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on

BENTHIC ALGAL AND FAUNAL MONITORING AT THE PILGRIM NUCLEAR POWER STATION
January-June 1990

to

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Regulatory Affairs Department
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EXECUTIVE SUMMARY

This report represents results of quantitative data collected in April 1990 at established stations in the vicinity of the Pilgrim Nuclear Power Station (PNPS) and qualitative transect surveys conducted in the thermal effluent in April and June of 1990. These investigations represent the most recent phase of the long-term efforts to monitor the effects of thermal effluents on the benthic communities adjacent to the PNPS.

A variety of analytical techniques were used to assess community structure. Specific data on algal biomass, dominant fauna, species diversity, and faunal densities were analyzed along with overall community relationships. Field collections and laboratory techniques were identical with previous efforts. Every effort was made to ensure that the long-term comparability of the database would not be compromised because of a change in contractors in 1990.

QUANTITATIVE STUDIES

Faunal Studies

A total of 112 species of benthic invertebrates were found in the April 1990 samples. The majority of species consisted of polychaetes (40), molluscs (35), and crustaceans (30). The total number of species recorded at the Effluent (70), Manomet Point (71), and Rocky Point (79) stations were higher than recorded in the spring samples in 1989 (Eff: 36; MP: 46; RP: 42).

Total densities recorded at the three stations was very high, due in large part to high counts of the blue mussel, *Mytilus edulis*. The Effluent station was lowest in total density (202,424) individuals per m^2), whereas the Manomet Point station was highest (430,266) individuals per m^2). Densities of each of the three highest ranked species, *Mytilus edulis*, the amphipod *Jassa falcata*, and the northern lacuna *Lacuna vincta*, were also highest at Manomet Point.

The 15 highest ranked species at each station accounted for approximately 98% of the total density at each station. The larger list of rare species (55 to 64) recorded at each station thus contributed little to total density. *Mytilus edulis*, *Jassa falcata*, and *Lacuna vincta* are the first, second, and third ranked species at all three stations. A total of 21 species comprise the lists of 15 highest ranked species at all three stations. Among the dominance lists, amphipods are the dominant taxon in terms of species with nine different species among the top 21 listed.

Species diversity indices are obscured by the high density of *Mytilus edulis*. When the mussels are removed from the species list, the diversity patterns reflect the high values expected of

communities having high numbers of species. For example, Shannon's H' ranged from 3.35 (Manomet Point), 3.65 (Effluent station), to 4.13 (Rocky Point). These values are indicative of high diversities expected in healthy faunal communities of subtidal coastal environments.

Community analysis by clustering or similarity techniques indicates that there is little difference between the three stations. Replicates of the Effluent, Manomet Point, and Rocky Point stations intermix to some extent regardless of whether the Bray-Curtis or NESS similarity measures are used. Historically, the Effluent station has been different from the two reference stations. That situation does not appear to be present today.

Similarity analysis by species reveals that species groups are joined by their dominance patterns. For example, most of the species that comprise the lists of highest ranked dominant species tend to cluster together, while the rare or infrequently encountered species comprise other groups.

Algal Studies

No additions to the cumulative algal lists were made as a result of analysis of the April 1990 samples. The rock and cobble substrata found at the Effluent, Manomet Point, and Rocky Point stations were heavily populated with red algae, especially Irish moss, *Chondrus crispus* and *Phyllophora* spp. Epiphytic algal species were observed at all stations, with *Chondrus* and *Phyllophora* serving as primary hosts.

Algal community overlap measures the similarity in algal species composition between stations. In April 1990, the percent of replicate overlap was higher at the Effluent station (27.7%) than for either the Manomet Point (24.0%) or Rocky Point (22.5%) stations, indicating that individual samples at the Effluent station were less similar to one another than the samples from the reference stations. Community overlap between the three stations was very high, indicating a high degree of homogeneity in species shared.

Total algal biomass was highest at the Effluent station and lowest at Rocky Point. Biomass of *Chondrus crispus* was highest at Manomet Point and lowest at Rocky Point. *Phyllophora* spp. biomass was highest at the Effluent station and lowest at Manomet Point. The highest biomass of benthic algal species other than *Chondrus* and *Phyllophora* was at Rocky Point. The highest biomass of epiphytic algae was found at the Effluent station. Analysis of variance (ANOVA) indicated no significant differences in biomass values between the three stations.

QUALITATIVE TRANSECT SURVEYS

The qualitative transect studies performed to evaluate *Chondrus crispus* community in the effluent canal indicates that the denuded and stunted areas have returned to a condition that is typical of full operation of the plant. The *Chondrus* denuded and stunted areas encompassed 904 and 90 m^2, respectively in the April 1990 survey and 1835 and 300 m^2 in June. The size of the affected area in June was similar to areas affected before the 2½-yr shutdown of the plant.

The most important observation taken during these surveys was the remarkable development of dense mats of blue mussels (*Mytilus edulis*) in June. The mats were so thick that the algae were completely buried under mussels that measured 1 to 2 cm in length. The size of these mussels suggests that they migrated to the effluent canal as postlarval plantigrades that had originally settled on filamentous red algae in surrounding areas. The continuous water flow and warmer temperature present in the effluent canal along with rock surfaces that were largely devoid of algal growth are possible attractive factors that might account for this unprecedented event.

1.0 INTRODUCTION

This report represents a continuation of the long-term (17 yr) algal and faunal studies at Pilgrim Nuclear Power Station (PNPS) that are intended to monitor the effects of the thermal effluent (under Boston Edison Company Purchase Order No. 76261). The 1990 program is essentially the same as previous monitoring efforts conducted over the last 10 years. Quantitative benthic algal and faunal sampling is conducted during the spring and summer at two reference sites at Rocky Point and Manomet Point and at a site offshore of the effluent canal (Figure 1). Qualitative SCUBA surveys of algal cover at the effluent canal are conducted quarterly during March, June, September, and December. This Semi-Annual Report includes quantitative data from samples that were collected in April 1990 and qualitative observations recorded in April and June 1990.

2.0 METHODS

2.1 FIELD SAMPLING

The sampling sites are the same locations that have been sampled since the beginning of the current monitoring program, approximately 10 years ago. The stations are located by the following established procedures. Line-of-sight positions are established using highly visible structures located on the shore as reference points. The Rocky Point station is located by lining up the microwave relay tower with the PNPS red and white off-gas stack. The Effluent station is identified along the center line between the two discharge jetties, located approximately 120 m offshore. The Manomet Point station is fixed by lining up the two southernmost telephone poles on top of Manomet Point. Line-of-sight position combined with lead-line depth checks ensures station relocation to within a radius of 20 to 30 m of the original station position.

All sampling is done by SCUBA-equipped biologists operating from a small boat. For the quantitative algal and faunal studies, five replicate samples delineated by a metal pipe frame quadrant measuring 0.33 m on a side (0.1089 m^2) are taken from the surface of rocks at each station.

Upon arrival at a station, the divers descend to the bottom and locate suitable rocks for placement of the quadrat. Divers are able to assess algal and faunal cover and select rocks that are considered typical for the station.

All attached flora and fauna within the quadrat are scraped from the rock and drawn through an airlift device into a 0.5-mm mesh bag (Figure 2). Field labels with station, collection date, and replicate number are placed in sample bags before sample collection. The bag is tied and placed in a large catch bag; a new bag is then attached to the airlift. The divers then locate the next suitable rock

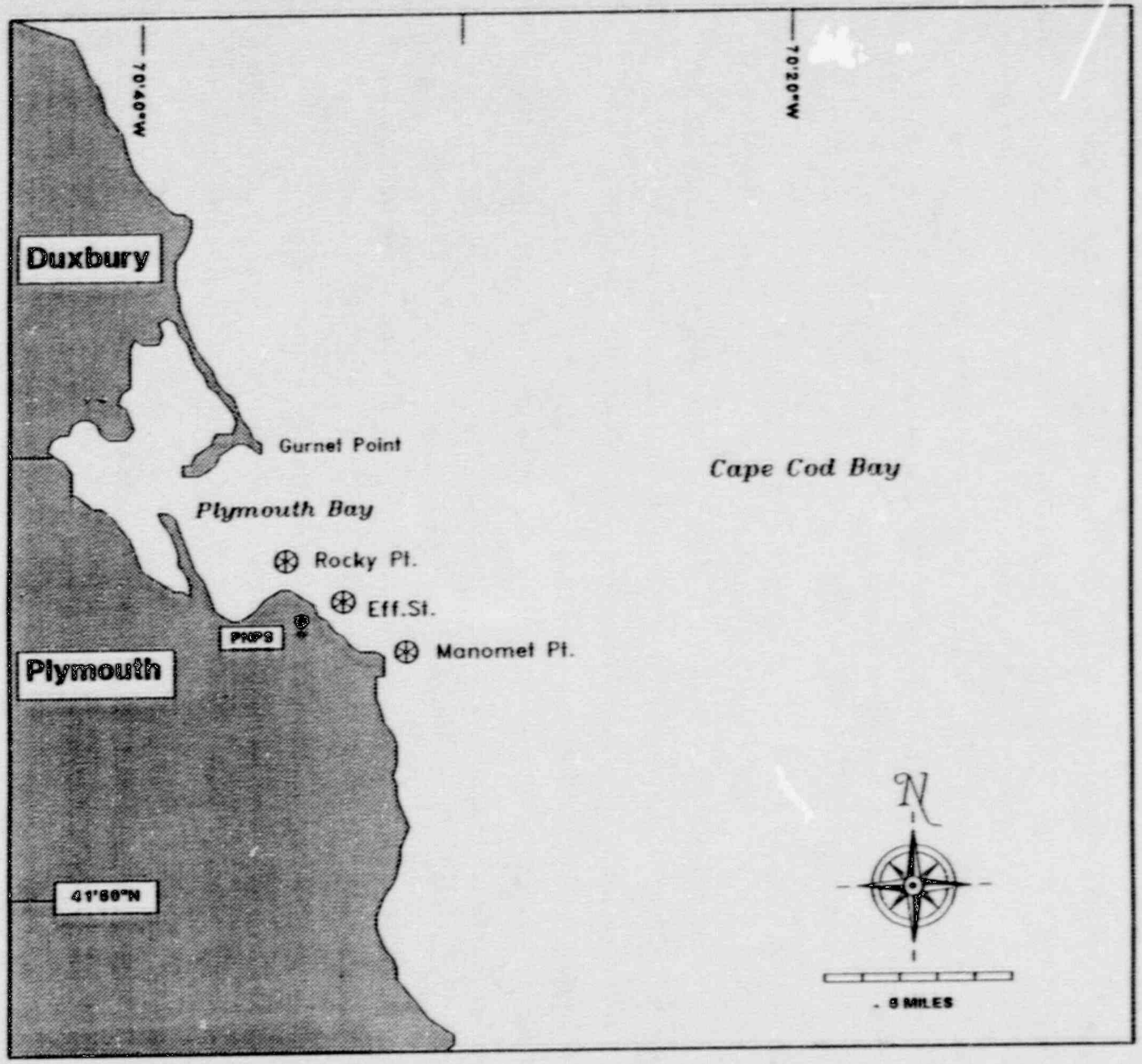

Figure 1. Location of Benthic Sampling Sites near Pilgrim Station.

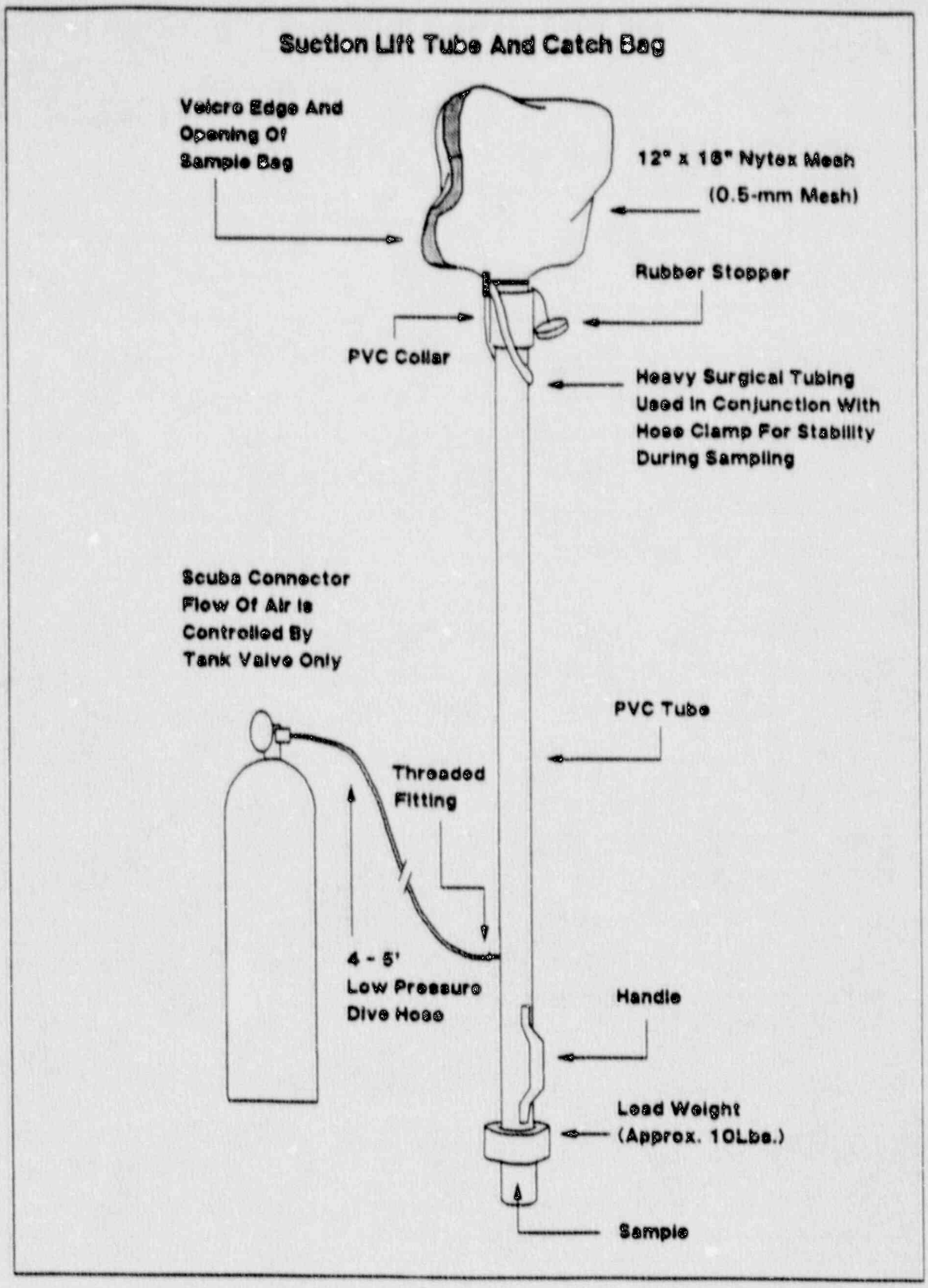

Figure 2. Suction Lift Device Used by Divers to Collect Benthic Samples.

and repeat the sampling process. After the five replicates are collected at a station they are delivered to a biologist on the boat for processing.

While the vessel is underway to the next station, the contents of each bag are transferred to a 1-gal plastic jar, labeled, and preserved with 10% buffered formalin. Approximately 100 g of Borax is added to each jar as a buffering agent to prevent softening of calcified shells.

For the qualitative transect survey, SCUBA observations are made along the axis of the discharge canal. A line is extended across the mouth of the discharge jetty (Figure 3). A weighted transect line, marked at 10-m intervals, is then attached to the center of this line and deployed along the central axis of the canal to a distance of 100 m offshore. A 30-m measuring line, marked at 1-m intervals, is extended perpendicular to the transect line by the divers and oriented to the transect line with a compass. A diver traverses this third line underwater and records changes in algal cover at 10-m intervals from the transect line through the denuded and stunted *Chondrus* areas to where the algal cover becomes normal.

According to procedures established by Taxon (1982) and followed in subsequent years, the distinction between "denuded" and "stunted" is based on *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. In this area, *Chondrus* is found on the upper surfaces of rocks only where the microtopography of the rock surfaces creates small protected areas. In the stunted zone, *Chondrus* is found on the upper surfaces of the rocks but is noticeably inferior in height, density, and frond development. The normal zone is considered to begin at the point where these factors are typical for the depth and substratum in question.

In addition to observing algal cover, the divers record any unusual occurrences or events in the area and note the location of any distinctive algal or faunal associations.

2.2 LABORATORY ANALYSIS

In the laboratory, the algal and faunal fractions of the samples are separated by washing the animals off the algae onto a 0.5-mm-mesh screen. The animals are preserved in a solution of 70% ethanol. The algal fraction is preserved in a 10% formalin solution. The faunal samples are labeled and stored in 16-oz glass or plastic jars until sorting. Algal samples are labeled and stored in 1-gal plastic jars until sorting.

Each replicate sample is processed separately. The algal component of each sample is examined, using both dissection and compound microscopes, to identify all species of macroalgae and

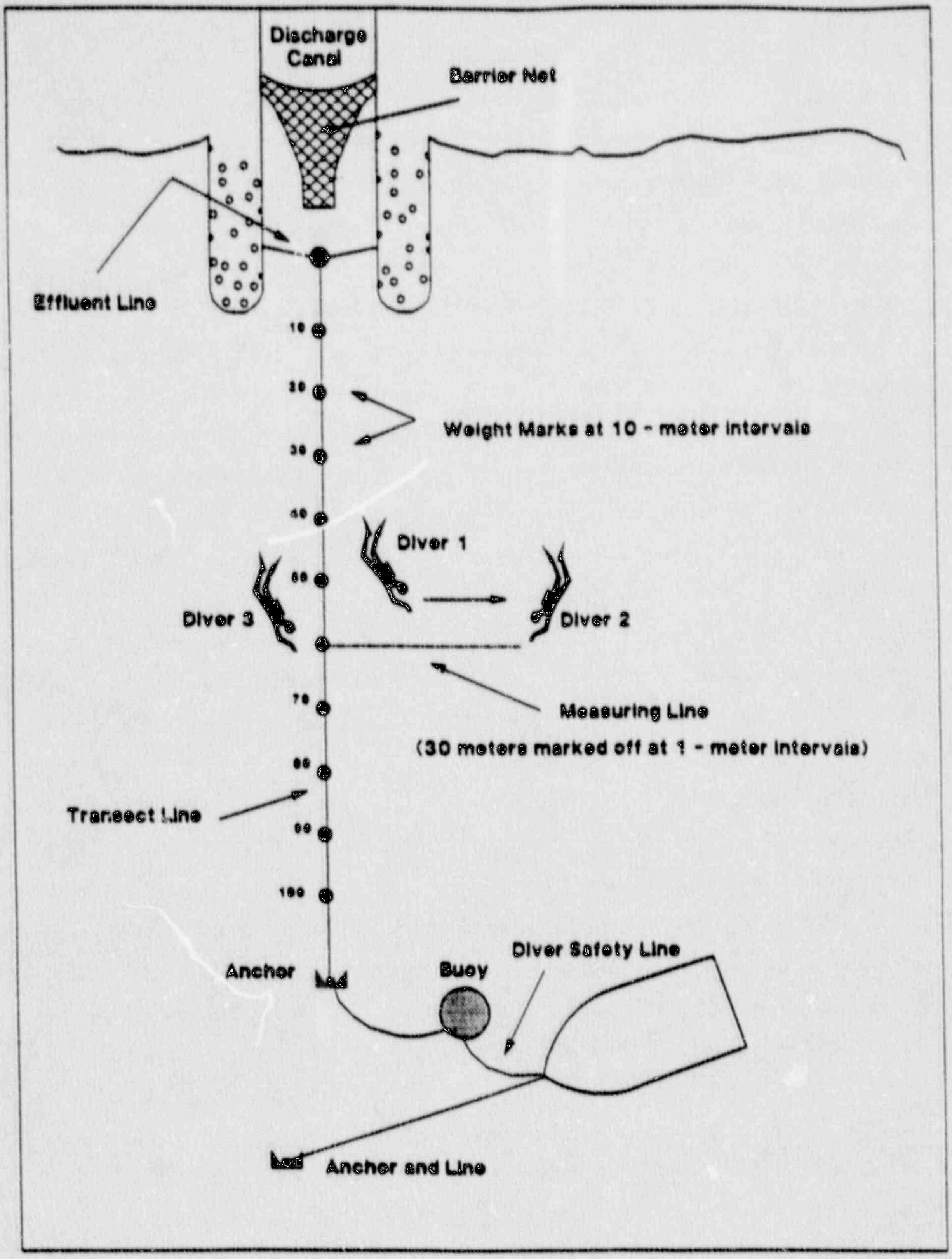

Figure 3. Design of the Qualitative Benthic Transect Sampling Program at Pilgrim Station.

to determine the presence or absence of 38 indicator species. Important algal references used to identify and confirm names are Taylor (1957), Parke and Dixon (1976), and South (1976). The indicator species were originally chosen in September 1978, and were carefully selected from a list of the several hundred algal species recorded from the PNPS study sites during the 1974-1978 period (Taxon, 1982). The indicator species include members of each of the major algal families from a variety of habitats, including all of the dominant species within the study area, the majority of the macrophytic species, and the most common epiphytic species (Table 1). Therefore, the indicator species comprise the most substantial part of the algal community as measured by both percent cover and biomass, although they constitute only a small fraction of the flora inhabiting the study area in terms of the number of species. Dry-weight biomass of each sample is reported for four separate algal fractions: *Chondrus crispus*, *Phyllophora* spp., epiphytic species, and the remaining benthic species. Total algal biomass is also reported. Each fraction is weighed on a Mettler balance after drying for 72 h in a drying oven set at 80°C.

A 25% aliquot of the faunal fraction of each sample is processed, and the remaining 75% of the sample is archived. Prior to sorting, the 25% aliquot is stained with a saturated alcoholic solution of Rose Bengal for at least 4 h, but no longer than 48 h to avoid overstaining. The samples are examined under a dissecting microscope and each organism or fragment thereof removed. Invertebrates are sorted to major taxonomic groups, such as polychaetes, crustaceans, bivalves, gastropods, echinoderms, and other miscellaneous phyla. The blue mussel *Mytilus edulis* is left with the residue and counted during the sorting process.

Final identification is to the lowest possible taxon (usually to species). During identification, the counts of each species are recorded. A new reference collection for the PNPS program has been developed from the April 1990 samples and will serve as a voucher collection for subsequent identifications. The samples are archived for a minimum of three years after collection.

2.3 DATA ANALYSIS

All faunal data are kept on specially designed project data sheets to facilitate computer entry. Data are keypunched into a spreadsheet, using Quattro Pro®, on a personal computer. Some basic data summaries and calculations can be made while the data is in this form. Following data entry and reorganization in the spreadsheet, a hard copy of the raw data is generated and verified against the original coding sheets. All keypunching errors are corrected at this point. Data files are then transferred to the WHOI (Woods Hole Oceanographic Institution) VAX computer for analysis.

Table 1. Algal Indicator Species used in the Quantitative Community Analysis.

Chlorophyta (Green Algae)

Bryopsis plumosa
C. melagonium
Enteromorpha flexuosa
Rhizoclonium riparium
Ulva lactuca

Phaeophyta (Brown Algae)

Chordaria flagelliformis
Desmarestia aculeata
D. viridis
Laminaria digitata
L. saccharina
Sphacelaria cirrosa

Rhodophyta (Red Algae)

Ahnfeltia plicata
Antithamnion americanum
Bonnemaisonia hamifera
Callophyllis cristata
Ceramium rubrum
Chondrus crispus
Corallina officinalis
Cystoclonium purpureum
Gracilaria tikvahiae
Gymnogongrus crenulatus
Membranoptera alata
Palmaria palmata
Phycodrys rubens
Phyllophora truncata
P. pseudoceranoides
P. traillii
Polyides rotundus
Polysiphonia elongata
P. fibrillosa
P. harveyi
P. nigrescens
P. urceolata
Rhodomela confervoides
Spermothamnion repens

Analytical software consists of a suite of programs developed specifically for the analysis of benthic data. In addition to a variety of data-management and modification utilities, these programs include PRARE1 and COMPAH. PRARE1 summarizes the data for each sample, calculates a variety of diversity-related indices, and generates a rarefaction curve. COMPAH is a multivariate classification package that allows a wide variety of user-specified options for similarity indices and clustering strategies, including both normal (i.e. by station) and inverse (i.e. by species) analyses.

The individual species composing the fauna at each station are rank ordered by abundance. The most abundant species is listed first, followed in order by less abundant forms. The percent contribution of each species to the total fauna is denoted by a decreasing total percentage starting with the most abundant species and ending with the most rare. Basic statistical treatments include calculation of means of abundances per station and extrapolation to density per m^2.

Species richness is interpreted by using a jackknife procedure in combination with pooled species data to evaluate the contribution of rare species in the communities (Heltshe and Forrester, 1983). This procedure takes into account that random samples are not necessarily representative of a population. The jackknife estimate of species richness is a function of the number of so-called "unique" species present at a station, that is those that are present in one and only one replicate out of five. The jackknife estimate of species richness ($\hat{S}$) is expressed as:

$$\hat{S} = S + \left[\frac{(n-1)}{n}\right] k$$

where S represents the pooled species numbers at each station, n is the number of replicates, and k is the number of unique species. The variance of estimated species richness [**var** ($\hat{S}$)] is also calculated to measure the spatial distribution of unique species.

Measures of diversity calculated for each sample and station include the Shannon-Wiener information (H') and evenness (J') indices and rarefaction curves according to the method of Hurlbert (1971). Shannon's H' has been shown to be a biased estimator and for small samples will underestimate true population information (Smith and Grassle, 1977). Hurlbert's expected species index of diversity is an unbiased estimator and is thus particularly useful when small and unequal sample sizes must be compared.

The measure of similarity developed by Grassle and Smith (1976), the Normalized Expected Species Shared (NESS), combined with group average sorting is used for cluster analysis. NESS is based on the expected number of species shared between random samples of size *m* drawn from a population, and is sensitive to the less common species in the populations to be compared.

The Bray-Curtis similarity measure, combined with group average sorting, is also used (Boesch, 1977). These values are calculated for stations (normal) and species (inverse), using numbers of individuals of species.

In the event that patterns in the station and species analysis require further interpretation, a nodal analysis is performed using the results of the similarity procedures described above. This procedure is especially useful when evaluating the combined spring and summer data. Nodal analysis is a method of relating normal and inverse classifications to aid in the interpretation of cluster analyses. The method uses two-way tables that show replicate groups on the vertical side and species groups on the horizontal side. This technique is used to measure constancy and fidelity. Constancy is a proportion derived from the number of occurrences of a species group in a replicate group as compared with the total possible occurrences. Fidelity is the degree of restriction of a species group to a replicate group. In this report we elected to not use nodal analysis because the stations and species clustering patterns were readily explained.

For the algae, community overlap was calculated using Jaccard's coefficient of community (Grieg-Smith, 1964) to measure the similarity in algal species composition among the Effluent, Manomet Point, and Rocky Point stations. Jaccard's coefficient provides a mathematical evaluation of the similarity between two replicates or stations using only species occurrence and does not consider differences in their abundance.

3.0 RESULTS

3.1 QUALITATIVE TRANSECT SURVEY

Qualitative transect surveys of acute nearfield impact zones were initiated in January 1980 and have been conducted quarterly since 1982. Two surveys were performed (April 9 and June 19) during the current reporting period, bringing the total number of surveys conducted since 1980 to 38. Results of the four surveys performed in 1989 are reviewed in Semi-Annual Report No. 35 (BECO, 1990). Detailed results of the mapping conducted in April and June 1990 are presented in the next two sections.

3.1.1 April 1990 Transect Survey

The extent of the denuded and stunted areas mapped on April 6 1990 immediately offshore from PNPS is shown in Figure 4. A large boulder that is nearly exposed at mean low water, and that is used as a landmark by both the SAIC and the Massachusetts Division of Marine Fisheries dive teams is plotted in the figure. The denuded zone is essentially devoid of *Chondrus crispus* whereas the stunted zone has *Chondrus* that is smaller and less dense than that growing under normal conditions. The dive team must keep in mind while taking measurements that the shallower depths to the northwest of the discharge canal preclude normal *Chondrus* growth.

In April 1990, the denuded zone extended approximately 70 m offshore along the centerline of the effluent discharge canal. As in previous surveys the denuded zone was asymmetrically distributed around the transect line, extending further toward the northwest than to the southeast. The general configuration of the denuded zone was similar to that observed during the December 1989 survey but the area (approximately 904 m^2) was 25% smaller. Within the denuded zone, from the 10-m to 50-m mark, some rocks were completely devoid of all macroflora and others were covered with patches of young *Chondrus*, *Enteromorpha* and *Ulva*. The latter two species were predominant within and adjacent to the discharge canal. A dark red alga, believed to be *Gracilaria tikvahiae*, was present between the 10- to 30-m mark of the transect. At the 60-m mark and north of the transect, many rocks within and outside the denuded zone were densely covered with the coralline alga, *Corallina officinalis*. Also at the 60-m mark, some rock weed of the genus *Fucus* was observed within the denuded zone south of the transect and was the predominant species beyond the denuded zone to the north. In contrast to the previous two surveys, very few mussels were observed within the survey area.

The stunted zone, with an area of about 90 m^2, extended only along the south side of the transect from the tip of the southern submerged jetty to the 65-m mark. The greatest width reached by the stunted zone was five meters at the 50-m mark on the transect.

3.1.2 June 1990 Transect Survey

Results of the transect mapping for June 19, 1990 are shown in Figure 5. The denuded zone extended approximately 100 m along the transect line. The configuration of the denuded zone was quite different from that seen in the April survey: it was shaped like an hourglass with the waist at the 70-m mark and extended up to 18 meters northwest of the transect line at the 90-m mark. The area of the denuded zone had doubled in size (to approximately 1835 m^2) since the April survey.

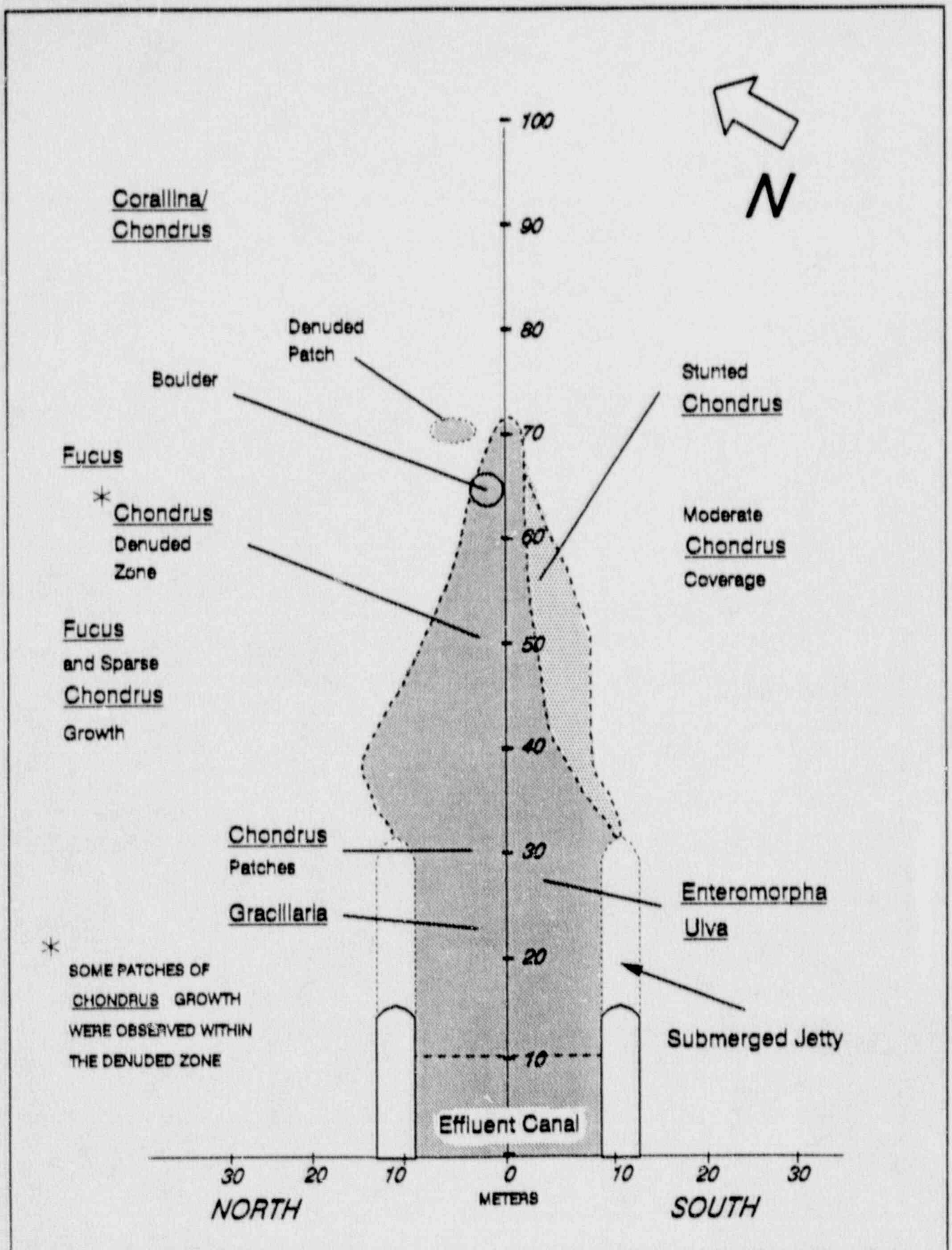

Figure 4. Configuration of the Denuded (904 m^2) and Stunted (90 m^2) Zones in the Effluent Canal for April 6 1990. Dark Shaded area denotes denuded zone; light shaded area denotes stunted zones.

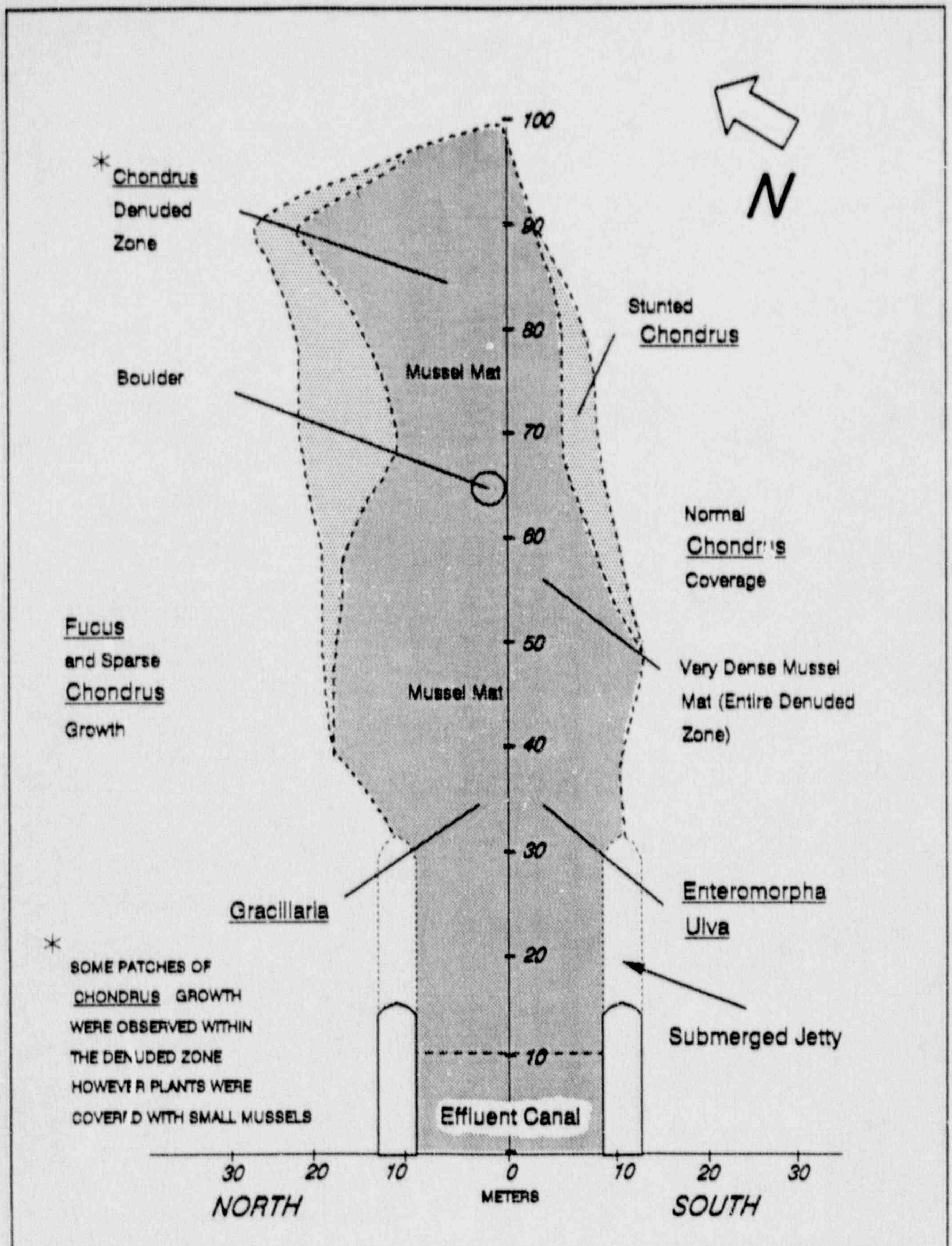

Figure 5. Configuration of the Denuded (1835 m²) and Stunted (300 m²) Zones in the Effluent Ci nal for June 19 1990. Dark Shaded area denotes denuded zone; light sł ded are denotes stunted zones.

In contrast to the April 1990 survey when very few mussels were seen by the divers, a very dense mat of blue mussels (*Mytilus edulis*), each about 1 to 2 cm in length, covered the entire survey area. The mussel mat was most dense between 50 and 100 m on the transect line. Mussels had invaded all available substrata including living *Chondrus* plants. The scattered groups of *Chondrus* seen within the denuded zone were low mounds covered by mussels; dissecting these mounds revealed living *Chondrus* beneath. Numerous starfish (*Asterias forbesi*) (up to 10 per m^2) were seen grazing on the mussels from the 70-m to 90-m mark on the transect. Between the 10-m and 40-m mark in the denuded zone scattered patches of *Chondrus* were present as were some *Enteromorpha*, *Ulva*, *Codium*, and *Gracillaria* plants. Striped bass and tautog were seen swimming in the effluent canal.

The stunted zone was present on both sides of the denuded zone during the June survey and had tripled in area from the April survey to about 300 m^2. The stunted zone on the southeast side extended from the 50-m to the 90-m mark on the transect and was narrow, averaging about 2 m wide. On the northwest side, the stunted zone extended from the 40-m to 97-m mark and was up to 9 m wide.

3.2 QUANTITATIVE FAUNAL MONITORING

3.2.1. Systematics

In the spring of 1990, 112 species were found in the study area. The greatest fraction of the total fauna consisted of polychaetes (40 species, 36%), followed by molluscs (35 species, 31%), crustaceans (30 species, 27%), echinoderms (5 species, 4%) and several smaller phyla such as nemerteans, anemones, and tunicates. A list of the species collected in the April 1990 survey is included in Appendix A.

The total number of species reported here is considerably lower than the cumulative total of more than 483 species indicated in previous reports (i.e. BECO, 1989). The previously reported totals were the result of cumulative identifications observed over several years and do not represent a true picture of the fauna from any one year. It is likely that no more than 100 to 125 species are found in the study area at any one time. Some species will be dominant and are likely to be present from one year to the next. Others, however, are rare and their occurrence in the *Chondrus* communities is probably ephemeral. It is also possible that some of the names of the comprehensive species code list represent different identifications of the same species made over the years. Most taxonomic problems probably reside with the rare species because they appear so infrequently that there is little chance for exchange of information among project technicians.

3.2.2. Species Richness

Species richness values for all three stations for April 1990 are presented in Table 2. Data are presented as total species per replicate for each station, with a mean value over all replicates at each station and a cumulative total representing pooled species numbers at each station. Because the area included within each replicate is 0.1089 m^2, the cumulative species total at each station represents a total area of 0.5445 m^2.

In April 1990, the Rocky Point reference station had 79 species for pooled replicates, the highest number among the three stations. Manomet Point followed Rocky Point with 71 species, the Effluent station had 70 species. The average number of species per replicate again resulted in Rocky Point being first (48.2) followed by Manomet Point (47.6) and the Effluent station (39). An analysis of variance (ANOVA) that compared the mean number of species occurring at each of the stations indicated no significant difference at $p = 0.05$.

In order to assess the rare species that might be present at the stations but were not found because of the relatively small area sampled, the jackknife estimate of Heltshe and Forrester (1983) was calculated (See Section 2.3). At all three stations, species richness was higher than had been measured in the spring samples from previous years. For example, $\hat{S}$ values for April 1990 are 84.4 (Effluent), 82.2 (Manomet Point), and 97.4 (Rocky Point), whereas the same measurements for March 1989 were 43.2, 57.6, and 49.2 respectively. These results also agree with the considerably higher total number of species actually present in the samples (1990: 70, 71, and 79 versus 1989: 36, 48, and 42, respectively). The variance of the Rocky Point Station differs the greatest from the other two stations suggesting that the contribution of rare species is greatest at that station.

Table 2. Faunal Species Richness at the Effluent, Manomet Point, and Rocky Point Stations in April 1990.

	Effluent	Manomet Point	Rocky Point
No. Species/Replicate	41, 41, 42, 30, 41	48, 46, 41, 51, 52	51, 50, 52, 45, 43
Mean ± Standard Deviation	39.0 ± 5.04	47.6 ± 4.39	48.2 ± 3.96
No. Species/Station	70	71	79
Jackknifed Estimate Species Richness ($\hat{S}$)	84.4	82.2	97.4
Variance ($\hat{S}$)	3.20	7.20	-9.00

3.2.3 Faunal Density

Total faunal densities recorded at the three stations in April were very high. Table 3 shows the total density figures for each replicate and extrapolated to square meters. Total densities were greatly influenced by the *Mytilus edulis* population. The Effluent station was lowest in terms of total density and numbers of *M. edulis*, whereas the Manomet Point Station was highest. However, the densities at the Effluent station (202,424 individuals per m²) were considerably higher than recorded from the same time period in 1989 (BECO, 1990). Densities of *M. edulis* ranged from 151,588 per m² at the Effluent Station to 332,231 per m² at Manomet Point. These very high populations of *M. edulis* have continued since 1988 (BECO, 1989). In 1987, mussel populations were very low (BECO, 1988). Figure 6 depicts the total faunal densities and densities of *Mytilus edulis*, *Jassa falcata*, and *Lacuna vincta* at the three stations from the April 1990 data. In all instances, the Manomet Point densities were higher than either the Effluent or Rocky Point stations.

Table 3. Faunal Densities at the Effluent, Manomet Point, and Rocky Point Stations in April 1990.

Station	Total Density				Density of *Mytilus edulis*	
	With *Mytilus edulis*		Without *Mytilus edulis*			
	Mean ($\bar{x}$) No. Indiv./ Rep.	Density per m²	Mean ($\bar{x}$) No. Indiv./ Rep.	Density per m²	Mean ($\bar{x}$) No. Indiv./ Rep.	Density per m²
Effluent	22,044	202,424	5,536	50,836	16,508	151,588
Manomet Point	46,856	430,266	10,676	98,035	36,180	332,231
Rocky Point	31,157	286,105	6,549	60,136	24,608	225,969

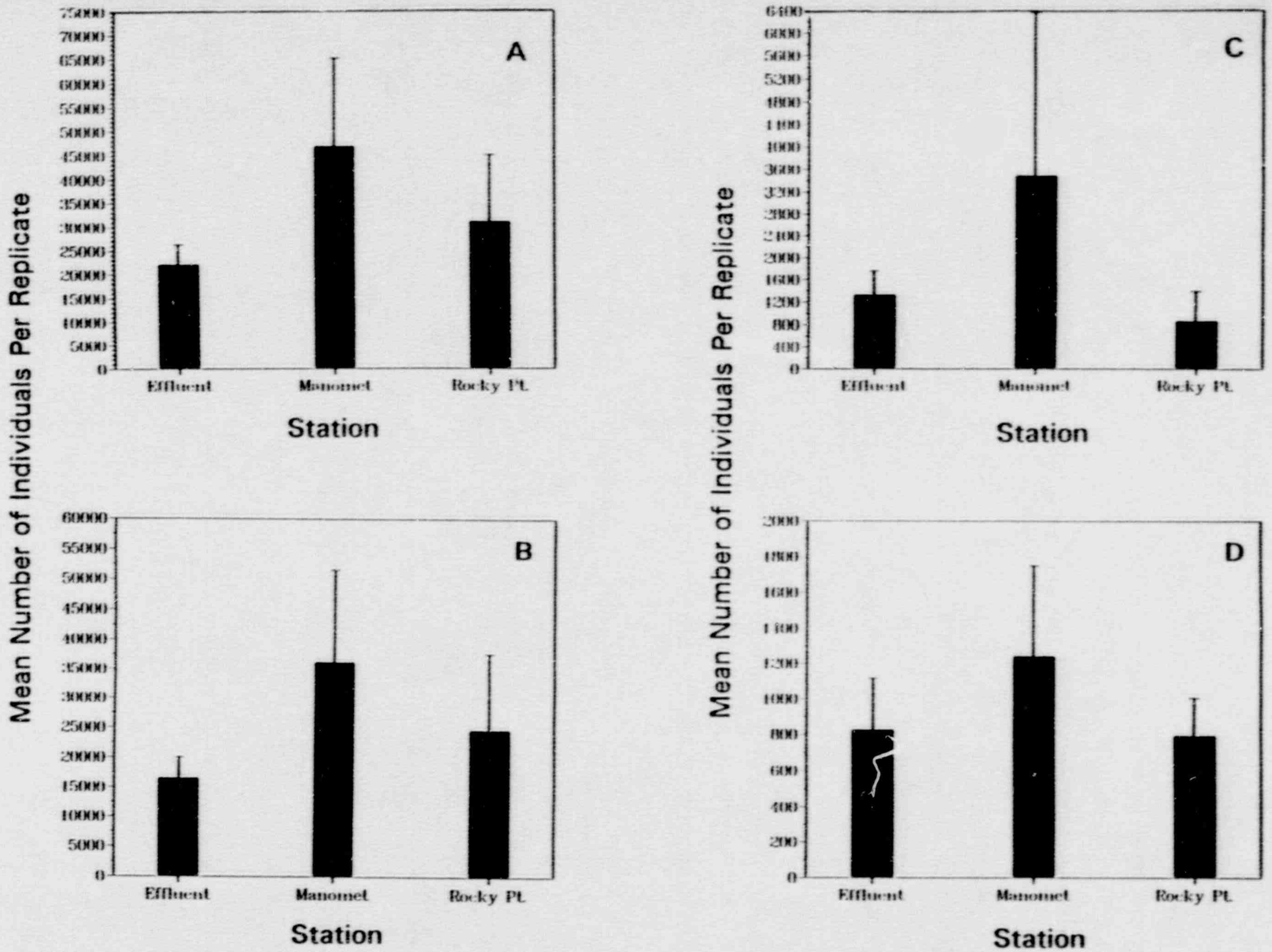

Figure 6. **Density of Benthic Fauna in April 1990: A, Total Density; B, *Mytilus edulis*; C, *Jassa falcata*; D, *Lacuna vincta*.**

3.2.4 Species Dominance

The 15 numerically dominant species collected at the Effluent, Manomet Point, and Rocky Point stations in April 1990 are shown in Table 4. Data are presented as the average number per replicate (¼ aliquot) and percent composition at each station. Fifteen species were shared among 21 dominant species present in the dominance lists developed for the three stations. The highest ranked 15 species generally accounted for 98% of the total density at each station. The longer list of rare or infrequently encountered species (55 to 64, depending upon station) accounted for no more than 1.3 to 2.2% of the total density.

The benthic communities at all three stations were dominated by the blue mussel *Mytilus edulis* (Effluent, 76.5%, Manomet Point, 79.04%, and Rocky Point, 82.5%). The very high contribution of juvenile and adult mussels obscures the importance of other resident fauna. Nevertheless, it is interesting that the second and third ranked species, the amphipod *Jassa falcata* and the gastropod *Lacuna vincta*, were the same at all three stations. Eighteen additional species filled the remaining position ranks at the three stations. After mussels, the amphipods were the dominant group with 9 of the 20 species on the dominance lists. The high percentages of amphipods were consistent with previous results in the study area (Davis and McGrath, 1984; BECO, 1990).

The results listed in Table 4 are remarkable in that only six of the top 15 species at each station are restricted to that station, indicating that there is a consistency in the predominant fauna at each of the three sites. Of six species that occur only once among the 15 highest ranked species, two occur at the Effluent Station, three at Manomet Point, and one at Rocky Point. Thirteen dominant species are shared among all stations, and two dominant species are shared between the Effluent and Rocky Point Station.

3.2.5 Species Diversity

Species diversity was measured using the Shannon-Wiener Information Index (H') and the Hurlbert rarefaction method. Both techniques clearly indicate that the high numbers of *Mytilus edulis* in the samples greatly affect the concept of species diversity in the benthic community. Results of species diversity calculations both with and without the mussels is shown in Table 5. From these results it is seen that the presence of mussels in the samples alters the diversity indices by approximately a factor of 2.

The highest species diversity is found at the Rocky Point Station, where the H' index measures 4.13 and the number of species per 5000 individuals is 73.4 when mussels are not included. Effluent Station is slightly higher than Manomet Point for these same parameters. The April 1990 results are very similar to those recorded in March 1989 (BECO, 1990), where H' ranged from 3.69 (Rocky Point), 3.82 (Effluent), to 4.02 (Manomet Point). Rarefaction values were not presented for 1989. It is interesting

Table 4. Rank Order of 15 Dominant Species Collected in April 1990.

Sta.	Rank	Species	Mean Number per Replicate[1]	Percent of Identified Fauna
EFF	1	*Mytilus edulis* (Bivalve)	4,126.6	76.50
	2	*Jassa falcata* (Amphipod)	330.0	6.12
	3	*Lacuna vincta* (Gastropod)	221.4	4.11
	4	*Corophium acutum* (Amphipod)	129.6	2.40
	5	*Pontogeneia inermis* (Amphipod)	124.2	2.30
	6	*Calliopius laeviusculus* (Amphipod)	80.4	1.49
	7	*Ischyrocerus anguipes* (Amphipod)	68.8	1.28
	8	*Caprella penantis* (Caprellid)	49.8	0.92
	9	*Dexamine thea* (Amphipod)	40.6	0.75
	10	*Anomia simplex* (Bivalve)	36.2	0.67
	11	*Idotea phosphorea* (Isopod)	32.0	0.59
	12	*Corophium bonelli* (Amphipod)	29.4	0.55
	13	*Protoboides holmesi* (Amphipod)	15.6	0.29
	14	*Odostomia seminuda* (Gastropod)	12.2	0.23
	15	*Molgula* sp. (Tunicate)	9.2	0.17
	TOTAL OF 15 SPECIES		5,306.0	98.37
	REMAINING IDENTIFIED FAUNA - 55 SPECIES		87.4	1.63
	TOTAL IDENTIFIED FAUNA - 70 SPECIES		5,393.4	100.00
MP	1	*Mytilus edulis* (Bivalve)	9,045.6	79.04
	2	*Jassa falcata* (Amphipod)	871.6	7.62
	3	*Lacuna vincta* (Gastropod)	378.0	3.30
	4	*Ischyrocerus anguipes* (Amphipod)	269.2	2.35
	[illegible]	*Pontogeneia inermis* (Amphipod)	146.0	1.28
	[illegible]	*Corophium bonelli* (Amphipod)	122.8	1.07
	[illegible]	*Caprella penantis* (Caprellid)	106.4	0.93
	[illegible]	*Dexamine thea* (Amphipod)	100.4	0.88
	9	*Corophium acutum* (Amphipod)	72.0	0.63
	10	*Odostomia seminuda* (Gastropod)	39.4	0.34
	11	*Margarites helicinus* (Gastropod)	36.0	0.31
	12	*Calliopius laeviusculus* (Amphipod)	32.0	0.28
	13	*Hiatella arctica* (Bivalve)	28.4	0.25
	14	*Pholoe minuta* (Polychaete)	22.2	0.19
	15	*Pleusymtes glaber* (Amphipod)	21.2	0.19
	TOTAL OF 15 SPECIES		11,291.2	98.66
	REMAINING IDENTIFIED FAUNA - 56 SPECIES		172.3	1.34
	TOTAL IDENTIFIED FAUNA - 71 SPECIES		11,463.5	100.00
RP	1	*Mytilus edulis* (Bivalve)	6,152.2	82.51
	2	*Jassa falcata* (Amphipod)	214.8	2.88
	3	*Lacuna vincta* (Gastropod)	198.4	2.66
	4	*Ischyrocerus anguipes* (Amphipod)	135.0	1.81
	5	*Corophium bonelli* (Amphipod)	112.0	1.50
	6	*Dexamine thea* (Amphipod)	101.0	1.35
	7	*Pontogeneia inermis* (Amphipod)	99.4	1.33
	8	*Corophium acutum* (Amphipod)	48.2	0.65
	9	*Odostomia seminuda* (Gastropod)	43.4	0.58
	10	*Margarites helicinus* (Gastropod)	42.4	0.57
	11	*Caprella penantis* (Caprellid)	30.8	0.41
	12	*Anomia simplex* (Bivalve)	30.8	0.41
	13	*Calliopius laeviusculus* (Amphipod)	30.4	0.41
	14	*Skeneopsis planorbis* (Gastropod)	28.0	0.38
	15	*Molgula* sp. (Tunicate)	25.0	0.34
	TOTAL OF 15 SPECIES		7,291.8	97.79
	REMAINING IDENTIFIED FAUNA - 64 SPECIES		164.2	2.21
	TOTAL IDENTIFIED FAUNA - 79 SPECIES		7,456.0	100.00

[1] The number per replicate are based on the ¼ aliquots.

Table 5. Community Parameters for the Effluent, Manomet Point, and Rocky Point Stations in April 1990.

Station	Density (m²)	Total No. Species	Species per 100 Indiv.	Species per 500 Indiv.	Species per 1000 Indiv.	Species per 2500 Indiv.	Species per 5000 Indiv.	Shannon-Wiener (H')	Evenness (J)
Effluent	202,424	70	10.9	20.9	27.1	38.2	48.1	1.64	0.268
Effluent Without *Mytilus*	50,836	69	18.7	35.1	44.7	57.6	66.1	3.65	0.598
Manomet Point	481,586	71	9.6	19.0	24.6	33.7	41.9	1.44	2.340
Manomet Point Without *Mytilus*	149,355	70	17.7	32.2	40.3	51.9	60.4	3.35	0.545
Rocky Point	379,129	79	11.0	22.6	28.7	38.5	47.6	1.39	0.220
Rocky Point Without *Mytilus*	153,160	78	22.7	39.2	48.4	62.3	73.4	4.13	0.658

that the number of species recorded at these stations, however, is considerably higher in the 1990 samples than in the 1989 samples. In March 1989, 38 species were recorded at the Effluent Station, 48 at the Manomet Point Station, and 42 at Rocky Point. In contrast, the numbers of species recorded at these same stations in April 1990 were 70, 71, and 79 respectively.

3.2.6 Community Analysis

Similarity Analysis by Station

Results of the similarity analysis by station are shown in Figures 7 and 8. Figure 7 depicts a cluster analysis using the Bray-Curtis similarity measure. Two groups of replicates separate distinctly. A small group contains three samples from Manomet Point and one from Rocky Point, while all the remaining Manomet Point and Rocky Point samples along with all of the Effluent samples reside in the larger cluster. Results of the same analysis using the NESS are shown in Figure 8. Again two large clusters separate in the analysis. Samples from all three stations are intermixed within both of these clusters. These results indicate that individual samples from single stations are not more similar among themselves than to replicates from other stations. The only exception is that four Effluent replicates cluster tightly on the left side of the NESS diagram. The fifth Effluent sample, however, is joined to the group on the right side of the diagram.

Similarity Analysis by Species

Forty-eight of the highest ranked species were used to prepare the Bray-Curtis similarity analysis (Figure 9). The separation of groups of species by this analysis generally follows dominance patterns. For example, *Mytilus edulis*, the most abundant species found in the study area forms a separate cluster that is most dissimilar to any other cluster in the analysis. Two very large and dissimilar groups of species separate at the .123 level. Within these larger clusters are distinct groupings of species that represent species that are either abundant and present at all stations or less common and distributed unevenly throughout the three stations. For example, the two species groups identified on the left side of the diagram contain all of the species found in the dominance table (Table 4) previously described.

A nodal analysis has not been performed on this single set of samples. This type of analysis is best performed on the combined spring and summer samples in order to elucidate seasonal trends.

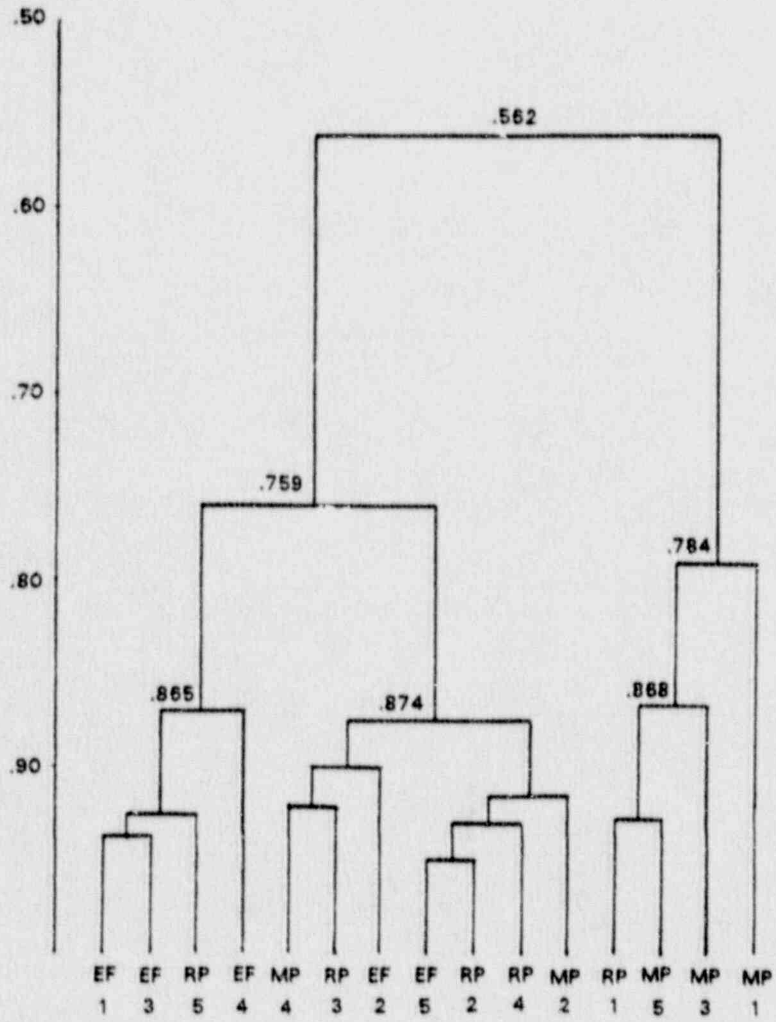

Figure 7. **Dendrogram Showing Results of Cluster Analysis by Station Replicates of the April 1990 Data Using Bray-Curtis and Group Average Sorting.**

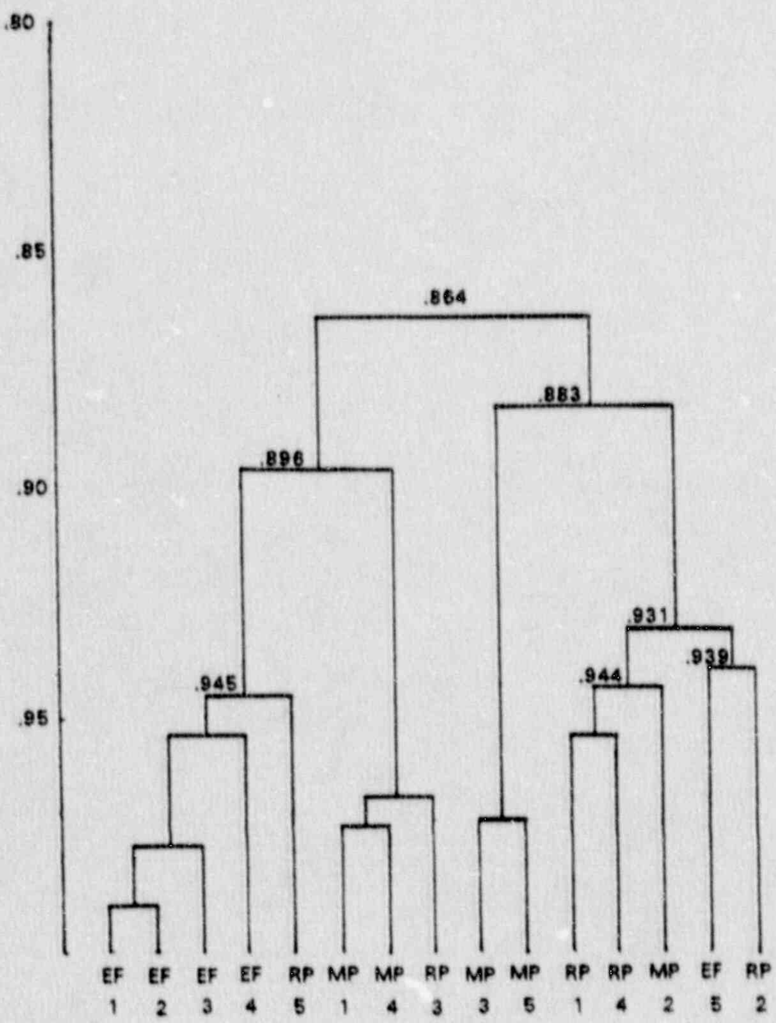

Figure 8. **Dendrogram Showing Results of Cluster Analysis by Station Replicates of April 1990 Data Using NESS and Group Average Sorting.**

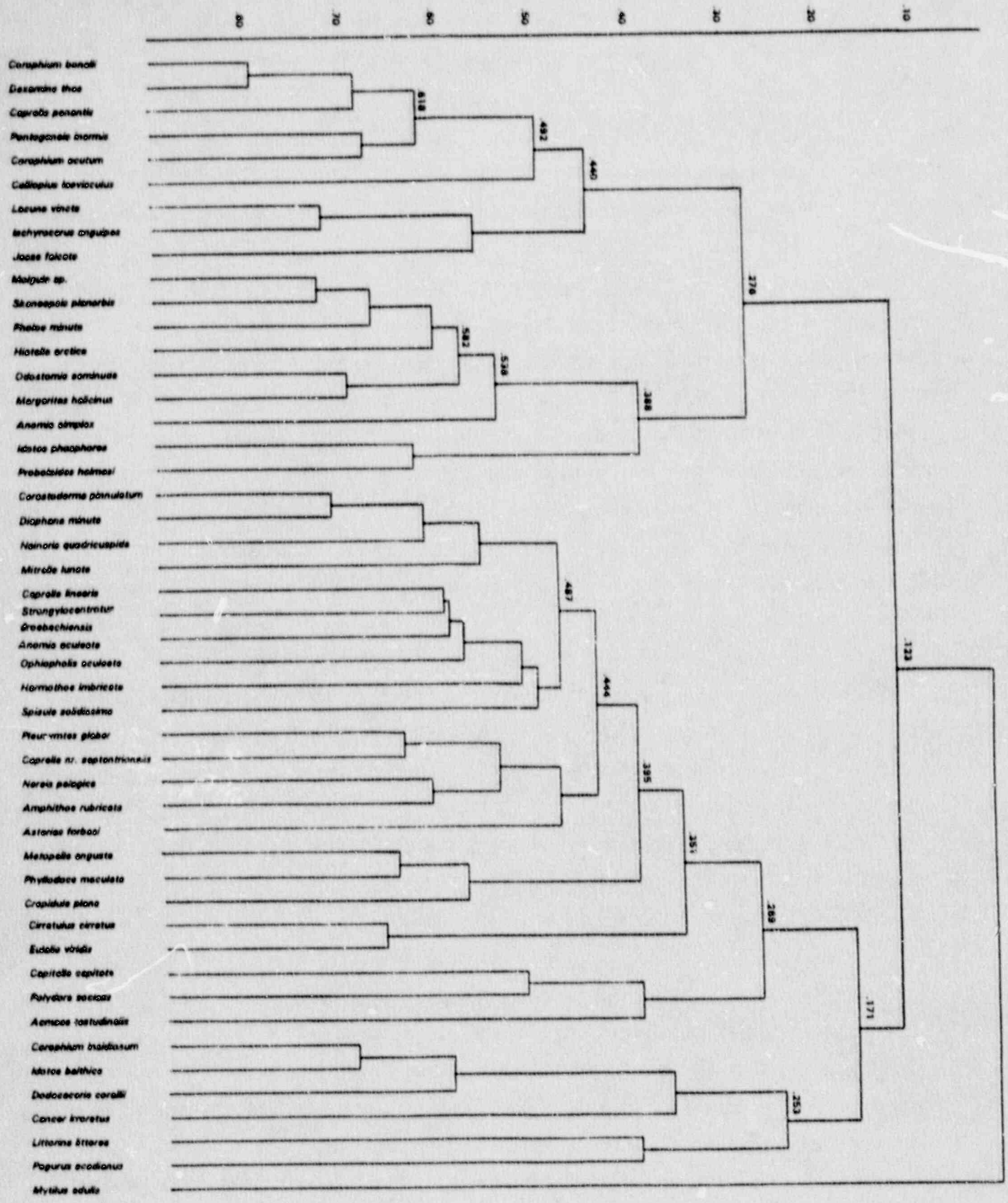

Figure 9. Dendrogram Showing Results of Inverse Cluster Analysis of the 48 Most Abundant Species of the April 1990 Data Using Bray-Curtis and Group Average Sorting.

3.3. QUANTITATIVE ALGAL MONITORING

3.3.1 Systematics

No additions to the cumulative algal species list presented in Semi-Annual Report No. 16 (BECO, 1980) were made as a result of analysis of the April 1990 samples. The 27 species present included 26 of the 38 indicator species and one additional species. The indicator species are listed in Table 1.

3.3.2 Algal Community Description

The rock and cobble substrata found at the Effluent, Manomet Point, and Rocky Point stations were heavily colonized by red macroalgae during the April 1990 survey. Two-thirds of the species collected belonged to the Rhodophyta (red algae). In addition to the dominant species *Chondrus crispus* and *Phyllophora* spp., other benthic rhodophytes included *Ahnfeltia plicata, Corallina officinalis*, and *Polyides rotundus*. Epiphytic rhodophytes found in all replicate samples were *Ceramium rubrum, Cystoclonium purpureum, Membranoptera alata, Polysiphonia harveyi*, and *Spermothamnion repens*. Other species collected in all samples were the chlorophytes (green algae) *Chaetomorpha linum, Chaetomorpha melagonium* and *Rhizoclonium riparium* and the phaeophyte (brown alga) *Desmarestia aculeata*.

Total algal biomass was highest at the Effluent station and lowest at Rocky Point. Biomass of *Chondrus crispus* was highest at Manomet Point and lowest at Rocky Point. *Phyllophora* spp. biomass was highest at the Effluent station and lowest at Manomet Point. The highest biomass of benthic species other than *Chondrus* and *Phyllophora* was at Rocky Point. The highest biomass of epiphytic algae was found at the Effluent station.

Gracilaria tikvahiae, an indicator of warm water, was not collected in any of the replicate samples in April 1990. However, a dark red species, believed to be *Gracilaria*, was observed by the divers within the denuded zone between 10 and 30 m along the transect line during the April and June, 1990 surveys.

3.3.3 Algal Community Overlap

Community overlap was calculated for the April 1990 data using Jaccard's coefficient that provides a mathematical evaluation of the similarity between two replicates or stations using only species occurrence. Species occurrence records of all 26 indicator and one non-indicator species that were found were used for community overlap calculations.

Results of community overlap comparisons between replicate samples for each station for the April 1990 collecting period are presented in matrix form in Figure 10. Ranges of percent overlap were

	1	2	3	4	5
1		17	19	19	23
2	68.0		16	16	17
3	73.1	76.2		16	19
4	76.0	80.0	69.6		18
5	92.0	77.3	82.6	78.3	

A

	1	2	3	4	5
1		13	16	14	16
2	56.5		16	13	14
3	69.6	84.2		13	17
4	66.7	72.2	61.9		14
5	66.7	63.6	77.3	66.7	

C

	1	2	3	4	5
1		20	18	19	18
2	74.1		22	22	19
3	69.2	84.6		22	19
4	73.1	84.6	91.7		19
5	78.3	69.2	82.6	82.6	

B

	MP	RP	EFF
MP		26	24
RP	96.3		25
EFF	88.9	92.6	

D

Figure 10. Algal Community Overlap (Jaccard's Coefficient of Community) and Number of Species Shared Between Replicate Pairs: A, Manomet Point Station; B, Rocky Point Station; C, Effluent Station; D, Station Overlap.

56.5 to 84.2 at the Effluent station, 68.0 to 92.0 at the Manomet Point station, and 69.2 to 91.7 at the Rocky Point station. Replicate percent overlap for the Effluent station was higher (27.7) than that for the Manomet Point (24.0) or Rocky Point (22.5) stations, indicating that the replicates at the Effluent station were less similar to each other than to the replicates at the other two stations.

Community overlap between stations was very high for all three pairs of stations, indicating a high degree of homogeneity in terms of species present at all three stations. Community overlap was higher between the Manomet Point and Rocky Point stations (96.3 %) than between the Manomet Point and Effluent stations (88.9%) or between the Rocky Point and Effluent stations (92.6%). This indicates that the algal communities at the Manomet Point and Rocky Point stations were more similar to each other than either was to the Effluent station.

3.3.4 Algal Biomass

Chondrus crispus

Chondrus crispus biomass values recorded for the Manomet Point, Rocky Point, and Effluent stations for April 1990 are presented in Table 6. In April 1990, the range of individual biomass values was greatest at Manomet Point (39.57 to 325.25 g/m^2), followed by the Effluent station (18.18 to 180.57 g/m^2), and Rocky Point (43.61 to 128.98 g/m^2). At the Effluent, Manomet Point, and Rocky Point stations, mean *Chondrus* biomass was 34%, 48%, and 31% of the total algal biomass, respectively.

The Manomet Point station had the highest mean biomass value for *Chondrus* (133.50 g/m^2), followed by the Effluent station (118.92 g/m^2), and the Rocky Point station (67.25 g/m^2). An ANOVA showed no significant differences between any of the stations when mean *Chondrus* biomass values were compared (at p=0.5).

Phyllophora spp.

Phyllophora spp. biomass values for the April 1990 collecting period are given in Table 6. The range of individual biomass was greatest at the Effluent station (14.41 to 215.18 g/m^2), followed by Rocky Point (33.87 to 159.64 g/m^2), and Manomet Point (16.98 to 105.48 g/m^2). *Phyllophora* spp. were 37% of the total algal biomass at the Effluent station, 36% at Rocky Point, and 26% at Manomet Point.

The Effluent station had the highest mean biomass value for *Phyllophora* spp. (130.87 g/m^2), followed by the Rocky Point (78.20 g/m^2), and Manomet Point (70.65 g/m^2). No significant differences existed between the stations in April 1990 when comparing *Phyllophora* biomass (at p=.05).

Table 6. Dry Weight Biomass (g/m²) for *Chondrus crispus*, *Phyllophora* spp., Epiphytes, The Remaining Benthic Species, and Total Algal Biomass at the Effluent, Manomet Point, and Rocky Point Subtidal (10 ft MLW) Stations in April 1990.

Station/ Replicate	*Chondrus crispus*		*Phyllophora* spp.		Remaining Benthic Species		Epiphytic Species (Total)		All Algae
	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass	Percent	Biomass
EFF 1	148.62	36.76	163.50	40.44	5.60	1.39	86.57	21.41	404.28
EFF 2	158.81	28.55	215.18	38.68	62.97	11.32	119.34	21.45	556.29
EFF 3	88.40	28.46	135.77	43.72	5.88	1.89	80.51	25.92	310.56
EFF 4	180.57	44.98	125.49	31.26	13.77	3.43	81.61	20.33	401.44
EFF 5	18.18	19.51	14.41	15.46	29.38	31.53	31.21	33.49	93.18
x̄ EFF	**118.92**	**33.67**	**130.87**	**37.06**	**23.52**	**6.66**	**79.85**	**24.52**	**353.15**
MP 1	97.58	37.61	16.98	6.55	12.58	4.85	132.28	50.99	259.43
MP 2	39.57	20.38	105.48	54.33	13.22	6.81	35.89	18.48	194.16
MP 3	325.25	75.14	51.87	11.98	0.83	0.19	54.90	12.68	432.84
MP 4	103.83	39.88	98.59	37.87	5.97	2.29	51.96	19.96	260.35
MP 5	101.26	42.67	80.33	33.85	21.02	8.86	34.70	14.62	237.32
x̄ MP	**133.50**	**48.23**	**70.65**	**25.52**	**10.72**	**3.87**	**61.95**	**22.38**	**276.82**
RP 1	60.59	45.90	33.87	25.66	19.37	14.67	18.18	13.77	132.01
RP 2	50.21	24.02	86.66	41.46	47.92	22.92	24.24	11.60	209.03
RP 3	128.98	38.19	62.52	18.51	32.22	9.54	114.02	33.76	337.73
RP 4	52.88	34.76	48.29	31.74	20.20	13.28	31.95	21.00	152.12
RP 5	43.61	17.50	159.64	64.05	26.53	10.64	19.46	7.81	249.24
x̄ RP	**67.25**	**31.13**	**78.20**	**36.20**	**29.25**	**13.54**	**41.57**	**19.24**	**216.03**

EFF: Effluent; MP: Manomet Point; RP: Rocky Point; x̄: Mean biomass

Biomass of Remaining Benthic Species

The remaining benthic species exclude *Chondrus crispus*, *Phyllophora spp.*, *Laminaria* spp., and algal epiphytes. Biomass data for the remaining benthic species for April 1990 are presented in Table 6. The Effluent station had the highest range of biomass values (5.60 to 62.97 g/m²), followed by Rocky Point (19.37 to 47.92 g/m²), and Manomet Point (0.83 to 21.02 g/m). The percentage that the remaining benthic species contributed to the total algal biomass was greatest at Rocky Point (14%), followed by 7% at the Effluent station and 5% at Manomet Point.

The highest mean biomass values occurred at the Rocky Point station (29.25 g/m²), with the Effluent and Manomet Point station equaling 23.52 g/m² and 10.72 g/m², respectively. No significant differences were found between the three stations for biomass of the remaining benthic species (at p=.05).

Epiphytic Algal Biomass

Epiphytic algal biomass values for April 1990 are given in Table 6. In April 1990, mean epiphytic biomass values were highest at the Effluent station (79.85 g/m²), followed by the Manomet Point station (61.95 g/m²), and the Rocky Point station (41.57 g/m²). No significant differences in epiphytic biomass were found between the three stations (at p=.05).

Total Algal Biomass

Total mean algal biomass for April 1990 is given in Table 6. The Effluent station had the highest biomass value (353.15 g/m²), the Manomet Point station ranked second (276.82 g/m²), and the Rocky Point station ranked third (216.03 g/m²). Individual replicate ranges for total algal biomass in April 1990 at the Effluent, Manomet Point, and Rocky Point stations were 93.18 to 556.29 g/m², 194.16 to 432.84 g/m², and 132.01 to 337.73 g/m², respectively. An ANOVA showed no significant differences in total algal biomass for the three stations (at p=0.5).

4.0 DISCUSSION

Efforts to interpret the effects of thermal discharges of Pilgrim Station on the benthic communities are complicated by the year-to-year differences in operational levels of the plant. The recent 2½-year outage resulted in the benthic communities associated with the effluent canal resuming a "normal" appearance. For example, the transect surveys of the effluent canal conducted in March and June 1989 showed essentially no impact. The denuded zone reappeared in September 1989 and has continued to be present in subsequent surveys in December 1989, April 1990, and June 1990.

Faunal communities observed at the Effluent station have typically exhibited a low degree of similarity with the reference stations (<60% Bray-Curtis similarity). However, beginning in 1984 at the time of a prolonged outage of the plant, similarity began rising to levels exceeding 70%, only to slowly decline again in 1985 (BECO, 1986). Similarity again increased during the first half of 1987. The results of the Bray-Curtis similarity analysis in subsequent surveys suggest that there is no longer any difference between the Effluent station and the reference stations because the replicates of each station tend to intermix to varying degrees rather than retaining a station-specific identity or signature. This result may be explained in part by the enormous increase in mussel populations that has occurred since 1988. In 1987, mussels were not the highest ranked species (BECO, 1987). Bray-Curtis is believed to be influenced by the presence of species that occur in very high numbers and this has undoubtedly obscured the similarity analysis. However, this is not the case with NESS, which is more sensitive to the rare species. An examination of the NESS similarity results indicates that the Effluent station was distinct from the reference stations in 1989, but not in 1990. The NESS similarity between the Effluent station replicates and the reference stations was >90, suggesting that the Effluent station does not differ significantly from the reference stations. In April 1990, there is no distinction between the Effluent station and the reference stations in terms of benthic assemblages. Results of the algal studies also indicate that there are no significant differences among the Effluent, Manomet, and Rocky Point stations. These results might call into question the adequacy of the Effluent station as representative of an impacted area. However, Pilgrim Station was not operating in the month preceeding the collection of the April samples, and the timing of this shutdown might explain the apparent lack of impact at the Effluent station.

The size of the *Chondrus* denuded zone in June 1990 was indicative of pre-outage impacts. The major difference, however, between these observations and those of previous years were the incredible populations of mussels observed in the area encompassed by the transect surveys. The mussels were reportedly so thick that they buried the attached algae by several layers. Active predation of starfish was observed throughout the area.

Most of the mussels observed in the April quantitative and June qualitative samples are juveniles and capable of migration. It is likely that the unusually high concentrations noted in June 1990 in the effluent canal during the qualitative transect survey were due to migration from surrounding areas to a more favorable site. When mussel larvae first settle from the plankton, they initially settle on filamentous red algae. At this stage they are called plantigrade larvae and are capable of considerable movement (Bayne, 1964; 1965). Normally, the plantigrades move from the primary settlement site to a suitable rock surface or mussel bed where they eventually secrete byssal threads and undergo a secondary settlement.

Even at this stage, however, mussels can exhibit movement, and when removed from a mussel bed, can readily secrete new threads and reattach. Thus, the settlement and migratory patterns exhibited by *M. edulis* might account for the decrease in populations at the control stations between March and September in 1989 and the increase at the Effluent station. Plantigrades have been postulated to move from areas of primary settlement to other areas by means of gas bubbles in the mantle cavity that permit them to adhere to the surface tension and float to new sites. Bayne (1964) postulated that this migratory phase could occur several times as the plantigrade *M. edulis* attach to and leave several algal substrates before finding a suitable mussel bed for attachment. It is probable that the relatively exposed denuded areas and the warm water were attractive to migrating plantigrades. In warm waters, when food resources are available, most invertebrates are able to undergo rapic growth. Numerous studies have shown that the filtration rate (due to ciliary activity) of *M. edulis* and other filter-feeding bivalves is increased when temperature is increased (Newell, 1979).

Benthic community parameters 'ncluding species richness, species diversity, and faunal density indicate that all of the stations are hea'thy and support a rich fauna. Species richness data suggest that there are more species present than in recent years. For example, at all stations, many more species were present in the April 1990 collections than in March 1989.

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APPENDIX A

APPENDIX A. LIST OF SPECIES IDENTIFIED AT THE EFFLUENT, MANOMET POINT, AND ROCKY POINT STATIONS IN APRIL 1990

Smaller Phyla

Anemone
Nemertea
Sipunculoidea

Polychaeta

AMPHARETIDAE
Asabellides oculata

ARENICOLIDAE
Arenicola marina

CAPITELLIDAE
Capitella capitata

CIRRATULIDAE
Caulleriella bioculata
Chaetozone setosa
Cirratulus cirratus
Dodecaceria corallii

NEPHTYIDAE
Nephtys caeca

NEREIDIDAE
Nereis pelagica
Nereis zonata
Nereis spp. juv.

ORBINIIDAE
Naineris quadricuspida

PHOLOIDIDAE
Pholoe minuta

PHYLLODOCIDAE
Eteone longa
Eulalia viridis
Eumida sanguinea
Phyllodoce (Anaitides) maculata

POLYNOIDAE
Harmothoe (Lagisca) extenuata
Harmothoe imbricata
Harmothoe spp. juv.
Harmothoe spp. indet.
Lepidonotus squamatus

SABELLARIIDAE
Sabellaria vulgaris

SABELLIDAE
Fabricia sabella
Potamilla neglecta
Potamilla reniformis

SPIONIDAE
Polydora cornuta
Polydora socialis
Polydora websteri
Polydora spp. indet.
Prionospio steenstrupi
Spio filicornis
Spionidae spp. juv.

SYLLIDAE
Autolytus alexandri
Autolytus fasciatus
Autolytus prismaticus
Autolytus spp. juv.

TEREBELLIDAE
Nicolea venustula
Polycirrus phosphoreus
Polycirrus spp. indet.

Crustacea

ISOPODA
Idoteidae
Idotea phosphorea
Idotea balthica

AMPHIPODA

Amphitoidae

Amphitoe rubricata

Calliopidae

Calliopus laevisculus

Corophiidae

Corophium acutum

Corophium bonelli

Corophium insidiosum

Corophium spp. indet.

Corophium spp. juv.

Dexaminidae

Dexamine thea

Gammaridae

Gamarellus angulosus

Gammarus oceanicus

Gammarus sp.

Marinogammarus stoerensis

Ischyroceridae

Ischyrocerus anguipes

Jassa falcata

Phoxocephalidae

Phoxocephalus holbolli

Pleustidae

Pleusymtes glaber

Pontogeneiidae

Pontogeneia inermis

Stenothoidae

Metopella angusta

Proooloides holmesi

CAPRELLIDEA

Caprellidae

Caprella linearis

Caprella penantis

Caprella nr. *septentrionalis*

Caprellidae spp. juv.

DECAPODA

Cancer irroratus

Carcinus maenas

Eualus pusiolus

Pagurus acadianus

Pagurus sp.

<u>Mollusca</u>

GASTROPODA

Acmaeidae

Acmaea testudinalis

Aeolidiidae

Aeolidia papillosa

Calyptraeidae

Crepidula plana

Columbellidae

Anachis avara

Mitrella lunata

Cratenidae

nr. *Cratena aurantia*

Diaphanidae

Diaphana minuta

Eubranchidae

Eubranchus exiguus

nr. *Eubranchus pallidus*

Lacunidae

Lacuna vincta

Lamellidorididae

nr. *Acanthodoris pilosa*

Littorinidae

Littorina littorea

Littorina saxatilis

Nassariidae

Nassarius trivittatus

Naticidae

Lunatia heros

Pyramidellidae
Odostomia seminuda
Odostomia sp.

Rissoidae
Alvania areolata

Skeneopsidae
Skeneopsis planorbis

Trochidae
Margarites helicinus

Gastropoda spp. indet.
Gastropoda spp. juv.
Nudibranch spp. indet.

BIVALVIA

Anomiidae
Anomia aculeata
Anomia simplex

Cardiidae
Cerastoderma pinnulatum

Hiatellidae
Hiatella arctica

Mactridae
Spisula solidissima

Myidae
Mya arenaria

Mytilidae
Modiolus modiolus
Mytilus edulis

Tellinidae
Macoma tenta
Tellina agilis

Bivalvia spp. indet.

POLYPLACOPHORA
Lepidochiton ruber

Echinodermata

ASTEROIDEA
Asterias forbesi
Henricia sanguinolenta

ECHINOIDEA
Strongylocentrotus droebachiensis

OPHIUROIDEA
Ophiopholis aculeata
Amphipholis squamata

Tunicata

POLYCLINIDAE
Amaroucium constellatum

MOLGULIDAE
Molgula sp.