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A Trophic Resource Analysis of Dominant Benthic microfauna of the Lower Chesapeake Bay

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A TROPHIC RESOURCE ANALYSIS
OF DOMINANT BENTHIC
MACROFAUNA OF THE LOWER
CHESAPEAKE BAY

A Thesis

Presented to

The Faculty of the School of Marine Science

The College of William and Mary in Virginia

In partial Fulfillment

of the Requirements for the Degree of

Master of Arts

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by

Douglas V. Huggett

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements of the degree of

Master of Arts

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To my mother, Nancy and the memory of my father, Henry.

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ABSTRACT

Benthic invertebrates represent a major link between primary productivity and higher trophic levels, such as bottom feeding fish and crabs. When anthropogenic activities, such as dredge material disposal, threaten the benthic community, the potential damage to higher trophic levels should be considered. Studies of secondary productivity allows for an estimate of potential production losses as a result of dredge material disposal activities. However, predatory fish are usually unable to feed on organisms deep in the sediment, therefore secondary production is not equally available. Partitioning benthic production into available and unavailable units facilitates a more reliable estimate of potential biomass losses to higher trophic levels.

Two sites from the Wolf Trap region of the Chesapeake Bay have been selected as potential dredge disposal areas. A study of benthic secondary production was carried out to determine potential disposal related effects on production availability to higher trophic levels of the disposal. From stomach content analysis of fish taken in the area, four species were determined to be trophically important; *Euclymene zonalis*, *Paraprionospio pinnata*, *Nephtys picta* (cf. *cryptomma*) and *Macoma tenta*. The polychaete *Chaetopterus variopedatus* was included in the study because of its role in structuring the community and adding biogenic refuges. The species was not found in the available portion of the sediment, and thus did not bias the available productivity estimates. These five species produced 26.42 +/- 6.79 g AFDW/m^2/yr at the Wolf Trap Primary site and 31.52 +/- 13.11 g AFDW/m^2/yr at the Wolf Trap Alternate site. Available production to fish species in the upper two centimeters from these two sites was estimated to be 6.82 +/- 5.44 g AFDW/m^2/yr and 7.44 +/- 6.45 g AFDW/m^2/yr respectively at the two sites. Using a transfer efficiency of 15%, the Wolf Trap Primary site could support fish production of 35.8 +/- 28.6 metric tons of ash-free dry weight and the Wolf Trap Alternate site could support 54.6 +/- 47.4 metric tons of ash-free dry weight. Damage of the benthic community could result in a loss of some or all of this biomass production.

INTRODUCTION

Benthic invertebrates represent a major link between primary production and higher trophic levels such as bottom feeding fish and crabs, both in the simplified primary producer-benthic organism-pelagic consumer food chain (Parsons and Takahashi, 1973; Houston and Haedrich 1986), and in more realistic food webs (Steele, 1974; Mills and Fournier, 1979; Moeller et al., 1985). Energy, in the form of biomass, flows from primary producers through the benthic community to higher trophic levels. The structural complexity of a community is an insufficient basis for constructing energy flow pathways of this nature. Many benthic community impact studies deal only with the community structure, such as abundances and biomass values. Changes of these parameters, however, are not always linked to other ecosystem changes (Mathews et al., 1982). It is now accepted that measurements of benthic secondary production are needed in order to assess a resource value of a benthic community (Borkowski, 1974; Burke and Mann, 1974; Mills, 1975; Warwick and Price, 1975, and Diaz and Fredette, 1982).

Since estuarine and shallow water marine environments serve as important spawning, nursery, and feeding grounds for many economically important species, activities that may potentially disrupt the bottom fauna need to be thoroughly investigated (De La Cruz, 1973; Oviatt and Nixon, 1973; Diaz and Fredette, 1982). Many studies have reported community structure alterations by waste and dredge material disposal activities, but these did not address the potential effects of disposal on the benthic food base responsible for supporting a fishery (Taylor and Saloman, 1968; Reish and Kauwling, 1971; Pearce, 1972; Diaz and Boesch, 1977; Reid et al., 1982; Steimle et al., 1982; and Johnson and Nelson, 1985). Secondary production studies are especially important for predicting the impact from this type of disruption.

Production estimates have long been of interest. The term "production" has been defined by Crisp (1971) as: "The part of the assimilated food or energy that is retained and incorporated in the biomass of the organism, but excluding the reproductive bodies". While numerous authors have used the definition (Clark, 1946; Peer, 1970; Winberg, 1971; Maitland and Hudspeth, 1974, and Wolf and de Wolff, 1977, among others), methods of estimating secondary production have varied. Boysen-Jensen (1919), Anderson and Hooper (1956), Sanders (1956), and Teal (1957) estimated secondary production by summing the mortality of a species between successive sample intervals, taking into account the weight of the organism at the time of loss. This method is commonly known as the removal-summation method. Ricker (1946) and Allen (1949) estimated productivity by multiplying the instantaneous rate of growth of a species by the standing stock weight over a given time interval. This method is known as the instantaneous growth method.

The problem with these methods, as well as their modified versions, is that they require having a single species of a known life cycle with easily recognizable cohorts to determine rates. These conditions are extremely difficult, if not impossible, to achieve with many organisms (Hynes, 1961). Recognition of the inherent problems with these methods lead Hynes (1961) to formulate a new secondary production estimation theory and approach, the Hynes method, which calculates production on the basis of summing biomass losses between successive size classes. Conceptual errors for the original method were corrected by various authors (Hynes and Coleman, 1968; Hamilton, 1969; Benke, 1979; and Menzi, 1980), and the technique is now known as the size-frequency method (Waters and Hokenstrom, 1980). Although Hynes original idea was to treat all species together to derive one community production estimate, later modifications showed that this method was most valuable when working with single, multivoltine species for which individuals cohorts are not clearly recognizable (see Waters and Crawford, 1973 for more detailed examples of production estimate methods).

The original concept of secondary production estimation dealt only with species that possessed clearly recognizable cohorts. For a species which exhibits continuous reproduction, or steady state conditions in Rigler and Downings' (1984) terminology, there is little to be gained by trying to follow developmental stages or cohorts on a temporal scale (Kimmerer, 1987). Sampling frequencies for steady state species need not be timed to catch particular developmental stages, greatly simplifying the task of production estimation in many instances.

Although benthic microfauna can make up as much as 87% of the total community secondary production with meiofauna accounting for up to 10% and benthic macrofauna (organisms which are retained on a 0.5 mm sieve) as little as 3% (Koop and Griffiths, 1982) to 8% (Rhoads et al., 1978), it has been shown that micro- and meiofauna may not be directly available to most demersal feeding fish (Sissenwine et al., 1984; Collie, 1987). Therefore, benthic macrofauna appear to be especially important as food items for demersal fish, and must be thoroughly examined when studying the economic resource value of a benthic community.

The majority of benthic secondary production estimates have been conducted in stream or fresh water systems (Johnson and Brinkhurst, 1971a,b; Jonasson, 1972; Morgan, 1972; Mason, 1977; Waters, 1977; Tudorancea et al., 1979; Strayer et al., 1981; and Strayer and Likens, 1986). There have been fewer studies in marine or estuarine systems (Sanders, 1956; Warwick et al., 1978; Diaz and Fredette, 1982; Howe and Leathem, 1984). Production estimates alone are not sufficient to describe the energetics of an ecosystem; details of trophic relations are required. Studies focusing on individual species production often give little or no thought to the trophic role of the organism, or how the energetics of the species effect the ecosystem. To evaluate the trophic resource value of the bottom, two types of data are required. First, knowledge of the prey species of the major predators are needed. Second, secondary production calculations of the prey species are required.

A few studies have incorporated trophic links when dealing with benthic secondary production resource estimates. Smith (1950) calculated quantities of invertebrates and related these values to the fishery of Block Island Sound. Kuipers (1977) and Beukema (1974; 1976) examined benthic prey production and related these data to predation pressures. Production of nine trophically important macrofaunal species in a Chesapeake Bay submerged aquatic vegetation habitat was estimated by Diaz and Fredette (1982). Evans (1983) investigated secondary production of a shallow soft bottom community in a Swedish fjord to determine the effects of epibenthic predators on the overall fishery. The importance of a benthic invertebrate community to trout in a small Danish stream was studied by Mortensen and Simonsen (1983). Howe and Leathem (1984) determined macrofauna productivity at three stations in the Delaware Bay and Coastal Delaware and briefly related these values to trophic transfer rates. Steimle (1985) estimated production in a stressed coastal area in the New York Bight, and studied contaminated sediment effects on the local fishery via the benthic trophic link of the food web. Probert (1986) studied energy transfer, in the form of carbon flow, through the different components of the benthic community (bacteria, meio- and macrofauna) into the higher trophic levels occupied by demersal feeding fish.

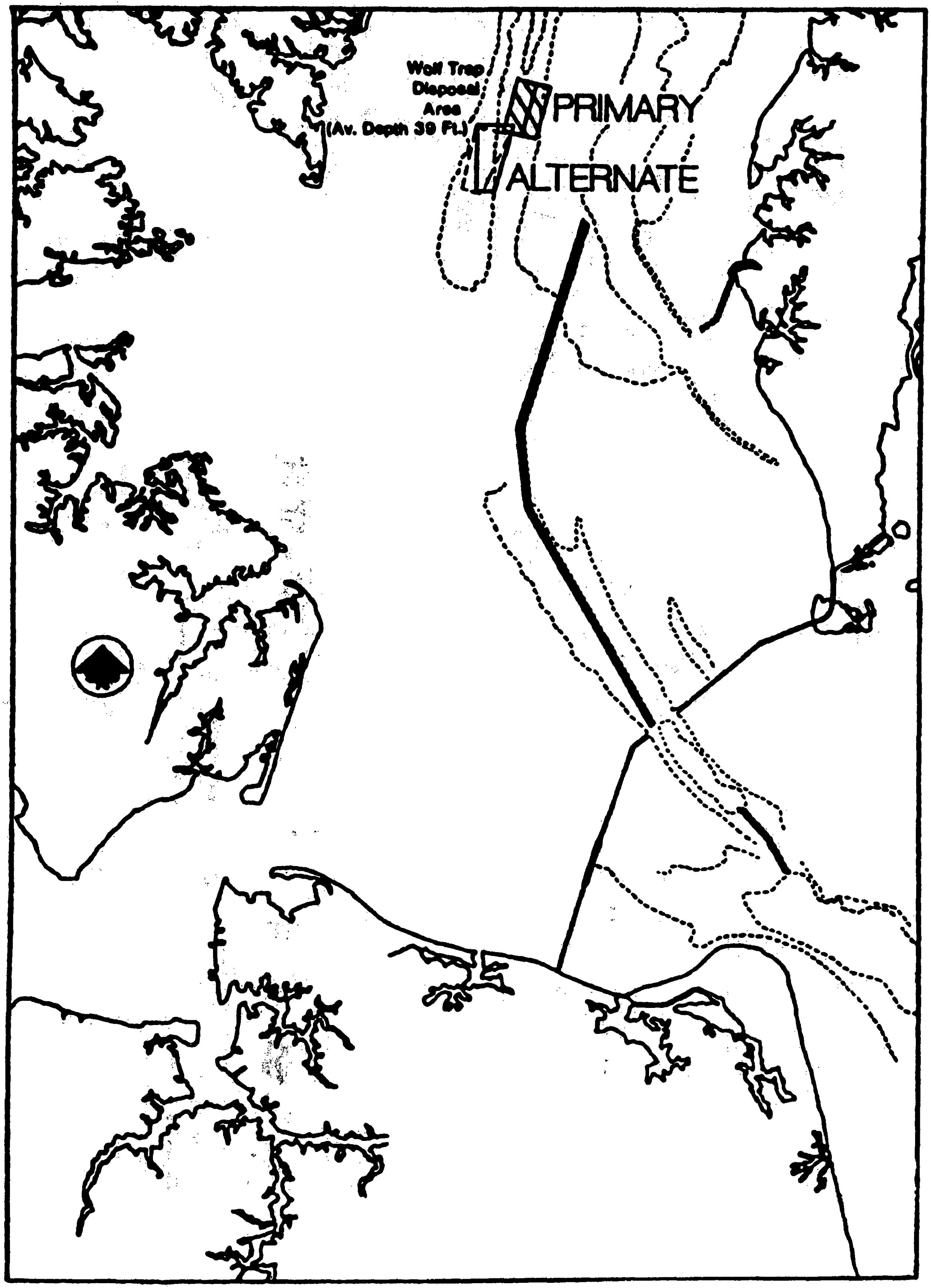
A refinement on trophic-production link studies has been introduced by Lunz and Kendall (1982) who developed the Benthic Resources Assessment Technique (BRAT). This technique utilizes both fish feeding habit data and benthic invertebrate community biomass data to make an estimate of potential prey biomass (g/m^2) or energy ($Kcal/m^2$) available in a benthic area as a way to perform more detailed environmental impact studies. The vertical partitioning of biomass within the sediment column is assumed to determine the percentage of the total biomass is available to benthic predators. An assumption of the technique is that only biomass found in the upper two centimeters is available for transfer to the higher trophic levels. This technique allows for an improved resource estimate to be made, as it disregards biomass unavailable to higher trophic levels. However, BRAT generates biomass data for only the time at which sampling occured, and therefore does not allow for an estimation of potential transfer of biomass over time. Secondary production estimations used in association with the fish feeding habit data and biomass availability data from the BRAT analysis will avoid this problem and produce an even stronger assessment of resource value.

The Army Corps of Engineers is planning to deepen the Baltimore Channel, the main navigational channel in the Chesapeake Bay, from 42′ to 50′, which will result in approximately 33 million cubic yards of dredge material which is to be disposed of in two open water disposal sites in the bay. Three channels are to be deepened. Part of the Cape Henry and all of the York Spit channels will go to the Wolf Trap disposal area (Figure 1). The third channel slated for deepening, the Rappahannock Shoals channel, is not a subject of this study. A preoperational benthic baseline evaluation of the potential dredge disposal sites was performed by the Virginia Institute of Marine Science in coordination with the Army Corps of Engineers. Quantitative samples were taken to determine macrobenthic community composition (Diaz et al., 1985) and these data were then used for the BRAT analysis, the results of which are reported by Kendall et al. (1985).

Dredge material disposal may effect organisms living on or in the bottom in several different ways. The material may cause smothering or burial, long-term changes in species diversity and biomass, uptake of toxic organics and may result in changes in sediment type and water circulation (Allen and Hardy, 1980). Recovery times of the benthic community vary greatly. Material composition has a large impact on recovery times. The time required for recolonization or recovery from fluid mud disposal ranges from three weeks to three months (Diaz and

Figure 1

Wolf Trap Study Sites


Wolf Trap
Disposal
Area
(Av. Depth 39 Ft.)
PRIMARY
ALTERNATE

Boesch, 1977). Organisms buried by more consolidated materials may require a much longer recovery time (Mauer et al., 1981). If the sediment substrate is altered by the disposal material, predisposal species may not be able to recolonize the area (Allen and Hardy, 1980). After recovery, the community may become more productive than the predredging state (Saila et al. 1972), yet Hirsch et al. (1978) and Wright (1978) have shown varying degrees of negative effect of dredge material disposal activities on demersal finfish populations due to impacts on benthic invertebrates. One possible reason for these negative impacts on fish populations while benthic productivity is high was proposed by Rhoads et al. (1978), who speculated that the species responsible for this increased production are pioneering species with high growth rates and short generation times, and this type of species may not be an important food item for the demersal feeding fish of the region. These data again point out the need for an understanding of trophic links of a food chain, and illustrate how simple production estimates may be misleading.

The aim of this study was to perform a trophic resource analysis of the Wolf Trap disposal sites, in association with the Baltimore Channel Aquatic Benthos Investigation, employing different secondary production estimates of the major benthic macrofauna utilized by fish as food.

OBJECTIVES:

1.) To estimate secondary production for trophically important benthic macrofauna.

2.) To use these estimates to determine an overall study site production estimate for trophically important benthic macrofauna.

3.) To determine the trophic resource value of the disposal areas.

STUDY AREA

The Wolf Trap study area is located in the main basin of the lower Chesapeake Bay. There are two potential disposal sites, the Wolf Trap Primary (WTP) and the Wolf Trap Alternate (WAP) sites (Figure 1). The Wolf Trap Primary site is centered at 37° 21′ N, 76° 06′ W and is approximately 35 km^2 in area. The Wolf Trap Alternate site is centered at 37° 19′ N, 76° 09′ W and is approximately 49 km^2 in area. The average depth of the sites is 39 feet.

Chesapeake Bay is the largest estuary in the United States, with a drainage area of 120,000 km^2 and a yearly fresh water runoff rate of 1,600 $m^3 sec^{-1}$ (Ludwick, 1973). The bay and its tributary estuaries have a surface area of $11.5 \times 10^3 Km^2$ a mean low water volume of 74 km^3 with a mean depth of 6.5 m (Schubel and Pritchard, 1986). The circulation pattern of the bay generally follows that of a partially mixed coastal plain estuary, with low salinity water flowing seaward overriding a lower layer of higher salinity water coming into the bay.

Details on the study area are presented in Schaffner (1987) and Wright et al. (1987). Briefly, the study site characteristics are as follows. The study sites are in a section of the bay described as bay-stem plains or basin. These plains experience near bottom currents of over 20 cm sec^{-1} at an elevation 20 cm above the bed and 40 cm sec^{-1} one meter above the bed. The plains are flat and composed of fine-grained sediments and exhibit small-scale biologically induced roughness. On both the mesoscale and large scales, the plains are relatively smooth in texture. The surface is characterized by high densities of tube dwelling organisms (Wright et al. 1987). There is an east-west gradient in sediment size for both study sites, with a higher sand content on the eastern side of the bay, agreeing with the cross bay gradient described by Byrne et al. (1982).

SAMPLING SCHEDULE

In association with the Baltimore Channel Aquatic Benthos Investigation, samples were taken at the WTP and WAP disposal areas five times;

Fall	November, 1983
Winter	February, 1984
Spring	May, 1984
Summer	August, 1984
Fall	November, 1984

Six sampling stations were used at the WTP site and eight at the WAP site. Station coordinates are listed in Table 1.

TABLE 1. Station longitude and latitude coordinantes for stations used for secondary production estimations.

STATION	LATITUDE	LONGITUDE
WTP 01	37°23.56'	76° 7.97'
WTP 02	37°23.44'	76° 6.63'
WTP 08	37°21.75'	76° 6.93'
WTP 09	37°21.75'	76° 5.71'
WTP 17	37°19.62'	76° 8.11'
WTP 18	37°19.46'	76° 6.82'
WAP 01	37°21.02'	76°10.99'
WAP 04	37°18.77'	76°11.01'
WAP 05	37°18.84'	76° 9.56'
WAP 06	37°18.89'	76° 8.02'
WAP 09	37°17.73'	76° 8.91'
WAP 11	37°16.64'	76° 9.86'
WAP 13	37°15.45'	76°11.89'
WAP 15	37°15.41'	76° 9.28'

METHODS

SAMPLING TECHNIQUES

All samples were collected from the 28 meter research vessel Tern using a U.S. Naval Electronics Laboratory spade box-corer. The box-corer samples a surface area of $0.06m^2$. Three cores per station were taken and used in this study. Two cores were sieved shipboard on a 0.5 mm mesh sieve, transferred to cloth bags and fixed in 10% buffered formalin. In the laboratory the nonpartitioned cores were sorted to major taxonomic levels (polychaetes, gastropods, bivalves, crustaceans, nemerteans, echinoderms, anemones, phoronids, flatworms and others). Taxa were biomassed to the nearest 0.01 gram and then identified to the lowest possible taxonomic level. The third core was partitioned into four depths (0-2 cm, 2-5 cm, 5-10 cm and 10-15 cm), each sieved and preserved separately. After sorting the partitioned core, each taxonomic group from each depth interval was washed through a nested sieve series (6.3 mm, 3.3 mm, 2.0 mm, 1.0 mm and 0.5 mm) and the formalin fixed biomass values of all organisms of each size interval determined. All organisms were then stored in 70% ethanol for later secondary production estimation. Dissolved oxygen concentrations were measured from bottom water samples using standard titration methods.

The depth of the Redox Potential Discontinuity, a measure of the depth at which the sediment approaches anaerobic conditions, was estimated from photographs taken with a sediment profiling camera system. Small sediment core samples were taken and analyzed in the laboratory. Organic content samples were taken and frozen for laboratory analysis to determine total organic carbon.

DETERMINATION OF TROPHICALLY IMPORTANT SPECIES

Trophic resource analysis necessitates the identification of species which are trophically important to primary predators. In this region of the Chesapeake Bay fish predators are primarily the demersal feeding spot Leiostomus xanthurus Lacepede and Atlantic croaker Micropogonias undulatus (Linnaeus) (Kendall et al., 1985). Trawl surveys and stomach content analysis of these species collected in the study area by Kendall et al. indicated that the polychaete species Euclymene zonalis (Verrill) was a primary prey item. The polychaete species Nephtys picta (Ehlers; cf. cryptomma), a species identified in Chesapeake Bay as Nephtys picta, but which may be Nephtys cryptomma (Harper, 1986), Glycera americana Leidy and Paraprionospio pinnata (Ehlers), and siphons of the tellinid bivalve Macoma tenta Say also appeared to be utilized by the spot and croaker (Kendall et al., 1985). The large polychaete Chaetopterus variopedatus (Renier) did not appear to be an important fish prey item. While not directly available to higher trophic levels, C. variopedatus is an important structuring agent in the region, increasing habitat complexity and possibly adding biogenic refuges for infauna (Schaffner, 1987). Biogenic refuges have been shown to elevate infaunal densities (Orth, 1975, Dauer et al., 1982). Thus this species was included in the study because of its structural importance. The production estimates of C. variopedatus should not bias the estimates for available production to higher trophic levels because this species is rarely found in the upper two centimeters (L. Schaffner, pers. comm.). These five species accounted for 51% of the total community macrofaunal abundance, and an even higher percentage of the community biomass (>90%). The abundance of the polychaete G. americana later proved to be too low for use with the various secondary production estimation techniques, and was subsequently removed from consideration.

The Bray-Curtis index measured the similarity of species composition among stations. Overall, there was compositional similarity of species between stations in both study sites (Diaz et al., 1985). Because of this similarity, it was assumed that the different stations from each study area were all part of a single benthic community. Therefore, individuals of each of the important prey species from the fixed stations were pooled and assumed to be representative of their respective study sites.

SECONDARY PRODUCTION ESTIMATION METHODS

Weight Determinations

Length-weight equations and secondary production estimates were calculated for the individual species based on alcohol preserved wet weights (WW). Dry weights (DW) were determined by drying samples for 24 hours at 60°C. Ash-free dry weights (AFDW) were determined by ashing dried samples at 500°C until a constant weight was obtained. Biomass or production values expressed in AFDW are more reliable because variations in moisture and inorganic content are taken into account (Leuven et al., 1985). AFDW also gives a more reliable measurement of organic matter for organisms with calcareous skeletons or shells. Ratios of DW/WW, AFDW/DW and AFDW/WW were calculated for each species.

Correction Due To Preservation

In this study, the preservation techniques employed of preserving the sample first in formalin then alcohol causes a great deal of weight loss from the initial live weights (Howmiller, 1972; Leuven et al., 1985). Since production measurements were made long after preservation of the organisms, this weight loss must be corrected for. Few studies have looked at weight loss of unpreserved tissue upon preservation in formalin. Howe and Leathem (1984) applied a conversion factor of 1.15 to convert benthic macrofaunal preserved tissue weights to unpreserved tissue values. Howmiller (1972) reported that formalin preserved oligochaete weights were 76 percent (conversion factor of 1.3) of live weights after 44 days. Ethanol preservation (70%) will cause a much greater weight loss relative to the original live weights. Howmiller reported over a 50% wet weight loss after 57 days of ethanol preservation. Leuven et al. (1985) showed a significant effect of alcohol preservation on AFDW (organic weight), demonstrating that factors other than just water loss produce preservation artifacts. If water loss was the sole cause of weight loss after preservation, the ashing procedure would not detect this loss because ashing dries out all moisture. The weight loss due to preservation will result in a greatly reduced biomass measure, leading directly to a large production underestimation. Corrections for this weight loss therefore had to be determined and applied to the biomass values in order to provide more reliable production values.

Because biomass measurements were not made until after formalin preservation, no precise live weight to formalin preserved weight conversion factor could be determined. Therefore, a factor of 1.15 (Howe and Leathem, 1984) was employed. Conversion factors between biomass of ethanol preserved tissue and initial formalin preserved tissue biomass could not be determined for individual species. Rather, a determination was made for major taxa, polychaetes and bivalves, by comparing long term post-preservation biomass to the initial formalin preserved biomass. Because most biomass loss due to preservation occurs during the first 30 days post-preservation, the long-term post-preservation samples used (preserved > 1 yr) should yield an accurate conversion factor.

Error terms associated with the species production estimates were calculated by summing the standard deviations of the biomass data used to determine size class or time interval biomasses.

Euclymene zonalis

The size-frequency method for productivity estimation is the most ideally suited for this type of study. Severe fragmentation of *Euclymene zonalis* during shipboard sieving and preservation prohibited placing this species into size classes and made it impossible to use the size frequency method. Therefore the instantaneous growth method was the best available method of estimating production for *E. zonalis*. The instantaneous growth method claims that production is proportional to the biomass of a steady state population and may be calculated by:

$$P = Bg$$

where P= production, B= mean biomass over a time interval, and g= instantaneous growth constant over the time interval, where growth is defined as:

$$g = \ln(m_2 - m_1)$$

where m_1 and m_2 are the average mean weight per individual values of dates 1 and 2, respectively (Rigler and Downing, 1984). Mean weight per individual for each sampling date was determined by dividing the total biomass of all apparent *E. zonalis* fragments from a sample by the number of individuals determined to be in the sample, based on the number of head sections found.

Chaetopterus variopedatus

Chaetopterus variopedatus also severely fragmented during collection. The removal-summation method, which is calculated as the sum of weight losses from one sampling time to the next, was the most appropriate production estimation method for use with *C. variopedatus* data. Mean weight per individual was again determined by dividing total fragment biomass by numbers of individuals, as indicated by the number of head segments found. This method involves multiplying the numbers lost over a time interval by the average weight of the individual at the time of loss. The weight at loss was determined by using a exponential curve function based on the mean weight per organism at the different cruise dates. The production estimates for each time interval were summed to get an annual production estimate.

Macoma tenta

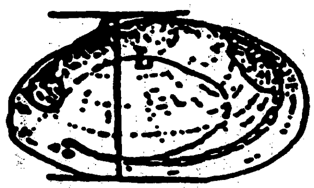
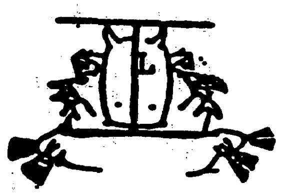
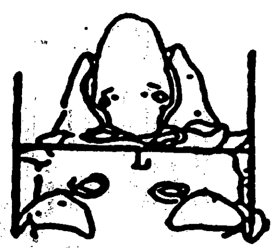
The annual production of the bivalve *Macoma tenta* was estimated by the size-frequency method. This method involves placing each individual into a size class, and multiplying the numbers lost between each size class by the mean weight per individual at the time of the loss, determined by length-weight regression equations. The resultant values were then summed and multiplied by the number of increments to produce an annual production estimate. The individuals were placed into 1 mm size groups, based on the cross body length from the top of the umbo across to the outer shell boundary (Table 2). A disecting microscope fitted with an ocular micrometer was used to make these measurements.

Paraprionospio pinnata

The Size-frequency method was used for *Paraprionospio pinnata*. Individuals were placed into 1 mm size classes based on body width at the first setiger, including parapodia (Table 2). Mean weight per individual was calculated for each size class and these data fitted to an exponential curve to derive a length-weight relationship which was used to determine weight at loss between successive size groups.

TABLE 2. Length-weight regression equations for major species.
W = weight; L = length.

LENGTH-WEIGHT REGRESSION CURVE EQUATIONS

SPECIES	MEASUREMENT BASED ON	WTP	WAP
Macoma tenta		$W=0.18L^{3.25}$ $r^2=0.98$	$W=0.10L^{3.55}$ $r^2=1.00$
Nephtys picta (cf. *cryptomma*)		$W=0.15L^{2.96}$ $r^2=0.96$	$W=0.15L^{2.99}$ $r^2=0.97$
Paraprionospio pinnata		$W=0.24L^{1.53}$ $r^2=0.95$	$W=0.27L^{1.51}$ $r^2=0.98$

Nephtys picta (cf. *cryptomma*)

Individuals from the polychaete species *Nephtys picta* (cf. *cryptomma*) were placed into size classes required by the Size-Frequency secondary production estimation method. The individuals were measured from tip of the prostomium to the anterior edge of the first setiger (Table 2) and a 2 mm size-frequency histogram developed from the data.

Community Production

Total community production was estimated using biomass derived from depth distribution cores and converted to mean annual biomass per station. The error terms associated with community production estimates were determined using the standard deviations of the mean annual biomass values per station. Large hard clams, *Mercenaria mercenaria* (Linnaeus), rarely found in the cores, were excluded from the community production determination due to the fact that the sampling scheme used did not allow for an adequate sampling of this species. Mean biomass values were subsequently multiplied by a weighted annual P/B ratio (Tables 3 and 4) for either polychaetes or bivalves to give the total production for all members of that particular taxonomic group. For the bivalves, the P/B ratios for *Macoma tenta* were applied to bivalve biomass values. This is a valid use of the the P/B ratio because *M. tenta* was the numeric and biomass dominant bivalve species. In the case of the polychaetes the weighted P/B ratios were determined by using the P/B ratios of *Euclymene zonalis*, *Nephtys picta* (cf. *cryptomma*) and *Paraprionospio pinnata*. When considering only the trophically important polychaete species the majority of the polychaete biomass (75% to 85%)

TABLE 3. Weighted polychaete community P/B ratio determination for the WTP study site.

SPECIES	P/B RATIO	x	APPROX. % DOMINANT SPECIES BIOMASS	
Euclymene zonalis	0.39		85%	.33
Nephtys picta (cf. *cryptomma*)	4.26		8%	.34
Paraprionospio pinnata	3.59		8%	.29

Weighted WTP P/B Ratio = 1.0

TABLE 4. Weighted polychaete community P/B ratio determination for the WAP study site.

SPECIES	P/B RATIO	x	APPROX. % DOMINANT SPECIES BIOMASS	
Euclymene zonalis	0.40		75%	.30
Nephtys picta (cf. *cryptomma*)	4.39		12%	.52
Paraprionospio pinnata	3.41		12%	.41

Weighted WAP P/B Ratio = 1.2

was accounted for by *Euclymene zonalis*, a species that exhibited a very low P/B ratio, the average community P/B ratios were weighted heavily in favor of this species. The approximate percent of biomass represented by each species was multiplied by the annual P/B ratio of that species. These values were then summed to derive a weighted community P/B ratio (Tables 3 and 4). These ratios are extremely general and should be treated as such. A student T-test was run on total production from the two study sites to determine if the values from the two sites were significantly different from each other.

Available Production

Not all biomass of the benthic community appears to be available for predation by bottom feeding fish. Virnstein (1977), Holland et al. (1980) and Blundon and Kennedy (1982) have shown that prey availability is a function of the depth of burial. Kendall et al. (1985) reported that demersal feeding fish from the Wolf Trap region of the bay were foraging only in the 0-2 centimeter layer of the sediment for most of the year, occasionally foraging in the 2-5 centimeter layer at times in the summer. Therefore community production data were arranged to estimate the amount of production theoretically available to fish. Based on the data of Kendall et al. (1985), biomass from the 0-2 centimeter layer was assumed to be available for transfer to higher trophic levels. Because bottom feeding fish from the area may at times feed below two centimeters, this value is somewhat arbitrary. However, because the majority of fish foraging occurred from the upper two centimeter layer, the data generated from this layer will give a stronger assessment of the resource value of the benthic community to demersal feeding fish than data from the top five centimeters. A limitation of this method is that it does not take into account crab predation on the benthos. Blundon and Kennedy (1982) report that blue crabs (*Callinectes sapidus* Rathburn) may forage on organisms 20 centimeters deep in the sediment column. Therefore a resource assessment of the importance of the benthos to demersal feeding fish populations will not assess the importance of the benthic community to crab populations.

Available production was determined by multiplying the biomass from the upper 0-2 centimeter depth for polychaetes or bivalves by the weighted polychaete or bivalve annual P/B ratios. A student T-test was run on available production from the two study sites to determine if the values from the two sites were significantly different from each other.

RESULTS

BIOMASS DATA

Length-weight regression curve equations are listed in Table 2. Wet weight/dry weight and dry weight/ash-free dry weight conversion ratios for the species are listed in Table 5. An alcohol preserved weight to formalin preserved weight conversion factor of 1.6 was determined for the polychaetes and 1.2 for bivalves. The bivalve factor is lower because of the high degree of inorganics found in the shell, which do not change appreciably upon preservation. A formalin preserved weight to live weight conversion factor of 1.15 (Howe and Leathem, 1984) was used to estimate live organism biomass from alcohol preserved values. By multiplying these two factors together, a alcohol preserved biomass to live weight biomass conversion was determined (polychaete factor = 1.84; bivalve factor = 1.38).

PRODUCTION ESTIMATES

All production estimates were calculated using alcohol preserved biomass values. Species production estimates were then converted to estimated live weight values. All values of production referred to in

TABLE 5. Biomass conversion ratios for dominant species.

SPECIES	DW/WW	AFDW/DW	AFDW/WW
Euclymene zonalis	17.35%	82.28%	14.28%
Chaetopterus variopedatus	11.05%	63.75%	7.04%
Macoma tenta	30.58%	19.92%	6.12%
Paraprionospio pinnata	12.74%	79.60%	10.14%
Nephyts picta (cf. *cryptomma*)	13.36%	71.95%	9.83%

this report will be expressed in units of live weight unless otherwise stated. Both alcohol preserved and live weight converted biomass values produced the same results.

Euclymene zonalis

Although abundances remained relatively constant (Figure 2) the mean weight per individual *Euclymene zonalis* increased over the first four sampling intervals and then exhibited a sharp drop in mean weight per individual over the last sample interval (Tables 6 and 7). This decrease in mean weight caused a negative production over the last time interval for both sites. Total annual production was WTP= 5.25 +/-1.32 g AFDW/m^2/yr; WAP= 2.65 +/-1.07 g AFDW/m^2/yr.

The annual production for *Euclymene zonalis* was much higher at the WTP site than at the WAP site, yet the production to biomass ratio (P/B), calculated by dividing annual production by the annual mean standing crop, were extremely close for the two areas (WTP=0.39; WAP=0.40). This closeness indicates that the higher production found at the WTP site resulted from a higher species standing stock. *E. zonalis* from the WTP site had greater mean weights than those from the WAP site at every sampling interval.

Chaetopterus variopedatus

The removal-summation method chosen as the appropriate production estimation method for *Chaetopterus variopedatus* requires that mean weight per individual be multiplied by numbers lost over the same time interval. The mean weights at each interval were used to construct a

TABLE 6. *Euclymene zonalis* secondary production estimate for WTP study site.

Date	Mean wt. (mg)	# INDS. (m^2)	Standing crop (g/m^2) B	G	$\bar{B}$ (g/m^2)	P (g/m^2)
Nov. 1983	32(+/- 4)	1465	46.889			
				.32(+/-.22)	47.74	15.28 (+/-10.50)
Feb. 1984	44(+/- 5)	1104	48.583			
				.20(+/-.33)	59.85	11.97 (+/-19.75)
May 1984	54(+/- 7)	1317	71.100			
				.41(+/-.00)	65.75	29.96 (+/-0.00)
Aug. 1984	81(+/- 7)	746	60.413			
				-.76(+/-.15)	45.04	-34.23 +/-(-25.2)
Nov. 1984	36(+/-7)	604	21.750			

Total Production = 19.98 g WW/m^2/yr (+/-5.04) = 2.85 g AFDW/m^2/yr (+/-0.72)

x Preservation Conversion (1.84) = 5.25 g AFDW/m^2/yr (+/-1.32)

P/b = 0.39

TABLE 7. *Euclymene zonalis* secondary production estimate for WAP study site.

Date	Mean wt. (mg)	# INDS. (m^2)	Standing crop (g/m^2) B	G	$\bar{B}$ (g/m^2)	P (g/m^2)
Nov. 1983	25(+/- 7)	795	19.870			
				.15(+/-.45)	20.46	3.07 (+/-9.21)
Feb. 1984	29(+/-11)	726	21.055			
				.32(+/-.16)	26.78	8.57 (+/-4.28)
May 1984	40(+/-13)	813	32.500			
				.30(+/-.00)	34.20	10.26 (+/-0.00)
Aug. 1984	54(+/-13)	666	35.888			
				-.41(+/-.61)	28.82	-11.82 +/-(-17.8)
Nov. 1984	36(+/-7)	604	21.750			

Total Production = 10.09 g WW/m^2/yr = 1.44 g AFDW/m^2/yr
(+/-4.09) (+/-0.58)

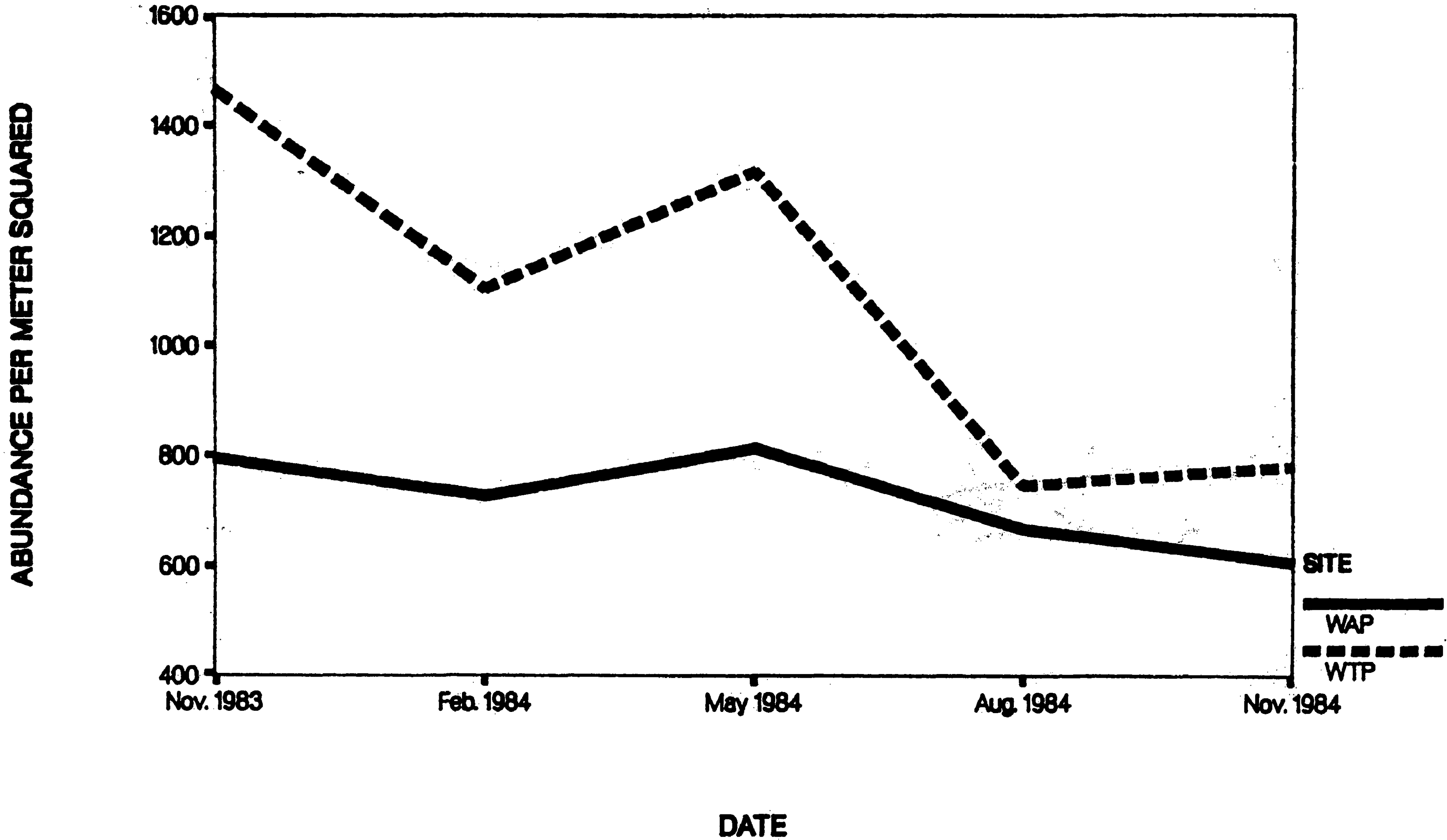
x Preservation Conversion (1.84) = 2.65 g AFDW/m^2/yr
(+/-1.07)

P/b = 0.40

Figure 2

Euclymene zonalis abundances

Euclymene zonalis



exponential time-weight curve function for each site. The curve equations were used to estimate weight at time of loss, assumed to be the midpoint between successive dates. The production estimates from each date were summed to derive an annual production estimate (Tables 8 and 9).

The annual production from the WAP site was one third higher than that of the WTP (WAP= 23.64 +/-10.96 g AFDW/m^2/yr; WTP= 18.00 +/- 4.59 g AFDW/m^2/yr). The abundances from both sites dropped from May 1985 to November 1985 (Figure 3). No *Chaetopterus variopedatus* appeared during the last two sampling periods at the WTP site. Over the first three sample intervals, the WTP production was actually higher than the WAP production, but because of the population crash, there appears to be a potential for underestimating production potential from the WTP site. The WTP P/B ratio was higher than the WAP ratio (WTP=4.52; WAP=3.08), but if the last two intervals of the WTP data are ignored, then the WTP ratio is slightly lower than that of the WAP site.

Macoma tenta

Annual secondary production of this tellinid bivalve was estimated using the size-frequency method. Individuals of the species were placed into 2 mm size classes based on cross body length from the umbo to the outer shell boundary. Size-frequency histograms (Figures 4 and 5) show a gradual increase in size of these organisms. There was a large drop in abundance at both sites during the last sampling period (Figure 6).

WTP secondary production was estimated to be 1.62 +/- 0.36 g AFDW/m^2/yr (Table 10). Size class mean weights were used to construct a

TABLE 8. Chaetopterus variopedatus secondary production estimate for WTP study site.

Date	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)
Nov. 1983	210	241(+/-112)	50.61			
				75	407(+/-186)	30.52 +/-13.95
Feb. 1984	135	608(+/-260)	82.08			
				113	755(+/-174)	87.57 +/-19.60
May 1984	22	950(+/- 87)	20.90			
				22	950(+/- 87)	20.90 +/-(-1.91)
Aug. 1984	0	-	0.00			
				0	-	-
Nov. 1984	0	- m	0.00			
				0	-	-

Total Production = Total Losses = 138.99g WW/m^2/yr (+/-35.46) = 9.78g AFDW/m^2/yr (+/-2.49)

x Live Weight Conversion (1.84) = 18.00g AFDW/m^2/yr (+/- 4.59)

P/B = 4.52 (For All Intervals)

P/B = 2.71 (For Intervals With Organisms Present)

TABLE 9. *Chaetopterus variopedatus* secondary production estimate for WAP study site.

Date	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)
Nov. 1983	108	467(+/-276)	50.43			
				63	701(+/-300)	44.16 +/-18.90
Feb. 1984	455	1012(+/-573)	45.54			
				22	1118(+/-578)	26.14 +/-12.72
May 1984	23	1938(+/-783)	44.57			
				-10	2014(+/-893)	-20.14 +/-(-8.93)
Aug. 1984	33	2171(+/-1020)	71.64			
				14	3412(+/-1565)	47.77 +/-21.91
Nov. 1984	19	4455(+/-2110)	84.64			
				19	4555(+/-2110)	84.65 +/-40.09

Total Production = Total Losses = 182.58g WW/m^2/yr (+/-84.69) = 12.85g AFDW/m^2/yr (+/-5.96)

x Live Weight Conversion (1.84) = 23.64g AFDW/m^2/yr (+/-10.96)

P/B = 3.08

TABLE 10. <u>Macoma tenta</u> secondary production estimate for WTP study site.

Size group length (mm)	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)	Prod. (g/m^2) X 9
0-2	24	0.3	.0072				
		(+/-0.30)		6	0.7	.0042	.0376
2-4	18	0.8	.0144		(+/-0.40)		+/-.0036
		(+/-0.50)		6	3.5	.0210	.1890
4-6	12	6.3	.0756		(+/-1.20)		+/-.0648
		(+/-1.80)		7	10.6	.0742	.6678
6-8	5	16.2	.0810		(+/-4.30)		+/-.2709
		(+/-6.80)		-3	24.1	-.0723	-.6507
8-10	8	36.5	.2920		(+/-8.30)		+/-.2241
		(+/-9.70)		-5	46.3	-.2315	-2.0835
10-12	13	60.3	.7839		(+/-15.60)		+/-.7020
		(+/-21.50)		2	79.8	.1596	1.4364
12-14	11	119.9	1.3189		(+/-12.60)		+/-.2268
		(+/-3.70)		2	127.1	.2542	2.2878
14-16	9	162.5	1.4625		(+/-7.70)		+/-.1386
		(+/-11.70)		5	191.0	.9550	8.5950
16-18	4	241.0	.9640		(+/-26.10)		+/-1.1745
		(+/-40.40)		4	241.0	.9640	8.6760
					(+/-40.40)		+/-1.4549

Total Production = 19.1938 g WW/m^2/yr = 1.1747 g AFDW/m^2/yr
(+/-4.2597) (+/-0.2607)

x Live Preservation Conversion (1.38) = 1.6211 g AFDW/m^2/yr
(+/-0.3597)

P/B = 3.84

Figure 3

Chaetopterus variopedatus abundances

Chaetopterus variopedatus

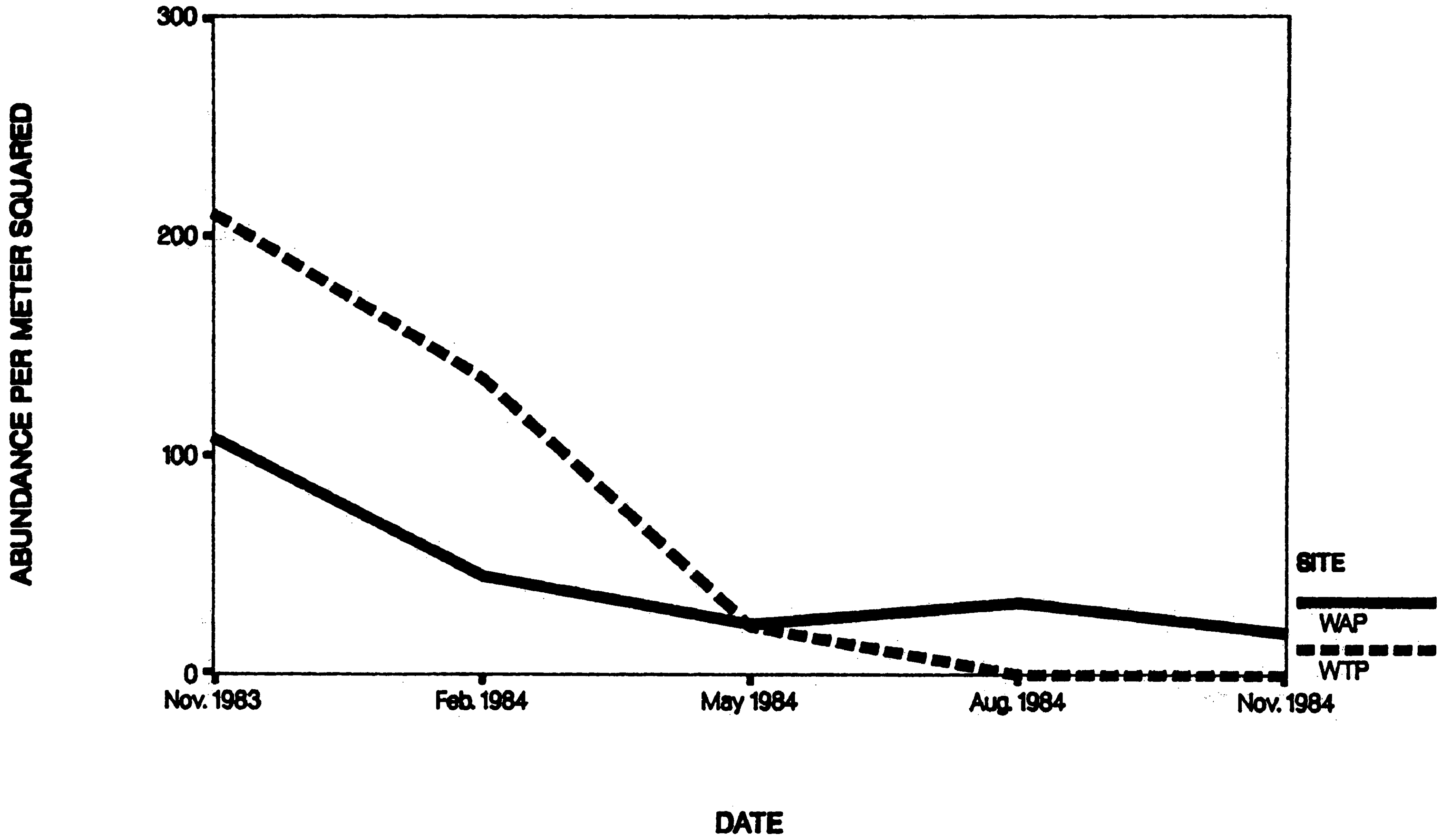
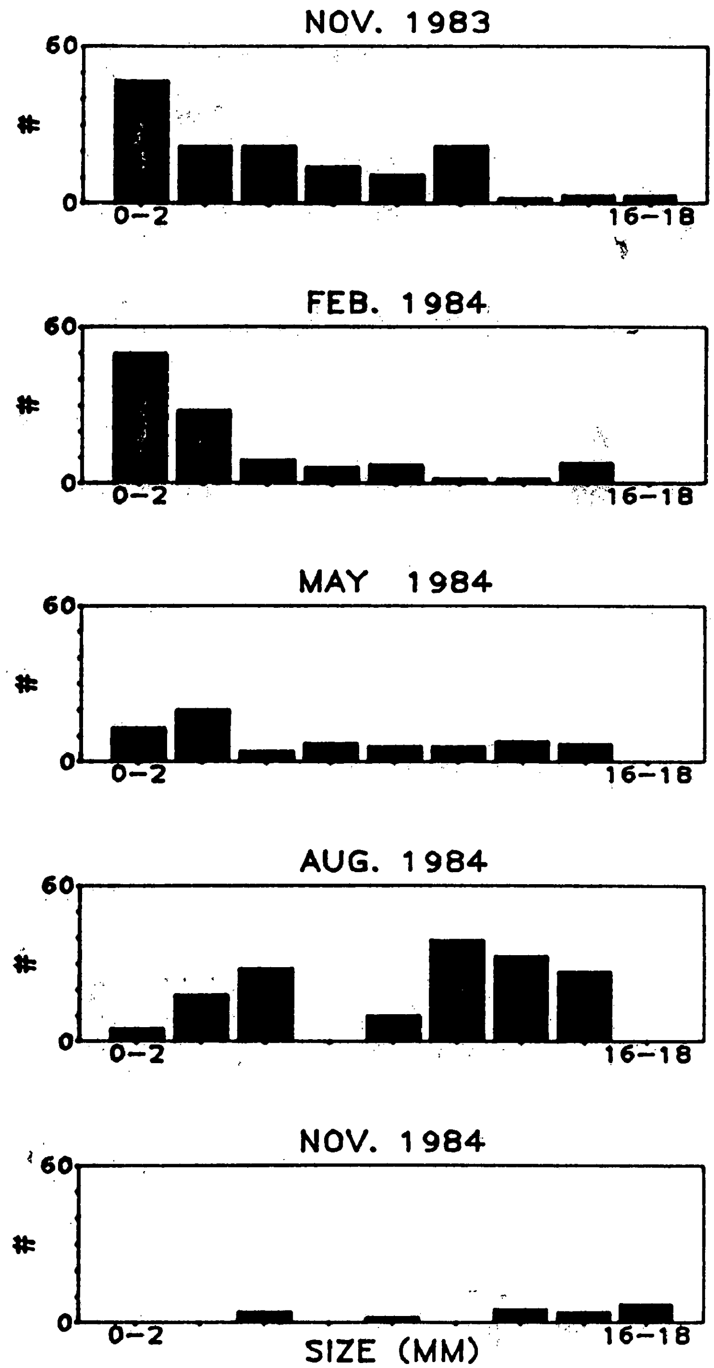


Figure 4

Macoma tenta size-frequency

histogram for WTP site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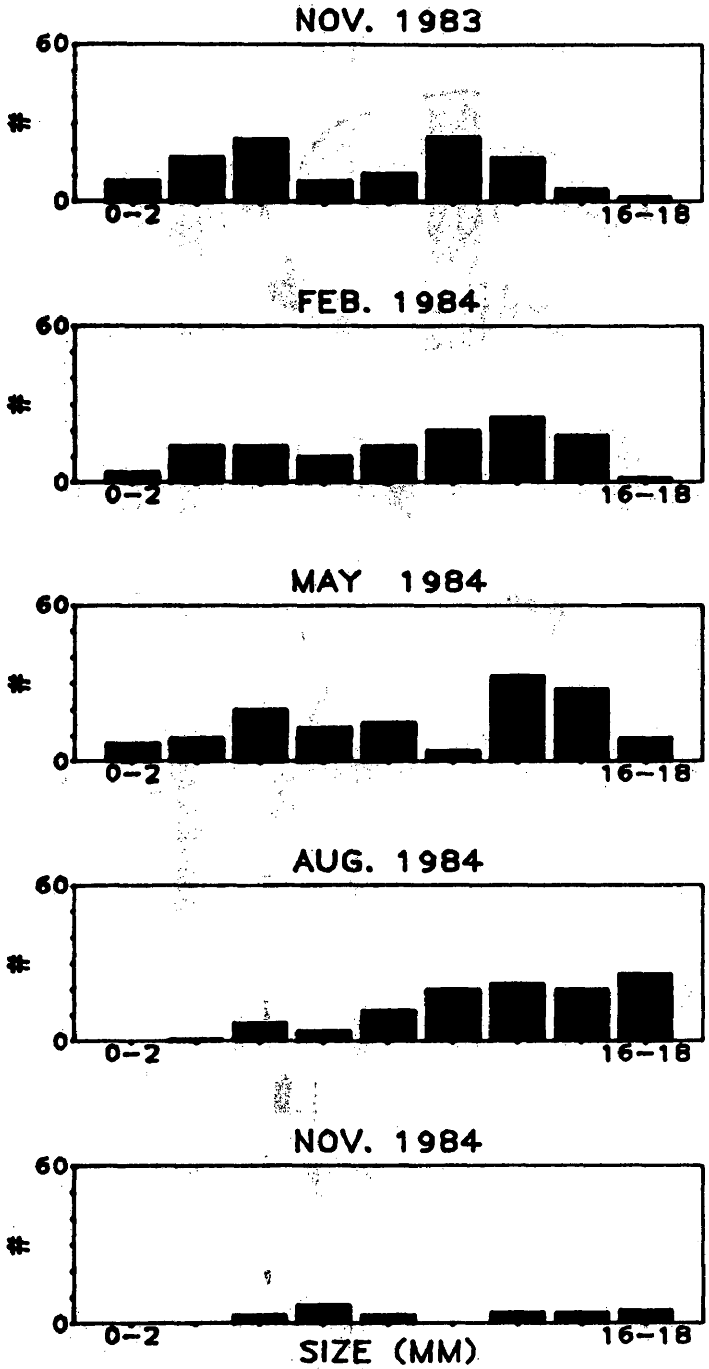
#
0
0-2
16-18
FEB. 1984
60
#
0
0-2
16-18
MAY 1984
60
#
0
0-2
16-18
AUG. 1984
60
#
0
0-2
16-18
NOV. 1984
60
#
0
0-2
16-18
SIZE (MM)

Figure 5

<u>Macoma tenta</u> size-frequency

histogram for WAP site

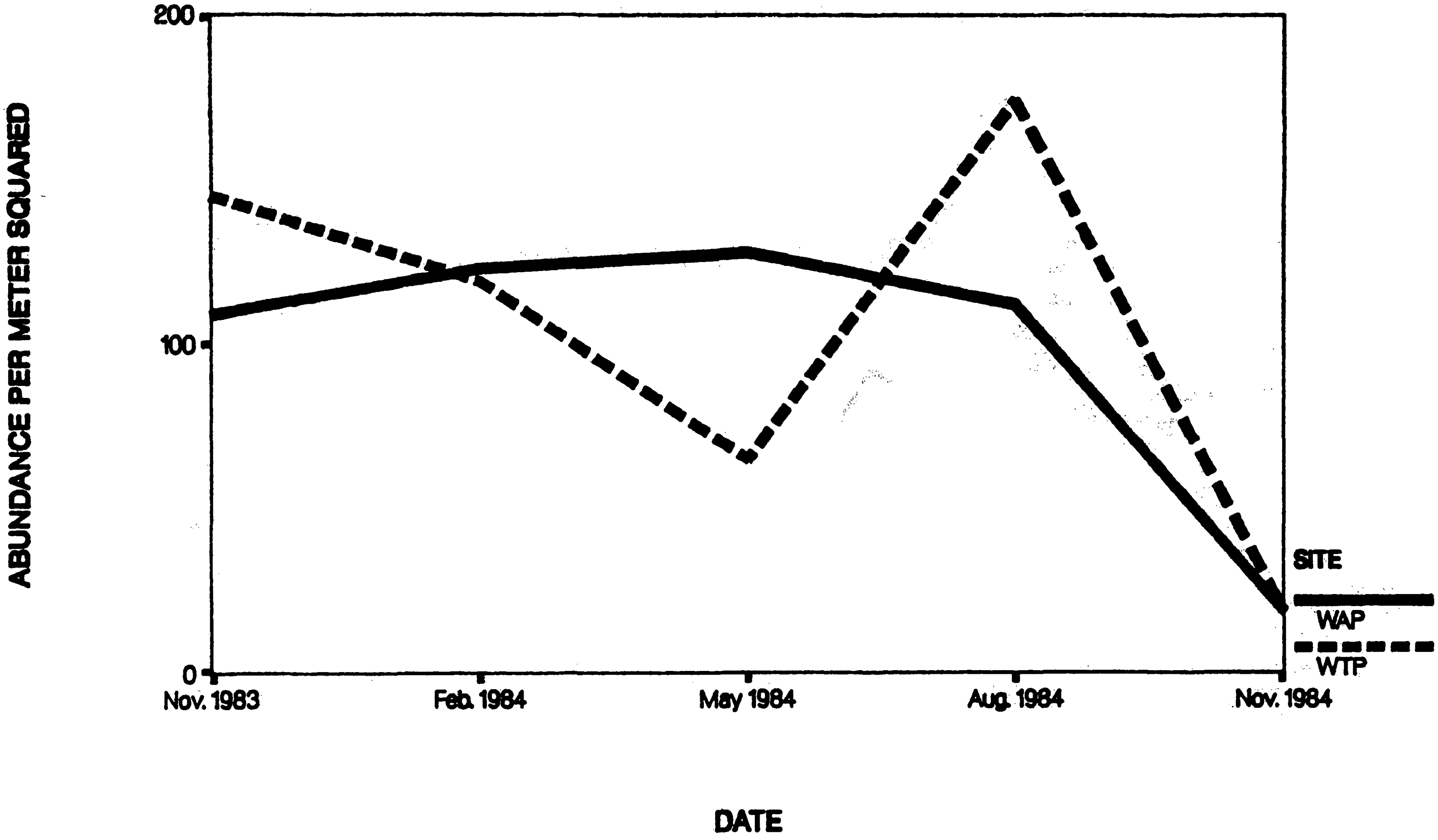


NOV. 1983
60
#
0
0-2
16-18
FEB. 1984
60
#
0
0-2
16-18
MAY 1984
60
#
0
0-2
16-18
AUG. 1984
60
#
0
0-2
16-18
NOV. 1984
60
#
0
0-2
16-18
SIZE (MM)

Figure 6

Macoma tenta abundance

Macoma tenta



length-weight regression best fit power curve equation. This equation was used to estimate weight at time of loss of an individual between two successive size classes. Animal size ranged from 0-2 mm to 16-18 mm. A P/B ratio of 3.84 was calculated.

Organisms from the WAP site were placed into 2 mm size classes and the length-weight regression calculated. This method produced a secondary production estimate of 2.39 +/- 0.37 g AFDW/m^2/yr and a P/B ratio of 4.25 (Table 11).

Both production values are probably minimal estimates because of the organisms left in the last size class (Tables 10 and 11). The procedure for production estimates for organisms found in the last size group is to assume that the mean weight/individual for that interval is the maximum obtainable weight for the organism, and the individuals left are multiplied by this weight. This assumption is obviously flawed. It is unlikely that the organism did not grow in weight after the final sample collection date.

Nephtys picta (cf. *cryptomma*)

The size-frequency method was used to derive production estimates for *Nephtys picta* (cf. *cryptomma*). Individuals were placed into 1 mm size classes based on the length from the tip of the prostomium to the start of the first setiger segment. Organism sizes ranged from the 1-2 mm size group to 9-10 mm (Figures 7 and 8).

WTP annual production of *Nephtys picta* (cf. *cryptomma*) was calculated to be 1.13 +/- 0.22 g AFDW/m^2/yr with a P/B ratio of 4.26. WAP *N. picta* (cf. *cryptomma*) production (2.41 +/- 0.58 g AFDW/m^2/yr) was

TABLE 11. *Macoma tenta* secondary production estimate for WAP study site.

Size group length (mm)	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)	Prod. (g/m^2) X 9
0-2	3	0.1	.0003				
		(+/-0.10)		-5	0.4	-.0020	-.0180
2-4	8	1.2	.0096		(+/-0.40)		+/-.0180
		(+/-0.70)		-3	2.5	-.0675	-.0675
4-6	11	4.0	.0440		(+/-1.50)		+/-.0405
		(+/-2.20)		4	8.2	.2952	.2952
6-8	7	11.5	.0805		(+/-3.60)		+/-.1296
		(+/-4.90)		-3	19.9	-.0597	-.5373
8-10	10	31.5	.3150		(+/-6.50)		+/-.2340
		(+/-8.10)		-1	40.0	-.0400	-.3600
10-12	11	62.7	.6897		(+/-14.70)		+/-.1323
		(+/-21.30)		-8	73.6	-.5888	-5.2992
12-14	19	95.3	1.8107		(+/-18.90)		+/-1.3608
		(+/-16.40)		4	122.3	.4892	4.4028
14-16	15	142.9	2.1075		(+/-16.70)		+/-.6012
		(+/-17.00)		7	190.8	1.3356	12.0204
16-18	8	247.6	1.6176		(+/-15.40)		+/-.9702
		(+/-13.80)		8	247.6	1.9808	17.8272
					(+/-13.80)		+/-.9936

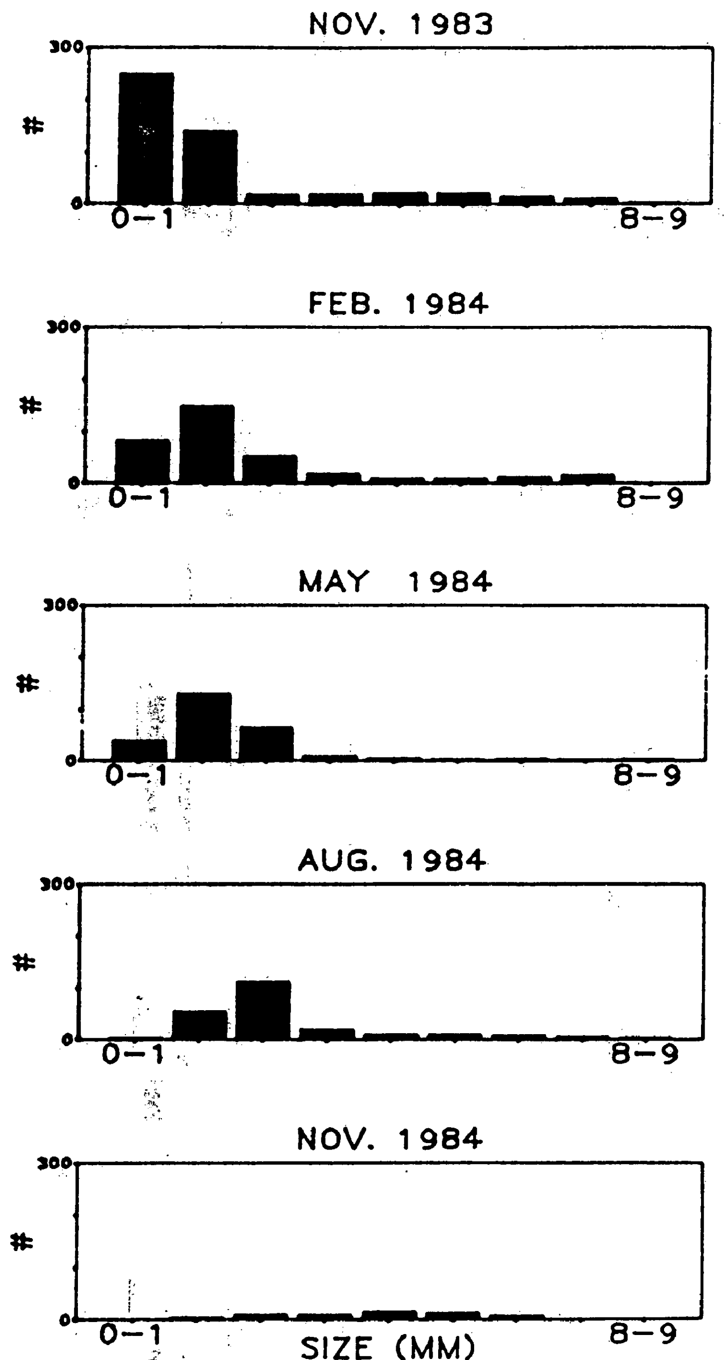
Total Production = 28.3491 g WW/m^2/yr = 1.7349 g AFDW/m^2/yr
(+/-4.4802) (+/-0.2741)

x Live Preservation Conversion (1.38) = 2.3942 g AFDW/m^2/yr
(+/-0.3784)

P/B = 4.25

Figure 7

Nephyts picta (cf. cryptomma) size-frequency histogram for WTP study site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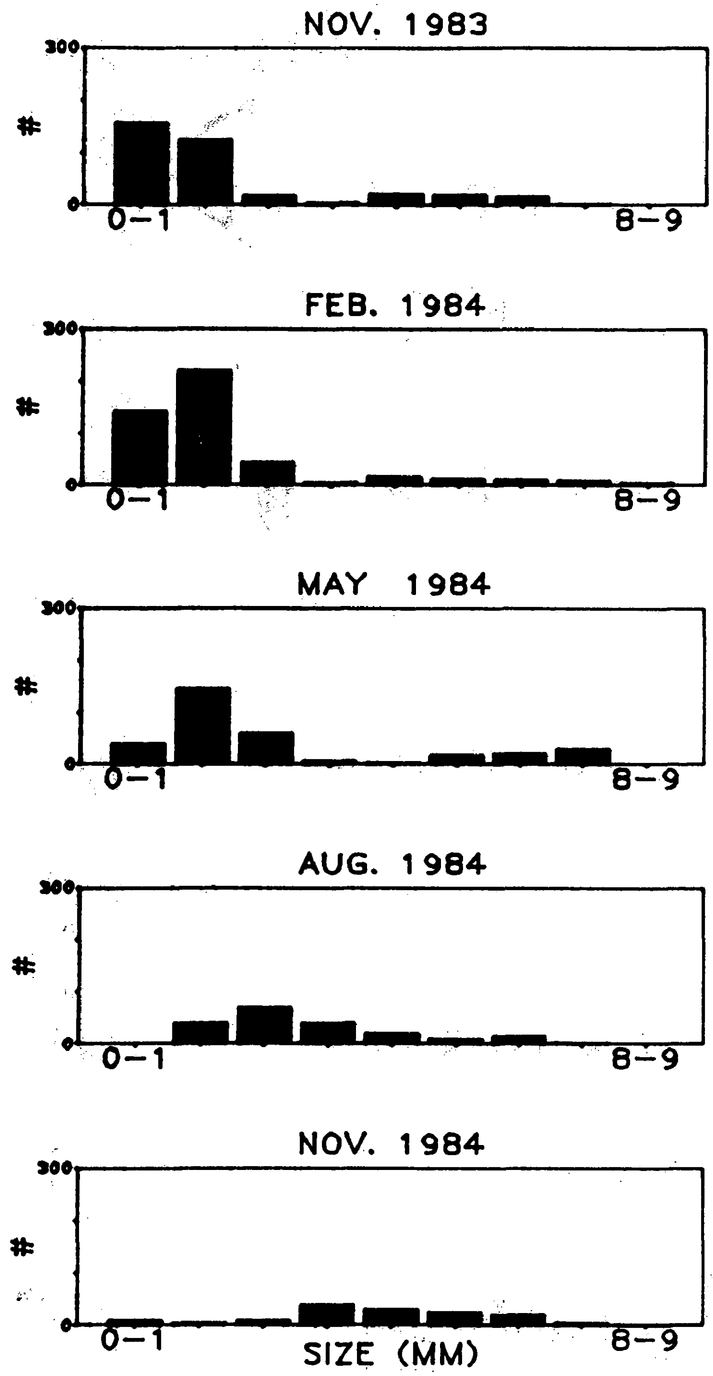
300
#
0
0-1
8-9
FEB. 1984
300
#
0
0-1
8-9
MAY 1984
300
#
0
0-1
8-9
AUG. 1984
300
#
0
0-1
8-9
NOV. 1984
300
#
0
0-1
SIZE (MM)
8-9

Figure 8

Nephyts picta (cf. cryptomma) size-frequency histogram for WAP study site


NOV. 1983
300
#
0
0-1
8-9
FEB. 1984
300
#
0
0-1
8-9
MAY 1984
300
#
0
0-1
8-9
AUG. 1984
300
#
0
0-1
8-9
NOV. 1984
300
#
0
0-1
8-9
SIZE (MM)

twice as high as the WTP site and the P/B ratio was slightly higher (4.39) (Tables 12 and 13). Mean weights at loss from each size class for the two sites were calculated using the length weight equations.

Paraprionospio pinnata

Paraprionospio pinnata was one of the most abundant animals found in the study area. Animals of this species were divided into 1 mm size groups based on cross body length from the tips of the parapodia on the first setiger segment, and the sizes ranged from 2-3 mm to 9-10 mm. There was an addition of smaller individuals into the population over the last two intervals, indicating recruitment (Figures 9 and 10). *P. pinnata* data from both study sites were very similar with respect to abundance (Figure 11), production (WTP= 0.43 +/- 0.30 g AFDW/m^2/yr; WAP= 0.44 +/- 0.13 g AFDW/m^2/yr) and P/B ratios (WTP= 3.59; WAP= 3.41) (Tables 14 and 15).

Community Production

The WAP five species secondary production estimate from pooled station data (31.52 +/-13.11 g AFDW/m^2/yr) was higher than that of the WTP site (26.42 +/-6.79 g AFDW/m^2/yr) (Table 16). The highest production values were generally on the east side of the sites (Figure 12). Total community production estimates for each station, based on polychaete and bivalve biomass and weighted P/B ratios, are listed in Table 17. The values appeared slightly higher than values derived from pooled station values for the five species. This discrepancy is likely caused by the fact that the total community production was determined

TABLE 12. *Nephtys picta* (cf. *cryptomma*) secondary production estimate for WTP study site.

Size group length (mm)	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)	Prod. (g/m^2) X 8
1-2	79	0.2	.0158				
		(+/-0.00)		-25	0.5	-.0125	-.1000
2-3	104	0.5	.0520		(+/-0.10)		+/-.0200
		(+/-0.20)		55	2.2	.1210	.9680
3-4	49	3.3	.1617		(+/-0.40)		+/-.1760
		(+/-0.50)		35	6.1	.2135	1.7080
4-5	14	11.8	.1652		(+/-1.90)		+/-.5320
		(+/-3.20)		2	12.8	.0256	.2048
5-6	12	28.0	.3360		(+/-4.70)		+/-.0752
		(+/-6.20)		3	23.1	.0693	.5544
6-7	9	36.9	.3321		(+/-4.10)		+/-.0984
		(+/-1.90)		2	37.9	.0758	.6064
7-8	7	42.5	.2975		(+/-5.00)		+/-.0800
		(+/-8.00)		3	58.0	.1740	1.3920
8-9	2	54.3	.1086		(+/-6.40)		+/-.1536
		(+/-4.80)		2	58.0	.1160	.9280
					(+/-4.80)		+/-.0768

Total Production = 6.2616 g WW/m^2/yr = 0.6155 g AFDW/m^2/yr
(+/-1.2120) (+/-0.1191)

x Live Preservation Conversion (1.84) = 1.1325 g AFDW/m^2/yr
(+/-0.2192)

P/B = 4.26

TABLE 13. *Nephtys picta* (cf. *cryptomma*) secondary production estimate for WAP study site.

Size group length (mm)	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)	Prod. (g/m^2) X 9
1-2	69	0.2	.0138				
		(+/-0.00)		-36	0.5	-.0180	-.1620
2-3	105	0.6	.0630		(+/-0.10)		+/-.0324
		(+/-0.20)		70	2.2	.1540	1.3860
3-4	35	3.0	.1050		(+/-0.40)		+/-.2520
		(+/-0.60)		10	6.3	.0630	.5670
4-5	25	8.5	.2125		(+/-0.70)		+/-.0630
		(+/-0.70)		3	13.3	.0399	.3591
5-6	22	33.1	.7282		(+/-5.60)		+/-.1512
		(+/-10.50)		6	24.3	.1458	1.3122
6-7	16	37.5	.6000		(+/-8.50)		+/-.4590
		(+/-6.50)		2	39.9	.0798	.7162
7-8	14	50.9	.7126		(+/-6.70)		+/-.1206
		(+/-6.80)		8	61.2	.4896	4.2624
8-9	6	69.6	.4176		(+/-8.10)		+/-.5832
		(+/-9.40)		4	88.9	.3556	3.2004
9-10	2	94.3	.1890		(+/-23.50)		+/-.8460
		(+/-37.5)		2	94.5	.1890	1.7010
					(+/-37.50)		+/-.6750

Total Production = 13.3423 g WW/m^2/yr = 1.3115 g AFDW/m^2/yr
(+/-3.1824) (+/-0.3128)

x Live Preservation Conversion (1.84) = 2.4132 g AFDW/m^2/yr
(+/-0.5755)

P/B = 4.39

TABLE 14. *Paraprionospio pinnata* secondary production estimate for WTP study site.

Size group length (mm)	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)	Prod. (g/m^2) X 7
2-3	46	0.3	.0138				
		(+/-0.03)		-18	0.5	-.0090	-.0630
3-4	64	0.5	.0320		(+/-0.05)		+/-.0063
		(+/-0.07)		-117	1.0	-.1170	-.8190
4-5	181	1.0	.1810		(+/-0.19)		+/-.1156
		(+/-0.30)		47	1.7	.0799	.5593
5-6	134	1.6	.2144		(+/-0.38)		+/-.1250
		(+/-0.30)		98	2.4	.2352	1.6464
6-7	36	2.8	.1008		(+/-0.80)		+/-.5488
		(+/-1.15)		15	3.3	.0495	.3465
7-8	21	4.4	.0924		(+/-1.61)		+/-.1690
		(+/-2.06)		20	4.2	.0840	.5480
8-9	1	6.0	.0060		(+/-4.03)		+/-.5642
		(+/-6.00)		1	6.0	.0060	.0420
					(+/-6.00)		+/-.0420

Total Production = 2.3002 g WW/m^2/yr = 0.2332 g AFDW/m^2/yr
(+/- 1.6115) (+/- 0.1634)

x Live Preservation Conversion (1.84) = 0.4291 g AFDW/m^2/yr
(+/- 0.3006)

P/B = 3.59

TABLE 15. <u>Paraprionospio pinnata</u> secondary production estimate for WAP study site.

Size group length (mm)	No./m^2	Mean wt. (mg)	Standing crop (g/m^2)	No. loss/m^2	Wt. at loss (mg)	Wt. loss (g/m^2)	Prod. (g/m^2) X 8
2-3	40	0.3	.0120				
		(+/-0.00)		-47	0.5	-.0235	-.1880
3-4	87	0.6	.0522		(+/-0.10)		+/-.0376
		(+/-0.20)		-32	1.0	-.0320	-.2560
4-5	119	1.4	.1666		(+/-0.18)		+/-.0461
		(+/-0.16)		50	1.7	.6800	.6800
5-6	69	1.8	.1242		(+/-0.20)		+/-.0800
		(+/-0.23)		34	2.6	.7072	.7072
6-7	35	3.0	.1050		(+/-0.42)		+/-.1142
		(+/-0.61)		0	3.3	-	-
7-8	35	3.9	.1365		(+/-0.80)		+/-.0000
		(+/-0.99)		21	4.5	.0945	.7560
8-9	14	5.7	.0798		(+/-0.76)		+/-.1276
		(+/-0.53)		12	5.7	.0684	.5472
9-10	2	7.3	.0146		(+/-2.21)		+/-.2121
		(+/-3.89)		2	6.8	.0136	.1088
					(+/-3.89)		+/-.0622

Total Production = 2.3552 g WW/m^2/yr = 0.2388 g AFDW/m^2/yr
(+/- 0.6798) (+/- 0.0689)

x Live Preservation Conversion (1.84) = 0.4394 g AFDW/m^2/yr
(+/- 0.1268)

P/B = 3.41

TABLE 16. Total study site production estimates based on trophically important species.

SPECIES	WTP PRODUCTION (g AFDW/m^2/yr)	WAP PRODUCTION (g AFDW/m^2/yr)
Euclymene zonalis	5.25 +/-1.32	2.65 +/-1.07
Chaetopterus variopedatus	18.00 +/-4.59	23.64 +/-10.96
Macoma tenta	1.62 +/-0.36	2.39 +/-0.37
Nephtys picta (cf. *cryptomma*)	1.13 +/-0.22	2.41 +/-0.58
Paraprionospio pinnata	0.42 +/-0.30	0.43 +/-0.13
TOTAL PRODUCTION	26.42 +/-6.79	31.52 +/-13.11

TABLE 17. Annual total and annual available production per station using averaged taxonomic group P/B and preservation conversion factors.

STATION	AVG. BIOMASS g AFDW/m^2	AVG. P/B	ANNUAL PRODUCTION g AFDW/m^2/yr	AVERAGE PERCENT AVAILABLE	TOTAL AVAILABLE PRODUCTION g AFDW/m^2/yr
			POLYCHAETE		
WTP01	24.66 +/-10.60	1.00	24.66 +/-10.60	12%	2.96 +/-1.27
WTP02	33.59 +/-23.51	1.00	33.59 +/-23.51	5%	1.70 +/-1.17
WTP08	31.46 +/- 3.77	1.00	31.46 +/- 3.77	6%	1.89 +/-0.23
WTP09	34.87 +/- 8.72	1.00	34.87 +/- 8.72	8%	2.79 +/-0.70
WTP17	57.66 +/-52.47	1.00	57.66 +/-52.47	6%	3.46 +/-3.15
WTP18	50.06 +/-19.02	1.00	50.06 +/-19.02	10%	5.06 +/-1.90
WAP01	6.00 +/- 3.18	1.20	7.20 +/- 3.81	19%	1.37 +/-0.73
WAP04	30.41 +/-11.85	1.20	36.49 +/-14.23	7%	2.55 +/-0.07
WAP05	34.49 +/-18.96	1.20	34.49 +/-22.76	10%	3.50 +/-2.28
WAP06	35.52 +/-17.05	1.20	42.38 +/-20.46	6%	2.54 +/-1.23
WAP09	53.33 +/-18.67	1.20	64.00 +/-22.40	4%	2.56 +/-0.90
WAP11	28.78 +/-10.65	1.20	34.54 +/-12.78	9%	3.11 +/-1.15
WAP13	19.00 +/- 4.75	1.20	22.80 +/- 5.70	15%	3.42 +/-0.86
WAP15	32.56 +/- 7.81	1.20	39.07 +/- 9.38	19%	7.42 +/-1.78
			BIVALVE		
WTP01	0.87 +/- 1.48	3.84	3.34 +/- 5.68	53%	1.77 +/- 3.01
WTP02	0.71 +/- 0.50	3.84	2.73 +/- 1.94	18%	0.49 +/- 0.35
WTP08	2.11 +/- 2.02	3.84	8.10 +/- 7.78	55%	4.46 +/- 4.28
WTP09	1.00 +/- 2.00	3.84	3.84 +/- 7.68	47%	1.80 +/- 3.61
WTP17	1.79 +/- 1.20	3.84	6.89 +/- 4.61	68%	4.68 +/- 3.13
WTP18	3.67 +/- 3.00	3.84	14.08 +/-11.51	70%	9.86 +/- 8.06

TABLE 17. Cont.

WAP01	2.24 +/- 3.81	4.25	9.52 +/-16.18	83%	7.90 +/-13.43
WAP04	0.87 +/- 1.74	4.25	3.70 +/- 7.40	39%	1.44 +/- 2.80
WAP05	2.10 +/- 2.08	4.25	8.93 +/- 8.84	74%	6.61 +/- 6.54
WAP06	1.78 +/- 1.55	4.25	7.56 +/- 6.58	50%	3.78 +/- 3.29
WAP09	2.30 +/- 1.63	4.25	9.78 +/- 6.94	38%	3.72 +/- 2.64
WAP11	2.37 +/- 1.00	4.25	10.06 +/- 4.25	46%	4.63 +/- 1.96
WAP13	0.52 +/- 0.90	4.25	2.20 +/- 3.82	75%	1.65 +/- 2.86
WAP15	2.00 +/- 0.64	4.25	8.50 +/- 2.72	39%	3.32 +/- 1.06

Figure 9

Paraprionospio pinnata size-frequency histogram for WTP study site

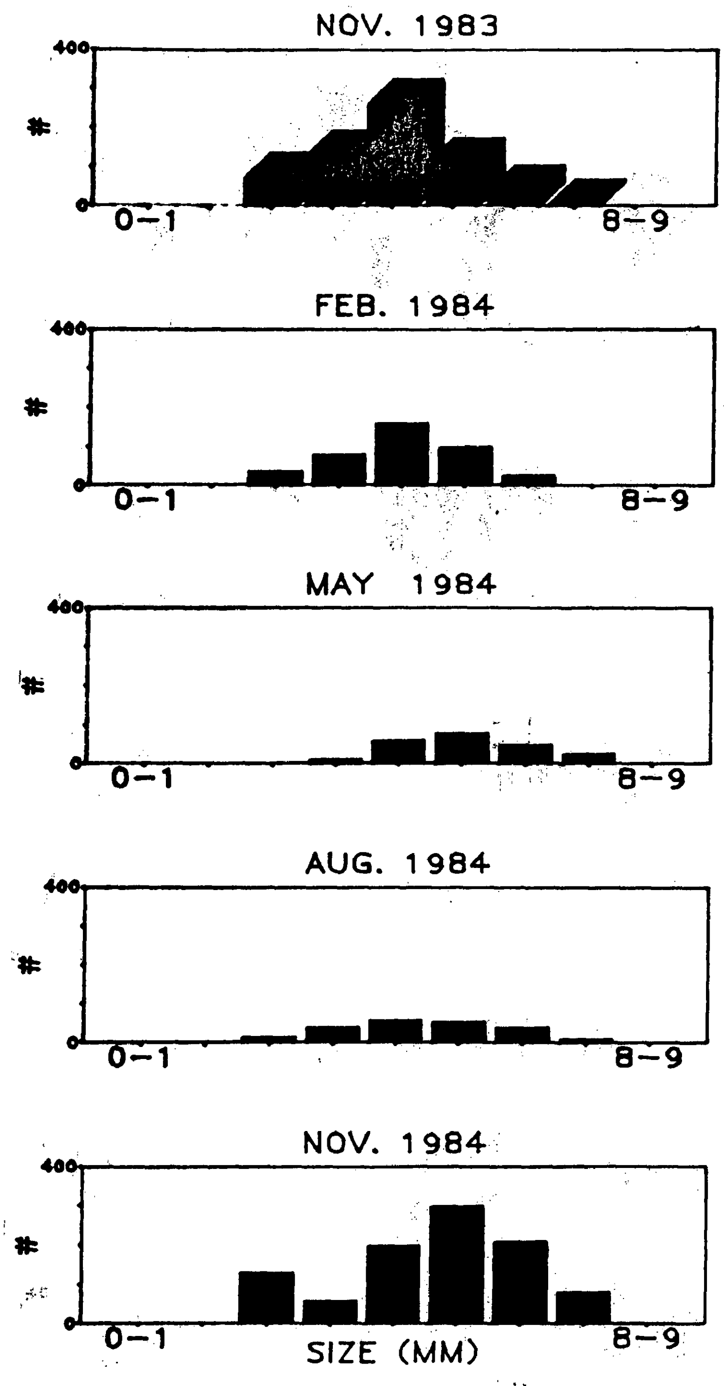

NOV. 1983
400
#
0
0−1
8−9
FEB. 1984
400
#
0
0−1
8−9
MAY 1984
400
#
0
0−1
8−9
AUG. 1984
400
#
0
0−1
8−9
NOV. 1984
400
#
0
0−1
8−9
SIZE (MM)

Figure 10

Paraprionospio pinnata size-frequency

histogram for WAP study site

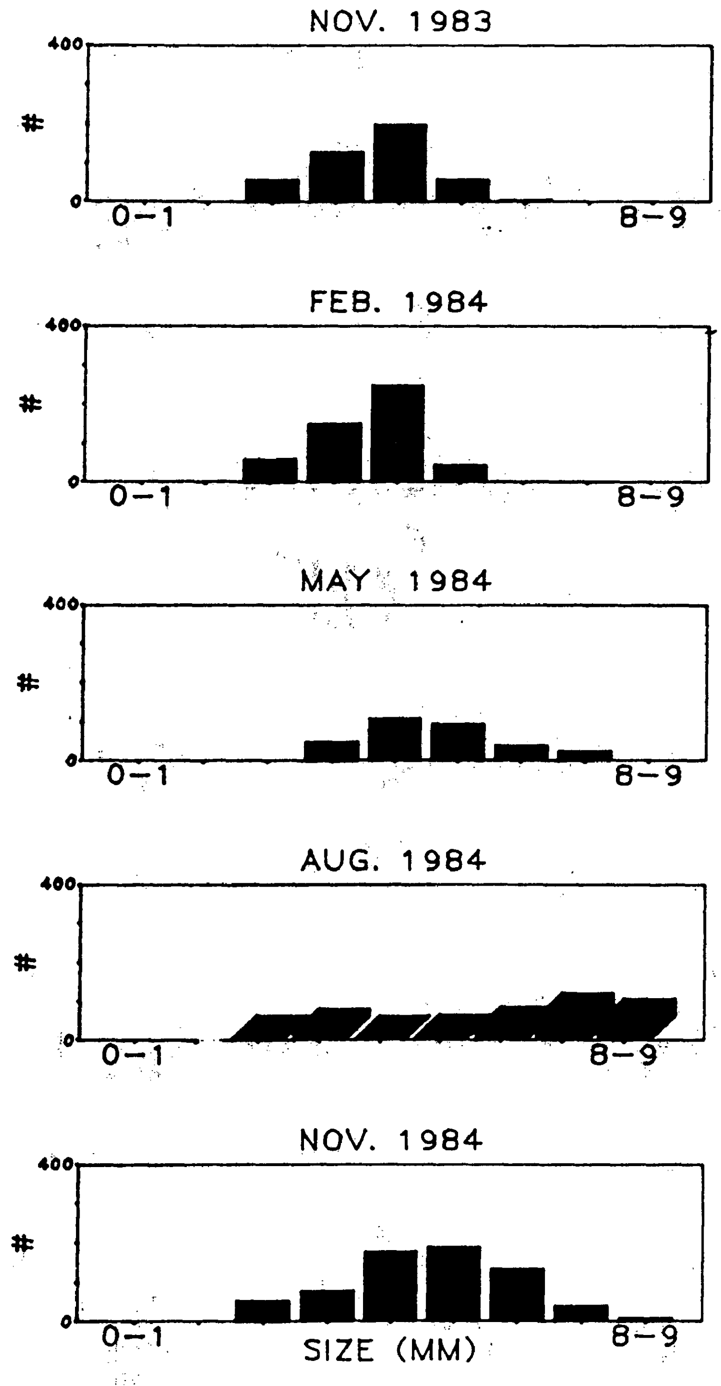

NOV. 1983
400
#
0
0−1
8−9
FEB. 1984
400
#
0
0−1
8−9
MAY 1984
400
#
0
0−1
8−9
AUG. 1984
400
#
0
0−1
8−9
NOV. 1984
400
#
0
0−1
8−9
SIZE (MM)

Figure 11

Paraprionospio pinnata abundance

Paraprionospio pinnata

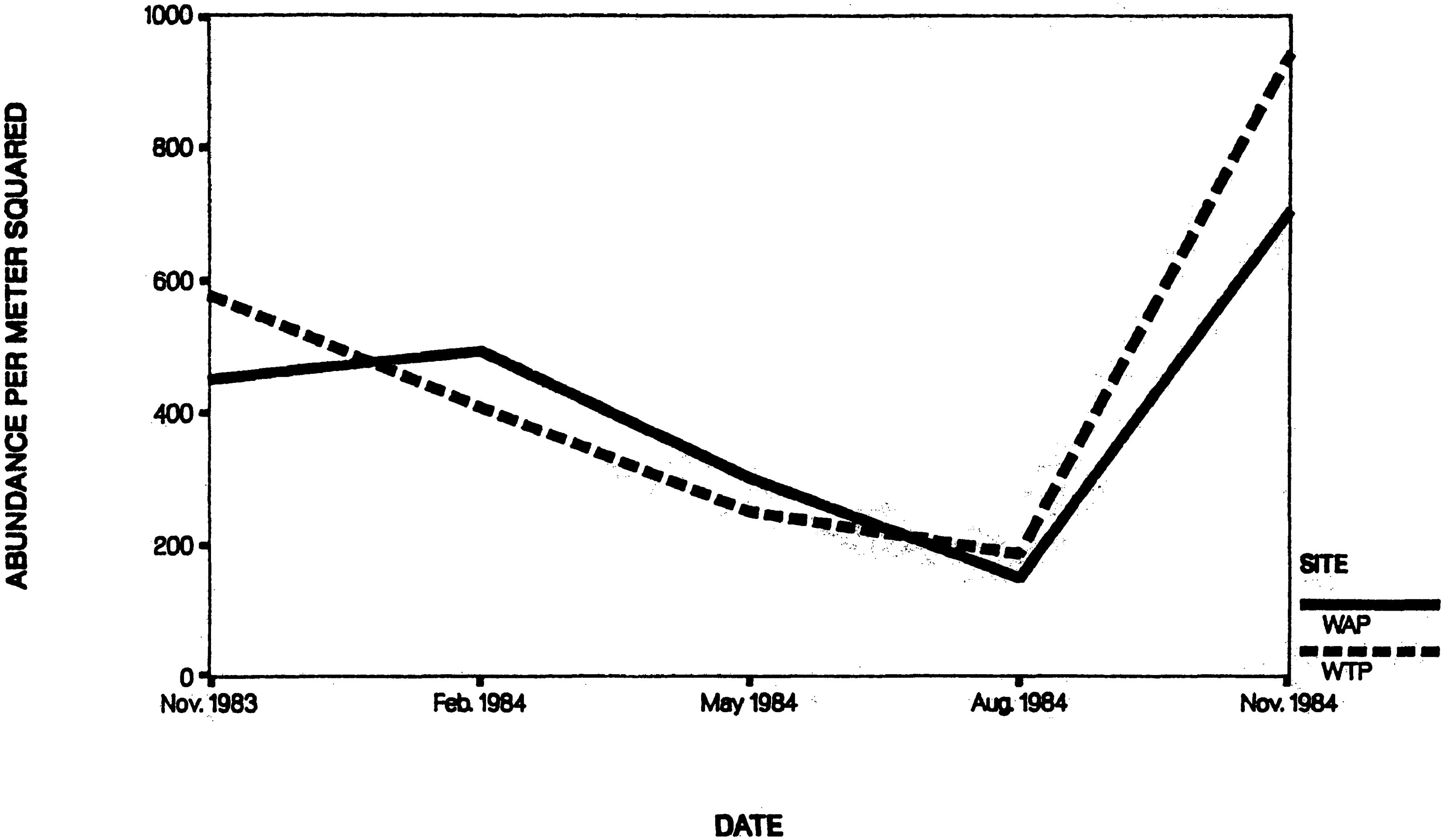
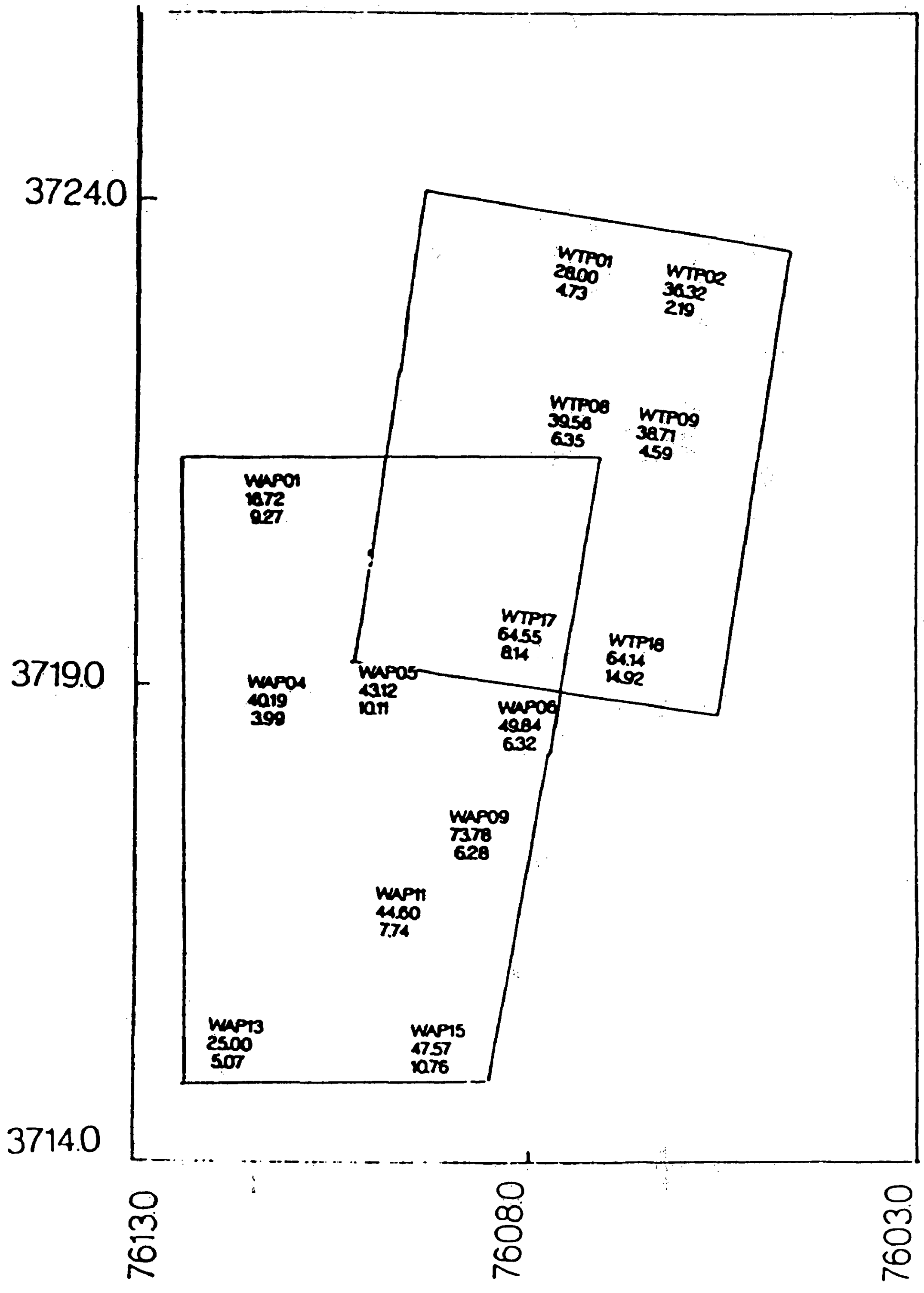


Figure 12

STATION PRODUCTON

TOP VALUE: TOTAL PRODUCTION (g AFDW/m^2/yr)

BOTTOM VALUE: AVAILABLE PRODUCTION (g AFDW/m^2/yr)



3724.0
3719.0
3714.0
7613.0
7608.0
7603.0
WTP01 28.00 4.73
WTP02 36.32 2.19
WTP08 39.56 6.35
WTP09 38.71 4.59
WAP01 16.72 9.27
WTP17 64.55 8.14
WTP18 64.14 14.92
WAP04 40.19 3.99
WAP05 43.12 10.11
WAP06 49.84 6.32
WAP09 73.78 6.28
WAP11 44.60 7.74
WAP13 25.00 5.07
WAP15 47.57 10.76

using total estimated live biomass of a core, not just the biomass of the five dominant species. The five species accounted for approximately 80 percent of the total biomass.

Available Productivity

Production available for transfer to higher trophic levels was estimated by multiplying the weighted P/B ratios by the average annual polychaete or bivalve biomass value per station found in the upper two centimeters (Table 17). Values ranged from 2.19 +/-1.52 g AFDW/m^2/yr at WTP site 2 to 14.92 +/-9.96 g AFDW/m^2/yr at WTP site 18 (Figure 12). The available production values follow the same general spatial trend as seen in the total community production values, with higher values generally lying on the eastern sides of the study sites, although the trend is not as distinct (Figure 12). The high value shown at WTP station 09 may be accounted for by a very high bivalve biomass, caused by a high number of the mussel <u>Mytilus edulius</u> Linnaeus found in a core from the August cruise.

DISCUSSION

Benthic invertebrate macrofauna certainly play an important role in the transfer of energy from primary producers to higher trophic levels (Steele, 1974; Mills and Fournier, 1979). When disruption or destruction of the benthic community may occur due to anthropogenic activities, an analysis of the resource value of the community and the potential effects on higher trophic levels this energy loss may cause should be estimated. This estimation may best be made using a detailed secondary production study of the trophically important benthic species.

Secondary production estimation studies are very labor intensive, therefore cost-efficient assessments of environmental impacts should concentrate on trophically or otherwise important species. In this case, after looking at species abundances and biomass data (Diaz et. al., 1985) and area demersal feeding fish stomach contents data (Kendall et al., 1985), four species were selected as trophically important species in the Wolf Trap region of the bay, as well as important with respect to community structure: the polychaetes *Euclymene zonalis*, *Nephtys picta* (cf. *cryptomma*), *Paraprionospio pinnata*, and the tellinid bivalve *Macoma tenta*. These four species were assumed to be representitive of the food web link between the benthic community and organisms of higher trophic levels, in this case specifically demersal feeding fish.

Production estimations were also made for the polychaete Chaetopterus variopedatus. While this species is apparently not important in terms of direct energy transfer to higher trophic levels, it was a large contributor to community biomass in the area. The tube of C. variopedatus was also the main substrate for attachment of epifaunal species. C. variopedatus may alter the resource value of a community because it provides habitat or refuge for other species (Schaffner, 1987). Because of the high biomass of this species, production estimation will allow for a more reliable community production comparison with other benthic communities.

Secondary production estimates are best made with frequent sampling, weekly or monthly, in order to catch recruitment peaks, rapid growth of young individuals, and rapid mortality of short-lived species. However, the P/B ratios of the species in this study indicate that they all possess life spans of at least one year (Mann, 1967). According to Mann, species with more than one cohort per year should have a P/B ratio of approximately 10, while species that live for one year should have a ratio of around 5. From the P/B ratios of species from this study, it appears that none of these species are multivoltine (possessing more than one cohort per year). The sampling scheme employed thus will allow adequate sampling of relatively long lived species such as the five species used in this study.

The benthic communities found in the two study areas were basically similar in species composition, species percentages and other community parameters. The fauna of the region were representative of an advanced, mature successional stage community (Sensu Rhoads et al., 1977). The dominants were large, long-lived species which characterize an equilibrium community. There was a general gradual decline in abundances for many of the species over the year. The two major tube-builders in the area, Euclymene zonalis and Chaetopterus variopedatus, declined in numbers over the year. The drop in numbers of C. variopedatus, which builds a "U" shaped tube, was possibly due to intense winter crab dredging in the area by Chesapeake Bay watermen (Linda Schaffner, per. comm.), the natural decline of a single age class dominated population, or some unknown intense bottom destabilization event. The change in these species numbers probably lead to declines in other species associated with its tube. This phenomenon has been shown to occur around polychaete tubes (Fager, 1964; Woodin, 1978 and Luckenbach, 1986). Macoma tenta declined in numbers over the year while showing a small recruitment peak in the winter of 1984, and then declining after the recruitment event. Nephtys picta (cf. cryptomma) and juvenile Nephtydae, which are in all probability juvenile N. picta (cf. cryptomma) but could not be identified to species level, showed recruitment during fall 1983 and winter 1984 sample dates, and then declined. Paraprionospio pinnata exhibited fall recruitment.

The low P/B ratio of Euclymene zonalis over the year indicate that the species is long-lived with a life span greater than one year (Mann, 1967; Robertson, 1979). The mean weight/individual for E. zonalis for the different cruise dates showed the same trend at both areas. Mean weight values increased from fall 1983 until fall 1984, then exhibited a large drop over the last sample interval, yet the abundance remained relatively constant over time (Figure 2). The WTP values were higher than the WAP values. The large weight loss, which lead to negative production over the last sample interval, may possibly be explained by unusually low dissolved oxygen concentrations of the bottom water in the area, which decreased to a low point in the fall of 1984 (Seliger et al., 1985). Low D.O. concentrations may force the animals higher up in the sediment, exposing more of the organism to possible predation by bottom-feeding predators.

The production estimates for the bivalve Macoma tenta and the polychaete Euclymene zonalis may be underestimated due to the ability of these organisms to regenerate body parts that are lost to predators. Siphons of tellinid bivalves are a prime component of the diet of many bottom feeding fish (Macer, 1967; Edwards and Steele, 1968; Kuipers, 1977; de Vlas, 1979), as are tail segments of maldanid polychaetes (Mangum, 1964) These species are generally able to regenerate the lost body parts (Mangum, 1964; Trevallion et al., 1970; De Vlas 1985). De Vlas (1985) determined that up to 50% of the Tellinid species Macoma balthica's (L.) annual secondary production may be accounted for by siphon regeneration. While M. balthica and M. tenta are not the same species, the implication is clear. Regeneration of body parts may lead to large amounts of biomass production which quarterly sampling may not adequately measure.

The total annual secondary production of the dominant species at the WAP study site was 31.52 +/-13.11 g AFDW/m^2/yr and 26.42 +/-6.79 g AFDW/m^2/yr at the WTP study site. Translated to the entire study area, 1544.48 +/- 642.39 metric tons of ash-free dry weight were produced over the year for the 49 km^2 WAP study site and 924.70 +/- 237.65 metric tons over the year for the 35 km^2 WTP study site.

The differences in both total and available production per unit area derived from use of weighted P/B ratios and biomass values for polychaetes and bivalves between the two study sites is not significant (total production: t = 1.23, 2-tailed probability = 0.846; available production: t = 3.32, 2-tailed probability = 0.149). These statistics indicate that the two study sites have similar secondary production potential per unit area, and that disposal of dredge disposal materials at either site should effect higher trophic levels in a similar fashion.

The study sites appeared to be as productive or more productive than other sites where secondary production studies have been conducted. A dominant species production averaged for the two sites of 28.7 g AFDW/m^2/yr and a total community production value averaged for the two sites of 43.7 g AFDW/m^2/yr will be used as reference points for comparisons with various studies in aquatic habitats.

In a Danish stream community, Mortensen and Simonsen (1983) estimated a production value of 1.1 g AFDW/m^2/yr for all species present. Evans (1983) estimated dry weight values of 26.5 g/m^2/yr and 20.7 g/m^2/yr for all macrofauna from a Swedish fjord. Wolf Trap community and dominant species production estimates are higher than all of these estimates. Comparisons with these non-estuarine habitats point out that the estuarine benthic environment is one of the most productive habitats in the aquatic realm.

Wolf Trap production values are greater than or similar to other bays and estuaries. Sanders (1956) in a _Nephtys incisa_ (Malmgren)/_Yoldia limulata_ (Say) community from Long Island Sound calculated a production value of 29.6 g AFDW/m^2/yr. Off the coast of England, Buchanan and Warwick (1974) estimated yearly production at 1.43 g AFDW/m^2/yr for 18 dominant species. Warwick and Price (1975), in a Macoma intertidal community, estimated community production at 13.31 g AFDW/m^2/yr. In Carmarthen Bay, South Wales, using 15 dominant species, Warwick et al. (1978) estimated production at 25.8 g AFDW/m^2/yr. Howe and Leathem (1984) derived production estimates as high as 46.5 g AFDW/m^2/yr for all species at the mouth of Delaware Bay. In a Chesapeake Bay submerged aquatic vegetation bed, dominant species production was calculated to be 30.94 g AFDW/m^2/yr (Diaz and Fredette, 1982). All of these production estimates are very similar to the corresponding production estimates produced in this study. All of these production estimates point out the relative productivity of estuarine habitats compared with other aquatic habitats. The values derived from the Chesapeake Bay are equivalent to values of most other estuaries.

One purpose of this study was to determine the effects dredge disposal could have on organisms in higher trophic levels. Several studies have approached this type of problem, but few have tried to partition the community production into fractions available and unavailable to the higher trophic levels. Averaged available production for the two areas were determined using the available station production (Figure 12). Available station biomass for bivalves was determined by multipling bivalve biomass values from the upper two centimeters by the P/B ratio of Macoma tenta. Available station production for polychaetes was determined by multiplying the polychaete biomass value for the upper two centimeters of the station by an average P/B ratio weighted heavily in favor of the high biomass species Euclymene zonalis (Tables 3 and 4). Because Chaetopterus variopedatus was rarely found in the upper two centimeters, this species does not contribute to available productivity estimates. The other four species were all found frequently in the upper sediment layer. A total available production in the upper two centimeters for the dominant species of 6.82 +/- 5.44 g AFDW/m^2/yr at the WTP site and 7.44 +/- 6.45 g AFDW/m^2/yr at the WAP site was found. These values translate to 238.7 +/- 190.4 metric tons of ash-free dry weight biomass production per year at the WTP site and 364.5 +/- 316.1 metric tons of ash-free dry weight biomass production per year at the WAP site. These are the biomass production values from the two study sites that appear to be directly available to the upper trophic levels.

The value of this production to demersal feeding fish stock in the Chesapeake Bay may be roughly estimated. Transfer efficiencies give the percentage of annual production of a trophic level that is expected to be transferred to the next trophic level. A transfer efficiency of 15 % (Collie, 1987) will be used in this study. Applying this transfer efficiency to benthic secondary production values we can estimate that benthic invertebrates in these areas may support demersal fish production of 35.6 +/- 28.6 metric tons of ash-free dry weight for the WTP study area and 54.6 +/- 47.4 metric tons of ash-free dry weight for the WAP study area.

Given these estimates that available benthic prey species from the two study sites may support an annual fishery production of roughly 35 to 55 metric tons, dredge disposal activities have the potential to cause large declines in fish production, by effecting the benthic food base. The degree to which fish production may be effected by disposal activities depend on two factors. First, the extent to which the fish community is food limited is important. If the fishery is not food limited, even after dredge material disposal, then no change in fish production would be evident. If, on the other hand, the fish population is food limited before the disposal event, then the potential exists for large losses of fish production. Second, the rate of recovery of the community is important. If the benthic community is able to rebound rapidly to its original state, then little or no effect on the fish population may be noticed. Yet if the benthic community can not recover or recovers slowly from disposal activities, fish productivity may decline. Rhoads et al. (1977) reported that three months after dredge disposal, a disposal area off the coast of Connecticut was barren of macrofauna. Recruitment of new individuals in the study of Rhoads et al. (1977) started during the second three months postdisposal, and after a year the community appeared to have recovered. These recovery times are dependent on the type and volume of the disposal material, physical aspects of the overlying water column, rates of benthic settlement and survival and the type of organism recruited into the area (Mauer et al., 1981). All of these factors will act on the actual degree to which fish production may decline due to dredge disposal activities.

This study has shown that a large amount of biomass was produced by benthic organisms at the two study sites. The potential exists that disturbance of the benthic community by dredge material disposal may have a negative effect on the bottom-feeding fish population in the area. What the magnitude of the effect will actually be remains to be seen. An answer to this question along with the information generated from this study would allow for a much better understanding of how disturbance of the benthos affects production and trophic links in an estuarine ecosystem.

CONCLUSIONS

1. The dominant benthic macrofauna of the Wolf Trap region of the Chesapeake Bay were responsible for an annual production of 26.42 +/-6.79 g AFDW/m^2/yr at the Wolf Trap Primary (WTP) study site and 31.52 +/-13.11 g AFDW/m^2/yr at the Wolf Trap Alternate (WAP) study site.

2. Translated to the the entire study area, secondary production of the dominant benthic species would account for 924.70 +/- 237.65 metric tons of ash-free dry weight biomass per year at the WTP study site and 1544.48 +/- 642.39 metric tons of ash-free dry weight biomass per year at the WAP study site.

3. Production assumed to be available for transfer to bottom feeding fish populations was estimated to be 6.82 +/- 5.44 g AFDW/m^2/yr at the WTP site and 7.44 +/- 6.45 g AFDW/m^2/yr at the WAP site.

4. Available secondary production of the benthic community would account for 238.7 +/- 190.4 metric tons of ash-free dry weight biomass per year at the WTP study site and 364.5 +/- 316.1 metric tons of ash-free dry weight biomass per year at the WAP study site.

5. Using a transfer efficiency of 15%, the WTP benthic community could support fish production of 35.8 +/- 28.6 metric tons of ash-free biomass over a year and the WAP benthic community could support fish production of 54.6 +/-47.4 metric tons of ash-free biomass over a year.

6. The secondary productivity of the benthic communities of the two Wolf Trap study sites are of equal or higher magnitude than estimates of secondary productivity of other aquatic habitates.

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