscure patterns of other important species, data are presented with and without Mytilus. Total faunal densities, densities without Mytilus, and Mytilus densities only are plotted in Figures 6, 7, and 8, respectively.

Greatest faunal densities in September were recorded at the Effluent station, with individual replicates ranging from 7,716 to 39,376 ($\bar{x}$ = 21,985) individuals per sample. Faunal densities at the Manomet Point and Rocky Point control sites were markedly lower and generally similar to each other. Densities at Manomet Point ranged from 6,944 to 16,192 ($\bar{x}$ = 10,735) individuals, while at Rocky Point the range was 7,472 to 14,244 ($\bar{x}$ = 9,950) individuals per sample. Extrapolating to densities per square meter, Effluent had 197,865/m^2, while Manomet Point and Rocky Point had much lower densities of 78,845/m^2 and 76,853/m^2, respectively. This pattern was even more evident when densities of Mytilus edulis were excluded from the data. Mytilus densities at the Effluent were low, comprising only 6.2% of the total fauna; densities without Mytilus averaged 20,528 per sample, or 184,752/m^2. At Manomet Point and Rocky Point, however, Mytilus was much more common, comprising 18.38% and 14.17% of the fauna, respectively. Consequently, their removal decreased the faunal densities at these two sites considerably. At Manomet Point, faunal densities without Mytilus averaged 8,762 per sample (78,845/m^2), and Rocky Point had an average density per sample of 8,539 (76,853/m^2).

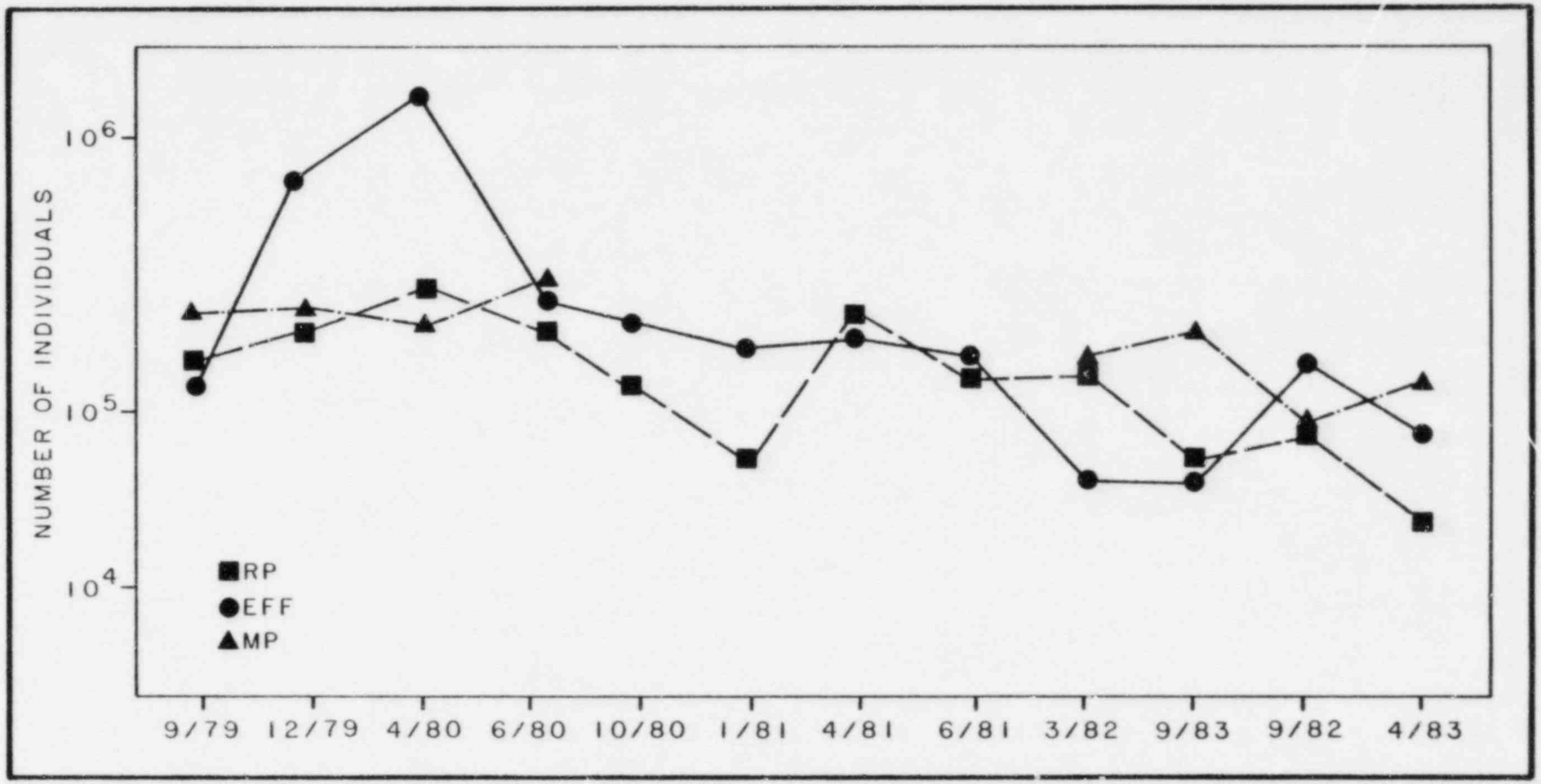


Figure 6. Faunal densities (m^2) for the period September, 1979 through April, 1983.

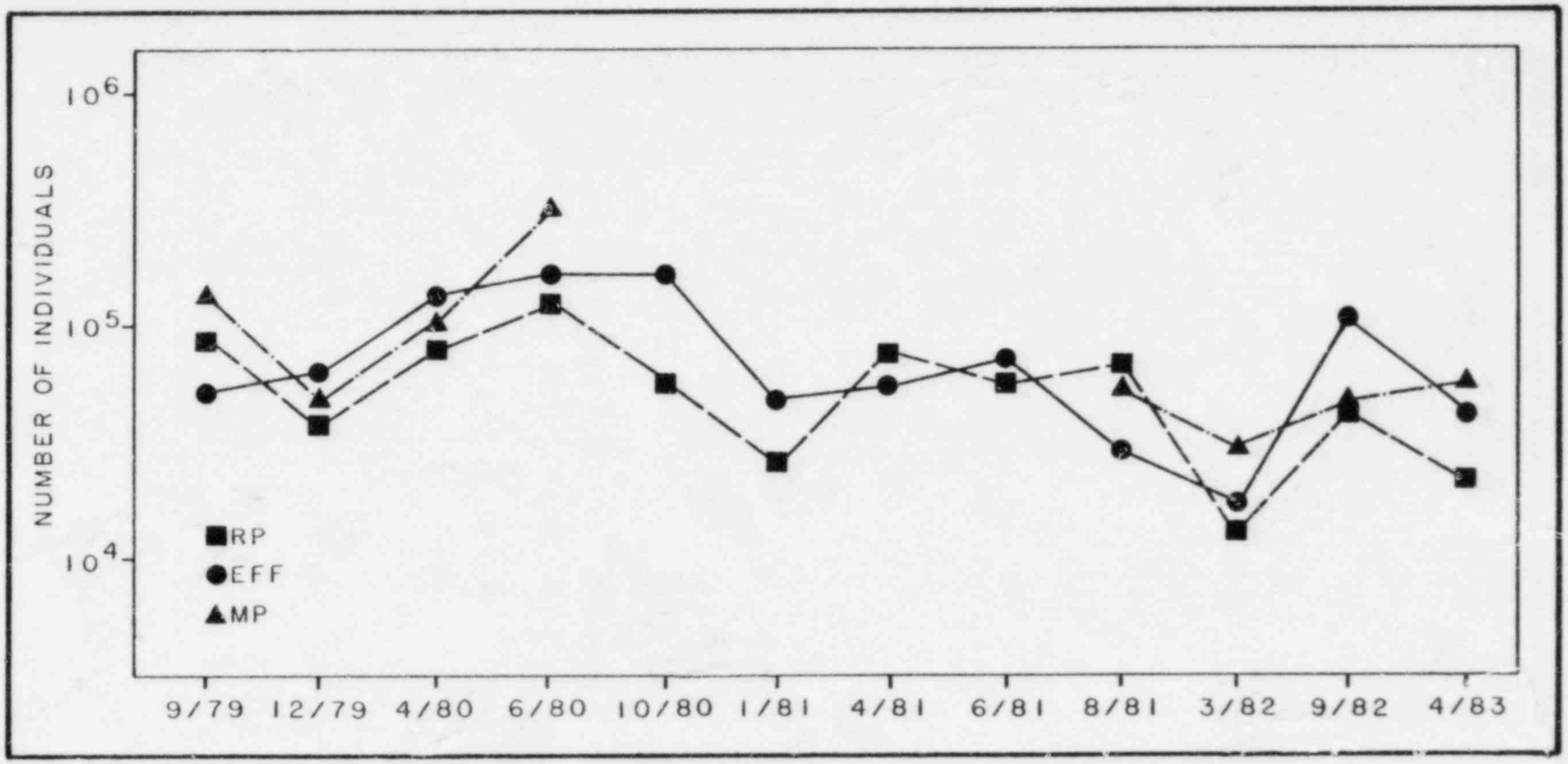


Figure 7. Faunal densities (m^2) excluding Mytilus edulis for the period September, 1979 through April, 1983.

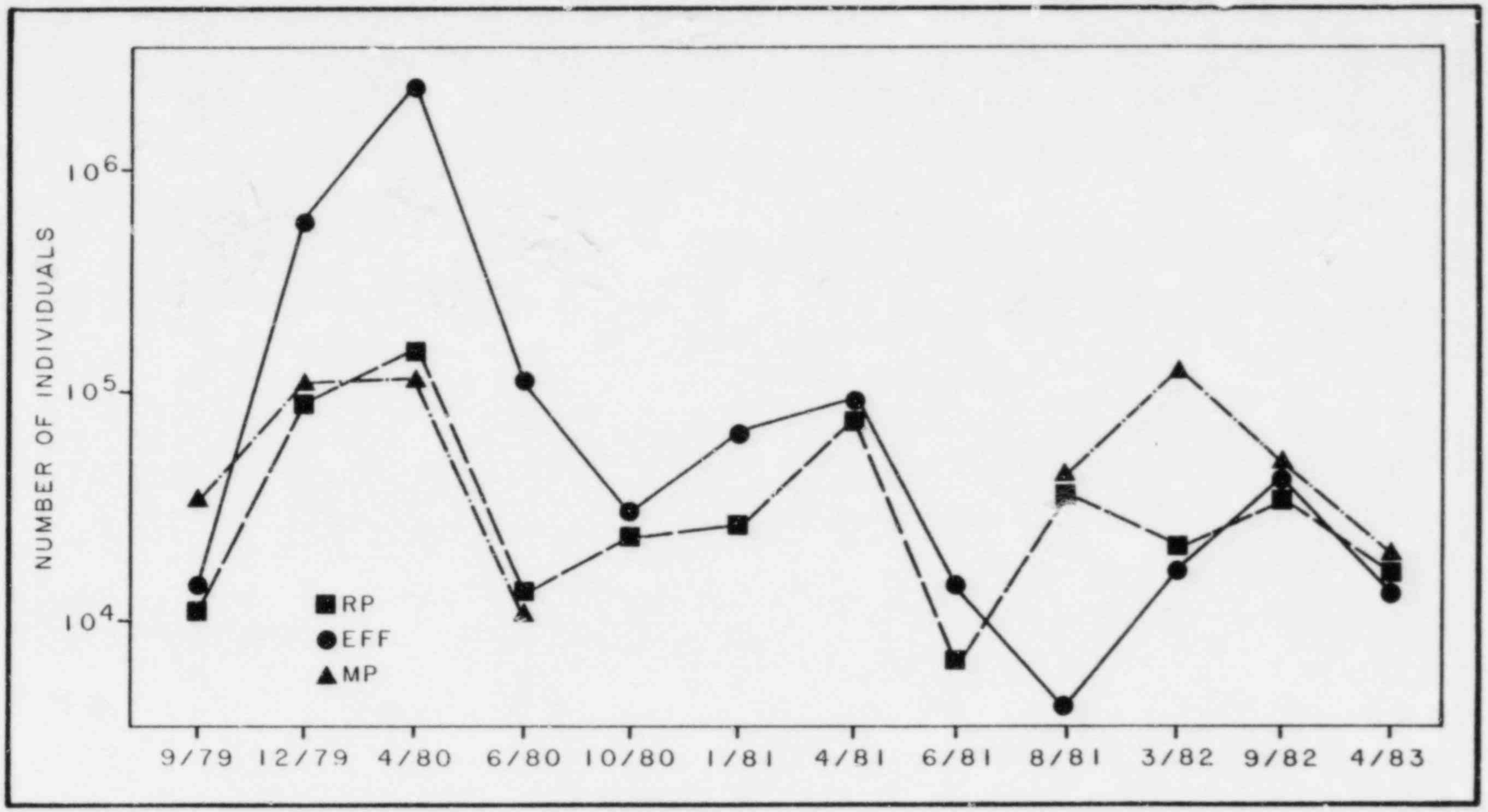


Figure 8. <u>Mytilus</u> <u>edulis</u> densities (m^2) for the period September, 1979 through April, 1983.

The September pattern of faunal density was not repeated in April, 1983. Total faunal densities were different at all three sites. Greatest densities were found at Manomet Point where the individual replicates ranged from 12,948 to 23,548 ($\bar{x}$ = 15,673); this is equivalent to a mean density per square meter of 144,055 individuals, or approximately 50% greater densities than were seen in September.

April densities at the Effluent station were greatly lower than at Manomet Point and densities at Rocky Point were greatly lower than at the Effluent. At Effluent, densities in the replicates ranged from 8,192 to 13,236 ($\bar{x}$ = 9,242) individuals per replicate which is equivalent to a mean density of 83,181 individuals per square meter, a density which is approximately 60% of that found at Manomet Point, in April, and only 42% of the densities recorded from Effluent the preceding September.

At Rocky Point, densities in April ranged from 3,572 to 5,828 individuals per replicate with a mean value of 4,873 (43,855 per square meter). This value was much lower than the densities at the other two sites and was only 53% of the density recorded at Effluent.

When faunal densities excluding Mytilus were calculated, the pattern of densities for April described above was altered. Densities of juvenile Mytilus in April were greater than in September both in actual numbers and as a proportion of the total fauna. This was especially evident at the Effluent station, where Mytilus comprised 71% of the fauna. Percent composition was considerably lower at the two reference sites: 31% at Manomet Point and only 11% at Rocky Point. Manomet Point retained the greatest densities (97,315 individuals per square meter) but the position of the Effluent and Rocky Point stations was reversed. Rocky Point densities were 38,462/m^2 while densities at the Effluent, excluding Mytilus, were only 24,088/m^2.

The observed differences in faunal densities were examined via one-way and two-way (sites x times) ANOVAs. For both the September, 1982 and April, 1983 data, the differences described above between stations were not statistically significant at $p<.05$ for total densities and densities excluding mussels. When all data for the present contract year (i.e. September, 1982 and April, 1983 collections) were examined simultaneously via a two-way ANOVA, only the station effect was found to be significant ($p = .03$); the interaction effect was marginally significant at $p = .054$.

Species Dominance

The 15 numerically dominant species at each station for the September, 1982 and April, 1983 samplings are shown in Tables 3 and 4. In September it was apparent that the Effluent station was somewhat different from the Manomet Point and Rocky Point reference sites in its dominance structure. Additional differences between the two reference sites were also apparent.

The Effluent station in September was dominated by three amphipods, Jassa falcata, Corophium bonelli and C. acutum, which together comprised over 78% of the total fauna. Jassa falcata alone included over 50% of the total individuals and was over three times more abundant than the next most common species. The common mussel, Mytilus edulis, comprised only 6.6% of the fauna and was the fourth dominant. The most common 15 species together comprised 97.6% of the total fauna with the remaining 60 species comprising the remaining 2.4%.

At Rocky Point, Corophium bonelli was the most abundant species, with Jassa falcata dropping to sixth. Mytilus edulis was more abundant at this site, ranking second with a percent composition of 14.2%. This species was followed closely by Dexamine thea, an amphipod species which was not particularly common at the other sites. The top 15 species did not comprise such a dominant fraction of the total fauna at Rocky Point, together including only 86.9% of the individuals.

Mytilus edulis was the dominant species at Manomet Point in September, with Jassa falcata also being present in large numbers. These two species together comprised over 40% of the fauna. The top 15 species at this station together comprised 88.9% of the fauna.

In April, 1983 all three stations were generally similar to each other in their dominance pattern. Three species, Ischyrocerus anguipes, Mytilus edulis and Jassa falcata, occurred among the top four dominants at each station. Of these, I. anguipes, was most common, comprising of 27.7% and 31.3%, respectively, of the total fauna at Effluent and Rocky Point where it was the dominant species and 30.8% of the fauna at Manomet Point where it was ranked second. Mytilus edulis was more numerous at the Effluent and Manomet Point in April, increasing to 23.1% and 31.0% of the fauna, respectively. Mytilus was slightly less well represented at Rocky Point in April, decreasing to 12.3% of the total fauna.

TABLE 3. RANK ORDER OF ABUNDANCE FOR THE DOMINANT 15 SPECIES, SEPTEMBER, 1982.

Station/Species	Number (x/replicate)	Percent
Effluent		
Jassa falcata	11,903	54.14
Corophium bonelli	3,347	15.22
Corophium acutum	1,930	8.78
Mytilus edulis	1,457	6.62
Calliopus laevisculus	811.2	3.68
Caprella penantis	745.6	3.39
Acarina sp.	568.0	2.58
Dexamine thea	268.0	1.22
Idothea phosphorea	196.0	0.89
Asterias forbesii	77.6	0.35
Lacuna vincta	69.6	0.31
Idotea baltica	64.8	0.29
Aeolidia papillosa	60.8	0.27
Metridium senile	51.2	0.23
Mysella planulata	50.4	0.22
Total of 15 Species	21,600.4	97.63%
Remaining fauna — 60 spp.	384.4	2.37%
Total Fauna — 75 spp.	21,984.8	100.0%
Manomet Point		
Mytilus edulis	2,776.8	25.86%
Jassa falcata	1,766.4	16.45
Acarina sp.	746.4	6.95
Pleusymtes glaber	636.0	5.92
Ischyroceros anguipes	529.6	4.93
Corophium acutum	513.6	4.78
Caprella penantis	464.8	4.32
Margarites helicinia	380.8	3.54
Corophium borelli	377.6	3.51
Calliopus laevisculus	304.0	2.83
Nicolea zostericola	248.8	2.31
Dexamine thea	240.8	2.24
Hiatella arctica	217.6	2.02
Caprella linearis	176.8	1.64
Idotea phosphorea	172.0	1.60
Total of 15 Species	9,552.0	88.90
Remaining fauna -- = 74 spp.	1,183.2	11.10%
Total Fauna — 89 spp.	10,735.2	100.0%
Rocky Point		
Corophium bonelli	1,612.8	16.20
Mytilus edulis	1,410.4	14.17
Dexamine thea	1,049.6	10.54
Margarites helicinia	632.0	6.35
Caprella penantis	604.8	6.07
Jassa falcata	600.0	6.03
Corophium acutum	493.6	4.96
Acarina sp.	473.6	4.75
Pleusymtes glaber	403.2	4.05
Lacuna vincta	300.0	3.01
Hiatella arctica	257.6	2.58
Ischyrocerus anguipes	244.0	2.45
Cingula aculeus	218.4	2.19
Calliopius laevisculus	182.4	1.83
Nicolea zostericola	174.4	1.75
Total of 15 Species	8,656.8	86.93
Remaining fauna — 68 spp.	1,292.8	13.07%
Total Fauna — 83 spp.	9,949.6	100.0%

TABLE 4. RANK ORDER OF ABUNDANCE FOR THE DOMINANT 15 SPECIES, APRIL, 1983.

Station/Species	Number ($\bar{x}$/replicate)	Percent
Effluent		
Ischyrocerus anguipes	2,968.0	27.73
Mytilus edulis	2,470.4	23.08
Jassa falcata	2,168.0	20.26
Acarina	659.2	6.16
Corophium insidiosum	626.4	5.85
Lacuna vincta	350.4	3.27
Corophium acutum	344.0	3.21
Calliopius laevisculus	238.4	2.23
Pontogeneia inermis	210.4	1.96
Caprella penantis	197.6	1.85
Dexamine thea	168.8	1.58
Idotea phosphorea	88.0	0.82
Caprella linearis	24.0	0.22
Natantia	20.0	0.19
Nassarius vibex	13.6	0.13
Total of 15 Species	**10,547.2**	**98.54%**
Remaining fauna — 36 spp.	**155.2**	**1.46%**
Total fauna — 51 spp.	**10,702.4**	**100.00%**
Manomet Point		
Mytilus edulis	4,860.0	31.00
Ischyrocerus anguipes	4,824.0	30.77
Jassa falcata	2,695.2	17.19
Lacuna vincta	1,219.2	7.78
Corophium acutum	440.8	2.81
Caprella penantis	320.0	2.04
Acarina	240.8	1.54
Nicolea zostericola	181.6	1.16
Dexamine thea	147.2	0.94
Pontogeneia inermis	139.2	0.89
Margarites helicinus	108.8	0.69
Pleusymtes glaber	65.6	0.42
Idotea phosphorea	56.0	0.36
Corophium bonelli	36.8	0.23
Caprella linearis	32.8	0.21
Total of 15 Species	**15,220.8**	**98.03%**
Remaining fauna — 50 spp.	**309.6**	**1.97%**
Total fauna — 65 spp.	**15,530.4**	**100.00%**
Rocky Point		
Ischyrocerus anguipes	1526.4	31.29
Jassa falcata	707.2	14.50
Lacuna vincta	669.6	13.72
Mytilus edulis	599.2	12.28
Pontogeneia inermis	353.6	7.25
Dexamine thea	291.2	5.97
Corophium acutum	154.4	3.16
Acarina	132.0	2.71
Caprella penantis	102.4	2.10
Margarites helicinus	32.8	0.67
Mitrella lunata	30.4	0.62
Corophium bonelli	29.6	0.61
Corophium insidiosum	25.6	0.52
Nicolea zostericola	23.2	0.48
Pleusymtes glaber	20.8	0.43
Total of 15 Species	**4,698.4**	**96.31%**
Remaining fauna — 39 spp.	**900.0**	**3.69%**
Total fauna — 54 spp.	**5,598.4**	**100.00%**

The patterns of dominance described above were tested for significant correlation in space and time using Spearman's rank correlation (~ .:, 1974). The results of this analysis indicated that the dominance pattern at Manomet Point was significantly correlated (p<.05) with both Rocky Point and Effluent but that the relationship between Rocky Point and Effluent was not significant (.05<p<.10) though suggestive of a close similarity.

Species Diversity

Shannon-Wiener diversity (H') and evenness (J') were calculated for each replicate and for the combined data for each station. These values are presented in Table 5 (September, 1982), Table 5A (excluding Mytilus edulis) and Table 6 (April, 1983). This type of data presentation has been followed in previous reports because the Shannon-Wiener index can be disproportionately influenced by the presence of a single overwhelming dominant species, as is often the case for Mytilus in the study area. Because of the comparatively lower densities of Myt:lus in these two samplings, however, there is relatively little difference between diversit'es with and without Mytilus.

In September, highest diversity val' as were found at Manomet Point and Rocky Point where the recorded values (both : 4.0) would be considered quite high for these two sites. Values at the Effluent site were significantly lower (ANOVA, F = 34.92, df = 2/12, p<.001). This result is caused by the combination of lower species richness and strong dominance of Jassa falcata at Effluent in September.

For the April sampling, a different pattern of diversity values was found. Diversities were generally lower due to stronger dominance and decreased species richness throughout the area. Manomet Point and Rocky Point diversities were 2.68 and 3.21, respectively, both values much less than those seen in September. This appeared to be related to decreased species richness combined with increased dominance by a small number of species.

Diversities at the Effluent station were also lower in April than in September, though the difference was less than that seen at the other two sites. This appeared due to two offsetting factors: species richness at Effluent was lower in April which would tend to produce lower diversity values, but the strong dominance by Jassa falcata was not repeated. A one-way ANOVA performed on the April diversity values indicated all stations were significantly different (F = 10.94, df = 2/12, p<.01).

TABLE 5. INFORMATION THEORY DIVERSITY VALUES (SHANNON-WIENER) BY REPLICATE AND FOR M^2 DATA, SEPTEMBER, 1982.

Replicate	Manomet Point		Rocky Point		Effluent	
	H'	J'	H'	J'	H'	J'
1	4.04	0.71	4.23	0.73	2.03	0.38
2	4.21	0.74	4.14	0.72	2.56	0.47
3	3.95	0.67	3.88	0.67	3.30	0.59
4	3.71	0.64	4.34	0.76	2.76	0.51
5	4.17	0.72	4.08	0.71	2.14	0.41
m^2	4.22	0.65	4.27	0.67	2.41	0.39

TABLE 5A. INFORMATION THEORY DIVERSITY VALUES (SHANNON-WIENER) EXCLUDING MYTILUS EDULIS BY REPLICATE AND M^2 DATA, SEPTEMBER, 1982.

Replicate	Manomet Point		Rocky Point		Effluent	
	H'	J'	H'	J'	H'	J'
1	4.11	0.72	4.30	0.74	1.76	0.33
2	4.29	0.75	4.10	0.72	2.31	0.43
3	3.98	0.68	3.89	0.67	3.20	0.58
4	3.75	0.65	4.34	0.76	2.64	0.50
5	4.27	0.74	4.04	0.71	1.95	0.38
m^2	4.33	0.67	4.29	0.68	2.20	0.35

TABLE 6. INFORMATION THEORY DIVERSITY VALUES (SHANNON-WIENER) BY REPLICATE AND STATION, APRIL, 1983.

	Manomet Point		Rocky Point		Effluent	
Replicate	H'	J'	H'	J'	H'	J'
1	2.53	0.45	3.13	0.60	2.64	0.55
2	2.55	0.47	3.31	0.63	2.58	0.54
3	2.61	0.48	2.74	0.56	2.89	0.59
4	2.72	0.51	3.04	0.69	3.02	0.59
5	2.48	0.47	3.17	0.66	2.91	0.57
Station Summary	2.68	0.44	3.21	0.56	2.97	0.52
Station Summary (w/o *Mytilus*)	2.59	0.43	2.60	0.43	2.85	0.50

Cluster Analysis

Cluster analysis, also known as classification analysis, was performed on both the September, 1982 and April, 1983 samplings. Because this technique of visualizing benthic data is still undergoing development, and because of the number of options available for similarity measures and clustering algorithms, we have followed two distinct procedures for each analysis. The first uses the most widely accepted methods in benthic ecology, the Bray-Curtis similarity measure combined with unweighted pair-group clustering (Boesch, 1977). The second method uses two newer procedures, involving calculation of normalized expected species shared (NESS) as a similarity measure (Grassle and Smith, 1976) and flexible sorting with a β of -0.25.

The results using the Bray-Curtis similarity measure are shown in Figures 9 and 10 for September, 1982 and April, 1983, respectively. For the September collection, the differences in faunal composition at the three sites are immediately apparent in the dendrogram. The Effluent site forms a distinct cluster to the left of the dendrogram which includes all five replicates and does not link with the remaining samples until much lower similarity levels are reached.

The samples from the Manomet Point and Rocky Point reference sites comprise the remainder of the dendrogram and also show a strong tendency to form clusters based on station. Within the larger two-station cluster, all Rocky Point replicates except RP2 form an extremely homogeneous cluster to the far left of the dendrogram. To the right of this cluster is the cluster formed primarily by Manomet Point samples. Although this last cluster is somewhat more heterogeneous than the Rocky Point cluster, the linkages are still completed at very high levels of similarity (>0.80).

The data from April, 1983, (Figure 10) result in a considerably different pattern of similarity. The Rocky Point replicates are clearly distinguishable from the remaining two sites and form a distinct cluster at the far right of the dendrogram. This cluster is completed at a similarity of approximately 0.75, which indicates moderately intense similarity although somewhat less than seen in September.

Effluent and Manomet Point are essentially indistinguishable as separate stations from the April data, forming a heterogeneous cluster to the left of the dendrogram. This type of result tends to support a conclusion of no impact at the Effluent in April, 1983.

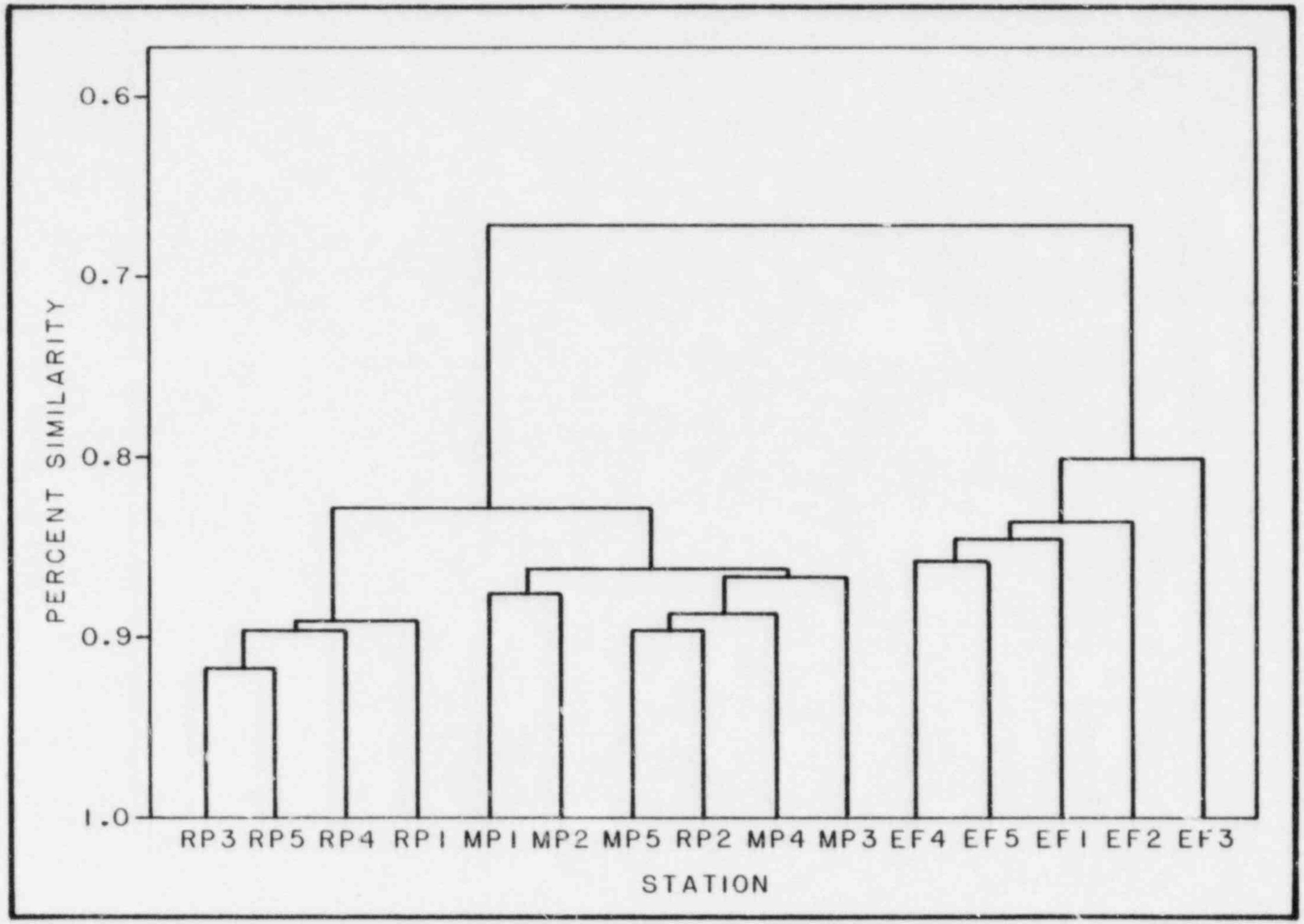


Figure 9. Replicates of Manomet Point, Rocky Point, and Effluent Stations clustered by Bray-Curtis, September, 1982.

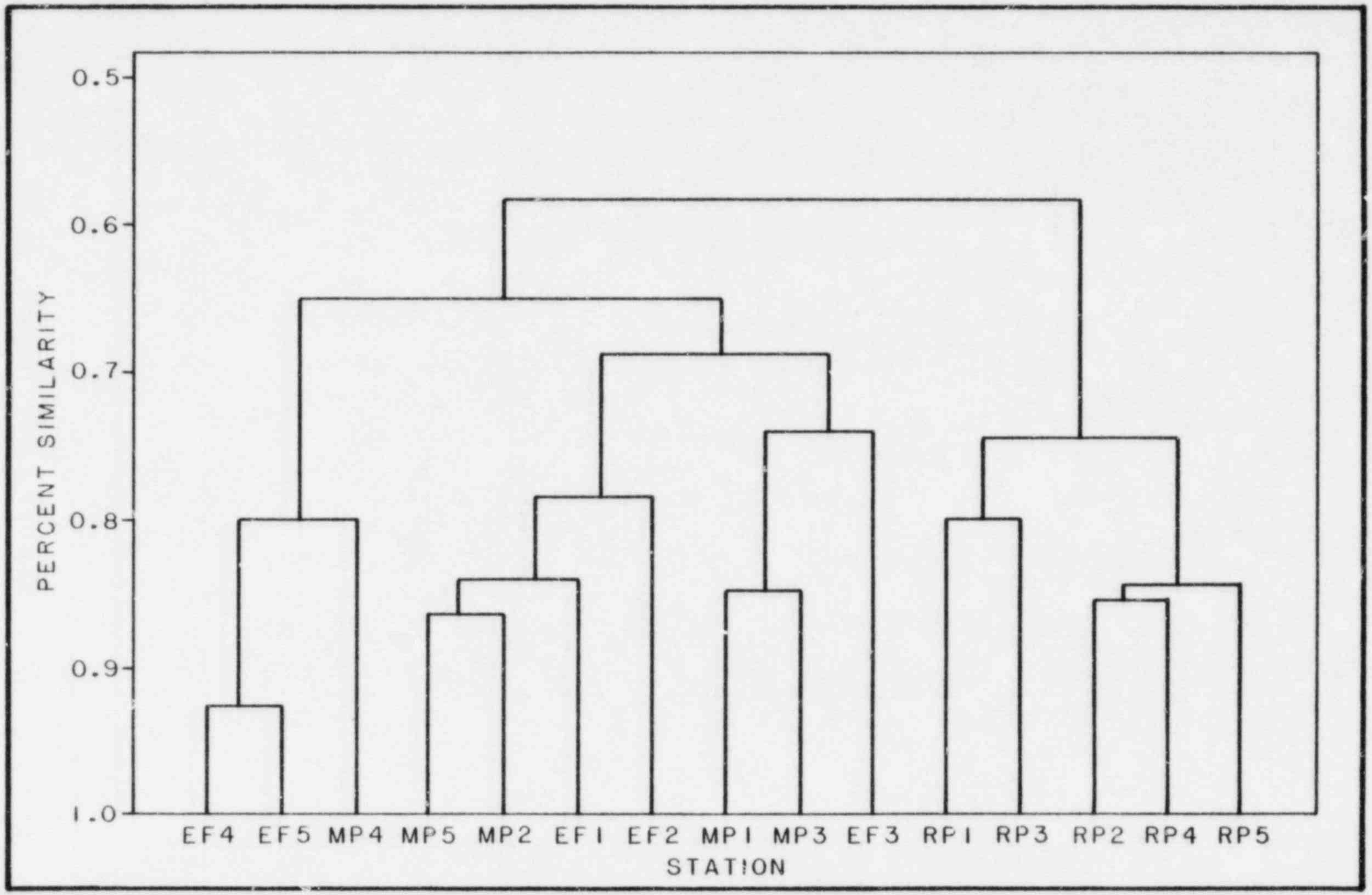


Figure 10. Replicates of Manomet Point, Rocky Point, and Effluent Stations clustered by Bray-Curtis, April, 1983.

The results of the analysis using NESS are essentially identical to those described above for the September data (Figure 11). The Effluent station is readily separated from the two reference sites which form two very closely related clusters grouping the replicates from each station first before linking with each other.

For the April, 1983 data (Figure 12) the NESS results indicate even greater homogenity between Effluent and reference sites than was apparent from Bray-Curtis. Although Rocky Point again tends to cluster separately, in this case in the center of the dendrogram, the cluster is weak and shows close relationships to both Manomet Point and Effluent samples, the remainder of the dendrogram comprises closely related replicates from Effluent and Manomet Point and emphasizes the similarity of these two sites in April, 1983.

ALGAL STUDIES

Systematics

No additions to the cumulative algal species list presented in BECo Report No. 16 (BECO, 1980) have been made as a result of the September, 1982 and April, 1983 sample analyses. The warm-water alga Gracilaria foliifera has been referred to its senior synonym G. tikvahiae (McLachlan, 1979), and we will be using the latter name in this and subsequent reports. Species identifications and taxonomic determinations were based on the works of Bold and Wynne (1978), Dawson (1966), Parke and Dixon (1976), South (1976), and Taylor (1957).

Algal Community Description

Throughout the Manomet Point, Rocky Point, and Effluent survey areas, the rock and cobble substratum was heavily colonized by red macroalgae. The most abundant species were Chondrus crispus and Phyllophora spp., both representatives of the Order Gigartinales. Chondrus densities appeared similar at all three sampling areas. Phyllophora spp. was present at all three sample areas, but was less dense than Chondrus. Additional benthic macroalgal species were also represented within the three sampling areas. The most noticeable red algae were Polyides rotundus, Ahnfeltia plicata, and Corallina officinalis.

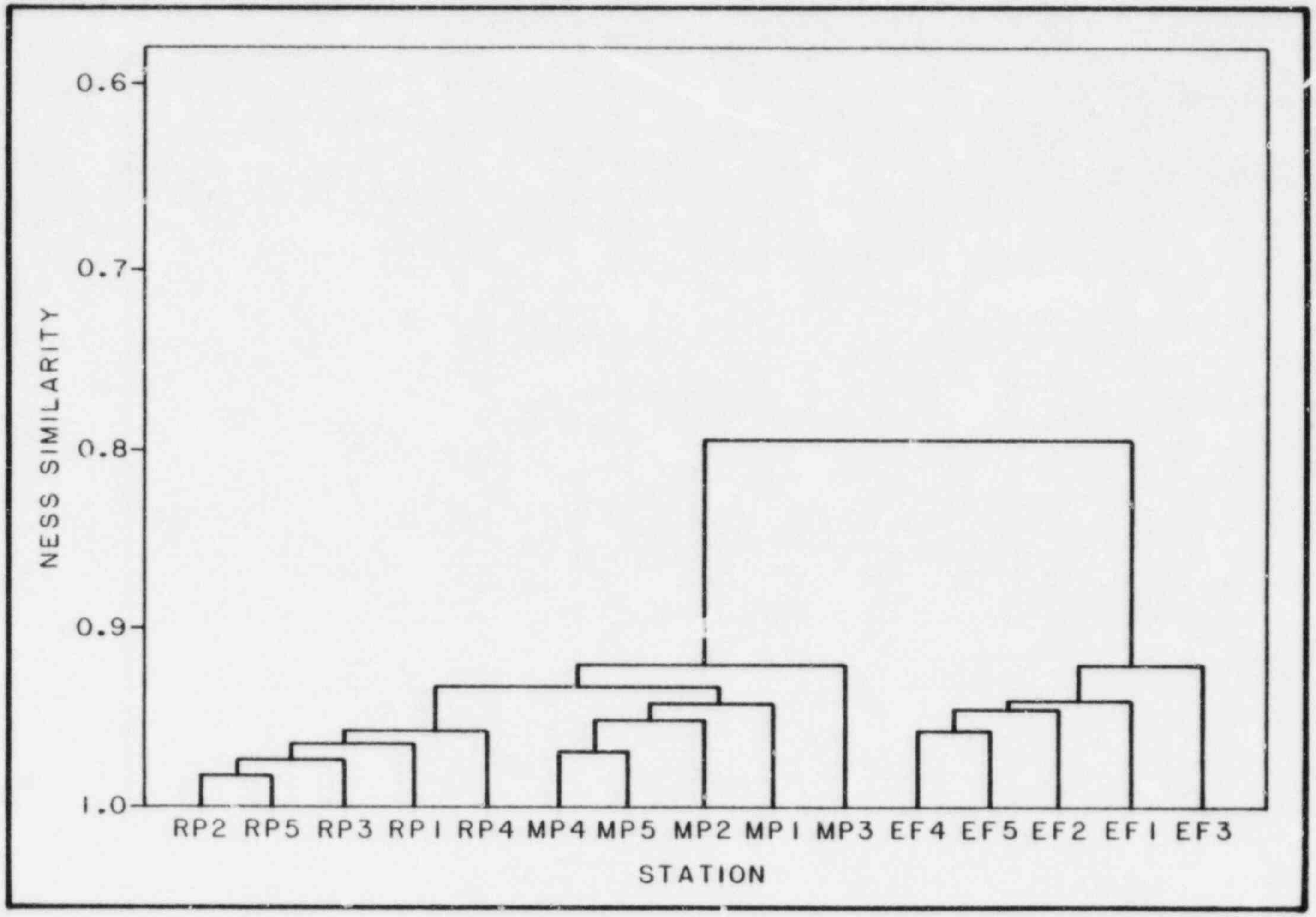


Figure 11. Replicates of Manomet Point, Rocky Point, and Effluent Stations clustered by NESS, September, 1982.

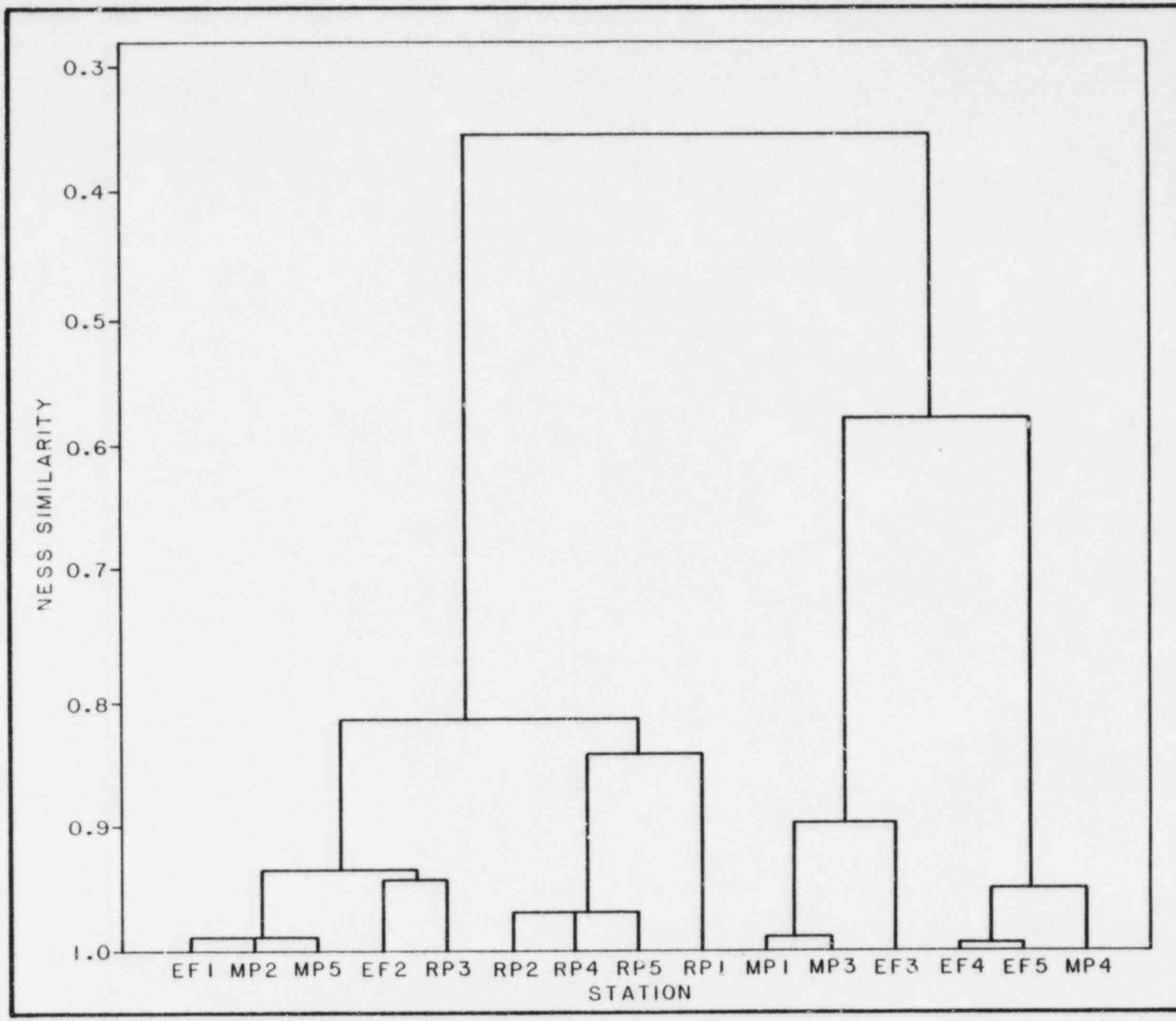


Figure 12. Replicates of Manomet Point, Rocky Point, and Effluent Stations clustered by NESS, April, 1983.

The most conspicuous brown algae were isolated specimens of Laminaria spp. Green algae within the sampling area included mostly Chaetomorpha sp. filaments and scattered Ulva lactuca. While each of these taxa were occasionally observed to form well defined populations, their most common mode of occurrence was either as isolated individuals, r as weakly developed populations occurring within the Chondrus and Phyllophora.

Gracilaria tikvahiae blanketed the rocks within the effluent canal, decreasing to sparse patches at a distance of 60 meters from the jetties. Also common in clumps among the Gracilaria was the introduced green alga Codium fragile tomentosoides. Since its introduction in Long Island Sound in 1957, Codium has spread to the south side of Cape Cod. In recent years, Codium has been documented in Cape Cod Bay and presently a local population exists year round in Duxbury Bay (Carlton and Scanlon, MS. in preparation). The shallower stunted zone interface was dominated by sparse Chondrus and the brown alga Fucus spp.

The epiphytic algal population encompassed a large number of species and comprised an important component of the algal community. Chondrus and Phyllophora served as the primary host species although Polyides rotundus was also colonized when it was present. Epiphytic species are prevalent throughout the year, but attain their maximum development during summer and early autumn. During this time, the dominant epiphytic species included Spermothamnion repens, several species of Polysiphonia, Cystoclonium pupureum and Ceramium rubrum. The dominant species present in the April, 1983 samples included those and Phycodrys rubens and Rhodomela confervoides.

Algal Community Overlap

Community overlap was calculated using Jaccard's Coefficient of Community (Greig-Smith, 1964) to measure the extent of similarity in algal species composition between the Manomet Point, Effluent, and Rocky Point stations. The coefficient model provides a mathematical evaluation of the similarity of two stations or replicates using only the species content, and without reference to any differences in the abundance of the species involved. Species occurrence records of the 38 indicator species were used for all community overlap calculations.

Results of community overlap comparisons between replicate samples of each station for the September, 1982 and April, 1983 collecting periods are presented in matrix

form in Figures 13 and 14. For September, 1982, ranges of replicate overlap values were 65%-90% at Manomet Point and Rocky Point stations, and 70%-95% at the Effluent. For April, 1983, ranges for the same three stations were 64%-86%, 68%-94% and 72%-96%. Mean replicate overlap values for Manomet Point, Rocky Point and Effluent were 79.6%, 77.6%, and 82.9% in September, and 77.4%, 77.0% and 83.1% in April. Similar ranges and means of these values at the three stations indicate that the algal species composition of each was similarly homogeneous.

Algal Biomass

Chondrus crispus Biomass. Chondrus crispus biomass values for Manomet Point, Rocky Point and Effluent stations for September, 1982 and April, 1983 are presented in Tables 7 and 8.

In April, 1983, the range of individual biomass was greatest at Rocky Point (142.47-362.52 g/m^2). Ranges were slightly lower at Manomet Point and Effluent, 194.58-385.47 g/m^2, and 13.59-187.74 g/m^2, respectively. For the September, 1982 collecting period, the range of individual biomass was greatest at Effluent (56.25-990.27 g/m^2), followed by Rocky Point (225.72-574.38 g/m^2) and Manomet Point (189.72-594.90 g/m^2). At Manomet Point, Rocky Point and Effluent, respectively, the mean Chondrus biomass comprised 54%, 48% and 54% of the total algal biomass present in September, 1982. In April, 1983 these values for the same three stations were 61%, 74% and 22%, respectively.

During September, 1982, the Effluent station had the highest mean Chondrus biomass (474.19 g/m^2) followed by Manomet Point (465.44 g/m^2). Rocky Point mean biomass was the lowest of the three stations (325.85 g/m^2), 31% lower than the Effluent value, and 30% lower than the Manomet Point value. During April, 1983, the Manomet Point station had the highest mean Chondrus biomass (269.73 g/m^2) followed closely by Rocky Point (233.46 g/m^2). Effluent mean biomass was the lowest of the three stations (106.58 g/m^2), 54% lower than the Rocky Point value, and 61% lower than the Manomet Point value.

Highest mean Chondrus biomass occurred in September at all three stations. The decline in biomass between the two periods was 42.1% for Manomet Point, 28.4% for Rocky Point, and 77.5% for Effluent. Lower Chondrus biomass values in winter and early spring have been observed in previous collections, and this observation reflects the normal

	1	2	3	4	5	
1		19	16	18	17	
2	82.6		18	19	18	Number of Species Shared
3	66.7	81.8		17	18	
4	81.8	90.5	81.0		17	
5	70.8	78.3	85.7	77.3		

Percent Overlap

A. MANOMET POINT STATION

	1	2	3	4	5	
1		17	21	20	19	
2	63.0		19	18	17	Number of Species Shared
3	70.0	79.2		21	21	
4	74.1	85.7	84.0		20	
5	67.9	77.3	84.0	90.9		

Percent Overlap

B. ROCKY POINT STATION

	1	2	3	4	5	
1		20	22	18	20	
2	83.3		20	17	19	Number of Species Shared
3	95.7	87.0		18	21	
4	75.0	73.9	78.3		18	
5	95.7	79.2	91.3	69.2		

Percent Overlap

C. EFFLUENT STATION

OVERLAP BETWEEN STATIONS

Station Pair	Number of Shared Species	Community Overlap
Manomet Point-Rocky Pt.	23	79.31%
Manomet Point-Effluent	20	68.97%
Rocky Point-Effluent	23	76.67%

FIGURE 13. ALGAL COMMUNITY OVERLAP (JACARD'S COEFFICIENT OF COMMUNITY) AND NUMBER OF SPECIES SHARED BETWEEN REPLICATE PAIRS AT THE MANOMET POINT, ROCKY POINT AND EFFLUENT SUBTIDAL STATIONS (10' MLW), SEPTEMBER, 1982

	1	2	3	4	5
1		17	16	18	17
2	74.0		18	17	17
3	64.0	78.3		18	18
4	86.0	77.3	82.0		18
5	74.0	74.0	78.3	86.0	

Number of Species Shared

Percent Overlap

A. MANOMET POINT STATION

	1	2	3	4	5
1		14	14	15	15
2	77.8		16	15	16
3	73.7	94.1		15	16
4	75.0	75.0	71.4		18
5	68.1	76.2	73.0	82.0	

Number of Species Shared

Percent Overlap

B. ROCKY POINT STATION

	1	2	3	4	5
1		19	21	18	22
2	79.2		19	18	19
3	88.0	82.6		19	21
4	72.0	81.8	82.6		18
5	95.7	82.6	91.3	75	

Number of Species Shared

Percent Overlap

C. EFFLUENT STATION

OVERLAP BETWEEN STATIONS

Station Pair	Number of Shared Species	Community Overlap
Manomet Point-Rocky Pt.	21	81.00%
Manomet Point-Effluent	23	85.20%
Rocky Point-Effluent	21	81.00%

FIGURE 14. ALGAL COMMUNITY OVERLAP (JACARD'S COEFFICIENT OF COMMUNITY) AND NUMBER OF SPECIES SHARED BETWEEN REPLICATE PAIRS AT THE MANOMET POINT, ROCKY POINT AND EFFLUENT SUBTIDAL STATIONS (10' MLW), APRIL, 1983.

TABLE 7. DRY WEIGHT BIOMASS VALUES (g/m^2) FOR CHONDRUS CRISPUS, PHYLLOPHORA spp., EPIPHYTES, THE REMAINING BENTHIC SPECIES, AND TOTAL ALGAL BIOMASS FOR MANOMET PT., ROCKY PT., AND EFFLUENT SUBTIDAL (10' MLW) STATIONS FOR SEPTEMBER, 1982.

Station Rep.	Chondrus Crispus		Phyllophora spp.		Remaining Benthic Species		Epiphytic Species (Total)		Total Algal Biomass
MANOMET PT.									
1	521.55	(60%)	218.88	(25%)	3.78	(0.4%)	121.68	(14%)	865.89
2	448.65	(55%)	235.08	(29%)	36.63	(5%)	90.00	(11%)	810.36
3	572.40	(60%)	324.45	(34%)	1.08	(0.1%)	53.64	(6%)	951.57
4	189.72	(23%)	540.36	(66%)	8.19	(1%)	75.51	(9%)	813.78
5	594.90	(66%)	228.60	(25%)	8.73	(1%)	71.10	(8%)	903.33
X	**465.44**	**(54%)**	**309.47**	**(36%)**	**11.68**	**(1%)**	**82.39**	**(9%)**	**868.99**
ROCKY PT.									
1	272.25	(38%)	145.17	(20%)	188.28	(26%)	113.22	(16%)	718.92
2	574.38	(67%)	196.11	(23%)	3.15	(0.4%)	79.11	(9%)	852.75
3	225.72	(37%)	126.90	(21%)	174.87	(29%)	78.03	(13%)	605.52
4	280.80	(48%)	170.10	(29%)	58.59	(10%)	72.54	(13%)	582.03
5	276.12	(45%)	190.17	(31%)	12.10	(2%)	129.96	(21%)	608.35
X	**325.85**	**(48%)**	**165.69**	**(25%)**	**87.40**	**(13%)**	**94.57**	**(14%)**	**673.51**
EFFLUENT									
1	990.27	(77%)	247.32	(19%)	4.68	(0.4%)	50.67	(4%)	1292.94
2	889.29	(84%)	123.66	(12%)	0.45	(.04%)	46.35	(4%)	1059.75
3	84.15	(14%)	235.35	(39%)	124.38	(21%)	163.80	(27%)	607.68
4	56.25	(10%)	374.22	(69%)	14.40	(3%)	99.99	(18%)	544.86
5	351.00	(39%)	285.30	(31%)	188.10	(21%)	85.32	(9%)	909.72
X	**474.19**	**(54%)**	**253.17**	**(29%)**	**66.40**	**(8%)**	**89.23**	**(10%)**	**882.99**

TABLE 8. DRY WEIGHT BIOMASS VALUES (g/m²) FOR CHONDRUS CRISPUS, PHYLLOPHORA SPP., EPIPHYTES, THE REMAINING BENTHIC SPECIES, AND TOTAL ALGAL BIOMASS FOR MANOMET PT., ROCKY PT., AND EFFLUENT SUBTIDAL (10' MLW) STATIONS FOR APRIL, 1983.

Station Rep.	Chondrus Crispus		Phyllophora spp.		Remaining Benthic Species		Epiphytic Species (Total)		Total Algal Biomass
MANOMET PT.									
1	282.78	(57%)	185.94	(37%)	6.12	(1%)	24.30	(5%)	499.14
2	251.28	(67%)	105.21	(28%)	0.18	(0.1%)	18.72	(5%)	375.39
3	238.23	(53%)	151.29	(33%)	56.97	(13%)	7.11	(2%)	453.60
4	190.89	(49%)	182.43	(47%)	2.61	(0.7%)	10.98	(3%)	386.91
5	385.47	(80%)	61.02	(13%)	3.15	(0.7%)	34.74	(7%)	484.38
$\bar{X}$	**269.73**	**(61%)**	**137.18**	**(31%)**	**13.81**	**(3%)**	**19.17**	**(4%)**	**439.88**
ROCKY PT.									
1	362.52	(89%)	30.15	(7%)	12.96	(3%)	0.00	(0%)	405.63
2	230.04	(74%)	47.61	(15%)	22.77	(7%)	11.34	(4%)	311.76
3	226.98	(63%)	21.87	(6%)	100.62	(28%)	12.96	(4%)	362.43
4	205.29	(92%)	1.80	(0.8%)	4.77	(2%)	11.43	(5%)	223.29
5	142.47	(50%)	76.41	(27%)	39.42	(14%)	24.03	(9%)	282.33
$\bar{X}$	**233.46**	**(74%)**	**35.57**	**(11%)**	**36.11**	**(11%)**	**11.95**	**(4%)**	**317.09**
EFFLUENT									
1	74.88	(14%)	397.71	(74%)	25.02	(5%)	38.79	(7%)	536.40
2	180.81	(40%)	251.01	(55%)	1.08	(0.2%)	22.05	(5%)	454.95
3	13.59	(3%)	264.51	(63%)	24.39	(6%)	120.33	(28%)	422.82
4	75.87	(15%)	429.75	(82%)	0.00	(0%)	17.28	(3%)	522.90
5	187.74	(38%)	266.85	(54%)	13.14	(3%)	27.27	(6%)	495.00
$\bar{X}$	**106.58**	**(22%)**	**321.97**	**(66%)**	**12.73**	**(3%)**	**45.14**	**(9%)**	**486.41**

seasonal growth cycle. Chondrus germination and growth rates are highest from late spring to early autumn (Taylor, 1957), and typically result in an increase in the population during the summer months; conversely, markedly reduced winter germination and growth rates, coupled with a high incidence of adult and juvenile plant mortality as a consequence of harsh winter storms, typically results in a reduction in the Chondrus population from the late autumn to early spring months.

Chondrus/Phyllophora biomass ratios at Rocky Point, Effluent and Manomet in September, 1982 were similar at 1.9:1, 1.8:1 and 1.5:1, respectively. In April, 1983 at the same stations this parameter varied greatly with Chondrus/Phyllophora ratios of 6.6:1, 0.33:1, and 2.0:1. The divergent ratio at the Effluent station reflects the low Chondrus biomass (106.58 g/m^2) and high Phyllophora biomass (321.97 g/m^2). Phyllophora is a principal competitor for available substratum due to its sturdier morphology, and is believed to be more tolerant of sediment scouring and epiphytes.

Previous BECo Semi-Annual Reports have advanced the hypothesis that sand scour at the Effluent site may be primarily responsible for a decreased Chondrus biomass observed from October, 1975 to August, 1981. Chondrus is relatively delicate and is considered to be particularly susceptible to the effects of scouring (Prince, 1971). Inhibition of germination and abrasion-induced dislodging of established plants (Newroth, 1970), could contribute to locally-depressed biomass.

The observed differences in Chondrus crispus biomass over the sampling year were examined via a two-way analysis of variance (ANOVA). The ANOVA table resulting from this analysis is presented in Table 9. Of the three sources of variation (site, time, and site x time interaction) only the effect of time was significant ($p = .008$). This indicates that Chondrus crispus biomass was significantly lower over all stations in April, 1983 than it was in September, 1982.

Phyllophora spp. biomass. Phyllophora spp. biomass is given in Table 7 and Table 8 for the September, 1982 and April, 1983 collecting periods.

The data show a decrease in Phyllophora biomass at both Manomet Point and Rocky Point stations between September and April, and an increase at the Effluent station. An examination of the replicate biomass values for these stations in April shows the range of individual biomass to be greatest at the Effluent station (251.01-429.75 g/m^2). Ranges were lower at Manomet Point and Rocky Point, 61.02-185.94 g/m^2 and 1.80-76.41 g/m^2), respectively. For the September collecting period, the range of

individual biomass was highest at the Manomet Point station (218.88-540.36 g/m^2), followed by 126.90-196.11 g/m^2 at Rocky Point and 123.66-374.22 g/m^2 at Effluent. At Manomet Point, Rocky Point, and Effluent, the mean Phyllophora biomass comprised 36%, 25% and 29% of the total algae present in September, 1982. In April, 1983 these values for the same stations were 31%, 11%, and 66%. The high percent of Phyllophora at the Effluent station is inversely related to that of its competitor, Chondrus crispus.

Table 7 indicates that during September, 1982 the Manomet Point station had the highest mean Phyllophora biomass (309.47 g/m^2) followed by Effluent (253.17 g/m^2). Rocky Point had the lowest value (165.69 g/m^2), 46% lower than at Manomet Point, and 35% lower than at the Effluent. During April, 1983 the Effluent station had the highest mean Phyllophora biomass (321.97 g/m^2), with Manomet Point and Rocky Point producing 137.18 g/m^2 and 35.57 g/m^2 respectively. Rocky Point mean biomass was 89% lower than the Effluent value, and 57% lower than the Manomet Point values.

A comparison of mean Phyllophora biomass between the fall and spring shows highest values occurring in September except at the Effluent where mean Phyllophora biomass increased in April. The decline in biomass from fall to spring was 55.7% at Manomet Point, and 79% at Rocky Point. At Effluent, there was a 27.2% increase from fall to spring collecting periods. Although Phyllophora biomass was highest at the Effluent station in April, 1983, it had the lowest mean value at this station in March, 1982. The absence of a uniform seasonal pattern for biomass among the three stations is not unusual. In previous years, Phyllophora biomass has tended to increase during the winter months. However, the pattern has only irregularly been recorded and has rarely been observed to occur simultaneously at all stations.

The observed difference in Phyllophora spp. biomass were examined via a two-way ANOVA (Table 9). The results of this analysis indicated that both main effects (site and time) and the site x time interaction were highly significant.

Biomass of Remaining Benthic Species

The algal biomass category designated as "remaining benthic species" (RBS) comprises all benthic algae excluding Chondrus, Phyllophora, Laminaria spp. and algal epiphytes. For all stations, the dominant algal species were Polyides rotundus, Ahnfeltia plicata, Corallina officinalis, Chaetomorpha linum, Chaetomorpha melagonium and Ulva lactuca.

TABLE 9. RESULTS OF TWO-WAY ANOVAS INDICATING SIGNIFICANT DIFFERENCES FOR ALGAL BIOMASS PARAMETERS.

Chondrus crispus:

Source of Variation	DF	SS	MS	p
Location	2	45696	22848	.596
Time	1	357217	357212	.008
Location x Time	2	97275	48637	.341
Error	24	1036147	43172	
Total	29	1536336	52977	

Phyllophora spp.

Source of Variation	DF	SS	MS	p
Location	2	180426	90212	<.001
Time	1	45483	45483	.013
Location x Time	2	82897	41447	.006
Error	24	153440	6393	
Total	29	462242	15939	

Chondrus crispus epiphytes

Source of Variation	DF	SS	MS	p
Location	2	35.8	17.9	<.001
Time	1	1933.5	1933.5	.730
Location x Time	2	26.0	13.0	.795
Error	24	1346.3	56.1	
Total	29	3341.6	115.2	

Phyllophora spp. epiphytes:

Source of Variance	DF	SS	MS	p
Location	2	798	399	.004
Time	1	4590	4590	.436
Location x Time	2	4105	2052	.023
Error	24	11147	464	
Total	29	20640	712	

Total Algal Biomass:

Source of Variation	DF	SS	MS	p
Location	2	18081736	9040868	.001
Time	1	50973888	50973888	.029
Location x Time	2	26821044	13410522	.007
Error	24	52415808	2183992	
Total	29	148292480	5113534	

Biomass data for the RBS for September, 1982 and April, 1983 are presented in Tables 7 and 8. In September, Rocky Point had the highest RBS mean biomass value (87.40 g/m^2) Manomet Point the lowest (11.68 g/m^2), and Effluent the intermediate level (66.40 g/m^2). The April mean biomass values show that Rocky Point continued to have the highest standing stock of RBS (36.11 g/m^2). Manomet Point and Effluent were similar with mean biomass values of 13.81 g/m^2 and 12.73 g/m^2 respectively. The pattern of highest RBS biomass values at Rocky Point appears to be consistent and was also observed in the August, 1981 and March, 1982 data.

For the April, 1983 collections, the mean RBS biomass values for Manomet Point was 62% lower and Effluent 65% lower than RBS biomass for Rocky Point. The range among individual replicates at Manomet Point, Rocky Point, and Effluent were 0.18-56.97 g/m^2, 4.77-100.62 g/m^2, and 0.00-25.02 g/m^2 respectively. Elevated Rocky Point biomass was primarily due to the higher abundance of Polyides rotundus and Ahnfeltia plicata, and a much lower mean biomass value of Phyllophora which would normally compete for available substratum. For the April, 1983 collections, the RBS comprised only 3% of the total algae present at both Manomet Point and Effluent stations, and 11% at Rocky Point. Seasonal comparisons between the September, 1982 and April, 1983 indicate that RBS biomass increased 18% at Manomet Point, and decreased of 59% and 81% at Rocky Point and Effluent stations. Absence of shared seasonal biomass patterns between the three stations is not unusual.

The observed variation in biomass of remaining benthic species was examined for differences between samplings and among stations via a two-way ANOVA. No significant differences were found.

Epiphytic Algal Biomass. Epiphytic algal biomass for September, 1982 and April, 1983 is included in Tables 7 and 8. Epiphytes were usually more abundant on Phyllophora than on Chondrus at all three stations, with the highest amounts of algal epiphytes occurring at Rocky Point in the fall, and at Effluent in the spring. The higher epiphyte biomass value at the Effluent station appears to be related to high biomass of the prime host taxon, Phyllophora spp. Table 10 shows a percent change of algal biomass for the current (September 1982 and April 1983) and previous year's (August 1981 and March 1982) collections. Percent change of epiphytic species and Phyllophora at Effluent, between the two collecting years show percent changes of + 82.0% and + 84.0% respectively.

Table 8 indicates that epiphytic biomass in April comprised 45.14%, and Phyllophora 66% of the total algae present at the Effluent station. Epiphytic species only made up 19.2% and 12% of the total algal biomass at Manomet Point and Rocky Point stations, respectively. The decline in epiphytic biomass from fall to spring was 77% at Manomet Point, 87.4% at Rocky Point, and 49.4% at Effluent. The lower biomass levels for April are primarily a reflection of the loss of numerous summer annual epiphytic species over the winter months, and lower biomass values of the host species Chondrus and Phyllophora.

Higher epiphyte biomass values in conjunction with elevated Phyllophora biomass values are believed to reflect, at least in part, the greater capability of Phyllophora to tolerate the increased stress associated with increased infestation. Morphologically, the wirey Phyllophora may be able to withstand levels of colonization which, for Chondrus, would be sufficient to dislodge the alga from the substratum. Results of the Chondrus/Phyllophora Condition Index study (Table 11), also showed that Phyllophora was more heavily colonized than Chondrus with both algal epiphytes and fauna.

The observed variation in biomass of Chondrus epiphytes was examined for differences between samplings and among stations via a two-way ANOVA (Table 9). The results of this analysis indicate that of the three potential sources of variation (sites, time, and site x time interaction) only the effects of time (sampling period) were significant. This indicates that Chondrus crispus epiphyte biomass was significantly lower over all stations in April than it was in September. Since this pattern was also found for the host species, it appears that availability of suitable substratum (i.e. Chondrus) is an important controlling factor for Chondrus epiphytes.

The observed variation in Phyllophora epiphyte biomass was examined for significant differences in space and time via a two-way ANOVA (Table 9). Both the main effect of time (sampling period) and the site x time interaction term were found to be significant at $p = .004$ and $p = .023$, respectively; the effect of station was not significant. Although this pattern is similar to that described for the host taxon (Phyllophora spp.), the relationship does not appear to be as consistent as that described previously for Chondrus.

TABLE 10. (MEAN) DRY WEIGHT BIOMASS VALUES (g/m^2) FOR PREVIOUS AND CURRENT YEARS AND PERCENT CHANGE BETWEEN YEARS FOR CHONDRUS CRISPUS, PHYLLOPHORA SPP, THE REMAINING BENTHIC SPECIES, EPIPHYTES OF CHONDRUS, EPIPHYTES OF PHYLLOPHORA, AND TOTAL ALGAL BIOMASS FOR THE CURRENT (SEPTEMBER, 1982 AND APRIL, 1983) AND PREVIOUS YEAR'S (AUGUST, 1981 AND MARCH, 1982) COLLECTIONS.

	Previous Year's Collections	Current Year's Collections	% Change
Chondrus crispus			
Manomet Point	409.0	367.6	- 10.1
Rocky Point	220.2	279.7	+ 27.0
Effluent	132.9	290.4	+119.0
Phyllophora spp.			
Manomet Point	156.8	223.3	+ 42.4
Rocky Point	105.7	101.0	- 4.5
Effluent	156.7	287.6	+ 84.0
Remaining Benthic Species			
Manomet Point	38.0	12.8	- 66.3
Rocky Point	98.8	61.8	- 37.5
Effluent	64.3	39.6	- 38.4
Epiphytic Species			
Manomet Point	69.0	50.8	- 26.4
Rocky Point	65.0	53.3	- 18.0
Effluent	37.0	67.2	+ 82.0
Total Algal Biomass			
Manomet Point	672.7	654.4	- 3.0
Rocky Point	489.6	495.3	+ 1.2
Effluent	390.8	685.0	+ 75.3

Total Algal Biomass

Total mean algal biomass values for September, 1982, and April, 1983 are given in Tables 7 and 8.

Biomass values were highest at the Effluent station for both September and April collections (882.99 g/m and 486.41 g/m), followed by Manomet Point (868.99 g/m^2 and 439.88 g/m^2). Rocky Point had the lowest total algal biomass for both September and April collecting periods with biomass values of 673.50 g/m^2 and 317.09 g/m^2 respectively. For September and April, the biomass values for Manomet Point was 2% and 10% lower, and Rocky Point 24% and 35% lower than the Effluent value. Individual replicate ranges for September, 1982 at Manomet Point, Rocky Point, and Effluent were 810.36-951.57 g/m^2, 582.03-852.75 g/m^2 and 544.86-1292.94 g/m^2 respectively. Individual replicate ranges for April, 1983 collections for the same three stations were 375.39-499.14 g/m, 223.29-405.63 g/m^2 and 422.82-536.40 g/m^2.

Higher algal biomass values at the Effluent station are in part due to the abundance of Phyllophora which represented over 50% of the total algae present during both collecting periods. The lower total algal biomass values in April at all three stations has been recorded in previous years, and reflects the seasonal elementation of numerous summer annual and pseudoperennial species over the winter months. More specifically, the reduced April biomass levels are a reflection of the seasonal reduction of Chondrus crispus, which is usually the dominant species and single most important contributor to total algal biomass at each station.

The observed variation in total algal biomass was examined for significant differences between samplings and among stations via a two-way ANOVA. Both main effects (stations and sampling periods) and the site x time interaction were significant. This type of variation is not unusual in the study area, which appears to be characterized by wide variation in both space and time.

Chondrus/Phyllophora Condition Index Study

Colonization values for Chondrus and Phyllophora for September, 1982, and April, 1983 are presented in Table 12. Condition Index values comparing the past four collecting periods are presented in Table 11. An inspection of the data indicates that Phyllophora was more heavily colonized with both epiphytes and encrusting fauna than

TABLE 11. CONDITION INDEX VALUES FOR CHONDRUS CRISPUS AND PHYLLOPHORA SPP. FOR THE MANOMET POINT, ROCKY POINT, AND EFFLUENT SUBTIDAL (10' MLW) STATIONS FOR AUG 1981, MAR AND SEP 1982, AND APR 1983.

	Collecting Period			
Station	Aug. 1981	Mar. 1982	Sep. 1982	Apr. 1983
Chrondrus crispus Condition Index				
Manomet Point	22	14	23	11
Rocky Point	19	12	17	11
Effluent	21	10	14	14
Phyllophora spp. Condition Index				
Manomet Point	30	24	33	22
Rocky Point	23	15	26	12
Effluent	29	11	26	30

TABLE 12. COLONIZATION VALUES FOR CHONDRUS CRISPUS AND PHYLLOPHORA SPP. FOR THE MANOMET POINT, EFFLUENT, AND ROCKY POINT SUBTIDAL (10' MLW) STATIONS FOR SEPTEMBER,1982 AND APRIL, 1983.

A) CHONDRUS CRISPUS

	Algal Colonization						Faunal Colonization					
	Manomet Pt.		Rocky Pt.		Effluent		Manomet Pt.		Rocky Pt.		Effluent	
Replicate	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.
1	3	1	2	1	1	1	3	1	2	1	1	1
2	2	1	3	1	1	2	3	2	3	1	1	2
3	2	1	1	1	2	2	2	1	1	1	1	2
4	1	1	2	1	1	1	2	1	1	1	1	1
5	2	1	1	2	2	1	3	1	1	1	3	1
Total	**10**	**5**	**9**	**6**	**7**	**7**	**13**	**6**	**8**	**5**	**7**	**7**

B) PHYLLOPHORA spp.

	Algal Colonization						Faunal Colonization					
	Manomet Pt.		Rocky Pt.		Effluent		Manomet Pt.		Rocky Pt.		Effluent	
Replicate	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.	Sep.	Apr.
1	3	1	3	1	1	3	4	2	4	2	4	3
2	3	2	2	1	2	3	4	3	3	1	3	3
3	2	1	2	1	3	3	3	2	3	1	2	3
4	3	2	2	1	3	3	4	3	2	1	3	3
5	3	3	2	1	2	3	4	3	3	2	3	3
Total	**14**	**9**	**11**	**5**	**11**	**15**	**19**	**13**	**15**	**7**	**15**	**15**

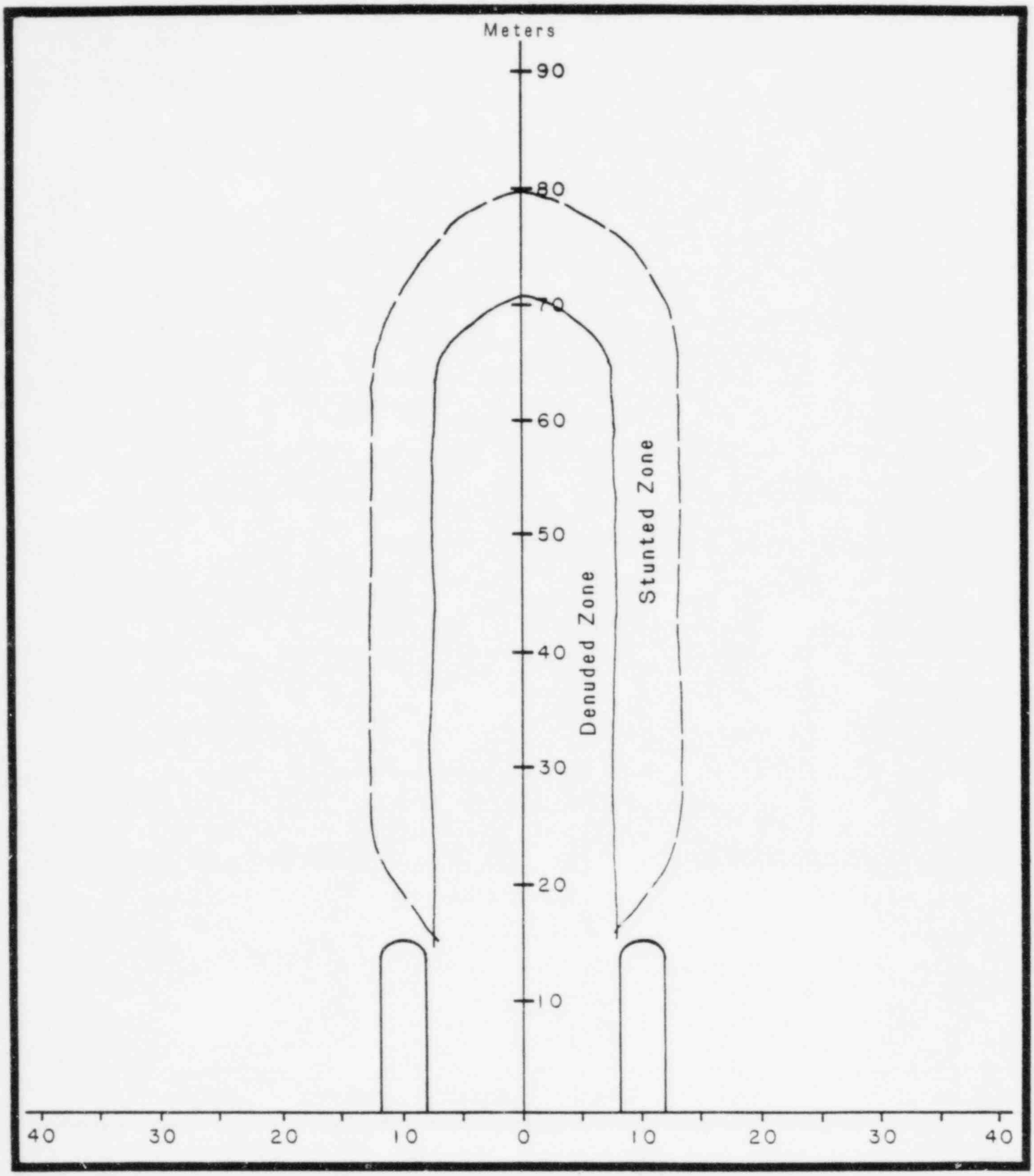


FIGURE 15. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, JUNE, 1975 (AFTER RYTHER, 1975).

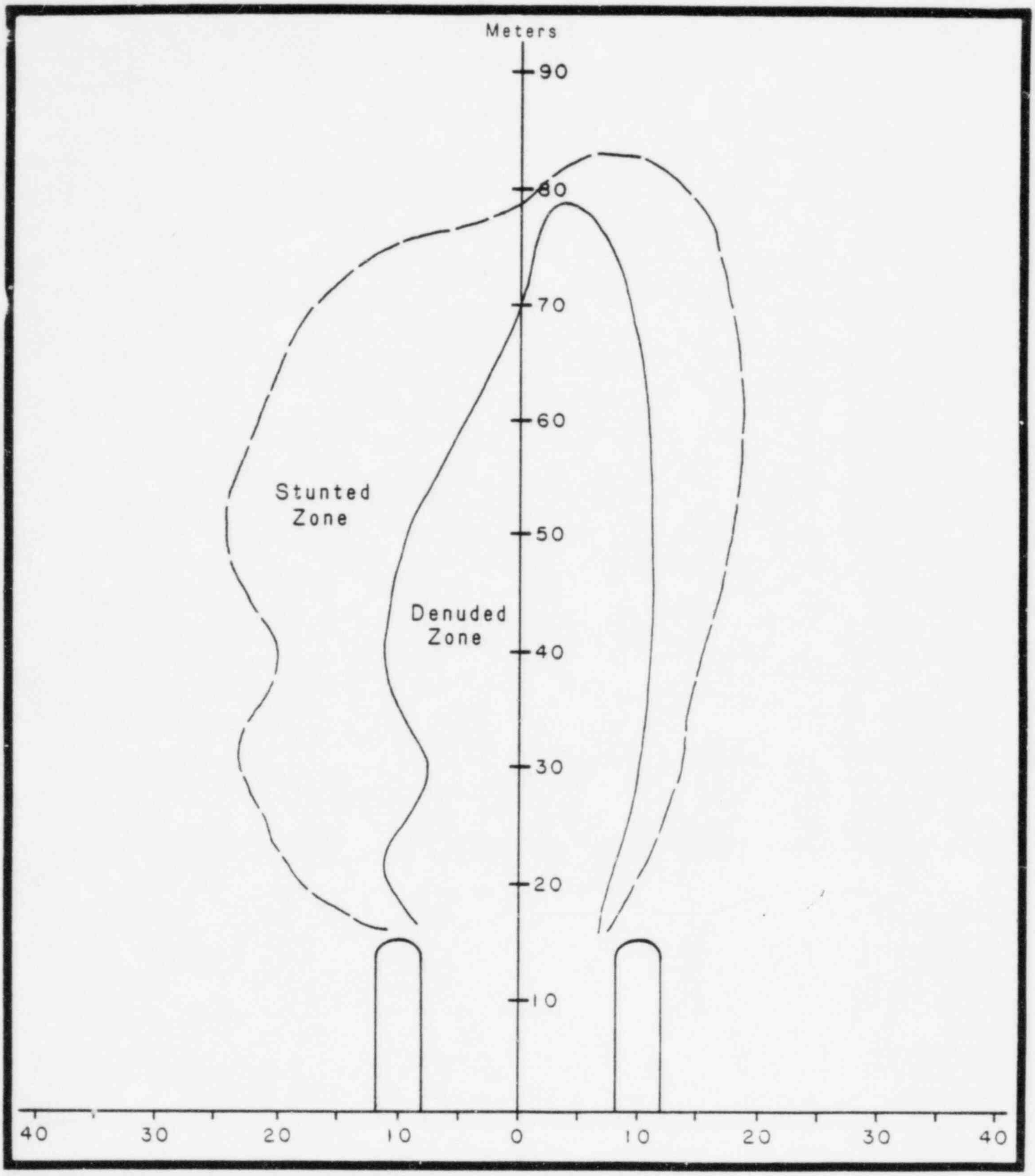


FIGURE 16. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, JANUARY, 1980.

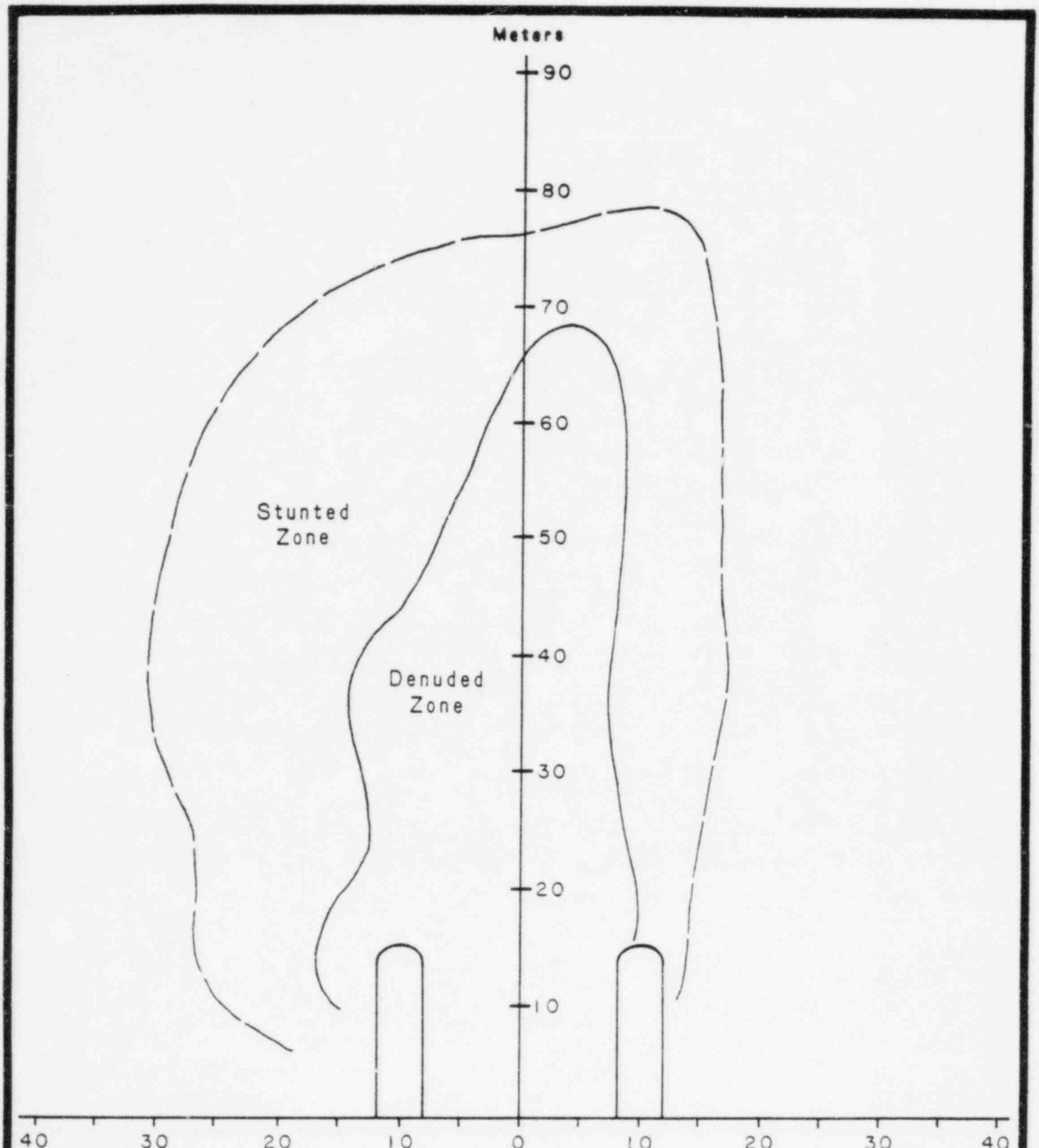


FIGURE 17. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, AUGUST, 1980.

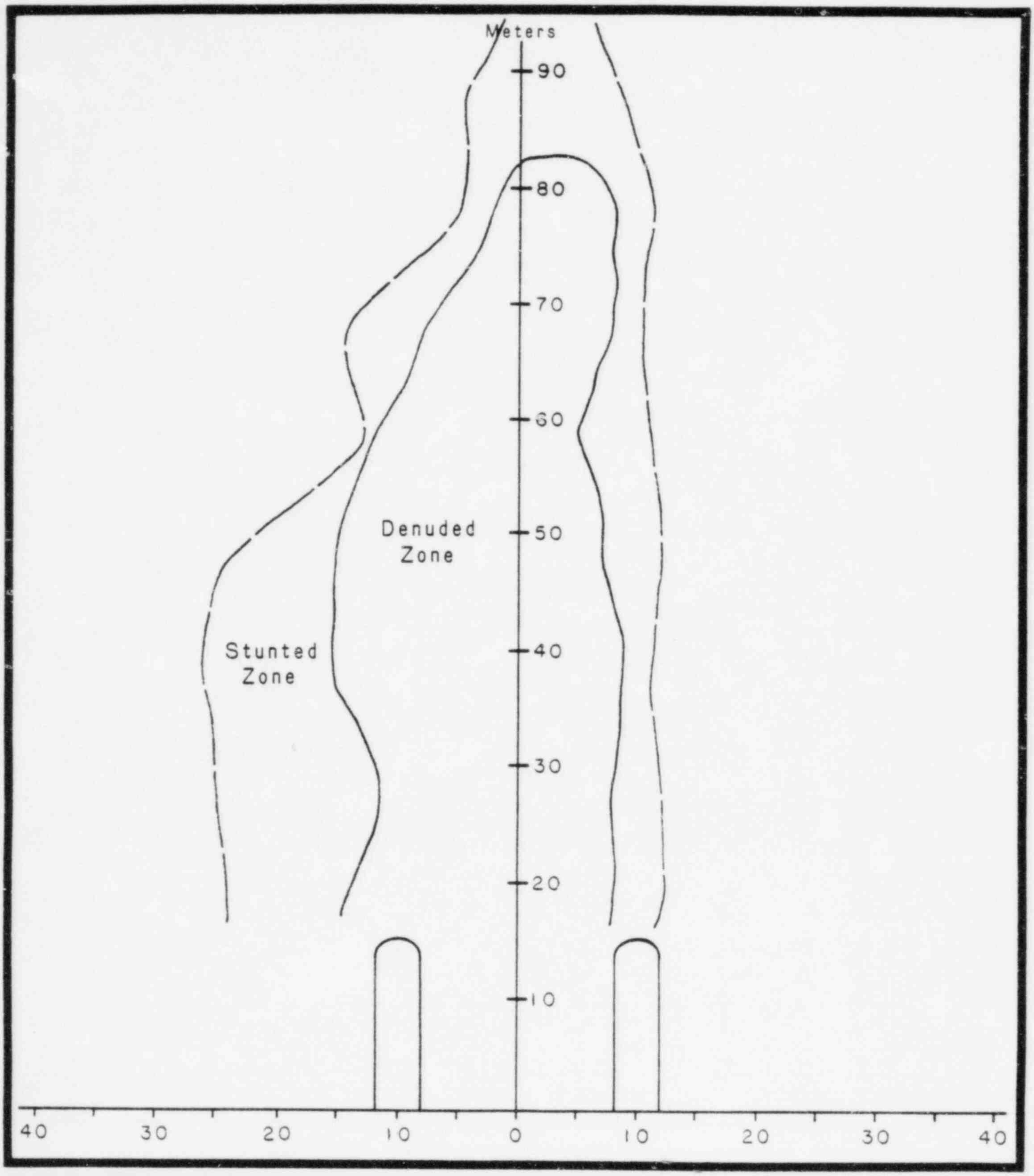


FIGURE 18. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, AUGUST, 1981.

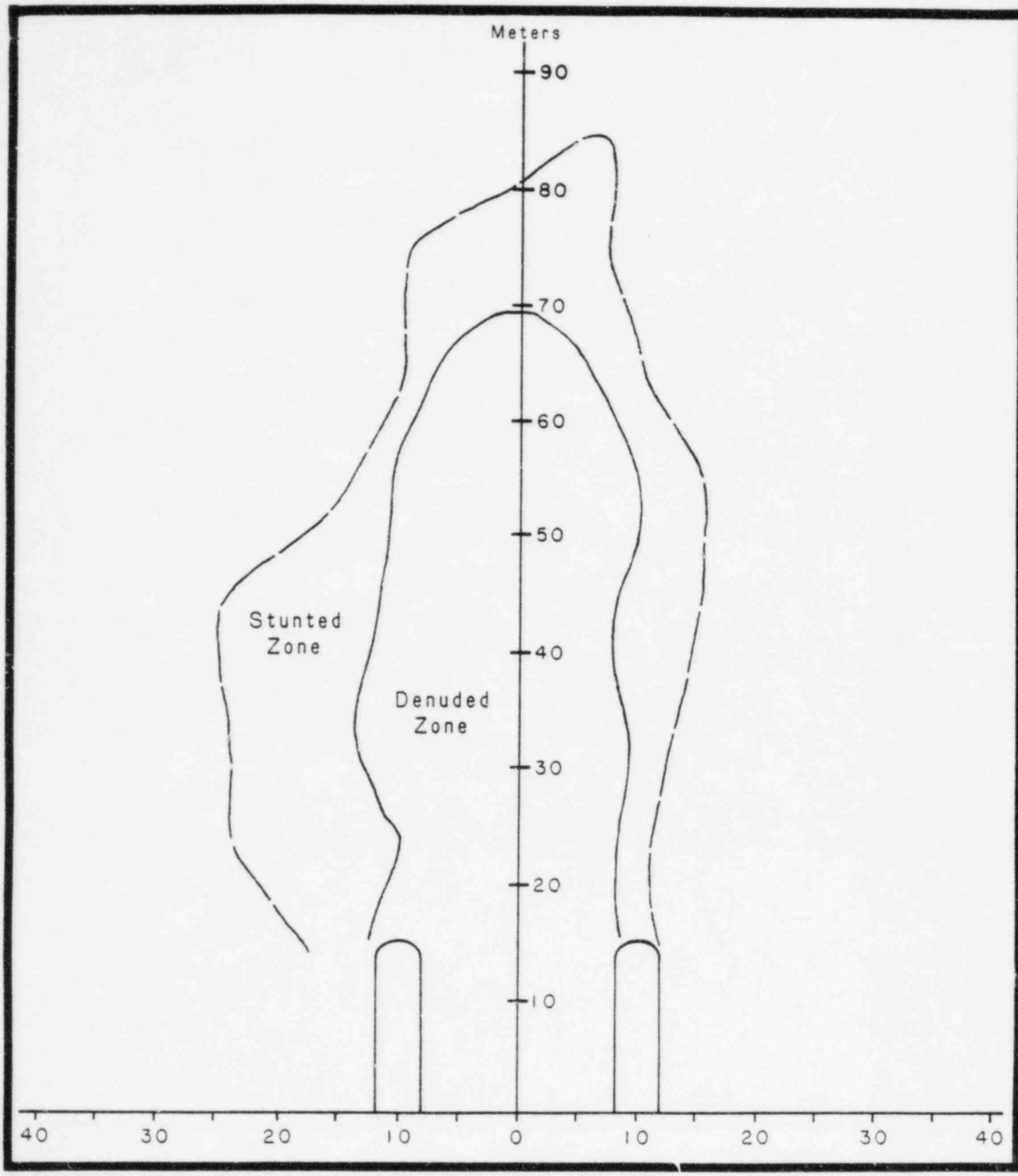


FIGURE 19. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, MARCH, 1982.

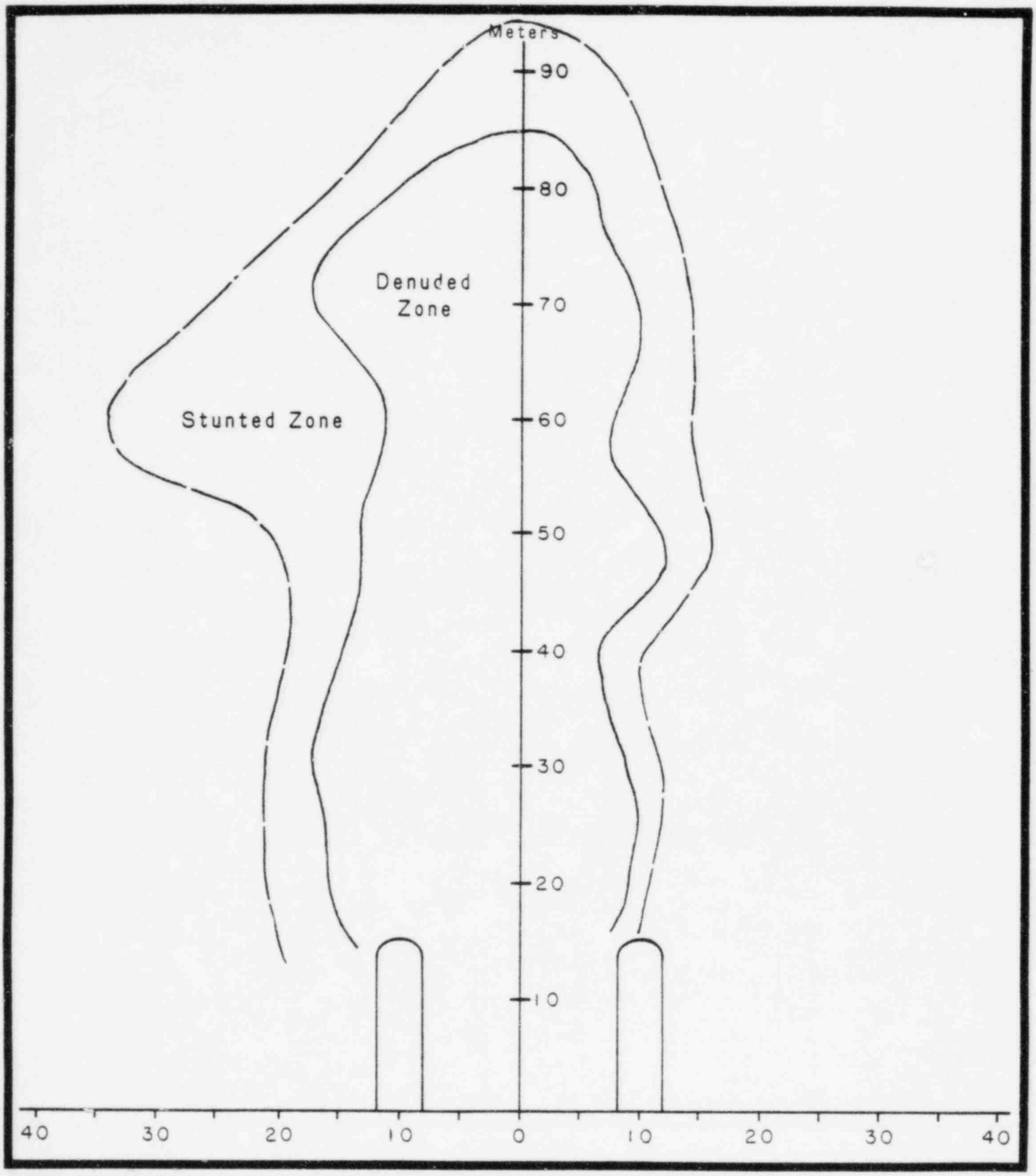


FIGURE 20. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, MAY, 1982.

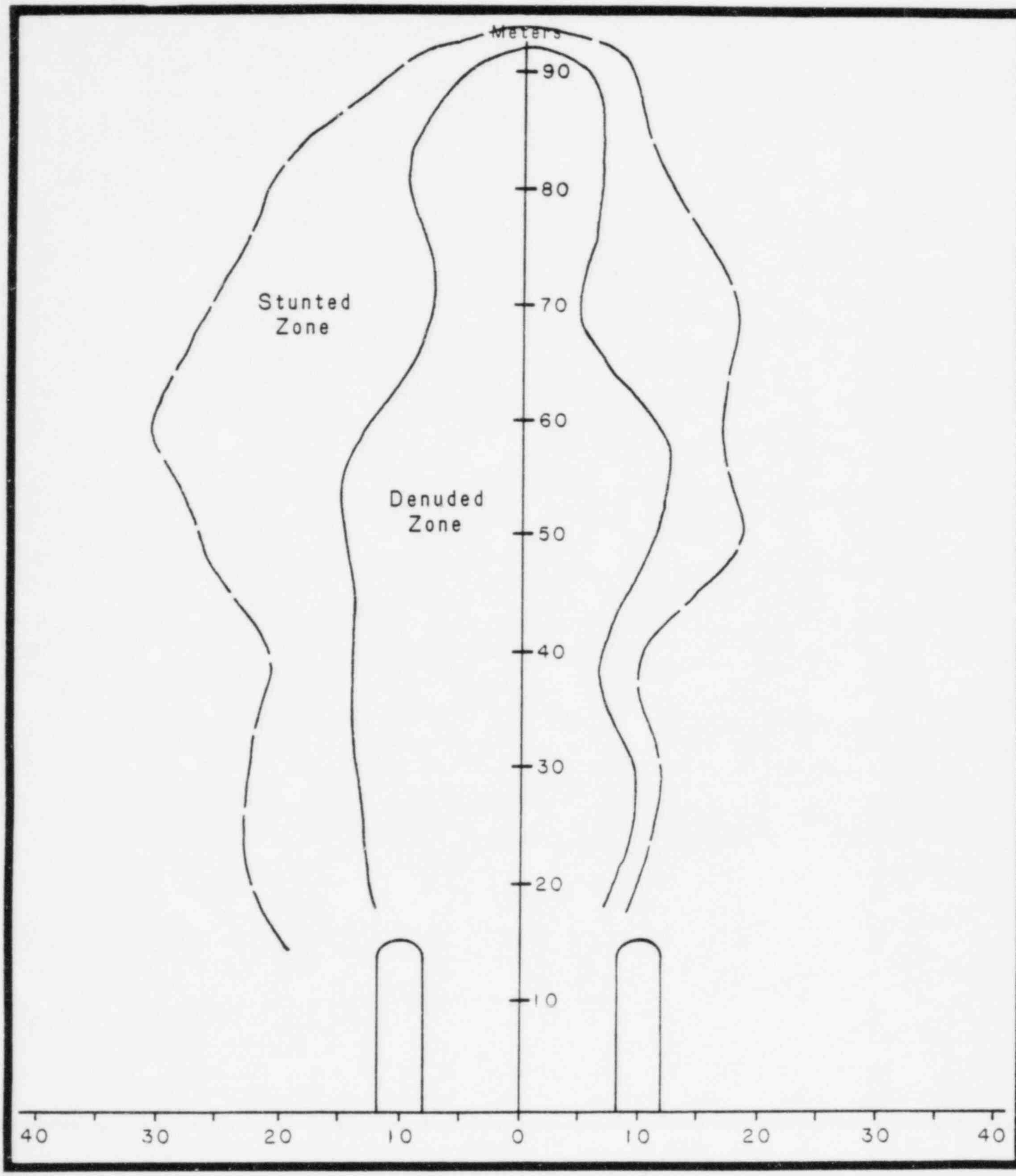


FIGURE 21. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, JUNE, 1982.

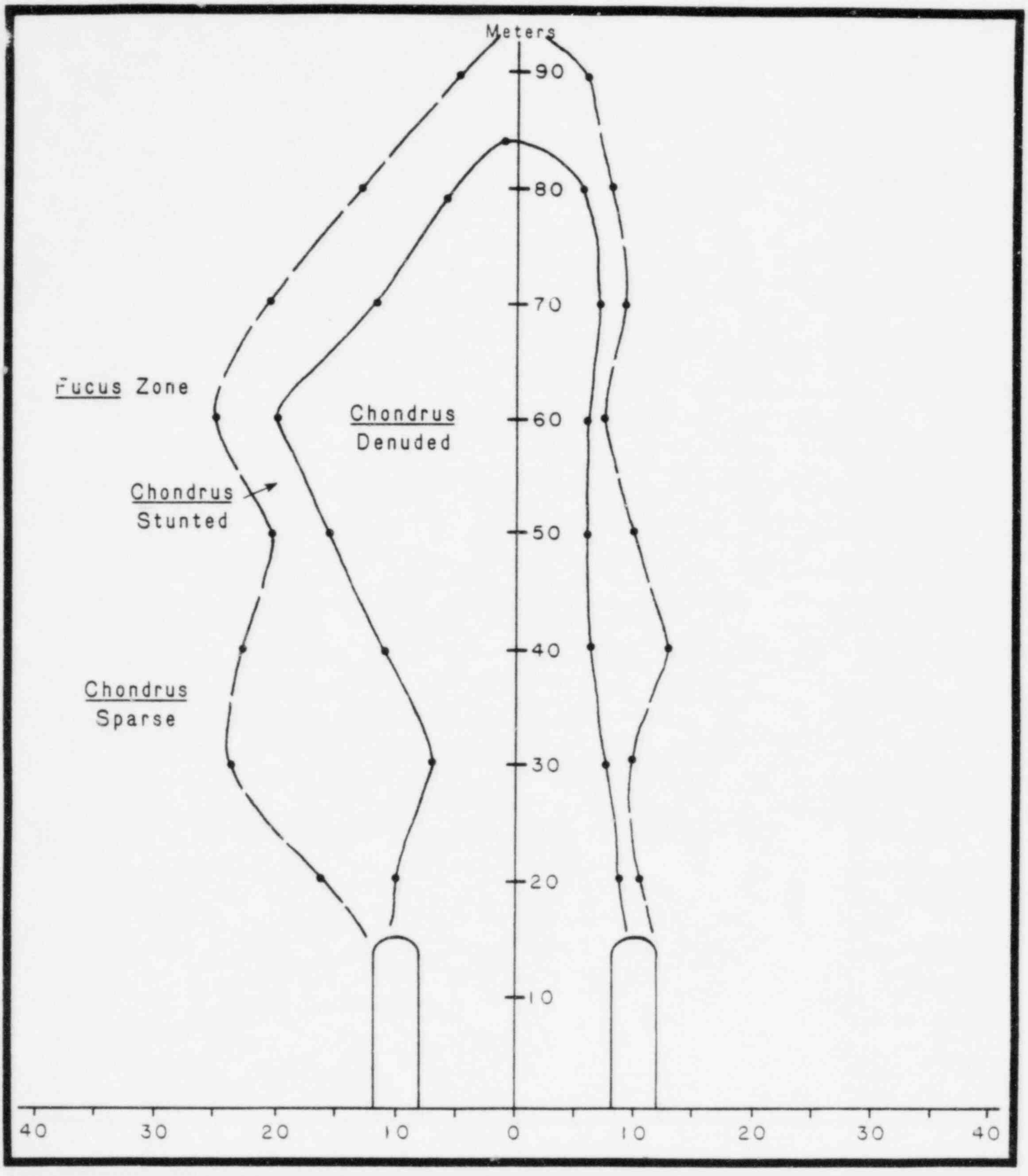


FIGURE 22. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, SEPTEMBER 24, 1982.

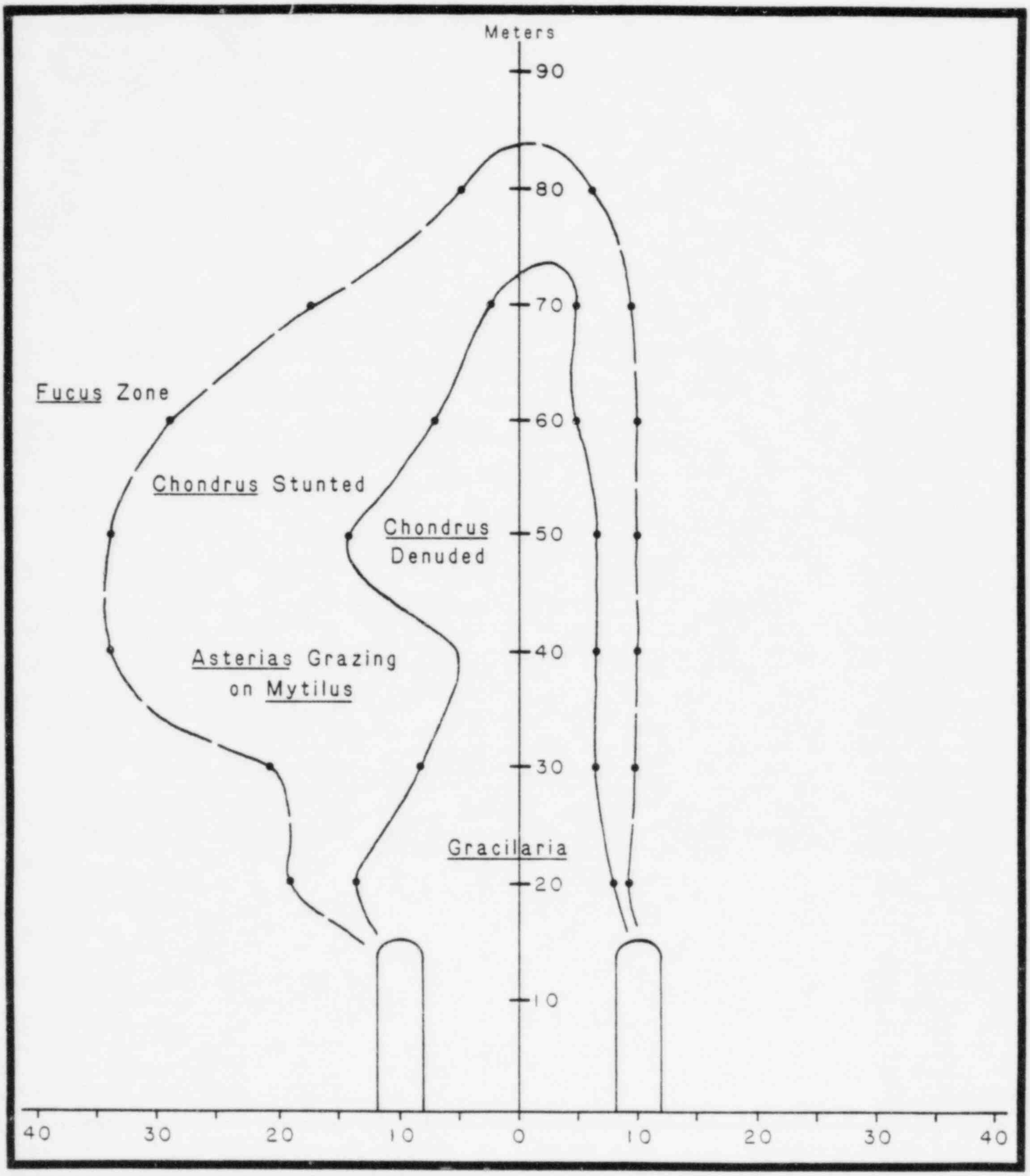


FIGURE 23. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, DECEMBER 1, 1982.

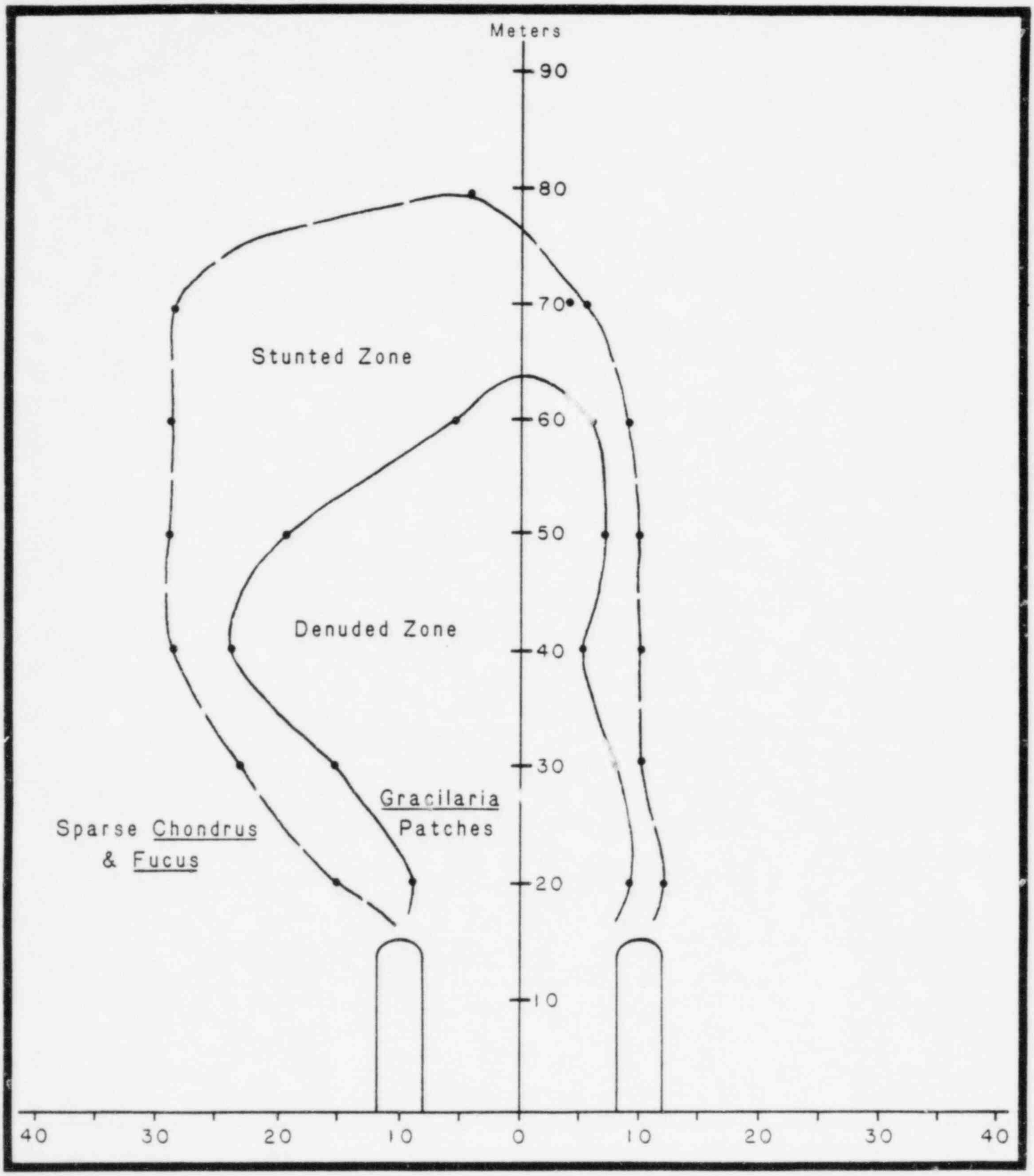


FIGURE 24. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, APRIL 13, 1983.

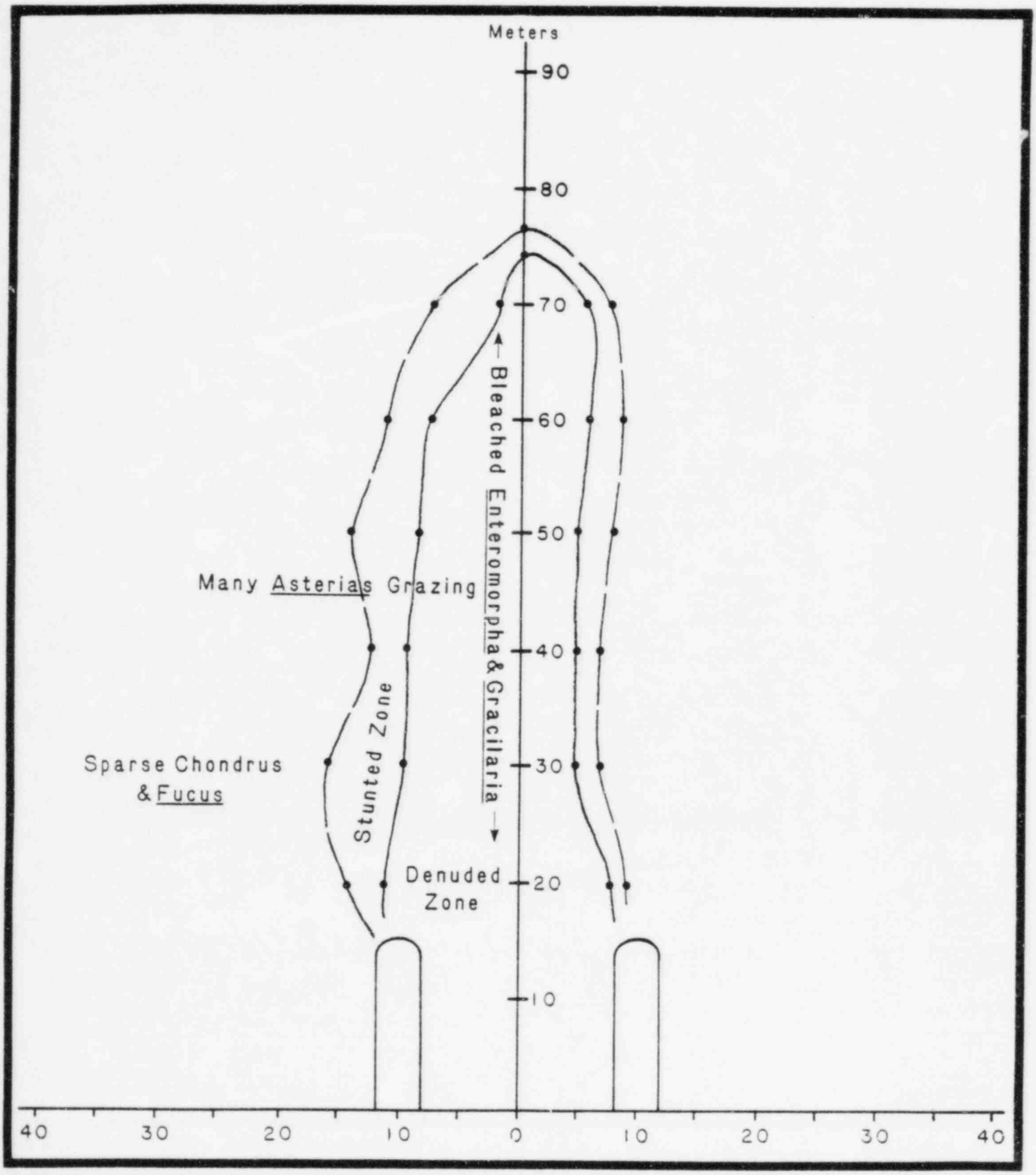


FIGURE 25. CONFIGURATION OF DENUDED AND STUNTED ALGAL ZONES IN THE VICINITY OF THE PILGRIM NUCLEAR POWER STATION DISCHARGE, JUNE 23, 1983.

was Chondrus. Higher infestation values for Phyllophora reflect a greater capability for tolerate increased stresses assocaited with heavy algal and animal colonization.

The tables also show that for all stations, there is usually a decline in algal and faunal colonization in both Chondrus and Phyllophora from fall to spring. This decline reflects the normal seasonal loss of numerous summer annual species over the winter months.

Epiphytic and epifaunal colonization values were usually highest at the Manomet Point station. An exception existed at the Effluent station where in April 1983, Condition Index values were highest. This is in part directly related to the higher biomass values for Phyllophora a prime host species. Colonization and Condition Index values in general showed similar seasonal fluctuations for all stations for all years. There does not seem to be any direct correlation between epiphytic and epifaunal colonization and the PNPS discharge.

QUALITATIVE TRANSECT SURVEY

The quarterly transect surveys of acute nearfield impact zones were initiated in January, 1980 and have now been conducted ten times. During the most recent contract year, mappings of this area were conducted in September and December, 1982 and in April and June, 1983. Each of these four surveys will be discussed in detail below. In addition, to facilitate comparisons among the various surveys, we have redrawn all mappings of this area, including the preliminary Chondrus survey conducted by Ryther et al. in 1975, to the same scale. These maps are presented as Figures 15 through 25.

Beginning with the September, 1982 survey we will include additional notes on the figures describing any observations of interest. These will allow readers to develop a better understanding of the spatial relationships among the various characteristic components of the impacted and normal communities traversed during the mapping.

In addition to the descriptive analyses of this phase of the study, we have initiated an examination of the influence of environmental variables on the size and configuration of the denuded and stunted areas. We have begun this effort by examining the interrelationships between certain key descriptive parameters (e.g. total area, extent offshore, width) of the impact area and two important classes of environmental data, ambient water temperature and meteorological conditions. The procedures and results of this analysis will be presented and discussed following presentation of the results of the four mappings conducted during the present contract year.

September, 1982 Transect Survey

The extent of the denuded and stunted areas immediately offshore from the PNPS discharge is shown in Figure 22. The denuded area is defined as being essentially devoid of Chondrus crispus, while the stunted area is identified as having Chondrus, but of a low height. As noted on Figure 22, the unimpacted area to the left of the impact area does not develop dense Chondrus populations. This is normal and is caused by naturally shallower water depths in this area, as evidenced by the presence of Fucus spp. well offshore.

In September, the denuded zone extended to about 84 m offshore as measured from the mean high water mark on the discharge canal jetties. The denuded area extended further westward (left) of the center line of the transect reaching a maximum extent of 15 m in that direction. To the right, the denuded zone was more or less continuous out to the 80 m mark, extending no more than 6-9 m from the center line. The total denuded area was estimated at 1193 m^2.

Beyond the denuded zone, the stunted Chondrus generally followed the contour of the denuded zone, but bulged westward 25 m at the 30 and 60 m marks. The total area encompassed by the denuded and stunted zones covered approximately 2328 m^2.

December, 1982 Transect Survey

For December, the overall configuration of the denuded zone was similar to that seen in September, except for 15 m bulges on the westerly side at the 20 and 50 m marks (Fig. 23). The easterly side was again relatively constant, only extending 5-6 meters from the center line. The denuded zone extended out about 73 m along the center line, and encompassed a total area of about 856 m^2.

The stunted zone was characterized by a large westerly bulge located between the 30 and 60 m marks and extending outward for 35 m. The area occupied by this bulge was shallow and the rocks were covered with juvenile Mytilus edulis which were being preyed upon by starfish (Asterias spp.). The stunted zone was uniform on the easterly side, extending no more than 10 m from the center line. The stunted zone was identified outward to 85 m along the transect and encompassed a total area with the denuded zone of 2082 m^2.

April, 1983 Transect Survey

The results of the April, 1983 survey are shown in Figure 24. The denuded zone extended approximately 64 m offshore, as measured from the MHW mark on the discharge jetties. This was the minimum distance offshore that this area had extended since the initiation of the study, and represented a decrease of approximately 20 m since September, 1982 and 10 m since December. The lateral extent of the denuded zone during this survey was not similarly reduced, however, and was particularly expanded to the left of the discharge, where shallow water allows greater plume contact with the bottom. The maximum lateral extent of the denuded zone was approximately 25 m at the 40 m offshore mark. As is typically the case, the denuded zone was less extensive to the right of the discharge, extending about as far as the midline of the right discharge jetty. the total area contained within the denuded zone in April was 1128 m^2.

Divers noted the presence of bleached Enteromorpha spp. and Gracilaria tikvahiae in the "denuded" area as well as large numbers of grazing Asterias spp. throughout the near-field area. Both these observations are not unusual for this area in the summer, as increased light incidence tends to bleach many species of algae and Asterias move in to feed on the rapidly-developing mussel populations from the spring settlement.

The stunted zone was also less extensive offshore in April, reaching only 80 m from the MHW mark. As was the case for the denuded zone, this was the minimum recorded distance since the study was initiated. The overall shape of the stunted zone was generally similar to that seen previously, in that it extended laterally for 30 m from the plume centerline to the left of the discharge and for approximately 13 m to the right, where rapidly increasing water depths promote rapid plume detachment from the bottom. It was somewhat unusual, however, for the stunted zone to reach its greatest lateral extent so far offshore, at approximately 70 m. Because of the June observations described below, this configuration was not judged to be of particular significance. The total extent of the combined impact zones was 2029 m^2 in April.

June, 1983 Transect Survey

Results of the most recent survey, conducted in June of 1983, are presented in Figure 25. It is immediately apparent that both impact zones in June were much reduced

in size in comparison with previous surveys. Although the stunted zone extended further offshore than in April (75 m) it was strikingly narrow and at no point did it extend beyond the outer edges of the discharge jetties. Primarily because of this, the area encompassed within the denuded zone was 829 m^2, the least recorded since the study was initiated in January of 1980.

The stunted zone in June was even more reduced and reached a minimum both for distance offshore (78 m) and for total impacted area (1332 m^2). This was the first time since the semi-diagrammatic mapping by Ryther et al. (1975), which is not truly comparable to our present mappings, that both the stunted and denuded zones were symmetrical about the discharge centerline rather than being more extensive in the shallower water to the left of the plume.

Summary and Discussion

Data are now available from 10 near-field mappings of the discharge area (Figure 26) spanning 3 1/2 years. Except for the August, 1980 survey, the extent of the stunted and denuded areas have tended to increase or decrease roughly parallel with each other.

As noted in the previous report, through 1982 there was a tendency for the extent of the impacted area to increase during the warmer period of the year and decrease during the winter. This has been most apparent when the total impacted zone is considered, rather than just the denuded zone. Consistent with this hypothesis were recorded maxima in August of 1980 and June of 1982 and it is at least possible that, if data were available, the single measurement in 1981 (August) would fit this general pattern.

Seasonal changes in the denuded zone are considerably less apparent over this same period and, in spite of the observation noted previously that the zones tend to co-vary, maximum extent of the denuded zone is not usually coincident with that of the total impacted area.

These observations are generally consistent with the hypothesis advanced in previous reports that the denuded zone is controlled primarily by the effects of scouring by the discharge plume while the stunted area is primarily determined by contact of the heated effluent with the bottom. Since the scouring effect is not seasonal, the denuded zone is relatively constant through time. The stunted zone, however, varies seasonally,

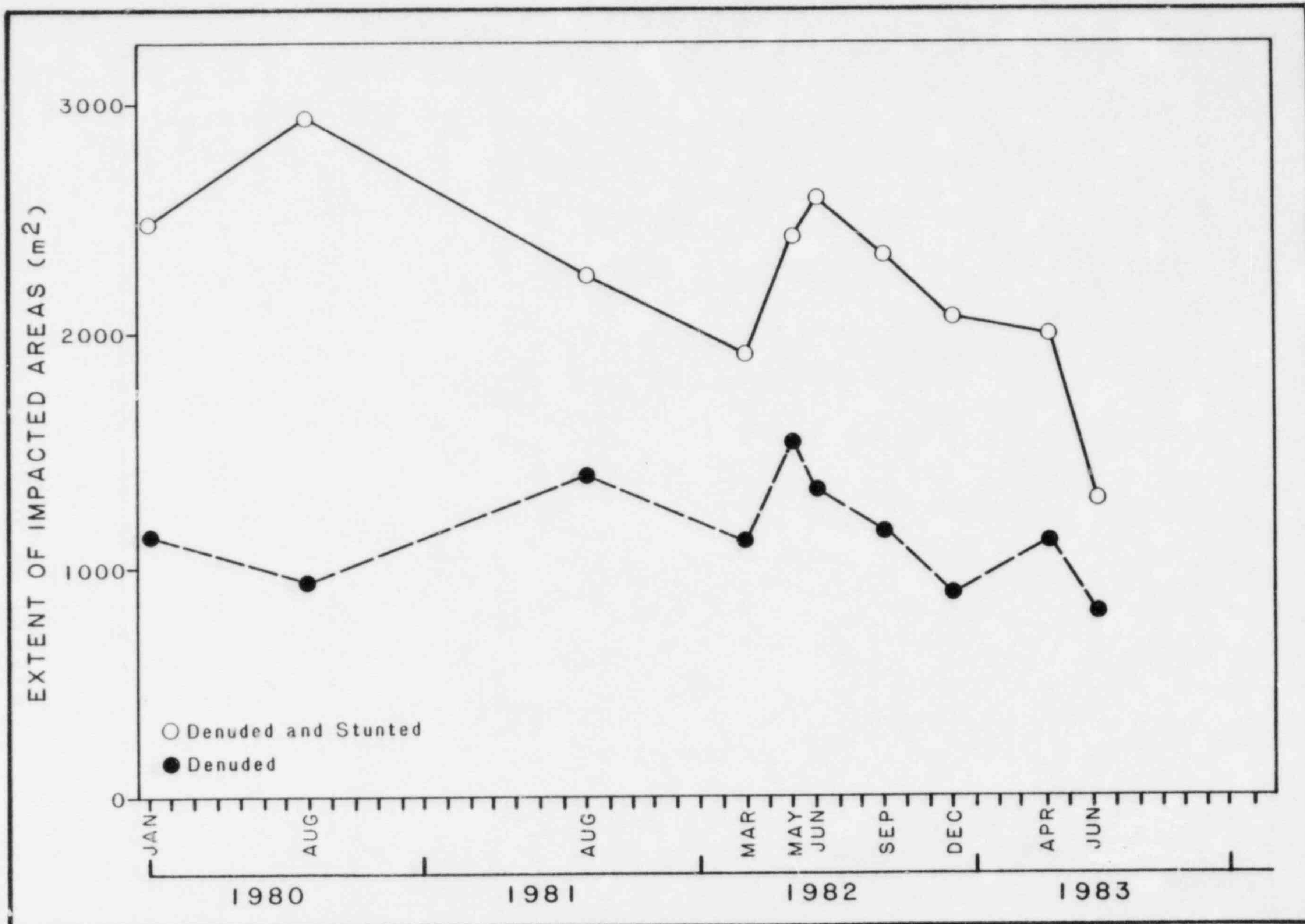


Figure 26. Measurements of denuded and stunted areas in the vicinity of the effluent discharge.

enlarging during the warmer months when the discharge temperatures are reaching their annual peak, and decreasing during the winter when the effects of the heated discharge may well promote enhanced growth.

The most recent mapping, in June of 1983, appears to contradict our working hypothesis. Both the denuded and stunted areas decreased substantially, reaching their smallest recorded extents in spite of the patterns of increase during this period in previous years. Since annual maxima appear to occur more commonly in August, this apparently anomalous observation may not be as inconsistent as it may appear, particularly in view of the abnormally low air temperatures experienced in New England in the spring of 1983.

Relation to Environmental Variables

METHODS

The basic procedure used to evaluate the possibility of functional relationships between impact area configuration and environmental variables was that of correlation analysis. The analysis was conducted using subprogram PEARSON CORR of the SPSS statistical package (Nie, et al.; 1975) on the Woods Hole Oceanographic Institution's VAX-11/780 computer.

For each of the 10 mappings of the denuded and stunted areas conducted to date (January, 1980 to June, 1983) a suite of variables was generated to summarize both the size and shape of the impacted areas. These seven parameters included:

- total area denuded
- total area stunted
- total combined impact area
- offshore extent of denuded area
- offshore extent of stunted area
- maximum lateral extent of impacted area to left and right of plume centerline, respectively

Environmental variables used in the analysis were of four types: (1) wind direction and velocity; (2) ambient and discharge water temperature; (3) reactor power level; and (4) presence or absence of elevated turbidity due to dredging.

Quarterly summaries of wind data from the 160' and 220' levels of the PNPS 220' meterological tower were supplied by Boston Edison Co. for the four most recent samplings (September, 1982 to June, 1983). For each summary, data were grouped into quadrants representing the northeast (directly onshore), southeast (laterally across the discharge toward Rocky Point), southwest (directly offshore) and northwest (laterally across the discharge toward Manomet Point). For each of these four directions a percent occurrence was calculated for total wind (all speeds), winds greater than 7.6 mph only, and winds greater than 18.6 mph only. Each of the four transects was thus associated with 12 (4 directions x 3 velocities) data points summarizing wind patterns for the three month period approximately preceding the mapping.

Temperature data were obtained from the Balance-of-Plant (BOP) logs supplied by Boston Edison Co. Data from the month preceding the month of observation were believed to be the most important for determining impact area configuration. For each of the seven most recent mappings (March, 1982 to June, 1983) intake and discharge water temperatures were read from the BOP logs at weekly intervals for the month preceding the mapping. These were summarized to provide the following four water temperature parameters:

- mean discharge temperature
- maximum discharge temperature
- mean ambient (intake) temperature
- maximum ambient (intake) temperature

Reactor power level was determined based on visual examination of plots of daily average reactor thermal power level as included in the Boston Edison Company Semi-Annual Reports. For this preliminary analysis, the plot for the month preceding the mapping was assigned a value ranging from 0 (shut-down) to 4 (at or near full power for the month).

Finally, an attempt was made to include a variable in the analysis to account for the effect of turbidity caused by maintenance dredging of the PNPS intake channel

during the last quarter of 1982. Although Boston Edison Company provided extensive data on turbidity and suspended solids during the dredging it was difficult to incorporate these data into the analysis effectively because only a single data point (the December, 1982 mapping) was available for the "dependent" variable. A dummy independent variable was introduced into the analysis; this was scored as 1 for the December, 1982 mapping and 0 for all other mappings.

RESULTS

Significant correlations between the impact area parameters and environmental variables are summarized in Table 14. For the purpose of this discussion we will consider a $p<.10$ to be sufficiently significant to merit further consideration. Significant correlations among the suite of impact area parameters or within the suite of environmental variables will not be discussed.

A number of generalizations are immediately apparent from an examination of these results. Fist, the number of significant correlations is high, particularly considering the small sample size (i.e. n=4 for wind data, n=7 for temperature data). In addition, of the large suite of environmental variables examined, relatively few (mean discharge temperature and southeast wind) appear to be related to the nearfield impact area size and extent. Lastly, while one may have had no a priori reason to suspect a positive correlation between a particular wind direction or velocity and impacts, it was reasonable to expect such a relationship between discharge temperature and impact; yet, all significant correlations were negative.

The observed relationship between mean discharge temperature and four of the impact area parameters (see Table 14) is probably the most expected result of the analysis. Discharge temperature and turbulence have been hypothesized previously (BECO Semi-Annual Report No. 16) as the two factors primarily responsible for determining the extent of the near-field acute impact zone. The negative correlation, indicating that higher temperatures result in a decrease in impact area size, is likely an artifact of the one month lag used for this preliminary analysis. This may indicate that the measured size of the impact area is determined by conditions well in advance of the date of the mapping. Additional analyses planned for the next reporting period will serve to clarify this point.

The relationship between southeast wind and impact area size is also interesting, though more difficult to interpret. The correlations are again all negative,

TABLE 14. SIGNIFICANT CORRELATIONS BETWEEN IMPACT AREA PARAMETERS AND ENVIRONMENTAL VARIABLES.

Parameter		Variable	n	r	p
denuded area	vs.	mean discharge T	7	-.8574	.014
stunted area	vs.	total SE wind	4	-.9090	.091
stunted area	vs.	SE wind >18.6mph	4	-.9895	.010
stunted area	vs.	SE wind >7.6mph	4	-.9581	.042
total impact area	vs.	SE wind >18.6mph	4	-.9160	.084
offshore denuded extent	vs.	NW wind >18.6mph	4	-.9854	.015
offshore denuded extent	vs.	mean discharge T	7	-.7156	.071
offshore stunted extent	vs.	mean discharge T	7	-.7882	.035
lateral extent left	vs.	total SE wind	4	-.9942	.006
lateral extent left	vs.	SE wind >7.6mph	4	-.9457	.054
lateral extent right	vs.	mean discharge T	7	-.6907	.086

indicating that persistent southeast winds during the quarter preceding a mapping are associated with a decreased impacted area. This is somewhat anomalous, since one might expect that a wind from right to left across the discharge might produce an extended impact area to the left of the plume.

As was the case for mean discharge temperature, it is possible that winds in the quarter immediately preceding mapping are not the ones of prime importance for determining impact area and we should be examining winds in other time periods. Also, correlation per se does not necessarily indicate causality, and it is quite possible that the presence of southeast winds (or high discharge temperatures) is associated with some other environmental variable which does result in decreased impacts.

In summary, it is clear that this preliminary analysis has provided evidence that variations in near-field impact areas are related to changes in certain environmental variables although the actual nature of these relationships and potential casual mechanisms are not identifiable at this time. No evidence was found that turbidity in the area during the last quarter of 1982 had any measurable effects on the impact areas, although it was difficult to incorporate the turbidity data into the analysis in a meaningful way.

We intend to continue the examination of the impact area in relation to environmental variables by (1) incorporating wind data from more years, if available (2) examining various time lags between environmental data and observed impacts and (3) including additional environmental variables in the analysis. Potential additional variables of interest include tide and current data, PNPS chlorination data, and the addition of a discrete variable for time of year.

The initial approach used will continue to be that of correlation analysis, but as we begin to more clearly define these relationships, we will shift to the more powerful techniques of regression and time-series analysis. Such techniques will ultimately allow the possibility of developing a mathematical model for changes in impact area configuration, though the extent to which we are able to achieve that result will depend largely on results obtained in the intermediate analyses.

SEDIMENT GRAIN SIZE ANALYSIS

During the September, 1982 sampling period, four of five replicates at the Effluent Station contained large amounts of sand. Analysis of the particle size

distribution is presented in Table 13). All of the large particles (>.500 mm) are Mytilus edulis shell fragments. The 0.250 mm fraction is a mixture of shell fragments and quartz sand grains. The 0.125 mm fraction is mostly sand grains with a few shell splinters. The 0.63 mm fraction is mostly minute sand grains, shell splinters and miscellaneous organic debris.

The source of this sediment is undoubtedly a combination of destruction of Mytilus edulis shells in the area and transport and entrapment of sand particles. Sediment concentrations of this sort are not present at the Rocky Point and Manomet Point Stations. It is not known at this time if the occurrence at the Effluent Station is related to the warm water discharge, but must in some manner, be related to the destruction of mussel shells.

TABLE 13. PARTICLE SIZE DISTRIBUTION FOR SEDIMENT SAMPLES COLLECTED AT EFFLUENT STATION SEPTEMBER, 1982.

Replicate	ØSize	Diameter (mm)	Corrected Weight (g)	Cumulative Weight (g)	Cumulative Percent	Individual Percent
1	-	2	14.5393	14.5393	40.37	40.37
	0	1-2	7.4900	22.0293	61.17	20.80
	1	0.5-1	7.5421	29.5714	82.11	20.94
	2	0.25-0.5	5.5120	35.0834	97.42	15.31
	3	0.125-0.25	0.8441	35.9275	99.76	2.34
	4	0.063-0.125	0.0856	36.0131	100.00	0.24
3*	-	2	12.5465	12.5465	24.72	24.72
	0	1-2	6.5130	19.0595	37.56	12.83
	1	0.5-1	10.6165	29.6760	58.48	20.92
	2	0.25-0.5	18.2945	47.9705	94.53	36.05
	3	0.125-0.25	2.5345	50.5050	99.53	4.99
	4	0.063-0.125	0.2405	50.7455	100.00	0.47
4	-	2	17.8939	17.8939	41.20	41.20
	0	1-2	9.3356	27.6295	63.61	22.41
	1	0.5-1	12.2471	39.8766	91.81	28.20
	2	0.25-0.5	2.5250	42.4016	97.62	5.81
	3	0.125-0.25	0.9241	43.3257	99.75	2.13
	4	0.063-0.125	0.1089	43.4346	100.00	0.25
5	-	2	11.1560	11.1560	30.62	30.62
	0	1-2	8.5159	19.6719	53.99	23.37
	1	0.5-1	7.8008	27.4727	75.39	21.41
	2	0.25-0.5	8.1207	35.5934	97.68	22.29
	3	0.125-0.25	0.7403	36.3337	99.71	2.03
	4	0.063-0.125	0.1056	36.4393	100.00	0.29

* Replicate No. 2 was free of sediment.

LITERATURE CITED

Blake, J.A. 1971. Revision of the genus Polydora from the east coast of North America (Polychaeta: Spionidae). Smiths. Contrib. Zool. 175:1-32.

Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. U.S. Environmental Protection Agency, EPA Report 600/3-77-033. 114 pp.

Bold, H.C. and M.J. Wynne. 1978. Introduction to the Algal Structure and Reproduction. Prentice-Hall.

Boston Edison Co. 1980. Marine ecology studies related to operation of Pilgrim Station. Semi-Annual Report No. 16.

______________ 1981a. Marine ecology studies related to operation of Pilgrim Station. Semi-Annual Report No. 17.

______________ 1981b. Marine ecology studies related to operation of Pilgrim Station. Semi-Annual Report No. 18.

______________ 1982a. Marine ecology studies related to operation of Pilgrim Station. Semi-Annual Report No. 19.

______________ 1982b. Marine ecology studies related to operation of Pilgrim Station. Semi-Annual Report No. 20.

______________ 1983. Marine ecology studies related to operation of Pilgrim Station. Semi-Annual Report No. 21.

Bousfield, E.L. 1973. Shallow-water Gammaridean Amphipoda of New England. Cornell Univ. Press. 312 pp.

Dawson, E.Y. 1966. Marine Botany An Introduction. Holt, Rinehart and Winston.

Grassle, J.F. and W.L. Smith. 1976. A similarity measure sensitive to the contribution of rare species and its use in investigation of variation in marine benthic communities. Oecologia, 25:13-22.

Greig-Smith, P. 1964. Quantitative Plant Ecology. 2nd Ed. Butterworths, Washington, 256pp.

Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology, 52:577-586.

Newroth, P.R. 1970. A study of the genus Phyllophora Grev. Ph.D. Thesis, University of New Brunswick. 313pp.

Nie, N.H., C.H. Hull, J.G. Jenkins, K. Steinbrenner and D.H. Bent. 1975. Statistical Package for the Social Sciences. 2nd Ed. McGraw-Hill, New York. 675pp.

McLachlan, J. "Gracilaria tikvahiae sp. nov. (Rhodophyta, Gigartinales, Gracilariaceae), from the northwestern Atlantic". Phycologia 18(1977):19-23.

Parke, M. and P. Dixon. 1976. Checklist of the British marine algae. 3rd revision. Jour. Mar. Biol. Assoc. U.K., 56:817-843.

Pettibone, M.H. 1963. Marine Polychaete worms of the New England Region. Bull. U.S. Nat. Mus., 227(1):1-356.

Prince, J.S. 1971. An ecological study of the marine red algae Chondrus crispus in the waters off Plymouth, Massachusetts. Ph. D. Thesis, Cornell University. 177pp.

Sokal, R.R. and F. Rohlf. 1969. Biometry. W.H. Freeman and Company, San Francisco. 775pp.

Smith, W. and J.F. Grassle. 1977. Sampling properties of a family of diversity measures. Biometrics, 33:283-292.

________, J.F. Grassle and D. Kravitz. 1979. Measures of diversity with unbiased estimators. In: Ecological Diversity in Theory and Practice. Statistical Ecology Vol. S6. Int. Coop. Publ. House, Fairland, MD.

South, G.R. 1976. A checklist of marine algae of eastern Canada. 1st Revision. Jour. Mar. Biol. Assoc. U.K., 56:817-843.

Taylor, W.R. 1957. Marine Algae of the Northeastern Coast of North America. 2nd. Ed. University of Michigan Press. Ann Arbor, Mich. 509pp.

Zar, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 620p.

APPENDIX 1

APPENDIX I. ALGAL SPECIES COLLECTED FROM THE REPLICATE SAMPLES OF THE EFFLUENT, ROCKY POINT, AND MANOMET POINT SUBTIDAL (10' MLW) STATIONS FOR THE SEPTEMBER, 1982 COLLECTING PERIOD.

Division Species	Effluent 1	2	3	4	5	Rocky Point 1	2	3	4	5	Manomet Point 1	2	3	4	5
CHLOROPHYTA (green algae)															
Bryopsis plumosa									R						
Chaetomorpha linum	C	O	O	C	O	O	O	O	C	C	R	C	O	O	O
C. melagonium	R	R	O	O	O	O	C	O	C	C	C	C	O	O	C
Enteromorpha flexuosa	A	A	A	C	C	R		R		R					
Rhizoclonium riparium	C	C	O	O	R	R	R	R	R	R	R	R	R	R	R
Ulva lactuca	R	R	R	R	R	R		R	O	O	R	R	R	O	R
PHAEOPHYTA (brown algae)															
Chordaria flagelliformis															
Desmarestia aculeata						R							R		
D. viridis															
Laminaria digitata						R		R			R	R		R	
L. saccharina						R		R			R	R		R	
Sphacelaria cirrosa	A	O	O	O	C	A	O	R	R	R	R				R
RHODOPHYTA (red algae)															
Ahnfeltia plicata	O	R	A	C	A	C	R	O	O	C		R	R		R
Antithamnion americanum	R		R		O	O	R	R	O		R	R	R	R	R
Bonnemaisonia hamifera						R									
Callophyllis cristata															
Ceramium rubrum	A	A	A	A	C	A	C	O	C	C	O	C	C	C	C
Chondrus crispus	A	A	R	R	O	O	C	R	O	O	C	C	C	R	C
Corallina officinalis	R	R	R	O	O	R	R	O	O	O	R	O	R	O	O
Cystoclonium purpureum	O	O	R	O	O	C	C	O	O	O	O	C	C	C	C
Gracilaria tikvahiae	R	R	R		R										
Gymnogongrus crenulatus											R				
Membranoptera alata	R				R	R									
Palmaria palmata															
Phycodrys rubens		R					R	R	R	R	O	O	R	C	R
Phyllophora truncata	O	O	O	O	O	O	O	O	O	O	O	O	O	A	O
P. pseudoceranoides	O	O	R	O	O	O	O	O	O	O	O	O	O	O	O
P. traillii											R	R			
Plumaria elegans															
Polyides rotundus	R		C	A	C	A		A	C	O					
Polysiphonia elongata				R											
P. fibrillosa	R	C	R			A	O	O	O	R	O	O	O	O	O
P. harveyi	O	C	C	A	A	A	C	C	C	C	A	A	A	A	A
P. nigrescens	R	O	O	O	O	C	O	R	R	O		R	R	R	R
P. urceolata	O	O	O	C	C	C	C	R	C	O	R	R	R	R	R
Rhodomela confervoides	R	R	R		R	R		R	R	R					R
Spermothamnion repens	O	O	C	C	C	C	C	C	C	C	O	O	C	C	O
Replicate species richness	23	21	22	19	22	26	18	25	21	21	21	21	19	19	20
Station species richness			25					28					24		

Legend: A = abundant; C = common; O = occassional; R = rare.

APPENDIX 2

APPENDIX 2. ALGAL SPECIES COLLECTED FROM THE REPLICATE SAMPLES OF THE EFFLUENT, ROCKY POINT, AND MANOMET POINT SUBTIDAL (10' MLW) STATIONS FOR THE APRIL, 1983 COLLECTING PERIOD.

Division Species	Effluent					Rocky Point					Manomet Point				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
CHLOROPHYTA (green algae)															
Bryopsis plumosa															
Chaetomorpha linum	O	O	C	O	R	R	R	R	R	R	R	R	R	R	R
C. melagonium	O	O	O	O	R	R	R	R	R	R		R	O	R	R
Enteromorpha flexuosa	R	O	O	R	R		R	R		R	R		R	R	
Rhizoclonium riparium	R	R	R	R	R										
Ulva lactuca	R	R	O	R	R						O	O	R	R	R
PHAEOPHYTA (brown algae)															
Chordaria flagelliformis															
Desmarestia aculeata															
D. viridis															
Laminaria digitata															
L. saccharina									R						
Sphacelaria cirrosa	R	R	R	R	R	R	R	R	O	R	O	R	R	R	R
RHODOPHYTA (red algae)															
Ahnfeltia plicata	R		R		R	O	R	A	R	C			R		
Antithamnion americanum	R	R			R	R				R	R	R	O	R	R
Bonnemaisonia hamifera				R					R	R		R	R		
Callophyllis cristata	R														
Ceramium rubrum	O	O	C	O	C	R	R	R	R	R	O	C	C	C	C
Chondrus crispus	R	O	R	R	C	A	C	C	C	O	A	C	C	C	A
Corallina officinalis	R	O	R	R	O	O	O	C	R	R	R	R	R	R	R
Cystoclonium purpureum	C	C	C	C	C	R	O	R	O	O	O	C	C	O	C
Gracilaria tikvahiae															
Gymnogongrus crenulatus											R	R			
Membranoptera alata	R		R		R			R		R					R
Palmaria palmata															
Phycodrys rubens	O	R	R	R	O						R	R	R	R	R
Phyllophora truncata	A	C	C	A	C	R	R	R	R	R	O	R	O	O	R
P. pseudoceranoides	A	C	C	A	C	R	R	R	R	R	O	R	O	O	R
P. traillii															
Plumaria elegans												R			
Polyides rotundus	C	O	C		O		C	O	R	O			R		R
Polysiphonia elongata															
P. fibrillosa	R		O	R	R	R			R	R	R	R	R	O	C
P. harveyi	O	C	O	C	C	R	R	R	R	R	O	O	O	O	O
P. nigrescens	O	O	O	R	R	O	R	R	O	R	R			O	R
P. urceolata	R	O	C	C	O	R	R	R	R	R	R	O	C	O	O
Rhodomela confervoides		R	R	R					A	R	R	R	R	R	O
Spermothamnion repens	C	C	A	C	C	R	R	R	R	R	O	C	C	C	O
Replicate species richness	23	20	22	20	22	16	16	17	19	21	20	20	21	19	20
Station species richness			25					22					25		

Legend: A = abundant; C = common; O = occassional; R = rare.

APPENDIX 3

APPENDIX 3. REPLICATE (TOTAL NUMBERS OF INDIVIDUALS PER SPECIES) AND STATION (NUMBERS OF INDIVIDUALS PER SPECIES PER M^2) FAUNAL DATA FOR EFFLUENT STATION SEPTEMBER, 1982.

PHYLUM	Replicate					Station
Species	1	2	3	4	5	(No./m^2)
COELENTERATA						
Haliclystis salpinx	--	--	--	--	--	--
Metridium senile	68	52	12	56	68	460.8
PLATYHELMINTHES						
Notoplana atomata	--	4	--	--	--	7.2
NEMERTEA						
Nemertea sp.	--	96	--	8	24	230.4
MOLLUSCA						
Acmaea testudinalis	--	4	--	--	--	7.2
Aeolidia papillosa	72	56	72	36	68	547.2
Alvania pseudoareolata	--	--	--	--	--	--
Anachis avara	--	--	--	--	--	--
Anachis translirata	--	--	--	--	--	--
Anomia simplex	--	--	--	--	--	--
Anomia sp.	--	--	--	--	--	--
Anomia squamula	--	--	--	--	--	--
Cerastoderma pinnulatum	--	--	--	--	--	--
Cingula aculeus	--	4	--	--	--	7.2
Crepidula fornicata	32	24	4	20	16	172.8
Diaphana minuta	--	--	--	--	--	--
Doto coronata	--	8	--	--	--	14.4
Ensis directus	--	--	--	--	--	--
Facelina bostoniensis	--	--	--	--	--	--
Hiatella arctica	16	16	--	16	--	86.4
Ishnochiton ruber	--	--	--	--	--	--
Lacuna vincta	80	--	--	16	40	244.8
Mysella planulata	120	56	4	28	44	252.0
Margarites helicinia	32	--	--	--	--	57.6
Mitrella lunata	48	--	8	4	16	15.2
Modiolus modiolus	--	--	--	--	--	--
Mytilus edulis	3,156	1,564	252	340	1,972	13,111.2
Mytilus sp.	--	--	--	--	--	--
Nassarius vibex	--	--	--	8	--	14.4
Odostomia gibbosa	--	--	--	--	--	--
Omalogyra atomus	--	--	--	--	--	--
Onchidoris aspera	12	--	4	4	8	50.4
Pandora sp.	--	--	--	--	--	--
Spisula solidissma	--	--	--	--	--	--
Tellina agilis	12	4	8	--	--	43.2
Turbonilla sumneri	--	4	--	--	--	7.2

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m²)
ANNELIDA						
Amphitrite johnsoni	--	--	--	--	--	--
Aricidea catherinae	--	--	4	--	--	7.2
Asabellides oculata	--	--	--	--	--	--
Autolytus cornutus	--	--	--	4	--	7.2
Autolytus prismaticus	--	--	--	--	--	--
Capitella capitata	8	4	140	16	20	338.4
Caulleriella bioculata	--	--	--	--	--	--
Cirratulidae sp. A	--	--	--	--	--	--
Dodecaceria sp.	24	4	--	--	--	50.4
Eteone longa	--	--	4	--	4	14.4
Eulalia bilineata	--	--	8	16	--	43.2
Eulalia viridis	28	8	--	--	40	76.0
Eumida sanguinea	--	--	12	--	--	21.6
Harmothoe extenuata	8	--	--	4	4	28.8
Harmothoe imbricata	24	8	12	--	12	100.8
Lepidonotus squamatus	4	4	8	8	4	50.4
Naineris quadricuspida	--	--	--	--	4	7.2
Nephtys bucera	--	--	12	--	--	21.6
Nephtys picta	--	--	--	--	--	--
Nephtys sp. (juv.)	--	--	--	--	--	--
Nereis pelagica	8	4	16	4	12	79.2
Nicolea zostericola	16	--	8	--	--	43.2
Oligochaeta sp.	--	--	4	--	--	7.2
Pectinaria granulata	--	--	4	--	--	7.2
Peloscolex apectinatus	--	--	4	--	--	7.2
Pholoe minuta	32	--	24	8	24	158.4
Phyllodoce maculata	4	20	4	28	64	216.0
Polycirrus sp. A	--	--	4	--	4	14.4
Polydora giardi	--	--	--	--	4	7.2
Polydora socialis	--	4	--	--	--	7.2
Polygordius sp.	--	--	52	4	--	100.8
Potamilla sp.	--	--	--	--	--	--
Potamilla reniformis	--	--	--	--	--	--
Pygospio elegans	--	--	--	--	--	--
Sabellaria vulgaris	--	4	--	--	--	7.2
Spio cf. armata	--	--	--	--	--	--
Schistomeringos caeca	--	--	4	--	--	7.2
Terebellidae	--	--	--	--	--	--
Tharyx acutus	--	--	16	--	--	28.8
Tubifex pseudogaster	--	--	4	--	--	7.2
Typosyllis sp.	--	--	--	--	--	--
ARTHROPODA						
Acarina sp.	620	328	248	860	784	5,112.0
Achelia scabra	--	--	--	--	--	--
Achelia spinosa	--	--	--	--	--	--
Amphipoda	--	--	--	--	--	--
Ampithoe rubricata	8	8	--	16	4	64.8
Anoplodactylus lentus	--	--	--	--	--	--
Brachyura (megalopa)	8	--	--	4	4	28.8

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m^2)
Calliopius laevisculus	1,608	348	388	508	1,204	7,300.8
Cancer irroratus	32	4	52	20	56	295.2
Caprella linearis	4	8	20	16	20	122.4
Caprella penantis	408	348	1,552	628	784	6,696.0
Caridea indet.	--	--	--	--	--	--
Corophium acutum	3,296	680	588	672	4,416	9,652.0
Corophium bonelli	3,936	1,540	2,124	2,260	6,876	16,736.0
Crangon septemspinosa	--	--	--	--	--	--
Decapoda indet.	--	--	--	--	--	--
Dexamine thea	288	--	384	240	148	1,908.0
Diastylis sculpta	--	--	--	--	--	--
Diastylis sp.	--	--	8	4	--	21.6
Edotea trilobata	4	--	--	--	--	7.2
Eualus pusiolus	--	--	--	--	--	--
Idotea balthica	132	24	36	48	84	583.2
Idotea phosphorea	252	200	112	120	296	1,764.0
Ischyrocerus anguipes	--	16	32	8	80	27.2
Jaera marina	8	--	--	--	--	14.4
Jassa falcata	24,840	6,792	1,304	4,500	22,080	107,128.0
Lamprops quadriplicata	--	--	--	--	--	--
Nantantia indet.	--	--	--	--	--	--
Pagurus acadianus	--	--	--	--	4	7.2
Pagurus sp.	--	--	4	--	--	7.2
Phoxocephalus holbolli	4	--	4	--	--	14.4
Pleusymtes glaber	--	4	4	--	--	14.4
Pontogeneia inermis	--	--	12	4	--	21.6
Proboloides holmesi	28	--	--	8	--	64.8
Stenopleustes inermis	--	--	--	--	--	--
Tanystylum orbiculare	--	--	--	--	--	--
Rhepoxynius hudsoni	--	--	12	--	--	21.6
ECHINODERMATA						
Amphipholis squamata	--	4	--	4	--	14.4
Asterias forbesi	104	108	52	60	64	698.4
Echinarachius parma	--	--	--	--	--	--
Henricia sanguinolenta	--	--	--	--	--	--
Ophiopholis aculeata	4	4	-	4	-	21.6
Strongylocentrotus droebachiensis	--	--	--	--	--	-
CHORDATA						
Colonial Ascidacea	--	--	--	--	--	--
Solitary Ascidacea	--	--	--	--	--	--

APPENDIX 4

APPENDIX 4. REPLICATE (TOTAL NUMBERS OF INDIVIDUALS PER SPECIES) AND STATION (NUMBERS OF INDIVIDUALS PER SPECIES PER M^2) FAUNAL DATA FOR MANOMET POINT SEPTEMBER, 1982.

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m^2)
COELENTERATA						
Haliclystis salpinx	--	--	--	--	4	7.2
Metridium senile	--	--	--	--	--	--
PLATYHELMINTHES						
Notoplana atomata	--	--	4	8	--	21.6
NEMERTEA						
Nemertea sp.	12	36	24	12	--	151.2
MOLLUSCA						
Acmaea testudinalis	--	--	--	16	4	36
Aeolidia papillosa	--	--	--	--	--	--
Alvania pseudoareolata	--	--	--	--	--	--
Anachis avara	--	--	--	8	--	14.4
Anachis translirata	--	--	--	--	--	--
Anomia simplex	12	--	12	8	--	57.6
Anomia sp.	--	8	--	--	--	14.4
Anomia squamula	--	--	--	--	--	--
Cerastoderma pinnulatum	4	40	8	48	32	244.8
Cingula aculeus	36	16	20	8	12	165.6
Crepidula fornicata	4	8	9	20	8	86.4
Diaphana minuta	--	4	--	--	4	14.4
Doto coronata	--	--	--	--	8	14.4
Ensis directus	--	--	--	--	--	--
Facelina bostoniensis	20	8	28	4	8	122.4
Hiatella arctica	116	280	140	108	144	1,418.4
Ishnochiton ruber	--	--	--	4	4	14.4
Lucuna vincta	220	92	176	112	84	1,231.2
Mysella planulata	--	24	--	24	4	93.6
Margarites helicinia	184	272	400	432	120	2,534.4
Mitrella lunata	68	--	8	44	20	252.0
Modiolus modiolus	40	52	40	56	60	446.4
Mytilus edulis	1,284	1,388	2,436	3,268	1,484	17,748.0
Mytilus sp.	--	1,560	2,456	--	--	7,228.8
Nassarius vibex	--	--	--	--	--	--
Odostomia gibbosa	--	--	--	--	--	--
Omalogyra atomus	--	--	--	--	--	--
Onchidoris aspera	32	92	100	44	44	561.6
Pandora sp.	--	12	--	--	--	21.6
Spisula solidissma	4	12	--	12	4	57.6
Tellina agilis	4	40	--	88	12	259.2
Turbonilla sumneri	--	--	--	4	--	7.2

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m^2)
ANNELIDA						
Amphitrite johnsoni	--	--	--	--	--	--
Aricidea catherinae	--	--	--	--	--	--
Asabellides oculata	4	8	8	--	12	58.5
Autolytus cornutus	--	--	4	--	--	7.2
Autolytus prismaticus	--	--	4	--	--	7.2
Capitella capitata	--	8	8	8	--	43.2
Caulleriella bioculata	4	12	28	--	28	129.6
Cirratulidae sp. A	--	--	--	--	4	7.2
Dodecaceria sp.	4	4	12	--	4	43.2
Eteone longa	--	--	--	--	--	--
Eulalia bilineata	--	--	--	16	8	43.2
Eulalia viridis	12	4	20	--	--	64.8
Eumida sanguinea	--	12	--	--	--	21.6
Harmothoe extenuata	16	28	24	4	20	165.6
Harmothoe imbricata	20	48	36	12	44	288.0
Lepidonotus squamatus	8	8	--	4	8	50.4
Naineris quadricuspida	--	4	12	--	--	28.8
Nephtys bucera	--	--	--	--	--	--
Nephtys picta	--	--	--	--	--	--
Nephtys sp. (juv.)	--	--	52	--	--	93.6
Nereis pelagica	8	20	--	28	8	115.2
Nicolea zostericola	292	220	320	296	408	2,764.8
Oligochaeta sp.	--	--	--	--	--	--
Pectinaria granulata	--	--	--	--	--	--
Peloscolex apectinatus	--	--	--	--	--	--
Pholoe minuta	--	--	4	--	12	28.8
Phyllodoce maculata	4	8	8	4	--	43.2
Polycirrus sp. A	4	--	--	--	--	7.2
Polydora giardi	4	--	20	--	8	57.6
Polydora socialis	4	4	4	8	--	36.0
Polygordius sp.	--	--	--	--	--	--
Potamilla sp.	--	--	4	--	--	7.2
Potamilla remiformis	--	--	--	--	4	7.2
Pygospio elegans	--	--	--	--	4	7.2
Sabellaria vulgaris	--	--	4	4	--	14.4
Spio cf. armata	--	--	--	--	--	--
Schistomeringos caeca	--	--	--	--	--	--
Terebellidae	--	--	4	--	--	7.2
Tharyx acutus	--	--	--	--	--	--
Tubifex pseudogaster	--	--	--	--	--	--
Typosyllis sp.	--	--	--	--	--	--
ARTHROPODA						
Acarina sp.	136	244	1,064	1,264	1,024	6,717.6
Achelia scabra	--	--	--	--	--	--
Achelia spinosa	--	--	--	--	--	--
Amphipoda	--	--	--	1	--	1.8
Ampithoe rubricata	76	84	64	72	60	640.8
Anoplodactylus lentus	--	--	--	--	4	7.2
Brachyura indet.	--	--	--	--	--	--
Calliopius laevisculus	260	124	396	308	432	2,736.0

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m^2)
Cancer irroratus	12	8	8	12	8	86.4
Caprella linearis	40	60	256	284	244	1,591.2
Caprella penantis	476	224	836	344	444	4,183.2
Caridea indet.	--	4	--	--	--	7.2
Corophium acutum	296	240	544	1,256	232	4,622.4
Corophium bonelli	288	532	248	640	180	3,398.4
Crangon septemspinosa	--	--	--	--	--	--
Decapoda indet.	--	--	--	--	--	--
Dexamine thea	120	304	296	316	168	2,167.2
Diastylis sculpta	4	--	8	--	8	36.0
Diastylis sp.	--	--	--	--	--	--
Edotea trilobata	--	--	8	--	--	14.4
Eualus pusiolus	--	--	12	16	16	79.2
Idotea balthica	4	--	8	12	24	86.4
Idotea phosphorea	136	148	124	264	188	1,548.0
Ischyrocerus anguipes	564	228	748	712	396	4,766.0
Jaera marina	--	--	--	--	--	--
Jassa falcata	1,156	544	2,008	4,160	964	15,898.0
Lamprops quadriplicata	--	--	--	--	--	--
Natantia indet.	--	4	4	4	--	21.6
Pagurus acadianus	--	--	--	--	--	--
Pagurus sp.	--	--	--	--	--	--
Phoxocephalus holbolli	--	--	--	4	--	7.2
Pleusymtes glaber	712	516	772	628	552	5,724.0
Pontogeneia inermis	--	52	148	144	168	921.6
Proboloides holmesi	20	12	132	140	116	756.0
Stenopleustes inermis	60	--	--	--	--	108.0
Tanystylum orbiculare	--	--	--	--	--	--
Rhepoxynius hudsoni	--	--	--	--	--	--
ECHINODERMATA						
Amphipholis squamata	4	48	20	24	28	223.2
Asterias forbesi	36	52	60	56	44	446.4
Echinarachius parma	--	--	--	20	--	36.0
Henricia sanguinolenta	4	--	--	--	--	7.2
Ophiopholis aculeata	12	24	12	12	16	136.8
Strongylocentrotus droebachiensis	48	48	20	--	24	252
CHORDATA						
Colonial Ascidacea	12	--	--	--	--	21.6
Solitary Ascidacea	4	--	--	--	--	7.2

APPENDIX 5

APPENDIX 5. REPLICATE (TOTAL NUMBERS OF INDIVIDUALS PER SPECIES) AND STATION (NUMBERS OF INDIVIDUALS PER SPECIES PER M^2) FAUNAL DATA FOR ROCKY POINT, SEPTEMBER, 1982.

PHYLUM	Replicate					Station
Species	1	2	3	4	5	(No./m^2)
COELENTERATA						
Haliclystis salpinx	--	12	--	8	--	36.0
Metridium senile	--	--	--	4	--	7.2
PLATYHELMINTHES						
Notoplana atomata	--	4	4	--	--	14.4
NEMERTEA						
Nemertea sp.	120	136	40	--	56	633.6
MOLLUSCA						
Acmaea testudinalis	--	12	4	12	--	50.4
Aeolidia papillosa	--	--	--	--	--	--
Alvania pseudoareolata	12	16	8	20	16	129.6
Anachis avara	--	--	--	--	--	--
Anachis translirata	--	--	--	--	--	--
Anomia simplex	4	--	16	--	--	36.0
Anomia sp.	--	--	--	--	--	--
Anomia squamula	--	--	--	--	8	14.4
Cerastoderma pinnulatum	16	20	20	12	12	144.0
Cingula aculeus	264	64	376	196	192	1,965.6
Crepidula fornicata	16	12	16	36	28	194.4
Diaphana minuta	8	20	4	8	8	86.4
Doto coronata	--	--	--	--	--	--
Ensis directus	--	--	4	--	--	7.2
Facelina bostoniensis	4	8	--	4	8	43.2
Hiatella arctica	356	304	268	136	224	2,318.4
Ishnochiton ruber	--	4	12	--	--	28.8
Lacuna vincta	620	196	192	248	244	2,700.0
Mysella planulata	88	16	28	4	60	352.8
Margarites helicinia	364	984	616	564	632	5,688.0
Mitrella lunata	32	48	28	16	48	309.6
Modiolus modiolus	48	12	60	56	24	360.0
Mytilus edulis	1,480	1,888	1,672	960	1,172	12,909.6
Mytilus sp.	--	--	--	--	--	--
Nassarius vibex	--	--	--	--	--	--
Odostomia gibbosa	--	--	--	--	4	7.2
Omalogyra atomus	12	--	4	--	8	43.2
Onchidoris aspera	80	120	72	180	88	972.0
Pandora sp.	--	--	--	--	--	--
Spisula solidissma	8	--	--	--	--	14.0
Tellina agilis	44	--	12	16	8	80.0
Turbonilla sumneri	--	--	--	--	--	--

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m²)
ANNELIDA						
Amphitrite johnsoni	--	--	--	4	--	7.2
Aricidea catherinae	--	--	--	--	--	--
Asabellides oculata	4	--	--	4	8	28.8
Autolytus cornutus	--	--	--	--	--	--
Autolytus prismaticus	--	--	--	--	--	--
Capitella capitata	20	--	--	--	--	36.0
Caulleriella bioculata	--	--	8	--	--	14.4
Cirratulidae sp. A	--	--	--	--	--	--
Dodecaceria sp.	4	4	--	--	4	21.6
Eteone longa	--	--	--	--	--	--
Eulalia bilineata	--	28	--	32	--	108.0
Eulalia viridis	--	--	4	--	8	21.6
Eumida sanguinea	--	--	--	--	--	--
Harmothoe extenuata	32	32	--	12	12	158.4
Harmothoe imbricata	64	68	32	68	44	496.8
Lepidonotus squamatus	--	8	4	12	8	57.6
Naineris quadricuspida	8	--	4	--	--	21.6
Nephtys bucera	--	--	--	--	--	--
Nephtys picta	--	--	4	--	--	7.2
Nephtys sp. (juv.)	4					7.2
Nereis pelagica	24	36	24	16	36	244.8
Nicolea zostericola	176	324	124	136	288	1,886.4
Oligochaeta sp.	--	--	--	--	--	--
Pectinaria granulata	--	--	--	--	--	--
Peloscolex apectinatus	--	--	--	--	--	--
Pholoe minuta	160	28	72	32	32	583.2
Phyllodoce maculata	16	4	8	4	20	93.6
Polycirrus sp. A	--	--	--	--	--	--
Polydora giardi	--	4	--	--	--	7.2
Polydora socialis	--	--	--	4	--	7.2
Polygordius sp.	--	--	--	--	--	--
Potamilla sp.	--	--	--	--	--	--
Potamilla reniformis	--	--	--	--	4	7.2
Pygospio elegans	--	--	--	--	--	--
Sabellaria vulgaris	--	--	--	--	4	7.2
Spio cf. armata	--	--	4	--	--	7.2
Schistomeringos caeca	--	--	--	--	--	--
Terebellidae	--	--	--	--	--	--
Tharyx acutus	--	4	--	--	--	7.2
Tubifex pseudogaster	--	--	--	--	--	--
Typosyllis sp.	4	--	--	--	--	7.2
ARTHROPODA						
Acarina sp.	344	924	260	200	384	3,801.6
Achelia scabra	--	--	--	--	--	--
Achelia spinosa	--	--	--	--	--	--
Amphipoda	--	--	--	--	--	--
Ampithoe rubricata	20	40	20	20	12	201.6
Anoplodactylus lentus	--	--	--	--	--	--
Brachyura indet.	--	--	--	--	--	--
Calliopius laeviscul us	168	328	124	148	144	1,641.6

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m^2)
Cancer irroratus	12	4	12	16	--	79.2
Caprella linearis	64	252	96	160	136	1,274.4
Caprella penantis	756	740	312	652	564	5,443.7
Caridea indet.	--	--	--	--	--	--
Corophium acutum	144	1,196	396	356	376	4,442.4
Corophium bonelli	808	1,540	2,500	904	2,312	14,515.2
Crangon septemspinosa	--	--	--	--	--	--
Decapoda indet.	--	--	4	--	--	7.2
Dexamine thea	1,428	1,404	708	824	884	9,446.4
Diastylis sculpta	4	--	--	--	--	7.2
Diastylis sp.	--	--	4	--	4	14.4
Edotea trilobata	4	4	--	4	--	21.6
Eualus pusiolus	16	16	8	24	56	216.0
Idotea balthica	16	72	4	4	24	216
Idotea phosphorea	56	416	52	60	144	1,310.4
Ischyrocerus anguipes	96	532	168	212	212	2,196
Jaera marina	--	--	--	--	--	--
Jassa falcata	184	1,844	340	284	348	5,400.0
Lamprops quadriplicata	--	--	--	--	--	--
Natantia indet.	--	--	--	--	--	--
Pagurus acadianus	--	--	--	--	--	--
Pagurus sp.	--	--	--	--	--	--
Phoxocephalus holbolli	68	4	48	60	20	360.0
Pleusymtes glaber	246	380	496	484	340	3,502.8
Pontogeneia inermis	152	100	80	136	108	1,036.8
Proboloides holmesi	--	--	--	--	--	--
Stenopleustes inermis	--	--	--	--	--	--
Tanystylum orbiculare	--	--	--	--	--	--
Rhepoxynius hudsoni	--	--	--	--	--	--
ECHINODERMATA						
Amphipholis squamata	20	20	16	12	36	187.2
Asterias forbesi	24	32	12	--	20	115.2
Echinarachius parma	--	--	--	--	--	--
Henricia sanguinolenta	--	--	--	4	4	14.4
Ophiopholis aculeata	4	32	12	40	8	172.8
Strongylocentrotus droebachiensis	40	12	24	48	12	244.8
CHORDATA						
Colonial Ascidacea	--	8	--	--	--	14.4
Solitary Ascidacea	--	--	--	--	--	--

APPENDIX 6

APPENDIX 6. REPLICATE (TOTAL NUMBERS OF INDIVIDUALS PER SPECIES) AND STATION (NUMBERS OF INDIVIDUALS PER SPECIES PER M^2) FAUNAL DATA FOR EFFLUENT STATION SEPTEMBER, 1982.

PHYLUM	Replicate					Station
Species	1	2	3	4	5	(No./m^2)
COELENTERATA						
Haliclystis salpinx	--	--	--	--	--	--
Metridium senile	--	--	--	--	--	--
PLATYHELMINTHES						
Notoplana atomata	--	--	--	--	--	--
NEMERTEA						
Nemertea sp.	--	--	--	--	--	--
MOLLUSCA						
Acmaea testudinalis	--	--	--	--	--	--
Aeolidia papillosa	--	--	--	--	--	--
Alvania pseudoareolata	--	--	--	--	--	--
Anachis avara	--	--	--	--	--	--
Anachis translirata	--	--	--	--	--	--
Anomia simplex	--	--	--	--	--	--
Anomia sp.	--	--	--	--	--	--
Anomia squamula	--	4	--	--	4	14.4
Cerastoderma pinnulatum	--	--	--	--	--	--
Cingula aculeus	--	--	8	4	--	21.6
Crepidula fornicata	--	--	--	--	4	7.2
Diaphana minuta	--	--	--	4	4	14.4
Doto coronata	--	--	--	--	--	--
Ensis directus	--	--	--	--	--	--
Facelina bostoniensis	--	--	--	--	--	--
Hiatella arctica	--	--	--	--	--	--
Ishnochiton ruber	--	--	--	--	--	--
Lacuna vincta	572	332	252	352	244	3,153.6
Leptonacea sp. A	8	--	32	--	--	72.0
Mysella planulata	--	--	--	--	--	--
Margarites helicinus	--	--	--	--	--	--
Mitrella lunata	--	--	12	--	--	21.6
Modiolus modiolus	--	--	12	--	--	21.6
Mytilus edulis	3,232	896	4,828	1,832	1,564	22,233.6
Mytilus sp.	--	--	--	--	--	--
Nassarius vibex	--	20	32	4	12	122.4
Odostomia gibbosa	--	--	--	--	--	--
Omalogyra atomus	--	--	--	--	--	--
Onchidoris aspera	--	--	--	--	8	14.4
Pandora sp.	--	--	--	--	--	--

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m^2)
Spisula solidissma	--	--	--	--	--	--
Tellina agilis	--	--	4	4	--	14.4
Turbonilla sumneri	4	--	--	--	--	7.2
ANNELIDA						
Amphitrite johnsoni	--	--	--	--	--	--
Aricidea catherinae	--	--	--	--	--	--
Asabellides oculata	--	--	--	--	--	--
Autolytus cornutus	--	--	--	--	--	--
Autolytus prismaticus	--	--	--	--	--	--
Capitella capitata	--	--	--	--	--	--
Caulleriella bioculata	--	--	--	--	--	--
Cirratulidae sp. A	--	--	--	--	--	--
Dodecaceria sp.	--	--	--	--	16	28.8
Eteone longa	--	--	--	--	--	--
Eulalia bilineata	--	--	--	--	--	--
Eulalia viridis	--	--	4	--	--	7.2
Eumida sanguinea	--	--	--	--	--	--
Harmothoe extenuata	--	--	--	--	--	--
Harmothoe imbricata	--	--	--	--	--	--
Lepidonotus squamatus	--	16	24	--	4	79.2
Naineris quadricuspida	--	--	--	--	--	--
Nephtys bucera	--	--	--	--	--	--
Nephtys picta	--	--	--	--	--	--
Nephyts sp. (juv.)	--	--	--	--	--	--
Nereis pelagica	32	--	20	4	8	115.2
Nicolea zostericola	12	12	4	4	--	57.6
Oligochaeta sp.	--	--	--	--	--	--
Pectinaria granulata	--	--	--	--	--	--
Peloscolex apectinatus	--	--	--	--	--	--
Pholoe minuta	12	--	--	--	--	21.6
Phyllodoce maculata	--	4	32	4	4	79.2
Polycirrus sp. A	--	--	--	--	--	--
Polydora giardi	--	--	--	--	--	--
Polydora socialis	--	--	--	--	--	--
Polygordius sp.	--	--	--	--	--	--
Potamilla sp.	--	--	--	--	--	--
Potamilla reniformis	--	--	--	--	--	--
Pygospio elegans	--	--	--	--	--	--
Sabellaria vulgaris	--	--	--	--	--	--
Spio cf. armata	--	--	--	--	--	--
Schistomeringos caeca	--	--	--	--	--	--
Terebellidae	--	--	--	--	--	--
Tharyx acutus	--	--	--	--	--	--
Tubifex pseudogaster	--	--	--	--	--	--
Typosyllis sp.	--	--	--	--	--	--

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m^2)
ARTHROPODA						
Acarina sp.	12	700	852	1,012	720	5,932.8
Achelia scabra	--	--	--	--	--	--
Achelia spinosa	--	--	--	--	--	--
Amphipoda	--	--	--	--	--	--
Ampithoe rubricata	--	--	--	--	4	7.2
Anoplodactylus lentus	--	--	--	--	--	--
Brachyura indet.	--	--	--	--	--	--
Calliopius laevisculus	436	212	364	88	92	2,145.6
Cancer borealis	--	--	--	--	4	7.2
Cancer irroratus	--	12	8	4	4	50.4
Caprella linearis	40	12	8	24	36	216.0
Caprella penantis	216	232	132	336	72	1,778.4
Caprella unica	--	--	--	4	--	7.2
Caridea indet.	--	--	--	--	--	--
Corophium acutum	404	216	388	420	292	3,096.0
Corophium bonelli	8	4	24	4	16	100.8
Corophium insidiosum	652	280	1,244	516	440	5,637.6
Crangon septemspinosa	--	--	--	--	--	--
Decapoda indet.	--	--	--	--	--	--
Dexamine thea	184	116	336	112	96	1,519.2
Diastylis sculpta	--	--	--	--	--	--
Diastylis sp.	--	--	--	--	--	--
Edotea trilobata	--	--	4	--	--	7.2
Eualus pusiolus	--	--	--	--	--	--
Idotea balthica	8	4	12	8	--	57.6
Idotea phosphorea	92	60	32	188	68	792.0
Ischyrocerus anguipes	5,120	4,720	1,680	1,840	1,480	26,712.0
Jaera marina	--	--	--	--	--	--
Jassa falcata	1,840	1,760	1,480	3,000	2,760	19,512.0
Lamprops quadriplicata	--	--	--	--	--	--
Marinogammarus sp. A	12	--	--	--	12	43.2
Marinogommarus stoerensis	--	--	--	4	--	7.2
Metopella carinata	--	--	--	4	--	7.2
Natantia indet.	--	--	--	100	--	180.0
Pagarus arcuatus	4	--	--	--	--	7.2
Pagurus acadianus	4	12	--	8	24	86.4
Pagurus sp.	12	4	--	4	36	100.8
Phoxocephalus holbolli	--	--	4	--	--	7.2
Pleusymtes glaber	12	4	--	32	16	115.2
Pontogeneia inermis	296	200	328	116	112	1,893.6
Proboloides holmesi	8	20	--	20	4	93.6
Stenopleustes inermis	--	--	--	--	--	--
Tanystylum orbiculare	--	--	--	--	--	--
Rhepoxynius hudsoni	--	--	--	--	--	--

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m^2)
ECHINODERMATA						
Amphipholis squamata	--	--	--	--	--	--
Asterias forbesi	--	4	--	4	16	43.2
Echinarachius parma	--	--	--	--	--	--
Henricia sanguinolenta	--	--	--	--	--	
Ophiopholis aculeata	--	--	--	--	814.4	
Strongylocentrotus	--	--	--	--	--	--
droebachiensis	4	4	--	4	4	28.8
CHORDATA						
Colonial Ascidacea	--	--	--	--	--	
Solitary Ascidacea	--	--	--	--	--	--

APPENDIX 7

APPENDIX 7. REPLICATE (TOTAL NUMBERS OF INDIVIDUALS PER SPECIES) AND STATION (NUMBERS OF INDIVIDUALS PER SPECIES PER M^2) FAUNAL DATA FOR MANOMET POINT, APRIL, 1983.

PHYLUM	Replicate					Station
Species	1	2	3	4	5	(No./m^2)
COELENTERATA						
Haliclystis salpinx	--	--	--	--	--	--
Metridium senile	--	4	--	--	--	7.2
PLATYHELMINTHES						
Notoplana atomata	--	--	--	--	--	--
NEMERTEA						
Nemertea sp.	12	8	4	24	4	93.6
MOLLUSCA						
Acmaea testudinalis	--	--	--	--	--	--
Aeolidia papillosa	4	--	--	--	--	7.2
Alvania pseudoareolata	--	--	--	--	--	--
Anachis avara	--	--	--	--	--	--
Anachis translirata	--	--	--	--	--	--
Anomia simplex	--	4	--	--	--	7.2
Anomia sp.	--	--	--	--	--	--
Anomia squamula	--	--	--	4	--	7.2
Cerastoderma pinnulatum	--	--	--	--	--	--
Cingula aculeus	64	4	--	4	52	223.2
Crepidula fornicata	--	--	--	--	--	--
Diaphana minuta	4	--	4	--	--	14.4
Doto coronata	--	--	--	--	--	--
Ensis directus	--	--	--	--	--	--
Facelina bostoniensis	--	--	--	--	--	--
Hiatella arctica	24	12	4	4	4	86.4
Ishnochiton ruber	--	--	--	--	--	--
Lacuna vincta	1,680	1,120	768	1,348	1,180	10,972.8
Leptonacea sp. A	24	8	4	4	4	79.2
Mysella planulata	--	--	--	--	--	--
Margarites helicinus	168	80	68	144	84	979.2
Mitrella lunata	20	--	8	8	--	64.8
Modiolus modiolus	32	--	4	--	4	72.0
Mytilus edulis	10,300	3,300	4,776	3,096	2,828	43,740.0
Mytilus sp.	--	--	--	--	--	--
Nassarius vibex	--	--	--	--	--	--
Odostomia gibbosa	--	--	--	--	4	7.2
Omalogyra atomus	4	--	--	--	--	7.2
Onchidoris aspera	16	8	56	12	--	165.6
Pandora sp.	4	--	--	--	4	14.4

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m²)
Spisula solidissma	--	--	--	--	--	--
Tellina agilis	4	4	--	4	--	21.6
Turbonilla sumneri	--	--	--	--	--	--
ANNELIDA						
Amphitrite johnsoni	--	--	--	--	--	--
Aricidea catherinae	--	--	--	--	--	--
Asabellides oculata	--	--	--	4	--	7.2
Autolytus cornutus	--	--	--	--	--	--
Autolytus prismaticus	--	8	--	--	--	14.4
Capitella capitata	4	12	--	--	4	36.0
Caulleriella bioculata	4	4	--	--	--	14.4
Cirratulidae sp. A	--	--	--	--	--	--
Dodecaceria sp.	16	--	4	--	4	43.2
Eteone longa	--	--	--	--	--	--
Eulalia bilineata	--	--	--	--	--	--
Eulalia viridis	12	12	--	--	4	50.4
Eumida sanguinea	--	--	--	--	--	--
Exogone hebes	--	--	--	--	4	7.2
Harmothoe extenuata	--	--	8	8	--	28.8
Harmothoe imbricata	8	--	4	4	4	36.0
Lepidonotus squamatus	--	8	8	8	--	43.2
Naineris quadricuspida	4	--	--	--	--	--
Nephtys bucera	--	--	--	--	--	--
Nephtys picta	--	--	--	--	--	--
Nephyts sp. (juv.)	--	--	--	--	--	--
Nereis pelagica	20	24	8	12	12	136.8
Nicolea zostericola	308	200	64	212	124	1,634.4
Oligochaeta sp.	--	--	--	--	--	--
Pectinaria granulata	--	--	--	--	--	--
Peloscolex apectinatus	--	--	--	--	--	--
Pholoe minuta	28	12	4	12	20	136.8
Phyllodoce maculata	12	8	32	--	36	158.4
Polycirrus sp. A	--	4	--	16	--	36.0
Polydora giardi	4	--	--	--	--	7.2
Polydora socialis	--	--	--	--	--	--
Polygordius sp.	--	--	--	--	--	--
Potamilla sp.	--	--	--	--	--	--
Potamilla reniformis	--	--	--	--	--	--
Pygospio elegans	--	--	--	--	--	--
Sabella crassicorne	--	--	--	--	4	7.2
Sabellaria vulgaris	20	--	--	--	--	36.0
Spio cf. armata	--	--	--	--	--	--
Schistomeringos caeca	--	--	--	--	--	--
Terebellidae	--	--	--	--	--	--
Tharyx acutus	--	--	--	--	--	--
Tubifex pseudogaster	--	--	--	--	--	--
Typosyllis sp.	--	--	--	--	--	--

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m^2)
ARTHROPODA						
Acarina sp.	520	64	140	252	228	2,167.2
Achelia scabra	--	--	--	--	--	--
Achelia spinosa	--	--	--	--	--	--
Amphipoda	--	--	--	--	--	--
Ampithoe rubricata	4	16	8	8	4	72.0
Anoplodactylus lentus	--	--	--	--	--	--
Brachyura indet.	--	--	--	--	--	--
Calliopius laevisculus	8	16	12	4	8	86.4
Cancer borealis	--	--	--	--	--	--
Cancer irroratus	4	--	12	-	100.8	
Caprella penantis	552	248	244	92	464	2,880.0
Caprella unica	--	--	--	4	--	7.2
Caridea indet.	--	--	--	--	--	--
Corophium acutum	572	360	436	640	196	3,967.2
Corophium bonelli	36	72	20	44	12	331.2
Corophium insidiosum	652	280	1,244	516	440	5,637.6
Crangon septemspinosa	--	--	--	--	--	--
Decapoda indet.	--	--	--	--	--	--
Dexamine thea	132	112	212	120	160	1,324.8
Diastylis sculpta	--	--	--	--	--	--
Diastylis sp.	--	--	--	--	--	--
Edotea trilobata	--	--	--	--	--	--
Eualus pusiolus	4	--	4	4	--	21.6
Eudorella pusilla	4	--	--	--	--	7.2
Idotea balthica	24	4	12	8	12	108.0
Idotea phosphorea	80	32	68	52	48	504.0
Ischyrocerus anguipes	5,640	5,240	4,200	2,200	6,840	43,416.0
Jaera marina	--	--	--	--	--	--
Jassa falcata	2,880	2,760	1,156	4,640	2,040	24,256.8
Lamprops quadriplicata	--	--	--	--	--	--
Limnoria lignorum	4	--	--	--	--	7.2
Metopella carinata	16	4	12	--	--	57.6
Marinogammarus sp. A	12	--	--	--	12	43.2
Marinogommarus stoerensis	--	--	--	4	--	7.2
Metopella carinata	--	--	--	4	--	7.2
Natantia indet.	--	--	--	100	--	180.0
Pagarus arcuatus	4	--	--	--	--	7.2
Pagurus acadianus	--	--	12	--	--	21.6
Pagurus sp.	12	4	--	4	36	100.8
Phoxocephalus holbolli	--	--	4	--	--	7.2
Pleusymtes glaber	72	20	80	84	72	590.4
Pontogeneia inermis	132	52	424	52	36	1,252.8
Proboloides holmesi	64	28	40	20	8	288.0
Stenopleustes inermis	--	--	--	--	--	--
Tanystylum orbiculare	--	--	--	--	--	--
Rhepoxynius hudsoni	--	--	--	--	--	--

PHYLUM Species	Replicate 1	 2	 3	 4	 5	Station (No./m^2)
ECHINODERMATA						
Amphipholis squamata	--	12	8	12	20	93.6
Asterias forbesi	--	4	4	8	4	36.0
Echinarachius parma	--	--	--	--	--	--
Henricia sanguinolenta	--	--	--	--	--	
Ophiopholis aculeata	--	24	4	20	--	86.4
Strongylocentrotus	--	--	--	--	--	--
droebachiensis	4	8	4	36	24	136.8
CHORDATA						
Colonial Ascidacea	4	--	--	12	8	43.2
Solitary Ascidacea	--	--	4	--	--	7.2

APPENDIX 8

APPENDIX 8. REPLICATE (TOTAL NUMBERS OF INDIVIDUALS PER SPECIES) AND STATION (NUMBERS OF INDIVIDUALS PER SPECIES PER M^2) FAUNAL DATA FOR ROCKY POINT, APRIL, 1983.

PHYLUM	Replicate					Station
Species	1	2	3	4	5	(No./m^2)
COELENTERATA						
Haliclystis salpinx	--	--	--	--	--	--
Metridium senile	--	4	--	--	--	7.2
PLATYHELMINTHES						
Notoplana atomata	--	--	--	--	--	--
NEMERTEA						
Nemertea sp.	8	88	--	--	--	172.8
MOLLUSCA						
Acmaea testudinalis	--	--	--	--	--	--
Aeolidia papillosa	4	--	--	--	--	7.2
Alvania pseudoareolata	--	--	--	--	--	--
Anachis avara	--	--	--	--	--	--
Anachis translirata	--	--	--	--	--	--
Anomia simplex	4	8	--	4	--	28.8
Anomia sp.	--	--	--	--	--	--
Anomia squamula	--	4	--	--	--	7.2
Cerastoderma pinnulatum	--	--	--	--	--	--
Cingula aculeus	8	16	28	--	--	93.6
Crepidula fornicata	--	--	--	--	--	--
Diaphana minuta	4	--	4	--	--	14.4
Doto coronata	--	--	--	--	--	--
Ensis directus	--	--	--	--	--	--
Facelina bostoniensis	--	4	--	--	--	7.2
Hiatella arctica	24	12	4	4	4	86.4
Ishnochiton ruber	4	--	--	--	--	7.2
Lacuna vincta	916	660	712	380	680	6,026.4
Leptonacea sp. A	--	4	--	--	--	7.2
Mysella planulata	--	--	--	--	--	--
Margarites helicinus	72	16	32	16	28	295.2
Mitrella lunata	8	4	80	--	60	273.6
Modiolus modiolus	4	4	12	--	--	36.0
Mytilus edulis	540	616	624	432	784	5,392.8
Mytilus sp.	--	--	--	--	--	--
Nassarius vibex	--	20	32	4	12	--
Odostomia gibbosa	--	--	--	--	4	7.2
Omalogyra atomus	4	--	--	--	--	7.2
Onchidoris aspera	16	8	56	12	-	165.6
Pandora sp.	4	--	--	--	4	14.4

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m^2)
Spisula solidissma	--	--	--	--	--	--
Tellina agilis	4	8	--	--	--	21.6
Turbonilla sumneri	4	--	--	--	--	7.2
ANNELIDA						
Amphitrite johnsoni	--	--	--	--	--	--
Aricidea catherinae	--	--	--	--	--	--
Asabellides oculata	--	--	4	--	--	7.2
Autolytus cornutus	--	--	--	--	--	--
Autolytus prismaticus	--	8	--	--	--	14.4
Capitella capitata	4	12	--	--	4	36.0
Caulleriella bioculata	--	--	--	--	4	7.2
Cirratulidae sp. A	--	--	--	--	--	--
Dodecaceria sp.	24	32	--	--	--	100.8
Eteone longa	--	--	--	--	--	--
Eulalia bilineata	--	--	--	--	4	7.2
Eulalia viridis	12	12	--	--	4	50.4
Eumida sanguinea	--	--	--	--	--	--
Exogone hebes	--	--	--	--	4	7.2
Harmothoe extenuata	--	4	--	--	4	14.4
Harmothoe imbricata	--	4	4	--	--	14.4
Lepidonotus squamatus	12	--	--	--	--	21.6
Naineris quadricuspida	--	--	4	--	--	7.2
Nephtys bucera	--	--	--	--	--	--
Nephtys picta	--	--	--	--	--	--
Nephyts sp. (juv.)	--	--	--	--	--	--
Nereis pelagica	--	8	8	8	--	43.2
Nicolea zostericola	40	36	12	20	8	208.8
Oligochaeta sp.	--	--	--	--	--	--
Pectinaria granulata	--	--	--	--	--	--
Peloscolex apectinatus	--	--	--	--	--	--
Pholoe minuta	28	28	20	--	20	172.8
Phyllodoce maculata	--	--	--	--	8	14.4
Phyllodocidae juv.	--	4	--	--	--	7.2
Polycirrus sp. A	--	4	--	16	--	36.0
Polydora giardi	4	--	--	--	--	7.2
Polydora socialis	--	--	--	--	--	--
Polygordius sp.	--	--	--	--	--	--
Potamilla sp.	--	--	--	--	--	--
Potamilla reniformis	--	--	--	--	--	--
Pygospio elegans	--	--	--	--	--	--
Sabella crassicorne	--	--	--	--	4	7.2
Sabellaria vulgaris	20	--	--	--	--	36.0
Spio cf. armata	--	--	--	--	--	--
Schistomeringos caeca	--	--	--	--	--	--
Terebellidae	--	--	--	--	--	--
Tharyx acutus	--	--	--	--	--	--
Tubifex pseudogaster	--	--	--	--	--	--
Typosyllis sp.	--	--	--	--	--	--

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m²)
ARTHROPODA						
Acarina sp.	72	144	52	272	120	1,188.0
Achelia scabra	--	--	--	--	--	--
Achelia spinosa	--	--	--	--	--	--
Amphipoda	--	--	--	--	--	--
Ampithoe rubricata	--	4	--	--	--	7.2
Anoplodactylus lentus	--	--	--	--	--	--
Brachyura indet.	--	--	--	--	--	--
Calliopius laevisculus	16	16	20	32	8	165.6
Cancer borealis	--	4	--	--	--	7.2
Cancer irroratus	4	--	--	--	--	72
Caprella linearis	4	12	4	8	4	57.6
Caprella penantis	20	184	76	68	164	921.6
Caprella unica	--	--	--	4	--	7.2
Caridea indet.	--	--	--	--	--	--
Chironomidae	--	12	--	--	--	21.6
Corophium acutum	88	192	164	124	204	1,389.6
Corophium bonelli	8	52	20	--	68	266.7
Corophium insidiosum	16	32	12	28	40	230.4
Corophium insidiosum	652	280	1,244	516	440	5,637.6
Crangon septemspinosa	--	--	--	--	--	--
Decapoda indet.	--	--	--	--	--	--
Dexamine thea	344	424	136	160	492	2,620.8
Diastylis sculpta	--	--	--	--	--	--
Diastylis sp.	--	--	--	--	--	--
Edotea trilobata	--	--	4	--	--	7.2
Eualus pusiolus	4	--	--	4	--	14.4
Eudorella pusilla	4	--	--	--	--	7.2
Idotea balthica	16	12	8	--	8	79.2
Idotea phosphorea	8	4	32	--	48	165.6
Ischyrocerus anguipes	1,492	1,384	2,328	1,048	1,380	13,737.6
Jaera marina	--	--	--	--	--	--
Jassa falcata	324	1,332	228	688	904	6,364.8
Lamprops quadriplicata	--	--	--	--	--	--
Metopella angusta	12	--	--	--	--	21.6
Metropella carinata	--	--	--	--	4	7.2
Limnoria lignorum	4	--	--	--	--	7.2
Metopella carinata	16	4	12	--	--	57.6
Marinogammarus sp. A	12	--	--	--	12	43.2
Marinogommarus stoerensis	--	--	--	4	--	7.2
Metopella carinata	--	--	--	4	--	7.2
Natantia indet.	--	--	--	100	--	180.0
Pagarus arcuatus	4	--	--	--	--	7.2
Pagurus acadianus	--	--	12	--	--	21.6
Pagurus sp.	--	--	4	--	4	14.4
Phoxocephalus holbolli	--	--	4	--	--	7.2
Pleusymtes glaber	36	24	32	8	4	187.2
Pontogeneia inermis	444	540	284	252	248	3,182.4

PHYLUM Species	Replicate 1	2	3	4	5	Station (No./m²)
Proboloides holmesi	--	--	4	4	--	14.4
Stenopleustes inermis	444	540	284	252	248	3,182.4
Tanystylum orbiculare	--	--	--	--	--	--
Rhepoxynius hudsoni	--	--	--	--	--	--
ECHINODERMATA						
Amphipholis squamata	12	--	4	--	--	28.8
Asterias forbesi	16	8	--	--	--	43.2
Echinarachius parma	--	--	--	--	--	--
Henricia sanguinolenta	--	--	--	--	--	
Ophiopholis aculeata	12	--	--	12	--	43.2
Strongylocentrotus	--	--	--	--	--	--
droebachiensis	20	28	--	--	4	93.6
CHORDATA						
Colonial Ascidacea	--	--	--	--	--	--
Solitary Ascidacea	8	--	--	4	--	21.6

NUC153-A

INVESTIGATIONS OF ENTRAINMENT OF ICHTHYOPLANKTON AT PILGRIM NUCLEAR POWER STATION JANUARY - JUNE 1983

Prepared by: Lewis N. Scotton
Lewis N. Scotton
Senior Marine Fisheries
Biologist

Nuclear Management Services Department
Boston Edison Company
800 Boylston Street
Boston, MA 02199

October 1983

TABLE OF CONTENTS

*Appendix available upon request

FIGURES

TABLES

APPENDIX*

*Appendix available upon request.

JANUARY - JUNE
1983 ENTRAINMENT STUDY
SUMMARY

Ichthyoplankton samples were collected from the Pilgrim Nuclear Power Station discharge canal in triplicate, twice-monthly in January and February, and weekly March through June, 1983.

Eggs and/or larvae of 33 species of fish were obtained during the period January-June 1983.

No eggs were collected in January 1983. In February and March, the most abundant eggs were those of the American plaice, Hippoglossoides platessoides, followed closely by the Atlantic cod, Gadus morhua. Through March and April, Winter flounder eggs (Pseudopleuronectes americanus) were abundant. As in 1982, from early May through June the labrids and Atlantic mackerel (Scomber scombrus) were most abundant among the eggs. Windowpane (Scophthalmus aquosus) and Fourbeard rockling (Enchelyopus cimbris) were also abundant in late May. Labrids and Hake (Urophycis spp.) were abundant in June - September. Menhaden (Brevoortia tyrannus) were most abundant in September.

Larval collections were dominated by longhorn sulpin (Myoxocephalus octodecimspinosus) and rock gunnel (Pholis gunnellus) during the months of January through March, followed closely by sand lance (Ammodytes sp.) and grubby (Myoxocephalus aenaeus). Winter flounder (Pseudopleuronectes americanus) were prevalent during April and May, but were not abundant in June. Mackerel was

the most common larval species during June, followed closely by rockling and cunner (*Tautogolabrus adspersus*). Several larval rainbow smelt (*Osmerus mordax*) were collected in the May samples but not in June.

SECTION I

INTRODUCTION

This report summarizes the results of ichthyoplankton sampling conducted at the Pilgrim Nuclear Power Station (PNPS) during January through June 1983 by Marine Research, Inc., (MRI) for Boston Edison Company. MRI was also responsible for sample sorting and ichthyoplankton identification. Data analyses and report preparation were carried out by the Environmental and Radiological Health and Safety Group of Boston Edison Company's Nuclear Management Services Department.

This report is pursuant to operational environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (EPA) for Pilgrim Nuclear Power Station (PNPS), Unit I. The report describes organisms entrained at PNPS as determined by samples collected from the discharge canal.

Methods are discussed in Section II and results in Section III.

SECTION II

METHODS

The entrainment sampling plan for January-June 1983 at the PNPS specified triplicate samples to be collected twice monthly in January and February and weekly from March through June. All samples were collected from rigging mounted approximately 30 meters from the headwall of the discharge canal (Fig. 1) at low tide during daylight. A 0.333-mm mesh, 60-cm diameter plankton net affixed to this rigging was streamed in the canal for 6 to 15 minutes depending on the abundance of plankton and detritus. In each case, a minimum of 100 m^3 of water was sampled. Exact filtration volumes were calculated with the aid of a digital flowmeter (General Oceanics Model 2030) mounted in the mouth of the net.

All samples were preserved in 10% formalin and returned to the laboratory for microscopic analysis. All fish eggs and larvae were identified to the lowest distinguishable taxonomic category and counted (these tasks were conducted by MRI). In most cases, species were identifiable. In certain cases, however, eggs--particularly in the early stages of development--could not be identified at the species level in the preserved samples. In such cases, species were grouped. A brief description of each of these egg groupings is given below.

- Gadidae-*Glyptocephalus* group (Atlantic cod, *Gadus morhua*; haddock, *Melanogrammus aeglefinus*; pollock, *Pollachius virens*; and witch flounder, *Glyptocephalus cynoglossus*); egg diameters overlap, no oil globule present.

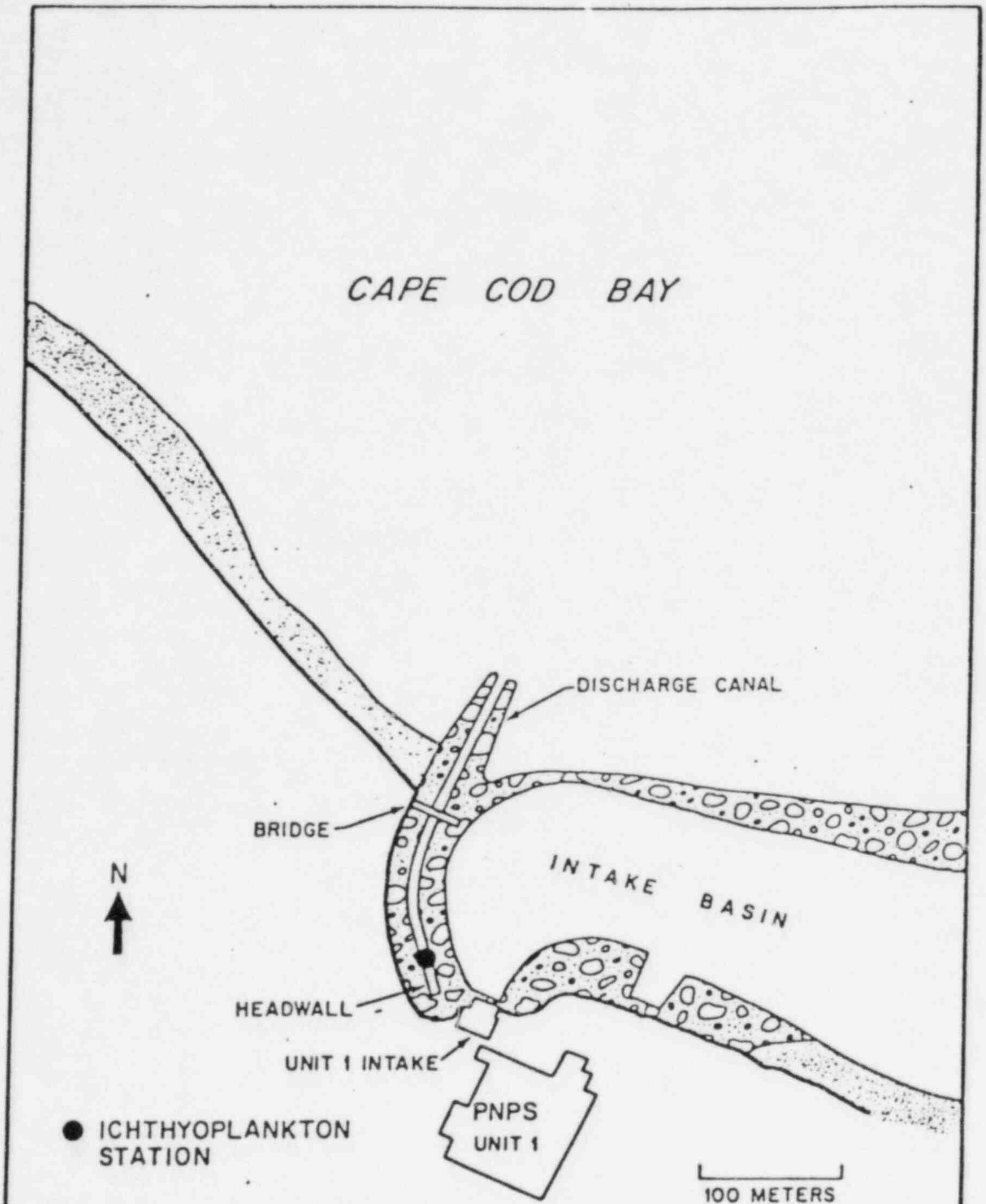


Figure 1: Entrainment sampling station in PNPS discharge canal.

Stage III eggs (those containing embryos whose tails have grown free of the yolk; Ahlstrom and Counts, 1955) are separated based on relative size and pigmentation combinations. Haddock eggs are difficult to identify until shortly before hatching (late stage III). Because of this, some early stage III haddock eggs may have been identified as cod eggs. This error should be quite small judging from the relatively low numbers of late stage III haddock eggs and haddock larvae collected during recent years. The gadidae-*Glyptocephalus* grouping was not necessary in January and February because it is unlikely that witch flounder spawn during these months, and haddock spawning is not likely to occur in January. We assumed haddock eggs were absent in February. All eggs of the gadidae-*Glyptocephalus* type were therefore classified as either cod or pollock based on differing egg diameters.

- *Brosme*-*Scomber* group (cusk, *Brosme brosme*, and Atlantic mackerel, *Scomber scombrus*): egg and oil globule diameters overlap. Differences in pigmentation permit separation of stage II (early embryo) and stage III eggs.

- *Enchelyopus*-*Urophycis*-*Peprilus* group (fourbeard rockling, *Enchelyopus cimbrius*; hake, *Urophycis* spp.; and butterfish, *Peprilus triancathus*): egg and oil globule diameters overlap. Stage III eggs are separated based on differences in embryonic pigmentation.

- *Merluccius*-*Stenotomus*-*Cynoscion* group (silver hake, *Merluccius bilinearis*; scup, *Stenotomus chyrysops*; and weakfish, *Cynoscion regalis*): egg and oil globule diameters overlap. Stage III eggs are separated into silver hake

and scup-weakfish based on differences in embryonic pigmentation. Scup and weakfish eggs, which have rarely been taken, remain grouped throughout their development because differences in embryonic pigmentation are subtle and not clearly understood.

- Labridae-Limanda group (tautog, Tautoga onitis; cunner, Tautogolabrus adspersus; and yellowtail flounder, Limanda ferruginea): no oil globule present, egg diameters overlap. Stage III eggs are separated into labridae and yellowtail flounder based on differences in embryonic pigmentation. A high percentage of the two species of labrid eggs are distinguishable, but only with individual, time-consuming measurement (Marine Research, 1977a). Labrid eggs are therefore grouped in all three stages of development in the 1982 samples.

- Paralichthys-Scophthalmus group (fourspot flounder, Paralichthys oblongus, and windowpane, Scophthalmus aquosus): oil globule and egg diameters as well as pigmentation are quite similar. Separation of these two species, even at stage III, remains uncertain. They are therefore grouped in all cases.

Eggs of the bay anchovy (Anchoa mitchilli) and striped anchovy (Anchoa hepsetus) are easily distinguishable, but their larvae are not. Eggs of these fishes were therefore listed by species while the larvae are listed simply as Anchoa spp.

Several other groups of eggs and larvae were not identified to the species level because adequate descriptions of each species are not available at this time. These groupings are as follows:

- Urophycis spp. - consists of the red hake (U. chuss), the spotted hake (U. regius), and the white hake (U. tenuis). Most larvae (and eggs) in this genus collected at PNPS are probably the red hake (see summary in Hardy 1978).

- Menidia spp. - consists of the tidewater silverside (M. beryllina) and Atlantic silverside (M. menidia). Atlantic silverside larvae are probably more likely to occur as far north as Plymouth based on their more northern distribution.

- Ammodytes sp. - No species designation was given the sand lance because considerable taxonomic confusion exists in the literature (see for example Richards et al. 1963; Scott 1968, 1972; Winters 1970). Meyer et al. (1979) examined adults collected on Stellwagen Bank and classified them as A. americanus (= A. hexapterus). This population is probably the source of larvae entrained at PNPS.

- Prionotus spp. - consists of the northern seaobin (P. carolinus) and the striped searobin (P. evolans).

- Liparis spp. - generally we are now separting Liparis spp. Most of these are L. atlanticus or L. coheni. They can also include striped seasnail

(L. liparis). Most of those collected at PNPS are probably L. atlanticus based on an identification by K. W. Able (personal communication, July 1978).

Because of particular interest in rainbow smelt (Osmerus mordax), cunner, and winter flounder (Pseudopleuronectes americanus), larvae of these species were classified into three or four arbitrary developmental stages. These stages and corresponding length ranges are given below.

Rainbow smelt

Stage I - From hatching until the yolk sac is fully absorbed (5-7 mm TL).

Stage II - From the end of stage I until dorsal fin rays become visible (6-12 mm TL).

Stage III - From the end of stage II onward (11.5-20 mm TL).

Cunner

Definitions of developmental stages are the same as for smelt larvae. Observed size ranges for each stage are: stage I, 1.6-2.6 mm TL; stage II, 1.8-6.0 mm TL; stage III, 6.5-14 mm TL.

Winter flounder

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

Stage II - From the end of stage I until a loop or coil forms in the gut (2.6-4 mm TL).

Stage III - From the end of stage II until the left eye migrates past the midline of the head during transformation (3.5-8 mm TL).

Stage IV - From the end of stage III onward (7.3-8.2 mm TL).

In most cases, entire samples were examined for fish larvae and the less common types of fish eggs. When a particular species was especially abundant, aliquot subsamples were taken. Such subsamples contained 100 or more specimens of a given species or grouping. Unpublished studies by Marine Research have indicated that subsampling error can be maintained at a low level if the number of specimens in an aliquot increases as the fraction represented by the aliquot grows smaller, e.g., 100 larvae are sufficient in a one-half split, but 200 should be present in a one-quarter split.

SECTION III

RESULTS

A. Ichthyoplankton Entrained

Population densities, per 100 m^3 of water, listed by date, station, and replicate for all samples collected in January-June 1983 are presented in the Appendix (available upon request). The occurrence of eggs and larvae of each species by month is summarized in Table 1. The occurrence of eggs and larvae over the period 1975-1982 and January-June 1983, are shown in Table 2. Table 3 lists the mean monthly densities of the numerically dominant fish eggs and larvae at PNPS for the period 1975-1982.

The ichthyoplankton collected may be summarized as follows:

January: No eggs were collected in January, 1983.

Five species of fishes were represented in the January larval collections. Longhorn sulpin composed 47% of the catch, with a monthly mean density of 3.8 larvae per 100 m^3. The other dominant species, represented were rock gunnel (Pholis gunnellus) (28%), and Atlantic herring, Clupea harengus harengus (13%).

February: Eight species of fish were collected, two species as eggs and seven as larvae. Plaice were the dominant egg with 56% of the catch. They were followed by cod which had a mean density of 0.3 per 100 m^3 accounting for about 44% of the egg catch. Larval collections were dominated by rock gunnel and sculpin with mean densities over the month of 4.0 and 1.9 per 100 m^3 of water, respectively. These two species accounted for 56.9% and 27.1%, respectively, of all larvae collected. The grubby (Myoxocephalus aenaeus) and sand lance together represented 29.2% of larvae collected.

March: The species count rose to 11 during the month. Three species were represented by eggs - plaice, cod, and winter flounder. Plaice represented 55% of the egg catch, and cod eggs were identified as Gadus morhua, not merely as part of the gadid - Glytocephalus grouping, and represented about 37% of the egg catch.

As in March 1982, ten species of fish were represented by larvae in March. Sand lance accounted for 26% of the month's catch with a monthly mean density per 100 m^3 of water of 7.2. Grubby and rock gunnel larvae composed an additional 46.4% of the month's larval catch. Their monthly mean densities were 6.7 and 6.4 per 100 m^3, respectively. Also the seasnails (Liparis spp.) comprised about 6.5% of the catch. Liparis coheni represented the second species of seasnail found, with L. atlanticus being the most common.

Other species represented included the wrymouth, (Cryptacanthodes maculatus), plaice, and winter flounder.

April: Only sixteen species were taken during the month, ten of these represented by eggs. Yellowtail flounder (Limanda ferruginea) were most abundant, followed by plaice and winter flounder eggs. Fourbeard rocking (Enchelyopus cimbrius) and cod composed most of the remainder of the catch.

Larvae representing only 10 species, versus 17 for April, 1982, were found. Sand lance rose to first place with a mean density over the month of 16.2 larvae per 100 m^3 of water accounting for 31.3% of the month's catch. Seasnail were the second most abundant, representing 29% of the catch, and grubby accounted for an additional 13.5% of the catch. Maximum weekly mean densities for the seasnail and grubby were 54.6 and 14.5 per 100 m^3, respectively.

May: Of the 21 species of fish collected in the May ichthyoplankton samples, 13 were represented by eggs. Mackerel eggs accounted for 36% of the egg total, becoming abundant in the second half of May. The Brosme-scomber egg grouping was second and the labrid-Limanda eggs were third in abundance. Over the month, weekly mean densities for the mackerel grouping ranged from 0 per 100 m^3 on May 2 and May 9 to 176 per 100 m^3 on May 17. Brosme-scomber eggs accounted for 26.3% of the eggs, with a mean density calculated over the month of 48 eggs per 100 m^3.

Fourteen species of fish larvae were taken in the May samples. Radiated shanny, winter flounder, seasnail and sand lance dominated the catch accounting for 89% of the total. Weekly shanny densities ranged from 8.4 to 57.1 per 100 m^3. Sand lance was not as dominant this year as in previous years. Fourbeard rockling, American plaice and sculpin accounted for an additional 11% of the larval catch. Mackerel were not collected. Several rainbow smelt (Osmerus mordax) larvae were found.

June: The species count reached 23 in June. Labrid eggs clearly dominated among the 15 species of eggs collected, assuming they dominated the labrid-Limanda group.* Combined with the grouped eggs they composed 94% of the June egg total with weekly mean densities averaging 7168 per 100 m^3 of water. Atlantic mackerel, Brosme-scomber, the Paralichthys-Scophthalmus and Enchelyopus-Urophycis-Peprilus egg groupings accounted for 5% of the remaining eggs. Within these two groups fourspot flounder and butterfish were probably comparatively uncommon, judging by very few of each of these species being collected in June.

---

*During the month of June, yellowtail flounder stage III eggs averaged 2.7 per 100 m^3 of water, respectively. These figures are quite low relative to the densities of stage III labrid eggs, and cunner and tautog larvae. Therefore the vast majority of labrid - Limanda eggs are assumed to be labrid eggs during June.

Seventeen species of fishes were represented by larvae. Atlantic mackerel accounted for 69% of the larvae. Rockling and cunner accounted for 15.5% of the larval densities with monthly mean densities of 13.6 and 12.6 per 100 m^3 of water, respectively. Winter flounder and Atlantic menhaden (*Brevoortia tyrannus*) represented about 1% of the catch with a mean density of 0.4 larvae per 100 m^3 of water. *Osmerus mordax* (Rainbow smelt) were not collected. Sand lance were absent from egg collections and barely represented in the larvae.

Table 2 summarizes by year all species by eggs and larvae collected in the PNPS discharge canal from 1975-1982, and January-June 1983. Monthly mean densities for the numerically dominant species of eggs and larvae taken in January-June 1983 are summarized in Table 3. Similar data for 1975 through 1979 were also tabulated for comparison after being standardized as follows:

1. Only 0.333-mm mesh net data were used in those cases (1975) when field sampling was carried out using both 0.333 and 0.505 mesh nets.

2. When, as in 1976 and 1977, 24-hour sampling series were conducted, the samples taken nearest the time of daylight low tide were selected for comparison, since this conforms to the routine specification for the time of entrainment sampling.

3. For the same reason only daylight low tide data were used when, in 1975, samples were also taken at high tide and/or at night.

4. Cod and pollock egg densities were summed to make up the category "gadidae" since these eggs, which are listed separately in recent reports, were not distinguished in earlier ones.

5. Sculpin larvae were identified to species beginning in 1979 following Khan (1971). They appear as Myoxocephalus spp. in Table 3 for comparison with past years.

Although samples were in fact taken once in April 1976 and once in March 1977, comparisons with other years when sampling was weekly are not valid

and consequently do not appear in the Table. Data collected in 1974 were not included because samples were not collected at low tide in all cases. Mean larval densities are summarized in Table 3. As indicated in Table 3, ichthyoplankton densities recorded in 1980 do not appear unusual. In each case, densities fell within the level of variation observed over the previous four years.

B. Lobster Larvae Entrained

No lobster larvae were collected for January-June 1983. This compares with past years as follows:

1982:	1 larva - stage I
1981:	1 larva - 1 stage IV
1980:	none found.
1979:	1 larva - 1 stage I on July 14.
1978:	none found.
1977:	3 larvae - 1 stage I on June 10; 2 stage I on June 17.
1976:	2 larvae - 1 stage I on July 22; 1 stage IV-V on August 5.
1975:	1 larva - 1 stage I, date unknown.
1974:	none found.

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

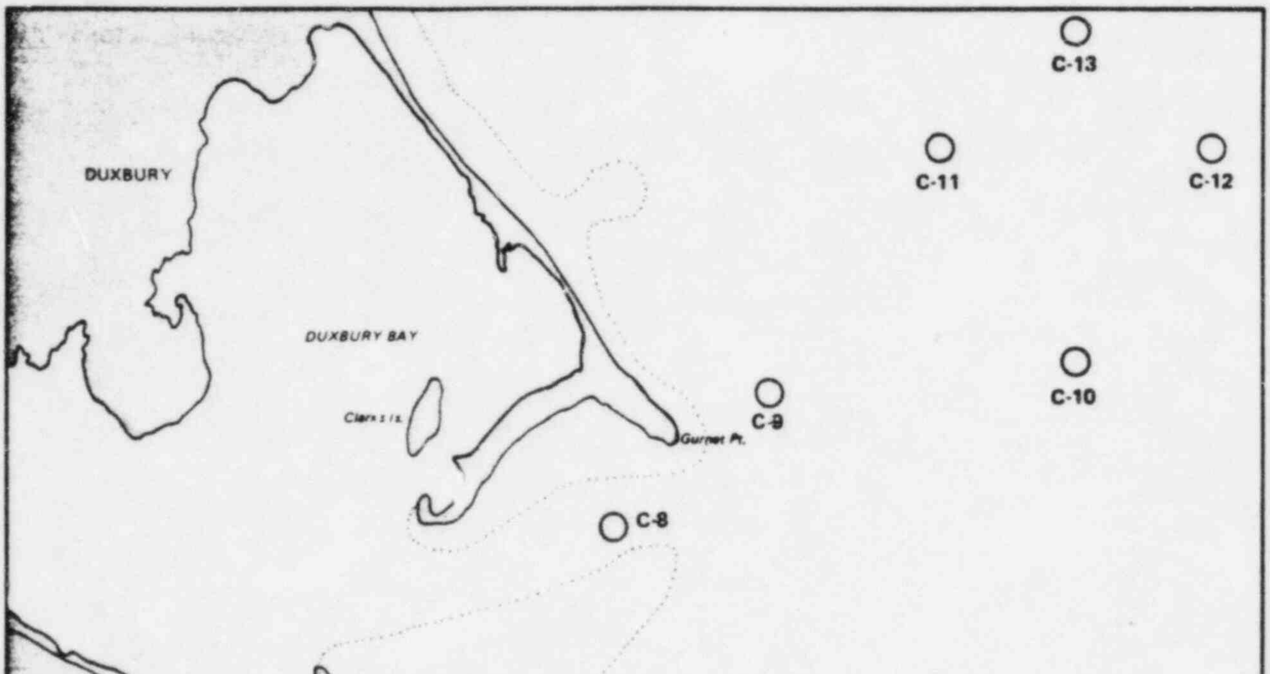


Figure 2. Location of Entrainment Contingency Plan Sampling Stations, C.

C. Contingency Sampling Plan Notification

Since the Cape Cod Bay ichthyoplankton surveys stopped in 1976, the entrainment monitoring program has always included a special contingency sampling plan (Fig. 2). This plan was designed to be implemented if the eggs or larvae of any species appear in unusually large numbers in the discharge canal when compared with previous years. For the 1983 entrainment program, as in 1981 & 1982, we attempted to quantify "unusually large" by defining it as any mean density (per 100 m^3 of water) which is 50% greater than the highest mean density recorded on or near that date over the past six years (1976-1982) as recorded in previous entrainment reports. BECo. was notified by MRI three times in January-June 1983 of the occurrence of unusually large numbers. No extra sets of entrainment samples were required to be taken since numbers returned to acceptable ranges. No bay contingency program had to be carried out.

SECTION IV

CONCLUSIONS

Fish eggs and larval densities from the PNPS entrainment collections for the period January - June 1983 fell within the level of variation observed during this period over the previous five years. The numbers entrained were not large enough to require the Cape Cod Bay contingency sampling program to be implemented.

The frequency of occurrence and levels of abundance of species represented by eggs and larvae in January - June 1983 were very similar to previous years.

Table 1: Species of fish eggs (E) and larvae (L) obtained in ichthyoplankton collections from the Pilgrim Nuclear Power Station discharge canal, January-June, 1983.

Species		Jan	Feb	Mar	Apr	May	Jun
Atlantic menhaden	Brevoortia tyrannus						E/L
Atlantic herring	Clupea harengus harengus	L	L	L	L	L	
Anchovy	Anchoa spp.						
Bay Anchovy	Anchoa mitchilli						
Rainbow Smelt	Osmerus mordax				L	L	
Goosefish	Lophius americanus						E
Cusk	Brosme brosme						E
Fourbeard rockling	Enchelyopus cimbrius				E/L	E/L	E/L
Atlantic cod	Gadus morhua		E/L	E	E	E	E/L
Haddock	Melanoarammus aeglefinus					L	
Atlantic Tomcod	Microgadus tomcod					L	
Silver hake	Merluccius bilinearis						E/L
Pollock	Pollachius virens						
Hakes	Urophycis spp.				E		E/L
Silversides	Menidia spp.					L	E/L
Northern pipefish	Syngnathus fuscus						J*
Wrasses	Labridae					E	E
Tautog	Tautoga onitis						L
Cunner	Tautogolabrus adspersus						L
Goby	Gobiosoma ginburgi						
Radiated shanny	Ulvaria subbifurcata				L	L	L

*J = Juvenile

Table 1 (Continued).

Species		Jan	Feb	Mar	Apr	May	Jun
Rock gunnel	Pholis gunnellus	L	L	L	L	L	
Snakeblenny	Lumpenus lumpretaeformis						
Sand lance	Ammodytes sp.	L	L	L	L	L	L
Wrymouth	Cryptaeanthodes maculatus			L			
Atlantic mackerel	Scomber scombrus					E	E/L
Butterfish	Peprilus triacanthus					E	E/L
Searobin	Prionotus spp.						E/L
Lumpfish	Cyclopterus lumpus				E	E	
Grubby	Myoxocephalus aenaeus	L	L	L	L/E	L	
Longhorn sculpin	Myoxocephalus octodecimspinosus		L	L			
Shorthorn sculpin	Myoxocephalus scorpius						
Alligatorfish	Aspidophoroides monopterygius						
Seasnail	Liparis coheni	L	L	L			
	Liparis atlanticus			L	L	L	L
Fourspot flounder	Paralichthys oblongus					E	E
Windowpane	Scophthalmus aquosus				E		L
Witch flounder	Glyptocephalus cynoglossus				E	E	E/L
American plaice	Hippoglossoides platessoides		E	E/L	E/L	E/L	
Yellowtail flounder	Limanda ferruginea				E	E/L	E
Winter flounder	Pseudopleuronectes americanus			E/L	E/L	E/L	L
Smooth flounder	Liopsetta putnami						
Hogchoker	Trinectes maculatus						

Table 2: Species of fish eggs (E) and larvae (L) collected in the PNPS discharge canal from 1975-1982, and January-June, 1983.

	Species	1975	1976	1977	1978	1979	1980	1981	1982	1983
American eel	*Anguilla rostrata*	J	J	J		J	J			
Alewife/blueback herring	*Alosa* spp.		L	L	J	L				
Atlantic menhaden	*Brevoortia tyrannus*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Atlantic herring	*Clupea harengus harengus*	L	L	L	L	L	L	L	L	
Anchovy	*Anchoa* spp.	L		L	L	L		E/L	E/L	
Bay anchovy	*Anchoa mitchilli*			E	E	E			E/L	
Rainbow smelt	*Osmerus mordax*	L	L	L	L	L	-	E/L	L	L
Goosefish	*Lophius americanus*	E/L	E	E/L	E/L	E/L	L	E/L	E/L	E
Cusk	*Brosme brosme*	E/L	E/L	E/L		E/L	E/L	E	E	E
Fourbeard rockling	*Enchelyopus cimbrius*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Atlantic cod	*Gadus morhua*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Haddock	*Melanogrammus aeglefinus*	L	E/L	E/L	E/L	L				L
Silver hake	*Merluccius bilinearis*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Atlantic tomcod	*Microgadus tomcod*			L	L		L	L	L	L
Pollock	*Pollachius virens*	E/L	E/L	E	E/L	E/L	E/L	L		
Hakes	*Urophycis* spp.	E/L	E/L	E/L	E/L	E	E/L	E/L	E/L	E/L

*J = Juvenile

Table 2: (Continued).

Species		1975	1976	1977	1978	1979	1980	1981	1982	1983
Rock gunnel	Pholis gunnellus	L	L	L	L	L	L	L	L	L
Wrymouth	Cryptacanthodes maculatus				L	L		L	L	L
Sand lance	Ammodytes sp.	L	L	L	L	E/L	L	L	L	L
Seaboard goby	Gobiosoma ginsburgi	L		L					L	
Atlantic mackerel	Scomber scombrus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Butterfish	Peprilus triacanthus	E/L	E/L	E/L	E	E	E/L	E/L	L	E
Searobins	Prionotus spp.	E/L	E		E	E	E/L	E/L	E	E/L
Sculpin	Myoxocephalus spp.	L	L	L	L	L	L	L	L	E/L
Alligatorfish	Aspidophoroides monopterygius					L		L		
Lumpfish	Cyclopterus lumpus		L	L				L	L	E
Seasnail	Liparis atlanticus	L	L	L	L	L	L	L	L	L
	Liparis coheni									L
Smallmouth flounder	Etropus microstomus	L								
Summer flounder	Paralichthys dentatus	E/L								
Fourspot flounder	P. oblongus		E/L	E/L		L	E/L	E/L	E/L	E
Windowpane	Scophthalmus aquosus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Witch flounder	Glyptocephalus cynoglossus	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L

Table 2: (Continued).

	Species	1975	1976	1977	1978	1979	1980	1981	1982	1983
Cusk-eels/Eelpouts	Ophidiidae-Zoarcidae	L								
Atlantic needlefish	*Strongylura marina*			L				L		
Killifish	*Fundulus* spp.		E	E						
Mummichog	*Fundulus heteroclitus*					E				
Striped killifish	*F. majalis*					J				
Silversides	*Menidia* spp.		L	L	L	L	E/L	E/L	E	E/L
Atlantic silverside	*Menidia menidia*	E/L	E/L	E						
Northern pipefish	*Syngnathus fuscus*	J	J	J	J	J	J	J	J	J
Black sea bass	*Centropristis striata*	L					L			
Weakfish	*Cynoscion regalis*						L			
Scup	*Stenotomus chrysops*	L		L						
Northern kingfish	*Menticirrhus saxatilis*	L				L				
Wrasses	Labridae	E	E	E	E	E	E	E	E	E
Tautog	*Tautoga onitis*	L	L	L	L	L	L	L	L	L
Cunner	*Tautogolabrus adspersus*	L	L	L	L	L	L	L	L	L
Snakeblenny	*Lumpenus lumpretaeformis*	L						L		
Radiated shanny	*Ulvaria subbifurcata*	L	L	L	L	L	L	L	L	L

*J = Juvenile

Table 2: (Continued).

Species		1975	1976	1977	1978	1979	1980	1981	1982	1983
American plaice	*Hippoglossoides platessoides*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Yellowtail flounder	*Limanda ferruginea*	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L	E/L
Winter flounder	*Pseudopleuronectes americanus*	E/L	E/L	L	E/L	E/L	E/L	E/L	E/L	E/L
Hogchoker	*Trinectes maculatus*			E	E			E	E	
Northern puffer	*Sphoeroides maculatus*			L						
Smooth Flounder	*Liopsetta putnami*							L	E/L	

Table 3: Mean monthly densities of the numerically dominant fish eggs and larvae entrained at the Pilgrim Nuclear Power Station, January-December, 1975-1982 and January-June, 1983. The total column represents the total for all species collected by month. See text for details.

Format: Mean / Range

	JANUARY 1975	1976	1977	1978	1979
EGGS					
Gadidae-Glyptocephalus	-			-	-
Gadidae*	0.5 / 0 - 1			0.2 / 0 - 0.7	2.2 / 0 - 5
Enchelyopus-Urophycis-Peprilus	-			-	-
Enchelyopus cimbrius**	0.1 / 0 - 0.6			0	0
Urophycis spp.	0			0	0
Labridae-Limanda	0			0	0
Labridae	0			0	0
Scomber scombrus	0			0	0
Paralichthys-Scophthalmus	0			0	0
Total	0.6 / 0 - 1			0.2 / 0 - 0.7	2.7 / 0 - 5
LARVAE					
Clupea harengus harengus	0.2 / 0 - 0.6			0	0
Enchelyopus cimbrius	0			0	0
Tautogolabrus adspersus	0			0	0
Ulvaria subbifurcata	0			0	0
Pholis gunnellus	0.7 / 0 - 3			5.1 / 2 - 9	1.0 / 0 - 5
Ammodytes sp.	6.7 / 0 - 18			1.4 / 0 - 4	4.8 / 0 - 11
Scomber scombrus	0			0	0
Myoxocephalus spp.	1.4 / 0 - 6			0.3 / 0 - 1	0.5 / 0 - 1
Liparis spp.	0			0	0
Pseudopleuronectes americanus	0			0	0
Total	9.4 / 0 - 25			7.4 / 3 - 13	8.1 / 0 - 12

*Represents all three egg stages from January through February.
**Represents all three egg stages from January through March.

Table 3: (Continued) Format: Mean / Range

	JANUARY 1980	JANUARY 1981	1982	1983
EGGS				
Gadidae-Glyptocephalus	-	0	0	0
Gadidus morhua	2.8 / 0.3-6.2	3.4 / 2.2-9.1	0.5 / 0-1.2	0
Enchelyopus-Urophycis-Peprilus	-	0	0	0
Enchelyopus cimbrius**	0	0	0	0
Urophycis spp.	0	0	0	0
Labridae-Limanda	0	0	0	0
Labridae	0	0	0	0
Scomber scombrus	0	0	0	0
Paralichthys-Scophthalmus	0	0	0	0
Total	2.8 / 0.3-6.2	3.4 / 0.8-9.1	1.1 / 0-1.20	0
LARVAE				
Clupea harengus harengus	0	0.1 / 0 - 0.4	0.1 / 0-0.6	1.0 / 0-1.9
Enchelyopus cimbrius	0	0	0	0
Tautogolabrus adspersus	0	0	0	0
Ulvaria subbifurcata	0	0	0	0
Pholis gunnellus	.3 / 0-1.2	0.06 / 0-0.4	0.1 / 0-.6	2.3 / 0.5-5.3
Ammodytes sp.	16 / 0.-38.4	1.6 / 2.3-4.8	0.6 / 0-1.2	0.75 / 0-1.49
Scomber scombrus	0	0	0	0
Myoxocephalus spp.	.3 / 0-0.6	0	0.3 / 0-1.2	3.8 / 0-11.5
Liparis spp.	0	0	0	0.16 / 0-0.5
Pseudopleuronectes americanus	0	0	0	0
Total	17.0 / 0-39.0	1.8 / 0-4.8	1.1 / 0-2.43	8.2 / 3.9-13.5

**Represents all three egg stages from January through March.

Table 3 (Continued). Format: Mean/Range

	FEBRUARY 1975	1976	1977	1978	1979
EGGS					
Gadidae-Glyptocephalus	-			-	-
Gadidae*	0.9 / 0 - 3			2.4 / 0 - 5	1.6 / 0 - 3
Enchelyopus-Urophycis-Peprilus	-			-	-
Enchelyopus cimbrius**	0			0	0
Urophycis spp.	0			0	0
Labridae-Limanda	0			0	0
Labridae	0			0	0
Scomber scombrus	0			0	0
Parlichthys-Scophthalmus	0			0	0
Total	1.0 / 0 - 3			2.5 / 0 - 5	1.6 / 0 - 3
LARVAE					
Clupea harengus harengus	0.1 / 0 - 0.5			0.6 / 0 - 2	0
Enchelyopus cimbrius	0			0	0
Tautogolabrus adspersus	0			0	0
Ulvaria subbifurcata	0			0	0
Pholis gunnellus	3.7 / 0 - 14			1.2 / 0 - 3	2.9 / 0 - 10
Ammodytes sp.	2.1 / 0 - 8			8.8 / 0.6 - 24	11.1 / 4 - 21
Scomber scombrus	0			0	0
Myoxocephalus spp.	2.2 / 0 - 7			0.2 / 0 - 1	6.6 / 0 - 26
Liparis spp.	0			0	0
Pseudopleuronectes americanus	0			0	0
Total	10.8 / 0 - 17			11.0 / 0.8 - 29	20.9 / 4 - 58

*Represents all three egg stages from January through February.
**Represents all three egg states from January through March.

Table 3: (Continued) — Format: Mean / Range

	FEBRUARY 1980	1981	1982	1983
EGGS				
Gadidae-*Glyptocephalus*	-	0	0	0
Gadidae*	1.5 / 0.3-2.9	1.1 / 0-2.5	0.1 / 0-0.6	0.3 / 0-1.0
Enchelyopus-*Urophycis*-*Peprilus*	-	0	0	0
*Enchelyopus cimbrius***	0	0	0	0
Urophycis spp.	0	0	0	0
Labridae-*Limanda*	0	0	0	0
Labridae	0	0	0	0
Scomber scombrus	0	0	0	0
Paralichthys-*Scophthalmus*	0	0	0	0
Total	1.8 / 0.8-2.9	3.5 / 0-13.0	0.1 / 0-1.2	0.6 / 0.5-2.1
LARVAE				
Clupea harengus harengus	0	0	0	0.29 / 0-1.7
Enchelyopus cimbrius	0	0	0	0
Tautogolabrus adspersus	0	0	0	0
Ulvaria subbifurcata	0	0.1 / 0-.4	0	0
Pholis gunnellus	0.6 / 0-1.6	2.1 / 3.7-4.6	0.5 / 0-2.6	4.0 / 0.6-1.8
Ammodytes sp.	3.1 / 0.4-7.6	10.2 / 2.6-15.7	2.7 / 0-9.1	0.4 / 0.5-1.4
Scomber scombrus	0	0	0	0
Myoxocephalus spp.	1.9 / 0-4.7	0	0.1 / 0-0.6	1.9 / 0.5-0.6
Liparis spp.	0	0	0	0.3 / 0-0.9
Pseudopleuronectes americanus	0	0	0	0
Total	5.9 / 1.5-9.7	14.8 / 2.6-24.1	3.5 / 0-23.4	7.1 / 4.9-11.4

*Represents all three egg stages from January through February.
**Represents all three egg stages from January through March.

Table 3 (Continued). Format: Mean / Range

	MARCH 1975	1976	1977+	1978	1979
EGGS					
Gadidae-Glyptocephalus	0.6 / 0 - 2			1.5 / 0 - 3	9.2 / 0 - 32
Gadidus* Morhua	0.8 / 0 - 3			0.5 / 0 - 1	0.5 / 0 - 3
Enchelyopus-Urophycis-Peprilus	-			-	-
Enchelyopus cimbrius**	0			0	0
Urophycis spp.	0			0	0
Labridae-Limanda	0			0	0
Labridae	0			0	0
Scomber scombrus	0			0	0
Parlichthys-Scophthalmus	0			0	0
Total	9.7 / 0.8 - 41			2.8 / 0 - 5	12.1 / 0.4 - 35
LARVAE					
Clupea harengus harengus	0.8 / 0 - 2			0	0.4 / 0 - 1
Enchelyopus cimbrius	0			0	0
Tautogolabrus adspersus	0			0	0
Ulvaria subbifurcata	0			0	0
Pholis gunnellus	34.0 / 26 - 47			11.2 / 0.7 - 28	9.3 / 1 - 34
Ammodytes sp.	29.5 / 11 - 60			11.1 / 0.7 - 22	54.0 / 9 - 228
Scomber scombrus	0			0	0
Myoxocephalus spp.	61.4 / 17 - 137			32.8 / 11 - 65	12.3 / 1 - 35
Liparis spp.	0.5 / 0 - 1			0	0.4 / 0 - 4
Pseudopleuronectes americanus	0			0	0.03 / 0 - 0.5
Total	127.5 / 66 - 236			55.7 / 26 - 96	76.8 / 11 - 293

*Represents all three egg stages from January through February.
**Represents all three egg states from January through March.

Table 3: (Continued) Format: Mean / Range

	MARCH 1980	1981	1982	1983
EGGS				
Gadidae-Glyptocephalus	.3 0-1.7	0	0	0.6 0-3.1
Gadidus morhua	.8 0-.5	1.5 0-8.5	0.4 0-1.8	5.2 1.0-23.7
Enchelyopus-Urophycis-Peprilus	-	0	0	0
Enchelyopus cimbrius**	0	0	0	0
Urophycis spp.	0	0	0	0
Labridae-Limanda	0	0	0	0
Labridae	0	0	0	0
Scomber scombrus	0	0	0	0
Paralichthys-Scophthalmus	0	0	0	0
Total	1.9 0-12	6.9 0.5-20.1	1.3 0-8.9	13.9 1.6-40.4
LARVAE				
Clupea harengus harengus	0.1 0-1.9	2.4 0-8.4	0.3 0-1.8	4.3 1.0-9.5
Enchelyopus cimbrius	0	0	0	0
Tautogolabrus adspersus	0	0	0	0
Ulvaria subbifurcata	0	0.1 0-.5	0	0
Pholis gunnellus	22.5 0-80.5	23.7 1-62.4	18.7 17.8-34.2	6.4 2.6-24.7
Ammodytes sp.	43 1-153	35.5 9.6-78.6	190.0 0-612.7	7.2 0-29.2
Scomber scombrus	0	0	0	0
Myoxocephalus spp.	63.1 1.1-181.9	0.04 0-.5	27.6 0-77.7	6.7 0-16.9
Liparis coheni	4.9 0-18.2	0	0.1 0.09	1.9 0-7.7
Pseudopleuronectes americanus	.15 0-0.7	.11 0-3	2.6 0-11.9	1.3 0-6.7
Total	26.8 3.2-382.2	99.6 42.6-169.1	240.6 31.1-714.2	28.1 1.0-83.2

*Represents all three egg stages from January through February.
**Represents all three egg stages from January through March.
+A single set of samples was taken in 1977. These data were not included in this comparison because weekly data sets were available in 1975, 1978, 1979, 1980 and 1981.

Table 3 (Continued).

Format: Mean / Range

	1975	1976+	APRIL 1977	1978	1979
EGGS					
Gadidae-Glyptocephalus	1.7 / 0 - 5		0.7 / 0 - 2	8.1 / 2 - 14	3.5 / 0.8 - 12
Gadidae*	2.4 / 0 - 6		0.3 / 0 - 3	8.4 / 0.6 - 14	1.1 / 0 - 3
Enchelyopus-Urophycis-Peprilus	0		0.3 / 0 - 1	0.1 / 0 - 1	0
Enchelyopus cimbrius**	2.9 / 0 - 10		0.2 / 0 - 2	0	0.3 / 0 - 2
Urophycis spp.	0		0.1 / 0 - 0.8	0	0
Labridae-Limanda	4.8 / 0 - 18		2.5 / 0 - 7	11.1 / 0 - 26	8.1 / 0 - 28
Labridae	0		0.2 / 0 - 0.9	0.5 / 0 - 3	0.08 / 0 - 1
Scomber scombrus	0			0	0
Parlichthys-Scophthalmus	0.1 / 0 - 0.7		0	0	0
Total	33.4 / 1 - 84		10.2 / 1 - 18	63.1 / 8 - 114	73.9 / 4 - 546
LARVAE					
Clupea harengus harengus	1.3 / 0 - 12		0.1 / 0 - 1	0.3 / 0 - 2	0.6 / 0 - 3
Enchelyopus cimbrius	0		0	0	0
Tautogolabrus adspersus	0		0	0	0
Ulvaria subbifurcata	5.4 / 0 - 19		3.9 / 0 - 19	0.2 / 0 - 2	0.3 / 0 - 1
Pholis gunnellus	1.8 / 0 - 8		4.0 / 0 - 19	1.5 / 0 - 5	3.7 / 0 - 13
Ammodytes sp.	6.6 / 0.8 - 18		36.8 / 6 - 85	388.8 / 6 - 1252	92.1 / 26 - 196
Scomber scombrus	0		0	0	0
Myoxocephalus spp.	7.2 / 3 - 12		30.7 / 14 - 57	21.3 / 0 - 57	16.3 / 1 - 32
Liparis spp.	3.5 / 0 - 11		16.9 / 0 - 72	1.8 / 0 - 7	2.1 / 0 - 8
Pseudopleuronectes americanus	3.1 / 0.8 - 10		9.5 / 0 - 21	35.6 / 0 - 127	2.9 / 0 - 8
Total	29.7 / 14 - 43		103.1 / 55 - 154	458.2 / 21 - 1324	120.5 / 57 - 238

*Represents all three egg stages from January through February.
**Represents all three egg states from January through March.
+A single set of samples was taken in 1976. These data were not inlcuded in this comparison because weekly data sets were available in 1975 and 1977-1981.

Table 3: (Continued) Format: Mean / Range

	APRIL 1980	APRIL 1981	APRIL 1982	APRIL 1983
EGGS				
Gadidae-Glyptocephalus	2.3 / 3.1-7.2	0	0	0.5 / 0-2.9
Gadidus morhua	1.1 / 0-4.1	0.4 / 0-2.8	0.2 / 0.6-2.5	0.4 / 0-1.5
Enchelyopus-Urophycis-Peprilus	0	0	0	0
*Enchelyopus cimbrius***	0.5 / 0-4.1	0.3 / 0-2.4	0.1 / 0-1.6	0.5 / 0-2.0
Urophycis spp.	0	0	0	0
Labridae-*Limanda*	0	0	0	0
Labridae	0.6 / 0-7.6	0	0	0
Scomber scombrus	0	0	0	0
Paralichthys-Scophthalmus	0	0	0	0
Total	26.1 / 0-17.6	13.5 / 0-77.4	5.8 / 0-41.6	8.1 / 0.7-18.6
LARVAE				
Clupea harengus harengus	0.1 / 0-0.5	0	1.0 / 0.4-5	1.9 / 0-9.3
Enchelyopus cimbrius	0	0	0	0.04 / 0-0.5
Tautogolabrus adspersus	0	0	0	0
Ulvaria subbifurcata	2.5 / 0-6.2	0.3 / 0-2.0	0	3.9 / 0-11.0
Pholis gunnellus	0.4 / 0-1.1	3.4 / 0-13.6	32.8 / 0-74.8	3.4 / 0-21.0
Ammodytes sp.	50.3 / 0-171.3	33.0 / 6.8-66.1	8.1 / 260.9	16.2 / 0-57.7
Scomber scombrus	0		0	0
Myoxocephalus spp.	16.4 / 0-58.8	0.4 / 0-1.7	88.6 / 0-167.2	7.0 / 0-24.0
Liparis coheni	5.3 / 0-20.3	0	0.9 / 0-4.4	15.3 / 0.9-58.0
Pseudopleuronectes americanus	8.9 / 1.5-23.8	2.1 / 0-3.0	5.6 / 0-36.2	3.6 / 0-13.4
Total	86.0 / 8.2-265.8	66.5 / 29.1-141.8	185.4 / 3.8-732.4	51.7 / 8.3-134.9

*Represents all three egg stages from January through February.
**Represents all three egg stages from January through March.

Table 3 (Continued). Format: Mean / Range

	MAY 1975	1976	1977	1978	1979
EGGS					
Gadidae-Glyptocephalus	1.0 / 0 - 3	2.3 / 0 - 6	3.4 / 0 - 11	3.4 / 0 - 14	1.4 / 0 - 5
Gadidae*	1.1 / 0 - 3	1.5 / 0 - 4	1.2 / 0 - 3	9.6 / 0 - 61	1.8 / 0 - 5
Enchelyopus-Urophycis-Peprilus	8.3 / 0 - 30	13.3 / 0 - 72	12.5 / 5 - 22	27.8 / 2 - 125	9.5 / 0.6 - 34
Enchelyopus cimbrius**	28.3 / 6 - 70	30.8 / 0 - 91	14.0 / 0 - 32	10.9 / 0 - 37	5.3 / 0 - 15
Urophycis spp.	0	0	0.4 / 0 - 3	0	0
Labridae-Limanda	145.8 / 2 - 1248	12.0 / 5 - 23	280.8 / 3 - 1240	1843.4 / 3 - 11809	1491.9 / 6 - 9475
Labridae	0.3 / 0 - 2	0	8.6 / 0 - 55	20.5 / 0 - 169	4.1 / 0 - 19
Scomber scombrus	1.8 / 0 - 6	1.2 / 0 - 5	12.7 / 0 - 67	8.5 / 0 - 62	37.5 / 0 - 155
Parlichthys-Scophthalmus	10.1 / 0 - 64	6.3 / 0 - 19	12.5 / 2 - 32	30.4 / 0 - 169	21.0 / 0 - 76
Total	196.5 / 12 - 1366	74.7 / 35 - 126	396.3 / 31 - 1324	2017.8 / 13 - 12428	1638.3 / 45 - 9925
LARVAE					
Clupea harengus harengus	2.2 / 0 - 24	0	0	0.1 / 0 - 1	0.03 / 0 - 0.5
Enchelyopus cimbrius	2.6 / 0 - 10	2.9 / 0 - 13	0.3 / 0 - 1	4.0 / 0 - 19	4.5 / 0 - 19
Tautogolabrus adspersus	0	0	0	0	0.2 / 0 - 2
Ulvaria subbifurcata	65.4 / 10 - 235	7.3 / 1 - 24	5.7 / 0 - 20	43.5 / 11 - 141	5.2 / 0 - 23
Pholis gunnellus	0.1 / 0 - 0.5	0	0	0.4 / 0 - 4	0.08 / 0 - 1
Ammodytes sp.	4.0 / 0 - 22	2.5 / 0 - 8	2.2 / 0 - 7	79.9 / 0 - 265	20.1 / 0 - 88
Scomber scombrus	0.1 / 0 - 0.4	0	0	2.6 / 0 - 27	6.1 / 0 - 29
Myoxocephalus spp.	3.2 / 0 - 11	0.5 / 0 - 2	1.2 / 0 - 9	0.3 / 0 - 37	5.9 / 0 - 17
Liparis spp.	9.2 / 0 - 30	13.0 / 6 - 31	38.9 / 0 - 112	37.0 / 1 - 92	20.3 / 6 - 40
Pseudopleuronectes americanus	13.9 / 2 - 36	7.4 / 2 - 18	16.3 / 4 - 29	38.0 / 0 - 129	18.4 / 13 - 40
Total	99.6 / 28 - 283	37.9 / 15 - 76	81.9 / 24 - 185	222.2 / 33 - 660	104.1 / 66 - 210

*Represents all three egg stages from January through February.
**Represents all three egg states from January through March.

Table 3: (continued) Format: Mean / Range

MAY	1980	1981	1982	1983
EGGS				
Gadidae-Glyptocephalus	8.5 / 1.1-5.9	0.3 / 0-2.3	0.4 / 0-1.9	4.0 / 0-18.1
Gadidus morhua	1.2 / 0-3.8	0.8 / 0-2.7	0.1 / 0-0.8	0.6 / 0-3.1
Enchelyopus-Urophycis-Peprilus	8.5 / 4.3-14.1	7.8 / 0.95-19.1	3.4 / 1.2-8.2	6.7 / 2.9-18.4
Enchelyopus cimbrius**	52 / 10.2-72.6	15.1 / 0-54.8	0.9 / 0-2.3	11.8 / 0-59.1
Urophycis spp.	0	0.1 / 0-1.4	0	0.1 / 0-0.5
Labridae-Limanda	3024 / 4.8-9331	74.1 / 1.9-94.0	917.8 / 4.0-248.2	30.2 / 0-208.8
Labridae	119 / 0-430.5	3.6 / 0-22.8	5.3 / 0.5-14.7	0.2 / 0-1.0
Scomber scombrus	94 / 32-256.7	32.8 / 0-167.5	15.0 / 0-63.3	67.5 / 22.9-246.4
Paralichthys-Scophthalmus	34 / 6.7-66.7	22.2 / 0-63.6	11.7 / 0-43.1	9.6 / 0-27.0
Total	3489 / 1-10,314	151.6 / 29-368	251.9 / 39.5-425.4	185.9 / 10.3-523.8
LARVAE				
Clupea harengus harengus	0	0	0.2 / 0-1.2	0.04 / 0-0.5
Enchelyopus cimbrius	5.4 / 4.5-11	1.0 / 0-2.5	0 / 0-0.6	0.3 / 0-1.4
Tautogolabrus adspersus	1.3 / 0-8.3	0.04 / 0-.2	0	0
Ulvaria subbifurcata	10.2 / 4.6-21.4	10.7 / 3.5-27.0	4.0 / 0-15.9	19.5 / 1.6-73.2
Pholis gunnellus	0	0	0.2 / 0-2.0	0.2 / 0-0.6
Ammodytes sp.	3.8 / 1.9-9.1	1.8 / 0-3.5	23.2 / 0-29.0	6.4 / 0.5-17.1
Scomber scombrus	3.8 / 10.9-12.0	0.9 / 0.5-4.9	0.1 / 0-1.1	0
Myoxocephalus spp.	0	0	1.5 / 0-9.9	6.2 / 3.1-25.2
Liparis atlanticus	27.8 / 15.7-44.9	0	2.7 / 0-12.5	13.5 / 0.5-37.5
Liparis coheni			0.1 / 0-1.5	0
Pseudopleuronectes americanus	29.1 / 11.1-74.8	11.1 / 0-97.5	30.3 / 1.3-49.3	15.8 / 0.5-7.2
Total	104 / 0-166	69.9 / 13-234	65.4 / 8.4-181.6	62.4 / 9.3-191.6

*Represents all three egg stages from January through February.
**Represents all three egg stages from January through March.

Table 3 (Continued). Format: Mean / Range

	JUNE 1975	JUNE 1976	JUNE 1977	JUNE 1978	JUNE 1979
EGGS					
Gadidae-*Glyptocephalus*	1.1 / 0 - 4	2.3 / 0 - 6	2.6 / 0 - 11	2.5 / 0 - 7	1.5 / 0 - 5
Gadidae*	0.8 / 0 - 3	1.5 / 0 - 4	5.3 / 0 - 27	2.0 / 0 - 7	0.4 / 0 - 2
Enchelyopus-*Urophycis*-*Peprilus*	28.5 / 16 - 55	11.3 / 2 - 25	24.4 / 0 - 96	75.8 / 0 - 308	38.0 / 17 - 98
*Enchelyopus cimbrius***	20.0 / 1 - 76	25.6 / 9 - 90	51.5 / 5 - 114	14.7 / 0 - 33	24.3 / 2 - 65
Urophycis spp.	1.5 / 0 - 6	0.7 / 0 - 2	4.7 / 0 - 15	4.3 / 0 - 14	10.2 / 0 - 27
Labridae-*Limanda*	2432.0 / 809-5501	699.0 / 147-2258	5739.1 / 289-19078	1317.7 / 24-3876	5217.8 / 1080-10505
Labridae	137.1 / 0 - 294	75.4 / 7 - 249	185.4 / 26 - 1181	90.6 / 0 - 262	216.3 / 50 - 774
Scomber scombrus	126.3 / 4 - 746	5.0 / 0.8 - 19	55.0 / 6 - 199	151.8 / 0 - 360	18.0 / 4 - 41
Parlichthys-*Scophthalmus*	18.2 / 2 - 78	17.2 / 0 - 73	38.6 / 3 - 129	41.8 / 0 - 132	61.2 / 20 - 141
Total	2819.8 / 819-5718	856.2 / 342-2393	6301.5 / 609-19425	1934.7 / 228-5917	5620.2 / 1401-11522
LARVAE					
Clupea harengus harengus	0	0	0	0	0
Enchelyopus cimbrius	50.1 / 0 - 137	28.7 / 0 - 46	128.2 / 84 - 248	40.2 / 0 - 145	7.4 / 1 - 15
Tautogolabrus adspersus	11.3 / 0 - 39	2.6 / 0 - 13	11.5 / 0 - 750	19.5 / 0 - 107	38.8 / 4 - 78
Ulvaria subbifurcata	0.6 / 0 - 2	5.1 / 0 - 28	0	4.3 / 0 - 12	1.3 / 0 - 3
Pholis gunnellus	0	0	0	0.2 / 0 - 2	0
Ammodytes sp.	0	0.1 / 0 - 2	0	0.2 / 0 - 2	0.1 / 0 - 1
Scomber scombrus	39.9 / 0 - 149	4.2 / 0 - 15	14.0 / 0 - 55	31.5 / 0 - 126	9.9 / 0 - 37
Myoxocephalus spp.	0	0	0	0	0
Liparis spp.	2.1 / 0 - 7	0.7 / 0 - 50	6.2 / 0 - 28	16.0 / 2 - 65	1.3 / 0 - 4
Pseudopleuronectes americanus	5.5 / 0.5 - 15	6.6 / 0 - 47	4.6 / 0 - 16	15.9 / 0 - 54	9.7 / 0 - 39
Total	117.9 / 14 - 260	55.1 / 8 - 139	297.2 / 125 - 641	176.7 / 51 - 343	82.5 / 27 - 154

*Represents all three egg stages from January through February.
**Represents all three egg states from January through March.

Table 3: (continued) Format: Mean / Range

	JUNE 1980	1981	1982	1983
EGGS				
Gadidae-Glyptocephalus	6.4 0-16	3.7 0-8.6	0.5 0-2.5	0.4 0-1.6
Gadidus morhua	10.6 0-24	5.0 0-21.7	0.2 0-0.9	0.8 0.9-4.9
Enchelyopus-Urophycis-Peprilus	14.7 1.9-25.6	143.8 3.9-634.4	8.8 0-18.7	39.8 5.6-159.5
Enchelyopus cimbrius	49.8 2.2-50.8	18.4 6.8-37.7	6.9 0-23.4	14.0 0-39.1
Urophycis spp.	2.2 3.7-4.9	9.9 0-56.2	1.8 0-5.7	2.7 0-5.8
Labridae-*Limanda*	631 248-1266	5371.8 184-12,537	1607.8 276.2-4588.4	6978.7 56.7-17,918.4
Labridae	101.6 12.7-190.5	302.5 81.7-1492	155.2 75.0-237.6	
Scomber scombrus	40.5 0-54.2	197.9 3.2-1083	135.2 0-663.1	144.1 5.1-201.8
Paralichthys-Scophthalmus	27.5 13.6-25.6	73.2 0-500.6	38.7 5.3-82.8	45.2 2.2-75.5
Total	760 499-1651	6291 407-22,226	1974.2 419.9-4912.2	7614.9 308.9-14,223
LARVAE				
Clupea harengus harengus	0	0	0	0
Enchelyopus cimbrius	34.5 3.9-101.8	32.2 0-94.3	0.9 0-5.2	13.6 0-47.1
Tautogolabrus adspersus	45.6 82.7	276 0-693	6.5 0-26.4	12.6 0.5-46.3
Ulvaria subbifurcata	2 0-1.6	1.6 0-3.4	1.4 0-4.9	0.9 0-4.6
Pholis gunnellus	0	0	0	0
Ammodytes sp.	0	0.1 0-.6	0	0.1 0-0.6
Scomber scombrus	35.3 0-108.8	544.9 1.3-3662	14.6 0-80.6	70.4 0-353.6
Myoxocephalus spp.	0.5 0-7.2	0	0	0
Liparis atlanticus	5.8 0-21.2	0	0.5 0-3.9	0.9 0-8.3
Pseudopleuronectes americanus	5.8 2.7-19.3	2.4 0-6.8	3.8 0-16.8	0.4 0-1.9
Total	145.8 48.7-377.3	910 18.4-5442	35.8 0-136.1	102.5 1.64-383.2

*Represents all three egg stages from January through February.

**Represents all three egg stages from January through March.

V. LITERATURE CITED

Ahlstrom, E.H. and R.C. Counts. 1955. Eggs and larvae of the Pacific hake Merluccius productus. U.S. Fish and Wildlife Service, Fish. Bull. 56(99): 295-329.

Hardy, J.D., Jr. 1978. Development of fishes of the mid-Atlantic Bight. An atlas of egg, larval and juvenile stages. Vol. II Anguillidae through syngnathidae. U.S. Fish Wildl. Serv., Biol. Serv. Progr., 458 pp.

Khan, N.Y. 1971. Comparative morphology and ecology of the pelagic larvae of nine cottidae (Pisces) on the northwest Atlantic and St. Lawrence drainage. Ph.D. thesis. Univ. Ottowa. 234 pp.

Lawton, R.P., E. Louloheras, P. Brady, and M. Borgatti. 1979. Progress report on smelt reproduction and spawning population structure in the Jones River run. In Boston Edison Company. 1979. Marine Ecology Studies related to operation of Pilgrim Station. Semi-annual report 14.

Lawton, R.P. 1980. Final Report on smelt reproduction and spawning population structure in the Jones River, Massachusetts. In Boston Edison Company. 1980. Marine Ecology Studies related to operation of Pilgrim Station. Semi-annual Report 15.

Marine Research, Inc. 1977a. Entrainment investigations and Cape Cod Bay ichthyoplankton studies, March-August 1977. 31 pp. and 78 pp. Appendix.

____________. 1977b. Entrainment investigations and Cape Cod Bay ichthyoplankton studies, July-September 1976. 69 pp. and 332 pp. Appendix.

____________. 1978. Investigations of entrainment of ichthyoplankton at the Pilgrim Station and Cape Cod Bay ichthyoplankton studies, March-December 1977. Twelve-month summary for 1977 Cape Cod Bay Ichthyoplankton Studies. 43 pp. and 180 pp. Appendix.

Meyer, T.L., R.A. Cooper, and R.W. Langton. 1979. Relative abundance, behavior, and food habits of the American sand lance, Ammodytes americanus, from the Gulf of Maine. Fish. Bull., U.S. 77: 243-253.

Richards, S.W., A. Perlmutter, and D.C. McAneny. 1963. A taxonomic study of the genus Ammodytes from the east coast of North America (Teleostei: Ammodytes). Copeia 1963(2): 358-377.

Scott, J.S. 1968. Morphometrics, distribution, growth, and maturity of offshore sand lance (Ammodytes dubius) on the Nova Scotia banks. J. Fish Res. Board Can. 25: 1775-1785.

____________. 1972. Morphological and meristic variation in Northwest Atlantic sand lances (Ammodytes). J. Fish. Res. Board Can. 29: 1673-1678.

U.S. Geological Survey. 1975. Water Resources Data for Massachusetts, New Hampshire, Rhode Island and Vermont. Part 1. Surface Water Records. Part 2. Water Quality Records. 429 pp.

______________. 1976 - 1981 Water Resources Data for Massachusetts and Rhode Island - Water Year 1975. Water data report MA-RI.

Winters, G.H. 1970. Meristics and Morphometrics of sand lance in the Newfoundland area. J. Fish. Res. Board Can. 27: 2104-2108.

Winter Flounder Studies in the Vicinity of Pilgrim Nuclear Power Station - 1983

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

September 30, 1983

Table of Contents

Figure

Tables

I. Introduction

In the spring of 1982 Marine Research, Inc. examined winter flounder (*Pseudopleuronectes americanus*) eggs collected in the discharge of the Pilgrim Nuclear Power Station (PNPS) to determine if spawning might be occurring along the coast near the plant. This was accomplished by aging entrained eggs using laboratory-reared series and an estimated transit time of seven days from Plymouth Harbor, Kingston, Duxbury Bay (PHKDB), the nearest estuary to PNPS. Results of the 1982 studies (MRI 1982) suggested that perhaps 41% of the live flounder eggs entrained at PNPS in 1982 were spawned nearer PNPS than PHKDB. These data were considered of some significance since previous analyses (Pagenkopf et al. 1976; Chau and Pearce 1977; MRI 1978) applied all entrainment impacts to the flounder spawning population in PHKDB.

Since transit time from PHKDB to PNPS is quite important in estimating the source of flounder eggs taken at PNPS, studies were conducted in 1983 to obtain additional data on drift time between the estuary and power plant using sea-bed drifters. The estimate of seven days used in previous discussions was based on results of fixed current meter recordings made at two stations located approximately 0.4 and 1.1 nautical miles (0.8 and 2.1 km) off Pilgrim Station (Stone and Webster 1975). It seems reasonable to suggest that net drift over the bottom of a four-mile course from the estuary to PNPS could be somewhat different and variable.

In addition to an examination of drift rates, winter flounder eggs were removed from 1983 entrainment samples as well as from supplementary tows made in the intake area. These were aged as in 1982 and compared with the estimated drift rates.

II. Methods

A. Sea-bed Drifter Study

Drift rates between Plymouth Harbor, Kingston, Duxbury Bay and Pilgrim Station were examined by releasing Woodhead sea-bed drifters (Kahl Scientific Instrument Corporation, El Cajon, California) at the beginning of ebb tide near the mouth of the estuary. Sea-bed drifters were selected because winter flounder eggs are demersal and those that drift probably do so near or on bottom. A total of 1001 drifters were released, divided about evenly between three dates selected to represent a spring, neap, and average tide. Each drifter was fitted with a serially numbered, postage prepaid, return data card requesting information on the recovered drifter.

Based on the manufacturer's product description, we did not use salt blocks* to increase the speed at which the drifters descend to the bottom on the first release date. After releasing several on that date, it was apparent that some drifters were slow to sink, being nearly neutrally buoyant, at least in the moderate chop present in the estuary at that time. Because of the slow descent rate among some of the drifters, all day 1 releases were made 0.75 nautical miles (1.4 km) west or upcurrent of Duxbury Pier (Figure 1). On release day 2 and 3 salt blocks were used to assure rapid descent to the bottom; therefore those drifters were released adjacent to Duxbury Pier in the entrance channel to PHKDB.

To increase the probability that drifters would be recovered as soon as possible after coming ashore (in spite of the fact that the area from Plymouth Beach to White Horse Beach is well covered by beachcombers), MRI personnel surveyed the shoreline at PNPS once per day beginning on day 3 extending through day 13 following each release, therefore bracketing the seven-day estimated transit time.

---

*Salt blocks were circular, 75 mm in diameter, and approximately 125 gms in weight with a 16 mm hole bored in the center. Four drifters were forced into the hole prior to release, the added weight greatly decreasing descent time. Blocks were designed to break apart in 20 to 30 minutes.

B. Winter Flounder Egg Studies

All winter flounder eggs found in 1983 ichthyoplankton entrainment samples were removed for age determination. Additional eggs were obtained by towing a 0.333-½ m modified Tucker net just above bottom in the intake area at PNPS. These tows were made in triplicate on 12 dates between late-March and the end of May. Bottom water temperature measurement was obtained on each date using a 2-liter Van Dorn sampler and 0.2 C stem thermometer. Samples were preserved in 10% formalin-seawater solutions and examined in the laboratory where all flounder eggs were removed.

Data used to age the eggs obtained from entrainment and intake samples included the egg-rearing series at 3, 8, and 12 C completed in 1982 and 2, 4, 6, 8, 10 C series completed in 1983. Eggs and milt in 1983 were obtained from ripe fish taken by the Massachusetts Division of Marine Fisheries using an otter trawl in the waters around PNPS. Adult fish were returned to the laboratory where eggs and milt were manually expressed from the fish and mixed in seawater at 4 C (32 $^{o}/oo$). Fertilized eggs were then divided into aerated, 1-liter, glass beakers containing seawater which were then placed in constant temperature (± 0.5 C) water baths set at incubation temperatures of 2, 4, 6, 8, 10 C. Every two or three days 90% of the water in each beaker was exchanged with fresh filtered seawater adjusted to the appropriate temperature. Each day from fertilization through hatching at approximately 0800 and 1630 about 50 eggs were removed from each bath and preserved in 5% buffered formalin. Eggs of known age were then compared with flounder eggs obtained at PNPS using the most comparable water temperature.

III. Results

A. Sea-bed Drifter Study

Tables 1 - 3 summarize the drifter returns received through September for each of the three release dates. For the purposes of this discussion those listed as Plymouth Beach returns included only those found on the Cape Cod Bay side of the beach (Figure 1). Bert's Restaurant was used to divide Plymouth Beach from Warren Cove since it was a frequently used reference point on the returned cards. White Horse Beach included Priscilla Beach returns. A total of 165 (50.0%), 198 (57.6%), and 143 (44.0%) of the drifters were reported found through September from the three respective release dates. Over all three dates an additional 18 cards were received with either illegible information or too vague a description of the location found to be tabulated. A total of 524 or 52.3% of the drifters were reported found.

Returns from release day 1 (May 13), representing a spring tide, were most numerous along Plymouth Beach (n = 83, 50.3%; Table 1). Within the objectives of this study, returns dated prior to May 21, i.e. drifters found within the first seven days, were of primary interest. Three drifters were reported found along White Horse Beach south of PNPS the day following release. One of these, at sea for only 22 hours, was found floating offshore, which suggests that at least some of the drifters may have been carried back to the surface, perhaps by the moderate chop prevailing May 13. The fact that salt blocks were not used with the first set of drifters probably increased the probability that this occurred. If some drifters returned to near surface, it seems reasonable to suggest that they may have drifted faster under the influence of wind-driven currents. (Winds were NW at about 10 mph May 13, shifting to E at 12 mph around midday May 14.) Additional returns on day 4 and 5 from Rocky Point and White Horse Beach also suggest that fairly rapid drift is possible.

From release day 2 (June 3), representing a neap tide, the greatest number of returns also came from Plymouth Beach (n = 97, 49.0%; Table 2). Among those in the second set none were found around Rocky Point or further to the south until two weeks or more had elapsed. Also a greater number of drifters from the second set moved into PHKDB than from the first set (n = 52 or 26.3% versus n = 10 or 6.1%).

Among those released on day 3 (June 24) when tides were about average in amplitude, the greatest number of returns came from PHKDB (n = 84, 58.7%; Table 3). Drifters were not found at Rocky Point or to the south until two weeks or more had elapsed.

Several general observations are worth noting based on the three sets of returns: 1) The fact that drifters were still appearing on Plymouth Beach in July, and that one was taken there 92 days after release, suggests that some drifters lodged in rocks or vegetation for long periods of time before washing ashore. 2) No drifters were returned from north of Gurnet Point which is consistent with the net counterclockwise drift reported by Bigelow (1924) and Fish (1928) for surface waters. 3) As of late September the furthest returns have come from Sandy Neck Beach, East Sandwich, Cape Cod.

B. Winter Flounder Egg Studies

Table 4 presents the winter flounder egg developmental series completed in 1982 and 1983 at various water temperatures. In 1982 when fertilization was completed at PNPS (see MRI 1982), eggs had reached the two-cell stage during the time necessary to transfer them from the field to the water baths. Therefore the 3, 8 (1982), 12, and 15 C series began at that point. The 1983 data suggest that for the purposes of this study such a difference is of little significance since at 2 and 4 C (1983 data) only 8 and 7 hours respectively elapsed before the first division was completed. As pointed out in

the 1982 report (MRI 1982), 100% mortality occurred on the third day among eggs reared at 15 C.

Information available in the literature (see Rogers 1976) indicates that a single batch of winter flounder eggs hatches over a long period of time. The PNPS rearing studies indicated that the staggering of development among eggs fertilized at the same time begins at or near the end of gastrulation and becomes quite dramatic once the early embryo forms. The data in Table 4 indicate the wide range in development times beyond that point. Some eggs continue to develop while others appear to slow or stop for periods of perhaps six or more days, this delay being most evident at the lowest temperatures. Viewed within the goals of this study, an egg collected at 3 C with an embryo just encircling the yolk could be as young as 10 or as old as 15.6 days; at 2 C the range could be 13.0 to 26.5 days.

As shown in Table 4, eggs were reared at 8 C in both 1982 and 1983 to compare two distinct batches of eggs. Results were quite similar with hatching beginning on day 8 in both groups.

From March through May, when winter flounder eggs are generally present at PNPS, 39 eggs were found in the 36 entrainment samples taken during the period. Among the 39, 17 (43.6%) were dead or abnormal and were therefore not useful for aging. Tows made in the PNPS intake area produced an additional 20 eggs, 15 (75.0%) of which were dead (Table 5).

As indicated in Table 5, 15 (55.7%) of the normal, live eggs taken (n = 27) appeared to be considerably younger than 7 days. An additional 4 eggs (14.8%) may have been under 7 days old but this could not be determined specifically because of the range in ages among the later developmental stages. In cases where ambient temperature fell between two rearing temperatures, e.g. April 20 (5 C), the series from the next higher temperature (6 C)

was used. If the next lower temperature (4 C) had been used, no change in the number of eggs considered less than seven days old would have occurred.

IV. Summary and Conclusions

Discussions of impact of Pilgrim Station (PNPS) on early life history stages of winter flounder have all assumed that flounder eggs and larvae near PNPS originated from spawning in Plymouth Harbor, Kingston, Duxbury Bay (PHKDB). This assumption maintained that eggs and larvae drifted at least four nautical miles from the mouth of the Bay to the power station. Early fixed current meter studies suggested that at a net drift rate of 0.04 ft/sec (0.01 m/sec) seven days would be required to reach PNPS. Studies conducted in 1982 which involved collection and aging of flounder eggs at PNPS by comparison with laboratory-reared series indicated that a high percentage of eggs taken there (41%) were considerably younger than 7 days. Based on these results, spawning must occur along the coast nearer to PNPS, or drift rates can be as short as one day.

Studies completed in 1983 were designed to explore drift rates between PHKDB and PNPS and to examine and age additional eggs. Woodhead sea-bed drifters released near the mouth of PHKDB on three dates provided drift information; and flounder eggs were removed from all entrainment samples as well as from bottom plankton tows made in the PNPS intake area.

A total of 1001 drifters were released divided about evenly between three days representing a spring, neap, and average tide. Releases were made near the mouth of PHKDB just after high water without salt blocks on day 1 but with them on day 2 and 3. Recoveries amounted to 50.0% from day 1, 57.6% from day 2, and 44.0% from day 3. Data from the first set of drifters (released May 13, spring tide) indicated that drift from PHKDB to White Horse Beach south of PNPS could occur in less than 24 hours.

Results remain uncertain however because one of those drifters was reported floating off White Horse Beach and therefore was probably influenced to a large extent by wind-driven currents. Among the second and third sets no drifters were reported found around the PNPS area until two weeks following release. Firm conclusions leading to a revision of the estimated seven-day transit time are difficult because the one drifter reported to be floating on May 14 casts doubt on results of the first set of drifters when salt blocks were not used to assure that all drifters reached bottom. If set 1 data are omitted, results from sets 2 and 3 provided no evidence that drift rates of less than seven days can occur.

Winter flounder egg studies in 1983 confirmed results obtained in 1982; 55.7% of the normal, live eggs sampled (n = 27) were considerably younger than 7 days. Seven of these (25.9%) were one to two days old and five (18.5%) were three to four days old. In 1982 40.9% of the live eggs (n = 44) appeared to be younger than 7 days; a total of 16 (36.4%) were in fact less than 3 days old and 7 of the 16 were about 1 day old.

In conclusion we believe the drifters did not provide sufficient data to discount the estimated seven-day drift time from PHKDB to PNPS. The fact that a high percentage of flounder eggs taken at PNPS are only one to two days old suggests that spawning occurs outside the estuary nearer to PNPS.

V. Literature Cited

Bigelow, H.B. 1924. Physical oceanography of the Gulf of Maine. Bull. U.S. Bur. Fish. 40:511-1027.

Chau, T.S. and B.R. Pearce. 1977. Real time simulation of the winter flounder larvae entrainment near Pilgrim Nuclear Power Station. (Ralph M. Parsons Laboratory, M.I.T.) In Marine Ecology Studies Related to the Operation of Pilgrim Station. Semi-annual Report No. 10. Boston Edison Company.

Fish, C.J. 1928. Production and distribution of cod eggs in Massachusetts Bay in 1924 and 1925. Bull. U.S. Bur. Fish. 1927 43 (part 2):253-296.

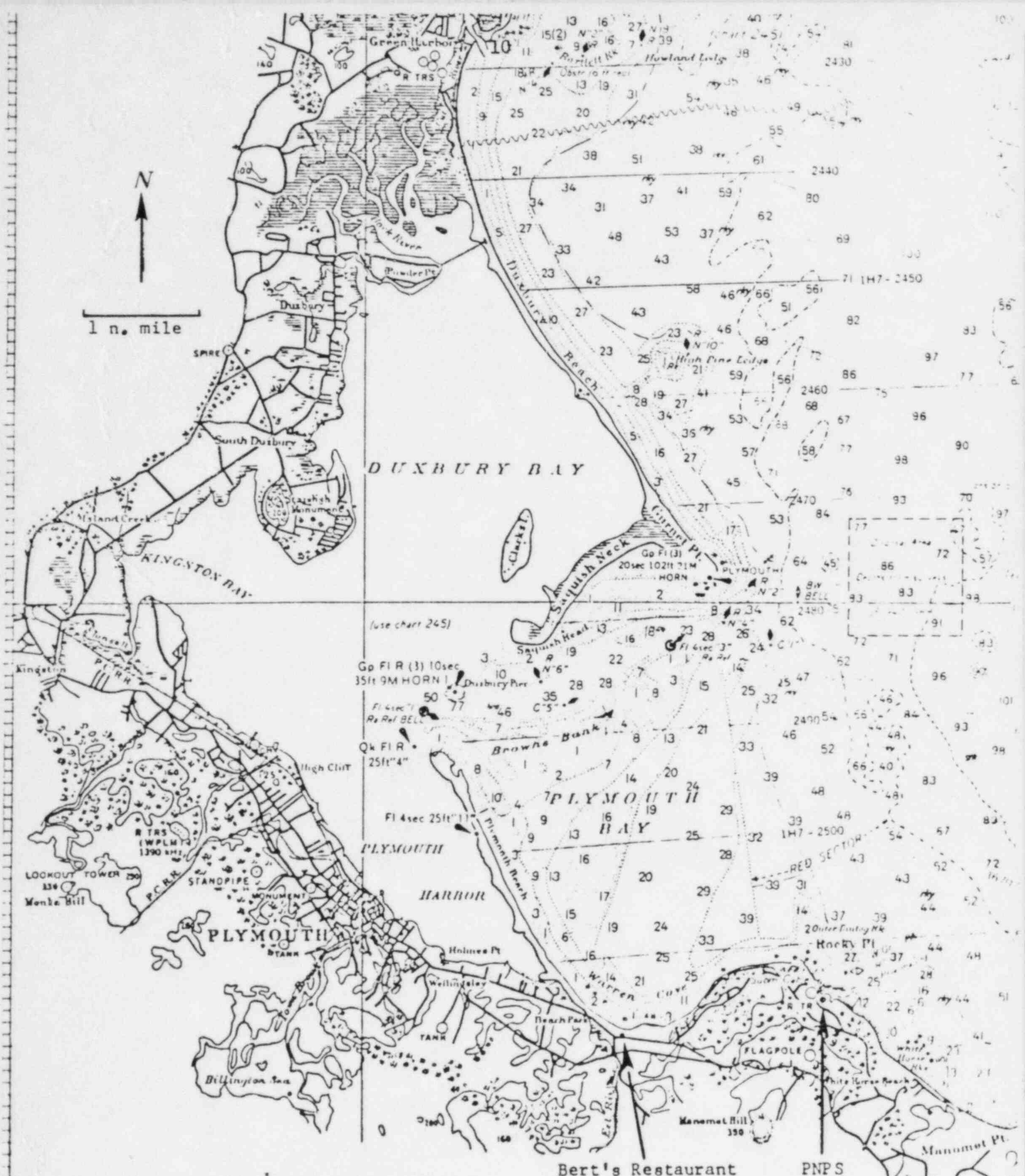
MRI (Marine Research, Inc.). 1978. Entrainment investigations and Cape Cod Bay plankton studies, March 1970-June 1972 and March 1974-July 1977. Vol. 2, p V.1-i-44. In Marine Ecology Studies Related to the Operation of Pilgrim Station. Final Report July 1969-December 1977. Boston Edison Company.

———. 1982. Final report larval winter flounder studies in Plymouth Harbor, Kingston, Duxbury Bay, and Green Harbor River estuaries - 1982. In Marine Ecology Studies Related to Operation of Pilgrim Station. Semi-annual Report 21. Boston Edison Company.

Pagenkopf, J.F., G.C. Christodoulou, B.R. Pearce, and J.J. Connor. 1976. Circulation and dispersion studies at the Pilgrim Nuclear Power Station, Rocky Pt, Mass. (Ralph M. Parsons Laboratory, M.I.T.) In Marine Ecology Studies Related to the Operation of Pilgrim Station. Semi-annual Report No. 7. Boston Edison Company.

Rogers, C.A. 1976. Effects of temperature and salinity on the survival of winter flounder embryos. Fish. Bull. U.S. 74(1):52-58.

Stone and Webster Engineering Corp. 1975. 316 Demonstration for Pilgrim Nuclear Power Station, Units 1 and 2. Boston, Mass.



Place	Height referred to datum of soundings (MLW)			
	Mean High Water	Mean Tide Level	Mean Low Water	Extreme Low Water
	feet	feet	feet	feet
Plymouth	9.5	4.7	0.0	-3.5
Barnstable Harbor				
Beach Point	9.5	4.7	0.0	-3.5
Provincetown	9.1	4.5	0.0	-3.5
Chatham (outer coast)	6.7	3.3	0.0	-3.0

TIDAL INFORMATION

(772)

Figure 1. Plymouth Harbor, Kingston, Duxbury Bay and adjacent waters.

Table 1. Drifter returns from release day 1, May 13, 1983 (spring tide).

Day Found	Return Area: Plymouth Beach	Warren Cove	Rocky Point	White Horse Beach	Manomet Point	Points South	PHKDB	Total
May Day								
14 = 1	15	-	-	3	-	-	1	19
15 = 2	31	-	-	-	-	-	1	32
16 = 3	7	-	-	-	-	-	-	7
17 = 4	20	2	1	1	-	-	-	24
18 = 5	-	1	-	3	-	-	-	4
19 = 6	-	-	-	-	-	-	1	1
20 = 7	-	-	-	-	-	-	1	1
21 = 8	-	-	-	-	-	-	2	2
22 = 9	3	-	-	-	-	-	1	4
23 = 10	1	-	-	-	-	-	-	1
24 = 11	1	-	-	-	1	-	-	2
25 = 12	-	-	2	-	1	-	-	3
26 = 13	-	-	-	-	-	-	-	0
27-31 = 14-18	2	1	4	-	1	-	1	9
June	1	-	2	-	1	5	1	10
July	2	-	1	2	9	7	-	21
August	-	1	1	1	5	11	1	20
September	-	-	-	-	-	5	-	5
Total	83	5	11	10	18	28	10	165

Table 2. Drifter returns from release day 2, June 3, 1983 (neap tide).

Day Found	Return Area							
	Plymouth Beach	Warren Cove	Rocky Point	White Horse Beach	Manomet Point	Points South	PHKDB	Total
June = Day								
4 = 1	-	-	-	-	-	-	-	-
5 = 2	-	-	-	-	-	-	-	-
6 = 3	2	-	-	-	-	-	-	2
7 = 4	4	-	-	-	-	-	1	5
8 = 5	7	-	-	-	-	-	3	10
9 = 6	24	-	-	-	-	-	3	27
10 = 7	13	-	-	-	-	-	5	18
11 = 8	9	1	-	-	-	-	2	12
12 = 9	9	-	-	-	-	-	6	15
13 = 10	-	-	-	-	-	-	-	-
14 = 11	-	-	-	-	-	-	2	2
15 = 12	4	-	-	-	-	-	-	4
16 = 13	1	-	-	-	-	-	-	1
17-30 = 14-27	9	7	5	-	-	-	9	30
July	14	10	8	1	2	3	15	53
August	-	-	3	-	3	4	4	14
September	1	-	-	-	-	2	2	5
Total	97	18	16	1	5	9	52	198

Table 3. Drifter returns from release day 3, June 24, 1983 (average tide).

Day Found	Return Area: Plymouth Beach	Warren Cove	Rocky Point	White Horse Beach	Manomet Point	Points South	PHKDB	Total
June = Day								
25 = 1	-	-	-	-	-	-	1	1
26 = 2	2	-	-	-	-	-	4	6
27 = 3	-	-	-	-	-	-	8	8
28 = 4	2	-	-	-	-	-	3	5
29 = 5	3	-	-	-	-	-	5	8
30 = 6	1	-	-	-	-	-	8	9
July								
1 = 7	7	-	-	-	-	-	1	8
2 = 8	2	-	-	-	-	-	5	7
3 = 9	2	-	-	-	-	-	7	9
4 = 10	-	-	-	-	-	-	3	3
5 = 11	-	-	-	-	-	-	3	3
6 = 12	-	-	-	-	-	-	2	2
7 = 13	3	-	-	-	-	-	3	6
8+ = 14-38	7	7	7	2	-	-	20	43
August	-	1	1	-	3	5	10	20
September	-	-	-	-	1	3	1	5
Total	29	8	8	2	4	8	84	143

Table 4. Elapsed time in hours and days ( ) during development of winter flounder eggs reared at eight water temperatures (C).

Stage	Temperature (C) 2	3*	4	6	8 (1983)	8 (1982)*	10	12*	15*
Two-cell stage	8 (0.3)	-	7 (0.3)	-	-	-	-	-	-
Four-cell stage	-	-	-	7 (0.3)	-	-	-	-	-
Eight-cell stage	-	-	-	-	8 (0.3)	-	-	-	-
Sixteen-cell stage	-	-	-	-	-	-	8 (0.3)	-	-
Early to mid blastula	24 - 48 (1.0-2.0)	15 (0.6)	24 (1.0)	-	-	15 (0.6)	-	-	-
Mid to late blastula	56 - 72 (2.3-3.0)	24 - 39 (1.0-1.6)	32 - 48 (1.3-2.0)	24 (1.0)	24 (1.0)	24 (1.0)	24 (1.0)	15 (0.6)	15 - 24 (0.6-1.0)
Early gastrula	80 (3.3)	48 (2.0)	56 (2.3)	32 (1.3)	32 (1.3)	-	-	-	-
Germ ring ¼ to ½ around yolk	96 (4.0)	62 (2.6)	-	48 (2.0)	-	-	32 (1.3)	-	-
Germ ring ½ to 3/4 around yolk	105 (4.4)	72 (3.0)	71 (3.0)	56 (2.3)	-	39 (1.6)	-	24 (1.0)	24 (1.0)
Germ ring 3/4 around to fully around	119 - 127 (5.0-5.3)	87 - 168 (3.6-7.0)	80 (3.3)	71 - 80 (3.0-3.3)	48 (2.0)	48 - 62 (2.0-2.6)	-	-	-
Late gastrula	127 - 144 (5.3-6.0)	120 - 168 (5.0-7.0)	96 - 104 (4.0-4.3)	-	-	-	48 (2.0)	-	-
Embryonic axis visible	153 - 175 (6.4-7.3)	135 - 144 (5.6-6.0)	119 (5.0)	96 (4.0)	56 (2.3)	62 - 72 (2.6-3.0)	51 (2.1)	39 - 62 (1.6-2.6)	39 - ** (1.6 -)
Head, optic vesicles visible	192 - 216 (8.0-9.0)	144 - 192 (6.0-8.0)	127 (5.3)	105 (4.4)	71 (3.0)	72 - 87 (3.0-3.6)	56 (2.3)	-	48 - ** (2.0-)
Embryo 9/12 around yolk	227 - 240 (9.5-10.0)	159 - 192 (6.6-8.0)	144 - 153 (6.0-6.4)	-	80 - 119 (3.3-5.0)	96 - 120 (4.0-5.0)	-	-	-

Table 4 (continued).

Stage	2	3*	4	6	8 (1983)	8 (1982)*	10	12*	15*
					Temperature (C)				
Embryo 10/12 around yolk	248 - 368 (10.3-15.3)	168 - 240 (7.0-10.0)	166 (6.9)	119 - 144 (5.0-6.0)	- 176 (-7.3)	-	72 - 144 (3.0-6.0)	48 - 144 (2.0-6.0)	62 - ** (2.6-)
Embryo 11/12 around yolk	272 - 466 (11.3-19.4)	207 - 335 (8.6-14.0)	175 - 227 (7.3-9.5)	144 - 168 (6.0-7.0)	96 - 176 (4.0-7.3)	111 - 264 (4.6-11.0)	80 - 144 (3.3-6.0)	62 - 159 (2.6-6.6)	
Embryo fully around yolk	312 - 636 (13.0-26.5)	240 - 375 (10.0-15.6)	216 - 263 (9.0-11.0)	168 - 216 (7.0-9.0)	105 - 216 (4.4-9.0)	120 - 264 (5.0-11.0)	96 - 168 (4.0-7.0)	72 - 159 (3.0-6.6)	
Tip of tail reaches front edge of eye	360 - 636 (15.0-26.5)	255 - 399 (10.6-16.6)	227 - 312 (9.5-13.0)	175 - 216 (7.3-9.0)	-	135 - 264 (5.6-11.0)	-	87 - 159 (3.6-6.6)	
Tip of tail reaches beyond rear of eye	431 - 658 (18.0-27.4)	288 - 399 (12.0-16.6)	272 - 416 (11.3-17.3)	192 - 227 (8.0-9.5)	144 - 228 (6.0-9.5)	144 - 264 (6.0-11.0)	105 - 176 (4.4-7.3)	-	
Tip of tail distinctly pointed	456 - 658 (19.0-27.4)	312 - 686 (13.0-28.6)	287 - 416 (12.0-17.3)	227 - 263 (9.5-11.0)	154 - 228 (6.4-9.5)	168 - 288 (7.0-12.0)	-	96 - 159 (4.0-6.6)	
Finfold well defined	467 - 680 (19.5-28.3)	360 - 686 (15.0-28.6)	299 - 416 (12.5-17.3)	240 - 273 (10.0-11.4)	154 - 228 (6.4-9.5)	168 - 288 (7.0-12.0)	-	-	
Hatching imminent	504 - 800+ (21.0-33.3)	384 - 740+ (16.0-30.8)	359 - 528+ (15.0-22.0)	273 - 416+ (11.4-17.3)	168 - 323+ (7.0-13.5)	192 - 375+ (8.0-15.6)	119 - 263+ (5.0-11.0)	96 - 159+ (4.0-6.6)	
Hatching	563 - 800+ (23.5-33.3)	399 - 740+ (16.6-30.8)	368 - 528+ (15.3-22.0)	312 - 416+ (13.0-17.3)	200 - 323+ (8.3-13.5)	207 - 375+ (8.6-15.6)	128 - 263+ (5.3-11.0)	111 - 184+ (4.6-7.7)	

*In 1982 series elapsed time began with 2-cell stage.

**Development appeared to cease at approximately 72 hours.

+Hatching largely completed.

Table 5. Approximate ages in hours and days ( ) for winter flounder eggs collected in the PNPS intake and discharge canal, March-May 1983.

Date	Total Number	Age Hours	Age (Days)	No. Eggs	Water Temp. (C)
March 8	7	24-39	(1.0-1.6)	2	3.4
		87-168	(3.6-7.0)	2	
		135-144	(5.6-6.0)	1	
		-		1 dead	
		-		1 deformed	
March 29	3	216-263	(9.0-11.0)	1	4.5
		-		2 dead	
March 30*	2	24	(1.0)	1	4.5
		-		1 dead	
April 4	8	71-80	(3.0-3.3)	1	6.0
		119-144	(5.0-6.0)	1	
		105	(4.4)	1	
		168-216	(7.0-9.0)	1	
		273-416	(11.4-17.3)	2	
		-		2 dead	
April 5*	1	-		1 dead	6.0
April 19	11	24	(1.0)	2	6.0
		71-80	(3.0-3.3)	2	
		144-168	(6.0-7.0)	2	
		168-216	(7.0-9.0)	1	
		175-216	(7.3-9.0)	2	
		-		2 dead	
April 20*	3	24	(1.0)	1	5.0
		168-216	(7.0-9.6)	1	
		-		1 dead	
April 29*	1	71	(3.0)	1	7.0
May 9*	4	-		4 dead	6.0
May 11*	1	-		1 dead	6.0
May 17	9	<72	(<3.0)	1	9.0
		-		8 dead	
May 17*	8	<48	(<2.0)	1	
		-		7 dead	
May 23	1	-		1 dead	8.5

*These represent results from PNPS intake tows. Additional samples were taken on April 11, 13, May 2, 4, 23, but no eggs were found.

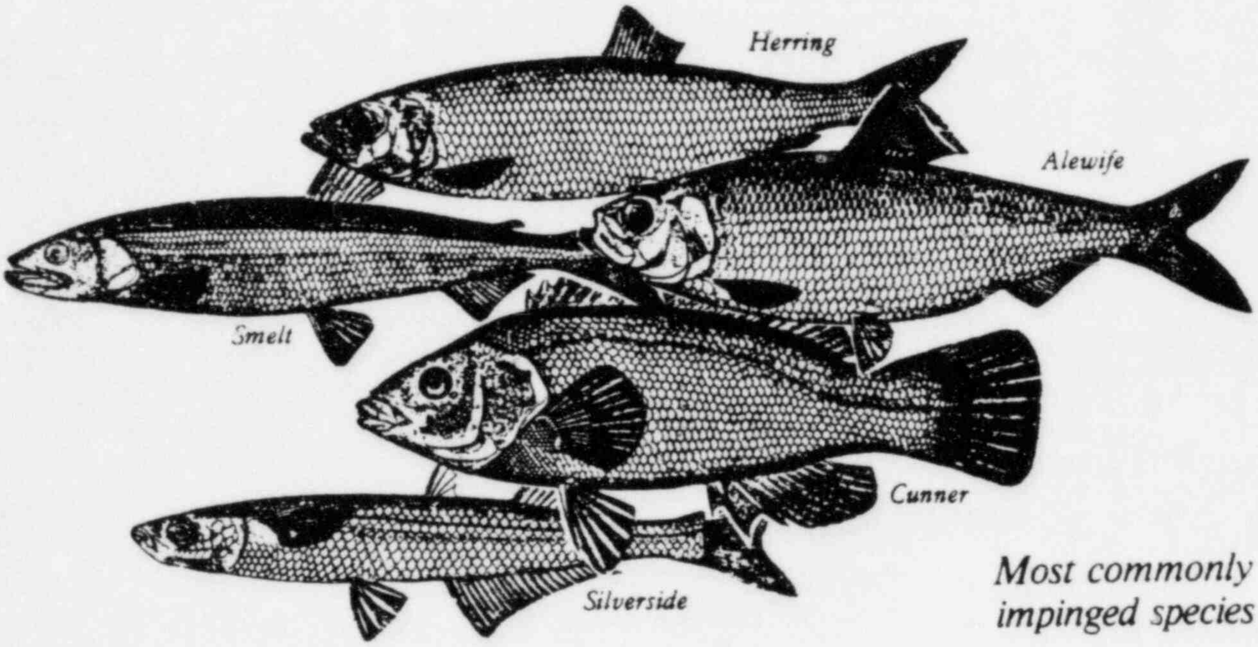
(NUC6-C1)

IMPINGEMENT OF ORGANISMS AT PILGRIM NUCLEAR POWER STATION (January - June 1983)

Prepared by: Robert D. Anderson
Robert D. Anderson
Senior Marine Fisheries
Biologist

Nuclear Management Services Department
Boston Edison Company
25 Braintree Hill Office Park
Braintree, Massachusetts 02184

October 1983



Most commonly impinged species

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1
SUMMARY

Fish impingement averaged 0.42 fish/hour during the period January-June 1983. Atlantic silverside (*Menidia menidia*), grubby (*Myoxocephalus aenaeus*), rainbow smelt (*Osmerus mordax*), winter flounder (*Pseudopleuronectes americanus*) and Atlantic tomcod (*Microgadus tomcod*), accounted for 67.7% of the fishes collected.

The collection rate (no./hr.) for all invertebrates captured from January-June 1983 was 2.94. The horseshoe crab (*Limulus polyphemus*), *Crangon* sp. and sand shrimp (*Crangon septemspinosa*) accounted for 95.2% of the invertebrates impinged. Mixed species of algae collected on intake screens amounted to 719 pounds.

SECTION 2
INTRODUCTION

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

This document is a report pursuant to operational environmental monitoring and reporting requirements of NPDES Permit No. 0003557 (EPA) for Pilgrim Nuclear Power Station, Unit 1. The report describes impingement of organisms carried onto the vertical travelling water screens at Unit I. It presents analysis of the relationships between impingement, environmental factors, and plant operational variables.

The report is based on data collected from screen wash samples from January-June 1983.

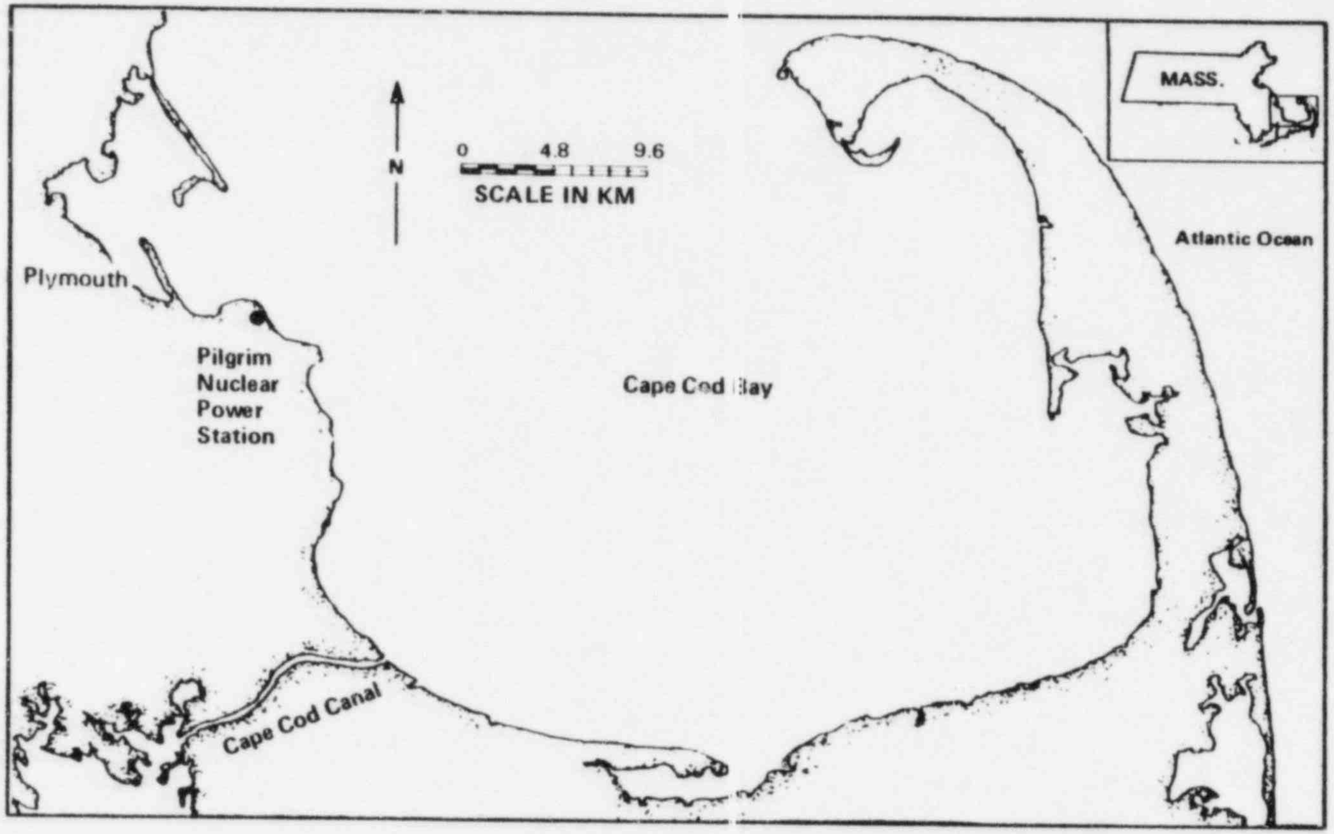


Figure 1. Location of Pilgrim Nuclear Power Station

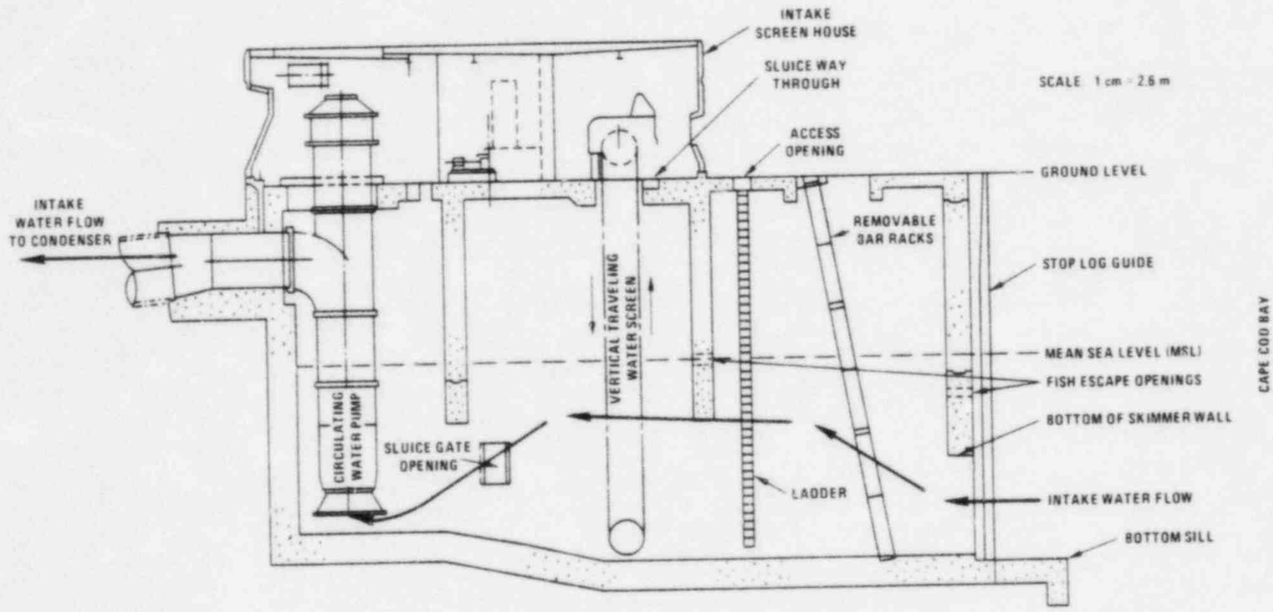


Figure 2. Intake Structure of Pilgrim Nuclear Power Station

SECTION 3
METHODS AND MATERIALS

Three screen washings each week were performed from January-June 1983 to provide data for evaluating the magnitude of marine biota impingement. The total weekly collection time was 24 hours (three separate 8-hour periods: morning, afternoon and night). Two collections represented dark period sampling and one represented light period sampling. At the beginning of each collection period, all four travelling screens were washed. Eight hours later, the screens were again washed (minimum of 30 minutes each) and all organisms collected. When screens were being washed continuously, one hour collections were made at the end of the regular sampling periods, and they represented two light periods and one dark period on a weekly basis.

Water nozzles directed at the screens washed impinged organisms and debris into a sluiceway that flowed into a trap. The original trap was made of galvanized screen (3/8-inch mesh) attached to a removable steel frame. A new trap was designed and used for sampling, in conjunction with new sluiceway survival studies, consisting of a section of corrugated pipe and fine mesh plankton netting.

Variables recorded for organisms were total numbers, and individual total lengths (mm) and weight (gms) for up to 20 specimens of each species. A random sample of 20 fish or invertabrates 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.

Intake seawater temperature, power level output, tidal stage, number of circulating water pumps in operation, time of day and date were recorded at time of collections. The collection rate (#/hour) was calculated as number of organisms impinged per collecting period divided by the total number of hours in that collecting period. All common and scientific names in this report follow the American Fisheries Society (1980) and Smith (1964).

SECTION 4
RESULTS AND DISCUSSION

4.1 Fishes

In 408 collection hours, 170 fishes of 26 species (Table 1) were collected from Pilgrim Nuclear Power Station intake screens during January-June 1983. The collection rate was 0.42 fish/hour. Atlantic silverside (Menidia menidia) was the most abundant species accounting for 33.5% of all fishes collected (Table 2). Grubby (Myoxocephalus aenaeus), rainbow smelt (Osmerus mordax), winter flounder (Pseudopleuronectes americanus) and Atlantic tomcod (Microgadus tomcod) accounted for 15.9, 6.5, 6.5, and 5.3% of the total number of fishes collected. Historically, Atlantic silversides have been impinged in high numbers during March/April which was true for this period in 1983. These were primarily adult fish that averaged 102 mm total length. The grubby were mostly impinged in April/May, and the rainbow smelt in January/February. Atlantic tomcod were mainly caught in January and winter flounder during March/April, reflecting the latter species inshore spawning migration.

4.2 Invertebrates

In 408 collection hours, 1200 invertebrates of 12 species (Table 3) were collected from Pilgrim Station intake screens between January-June 1983. The collection rate was 2.94 invertebrates/hour. Three species, horseshoe crab (Limulus polyphemus), Crangon sp. and sand shrimp (Crangon septemspinosa), accounted for 56.6, 26.0, and 12.7%, respectively, of the total number of invertebrates collected.

The greatest collections of horseshoe crabs occurred in May and June, and sand shrimp in March and April. No specimens of the commercially important American lobster (Homarus americanus) were captured. The hourly collection rates of horseshoe crabs for May (3.34) and June (6.97) were the highest recorded since 24-hour weekly impingement sampling commenced in 1979 (Table 4). This may reflect a natural population explosion of this species.

Approximately 719 pounds of mixed algae species were recorded during impingement sampling or 1.76 pounds/hr.

Table 1. Monthly Impingement For All Fishes Collected From Pilgrim Station Intake Screens, January - June 1983

Species	Jan.	Feb.	March	April	May	June	Totals
Atlantic silverside	1	7	40	7	2		57
grubby	1	1	1	16	8		27
rainbow smelt	6	3	1		1		11
winter flounder		1	3	6		1	11
Atlantic tomcod	6	2		1			9
lumpfish	5	1		1	1		8
windowpane			2	4	1		7
alewife			1	1	3		5
northern pipefish				4			4
rock gunnel				4			4
northern searobin					3		3
pollock					1	2	3
sandlance sp.					3		3
Atlantic herring				2			
cunner						2	2
fourspot flounder					1	1	2
northern puffer					2		2
threespine stickleback			2				2
Atlantic mackerel						1	1
Atlantic menhaden					1		1
blueback herring				1			1
little skate						1	1
seasnail		1					1
silver hake			1				1
striped killifish		1					1
winter skate						1	1
TOTALS	19	17	51	47	27	9	170
Collection Time (hrs.)	83	52	72	66	76	59	408
Collection Rate (#/hr.)	0.23	0.33	0.71	0.71	0.36	0.15	0.42

(NUC6-C10)

Table 2. Species, Number, Total Length(mm), Weight(gms) and Percentage For All Fishes Collected From Pilgrim Station Impingement Sampling, January - June 1983

Species	Number	Length Range	Mean Length	Weight Range	Mean Weight	Percent of Total Fish
Atlantic silverside	57	75-141	102	2-14	6	33.5
grubby	27	34-111	70	1-25	6	15.9
rainbow smelt	11	78-204	126	3-53	14	6.5
winter flounder	11	51-205	76	1-97	12	6.5
Atlantic tomcod	9	110-140	119	9-18	13	5.3
lumpfish	8	41-67	51	3-14	7	4.7
windowpane	7	52-170	75	1-69	12	4.1
alewife	5	70-122	109	3-18	12	2.9
northern pipefish	4	78-200	139	2-4	3	2.4
rock gunnel	4	65-110	82	2-11	5	2.4
northern searobin	3	225-284	263	98-174	146	1.8
pollock	3	215-245	228	87-133	118	1.8
sandlance sp.	3	212-165	139	6-15	10	1.8
Atlantic herring	2	26-37	31	.02-.1	.06	1.2
cunner	2	65-106	86	5-22	13	1.2
fourspot flounder	2	262-296	279	128-180	154	1.2
northern puffer	2	180-199	190	100-120	110	1.2
threespine stickleback	2	38-39	38	1	1	1.2
Atlantic mackerel	1	200	200	56	56	0.6
Atlantic menhaden	1	271	271	304	304	0.6
blueback herring	1	91	91	6	6	0.6
little skate	1	334	334	274	274	0.6
seasnail	1	79	79	7	7	0.6
silver hake	1	235	235	84	84	0.6
striped killifish	1	77	77	5	5	0.6
winter skate	1	770	770	4,000	4,000	0.6

Table 3. Monthly Impingement For All Invertabrates Collected From Pilgrim Station Intake Screens, January - June 1983

Species	Jan.	Feb.	March	April	May	June	Totals
horseshoe crab				14	254	411	679
Crangon sp.	31	48	233				312
sand shrimp			8	129	15		152
jellyfish					20+		20+
rock crab				1		13	14
long-finned squid					2	9	9
lady crab						4	4
clam worm					3		3
green sea urchin						2	2
common starfish				1			1
green crab					1		1
soft-shelled clam					1		1
TOTALS	31	48	241	145	296	439	1200
Collection Time (hrs.)	83	52	72	66	76	59	408
Collection Rate (#/hr.)	0.37	0.92	3.35	2.20	3.89	7.44	2.94

Table 4. Horseshoe Crab (Limulus Polyphemus)
Impingement Collections During May - July
From 1979-1983 at Pilgrim Nuclear
Power Station (Sampling Time 24 hr/wk)

I. IMPINGEMENT TOTAL (#)

YEARS	May	June	July	May-July Total
1979	26	21	2	49
1980	49	97	80	226
1981	27	143	29	199
1982	110	120	62	292
1983	254	411	250	915
MONTHLY TOTAL	466	792	423	1,681
Monthly $\overline{X}$	93	158	85	336

II. IMPINGEMENT RATE (#/hr)

YEARS	May	June	July	May-July $\overline{X}$
1979	.30	.38	.10	.26
1980	.46	1.36	1.04	.95
1981	.71	1.31	.52	.85
1982	1.53	2.07	.61	1.40
1983	3.34	6.97	3.03	4.45
Monthly $\overline{X}$	1.27	2.42	1.06	1.58

SECTION 5
CONCLUSIONS

1. The average Pilgrim I collection rate for the period January-June 1983 was 0.42 fish/hour. Historically, the collection rate has been relatively low.

2. Twenty-six species of fish were recorded in 408 impingement collection hours.

3. The major species collected and their relative percentages of the total collections were Atlantic silverside, 33.5%; grubby, 15.9%; rainbow smelt, 6.5%; winter flounder, 6.5%; and Atlantic tomcod, 5.3%.

4. The hourly collection rate for invertebrates was 2.94 with horseshoe crab, 56.6%; Crangon sp.; 26.0% and sand shrimp; 12.7%. No American lobsters were caught.

5. During May and June 665 horseshoe crabs were sampled during impingement collections. This represents the highest total during these two months for this species.

SECTION 6
LITERATURE CITED

Americal Fisheries Society. 1980. A list of Common and Scientific Names of Fishes From the United States and Canada. Spec. Pub. No. 12: 174 pp.

Smith, R. I. (Ed.). 1964. Keyes to Marine Invertebrates of the Woods Hole Region. Marine Biological Laboratory. Woods Hole, Massachusetts.

Assessment of Finfish Survival at
The Pilgrim Nuclear Power Station
Screenwash Sluiceway, April-August 1983

Submitted to

Boston Edison Company

Boston, Massachusetts

by

Marine Research, Inc.

Falmouth, Massachusetts

September 21, 1983

Revised

October 13, 1983

Table of Contents

Figures

Tables

I. Introduction

This progress report describes studies conducted at the Pilgrim Nuclear Power Station screenwash system from April through August of 1983. These investigations, carried out for Boston Edison Company under Purchase Order No. 69975, represent a continuation of work performed during 1980 through 1982. Initial studies were designed to observe the effectiveness of a permanent sluiceway constructed in late 1979 to return fish surviving impingement to Cape Cod Bay waters with little added mortality. Additional studies involved examination of mortality rates induced by impingement before and after installation of low-pressure spray wash nozzles and the preparation of a data base for assessment of possible future fish kills.

Studies conducted in 1983 were planned to complete the data base considered necessary for the assessment of any future fish kills at PNPS. The primary objectives were:

1) To develop meaningful sample sizes by monitoring survival under the routine screenwash regime established at the plant.
2) To obtain survival data on rainbow smelt (Osmerus mordax), alewives (Alosa pseudoharengus), and pollock (Pollachius virens) if possible using fish experimentally introduced to the screenwash system. These species have historically been among the most commonly impinged fishes, but little or no survival data are available for them.
3) To obtain survival data on experimental groups of fishes held in front of the screens for eight hours prior to impingement. These studies were designed to simulate normal eight-hour wash cycles and to provide comparisons with continuous wash introduction studies completed in 1982.

II. Methods

To determine survival rates, fish washed off the traveling screens were sampled at the end of the sluiceway (Figure 1). Special nets were constructed

of 3/16-inch (4.8 mm) "delta" mesh so that all water passing down the sluiceway was filtered. Net-induced injury was minimized by using two nets interchanged frequently so that fish were confined to the net for only short periods before being transferred to pails containing ambient seawater.

Upon collection initial mortality was determined by immediately transferring fish to 8-liter pails containing ambient seawater. Dead fish (condition categories are defined below) were removed and set aside for identification and length-weight measurements. Live fish, whether healthy or injured, were transferred quickly to five-foot (1.5 m) diameter, circular holding pools located about 20 feet (6.1 m) from the end of the sluiceway and supplied with continuous running seawater. The pools were fitted with screen and wire mesh covers to prevent fish from jumping out and to eliminate predation by shore birds and racoons.

Fish were observed in the holding pools for one hour following introduction, and any dead fish were removed following that time. All surviving fish were held in the pools until the next scheduled sampling period approximately 55 to 56 hours later. At the end of each holding period all fish were weighed ($\pm$ 0.1 gm) and measured ($\pm$ 1 mm) by condition category - alive, dead, or injured. Fish were not fed during the holding period.

The survival study was combined with the finfish impingement monitoring program so that sampling was conducted three times per week (Monday 0830, Wednesday 1630, and Saturday 0030). Studies were scheduled to be conducted during the months of March, April, August, September, November, and December 1983, as in previous years; these months were selected because historically they have represented periods of greatest impingement. In 1983 sampling was delayed until April due to problems with the power supply necessary for the holding pool pumps. To compensate for this delay sampling was extended through May.

Data were collected under both static and continuous wash cycles and therefore represented fish which might have spent up to eight hours on the screens (screens are routinely washed every eight hours), or only a brief time period. If the screens were static at the start of a sampling period, fish collected during the first ten minutes (the approximate time necessary for one revolution of the screens) were held in a separate pool and observed independently from any fish collected after the ten-minute period. Sampling was conducted for 0.5 hour if the screens were static prior to collection or one hour if the screens were in the continuous wash mode. Provisions were made to extend sampling beyond these time periods in any case where sampling personnel believed more fish would have been collected.

Since impingement rates are generally low at PNPS, additional studies were designed for 1982 and 1983 to obtain larger samples which might better define possible sources of impingement mortality. Samples of fish were collected from local waters by beach seine, otter trawl, or baited lift net and transferred to PNPS in large (32-50 gal; 121-189 l), plastic, aerated containers. At PNPS these fish were handled in one of two ways: 1) To simulate continuous screen-wash conditions, fish were released immediately in front of the traveling screens by lowering them in a specially designed container through the upstream access opening (Figure 2). 2) To simulate normal intermittent wash cycles where the screens remain idle for eight hours, the fish were transferred to a rigid holding pen measuring 36 in (90 cm) x 25 in (62.5 cm) x 22 in (55 cm) deep. The pen was then held in front of the screens in the intake water flow for eight hours at which time the fish were released by opening a downstream door in the pen. The container used for the continuous wash simulation studies was fitted with a hinged lid so that it could be lowered below the inner skimmer wall (Figure 2) before the fish were released. The holding pen used for the eight-hour studies was also lowered below the skimmer wall. In all cases the screens

and wash pumps were operating during the release period and for a minimum of one hour following the release period. Throughout these wash cycles sampling was conducted near the end of the sluiceway as described above by a second person. All fish collected this way were handled in a manner identical to that used with the naturally impinged fish. However, due to variations in collection times, holding periods for introduced fish varied from 44 to 69 hours.

The beach seine used to collect fish for these studies measured 100 by 6 feet (30.5 x 1.8 m) and was made of ¼-in (6.4 mm) "delta" mesh. It was used at several locations along the Plymouth Harbor side of Plymouth Beach, along the town beach in Plymouth, and along the north side of the PNPS intake. To collect alewives, beach seine collections were made in Mount Hope Bay (upper Narragansett Bay) using a 300 x 8-foot (91 x 2.4 m) beach seine with ½-in (12.5 mm) mesh.

Cunner (Tautogolabrus adspersus) and pollock were obtained in Sandwich, Massachusetts, along the southeast side of the Cape Cod Canal using a 28-in (0.7 m), 3/16-in (4.8 mm) mesh lift net baited with a fish carcass or squid. Rainbow smelt were collected at night during the spawning run in the Jones River just below the Elm Street dam (fresh water) using the same lift net (unbaited). Winter flounder (Pseudopleuronectes americanus), windowpane (Scophthalmus aquosus), and grubby (Myoxocephalus aenaeus) were obtained with a small otter trawl in Plymouth Harbor-Kingston, Duxbury Bay. Whenever eight-hour holding pen studies were conducted, the fish were transferred to the pen at the 0830 screenwash and then released at the 1630 screenwash. The logistics of this regime necessitated that the fish be held in a flow-through 50 gal (189 l) tank during one night following their collection. In the case of rainbow smelt a 5 ft (1.5 m) diameter, circular holding pool containing approximately 125 gal (473 l) was used to re-acclimate the smelt

tc seawater (32 ^{o}/oo). This was accomplished by filling the pool with fresh water from the Jones River, adding the fish, and pumping seawater on a flow-through basis at approximately 200 gal (757 l) per hour. Smelt were held for 14 hours in the pool until released in front of the screens.

The percentage recovered among fish released in front of the screens was expected to be relatively low since we anticipated that healthy fish would avoid the 0.5 to 1.0 ft/sec current velocity at the screens and escape upstream. Because of this every effort was made to obtain large samples for the introduction studies. When collections were large, a portion of the catch was transferred directly to the holding pools to represent a control. In cases where collections were marginal, no controls were held. This was not considered a problem however since control survival was consistently high when tested in 1983 as well as in 1980, 1981, and 1982.

Condition categories during all phases of the study were defined as follows: alive - fish swimming and behaving in an apparently normal manner; dead - no body movement, no opercular movement, no response to gentle prodding; injured - tissue damage visible, fish swimming erratically, loss of equilibrium.

III. Results

A. Screen/Sluiceway Survival Studies

Finfish collections made at the end of the PNPS sluiceway during the months of April, May, and August 1983 are summarized in Table 1. A total of 72 fish were taken representing 23 species. Grubby, Atlantic silversides (*Menidia menidia*), and alewives ranked one, two, and three numerically, representing 27.8, 12.5, and 6.9% of the total, respectively.

Overall survival among all species following 56-hour holding periods amounted to 27.1% for static or 8-hour wash cycles and 25.0% for continuous wash cycles. Although sample sizes were small in all cases, among the three

dominant species survival appeared to be low among both silversides and alewives (0%) and somewhat higher among grubbies (25.0%) when both static and continuous wash data were combined. These results are consistent with past years among silversides and alewives when overall survival has been 0%. Among grubbies the 1983 survival rate to date appears to be somewhat low since overall latent survival was 54.2% (n = 24) during 1980-1982 (MRI 1983).

B. Screen Introduction Studies

Table 2 summarizes information on species and numbers of fish released in front of the PNPS traveling screens through August of 1983. Among the species tested all were maintained in a holding pen in front of the screens for approximately eight hours prior to release with the exception of rainbow smelt. Smelt were released with no holding period in a continuous wash simulation since they had not been tested previously under that regime.

Cunner (n = 570), Atlantic silversides (n = 225), mummichogs (*Fundulus heteroclitus*, n = 158), winter flounder (n = 141), striped killifish (*Fundulus majalis*, n = 54), and rainbow smelt (n = 36*) accounted for the primary test species available; other species listed were taken as incidental to the catch. Recovery rates among the above species ranged from 69.6% among mummichogs to 0.9% among cunner. These data suggest that many healthy fish can successfully avoid impingement even following an eight-hour period in the intake current.

Among fish recovered at the end of the sluiceway, survival following 49 to 69-hour holding periods ranged from 0% among Atlantic silversides (n = 129) to 57.1% among striped killifish (n = 7). This range excludes smelt survival (100%) since only one fish was recovered. High control

---

*The sample size for smelt was considerably smaller than planned. The first test representing n = 36 treated fish, n = 25 controls, was purposely small since we were uncertain that these fish could be successfully transferred to seawater in a period of time estimated at perhaps one hour. Attempts to collect larger numbers of smelt on subsequent nights failed, suggesting that the spawning run ended early in 1983.

survival rates of 100% for smelt, mummichog, striped killifish, cunner; 95.5% for flounder; and 90.0 for silversides, indicate that little mortality could be attributed to collection methods or the holding facilities.

Sampling of naturally impinged fish will be conducted in the PNPS sluiceway during September, November, and December. Screen introduction studies will also continue during this period. A final report summarizing the 1983 work as well as all studies (1980-1983) will be prepared by February 29, 1984.

IV. Summary

Fish impinged on the traveling screens at PNPS were sampled at the end of the sluiceway during the months of April, May, and August 1983. A total of 72 fish were taken representing 23 species. Pooling all fish taken under both static and continuous wash periods, survival rates were 31.9% upon collection and 26.4% following 56-hour holding periods.

Additional studies involving introduction of locally collected, healthy fish to the screens and wash system were also conducted. These involved release of fish following an eight-hour period in front of the screens using a holding pen with a removable release door. Survival rates in these studies ranged from 0% among Atlantic silversides (n = 129) to 57.1% among striped killifish (n = 7) following 49 to 69-hour holding periods. Recovery rate in these studies, i.e. percentage collected in the screenwash relative to the number introduced, was generally quite low, ranging from 0.9% among cunner to 69.6% among mummichogs. These results suggest that healthy fish can successfully avoid impingement even after swimming ahead of the screens for an eight-hour period.

Studies are scheduled to continue through the remainder of 1983.

V. Literature Cited

MRI (Marine Research, Inc.). 1983. Assessment of finfish survival at Pilgrim Nuclear Power Station 1982. In: Marine Ecology Studies related to operation of Pilgrim Station. Semi-Annual Rept. 21. Boston Edison Company.

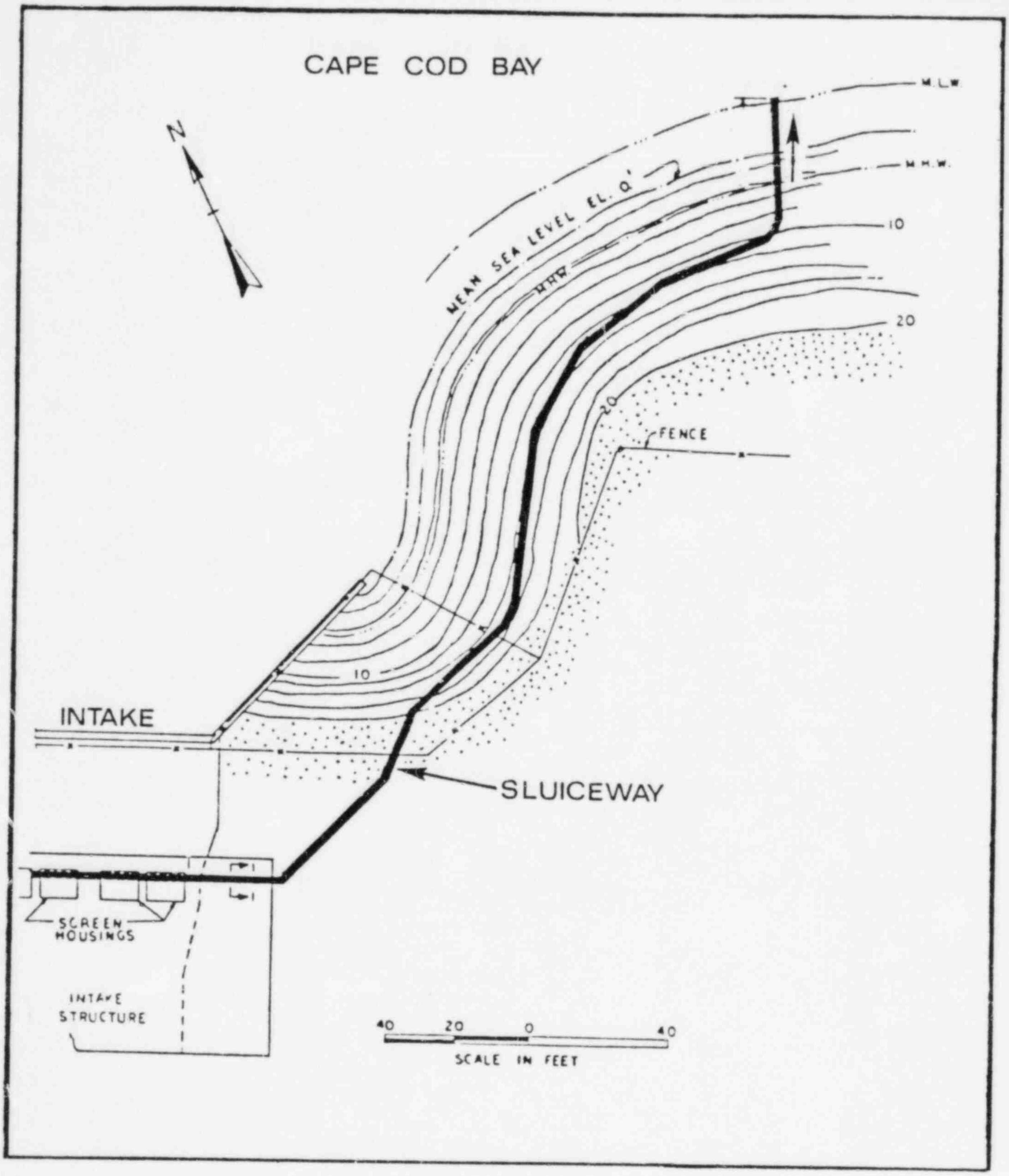


Figure 1: The PNPS sluiceway designed to return impinged fish to ambient temperature water in Cape Cod Bay.

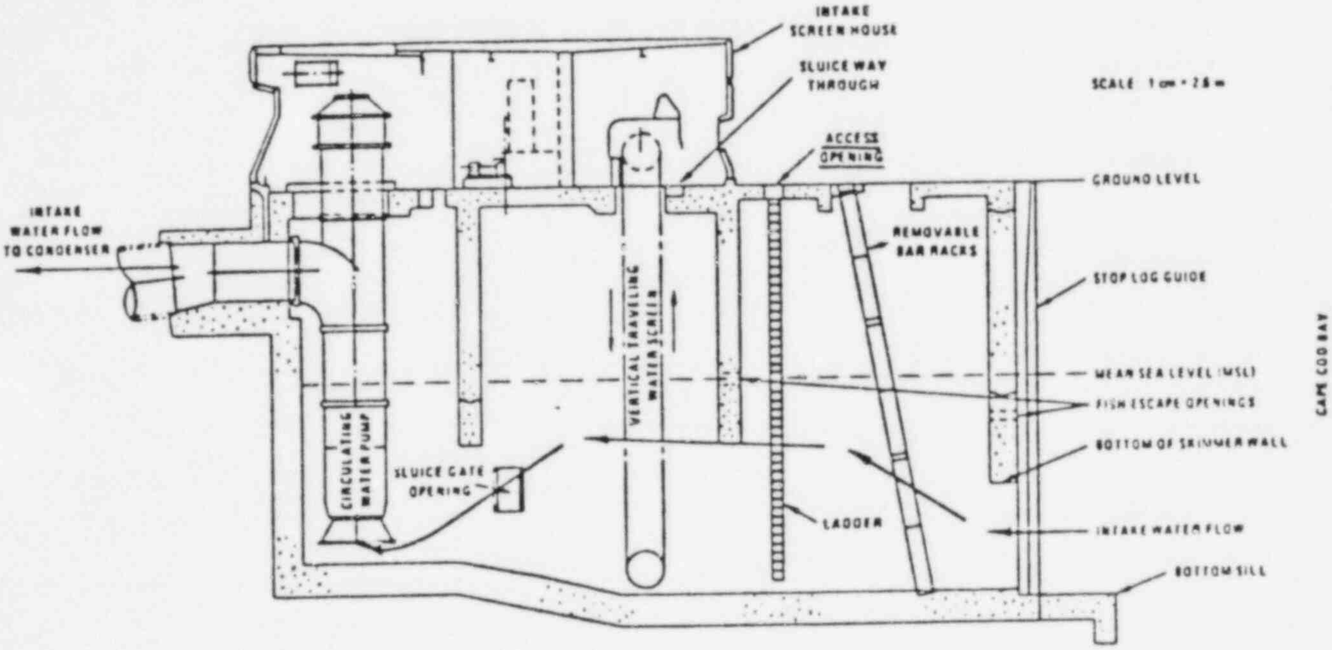


Figure 2. Diagram of the PNPS seawater intake system (illustration provided by Boston Edison Company).

Table 1. Total length mean and range (mm), total number of fish collected, number and percentage alive, and number and percentage surviving a 56-hour holding period by species in the PNPS sluiceway, April-August 1983.

Species	Total length (mm)		Number collected		Number (%) Collected alive		Number (%) Surviving 56 hours	
	Mean	Range	Static Washes	Contin. Washes	Static Washes	Contin. Washes	Static Washes	Contin. Washes
Spiny dogfish (*Squalus acanthias*)	1050	-	1	0	0	-	-	-
Little skate (*Raja erinacea*)	485	460 - 510	0	2	0	2(100)	-	1(50.0)
Blueback herring (*Alosa aestivalis*)	91	-	1	0	0	-	-	-
Alewife (*A. pseudoharengus*)	93	70 - 115	5	0	1(20.0)	0	0	-
Atlantic menhaden (*Brevoortia tyrannus*)	156	41 - 271	1	1	0	0	-	-
Atlantic herring (*Clupea h. harengus*)	32	26 - 37	0	2	0	0	-	-
Rainbow smelt (*Osmerus mordax*)	78	-	1	0	0	-	-	-
Silver hake (*Merluccius bilinearis*)	250	-	1	0	0	-	-	-
Atlantic tomcod (*Microgadus tomcod*)	173	125 - 220	2	0	1(50.0)	0	1(50.0)	-
Pollock (*Pollachius virens*)	225	-	0	1	0	0	-	-
Atlantic silverside (*Menidia menidia*)	98	84 - 110	7	2	0	0	-	-
Threespine stickleback (*Gasterosteus aculeatus*)	63	-	1	0	0	0	-	-
Northern pipefish (*Syngnathus fuscus*)	139	78 - 200	2	0	1(50.0)	0	1(50.0)	-
Cunner (*Tautogolabrus adspersus*)	99	75 - 143	1	2	0	1(50.0)	-	1(50.0)
Rock gunnel (*Pholis gunnellus*)	82	65 - 110	2	1	0	1(100)	-	1(100)
Sand lance (*Ammodytes* sp.)	139	121 - 165	0	3	0	0	-	-
Northern searobin (*Prionotus carolinus*)	263	225 - 284	0	3	0	0	-	-
Grubby (*Myoxocephalus aenaeus*)	68	34 - 102	15	5	4(26.7)	3(60.0)	4(26.7)	1(20.0)
Lumpfish (*Cyclopterus lumpus*)	55	42 - 67	2	0	2(100)	0	2(100)	-
Fourspot flounder (*Paralichthus oblongus*)	296	-	0	1	0	1(100)	-	1(100)

Table 1 (continued).

Species	Total length (mm) Mean	Range	Number collected Static Washes	Contin. Washes	Number (%) Collected alive Static Washes	Contin. Washes	Number (%) Surviving 56 hours Static Washes	Contin. Washes
Windowpane (*Scophthalmus aquosus*)	59	52 - 65	3	0	3(100)	0	3(100)	-
Winter flounder (*Pseudopleuronectes americanus*)	55	51 - 59	2	0	2(100)	0	2(100)	-
Northern puffer (*Sphoeroides maculatus*)	190	180 - 199	1	1	0	1(100)	-	1(100)
Total			48	24	14(29.2)	9(37.5)	13(27.1)	6(25.0)

Table 2. Species of fish released in front of the PNPS traveling screens, number recovered, survival rates, including control samples, and total length data, April-August 1983.

Species	Number Introduced	Number (%) Recovered	Number (%) Alive 1 hr	Number (%) Alive 49+hrs	% Control Survival	Total lengths (mm) Recovered Mean	Recovered Range	Controls Mean	Controls Range
Rainbow smelt* (*Osmerus mordax*)	36	1(2.8)	1(100)	1(100)	100 (n=25)	135	-	171	123 - 231
Mummichog (*Fundulus heteroclitus*)	158	110(69.6)	104(94.5)	44(40.0)	100 (n=37)	72	61 - 95	76	65 - 98
Striped killifish (*F. majalis*)	54	7(13.0)	5(71.4)	4(57.1)	100 (n=15)	79	62 - 110	76	66 - 106
Atlantic silverside (*Menidia menidia*)	225	129(57.3)	21(16.3)	0	90.0 (n=20)	88	68 - 122	88	80 - 99
Threespine stickleback (*Gasterosteus aculeatus*)	9	9(100)	9(100)	0	100 (n=3)	61	55 - 65	55	40 - 62
Cunner (*Tautogolabrus adspersus*)	570	5(0.9)	3(60.0)	2(40.0)	100 (n=44)	133	85 - 185	125	78 - 210
Sand lance (*Ammodytes* sp.)	3	2(66.7)	2(66.7)	0	-	140	-		-
Grubby (*Myoxocephalus aenaeus*)	8	1(12.5)	1(100)	1(100)	-	60	-		-
Windowpane (*Scophthalmus aquosus*)	4	4(100)	4(100)	2(50.0)	-	134	125 - 144		-
Winter flounder (*Pseudopleuronectes americanus*)	141	52(36.9)	25(17.7)	5(9.6)	95.5 (n=22)	156	83 - 280	182	110 - 301
Total	1208	320(26.5)	175(54.7)	59(18.4)	98.2 (n=166)				

*Rainbow smelt were released without a holding period; all others were maintained in a pen in front of the screens for approximately 8 hours prior to release.

MEMORANDUM

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

FROM: Phillips Brady, Recording Secretary, Marine Fisheries Biologist, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 57th meeting of the Pilgrim Administrative-Technical Committee

DATE: January 13, 1983

The 57th Administrative-Technical Committee meeting was called to order on 13 January, 1983 at 9:30 A.M. at the Pilgrim Nuclear Station Information Building, in Plymouth, Massachusetts by Chairman R. Leger. Following a monograph subcommittee meeting concerning document format and time submission to the American Fisheries Society, four agenda items were addressed.

I. Minutes of the 56th meeting.

Corrections to the 56th Committee minutes were tendered and are attached as a separate addendum to these minutes.

II. Monograph status update.

Leigh Bridges presented a summary of the monograph subcommittee's discussions. The group recommended that preparations continue for document submission to American Fisheries Society (A.F.S.) by mid-February. It is hoped that AFS's managing editor, Bob Kendall, can undertake a speedy determination of the document's suitability and notify editors as quickly as possible of its acceptance or rejection. If rejected, efforts will continue for alternative sources of publication. The N.O.A.A. Technical Memorandum NMFS-F/NEC and S.E.N.A. series, or Springer-Verlag are considered promising avenues for publication.

Bob Leger requested input and comments from the full A-T Committee. General discussion centered on a number of issues: including the ecological synthesis section, a submission time-table, and document continuity. At the conclusion of discussions, George Kelly moved that the full A-T Committee endorse the subcommittee recommendation and proceed with document submission to the American Fisheries Society. Bob Lawton second, and the motion passed unanimously.

III. 1983 Sluiceway study.

Bob Anderson highlighted a letter sent by Mike Scherer of MRI outlining proposed finfish survival studies at PNPS in 1983. Additional information desired for the assessment of any future fish kills at Pilgrim Station included: 1) survival data on rainbow smelt, alewives, and pollock, - important species for which little data have been obtained to date; and, 2) introduction of fish to the screenwash system after holding them in front of the screens for eight hours to simulate a normal wash cycle.

Bob Anderson supported the proposal and asked for full committee consideration. Following the discussion, George Kelly moved to support the study as presented, allowing final details to be worked out between MRI and Bob Anderson and to be reviewed at the next A-T Committee meeting. Gery Szal second, and the motion passed unanimously.

IV. 1984 Integration study proposal of Marine Research, Inc.

Lew Scotton requested that any questions on Marine Research's two proposals: 1) "Proposal for studies of the interrelationships between nutrient levels and fluctuations in abundance of planktonic organisms, in Plymouth Harbor/Kingston, Duxbury Bay (PKDB) and Western Cape Cod Bay," and 2) "Proposal for studying the correlation between and prediction of meroplankton and benthic organisms in the western region of Cape Cod Bay in the vicinity of the Pilgrim Nuclear Power Station," be directed to Dick Toner for clarification.

As the second proposal is dependent on samples obtained in the first, Bob Leger inquired into both the type and extent of review the work had received. Dr. Toner replied that MRI had submitted the study to Mr. Charles Warren, whom they considered fully qualified in the area, for his review. His response was favorable. Gery Szal had a number of concerns regarding the study and felt that there was no concrete hypothesis testing afforded by the work. Dick remarked that much of the testing has been conducted in the laboratory and results were, in turn, expanded and drawn upon for this proposal. There were expressed concerns of "noise confusion" being interjected into the results by the presence of migratory fish populations which would render the conclusions tenuous or speculatroy.

Mike Bilger asked what the company was really looking for from the study. Lew Scotton responded that the investigation would try to predict and relate the percent fluctuation in larval fish abundances subjected to entrainment at Pilgrim Station to that caused by natural variability. Previous data have indicated that there is as much as a ten-fold variation in annual larval abundance. Data from the proposed study would be used to, "place in proper perspective the relationship between such yearly variations in these populations and the probable impact of the power plant and other factors such as nutrient inflow which influences biological populations."

Following extensive discussion of statistical testing methods, sampling intensity and frequency, required length of the study, and the predictive value of the project, George Kelly moved that although the proposals were of interest and had merit, the committee did not presently see need for BECo to conduct such work. Therefore, it was recommended that both proposals not be adopted. Bob Lawton second, the motion which passed unanimously.

Lew Scotton asked for direction from the committee as to 1983 winter flounder studies conducted by MRI. The committee suggested Lew meet with an MRI representative following the meeting and encourage them to submit a separate winter flounder proposal for evaluation by the PATC Committee. Committee members were interested in determining the percent spawning and resultant number of flounder eggs and larvae occurring in the immediate vicinity of the plant. Also, the topic of flounder spawning within the station's intake embayment was considered pertinent.

V. Adjournment.

Meeting adjourned at 1:35 P.M.

Administrative-Technical Committee Meeting

January 13, 1983

Bob Leger, Chairman	U.S.E.P.A. (non-voting advisory member)
Phillips Brady, Recording Secretary	Mass. Division of Marine Fisheries
Bob Lawton	Mass. Division of Marine Fisheries
Bob Anderson	BECo
George Kelly	NMFS - Woods Hole
Michael Bilger	U.S.E.P.A., Lexington
Lew Scotton	BECo
Gerald M. Szal	Mass. DWPC/DEQE
Richard Toner	Marine Research Inc.
W. Leigh Bridges	Mass. Division of Marine Fisheries
Tom Horst	Stone & Webster Environmental Engineering
John Davis	Westford, Mass.
Joe Pelczarski	C.Z.M.

MEMORANDUM

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

FROM: Phillips Brady, Recording Secretary, Marine Fisheries Biologist, Massachusetts Division of Marine Fisheries

SUBJECT: Addendum to the 56th meeting minutes of the Administrative-Technical Committee

DATE: January 13, 1983

The minutes of the 56th Committee Meeting are corrected as follows:

Page 3, Section V, the third sentence shall read: Publication through the American Fisheries Society continues to be pursued with a submission goal of February 1, 1983.

MEMORANDUM

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

FROM: Phillips D. Brady, Recording Secretary, Marine Fisheries Biologist, Massachusetts Division of Marine Fisheries

SUBJECT: Minutes of the 58th meeting of the Pilgrim Administrative-Technical Committee

DATE: June 9, 1983

The 58th Administrative-Technical Committee meeting was called to order on 9 June, 1983 at 10:05 A. M. at the Headquarters of the Massachusetts Division of Water Pollution Control (Westview Building-Lyman School, Westboro, Massachusetts, by Chairman Robert Leger. Eight agenda items were addressed.

I. Minutes of the 57th meeting.

Corrections to the 57th Committee minutes were tendered and are attached as an addendum to these minutes. Bob Lawton moved the 57th minutes be accepted with the appropriate corrections made; Leigh Bridges second and the motion passed unanimously.

II. Cost/Benefit of environmental studies.

Bob Anderson addressed the topic of cost/benefit for environmental studies conducted at Pilgrim Station. For the first time, BECo is requesting the A-T Committee consider cost as well as technical merit in its recommendations for environmental programs. BECo presently spends between 250-300 thousand dollars per year to satisfy NPDES permit requirements. Current expenditures, for permit compliance, place them in the mid-range of costs by comparison to other power stations.

Leigh Bridges felt that, as in the past, the subcommittee and full committee should prioritize work by technical merit without cost consideration. Following program recommendations, cost factors could be evaluated and the areas of increase be flagged. It was recommended that the committees focus first on the development of the best technical programs possible.

Bob Anderson noted that study emphasis has changed over the years. With the present climate, company costs should be integrated with study efforts in some manner during the formation of study recommendations. Bob Leger mentioned that during his ten years on the A-T Committee, study costs have not been a determining factor in program formulations. There was a consensus that studies should first be evaluated on technical merit. Following this, cost could be considered in order to maximize return for money expended on monitoring studies.

III. Semi-Annual Report #21, review and comments.

Bob Lawton presented an overview of the 1982 marine fisheries studies. Committee members were referred to the January-December report for study specifics and more in-depth information.

Bob Anderson presented highlights of the impingement program, sluiceway survival studies, finfish barrier net, and the fish overflight program. Members were also referred to report #21 for expanded coverage.

IV. Benthic studies contract, 1983-1984.

Lew Scotton distributed copies of a document, "Development and future trends of the mussel control program at Pilgrim Nuclear Power Station, Plymouth, MA". The 1983-84 benthic studies' contract is up for renewal the end of August, 1983. Lew outlined the major aspects of the program. The benthic subcommittee had discussed the program and agreed on recommending continuation for the next year. Bob Leger suggested the full committee discuss the work and vote on the proposal, then cost factors could be considered. Following general discussion, Bob Lawton moved to continue the current benthic work through December of 1983. Gerald Szal second. Motion passed unanimously.

Final cost factors for the program were not available as a finalized proposal had not been received. The committee felt Lew should contact the contractor and evaluate the financial picture. If needed, the full committee could reconvene for further discussion and evaluation.

V. Assignment of members for Marine Fisheries and Benthic Subcommittees for 1984 studies.

Chairman Leger asked for names of people interested in serving on the Marine Fisheries subcommittee for 1984. The following people expressed interest: Mike Ross, Bob Anderson, Bob Leger, Jack Finn, and Gerald Szal. Chairman Leger suggested Alan Hulbert (George Kelly's replacement from NMFS) as a member of a subcommittee. Bob offered to call Mr. Hulbert and inquire which committee he would prefer to serve on. Bob Lawton volunteered to participate on the fisheries subcommittee, as an ex officio member, to present DMF studies and field any questions the subcommittee might have.

Individuals interested in participating on the benthic subcommittee were: Bob Leger, Lew Scotton and Bob Lawton. Mike Bilger of the EPA was also asked to serve. Committee members suggested that Don Miller continue as subcommittee chairman in light of his in-depth input and work on that committee.

VI. Renewal of Pilgrim NPDES permit.

Bob Anderson distributed draft copies of the "Authorization to discharge under the National Pollutant Discharge Elimination System", (NPDES) Federal permit, along with a NPDES fact sheet and joint public notice from

Massachusetts Water Resource Commission, D. W. P. C., and the U. S. Environmental Protection Agency.

Bob Leger noted that EPA received no outside comments on the permit from the public notice process, and the time for comments had passed. The CZM review of the operating permit was discussed. Permit issuance is currently awaiting completion of CZM's consistancy review.

VII. Mussel control program.

Lew Scotton presented a 20-minute slide talk on the Mussel Control Program at PNPS. Conclusions were that although mussel fouling has been a problem in the past, the implementation of continuous chlorination of the salt service water system and a heat treatment program for the circulating water system has all but eliminated the problem. Future studies will be aimed at reducing screen debris "carryover" and optimized application under the existing programs.

VIII. Other business.

A. Bob Leger inquired about the status of the monograph publication. Leigh Bridges stated that replies from the AFS reviewers were due back by the end of June. Document evaluation would be presented as either a tentative acceptance or a firm rejection. If rejected, alternative sources of publication would be pursued immediately. The CZM funding contract has currently been extended until 30 September 1983, by which time a firm commitment for document publication is hoped.

B. Leigh recommended that a letter of appreciation from the A-T Committee, be sent to Mr. George Kelly, NMFS, in recognition of his many contributions and years of service to the Pilgrim Administrative-Technical Committee.

This action was affirmed by all members.

IX. Adjournment.

Meeting adjourned at 2:35 P.M.

Administrative-Technical Committee Meeting

June 9, 1983

Bob Leger, Chairman	U.S.E.P.A. (non-voting advisory member)
Phillips Brady, Recording Secretary	Mass. Division of Marine Fisheries
Bob Lawton	Mass. Division of Marine Fisheries
Bob Anderson	BECo
Michael Bilger	U.S.E.P.A., Lexington
Lew Scotton	BECo
Gerald M. Szal	Mass. DWPC/DEQE
W. Leigh Bridges	Mass. Division of Marine Fisheries
Mike Ross	U. Mass., Amherst
Christine Sheehan	Mass. Division of Marine Fisheries

MEMORANDUM

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

FROM: Phillips Brady, Recording Secretary, Marine Fisheries Biologist, Massachusetts Division of Marine Fisheries

SUBJECT: Addendum to the 57th meeting minutes of the Administrative-Technical Committee

DATE: June 9, 1983

The minutes of the 57th Committee Meeting are corrected as follows:

Page 3, Section IV, the final sentence of the paragraph shall read: There were expressed concerns of "noise confusion" being interjected into the results by the presence of migratory fish populations which would render the conclusions tenuous or speculatory.

DESIGNATED ORIGINAL

Certified By *mal*

BOSTON EDISON COMPANY
800 BOYLSTON STREET
BOSTON, MASSACHUSETTS 02199

WILLIAM D. HARRINGTON
SENIOR VICE PRESIDENT
NUCLEAR

October 31, 1983

BECo. 5.83.011

U.S. Environmental Protection Agency
Region I
Permits Processing Unit
Room 2109, JFK Federal Building
Boston, MA 02203

Dear Sir:

In accordance with Part I, Paragraph A.7.c, of the Pilgrim Nuclear Power Station NPDES Permit No. MA0003557, the Semi-Annual Marine Ecology Report No. 22 is hereby submitted. This report covers the period from January through June, 1983.

Very truly yours,

W.D. Harrington

:lsd

cc: Regional Administrator
U.S. Environmental Protection Agency
Region I
John F. Kennedy Federal Building
Boston, MA 02203

IE25
1/1