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Secondary Production of Benthic Macrofauna at Three Stations of Delaware Bay and Coastal Delaware

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts
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NOAA TECHNICAL MEMORANDUM NMFS-F/NEC

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FOREWORD

The description and quantification of energy flows are major problems in developing useful ecosystem models. These models are used to examine the possible causes of fishery stock variability and the impacts of pollution or habitat alteration to the ecosystem. This report on the secondary production of benthic invertebrates (which are important in the diets of many resource species) is only the second such study to measure directly benthic community production on the east coast of the United States; Howard Sander's (1956) study in Long Island Sound being its only precedent. This report completely documents the methodology and much of the raw data. It has been edited for technical content but not fully for style, since a condensation is being prepared for journal publication.

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ABSTRACT

Benthic secondary production have been estimated for three stations in regions of Delaware Bay and coastal Delaware during the period March, 1980 through November, 1981. Objectives of this study are to: 1) develop the methods for estimating benthic secondary production and assess their potential for evaluating the "health" of a marine benthic community, 2) estimate annual variation in production and turnover for select species as well as total communities and compare these results with a concurrent study on community structure, and 3) establish baseline data for production and turnover measurements of benthic communities in temperate Atlantic waters for comparison with subsequent production studies, i.e., in impacted areas of the NY Bight.

Station 29 in Delaware Bay and station 31 off Cape Henlopen are similar with regard to their sediments (fine sand/silt) and benthic invertebrate assemblages. Total annual secondary production rates (mg ash-free dry weight/m^2/year) were 46,572 at station 29 and 30,124 at station 31 during 1980 though the latter decreased to 7,501 during 1981. This compares to station 32, off Bethany Beach, where production levels in a medium sand substratum were 4,485 during 1980 and 4,492 during 1981. Converting production values to account for effects of sample preservation, estimates of annual carbon production (mg C/m^2/year) were 24,101 at station 29, decreased from 15,589 to 3,882 at station 31, and increased from 2,321 to 2,424 at station 32.

Results indicated that the annual variability of total secondary production and turnover ratios were influenced primarily by the epifaunal species *Asabellides oculata* (Polychaeta, Ampharetidae) and *Mytilus edulis* (Mollusca, Bivalvia). These species accounted for the highest annual production rate observed in 1980. At all stations the infaunal species contribute low but annually consistent levels of total secondary production relative to the two epifaunal species.

The community concept of the diversity of production is discussed emphasizing observed relationships between structure and energetics. Lastly, it is hypothesized that the recruitment success of the epifaunal species represents a potentially valuable food resource for upper trophic levels though it may promote community instability. This study suggests that the consideration of functional processes of a benthic invertebrate community based on the assessment of secondary production is valuable in understanding temporal and spatial changes in community structure, integrating benthic analyses into a multidisciplinary framework, and quantifying benthic fauna as a potential food resource.

1. INTRODUCTION

The monitoring of macrobenthic invertebrates in the Delaware Bay area has been incorporated into the existing Northeast Monitoring Program (NEMP) of the National Marine Fisheries Service (NMFS) recognizing of Delaware Bay as a major estuary on the east coast. Delaware Bay has been described as having low densities of benthic invertebrate assemblages relative to other temperate estuaries and bays (Maurer et al., 1978). Industrial influences were inferred as possible causes. The present research assesses the health of three benthic invertebrate communities in regions of Delaware Bay and coastal Delaware based on two criteria: 1) community structure including densities of invertebrate species measured on a biannual basis; a convention currently used within NEMP, and 2) community energetics based on analysis of benthic secondary production; a new application of a commonly used method (Crisp, 1971; Buchanan and Warwick, 1974; Nichols, 1975). This report summarizes the secondary production phase of the study and synthesizes results with analyses of community structure (Leathem and Howe, 1982).

Historically, benthic monitoring programs are often concerned with site characterizations in hopes of assessing a community response to an environmental perturbation such as pollution (Maurer et al., 1976; Boesch et al., 1976; Lear et al., 1979). The monitoring of changes in community structure can reveal valuable information about such an impact (Pearce, 1969, 1979; Steimle and Sinderman, 1978; Maurer, Leathem, and Menzie, 1981; Reid, O'Reilly amd Zdanowicz, 1982) particularly when the pollutant impact is great, the chemical composition is toxic, and the impact duration is long-term (e.g. in Raritan Bay and NY Bight).

Effective applications of community structure as a monitoring tool are influenced by extensive spatial and temporal heterogeneity which are so much a part of marine benthic systems (Rosenberg, 1974; Holland and Polgar, 1976; Gage and Coghill, 1977; Maurer et al., 1979a; Brown, 1982). Because changes in taxonomic structure are not always linked to other ecosystem changes (Matthews et al., 1982) use of information indices alone often offer no clear biological meaning (Goodman, 1975) and are most meaningful in conjunction with other types of data analyses (Green and Vascotto, 1978). Steele (1974) suggests that it is the rates of energy flow in an ecosystem that may be the most significant parameters for the study of marine problems. Understanding the functional dynamics of the benthic community and its contribution to upper trophic levels, such as marine fisheries, requires assessment of production rates of organic matter by that community (Crisp, 1971).

According to Kinne (1978), the present day global ecosystem is characterized by logarithmically increasing manmade deformation due to 1) collection, concentration, utilization, modification, and redistribution of living as well as non-living materials; 2) accelerated degradation of biological energy; and 3) structural changes within the ecosystem. Estimates of these effects necessitate studies of ecological dynamics (McIntyre, 1977) including consideration of energy flow, transformation and utilization, functional and structural characteristics of an ecosystem, population dynamics, and trophic relationships.

The present study investigates the ecologically dynamic process of secondary production of benthic macrofauna defined as the movement and utilization of energy through those trophic levels above that of the primary producers (Crisp, 1971). Production, standing crop, and turn-over are summarized for the macrofaunal component of three benthic communities with emphasis on inter-community spatial variability as influenced by differences in sediment characteristics as well as intra-community temporal variability over a two year period. The dynamic processes of these communities are examined by incorporating a size dimension and corresponding cohort analysis into what is regarded as standard benthic monitoring procedures, namely the elucidation of species densities. This approach facilitates the integration of present results with previously reported studies of community structure for the same communities (Maurer et al., 1976, 1978, 1979a; Leathem and Howe, 1982).

2. METHODS

Marine benthic invertebrate communities were monitored at NEMP Stations 29, 31, and 32 during 1980 and at Stations 31 and 32 during 1981. Latitude and longitude coordinates are 38°56.3'N X 75°10.7'W for station 29, 38°44.8'N X 75°01.0'W for station 31; and 38°31.4 X 74°57.7'W for station 32 (Figure 1). Stations were sampled in March, June, July, August, September, and December in 1980, although station 29 was omitted during July and December due to inaccessability. In 1981, stations 31 and 32 were sampled again in April, June, July, September, October, and November.

Secondary production analyses were based on three replicate samples per station per month collected with a Smith-McIntyre grab (0.1 m^{-2}) with the exception of July 1980 and December 1980 when five replicates were used. Sediment aliquots were collected from each replicate sample for analyses of sediment particle size distribution and organic content. Station depths were recorded and bottom water sampled for temperature, salinity, and dissolved oxygen. Entire samples were fixed with 10% buffered formalin plus rose bengal, sieved (0.5 mm mesh) and subsequently stored in 70% alcohol.

Laboratory analysis consisted of sorting all samples to taxa of Polychaeta, Mollusca, Crustacea, Echinodermata, and large meiofauna (Oligochaeta and Archiannelida) from which wet weight biomass and total number of individuals were recorded. Miscellaneous taxa (Sipuncula, Nemertea, and Coelenterata) were noted though not included in production estimates. Polychaete and bivalve fauna were sorted to the species level with "select species" destined for direct secondary production analyses being determined following the criteria of: 1) relative abundance in March and June, 1980 samples, 2) expected consistency of occurrence throughout the study, and 3) sensitivity of methods to measurements of individual size. Following the criteria, 15 selected invertebrate species were analyzed for direct rates of benthic secondary production (Table 1). The select polychaete fauna included the following nine species: family Ampharetidae: Asabellides oculata and Ampharete arctica; family Capitellidae: Mediomastus ambiseta and Amastigos caperatus; family Nephtyidae: Nephtys incisa and Nephtys picta; family Paraonidae: Aricidea catherinae, Aricidea cerruti, and Paradoneis lyra. The select bivalve fauna included the following six species: the razor clam, Ensis directus; the blue mussel Mytilus edulis; the nut clams Nucula annulata and Nucula proxima, the surf clam Spisula solidissima and the dwarf tellin Tellina agilis. The remaining polychaete and mollusc fauna not directly measured (as "select species") were represented as cumulative groups per phylum (called "residual species").

Indirect estimates of production were determined for the residual bivalves and polychaetes as well as crustaceans, echinoderms, and the meiofauna group. This latter group was included because of its appreciable biomass observed in certain months relative to other taxa. Note that for convenience sake this group is labelled meiofauna though biomass and production estimates are restricted to the greater than 0.5 mm size fraction. Unsieved sediment cores from stations 31 and 32 were analyzed from the July and October, 1981 samples by Dr. Harlan Dean[1]. For size fractions less than 0.5 mm, meiofauna were either present in very low densities or absent during the two sampling periods. For the select species in each of the monthly samples, the following parameters were examined: total wet weight biomass, total density, and individual size. Subsampling methods were used to estimate total species densities when a species exceeded 500 individuals/sample. Size frequency distributions of each species were based on size measurements of a maximum of 100 randomly chosen individuals per replicate sample. Size indices include width of first chaetigerous segment for polychaetes and valve length for bivalves (valve width for Mytilus). The differention of size classes follow computer adapted methods of Harding (1949) and Cassie (1954).

Regression curves were prepared for conversion of individual size indices (mm) to ash-free dry weight (AFDW) (mg) of preserved animals. Whole individuals of molluscs and polychaetes were selected which encompassed the maximum size range encountered for each select species, respectively, throughout the study. Ash-free dry weight values were estimated for samples decalcified using dilute HCl which were oven dried for 24 hours at 90°C and then ignited in a muffle furnace for 2 hrs at 450°C. When possible, measurements were obtained for single individuals. Otherwise, individuals of the same size index were grouped cumulatively and a mean ash-free dry weight per individual was obtained.

Regression line characteristics of AFDW versus individual size are summarized in Table 2. Preliminary tests indicated that regression lines for species at station 29 and station 31 were not statistically different and composite curves were prepared using individuals from both stations. Only for the species Ampharete arctica was it necessary to combine individuals from station 31 (juveniles) and station 32 (adults). Sufficient whole individuals were unavailable for three species and the conversion values for Mediomastus ambiseta were used for Amastigos caperatus, Aricidea catherinae used for A. cerruti; and Nucula annulata used for Nucula proxima. Regression curve results of 1980 were compared with 1981 for the species Aricidea catherinae, Ampharete arctica and Tellina agilis. No statistical annual differences were observed. For those four species, regression results represent a composite of 1980 and 1981 data, otherwise only 1980 data were used.

Total production of each size class was calculated following Crisp (1971) for populations with distinguishable recruitment and age classes given as:

$$P = \quad Ndw = \Sigma \ 1/2 \ (N_t + (N_{t + \Delta t}) \ \Delta w$$

where P = production (mg AFDW/m^2/year), Δw = increment in mean individual weight (mg) between two consecutive samples separated by period ΔT for each size class, N = mean density/m^2 for each size class. Final production (P = mg AFDW/m^2/year), mean biomass (mg AFDW), and production: biomass ratio (P:$\bar{B}$) were calculated for each species based on individual size classes as well as cumulative annual totals.

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Production calculations estimates based on formalin preserved fauna were converted to unpreserved tissue using a conversion factor of 1.15. This allows for an assumed mean 15% decrease in preserved fauna relative to live tissue, although studies of preservation effect (Howmiller, 1972; Mills et al., 1982) have not specifically addressed formalin preserved fauna that are later transferred to alcohol. Values of non-preserved tissue production were converted to carbon production using a conversion factor of 0.45 following Nichols (1975) for a marine invertebrate though higher conversion factors $\geq$ 0.50 have been proposed (Winberg, 1971; Salonen et al., 1976).

Estimates of residual production for polychaetes and molluscs necessitated the conversion of wet weight to ash-free dry weight. These conversion values were calculated using results for the select species at each of the stations for both sampling years from which an overall mean conversion value was obtained. Mean wet to dry biomass conversion factor for polychaete fauna was 0.1156 (S.D. = $\pm$ 0.0589, N = 27) and for mollusc fauna was 0.1279 (S.D. = $\pm$ 0.0657, $\bar{N}$ = 23). For the remaining residual fauna a conversion factor of 0.10 was assumed.

The product of production:biomass ratios, or turnover ratios, and mean ash-free dry standing crop values were used to estimate production for all residual fauna groups as well as those select species for which size class data was limited. For residual fauna groups, turnover ratios were based on results for comparable fauna examined in other studies. Amphipod fauna were predominately of the families Haustoriidae and Aoridae (Leathem and Howe, 1982) and a turnover ratio of 8.0 was used for isopod and amphipod crustaceans (Albright and Armstrong, 1982). The remaining turnover ratios used for indirect production calculations were 2.0 for decapod crustaceans (Richards and Riley, 1967; Buchanan and Warwick, 1974), 0.5 for echinoid echinodermata (Buchanan and Warwick, 1974) and 8.0 for archiannelid and oligochaete meiofauna (McIntyre, 1964; Cederwall, 1977). For select species with insufficient densities for direct measurement, particularly in the larger size classes, turnover ratios were also used for production estimates. These ratios were based on direct measurement of comparable species and size classes from this study.

3. RESULTS

3.1 Physical Data

3.1.1 Sediments and Geology

Results of sediment analysis (Table 3) are limited to three sampling periods, with two analyses performed by NMFS and one by the University of Delaware, College of Marine Studies (CMS). Sample loss and faulty preservation (thawing) precluded analyses of remaining samples. One sample was analyzed for station 29 indicating a silt-clay content of 14.8% and a mean ϕ of 2.81, where ϕ is defined as - $\log_2$ mean sediment diameter (mm). For the NMFS samples at station 31, mean ϕ was 1.28 and mean silt-clay was 7.8 percent. Inclusion of the CMS analysis (67.9% silt-clay) gives an overall mean of 27.9% silt-clay. At station 32, mean ϕ was 1.67 and mean percent silt-clay was 0.6.

Station 29, located southwest of the Delaware Bay anchorage area, occurs in a region historically characterized as having medium to fine sands that are moderately to moderately-well sorted (Watling, Maurer, and Wethe, 1976). The topography of station 31 (Hen and Chicken Shoals) is described as an "...abrupt beach slope [which] yields to a shallow, relatively flat bottom (9m) which rises on the shoal. This in turn drops off rapidly into a series of deep holes (24m) and elongate depressions." Maurer et al. (1979a) describes station 32 (South Bethany Beach) as an "abrupt slope [which] yields gradually to a shallow bottom (9-12m)," with station 32 being "definitely more homogeneous" than station 31. Lastly, he characterized the sediments of the two areas as being medium sand with an occasional depression or hole serving as a trap for finer grained sediment.

Present physical data agree with the historical characterizations of the three stations. Mean ϕ at stations 31 and 32 indicate medium sand although silt-clay content is greater and far more variable at station 31. The present study describes sediments at station 29 as fine sand/silt-clay. Of importance is the fluctuating sampling depths ranging from 18 to 23 m at station 31 and 13 to 20 m at station 32. This is interpreted as resulting from within station variability due to sampling over a large spatial area where considerable variation in topography exists. At station 31, this may be particularly important, where spatial variability of sediment characteristics and, presumably, corresponding benthic fauna is high.

3.1.2 Hydrography

The mean salinity of bottom water was 30.2 $^o/oo$ at station 29, 31.7 $^o/oo$ at station 31, and 32.1 $^o/oo$ at station 32 (Table 3). No attempt was made to restrict sampling to a consistent phase of the tidal cycle, although the maximum variation in salinity throughout the study was observed at station 32 with a maximum difference of 2.5 $^o/oo$. Remaining hydrographic data at station 29 was limited. Bottom water temperature ranged from 7.4 (December, 1980) to 20.8^{o}C (August, 1980) at station 31 and 6.6 (December, 1980) to 20.4°C (August, 1980) at station 32 (Table 3). Corresponding mean annual temperatures at the two stations were 16.0 and 15.2°C, respectively. Dissolved oxygen in bottom water ranged from 3.04 (September, 1980) to 6.69 ml/l (December, 1980) at station 31 and from 3.21 (June, 1981) to 6.72 ml/l (December, 1980) at station 32. Corresponding mean dissolved oxygens at the two stations were 4.51 and 4.63 ml/l, respectively.

3.2 Biological Data

3.2.1 Annual Trends in Biomass and Density

Mean benthic wet weight biomass (g/m^2) and respective cumulative percent have been summarized for each monthly sample (Table 4). At station 29 during 1980, total monthly biomass ranged from 6.19 to 269.77 with the maximum occurring in June. Mean annual biomass was 74.83 $\pm$ 130.08 with molluscs and polychaetes accounting for 93.5%. The August sample was anomalous with molluscs alone accounting for 82.2 percent of the sample although total wet weight was an observed minimum of 6.19.

At station 31 during 1980, the standing crop maxima occurred in June and September. The mean annual biomass was 49.01 g/m^2 with the co-dominant polychaete and molluscan fauna accounting for 94.4%. In 1981, mean annual biomass decreased to 16.88 g/m^2 and a monthly total biomass maximum was observed in September.

During 1980, compared to stations 29 and 31, station 32 had the lowest mean annual biomass of 19.56 g/m^2. Mollusca and polychaeta were co-dominant phyla throughout all of the sampling periods with the exception of July, when an anomalous sampling of sand dollars, Echinarachnius parma, accounted for 89.5% of the total biomass and secondary dominant taxa were crustaceans and molluscs. Relative to 1980, mean annual biomass decreased in 1981 to 9.59 g/m^2 due primarily to a decrease in mollusc and echinoderm biomass.

Trends in mean total polychaete density and mean total mollusc density are presented in Figures 2 and 3. Within each station for each sampling year, the times of peak occurrence were consistent for both taxa. At station 29, density maxima were observed in June 1980 and again in September 1980 though the latter was observed for only polychaetes. At station 31, density maxima peaked in March 1980 and September 1980 though in 1981 maximum densities occurred in October for polychaetes and in June for molluscs. At station 32, density maxima for polychaetes were observed in June 1980, September 1980, and July 1981 whereas the mollusc maxima occurred in July 1980, September 1980 and April 1981.

3.2.2 Molluscan Production

Total mollusc production at stations 29, 31, and 32 are presented in Tables 5-7, respectively. The production and turnover ratios of select mollusc species are discussed below.

3.2.2.1 Ensis directus

Total production of the razor clam, Ensis directus, was highest at station 29 at a level of 8,674 mg AFDW/m^2/y; decreased from 2,932 in 1980 to 1,682 in 1981 at station 31; and was lowest at station 32 reaching levels of 6 and 19 during the two year period. Calculated turnover ratios were highest at station 31 in 1980 with P:B of 14.11; decreased in 1981 at this station with a P:B of 7.05; and decreased further at station 32 in 1981 to a level of 4.98.

First evidence for juvenile size classes of Ensis directus was observed in December with juveniles overwintering and recruitment continuing through the early spring. Few adults survived past July resulting in low mean annual biomass and high turnover values.

3.2.2.2 Mytilus edulis

Total production of the blue mussel, Mytilus edulis was 2,184 mg AFDW/m^2/y at station 29 during 1980. Production for this species was highest during 1980 at station 31 at a level of 13,384 although production decreased at this station during 1981 to a level of 77. Mussel production was low at station 32 with levels of 18 during 1980 and less than 1 during 1981. Calculated turnover ratios were highest at station 31 ranging from 6.17 to 5.94 during the two year period, as compared to low values of 2.23 and 1.15 determined at station 32.

Juvenile size classes were first observed in March with little evidence for survival of overwintering adults. At station 32, a minor peak in recruitment was observed in September although the principal recruitment period occurred in the early spring.

3.2.2.3 Nucula annulata and Nucula proxima

The present study recognized Nucula annulata and Nucula proxima as distinct species based on previous studies (Hampson, 1971; Scheltema, 1972; Howe, 1981) although previous NEMP convention recognizes only N. proxima (Bob Reid - personal communication). These species maintained allopatric distributions with Nucula annulata being found in Delaware Bay (station 29) and off Cape Henlopen (station 31) whereas only Nucula proxima was observed at station 32.

Total production of Nucula spp. was 17 mg AFDW/m^2/y at station 29 during 1980, and increased at station 31 to a level of 844 during 1980 and 511 during 1981. Corresponding production rates were low at station 32 with levels of 2 in 1980 and 1981. Turnover ratios were highest in 1981 at station 31 with a P:B of 6.17 and during the same year at station 32 with a P:B of 4.90. Evidence suggests that the juvenile size classes settle in the early spring. Data were inconsistent in supporting evidence for a second recruitment period.

3.2.2.4 *Spisula solidissima*

Total production of the surf clam, *Spisula solidissima*, was low at station 29 in 1980, and station 31 during 1980 and 1981 with levels of 22, 101, and less than 1 mg AFDW/m^2/y, respectively. At station 32, production levels were 874 during 1980 and 410 during 1981. Turnover ratios were highest at station 32 with a range of 4.49 to 5.75, as compared to 1.60 determined at station 31.

Juvenile size classes were observed in the early spring at station 31. At station 32, evidence suggests a second recruitment period may occur in the late summer with juveniles becoming evident in September and persisting through the winter and early spring at low densities.

3.2.2.5 *Tellina agilis*

Total production of the dwarf tellin, *Tellina agilis*, was 7,648 mg AFDW/m^2/y at station 29 during 1980. Production was decreased and consistent at station 31 with values of 1,167 during 1980 and 1,118 during 1981. Production was consistently low at station 32 with values of 257 during 1980 and 136 during 1981. Turnover ratios were 2.75 at station 29, ranged from 2.08 to 3.36 at station 31, and ranged from 2.53 to 7.03 at station 32.

One recruitment period was observed with juvenile size classes evident in September. This new age class was observed to overwinter at moderate densities and persisted through the following fall recruitment period as a one-year old age class.

3.2.2.6 Residual Mollusca

Residual mollusc species included *Astarte castanea*, *Crenella glandula*, *Lyonsia arenosa*, *Periploma leanum*, *Siliqua costata*, *Pandora* spp., *Yoldia sapotilla*, *Pitar morrhuana*, *Acteocina canaliculata*, and *Nassarius trivittatus*. Comparisons of mollusc species comprising the select and residual molluscs are summarized in Table 8 based on annual mean densities (# individuals/m^2) and annual mean biomass (g wet weight/m^2). Monthly means were first determined for triplicate samples at each station from which annual means were calculated. Relative to the total mean biomass, the six select mollusc species accounted for a range of 73.8 to 96.0% at stations 29 and 31 and a lower range of 41.0 to 73.7% at station 32. Similar trends were observed for density calculations though calculations of percent select species were increased over those based on biomass. Recruitment of juvenile molluscs were observed for all select as well as residual mollusc species with exception of *A. castanea*, *P. morrhuana*, *N. trivittatus*, and *Pandora* spp., where only adult individuals were observed.

Annual turnover ratios calculated for the composite select mollusc species for each station ranged from 3.7-6.0 (Tables 5-7). These ratios were applied in conjunction with the respective mean annual biomass of the residual molluscs to estimate residual production. Production estimates are 3,230 mg AFDW/m^2/y at station 29 during 1980. Residual mollusca production for station 31 ranged from 778.18 during 1980 to 1,236 mg AFDW/m^2/y during 1981, and from 414 during 1980 to 817 mg AFDW/m^2/y during 1981 at station 32.

3.2.3. Polychaeta Production

Total polychaete production at stations 29, 31, and 32 are summarized in Tables 9-11, respectively. The production and turnover ratios of select polychaete species are discussed below.

3.2.3.1 Mediomastus ambiseta

Total production of the capitellid, Mediomastus ambiseta, was 205 mg AFDW/m^2/y at station 29 during 1980, decreased at station 31 to levels of 49 in 1980 and 17 in 1981 and decreased substantially at station 32 to levels of 0.03 in 1980 and 0.04 in 1981. Turnover ratios were 2.41 at station 29 and ranged from 1.07 to 3.14 at station 31 during the two years, respectively.

Evidence supports several periods of recruitment occurring through the year with new juvenile size classes observed in the early spring of 1980, and again in June and October at stations 29 and 31. Recruitment classes from the early fall may be capable of overwintering through the following year.

3.2.3.2 Amastigos caperatus

Total production of the capitellid, Amastigos caperatus, was 3 mg AFDW/m^2/y at station 29, whereas at station 31 it ranged from 88 in 1980 to less than 1 in 1981, and at station 32 was less than 1 for both years. A turnover ratio of 1.72 was determined for station 31 during 1980, this being the only station with sufficient samples for direct calculation. Recruitment patterns followed those of M. ambiseta with new juvenile size classes observed in June, August, and December.

3.2.3.3 Asabellides oculata

Total production of the ampharetid, Asabellides oculata, was 22,617 mg AFDW/m^2/y at station 29 during 1980. Production at station 31 was 6929 during 1980 and 32 during 1981 and was present at station 32 only in 1980 at a rate of 241. A turnover ratio of 12.27 was determined at station 31 and used at station 29 for indirect production estimates of this species as compared to a low ratio of 3.99 determined for station 32. These tube dwelling polychaetes were far more dominant in 1980 than in 1981 with juvenile size classes first observed in March and to a limited extent again in August.

3.2.3.4 Ampharete arctica

Total production of the ampharetid, Ampharete arctica, was 162 mg AFDW/m^2/y at station 31 in 1980, and at station 32 ranged from 20 in 1980 to 95 in 1981. Turnover ratios were calculated only for specimens at station 32 where the P:B range was 2.87 to 3.16. Juvenile size classes were first observed in December and overwintered through the fall of the following year. A minor secondary recruitment peak was observed in July and August at station 32.

3.2.3.5 Aricidea catherinae

Total production of the paraonid, Aricidea catherinae, was less than 1 mg AFDW/m^2/y at station 29 during 1980, at station 31 ranged from 83 in 1980 to 45 in 1981, and at station 32 ranged from 30 in 1980 to 9 in 1981. Calculated turnover ratios ranged from 1.39 to 1.55 at station 31 and from 4.33 to 1.09 at station 32.

Two recruitment periods were evident. New juvenile size classes were observed in December with continued recruitment occurring during the early spring and growth persisting through the fall. Low densities of a juvenile size class were also evident during July and August and persisted through the late fall.

3.2.3.6 Aricidea cerrutii

Total production of the paraonid, Aricidea cerrutii, was less than 1 mg AFDW/m^2/y at station 31 during 1980 and at station 32 ranged from 25 in 1980 to 12 in 1981. Turnover ratios were calculated only for samples at station 32 and ranged from 1.17 in 1980 to 1.72 in 1981. Evidence supports a single recruitment period with a juvenile size class observed in July at station 31 and in September at station 32. Evidence suggests that recruited juveniles overwinter and grow through the following fall.

3.2.3.7 Paradoneis lyra

Total production of the paraonid, Paradoneis lyra, at station 31 ranged from 1 mg AFDW/m^2/y in 1980 to less than 1 in 1981, and at station 32 ranged from 10 in 1980 to 8 in 1981. A calculated turnover ratio of 0.72 was determined at station 32 in 1980. Recruitment patterns for this species are similar to those observed for the two other species of paraonid polychaetes. Juvenile size classes were observed in September and October at station 32 and persisted through the following fall. Recruitment was also observed in June of 1980.

3.2.3.8 Nephtys picta

During 1981, total production of the nephtyid polychaete, Nephtys picta, was 19 mg AFDW/m^2/y at station 31 and 31 at station 32. Turnover ratios were 1.13 at station 31 and 0.87 at station 32. One juvenile size class was observed in October 1981 at station 32. Evidence suggests that the newly recruited individuals appeared in the fall and overwintered.

3.2.3.9 Nephtys incisa

During 1981, total production of the nephtyid polychaete, Nephtys incisa, was 172 mg AFDW/m^2/y at station 31 and 1 at station 32. A turnover ratio of 2.23 was calculated for only station 31. Evidence is inconclusive for determining recruitment periods although results for this species are consistent with those for N. picta indicating a size class longevity of greater than one year with overlap of two size classes occurring through at least mid-summer.

3.2.3.10 Residual Polychaeta

Residual polychaetes are principally composed of the families Cirratulidae, Dorvilleidae, Glyceridae, Magelonidae, Nereidae, Opheliidae, Phyllodocidae, Spionidae, and Syllidae. Comparisons of polychaete families comprising the select and residual groups are summarized in Table 12 based on annual mean densities (# individuals/m^2) and annual mean biomass (g wet weight/m^2). Relative to the total mean polychaete biomass during 1980, the four select polychaete families accounted for a range of 53.6 to 84.1% at stations 29 and 31 with increased values observed for comparisons of these samples based on mean density. The ratio of select/total was lower for samples from station 32 in 1980 as well as stations 31 and 32 in 1981.

Composite turnover ratios of the residual polychaete group were calculated by eliminating the production and biomass contribution of Asabellides oculata from the select species group. The high production rate and turnover of this short lived species were considered inappropriate for comparisons with the small sized and longer lived individuals comprising the residual polychaete group. Turnover ratios calculated for residual polychaetes was 2.40 at station 29, for station 31 was 1.83 in 1980 and 2.15 in 1981, and for station 32 was 1.84 in 1980 and 1.62 in 1981. These turnover ratios were used in conjunction with the respective mean residual biomass to provide an estimate of residual polychaete production. Residual polychaete production was 475 mg AFDW/m^2/y at station 29; station 31 ranged from 1,509 in 1980 to 888 during 1981; and station 32 ranged from 455 in 1980 to 389 in 1981.

3.2.4 Miscellaneous Taxa

Miscellaneous taxa includes three groups: crustacea, echinodermata, and meiofauna. Indirect estimates of total crustacean production at station 29 was 1,025 mg AFDW/m^2/y. Similarly, crustacean production at station 31 was 1,631 during 1980 and 811 during 1981 and at station 32 was 796 during 1980 and 1,360 during 1981.

Indirect estimates of echinoderm production at station 31 was 3 during 1980 and 32 during 1981. Echinoderm production at station 32 was 470 during 1980 and 10 during 1981.

Indirect estimates of the meiofauna production (= macrofaunal size range of oligochaetes and archiannelids) at station 29 was 472 mg AFDW/m^2/y. At station 31, meiofaunal production was 462 during 1980 and 860 during 1981. At station 32, meiofaunal production was 870 during 1980 and 1,193 during 1981.

3.2.5 Total Annual Benthic Secondary Production

During 1980 at station 29, benthic macrofaunal production was 46,572 mg AFDW/m^2/y, which converts to an estimated 24,101 mg C/m^2/y and a community turnover ratio of 5.99 (Table 13). Three select mollusc species, E. directus, M. edulis and T. agilis, accounted for 39.7% of the observed total production with the remaining two observed molluscs, N. annulata and S. solidissima contributing insignificant production (<0.08%). One select polychaete species, A. oculata, accounted for 48.6% of the observed total production with the remaining three observed polychaete species, A. catherinae, A. caperatus, and M. ambiseta, accounting for less than 0.4% of the total. The remaining residual estimates were comprised predominately of molluscs (6.9%) and crustaceans (2.2%).

At station 31, benthic macrofaunal production was 30,124 mg AFDW/m^2/y (15,589 mg C/m^2/y) during 1980 and 7,501 mg AFDW/m^2/y (3,882 mg C/m^2/y) during 1981 (Table 14). Respective turnover ratios were 5.35 in 1980 and 4.30 in 1981. The select species, A. oculata and M. edulis, accounted for 67.4% of the total 1980 production estimate with 10 of the remaining 11 potential select species (excluding N. proxima) accounting for 18.0%. The remaining production was comprised predominately of the residual faunal groups of polychaetes (5.9%) and crustaceans (6.3%). Relative to 1980, total production in 1981 was decreased by 75% and major contributing fauna were limited to the select mollusc species, E. directus and T. agilis (combined contribution of 37.3%) and the residual mollusc group (16.5%) with the select polychaete species accounting for a minor component of 3.8%.

At station 32 during 1980, benthic macrofaunal production was 4,485 mg AFDW/m^2/y (2.321 mg C/m^2/y) and the turnover ratio was 2.32 (Table 15). Excluding N. annulata, all select species were observed in this year though the major producer was S. solidissima (accounting for 19.5%) with molluscan fauna (direct plus residual) accounting for 35% of the annual rate. Overall production persisted at a constant rate through 1981 with the turnover ratio increasing to 4.83. Spisula solidissima and residual molluscan fauna were again dominant producers in 1981, and for both years co-dominant constituent producers included the residual groups of crustaceans and meiofauna.

3.2.6 Total Monthly Production

Monthly production estimates were summarized for the major taxa as well as for overall total production at each station. Monthly estimates span the two year period for stations 31 and 32, though at station 29 estimates encompass the period March 1980 through September 1980. Production for polychaetes and molluscs represent a composite of both direct and residual estimates whereas the remaining taxa are based on residual estimates only.

At station 29 (Figure 4), total production (mg AFDW/m^2/y) during 1980 was 170 in March, reached a maximum of 43,526 in June and decreased to 2,204 in August and 670 in September. This maximum production in June was accounted for by polychaetes and molluscs, exclusively, with production levels of 22,993 and 19,378, respectively. Monthly crustacean production ranged from a maximum of 766 in June to a minimum of 45 in September. Echinoderms were absent throughout the year and meiofauna production was 389 in June decreasing to 19 in September.

Total production (mg AFDW/m^2/y) at station 31 showed seasonal and annual differences (Figure 5). During 1980, total production was 2,325 in March 1980, increased to a maximum of 14,004 in June 1980, and decreased slightly to 10,596 in July 1980. Production levels dropped to 600 in December 1980, and persisted at this level through June 1981. Production increased to a maximum of 2,234 in September 1981, decreased to 1,002 in October 1981, and increased to 1,601 in November 1981. Peak production were observed in June 1980 by polychaetes and molluscs with respective maxima of 4,278 and 9,226, although the polychaetes decreased to a minimum level of 124 by August 1980, whereas the mollusc minimum of 217 was observed in December 1980. During 1981 polychaete production persisted at low levels within the range of 105 to 271, while molluscan production was comparably low through June 1981 and increased to a maximum of 1,613 in September, 1981. Crustacean production was maximum in March 1980 at a level of 516 and decreased to a minimum range of 11 to 204 throughout the remaining study period. Meiofauna followed a similar trend with a March 1980 maximum of 767. Indirect estimates of echinoderm production were determined in July 1980 and September 1981 at 3 and 14 mg AFDW/m^2/y, respectively.

Total production (mg AFDW/m^2/yr) at station 32 showed seasonal and annual consistency (Figure 6). During 1980, total production was initially 152 in March, increased to a maximum of 1,050 in July with a slight decrease to 1,037 in December. During 1981, production decreased to 557 in April, increased to a maximum of 1,254 in July, and decreased to a minimum of 414 in November. Individual taxa followed sporadic oscillations in monthly production, with no consistent seasonal or annual pattern. Mollusc production increased from 71 in March 1980 to a maximum of 580 in September 1980. The 1981 trend was reversed with a maximum of 427 observed in April decreasing to 28 in November. Maximum levels of polychaete production were observed in June 1980 (352), December 1980 (182), and September 1981 (211) with remaining periods ranging from 17 to 106. Crustacean production was maximum in July 1980 (311) and again in September 1980 (191) as well as during the period

June 1981 through October 1981 with a range of 227 to 364. A single peak in echinoderm production of 439 was measured in July 1980 with remaining periods ranging from less than 1 to 17. Maximum meiofauna production was observed during the period August 1980 to December 1980 with a range of 166 to 341. During 1981, meiofauna production was maximum in July (459), decreased to a range of 155 - 180 in September and October, and increased to 296 in November.

4. DISCUSSION

Present methodology for secondary production assessment was developed for integration into an existing scheme for analysis of macrofaunal community structure. The accuracy of production and turnover estimates relative to actual field values are limited by methodological parameters of sampling periodicity, sample sieving, and sample preservation, though a correction factor was incorporated for the latter. In the present study, conventional methodology was followed for the procurement and processing of benthic samples allowing for the application of production and turnover results to other benthic studies of macrofaunal community structure.

The sampling frequency of six times per year was an increase over the often used seasonal approach for the analysis of benthic community structure (Bloom et al, 1972; Boesch, 1973; Peterson 1975; Stephenson et al, 1976; Cederwall, 1977; Maurer, 1977; Maurer et al, 1981). Occasional time lags of up to three months between samplings often precluded definitive assessment of growth and mortality in single size classes. Production assessments of groups with rapid turnover such as crustaceans and meiofauna require an increased sampling frequency over that used in the present study for accurate direct estimates.

The decalcification of molluscs using dilute HCl probably underestimates actual macrofaunal production. Relative to the total organic content (tissue plus shell) the proportion of shell organics alone have ranged from 1.3% in Mytilus (recalculated from Hughes, 1970) to 26.4% in Modiolus (recalculated from Kuenzler, 1961). Recalculations of the comparisons of Thayer et al. (1973) for six bivalve species treated with a dilute HCl rinse indicate a range of 0.96% shell organics in Modiolus to 13.16% in Tagelus.

Production estimates were limited to the fauna retained on a 0.5 mm. sieve. Based on the inverse relationship between individual biomass and turnover (Robertson, 1979; Banse and Mosher, 1980), elimination of this smaller size fraction underestimates total community production and turnover. The present results summarize only the growth component of an energy budget for benthic macrofauna. This includes predominately somatic growth though gametes stored within the individual will contribute to the total individual weight and are incorporated into our estimates.

4.1 Seasonal Variability of Benthic Macrofauna

Benthic communities associated with the fine sediments of stations 29 and 31 were characterized by similar species compositions during 1980, with polychaete and mollusc fauna comprising most of the total observed biomass and secondary production. Consistent patterns of seasonal flux were observed for total wet weight biomass (Table 4) and monthly secondary production (Figures 4 and 5) where values generally increased from the early spring, reached a maximum in June and decreased to minimal levels by August. Maximum densities for the dominant polychaete, A. oculata, and molluscs, T. agilis and M. edulis, (Figures 2 and 3) coincided with the June secondary production maxima at Station 29 though they occurred in March at station 31. Recruitment of pelagic larvae from coastal waters with subsequent entrainment into the estuarine system might account for this delay.

A secondary density maximum was observed in September which was attributed to the recruitment of juveniles for the species, A. oculata at station 29 and N. annulata at station 31. The corresponding secondary production for these species remained low. A secondary production maxima was observed at station 31 during this period, resulting from an anomalous sample containing high densities of adult Mytilus edulis.

During 1981 at station 31, trends in seasonal flux of monthly secondary production, biomass, and density were different from fluxes observed in 1980. Recruitment of juvenile size classes during the spring were observed for the polychaete species, N. incisa and A. catherinae, though densities were low relative to 1980 observations. Total biomass and secondary production maxima for polychaete species were observed in September, comprised principally of M. ambiseta. Seasonal trends in 1981 for mollusc species indicated maxima in biomass and production during both July and September. Our observations suggest that recruitment in the species T. agilis and M. edulis probably preceded the April sampling period. A secondary recruitment period in September was observed for only T. agilis.

The benthic fauna supported by the coarse sediments at station 32 exhibited consistently lower monthly values of secondary production, biomass, and density relative to the fauna at stations 29 and 31. Density maximum were observed in March 1980 for molluscan and polychaete fauna. A secondary recruitment period was observed in September 1980 for the polychaete species A. arctica and A. catherinae. Secondary production maxima occurred in June for polychaete fauna and in September for molluscan fauna.

Station 32 was further characterized by an annual consistency in seasonal trends for 1980 and 1981 observations. For dominant select polychaete species, recruitment was observed during the late winter (December 1980) as well as the spring (April 1981), and polychaete production was again maximum in the early summer. Two maxima for total mollusc production in 1981 coincided with the spring recruitment period (April) as well as the maximum monthly production rate of the species S. solidissima (July).

4.2 Annual Variability in Benthic Macrofauna

4.2.1. Fine Sand Substrates

For a given year, higher secondary production rates were observed for macrofauna associated with mud sediments compared to coarse sediments. Production rates measured as mg AFDW/m^2/y were highest in

Delaware Bay at station 29, relative to the other sites, for total community rates (46,572) as well as for the dominant taxa (residual and direct) of molluscs (46.7% of total) and polychaetes (50% of total).

In 1980, total secondary production of benthic macrofauna at station 31 was approximately two-thirds the rate observed at station 29 for the same year. Dominant taxa were again molluscs and polychaetes accounting for 63.8% and 29.3%, respectively of the total rates (30,124 mg AFDW/m^2/y).

At station 31, total secondary production of benthic macrofauna exhibited marked annual variability. The total production rate during 1981 of 7,501 mg AFDW/m^2/y represented approximately four-fold decrease relative to 1980. Total polychaete production decreased from 8,821 in 1980 to 1173 mg AFDW/m^2/y in 1981, an eight-fold decrease attributed to the absence of Asabellides oculata during 1981. Similarly, the absence of a single mollusc species, Mytilus edulis in 1981, resulted in a four-fold decrease in total annual mollusc production from 19,206 mg AFDW/m^2/y to 4,625.

The polychaete and mollusc fauna may be categorized into infaunal and epifaunal components based on the criteria of 1) availability to predators, 2) contribution to substrate surface area, and 3) feeding mode. In this context, Mytilus and Asabellides comprised the epifaunal component though, admittedly the tubes of Asabellides are both infaunal and epifaunal. Production of infaunal polychaetes (eliminating A. oculata production) at station 29 in 1980 was 208 mg AFDW/m^2/y (Table 9) whereas infaunal bivalve production (eliminating M. edulis) was 16,361 mg AFDW/m^2/y (Table 5). Consideration of the 1980 and 1981 production rates for the infaunal polychaetes at station 31 (eliminating A. oculata production) yields 1,893 and 1,141 mg AFDW/m^2/y, respectively (Table 10) whereas a similar comparison of infaunal bivalve production (eliminating M. edulis production) yields 5,822 and 4,548 mg AFDW/m^2/y, respectively (Table 6).

Secondary production of mollusc and polychaete infauna were generally consistent at station 31 through both years. Secondary production of the infaunal molluscs in Delaware Bay was higher than similar fauna in coastal waters during 1980. A similar trend was evident when comparing each of the two dominant epifaunal species at both sites in 1980.

Estuarine secondary production estimates (Table 16) observed in Long Island Sound (Sanders, 1956; Richards and Riley, 1967) as well as for Zostera beds communities in estuarine waters of eastern Canada (Burke and Mann, 1974) are approximately half that of station 29 and equal to the range of station 31. Secondary production estimates of benthic macrofauna have been observed at levels greater than that observed in Delaware Bay for the Ythan Estuary (Baird and Milne, 1981) and the Grevelingen Estuary (Wolff, 1977).

Annual turnover ratios were consistent for communities of soft sediments comparing station 31 during 1980 with 1981, as well as comparing station 29 with station 31 during 1980. Total annual community turnover ranged from 4.30 to 5.99 for two stations over the study period.

Estimates of annual turnover ratios for infaunal polychaetes were 2.40 at station 29 (Table 9), and a range of 1.83 (1980) to 2.15 (1981) at station 31 (Table 2). Turnover ratios of infaunal molluscs ranged from 4.22 (station 29) to 5.11 (station 31) and were similar to values calculated for the total molluscan group. Turnover ratios were annually consistent for infaunal molluscs and polychaetes.

These community turnover ratios are greater than values reported in comparable studies. Using data of Sanders (1956), Richards and Riley (1967) report a ratio of 2.58 for benthic epifauna of Long Island Sound though that study excluded large individuals of a species resulting in an overestimate of turnover. In silt sediments, turnover ratios of less than 1.0 have been reported for a subtidal Venus community (Warwick et al., 1978), and a deep water community (Buchanan and Warwick, 1974; Buchanan, Kingston, and Shearer, 1974). Community turnover rates comparable to those of the present study were reported for only single species estimates such as dominant Macoma population in silt sediments of the Baltic Sea (Ankar, 1980).

4.2.2. Coarse Sand Substrates

Total secondary production of benthic macrofauna at station 32 exhibited annual consistency with values ranging from 4,486 mg AFDW/m^2/y in 1980 to 4,492 in 1981. Total polychaete production decreased slightly from 779 mg AFDW/m^2/y to 544 again principally due to the absence of A. oculata. Total mollusc production decreased slightly from 1,571 mg AFDW/m^2/y in 1980 to 1,384 in 1981 with a decrease in the dominant producers, S. solidissima and T. agilis, being balanced by a concurrent increase in the production of the residual mollusc species. With the exception of protruding mollusc siphons, most of the bivalve and polychaete production in the coarse sediments of station 32 were contributed by infaunal species. Again crustaceans and meiofauna are significant producers at this station. Total levels of infaunal production at station 32 were similar to the estimates of infaunal production at station 31, though as mentioned, there are important differences with regard to constituent fauna and respective temporal fluxes. Turnover ratios in these sediments are 2.32 in 1980 and 4.83 in 1981.

In contrast to the soft bottom communities, the benthic macrofauna of the coarse sediments at station 32 exhibited total secondary production rates that were low, relative to the other stations, and consistent both seasonally and annually. During 1980, the total production (approximately 4.5 gm/m^2/y) was approximately one-tenth the level observed at station 29 and one-seventh the level of station 31 for that year. The similar total production estimated for 1981 was approximately two-thirds the level observed at station 31 for this year. A general similarity in production was observed in 1980 and 1981 for polychaetes (17.4% and 12% of the total production, respectively), molluscs (35% and 30.8%), crustaceans (17.7% and 30.3%) and meiofauna (19.4% and 26.6%) (Table 15). Results of coastal shelf production at this station are difficult to compare with other studies (Warwick et al., 1978; Evans, 1983) where sediments of the latter were similar but the physical environments were appreciately less energetic (Table 16).

Direct production estimates indicate qualitative difference in macrofauna between the coarse versus fine sediments. Mean densities of select mollusc species at station 32 represent a 5 fold decrease compared to station 31 for 1980 and a 10-fold decrease for 1981 with similar decreases observed in comparative biomass (Table 8). This contrasts with densities of select polychaete species where mean values at station 32 were half those of station 31 in 1980 and greater than those of station 31 in 1981 (Table 12). The decrease in production at station 32 was therefore due to fewer comparably sized molluscs and equally abundant but smaller polychaetes relative to station 31. In comparison, production levels of residual polychaetes, molluscs, crustaceans, and meiofauna were generally similar at both stations though relative to total production, crustaceans and meiofauna were proportionately larger at station 32.

4.3 Sediment Influences on Production and Turnover

For select species, consistent increases in production and turnover in a specific sediment type such as fine sand/silt or coarse sand may correlate with increased adaptive success and more favorable living conditions. For example, the total production of *M. ambiseta* was higher in fine sediments compared to coarse sand, though turnover ratios were fairly constant at all stations ranging from 1.07 (station 31, 1980) to 3.14 (station 31, 1981) with only indirect measurements made at station 32. In an earlier study in Delaware Bay (Maurer et al., 1979b) greatest densities of this species were observed in coarse sediments. The above turnover range compares favorably to the turnover ratio of 1.94 reported for a related capitellid polychaete, *Heteromastus filiformis* in mud sediments (Buchanan and Warwick, 1974). Similarly, a higher turnover ratio was observed for *Mytilus edulis* in fine sediments relative to coarse sediments. Total production was also much higher in the soft sediments probably indicating the poor adaptations of this epifaunal suspension feeder to the physical harshness of station 32.

The already described increased turnover and production of *A. oculata* at station 31 probably also partially reflects the favorable conditions for surface deposit feeding. The turnover ratios calculated for *Ampharete arctica* at station 32 ranged from 3.16 (1980) to 2.87 (1981) and were slightly lower than those estimated for a related species, *Ampharete acutifrons* (Sanders, 1956; Warwick and Price, 1975). The ampharetid polychaetes of the present study were also observed in maximum densities in fine sand sediments in the NY Bight apex, though only *A. oculata* was associated with organic-rich sediments (Caracciolo and Steimle, 1983).

Increased turnover and production were observed for *Nephtys incisa* in fine sediments (P:B = 2.23) compared to *Nephtys picta* in coarse sediments (P:B = 0.87). For the temperate region from Georges Bank to Cape Hatteras, Kinner (1978) observed a dominance of *N. incisa* in silt-clay sediments of the mid-outer shelf as compared to the dominance of *N. picta* on inner shelf sand sediments. For species of nephtyid polychaetes in subtidal fine sediments, similar turnover ratios have been reported ranging from 1.9 (Warwick and Price, 1975; Warwick, George and Davies, 1978) to 2.16 (Sanders, 1956) and 2.48 (Carey, 1962).

Nucula proxima and Nucula annulata exhibit preferences and adaptations for habitat sediment types of coarse sand and fine sand/silt clay, respectively (Hampson, 1971; Howe, 1981). Comparably high turnover ratios were observed in 1981 for Nucula proxima at station 32 (P:B = 4.90) and for Nucula annulata at station 31 (P:B = 6.17). These values are higher than those calculated for Nucula annulata in Long Island Sound (Carey, 1962), as well as for related Nucula species in coastal waters of Japan (Mukai, 1974) and in the German Bight (Rachor, 1975). Species of Nucula and Tellina observed in fine sand sediments exhibit higher secondary production compared with relative to coarse sediments. Tellina agilis was considered a dominant species in the sediments at the mouth of Delaware Bay, a transition between sand and mud (Kinner et al., 1974) and the clean sand sediments of coastal Delaware (Maurer et al., 1979a).

The infaunal suspension feeder, Spisula solidissima, was better adapted for coarse sediments of station 32 as reflected by the increased rates of both turnover and production observed at this station relative to station 31. Abundances of this species are strongly correlated with coarse sediments (Parker and Fahlen, 1968). At this station, no consistent trends were observed for paraonid polychaetes with respect to turnover, though increased production was observed in coarser sediments. Turnover ratios for A. catherinae at station 31 ranged from 1.39 to 1.55, similar to the turnover observed for Paraonis gracilis (P:B = 1.49) in a mud sediment (Buchanan, Kingston, and Sheader, 1974). Turnover for Paradoneis lyra and Aricidea cerrutii ranged from 0.72 to 1.72 at station 32.

4.4 Life History Strategies and Community Energetics

High seasonal fluxes of productivity and biomass are related to rapid turnover rates for dominant taxa having short life spans. The highest estimated turnover ratios for polychaetes were observed in the mud sediments of station 29 (P:B = 11.83) (Table 9) and station 31 (P:B = 9.44) (Table 10) during 1980 and are attributed to the successful recruitment and growth of Asabellides oculata. Individual cohorts of this species were relatively short-lived, present for less than 6 months, and were dominant producers with both factors resulting in high species turnover ratios in 1980. For similar reasons, a turnover ratio of 14.11 was observed for Ensis directus at station 31 in 1980 (Table 6). Consistently high turnover ratios (greater than 5.0) were also observed for Mytilus edulis in fine sand substrates and for Spisula solidissima in coarse substrates.

The range in turnover ratios and production of invertebrate communities are influenced by life history strategies of recruitment periods, number of cohorts, and longevity, as well as other ecological factors (Waters, 1979). Sander's (1956) suggested that a turnover ratio of 5.0 would be expected for short lived species or those having more than one generation per year whereas a P:B of 2.0 would be expected for long-lived species or those living longer than one year. For select species in regions of Delaware Bay and coastal Delaware, turnover ratios of long-lived species were generally consistent with that observed by Sanders though turnover ratios of short-lived species are far more variable, ranging from approximately 3 to 14.

When direct measurements of turnover are made for several co-occurring size classes of a given species there is an inverse relationship between turnover ratio and age of the cohort (Robertson, 1979). This trend was observed for *Nucula annulata* (Station 31, 1980), *Spisula solidissima* (Station 32, 1981), *Tellina agilis* (all stations, both years), *Mediomastus ambiseta* (Station 31, 1980), and *Amastigos caperatus* (Station 31, 1981).

4.5 Community Stability

The stability of communities has been inferred using indices with the generally most common concept implying a constancy of numbers through time. Community stability has been related to a number of pathways for energy flow (MacArthur, 1955), the predictability of environmental fluctuations (Slobodkin and Sanders, 1969), species diversity and structural complexity (Margalef, 1963; Leigh, 1965), and species composition (Lie and Evans, 1973). These relationships often hold only under specific conditions (McNaughton, 1968), and are often questioned as to their universal validity (Hairston et al., 1968; Slobodkin and Sanders, 1969; Hurd et al., 1971). Smedes and Hurd (1981) concluded that any relationship between stability and community parameters are far from being paradigm and are related to biological and physical properties, type and amount of perturbation, and both the criteria and measurements employed.

In the present study, community instability is suggested by the seasonal fluxes and annual differences observed in production and turnover for macrofauna associated with silt/sand sediments. These annual differences are due to the relative success of recruitment and growth of the "epifaunal" species *M. edulis* and *A. oculata*. Connell and Orias (1964) suggest that sessile epifaunal species such as *M. edulis*, require less energy for regulatory activities, resulting in increased energy available for production. The epifauna serves to dampen the turbulence of the medium resulting in decreased physical disturbance and the deposition of particulate organics. This leads to increases in habit complexity, species diversity, and ultimately to community stability. At station 31, the dense worm tubes of *A. oculata* were observed to entrap a fine flocculent layer and this phenomenon was also observed for a related species, *Melinna cristata* off northeastern England (Hutchings, 1973).

Based on macrofauna densities at station 31 during July 1980, December 1980, and July 1981, species diversity, richness, and evenness decreased through time with maximum values coinciding with the appearance of the dominant "epifaunal" species (Leathem and Howe, 1982). Diversity of change values ($\Delta H'$) suggested that actual species composition were most unique during July 1980, relative to the other two months.

Levinton (1972) suggests that high productivity and low stability are characteristic of suspension feeders due to: the uncertainty of food, increased exposure to the physical environment and decreased competitive interactions. In the present study, high secondary production and turnover rates were observed for suspension feeders as well as for surface tentaculate deposit feeders. However, only the epifaunal species follow the predicted r-selection strategy. The stability and diversity increase predicted by Connell and Orias (1964) was of a short duration at station 31. In contrast, the infaunal species exhibited consistent annual secondary production and turnover ratios. Generally, lowest production and turnover estimates were associated with deposit-feeders where "K" selective strategy is observed, food resources are more predictable, and competitive interactions increase (Levinton, 1972).

The assessment of annual species dominance based on production provides valuable insight into community energetics that are not apparent when using criteria of density or biomass. In 1980, A. oculata accounted for 56.2% of the total production (Table 17) at station 29 with this species and M. edulis accounting for 26.9% and 52% of the total production at station 31 (Table 18) in the same year. Based on mean density, the dominant species, M. ambiseta contributed only 0.5% and 0.2%, respectively of the total production at each of the two stations. Similarly, at station 32, Spisula solidissima was the dominant producer accounting for 34.3% (1980) and 42.4% (1981) of the total direct production estimate (Table 19). In terms of species densities, Paradoneis lyra was dominant for both years though accounted for only 0.1% and 1.6% respectively of the total direct production estimate.

At station 29 and 31 in 1980, few species accounted for most of the observed secondary production; dominance of production was high. In terms of community structure (based on densities), concurrent high values were also observed for species diversity, richness, and evenness (Leathem and Howe, 1982). Dominant producers were epifaunal, contributed to community instability and influenced community structure out of proportion to their numerical densities. These keystone species (Herricks and Cairns, 1982) may be most valuable in processes of trophic level transfer as well as conveniently defining general parameters of community structure.

For macrofaunal communities associated with fine sand sediment, species accounting for much of the measured production (diversity of production) was initially low in 1980 and increased through time while total production decreased. This relationship is consistent with that predicted by ecological theory for primary productivity (Margalef, 1963). In soft sediments, production was maximum when accounted for by relatively few epifaunal species.

High densities of epifaunal suspension feeders may effect subsequent recruitment success through processes of trophic group amensalism by feeding on recruiting pelagic larvae (Woodin, 1974). The selective deposit feeder, A. oculata, feeds on the sediment surface using retractable ciliated tentacles (Fauchald and Jumars, 1979). This species as well as the suspension feeder, M. edulis, potentially feeds on newly settled larvae. Both species may further limit recruitment success by limiting space for larvae to settle as well as altering the sediment characteristics (Rhoads and Young, 1970).

The decline in the epifaunal species observed in 1981 may be due to either a self-limiting result of trophic amensalism or predation. Other studies have reported plaice predation on Tellina siphons (Trevallion, 1971); flounder predation on Mytilus (Kautsky, 1981; Kautsky, 1982) and on the polychaetes Ampharete acutifrons (Richards and Riley, 1967) and Heteromastus filiformis (DeVlas, 1981); and haddock predation on the polychaetes Aricidea catherinae (Wigley, 1956) and Nephtys incisa (Wigley and Theroux, 1965).

In the coarser sediments of station 32 annual consistency was observed for both community structure and dynamics. Epifaunal producers include predominantly the crustaceans with a small contribution from the echinoderm E. parma. The appearance of A. oculata and M. edulis was short-lived in 1980, contributing little to the overall production relative to levels observed at stations 29 and 31 and their resulting influence on community structure was probably minor. During the three monitoring months, faunal densities, species diversity and evenness were statistically similar in December 1980 and July 1981, though both months were slightly higher than respective community indices in July 1980. No statistically significant differences in species richness were observed between the monitoring months at this station (Leathem and Howe, 1982).

Annual production levels and turnover rates at station 32 were also consistent implying increased community stability relative to the other sites. Annual turnover rates for select species were lower (P:B $\leq$ 7). Evenness of production and possibly diversity of production were consistantly high through both years. Ecological theory would therefore, predict low and constant production rates at this station. Relative to station 31 this low production level is principally accounted for by a decrease in individual size for the polychaetes with mean densities remaining similar, whereas, a decrease in density is observed for the molluscs.

Going from Delaware Bay (station 29) to increasing distances southward (station 31, then station 32) probably represents a gradient of increasing physical control and decreasing biological control on respective benthic communities. Station 32 may be regarded as a high energy area typically characterized by coarse sand sediments. Sedentary epifaunal species have limited success or are totally absent and the remaining infaunal species are controlled primarily by the physical factors. Station 31 represents an environment of decreased physical influence and is a highly depositional area for well sorted fine sand (Kraft et al., 1976). Benthic communities are probably controlled by a combination of biological and physical factors as is evident by the occasional recruitment and subsequent rapid production of epifaunal species. The benthic community of station 29 is probably least influenced by physical processes and although highest production of infauna and epifauna are observed here, assessment of long-term consistency is not possible.

4.6 Trophic Level Transfer

Epibenthic species such as Mytilus edulis and Asabellides oculata are probably most valuable as a potential food resource to finfish predators due to their accessability and high productivity. These species promote community instability and influence the diversity of co-occurring prey species. Infaunal suspension feeders may be more consistently available as a food resource, though production levels are minor relative to the epifaunal species.

The epibenthic species dominated only in 1980 and exhibited synchronous production maxima in the mid-late spring. Using 1981 data for Delaware Bay, the primary productivity maximum in the area of station 29 coincided with the peak in secondary production and was composed predominately of Skeletonema (Pennock et al., 1983). A similar synchrony has been observed by Ankar (1980) in the Baltic Sea.

Data are inconclusive to relate the observed differences in secondary production at the three stations to differences in regional primary productivity. Primary productivity of Delaware coastal waters were estimated as generally ranging from 700 g $C/m^2/y$ in 1980 to 900 g $C/m^2/y$ in 1981 based on ten measurements (O'Reilly - NMFS, NEMP data). This compares with a lower mean estimate of 190 gm $C/m^2/y$ estimated for Delaware Bay in 1981 (Pennock et al., 1983). Primary productivity alone cannot account for the maximum secondary production of epibenthic species observed at station 29 nor for the absence of these species in 1981.

Secondary production estimates for benthic macrofauna were approximately 2.4 g $C/m^2/y$ in coarse sediments and ranged from 3.8 to 24.1 g $C/m^2/y$ in fine sediments. Insufficient knowledge of zooplankton production and predatory-prey interactions within the macrofauna preclude estimates of trophic level transfer.

5. SYNTHESIS - BENTHIC COMMUNITY STRUCTURE AND FUNCTION

5.1 Fauna Associated with Fine Sediments

Stations 29 and 31 are characterized by sediments of very fine sand and silt-clay. The shoaling region of station 31 is geologically more dynamic than the Delaware Bay station with ebb tidal currents of Delaware Bay facilitating the transport and deposition of well sorted fine sand particles.

For both stations, dominant secondary producers during 1980 include *Asabellides oculata*, *Tellina agilis*, *Ensis directus* and *Mytilus edulis*. Total annual production ranged from 30.1 g AFDW/m^2/y at station 31 to 44.5 g AFDW/m^2/y at station 29. Total annual secondary production rates in 1980 for stations 29 and 31 were greater than rates estimated for Long Island Sound (however different methods were used). Monthly production rates were highest in the late spring and early summer following the peak recruitment periods of polychaetes and molluscs. At station 31 the production maxima (June and July, 1980) corresponded with highest values of species diversity and species evenness relative to December 1980 and July 1981. Additional fauna observed in high densities exclusively in this month include the amphipods, *Unciola irrorata* and *Pseudunciola obliquua*, and the polychaetes, *Paradoneis lyra*, *Ampharete arctica*, and *Parapionosyllis* spp. Identical or closely related species were observed in high densities in an earlier study of this site (Maurer et al., 1974) constituting a functionally similar community, though it is not possible to confirm the consistency in taxonomic identifications between the present and historical studies.

During 1981 at station 31, total annual production decreased (7.5 g AFDW/m^2/y), and monthly production fluctuations were dampened relative to 1980. Both species diversity and species evenness were minimal in July 1981 at this station relative to the other two monitoring months. Based on diversity of change estimates ($\Delta H'$), species composition in July 1980 was most different relative to that in December 1980 or July 1981 with species diversity consistently decreasing through the monitoring months. In July 1981, based on species densities, dominant species included the polychaetes, *Mediomastus ambiseta*, *Nephtys incisa*, *Caulleriella* spp., and *Ophiodromous obscura* and the bivalves, *Tellina agilis*, *Ensis directus*, and *Nucula annulata*.

The highest estimates of secondary production as well as species diversity correlated with the successful colonization of two species *Asabellides oculata* and *Mytilus edulis*. The sessile and epifaunal surfaces provided by both the worm tubes, blue mussel, and byssal thread mats serve to dampen out physical turbulence promoting greater stability and providing additional protected substrate for the colonization of other epifaunal species. During 1980, these two species accounted for 53% and 67.5%, respectively, of the total annual production estimated for stations 29 and 31. Dominance based on species production was therefore highest when dominance based on species densities was low. Seasonal and annual fluxes of secondary production and species composition indicate strong correlations with the presence or absence of these two species.

Present results suggest no consistent trends based on feeding modes though high annual consistency in production and turnover is observed for species with an infaunal rather than epifaunal living mode. However, epifaunal species are probably the most important in terms of trophic level transfer based on their increased level of production as well as accessibility. It is unknown whether the absence of these epifaunal species in 1981 was due to predation rather than other processes of biological and physical control.

5.2 Fauna Associated with Coarse Sediments

Station 32 was characterized by sediments of medium and coarse sand. Physical influences are far more rigorous at this station compared to those of stations 29 and 31. The most notable differences in faunal characteristics relative to those observed in fine sediments occurred in the mollusca and polychaeta. Mollusc densities decreased along with a proportional decrease in mollusc biomass. Polychaete densities were generally similar in both sediment types though corresponding biomass was greatly reduced. Total annual production rates are reduced and consistent for both years (4.5 g AFDW/m^2/y). Total monthly production levels were consistent throughout the year, though production peaks were asynchronous with each taxon alternating as dominant producers through any given season.

At station 32, there was a consistent annual pattern in community structure and energetics. With the exception of the successful recruitment of A. oculata in the spring of 1980, the dominant producers were polychaetes of the families Paraonidae and Nephtyidae and two bivalves, Tellina agilis and Spisula solidissima. This fauna, as well as the crustaceans, Protohaustorius wigleyi, Pseudunciola obliquua, and Tanaissus lilljeborgi, were numerically dominant based on Fager's Rank (Leathem and Howe, 1982) and characterized this site in a former study (Maurer et al., 1974).

The consistency in total annual secondary production rates correlates well with a consistency in values of species diversity and evenness calculated in July 1980 and 1981. In December 1980, however, species evenness and diversity were maximum relative to the other two monitoring months. The dominant producer, Spisula solidissima accounted for less than 20% of the total production in 1980 and less than 10% in 1981. No obvious trend was observed relating the presence of this infaunal bivalve to changes in community structure as was observed for the dominant epifaunal producers associated with the fine sediments.

The fauna in these coarse sediments exhibit a consistency in turnover as well as production. This seasonal consistency may be significant in providing a potential food source available to higher trophic levels available year round. Epifaunal prey resources include amphipod and isopod crustaceans, mollusc siphons, and occasionally tube dwelling polychaetes.

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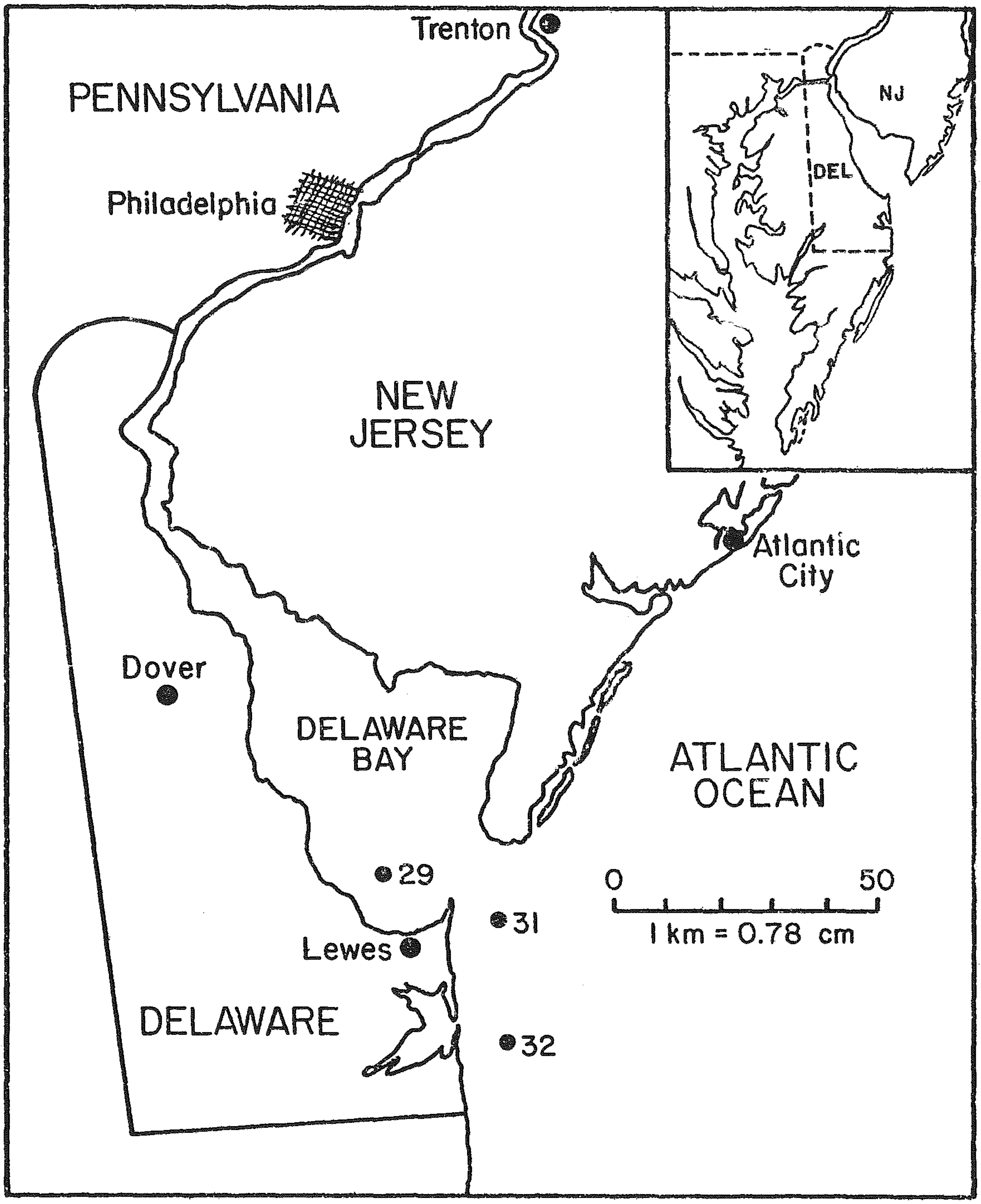

Figure 1. Station Locations

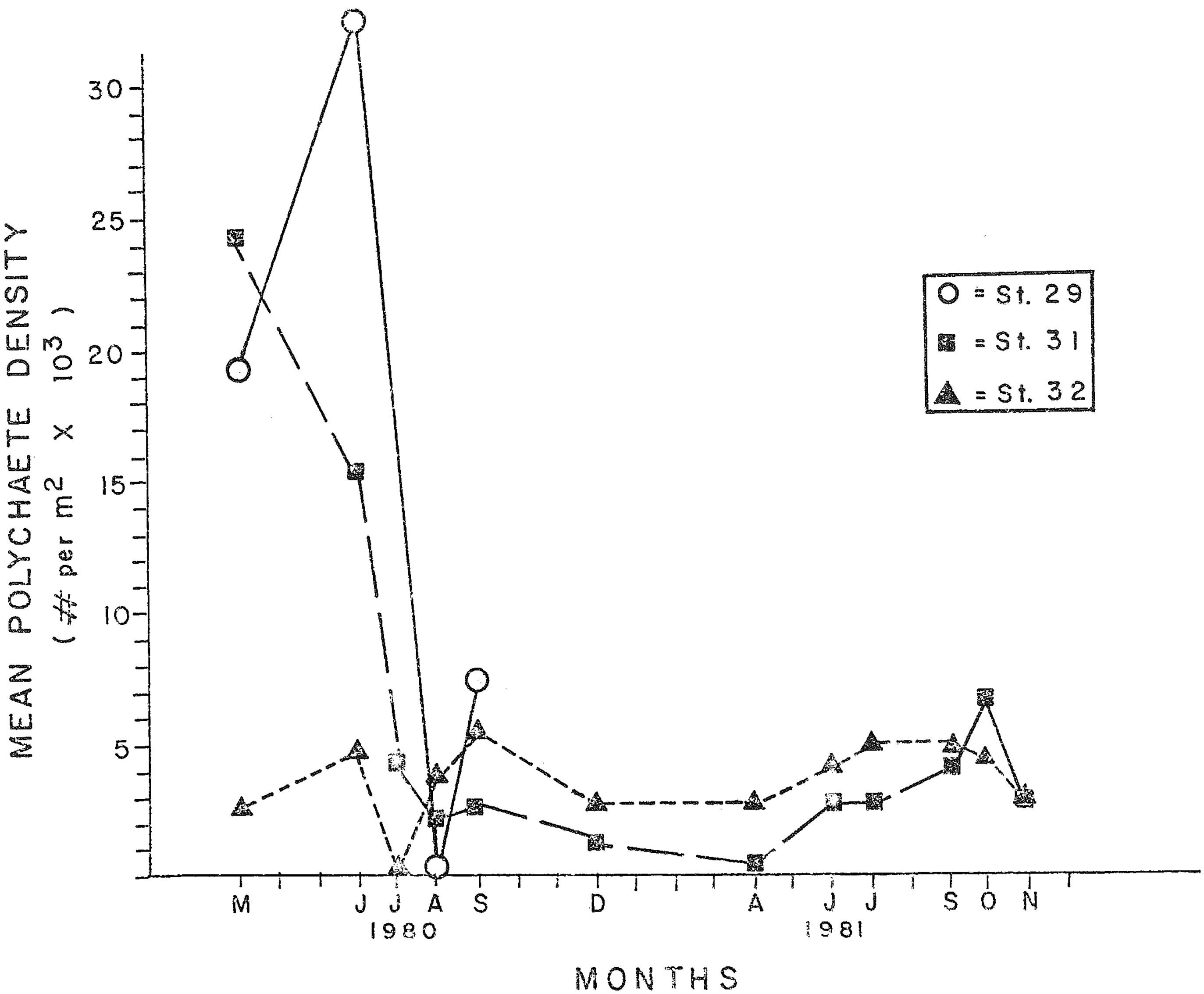

Figure 2. Monthly Mean Densities for Polychaeta (N/M^2)

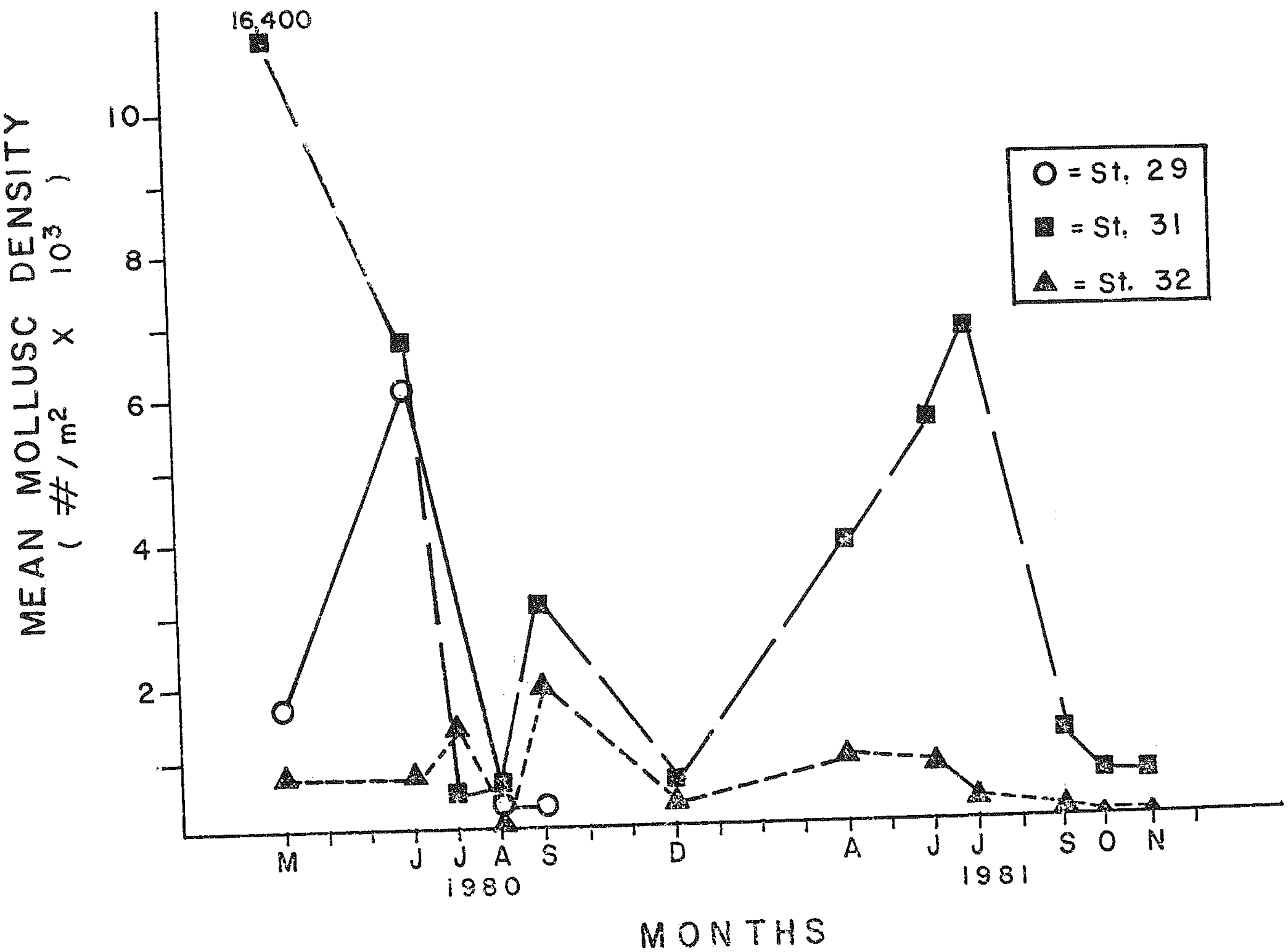

Figure 3. Monthly Mean Densities for Mollusca (N/M^2)

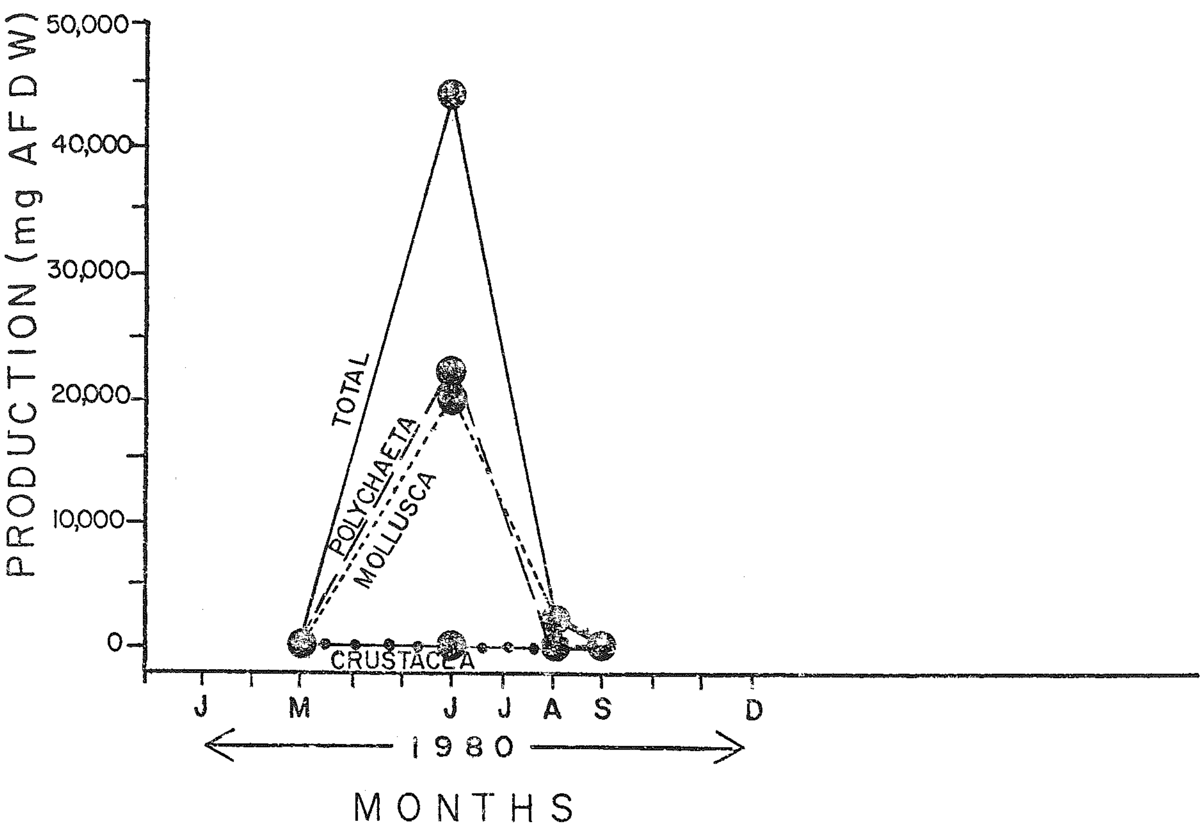

Figure 4. Monthly Production Rates for Station 29 (Delaware Bay)

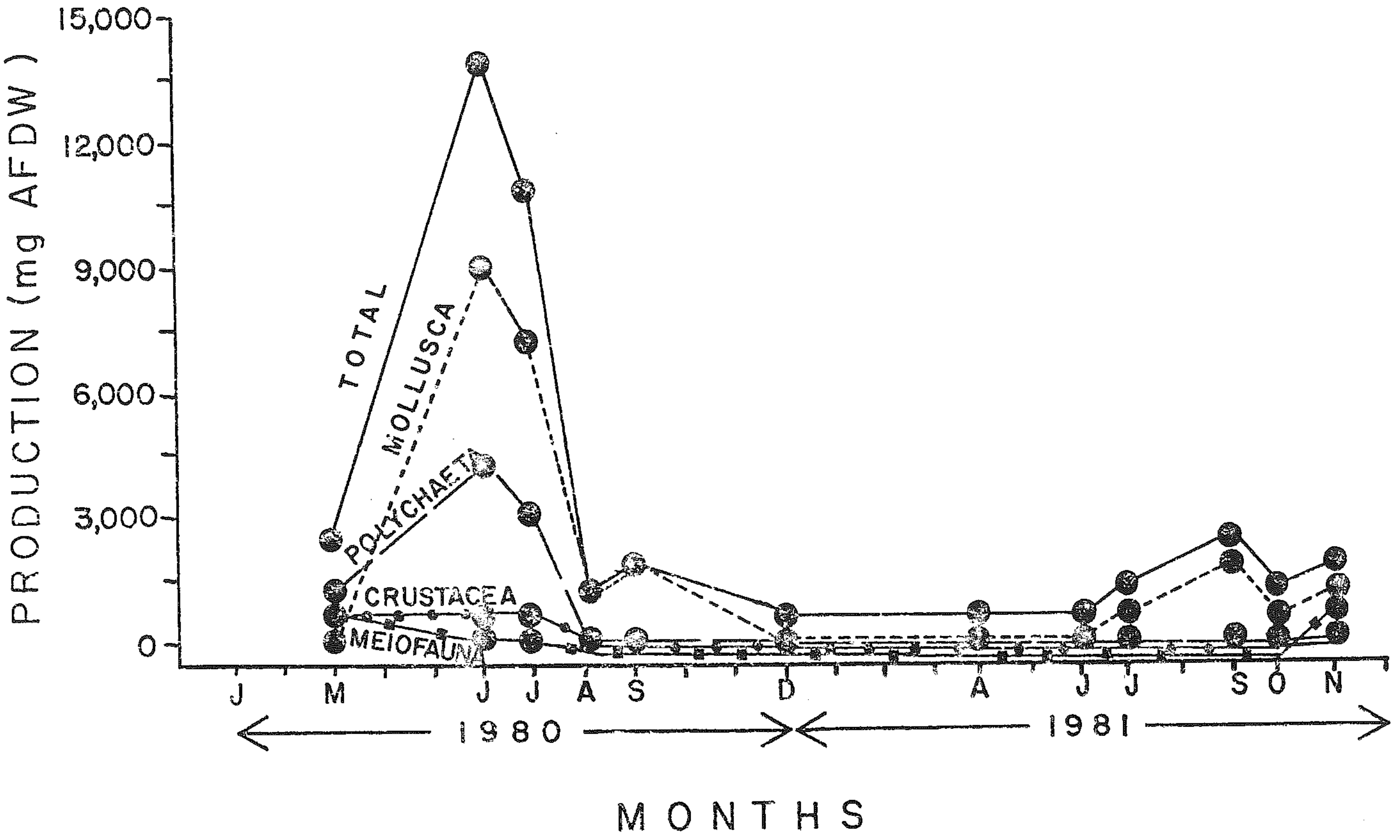

Figure 5. Monthly Production Rates for Station 31 (Hen and Chicken Shoals)

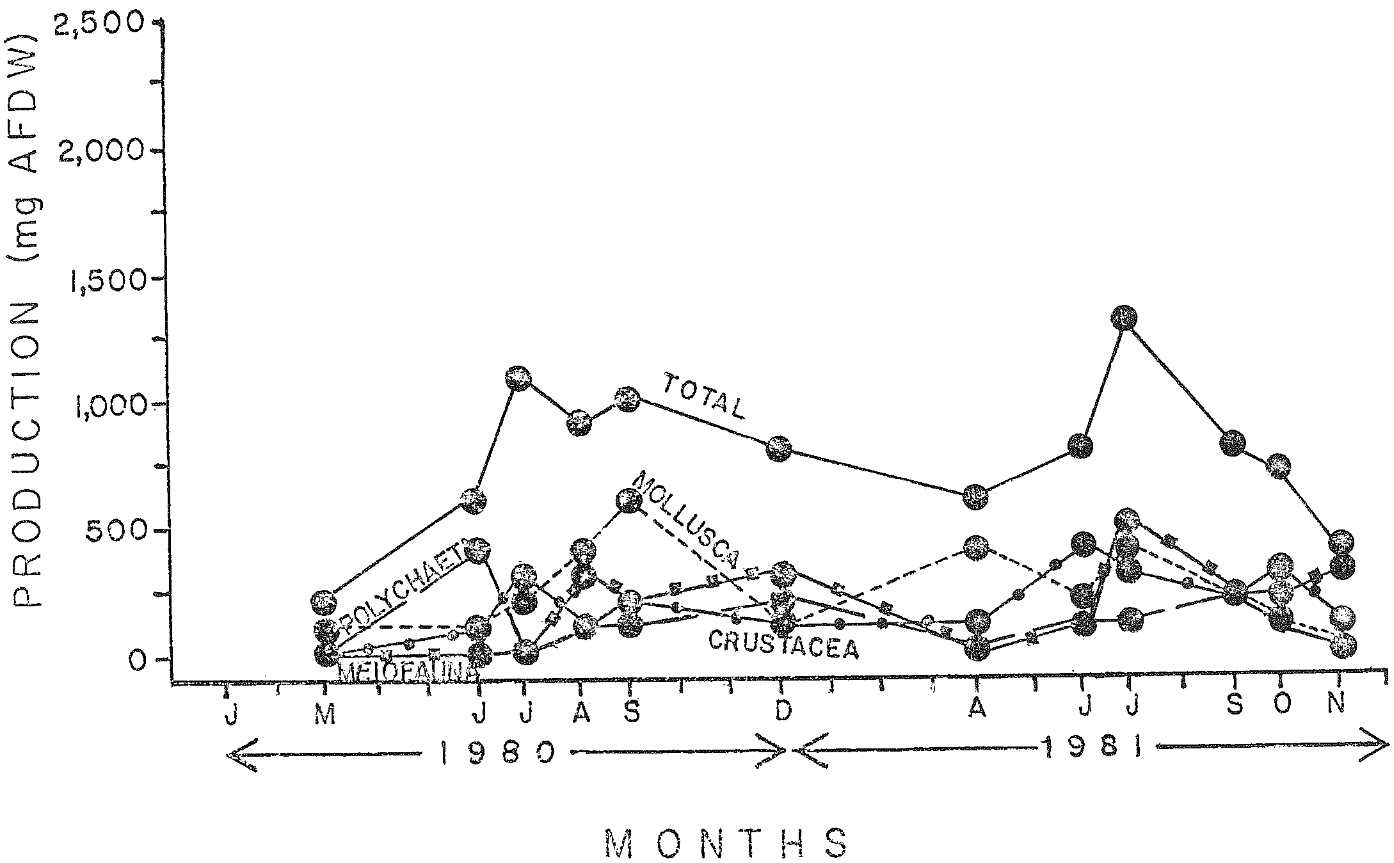

Figure 6. Monthly Production Rates for Station 32 (offshore South Bethany Beach)

Table 1

Select Species

Polychaeta	
Ampharetidae	
Asabellides oculata	(Webster)
Ampharete arctica	Malmgren
Capitellidae	
Mediomastus ambiseta	(Hartman)
Amastigos caperatus	Ewing and Dauer
Paraonidae	
Aricidea catherinae	(Laubier)
Aricidea cerrutii	Laubier
Paradoneis lyra	(Southern)
Nephtyidae	
Nephtys incisa	Malmgren
Nephtys picta	Ehlers
Mollusca	
Bivalvia	
Ensis directus	(Conrad)
Mytilus edulis	Linnaeus
Nucula annulata	Hampson
Nucula proxima	Say
Spisula solidissima	Dillwyn
Tellina agilis	Stimpson

Table 2

Regression Line Characteristics of Ash-Free Dry Weight Versus Individual Size

$\log_{10}$ (Mollusca AFDW) = a x $\log_{10}$ (valve length) + b

$\log_{10}$ (polychaeta AFDW) = a x $\log_{10}$ (segment width) + b

Species	Station	N	# Individuals	Size range (mm)	(a) Slope	(b) Y-intercept	r^{2*}
Polychaeta							
Capitellidae							
Mediomastus ambiseta	29/31	14	38	0.20 - 0.52	4.9844	1.0699	0.950
(Amastigos caperatus)				(SAME AS M. AMBISETA)			
Ampharetidae							
Asabellides oculata	29/31	19	32	0.25 - 3.33	2.8527	-0.7003	0.8624
Ampharete arctica	31/32	14	39	0.27 - 2.66	2.8792	-0.4331	0.8770
Paraonidae							
Aricidea catherinae	31	16	47	0.14 - 0.36	4.3209	1.4086	0.8844
(Aricidea cerrutii)				(SAME AS A. CATHERINAE)			
Paradoneis lyra	32	13	59	0.12 - 0.36	1.7272	-0.5483	0.9320
Nephtyidae							
Nephtys incisa	31	6	9	0.45 - 1.20	2.7219	0.3066	0.9877
Nephtys picta	32	9	14	0.26 - 1.26	2.9272	0.5199	0.9319
Bivalvia							
Ensis directus	29/31	26	58	3.84 - 27.0	2.9176	-2.8955	0.8581
Mytilus edulis	29/31	30	72	0.80 - 20.96	2.8475	-2.1727	0.9361
Nucula annulata	29/31	6	13	0.80 - 5.20	2.7616	-1.5826	0.9365
(Nucula proxima)				(SAME AS N. ANNULATA)			
Spisula solidissima	32	8	16	0.88 - 19.0	2.8766	-1.9917	0.9969
Tellina agilis	29/31	36	65	0.27 - 16.1	2.8098	-1.9441	0.9521

* Significance of all regression lines at $P < 0.001$

Table 3

Sediment and Hydrographic Parameters

STATION 29

Date	$06/80_B$	$07/80_A$	$08/80_B$	$09/80_A$	$12/80_A$	Mean
Depth (m)	21	-	21	22	-	21.3
Sediments						
% Silt-Clay	-	.	14.76	-	-	-
Mean ϕ	-	-	2.89	-	-	-
Organic carbon	-	-	-	-	-	-
Bottom Water						
Salinity ^{o}/oo	29.5	-	30 ^{o}/oo	31.2	-	30.2
Temp ^{o}C	16.1	-	19.8	21.9	-	19.3
Dissolved Oxygen (ml/l)	-	-	2.91	4.89	-	3.90

STATION 31

Date	$06/80_B$	$07/80_A$	$08/80_B$	$09/80_A$	$12/80_A$	$06/81_B$	$07/81_B$	$09/81_A$	$10/81_B$	Mean
Depth (m)	19	23	20	22	21	18	19	20	19	20.1
Sediments										
% Silt-Clay	-	0.9	67.9	14.8	17.7	-	-	-	-	27.9
Mean ϕ	-	1.03	-	1.53	1.20	-	-	-	-	1.28
Organic carbon (mg/g sed)	-	0.88	8.7	-	-	-	-	-	-	4.79
Bottom Water										
Salinity ^{o}/oo	30.0	32.1	31.0	32.3	32.2	33.0	31.0	32.5	31.0	31.7
Temp ^{o}C	15.1	14.6	20.4	18.2	6.60	16.5	20.4	17.6	14.6	16.0
Dissolved Oxygen (ml/l)	-	4.83	3.72	3.04	6.69	5.61	-	3.19	-	4.51

A = Collected by NMFS
B = Collected by CMS

Table 3.(continued)

	STATION 32									
Date	$06/80_B$	$07/80_A$	$08/80_B$	$09/80_A$	$12/80_A$	$06/81_B$	$07/81_B$	$09/81_A$	$10/81_B$	Mean
Depth (m)	14	18	14	15	20	13	14	15	-	15.4
Sediments										
% Silt-Clay	-	0.4	0.0	1.4	1.6	-	-	-	-	0.6
Mean ϕ	-	2.14	-	1.19	1.32	-	-	-	-	1.67
Organic carbon (mg/g sed.)	-	0.48	0.2	-	-	-	-	-	-	0.34
Bottom Water										
Salinity $^o/oo$	30.5	31.6	32.0	32.4	32.1	33.0	-	32.1	33.0	32.1
Temp ^oC	13.0	12.3	20.8	18.9	7.4	15.2	-	18.9	14.7	15.2
Dissolved Oxygen (ml/l)	-	5.61	5.00	3.51	6.72	3.21	-	3.72	-	4.63

A = Collected by NMFS
B = Collected by CMS

Table 4

Monthly and Annual Mean Biomass (g wet weight/m^2)
(figures in parentheses represent percent biomass of each taxa relative to each monthly total)

Station 29

Month	# Samples	Polychaeta	Mollusca	Crustacea	Echinodermata	Meiofauna	Total
0380	3	5.39 (33.6)	10.18 (63.5)	0.47 (2.9)	0	0	16.04
0680	3	106.11 (39.3)	146.11 (54.2)	15.33 (5.7)	0	2.22 (0.8)	269.77
0780	-	-	-	-	-	-	-
0880	3	0.15 (2.3)	5.08 (82.2)	0.60 (9.7)	0	0.36 (5.8)	6.19
0980	3	3.99 (54.5)	2.97 (40.6)	0.23 (3.4)	0	0.11 (1.5)	7.30
1280	-	-	-	-	-	-	-
1980 X̄		28.91 ± 51.51	41.09 ± 70.08	4.16 ± 7.45	0	0.67 ± 1.04	74.83±130.08

Station 31

Month	# Samples	Polychaeta	Mollusca	Crustacea	Echinodermata	Meiofauna	Total
0380	3	13.95 (37.7)	18.47 (50.0)	3.87 (10.5)	0	0.66 (1.8)	36.95
0680	3	43.13 (37.1)	69.22 (59.6)	3.44 (3.0)	0	0.34 (0.3)	116.13
0780	5	8.44 (34.9)	11.35 (46.9)	2.26 (9.3)	0.36 (1.5)	1.78 (7.4)	24.19
0880	3	4.37 (26.5)	11.21 (68.1)	0.59 (3.6)	0	0.29 (1.8)	16.46
0980	3	3.95 (4.3)	87.56 (94.4)	0.77 (0.8)	0	0.44 (0.5)	92.72
1280	5	3.69 (48.5)	2.17 (28.6)	1.29 (17.0)	0	0.45 (5.9)	7.60
1980 X̄		12.92±15.31	33.33±35.76	2.04±1.39	0.06±.15	0.66±0.56	49.01±44.61
0481	3	9.39 (73.5)	1.81 (14.2)	1.53 (12.0)	0	0.04 (0.3)	12.77
0681	3	5.71 (54.2)	3.36 (31.9)	0.82 (7.8)	0	0.65 (6.1)	10.54
0781	5	3.21 (17.3)	13.08 (70.4)	1.56 (8.4)	0	0.73 (3.9)	18.58
0981	3	8.12 (29.5)	12.92 (46.9)	1.44 (5.3)	3.83 (13.9)	1.22 (4.4)	27.53
1081	3	4.43 (32.5)	7.58 (55.5)	0.09 (0.7)	0	1.55 (11.3)	13.65
1181	3	3.52 (19.3)	10.88 (59.7)	0.63 (3.5)	0	3.18 (17.5)	18.21
1981 X̄		5.73±2.53	8.27± 0.31	1.01±0.60	0.64±1.56	1.23±1.09	16.88± 6.09

Table 4.(continued)

Station 32

Month	# Samples	Polychaeta	Mollusca	Crustacea	Echinodermata	Meiofauna	Total
0380	3	3.05 (62.9)	1.42 (29.3)	0.24 (4.9)	0	0.14 (2.9)	4.85
0680	3	6.70 (53.2)	3.05 (24.2)	0.69 (5.5)	2.00 (15.9)	0.15 (1.2)	12.59
0780	5	1.05 (1.8)	2.59 (4.4)	2.33 (4.0)	52.75 (89.5)	0.20 (0.3)	58.92
0880	3	2.74 (19.4)	8.18 (58.0)	0.57 (4.0)	0	2.62 (18.6)	14.11
0980	3	2.49 (19.5)	7.40 (58.1)	1.44 (11.3)	0	1.42 (11.1)	12.75
1280	5	6.70 (47.4)	2.17 (15.3)	0.70 (5.0)	1.65 (11.6)	2.92 (20.7)	14.14
1980 X		3.79±2.36	4.14±2.89	1.00±0.76	9.40±21.26	1.24±1.28	19.56±19.59
0481	3	1.49 (24.7)	3.76 (62.4)	0.75 (12.5)	0.01 (0.2)	0.01 (0.2)	6.02
0681	3	2.98 (37.2)	1.43 (17.8)	2.74 (34.2)	0	0.87 (10.8)	8.02
0781	3	4.23 (27.7)	4.60 (30.1)	1.92 (12.6)	0.59 (3.9)	3.93 (25.7)	15.27
0981	3	10.06 (65.9)	1.53 (10.0)	1.70 (11.1)	0.64 (4.2)	1.33 (8.7)	15.26
1081	3	4.37 (48.4)	0.56 (6.2)	2.54 (28.2)	0.01 (0.1)	1.54 (17.1)	9.02
1181	3	0.73 (18.6)	0.12 (3.1)	0.54 (13.7)	0	2.54 (64.6)	3.93
1981 X		3.98±3.31	2.00±1.79	1.70±0.90	0.21±0.32	1.70±1.37	9.59±4.73

Table 5

Benthic Mollusca Production at Station 29 (mg ash-free dry weight/m^2/year)
ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:$\bar{B}$ = turnover ratio

	-1980-		
	ΣP	$\bar{B}$	P:$\bar{B}$
Mollusca			
Direct Measurement			
Ensis directus	8673.95*	1230.35	7.05*
Mytilus edulis	2183.95*	353.97	6.17*
Nucula annulata	16.70	10.29	1.62
Nucula proxima	0	0	-
Spisula solidissima	22.30*	13.93	1.60*
Tellina agilis	7647.98	2782.37	2.75
Direct Subtotal	18,544.88	4390.91	4.22
Residual Measurement			
Mollusca	3,229.99*	765.40	4.22*
Mollusca Total	21,774.87	5156.31	4.22

* Estimated using P:B ratio

Table 6

Benthic Mollusca Production at Station 31 (mg ash-free dry weight/m^2/year)
ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:$\bar{B}$ = turnover ratio

	-1980-			-1981-			-Σ 1980/1981-		
	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:B
Mollusca									
Direct Measurement									
Ensis directus	2931.76	207.79	14.11	1682.24	238.63	7.05	4614.00	446.42	10.36
Mytilus edulis	13,384.24	2169.51	6.17	77.18	12.99	5.94	13,461.42	2182.51	6.17
Nucula annulata	844.04	604.84	1.40	511.18	82.91	6.17	1355.22	687.75	1.97
Nucula proxima	0	0	-	0	0	-	0	0	-
Spisula solidissima	100.67	62.95	1.60	0.62*	0.39	1.60*	101.29	63.34	1.60
Tellina agilis	1167.43	562.42	2.08	1118.07	333.08	3.37	2285.50	895.50	2.56
Direct Subtotal	18,428.14	3607.53	5.11	3389.29	668.00	5.07	21,817.43	4275.52	5.10
Residual Measurement									
Mollusca	778.18*	152.29	5.11*	1235.67*	243.54	5.07*	2013.85	395.83	5.09
Mollusca Total	19,206.32	3759.82	5.11	4624.96	911.54	5.07	23,831.28	4671.35	5.10

* Estimated using P:B ratio

Table 7

Benthic Mollusca Production at Station 32 (mg ash-free dry weight/m^2/year)
ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:$\bar{B}$ = turnover ratio

	-1980- ΣP	$\bar{B}$	P:$\bar{B}$	-1981- ΣP	$\bar{B}$	P:$\bar{B}$	-Σ 1980/1981- ΣP	$\bar{B}$	P:B
Mollusca									
Direct Measurement									
Ensis directus	6.05*	1.22	4.98*	19.13	3.84	4.98	25.18	5.06	4.97
Mytilus edulis	18.47	8.30	2.23	0.19	0.16	1.15	18.66	8.46	2.21
Nucula annulata	0	0	-	0	0	-	0	0	-
Nucula proxima	1.85*	0.38	4.90*	1.65	0.34	4.90*	3.50	0.72	4.90
Spisula solidissima	873.91	194.41	4.49	410.50	71.39	5.75	1284.41	265.80	4.83
Tellina agilis	256.95	101.48	2.53	136.11	19.35	7.03	393.06	120.83	3.25
Direct Subtotal	1157.23	305.79	3.78	567.58	95.08	5.97	1724.81	400.87	4.30
Residual Measurement									
Mollusca	413.60*	109.29	3,78*	816.75*	136.82	5.97*	1230.35	246.11	4.99
Mollusca Total	1570.83	415.08	3.78	1384.33	231.90	5.97	2955.16	646.98	4.57

* Estimated using P:B ratio

Table 8

Comparison of Select versus Residual Molluscan Fauna based on Mean Annual Biomass and Density (Select + Residual = Total)

	Mean Biomass (g wet weight/m^2)				Mean Density (# individuals/m^2)			
1980	Select	Residual	Total	Select/Total (%)	Select	Residual	Total	Select/Total (%)
Station 29	34.99	6.10	41.09	85.2	1,869.8	237.5	2,107.3	88.7
31	31.98	1.35	33.33	96.0	4,632.5	31.2	4,633.7	99.4
32	3.05	1.09	4.14	73.7	778.5	91.8	870.3	89.5
1981								
Station 31	6.10	2.17	8.27	73.8	3,029.5	106.3	3,135.8	96.6
32	0.82	1.18	2.00	41.0	266.2	76.5	342.7	77.7

Table 9

Benthic Polychaeta Production at Station 29 (mg ash-free dry weight/m^2/year)
ΣP = total annual production; $\bar{B}$ = mean annual biomass; $P:\bar{B}$ = turnover ratio

	-1980-		
	ΣP	$\bar{B}$	$P:\bar{B}$
Polychaeta			
Direct Measurement			
Mediomastus ambiseta	205.26	85.13	2.41
Amastigos caperatus	2.62*	1.52	1.72*
Asabellides oculata	22,616.83*	1843.26	12.27*
Ampharete arctica	0	0	-
Aricidea catherinae	0.01*	0.01	1.39*
Aricidea cerrutii	0	0	-
Paradoneis lyra	0	0	-
Nephtys picta	(in residual)		
Nephtys incisa	(in residual)		
Direct Subtotal	22,824.72	1929.92	11.83
Residual Measurement			
Polychaeta	474.78*	197.83	2.40*
Polychaeta Total	23,299.50	2127.75	10.95

* Estimated using P:B ratio

Table 10

Benthic Polychaeta Production at Station 31 (mg ash-free dry weight/m^2year)
ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:$\bar{B}$ = turnover ratio

	-1980-			-1981-			-Σ 1980/1981-		
	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:B
Polychaeta									
Direct Measurement									
Mediomastus ambiseta	48.59	45.52	1.07	17.29	5.51	3.14	65.88	51.03	1.29
Amastigos caperatus	87.98	51.01	1.72	0.27*	0.16	1.72*	88.25	51.17	1.72
Asabellides oculata	6928.33	564.94	12.27	32.11*	2.62	12.27*	6960.44	567.56	12.27
Ampharete arctica	162.29*	51.36	3.16*	0	0	-	162.29	51.36	3.16
Aricidea catherinae	83.31	59.75	1.39	44.75	28.90	1.54	128.06	88.65	1.44
Aricidea cerrutii	0.39*	0.33	1.17*	0	0	-	0.39	0.33	1.17
Paradoneis lyra	1.35*	1.87	.72*	0.01*	0.01	0.72*	1.36	1.88	0.72
Nephtys picta		(in residual)		18.88	16.75	1.13	18.88	16.75	1.13
Nephtys incisa		(in residual)		172.24	77.24	2.23	172.24	77.24	2.23
Direct Subtotal	7312.24	774.78	9.44	285.55	131.19	2.18	7597.79	905.97	8.39
Residual Measurement									
Polychaeta	1509.03*	824.60	1.83*	887.69*	412.88	2.15*	2396.72	1237.48	1.94
Polychaeta Total	8821.27	1599.38	5.52	1173.24	544.07	2.16	9994.51	2143.45	4.66

* Estimated using P:B ratio

Table 11

Benthic Polychaeta Production at Station 32 (mg ash-free dry weight/m^2/year)
ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:$\bar{B}$ = turnover ratio

	-1980-			-1981-			-Σ 1980/1981-		
	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:B
Polychaeta									
Direct Measurement									
Mediomastus ambiseta	.03*	.02	1.54*	0.04*	0.03	1.54*	.07	.05	1.54
Amastigos caperatus	0.03*	0.02	1.72*	0.03*	0.02	1.72*	0.06	0.04	1.72
Asabellides oculata	240.77	60.29	3.99	0	0	-	240.77	60.29	3.99
Ampharete arctica	19.57	6.19	3.16	94.81	32.98	2.87	114.38	39.17	2.92
Aricidea catherinae	29.27	6.87	4.33	8.69	8.00	1.09	38.43	14.87	2.58
Aricidea cerrutii	24.52	20.94	1.17	11.88	6.91	1.72	36.40	27.85	1.31
Paradoneis lyra	10.23	14.18	0.72	8.20	11.40	0.72	18.43	25.58	0.72
Nephtys picta	(in residual)			30.92	35.66	0.87	30.92	35.66	0.87
Nephtys incisa	(in residual)			1.12*	1.29	0.87*	1.12	1.29	0.87
Direct Subtotal	324.89	108.51	2.99	155.69	96.29	1.62	480.58	204.80	2.35
Residual Measurement									
Polychaeta	454.52*	246.97	1.84*	388.61*	239.88	1.62*	843.13	486.85	1.73
Polychaeta Total	779.41	355.48	2.19	544.30	336.17	1.62	1323.71	691.65	1.91

* Estimated using P:B ratio

Table 12

Comparison of Select versus Residual Polychaete Fauna based on Mean Annual Biomass and Density (Select + Residual = Total)

	Mean Biomass (g wet weight/m^2)				Mean Density (# individuals/m^2)			
	Select	Residual	Total	Select/Total (%)	Select	Residual	Total	Select/Total (%)
1980								
Station 29	24.32	4.59	28.91	84.1	14,266.5	681.8	14,947.5	95.4
31	6.93	5.99	12.92	53.6	6,583.2	1,782.7	8,365.9	78.7
32	0.97	2.82	3.79	24.4	1,228.5	2,016.3	3,244.8	37.9
1981								
Station 31	1.34	4.36	5.70	23.5	1,715.2	1,666	3,381.1	50.7
32	1.14	2.84	3.98	28.6	1,324.3	2,750.2	4,074.5	32.5

Table 13

Total Secondary Production of Benthic Macrofauna for Station 29 (mg ash-free dry weight/m^2/year)
(ΣP = total annual production; $\bar{B}$ = mean annual biomass; $P:\bar{B}$ = turnover ratio)

	-1980-		
	ΣP	$\bar{B}$	$P:\bar{B}$
Direct Measurement			
Polychaeta	22,824.72	1929.92	11.83
Mollusca	18,544.88	4390.91	4.22
Direct Subtotal	41,369.60	6320.83	6.54
Residual Measurement			
Polychaeta	474.78	197.83	2.40
Mollusca	3229.99	765.40	4.22
Crustacea	1025.15	415.53	8.0
Echinodermata	0	0	-
Meiofauna	472.15	67.45	7.0
Residual Subtotal	5202.07	1446.21	3.60
Total AFDW	46,571.67	7767.04	5.99
(Corrected Total)	(53,557.42)		
(Total Carbon)	(24,100.84)		

Table 14

Total Secondary Production of Benthic Macrofauna for Station 31 (mg ash-free dry weight/m^2/year)
(ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:B = turnover ratio)

	-1980-			-1981-			-Σ 1980/1981-		
	ΣP	$\bar{B}$	$P:\bar{B}$	ΣP	$\bar{B}$	$P:\bar{B}$	ΣP	$\bar{B}$	P:B
Direct Measurement									
Polychaeta	7312.24	774.78	9.44	285.55	131.19	2.18	7597.79	905.97	8.39
Mollusca	18,428.14	3607.53	5.11	3389.29	668.00	5.07	21,817.43	4275.52	5.10
Direct Subtotal	25,740.38	4382.31	5.87	3674.84	799.19	4.60	29,415.22	5181.49	5.67
Residual Measurement									
Polychaeta	1509.03	824.60	1.83	887.69	412.88	2.15	2396.72	1237.48	1.94
Mollusca	778.18	152.29	5.11	1235.67	243.54	5.07	2013.85	395.83	5.09
Crustacea	1630.96	203.87	8.0	810.88	101.36	8.0	2441.84	305.26	8.0
Echinodermata	3.04	6.07	0.5	31.95	63.89	0.5	34.99	69.96	0.5
Meiofauna	462.00	66.00	7.0	859.88	122.84	7.0	1321.88	188.84	7.0
Residual Subtotal	4383.21	1252.83	3.50	3826.07	944.51	4.05	8209.28	2197.34	3.74
Total AFDW	30,123.59	5635.14	5.35	7500.91	1743.70	4.30	37,624.50	7378.83	5.09
(Corrected Total)	(34,642.13)			(8626.05)			(43,268.18)		
(Total Carbon)	(15,588.96)			(3881.72)			(19,470.68)		

Table 15

Total Secondary Production of Benthic Macrofauna for Station 32 (mg ash-free dry weight/m^2/year)
(ΣP = total annual production; $\bar{B}$ = mean annual biomass; P:B = turnover ratio)

	-1980-			-1981-			-Σ 1980/1981-		
	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:$\bar{B}$	ΣP	$\bar{B}$	P:$\bar{B}$
Direct Measurement									
Polychaeta	324.89	108.51	2.99	155.69	96.29	1.62	480.58	204.80	2.35
Mollusca	1157.23	305.79	3.78	567.58	95.08	5.9	1724.81	400.87	4.30
Direct Subtotal	1482.12	414.30	3.58	723.27	191.37	3.78	2205.39	605.67	3.64
Residual Measurement									
Polychaeta	454.52	246.97	1.84	388.61	239.88	1.62	843.13	486.85	1.73
Mollusca	413.60	109.29	3.78	816.75	136.82	5.97	1230.35	246.11	4.99
Crustacea	795.60	99.45	8.0	1359.60	169.95	8.0	2155.20	269.40	8.0
Echinodermata	470.03	940.06	0.5	10.40	20.80	0.5	480.43	960.86	0.5
Meiofauna	869.61	124.23	7.0	1193.08	170.44	7.0	2062.69	294.67	7.0
Residual Subtotal	3003.36	1520.0	1.98	3768.44	737.89	5.11	677.80	2257.89	2.99
Total AFDW	4485.48	1934.30	2.32	4491.71	929.26	4.83	8977.19	2863.56	3.13
(Corrected Total)	(5158.30)			(5165.47)			(10,323.77)		
(Total Carbon)	(2321.24)			(2424.46)			(4645.70)		

Table 16

A Comparison of Benthic Community Production Rates for the Northern Atlantic Ocean
(mg AFDW/m^2/year)

Type	Locality	Condition	Species	Production	Author
Soft bottom					
Silt	England	80 m	Heteromastus Glycera	1,738	Buchanan and Warwick, 1974
"	"	"	Spiophanes	1,853	Buchanan et al., 1974
Mixed	Washington	34-250 m	Pectinaria	2800-4800	Nichols, 1975
Mud	E. Canada	Spartina bed	Mytilus Mya	6,500	Burke and Mann, 1974
"	"	Zostera bed	Littorina	21,200	Burke and Mann, 1974
Mud	L.I. Sound	8-29 m	Nephtys Pandora	29,600	Sanders, 1956
Mixed	L.I. Sound	9-17 m	Ampharete Neomysis Asterias	5,767 (20,025)	Richards and Riley, 1961
Mixed	Delaware Bay	21 m	Asabellides Ensis	46,572	Present Study
Mixed	Coastal Delaware	19 m	Mytilus	7,501-30,124	Present Study
Mixed	Ythan Estuary	2.5 m	Mytilus Hydrobia	108,250	Baird and Milne, 1981
Mixed	Grevelingen Estuary	6 m	Cardium Mytilus Hydrobia	57,400	Wolff, 1977
Hard bottom					
Fine sand	England	9-17 m	Pharus Spiophanes Venus	25,800	Warwick et al., 1978
Fine sand	Sweden	1 m	Pygospio Capitella Corophium	20,700-26,500	Evans, 1983
Med. sand	Coastal Delaware	14 m	Aricidea Ampharete Spisula	4,485- 4,492	Present Study

Table 17

Cumulative Percent of Mean Density, Mean Wet Biomass, Mean Ash Free Dry Biomass, and Total Production of Select Species Relative to Annual Totals of all Species at Station 29

	-1980-				-1981-			
	$\bar{D}$	$\bar{B}$ (wet)	$\bar{B}$ (AFDW)	ΣP	$\bar{D}$	$\bar{B}$ (wet)	$\bar{B}$ (AFDW)	ΣP
Annual Total	10,151.2	59,320.5	6,320.8	41,369.6				
Polychaeta								
Mediomastus ambiseta	59.6	3.4	1.3	0.5				
Amastigos caperatus	0.7	<0.1	<0.1	<0.1				
Asabellides oculata	23.4	37.6	29.2	56.2				
Ampharete arctica	-	-	-	-				
Aricidea catherinae	<0.1	<0.1	<0.1	<0.1				
Aricidea cerrutii	-	-	-	-				
Paradoneis lyra	-	-	-	-				
Nephtys picta	*							
Nephtys incisa								
Bivalvia								
Ensis directus	2.5	20.5	19.5	18.7				
Mytilus edulis	2.5	11.0	5.6	5.4				
Nucula annulata	0.5	<0.1	0.2	<0.1				
Nucula proxima	-	-	-	-				
Spisula solidissima	<0.1	0.2	0.2	<0.1				
Tellina agilis	10.8	27.2	44.0	19.1				

* Not Analyzed in 1980

Table 18

Cumulative Percent of Mean Density, Mean Wet Biomass, Mean Ash Free Dry Biomass, and Total Production of Select Species Relative to Annual Totals of all Species at Station 31

	-1980-				-1981-			
	$\bar{D}$	$\bar{B}$ (wet)	$\bar{B}$ (AFDW)	ΣP	$\bar{D}$	$\bar{B}$ (wet)	$\bar{B}$ (AFDW)	ΣP
Annual Total	10,581.9	38,775	4,382.4	25,740.4	4,095.1	7,569	799.2	3,674.8
Polychaeta								
Mediomastus ambiseta	26.8	1.2	1.0	0.2	27.7	1.7	0.6	0.6
Amastigos caperatus	11.0	0.6	1.2	0.3	0.3	<0.1	<0.1	<0.1
Asabellides oculata	13.4	14.0	12.9	26.9	0.1	0.2	0.3	0.9
Ampharete arctica	0.7	1.2	1.2	0.6	-	-	-	-
Aricidea catherinae	6.1	0.9	1.4	0.3	9.6	2.7	3.6	1.2
Aricidea cerrutii	0.1	<0.1	<0.1	<0.1	-	-	-	-
Paradoneis lyra	1.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nephtys picta	*				0.9	5.7	2.1	0.4
Nephtys incisa	*				4.2	6.4	9.1	5.1
Bivalvia								
Ensis directus	1.9	7.2	4.7	11.4	1.3	33.8	29.4	45.6
Mytilus edulis	29.6	62.3	49.5	52.0	2.2	0.8	1.6	2.1
Nucula annulata	2.8	2.1	13.8	3.3	34.7	8.4	12.2	13.8
Nucula proxima	-	-	-	-	-	-	-	-
Spisula solidissima	0.4	0.8	1.4	0.4	0.2	<0.1	<0.1	<0.1
Tellina agilis	6.0	9.7	12.8	4.5	18.8	40.2	41.0	30.3

* Not Analyzed in 1980

Table 19

Cumulative Percent of Mean Density, Mean Wet Biomass, Mean Ash Free Dry Biomass, and Total Production of Select Species Relative to Annual Totals of all Species at Station 32

	-1980-				-1981-			
	$\bar{D}$	$\bar{B}$ (wet)	$\bar{B}$ (AFDW)	ΣP	$\bar{D}$	$\bar{B}$ (wet)	$\bar{B}$ (AFDW)	ΣP
Annual Total	1,776.8	3,940	414.3	1,482.1	1,603.2	1,928	191.3	723.3
Polychaeta								
Mediomastus ambiseta	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Amastigos caperatus	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Asabellides oculata	9.7	11.1	14.7	13.1	-	-	-	-
Ampharete arctica	1.4	0.7	1.5	1.1	6.8	20.0	17.2	12.9
Aricidea catherinae	9.2	1.1	1.6	1.5	8.9	1.9	4.2	1.2
Aricidea cerrutii	15.1	2.7	5.1	1.3	9.5	5.0	3.6	1.6
Paradoneis lyra	34.3	8.6	2.9	0.7	42.4	8.6	6.0	1.6
Nephtys picta	*				2.7	20.5	18.7	4.4
Nephtys incisa	*				0.1	0.5	0.7	0.4
Bivlavia								
Ensis directus	1.0	0.9	0.3	0.3	3.6	2.3	2.0	2.7
Mytilus edulis	2.0	3.3	2.0	1.0	1.3	0.1	0.1	0.1
Nucula annulata	-	-	-	-	-	-	-	-
Nucula proxima	0.2	0.4	0.1	0.1	0.2	0.1	0.2	0.2
Spisula solidissima	16.2	61.0	47.1	66.9	6.8	33.0	37.3	55.9
Tellina agilis	10.8	10.2	24.7	14.0	17.5	8.0	10.1	18.8

* Not Analyzed in 1980

(continued from inside front cover)

20. ***Annual NEMP Report on the Health of the Northeast Coastal Waters of the United States, 1981.*** Northeast Monitoring Program Report No. NEMP-IV-82-65. February 1983. xii + 86 p., 21 figs., 15 tables, 1 app. NTIS Access. No. PB83-193912.

21. ***MARMAP Plankton Survey Manual.*** By Jack W. Jossi and Robert R. Marak. March 1983. xvii + 260 p., 41 figs., 3 tables, 2 app. NTIS Access. No. PB83-210203.

22. ***Status of the Fishery Resources Off the Northeastern United States for 1982.*** By Resource Assessment Division, Northeast Fisheries Center. June 1983. iii + 128 p., 44 figs., 44 tables. NTIS Access. No. PB83-236554.

23. ***Nantucket Shoals Flux Experiment Data Report I. Hydrography.*** By W. Redwood Wright. June 1983. i + 105 p., 100 figs., 1 table. NTIS Access. No. PB83-236562.

24. ***Residual Drift and Residence Time of Georges Bank Surface Waters with Reference to the Distribution, Transport, and Survival of Larval Fishes.*** By John B. Colton, Jr., and Jacquelyn L. Anderson. June 1983. ix + 45 p., 22 figs., 2 tables, 1 app. NTIS Access. No. PB84-107820.

25. ***Histological Techniques for Marine Bivalve Mollusks.*** By Dorothy W. Howard and Cecelia S. Smith. June 1983.

26. ***106-Mile Site Characterization Update.*** By John B. Pearce, Don C. Miller, and Carl Berman, eds. August 1983. xxxi + 483 p., 180 figs., 32 tables, 1 app. NTIS Access. No. PB84-118363.

27. ***Pelagic Distributions of Marine Birds Off the Northeastern United States.*** By Kevin D. Powers. November 1983. xvi + 201 p., 116 figs., 5 tables, 9 app. NTIS Access. No. PB84-187871.

28. ***Food of Seventeen Species of Northwest Atlantic Fish.*** By Ray E. Bowman and William L. Michaels. January 1984. xx + 183 p., 2 figs., 61 tables, 19 app. NTIS Access. No. PB84-219195.

29. ***Status of the Fishery Resources Off the Northeastern United States for 1983.*** By Resource Assessment Division, Northeast Fisheries Center; Emory D. Anderson, ed. July 1984. iii + 132 p., 44 figs., 48 tables. NTIS Access. No. PB85-106847.

30. ***Recent Estimates of Adult Spawning Stock Biomass Off the Northeastern United States from MARMAP Ichthyoplankton Surveys.*** By Peter Berrien, Wallace Morse, and Michael Pennington. July 1984. ix + iii p., 25 figs., 25 tables. NTIS Access. No. PB85-108991.

31. ***Evidence of Nearshore Summer Upwelling Off Atlantic City, New Jersey.*** By Merton C. Ingham and James Eberwine. November 1984. iii + 10 p., 5 figs.