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# Zooplankton communities in Chesapeake Bay seagrass systems

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# ZOOPLANKTON COMMUNITIES IN
# CHESAPEAKE BAY
# SEAGRASS SYSTEMS

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

by
Cathy E. Meyer
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# APPROVAL SHEET

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

Master of Arts

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# ABSTRACT

Zooplankton abundance, species composition, and community biomass were determined in a lower Chesapeake Bay seagrass meadow and an adjacent unvegetated area. Sampling was conducted at night monthly from March 1979 to April 1980 and during the day in May and August 1979 using a bow-mounted pushnet rigged with two-18.5 cm nets (0.202 mm mesh). Data were analyzed temporally, in terms of seasonal and diel availability, and spatially, in terms of vegetated versus unvegetated areas.

The zooplankton assemblage consisted of obligate (holo- and mero-) and facultative (demersal) planktonic forms. Two distinct seasonal communities were identified, a winter-spring assemblage peaking in March and a summer-fall assemblage peaking in August. Holoplankton, predominantly calanoid copepods, accounted for 70-90% of the zooplankton total of both assemblages.

Diel changes in zooplankton abundance varied among taxa. Copepods, most demersal taxa, and the larvae of fish, polychaete and pelecypod species were more abundant at night compared to day collections, usually by 1-2 orders of magnitude. Barnacle, gastropod, and decapod larvae abundances were similar between diel periods.

Holoplankton and meroplankton exhibited little spatial variability; abundance and species composition were uniform between vegetated and unvegetated stations. The holoplanktonic and meroplanktonic assemblages sampled in this study closely resembled published descriptions of deeper, open water zooplankton populations in the lower Chesapeake Bay. In contrast, demersal plankton defined in this study as resident members of the benthic substrate which emerge periodically into the water column, were more abundant and comprised a greater percentage of the zooplankton total at stations associated with seagrass. In particular, significantly higher numbers of amphipods, cumaceans, and isopods were collected in vegetated areas. Demersal taxa are important components of zooplankton communities in shallow-water seagrass systems.

Zooplankton biomass (AFDW) values were generally higher and more variable than those reported for the lower Chesapeake Bay proper. Within shallow-water seagrass systems, conventional gross community biomass estimates may not reflect actual trends in spatial or temporal distribution of zooplankton. Detritus and transient demersal taxa may significantly distort community biomass values.

# ZOOPLANKTON COMMUNITIES IN
# CHESAPEAKE BAY SEAGRASS SYSTEMS

# INTRODUCTION

Zooplankton composition, abundance and seasonality have been described and community structure characterized for the lower Chesapeake Bay in recent years (Jacobs, 1978; Grant and Olney, 1979; 1982). Using relatively large research vessels and standard sampling gear, these studies were limited to deeper, open Bay waters. The zooplankton assemblage of nearshore, shallow-water areas (<2 m) in the lower Bay is poorly known, particularly in and around beds of submerged aquatic vegetation (SAV).

Studies conducted in North Carolina estuaries have indicated that low standing stocks of zooplankton are typical for shallow embayments (Williams, et al., 1968). These authors concluded that the importance of zooplankton in the food chain decreases as the average depth of the water column decreases. This supports conclusions by Johannes et al. (1970) and Glynn (1973) that little energy input is derived from zooplankton within highly productive shallow-water ecosystems. Conversely, other researchers have visually observed swarms of planktonic organisms (> $10^6$ individuals per $m^3$), particularly copepods, over coral reefs and seagrass beds (Emery, 1968; Fenwick, 1978; Hamner and Carlton, 1979) and concluded that zooplankton had been numerically underestimated and may represent a significant source of energy to such systems. In seagrass systems, wave energy and current velocity are significantly reduced by the physically complex structure of the seagrass blades (Wayne, 1974). Swarming or concentrations of actively orienting zooplankton may be facilitated by these hydrodynamic changes.

Shallow-water zooplankton communities are characterized by obligate (holo- and meroplankton) and facultative (demersal plankton) components (Emery, 1968; Sale et al., 1976; Alldredge and King, 1977). Swarms or high density aggregations are predominantly composed of obligate zooplankton species. Most obligate plankters, including copepods, cladocerans, and many species of decapod zoea, originate in deeper adjacent waters and are not resident members of the shallow-water community (Hobson and Chess, 1978; 1979). Certain taxa traditionally regarded as resident members of the benthic substrate (i.e. amphipods, cumaceans, polychaetes) emerge periodically and move into the water column, especially at night (Porter and Porter, 1977; McWilliam et al., 1981). These facultative forms, or demersal plankters, exhibit diel vertical migration patterns which are species-specific (Alldredge and King, 1980).

Both obligate and facultative zooplankters serve as prey items for a number of adult planktivorous fish species and other invertebrates (Hobson and Chess, 1976; Robertson and Howard, 1978). In addition, studies conducted in the Newport River estuary, North Carolina demonstrated that zooplankton abundance may control the survival of specific postlarval fishes during their transition to juveniles (Thayer et al., 1974; Kjelson and Johnson, 1976). Since shallow-water seagrass systems are considered important nursery grounds for a variety of postlarval and juvenile fishes (Reid, 1954; Kikuchi, 1961; Carr and Adams, 1973; Adams, 1976), the input of zooplankton may represent a significant addition of energy to these areas with respect to the feeding of postlarval fishes.

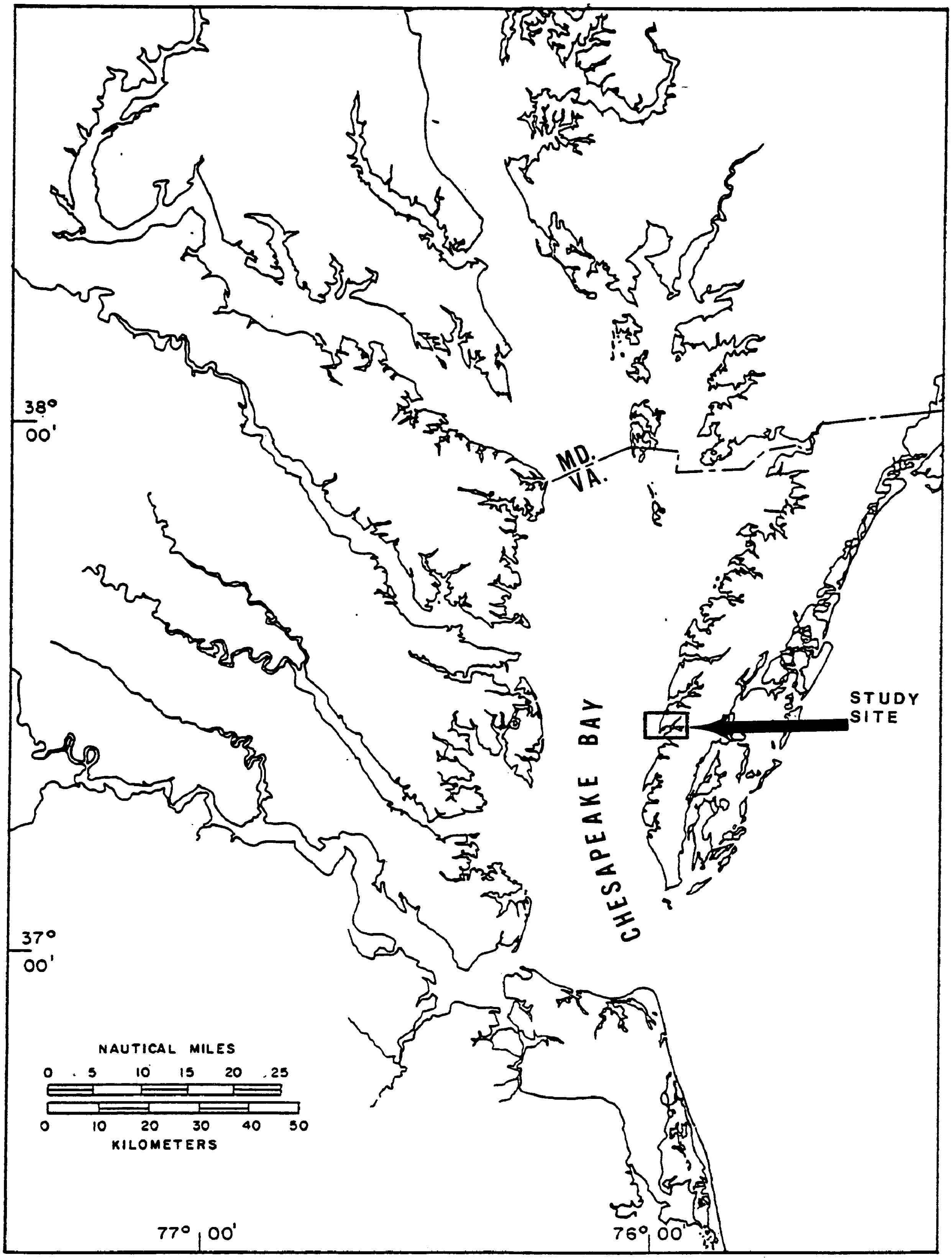
The purpose of this study was to characterize the general zooplankton assemblage within a shallow-water Chesapeake Bay seagrass bed. The abundance and species composition of obligate and facultative zooplankton within and adjacent to a bed of submerged aquatic vegetation were analyzed temporally, in terms of seasonal and diel availability, and spatially, in terms of vegetated vs non-vegetated areas.

# MATERIALS AND METHODS

The study site was located on bayside Eastern Shore of Virginia, approximately 37°25'N latitude and 75°59'W longitude, in an area locally known as Vaucluse Shores (Figure 1). A bed of submerged macrophytes, 140 hectares in area, was present, bounded by land to the east, a sandbar to the north and west, and the deep channel entrance of Hungars Creek to the south (Figure 2). Vegetation maps of this bed (Wetzel et al., 1981) indicated the presence of mixed stands as well as pure stands of *Zostera marina* and *Ruppia maritima*. Dye studies conducted in July 1978 prior to the initiation of this study, demonstrated that flooding water enters the bed from the deep channel of Hungars Creek, moving directly northward, then floods the shoaler areas to the east (Wetzel, pers. comm.). Water ebbs from the bed in the opposite direction; average tidal amplitude is about 1.0 m.

Two sampling stations, designated nominally as Ruppia and Zostera, were established within the seagrass system. The nominal Zostera station was located at the southern end of the bed, over a pure stand of *Z. marina* and was in close proximity to the deeper channel of Hungars Creek. The Ruppia station was positioned near the center of the bed over a mixed stand of *Z. marina* and *R. maritima*. This station was approximately 500 m north of the Zostera station, thus further from the deeper water channel and source of flooding water. Average high

Figure 1. Location of study area in lower Chesapeake Bay.



38°
00'
37°
00'
MD.
VA.
CHESAPEAKE BAY
STUDY
SITE
NAUTICAL MILES
0 5 10 15 20 25
0 10 20 30 40 50
KILOMETERS
77° 00'
76° 00'

FIGURE 1

Figure 2. Sampling stations at the Vaucluse Shores study site. SAV indicates coverage by submerged aquatic vegetation.

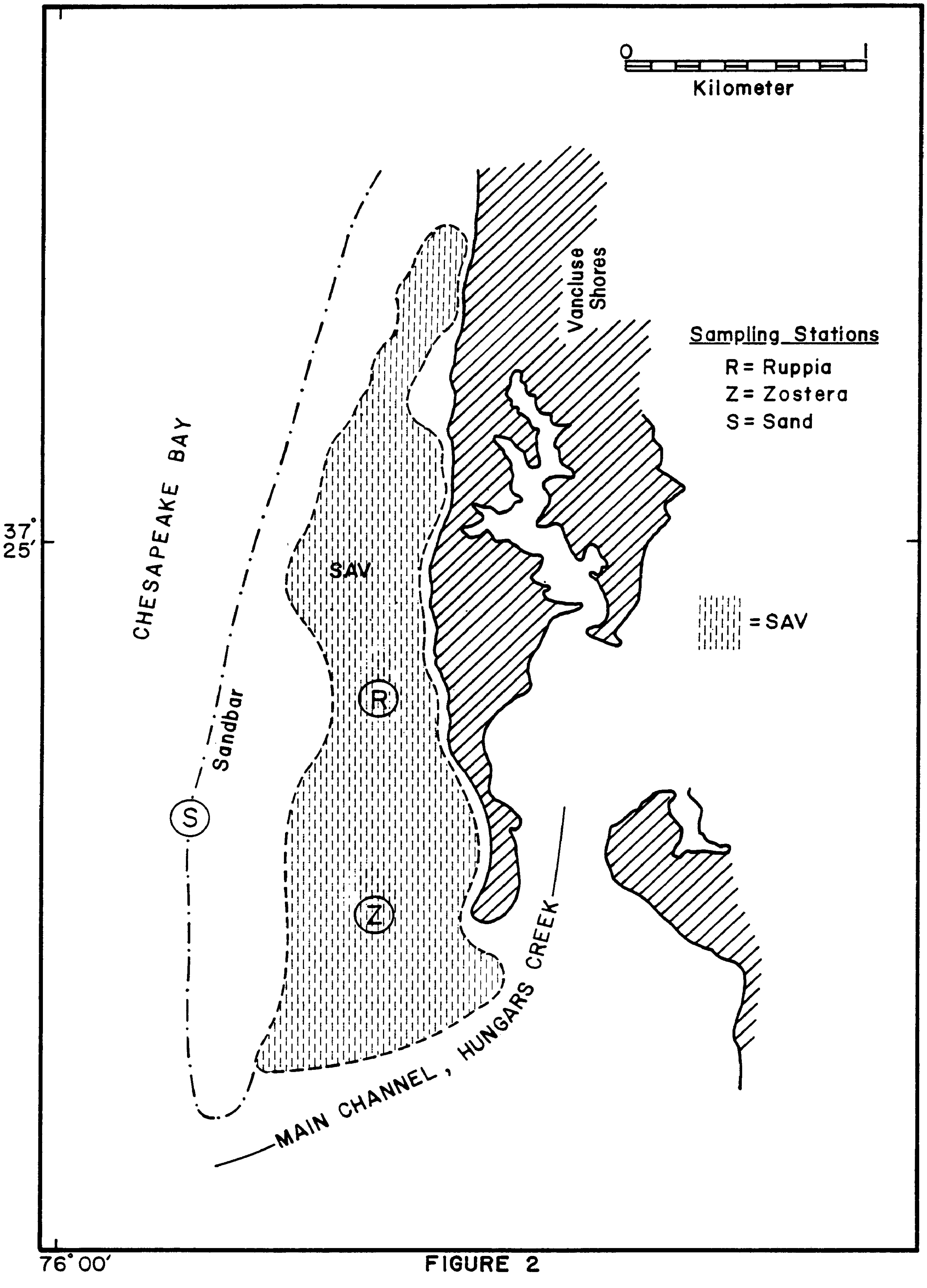

0
1
Kilometer
Vancluse Shores
Sampling Stations
R = Ruppia
Z = Zostera
S = Sand
CHESAPEAKE BAY
37° 25′
SAV
R
Sandbar
S
Z
= SAV
MAIN CHANNEL, HUNGARS CREEK
76° 00′

FIGURE 2

tide depth was 1.5 and 1.2 m at the Zostera and Ruppia station, respectively. A third station, designated as Sand, was established approximately 800-1000 m west of the seagrass bed across the sandbar in an unvegetated area; average high tide depth was approximately $\geq$ 2.0 m.

Monthly sampling was conducted at night from March 1979 to April 1980 at all three stations during high tide. The depth required for gear deployment (minimum of 1.0 m) necessitated sampling as close to high tide as possible. The diversity and abundance of zooplankton, particularly facultative forms is generally higher at night (Robertson and Howard, 1978; Alldredge and King, 1980), therefore sampling was undertaken at night. In addition day samples were taken during high tide in May and August 1979 to assess diel variability.

Standard sampling gears such as towed, bridled nets are unsatisfactory for shallow-water environments (Miller, 1973). Turbulence created by the vessel, propeller, and bridles may result in increased gear avoidance by some organisms (Kriete and Loesch, 1980). In addition, silt, detritus and vegetation may be suspended or dislodged resulting in "dirty" samples which are quite difficult to analyze quantitatively and may be "contaminated" with benthic organisms which are also dislodged. To avoid these difficulties a bow-mounted pushnet (Figure 3) was utilized (Merriner and Boehlert, 1979). The frame was constructed of 1/2" diameter galvanized pipe, rigged with a one-meter ichthyoplankton net (0.505 mm mesh) and two-18.5 cm zooplankton nets (0.202 mm mesh). Samples from the 0.505 mm ichthyoplankton net were analyzed by J. Olney (VIMS) and the data presented in Brooks et al.

Figure 3. Pushnet sampling apparatus. A. Frame dimensions.
B. Schematic diagram.

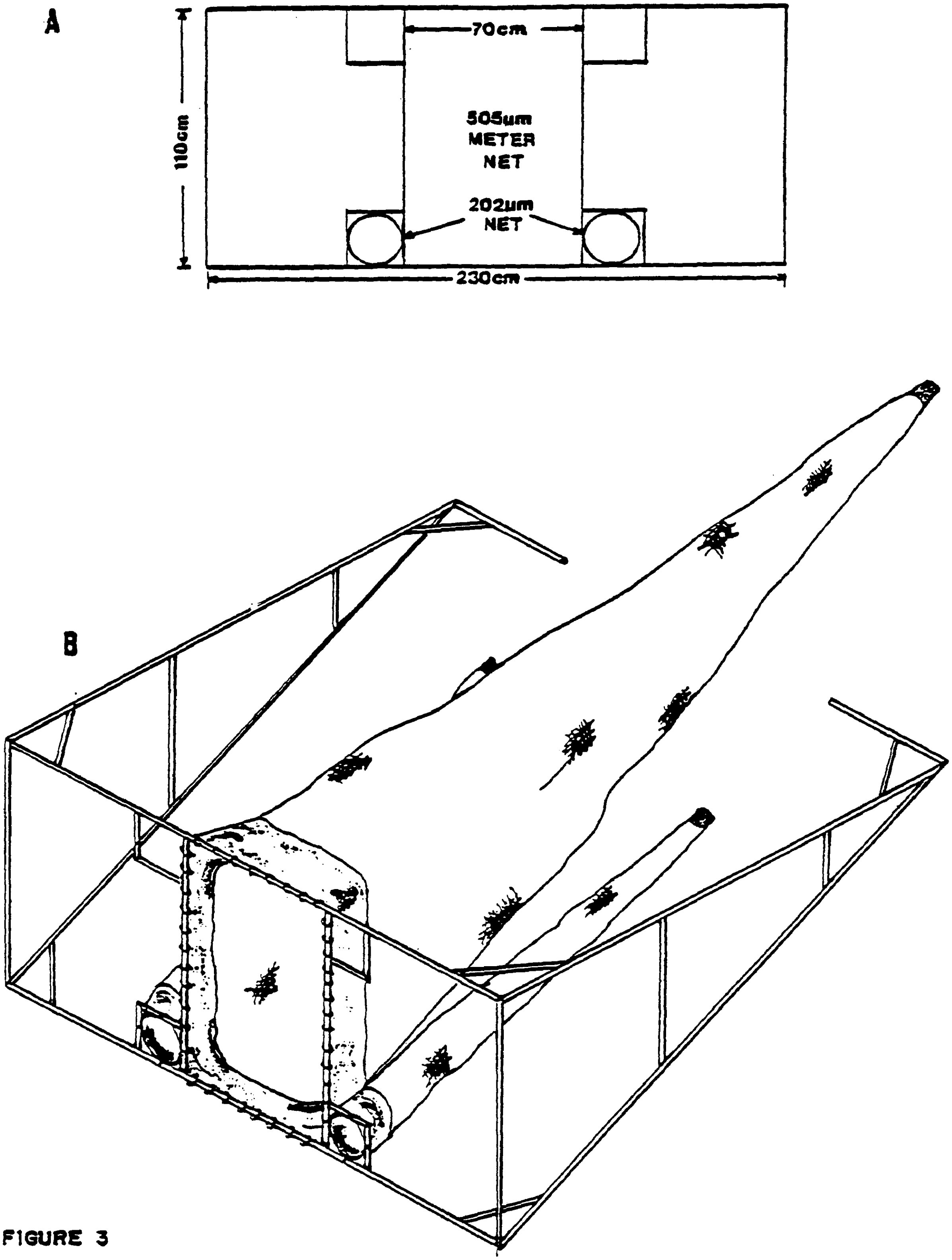


FIGURE 3

(1981). One of the 0.202 mm zooplankton samples from each tow was used for taxonomic analysis, the other for biomass determination. The left zooplankton net was equipped with a calibrated General Oceanics flowmeter to quantify volume of water filtered; it was assumed that both zooplankton nets sampled equal volumes. Averaged over the study period, the mean volume of water filtered by a zooplankton net was 5.77 $m^3$ ($\pm$ 1.7$m^3$ standard deviation) during a 3-minute tow.

The pushnet apparatus was deployed over the bow of a 5.8 m outboard craft and pushed for three minutes at a boat speed of approximately 1.5 knots (2.8 km/hour). The zooplankton net fished at a depth of 1-meter from the surface, while the ichthyoplankton net fished the entire area surface to 1-meter deep (Figure 3). During periods of high ctenophore abundance, tows were reduced to two minutes to decrease clogging. Two replicates were taken in each habitat each month. The presence of the shelled gastropod, Bittium varium, in either of the nets after a tow indicated that the nets had brushed attached live Zostera or Ruppia. Such samples were considered contaminated and discarded. The depth of the net was then raised and the tow repeated.

The left zooplankton net sample was rinsed with distilled water, placed in a whirlpak bag and frozen on dry ice to be used for biomass analysis. Incidentally collected pieces of dead Zostera, flotsam, or other nonbiological material was removed from biomass samples in the field prior to the treatment described above. The other sample was preserved with 5% buffered formalin for future taxonomic analysis.

Between replicates at each station, water was collected by bucket for surface measurements of temperature, salinity and dissolved oxygen (DO). Temperature was measured with a mercury thermometer. Salinity and DO bottle samples were returned to the lab and analyzed using a Beckman Induction Salinometer and a Modified Winkler Titration method, respectively. Water depth was recorded prior to each tow.

In the laboratory, biomass samples were lyopholized, weighed, ashed in a muffle furnace at 500°C for five hours and reweighed. Dry weight, ash weight, and ash-free dry weight were determined. The taxonomic samples were initially sorted for all rare, generally larger organisms. For smaller, more abundant groups, each sample was quantitatively split using a VIMS splitter (Burrell et al., 1974) into successively smaller aliquots. Between 100-200 individuals of each major taxonomic group were sorted. Specimens were later identified to the lowest taxon possible, in most cases to species. Major taxonomic references used in the identifications are presented in an Appendix.

Abundance data for each sample were standardized to the number of individuals per $m^3$ of water filtered, and biomass was standardized to mg ash-free dry weight per $m^3$. Replicate values were averaged to obtain a mean station value each month. In the case of a missing replicate, the single tow value was presented as the mean. Log transformed ($\log_{10}$ x+1) abundances were calculated for separate analyses of some of the more abundant taxa.

Each identified taxonomic group was placed in one of the following categories: holoplankton, meroplankton, or demersal plankton. Abundance and numerical percent of total zooplankters were determined for the three components and selected taxa. Spatial and temporal trends in abundance variability and gross biomass variability were examined graphically. The Wilcoxon signed-rank test was used to test for significant differences in mean values between stations over the 14-month study period. This is a nonparametric, distribution-free procedure which incorporates magnitude as well as direction of differences between paired values (Siegel, 1956; Hollander and Wolfe, 1973); only two stations may be compared at a time. The null hypothesis was that no significant differences existed between stations. Significance was chosen to be the alpha = 0.05 level, using a two-tailed test.

# RESULTS

Eighty-one night and twelve day zooplankton samples were collected between March 1979 and April 1980. Replicate tows at each station were successfully completed monthly with the following exceptions: only one tow for the Sand station in March 1979 and July 1979 and one tow at the Ruppia station in November 1979. Rough water associated with strong northwest winds delayed the October sampling until the first of November. Likewise, February sampling took place on the seventh of March due to a severe winter storm at the end of February.

## Hydrographic Data

Surface water temperatures for this shallow-water system were highest in July (28.0°C) and lowest in February (1.5°C) (Table 1). Salinity ranged from 15.2 ppt (April) to 23.0 ppt (August) and dissolved oxygen varied from 6.6 mg/liter to 12.6 mg/liter (Table 1). Water temperature increased and decreased maximally between March and April (+7.0°C 1979, +10.5°C 1980) and November and December (-8.0°C 1979), respectively (Figure 4A). Salinity values were high through the summer then decreased 6.0 ppt by mid-fall (Figure 4B). Erratic temporal changes in surface salinity were also apparent, particularly during spring months, coincident with local fluctuations in runoff. In general, dissolved oxygen was inversely related to temperature. Low hypoxic DO values (<3.0 mg/liter) were not observed during this study.

Table 1. Temperature (°C), salinity (ppt) and dissolved oxygen (mg/liter) by station, March 1979 through April 1980.

| MONTH | | RUPPIA | | | ZOSTERA | | | SAND | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | °C | ppt | mg/l | °C | ppt | mg/l | °C | ppt | mg/l |
| 1979 | MARCH | 8.0 | 17.7 | 12.6 | 8.0 | 17.4 | 12.6 | 8.0 | 17.3 | 11.8 |
| | APRIL | 15.0 | 18.5 | 9.6 | 15.0 | 18.5 | 9.6 | 15.0 | 18.5 | 9.6 |
| | MAY | 21.5 | 16.9 | 7.8 | 21.5 | 17.0 | 8.7 | 21.5 | 17.6 | 9.1 |
| | JUNE | 20.6 | 20.0 | 8.3 | 20.8 | 20.0 | 6.6 | 20.8 | 19.0 | 7.1 |
| | JULY | 27.0 | 15.8 | 8.9 | 27.0 | 15.3 | 8.9 | 28.0 | 15.2 | * |
| | AUGUST | 23.4 | 23.0 | 7.7 | 23.4 | 23.0 | 7.3 | 23.4 | 23.0 | 8.5 |
| | SEPTEMBER | 21.0 | 21.0 | 7.8 | 21.0 | 20.8 | 8.7 | 21.0 | 21.6 | 8.0 |
| | OCTOBER | 15.0 | 19.3 | 8.5 | 15.5 | 19.2 | 8.4 | 15.5 | 20.5 | * |
| | NOVEMBER | 12.5 | 16.4 | 12.0 | 12.0 | 17.0 | 11.1 | 12.0 | 16.8 | 11.1 |
| | DECEMBER | 4.0 | * | * | 4.5 | * | * | 4.0 | * | * |
| 1980 | JANUARY | 5.5 | * | * | 5.5 | * | * | 5.5 | * | * |
| | FEBRUARY | 2.0 | 18.8 | 11.4 | 2.0 | 19.0 | 11.7 | 1.5 | 19.0 | 11.8 |
| | MARCH | 7.5 | 20.9 | 11.2 | 7.0 | 20.8 | 10.5 | 7.0 | 20.8 | 10.5 |
| | APRIL | 17.5 | 15.2 | 9.7 | 17.5 | 15.2 | 9.7 | 17.5 | 15.2 | 9.9 |
| | | | | | | | | | | |
| 1979 | MAY DAY | 21.5 | 16.6 | 8.3 | 21.5 | 17.2 | 9.9 | 21.5 | 17.6 | 10.2 |
| | AUG DAY | 23.4 | 22.7 | 7.3 | 24.1 | 23.8 | 7.7 | 24.4 | 23.7 | 8.5 |

* missing value

Figure 4. Mean monthly surface values averaged over the Vaucluse Shores study area, March 1979 - April 1980. A. Temperature B. Salinity (* = missing values)

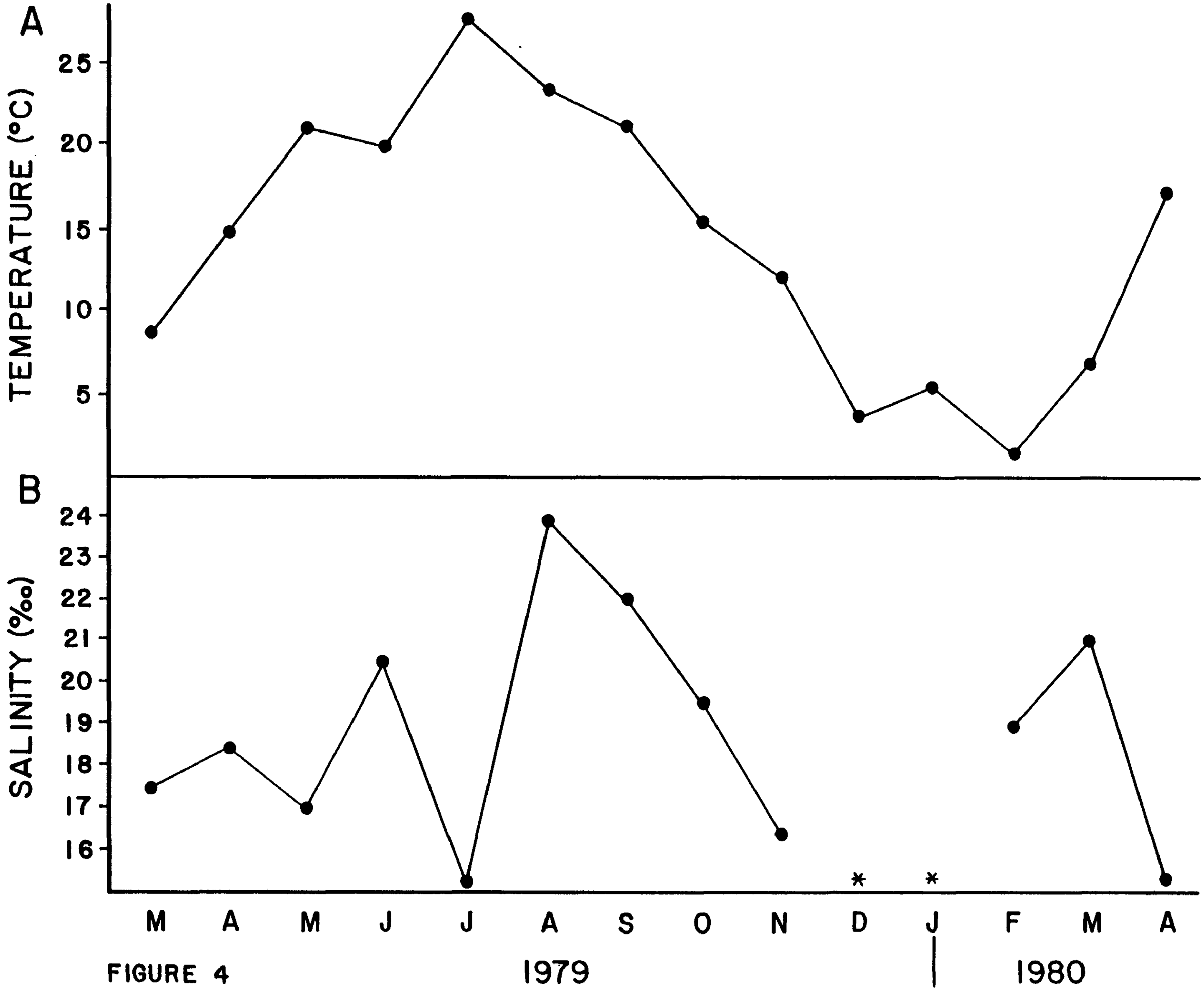

A
TEMPERATURE (°C)
25
20
15
10
5
B
SALINITY (‰)
24
23
22
21
20
19
18
17
16
*
*
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 4

Values differed only slightly or were the same between stations on each sampling date for temperature ($\leq$1.0°C), salinity ($\leq$1.2 ppt) and dissolved oxygen ($\leq$1.7 mg/liter). No consistent interstation pattern was evident for any of these parameters. Day temperature, salinity, and DO values were very similar to the night observations at each of the three stations. Therefore, these hydrographic parameters were not considered important factors influencing zooplankton distribution between the three stations or zooplankton diel variability during this study.

### Biomass

Ash-free dry weight (AFDW) values of zooplankton biomass ranged from 29.2 mg/m$^3$ to 783.0 mg/m$^3$ (Table 2). No values are presented for April 1980 collections due to problems with the muffle furnace. In 54% of the collections, AFDW values were between 100-400 mg/m$^3$. Zooplankton biomass was highest in September (780 mg/m$^3$); values >400 mg/m$^3$ were also observed in January (Ruppia, Zostera) and February (Sand, Zostera) (Figure 5). April, June, and November were characterized by low AFDW values (<100 mg/m$^3$) at all three stations.

In general, mean AFDW values differed between stations by greater than 100 mg/m$^3$ with a maximum difference of 500 mg/m$^3$ (February). Expressing the difference between station high and low AFDW estimates in any month as a percent of the high value, spatial variability ranged from 31.4% (November) to 90.0% (December) with a median of 53.9%. However no consistent interstation pattern was evident. Statistical

Table 2. Mean zooplankton ash-free dry weight (mg/m$^3$) by station and the variation between stations each month expressed as a percentage of (high-low value)/high value for March 1979 - March 1980.

| | STATION | | | |
|---|---|---|---|---|
| Month | Ruppia | Zostera | Sand | % Variation |
| 1979 March | 225.3 | 129.3 | 234.2 | 44.8 |
| April | 69.3 | 35.1 | 39.8 | 49.4 |
| May | 397.5 | 132.4 | 118.6 | 70.2 |
| June | 91.7 | 61.4 | 32.1 | 65.0 |
| July | 380.6 | 151.8 | 164.5 | 60.1 |
| August | 121.3 | 163.9 | 263.5 | 53.9 |
| September | 783.0 | 668.6 | 432.3 | 44.8 |
| October | 57.8 | 92.4 | 269.5 | 78.6 |
| November | 48.4 | 70.6 | 51.1 | 31.4 |
| December | 29.2 | 292.5 | 47.8 | 90.0 |
| 1980 January | 492.4 | 449.4 | 232.9 | 52.7 |
| February | 170.2 | 424.5 | 681.0 | 75.0 |
| March | 316.2 | 338.7 | 167.8 | 50.5 |

Figure 5. Mean monthly values of ash-free dry weight (mg/m$^3$) by station, (March 1979 - April 1980). (R = Ruppia, Z = Zostera, S = Sand).

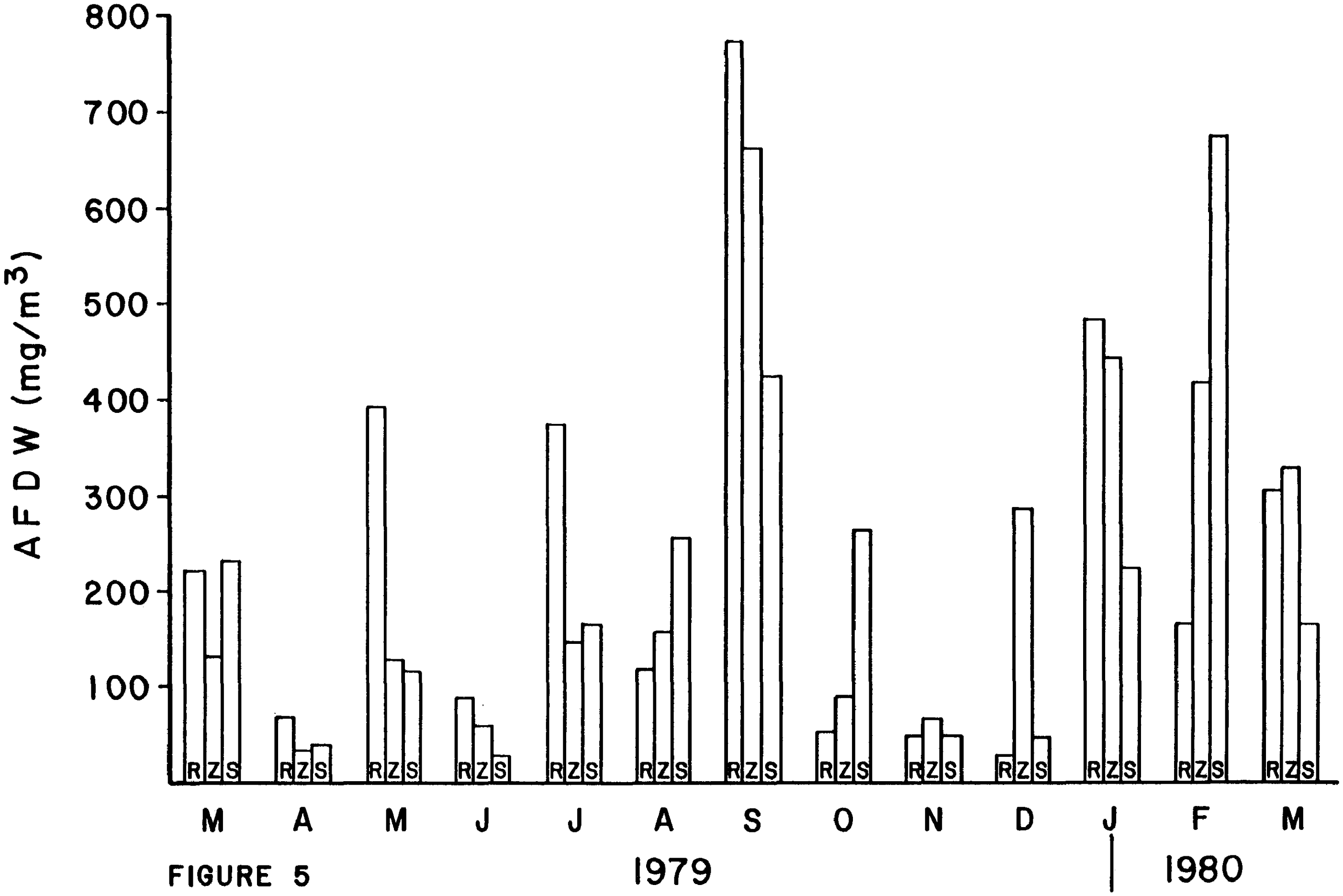

AFDW (mg/m$^3$)
800
700
600
500
400
300
200
100
R Z S
M
A
M
J
J
A
S
O
N
D
J
F
M
1979
1980

FIGURE 5

analysis using the Wilcoxon test indicated no significant difference in mean zooplankton biomass between stations over the thirteen-month period.

Variability between replicate AFDW values by station were also determined as a percentage. In general, percent variation between replicates was low and similar at all station: Ruppia, 2-48% median = 25%; Zostera, 7-51% median = 24%; and Sand, 11-75% median = 27%.

## Abundance and Species Composition

A total of 124 species was identified from 81 night collections over the 14-month study period. Occurrence of species by months is presented in Table 3. The zooplankton assemblage consisted of obligate (holo- and meroplankton) and facultative planktonic forms (demersal plankton). Holoplankton was the numerically dominant component (Figure 6) and included species of copepods (calanoids and cyclopoids), cladocerans, chaetognaths, rotifers, cnidarians and ctenophores. The meroplankton component ranked second numerically and consisted of fish eggs and larvae, decapod zoea, and larvae of gastropod, pelecypod, phoronid, polychaete and barnacle species. Demersal plankton, defined in this study as resident members of the benthic-substrate community which emerge periodically into the water column (Hobson and Chess, 1976; Robertson and Howard, 1978), generally represented less than 10% of the zooplankton numerical total (Figure 6). Amphipods, isopods, harpacticoid copepods, cumaceans, tanaids, adult polychaetes and mysids constituted the demersal component sampled in this study.

Table 3. Checklist of species identified and months of occurrence from zooplankton collections, March 1979 through April 1980. (H = holo-, M = mero-, D = demersal plankton)

| SPECIES | TYPE | 1979 |  |  |  |  |  | Date Sampled |  |  |  |  |  | 1980 |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| CNIDARIA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hydrozoa | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Nemopsis bachei* |  |  |  | X | X |  | X | X |  |  |  |  |  |  | X |
| Scyphozoa | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Chrysaora quinquecirrha* |  |  |  |  | X | X | X | X |  |  |  |  |  |  |  |
| *Cyanea capillata* |  |  |  |  |  |  |  |  |  |  |  | X |  | X |  |
| CTENOPHORA | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Mnemiopsis leidyi* |  |  |  |  | X | X | X | X | X |  |  |  |  |  |  |
| *Pleurobrachia pileus* |  |  |  |  |  |  |  |  |  |  |  | X |  |  |  |
| ROTIFERA | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| unid. soft-bodied species |  | X | X |  |  |  |  |  |  |  |  |  |  |  | X |
| ANNELIDA | D |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| unid. leech |  | X | X |  |  |  |  |  | X | X | X | X | X | X | X |
| *Autolytus* sp. |  |  | X | X | X |  |  | X |  |  |  |  |  |  |  |
| *Cistena gouldii* |  |  |  |  | X |  |  |  |  |  |  |  |  |  |  |
| *Eteone heteropoda* |  | X |  | X |  |  |  |  |  |  | X | X |  | X |  |
| *Eteone lactea* |  |  |  |  | X |  |  | X |  | X |  |  |  |  |  |
| *Glycera dibranchiata* |  |  | X |  |  | X | X | X |  | X | X |  |  |  |  |
| *Nereis succinea* |  | X | X | X | X | X | X | X |  |  |  |  |  |  |  |
| *Parahesione* sp. |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
| *Paraonis fulgens* |  |  |  |  | X | X |  |  |  |  |  |  |  |  | X |
| *Scoloplos* sp. |  | X | X | X | X | X | X | X |  |  |  |  |  |  | X |

Table 3. (continued)

| SPECIES | TYPE | 1979 |  |  |  |  | Date Sampled |  |  |  |  |  |  | 1980 |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| Spionidae spp. |  | X | X | X |  |  |  |  |  |  |  |  |  | X |  |
| Terebellidae spp. |  |  |  |  |  |  | X | X |  |  |  |  |  |  |  |
| *Tharyx setigera* |  |  |  | X | X | X |  |  |  |  |  |  |  |  |  |
| unid. polychaete larvae | M | X | X | X | X | X | X |  | X | X | X | X | X | X | X |
| MOLLUSCA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pelecypoda | M |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| unid. larvae |  |  |  |  | X | X | X | X |  |  |  |  |  | X | X |
| Gastropoda | M |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| unid. larvae |  |  |  |  | X | X | X |  |  |  |  |  |  |  | X |
| Cephalopoda | M |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Lolliguncula brevis* |  |  |  |  |  |  | X |  |  |  |  |  |  |  |  |
| ARTHROPODA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Crustacea |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Cladocera | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Podon polyphemoides* |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
| *Evadne nordmanni* |  |  |  |  |  |  |  |  |  |  |  |  |  |  | X |
| *Evadne tergestina* |  |  |  |  |  | X | X |  |  |  |  |  | X |  |  |
| Copepoda |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Calanoids | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Acartia clausi* |  | X | X |  |  |  | X |  |  | X | X | X | X | X | X |
| *Acartia tonsa* |  | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| *Centropages hamatus* |  | X | X |  |  |  |  |  |  | X |  | X | X | X | X |
| *Centropages typicus* |  |  |  |  |  | X |  |  |  |  |  |  | X |  |  |
| *Eurytemora affinis* |  | X | X |  |  |  |  |  |  |  |  |  | X | X |  |

Table 3. (continued)

| SPECIES | TYPE | | | 1979 | | | | Date Sampled | | | | | 1980 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| Labidocera aestiva | | | | | | | X | X | X | X | | | | | |
| Paracalanus sp. | | | | | | | | | X | | | | | | |
| Parvocalanus crassirostris | | X | X | X | X | X | X | | X | X | | | X | X | X |
| Pseudocalanus minutus | | X | X | | | | X | | | | X | X | X | X | X |
| Pseudodiaptomus coronatus | | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Temora longicornis | | X | X | | | | | | | | | | X | X | X |
| Cyclopoids | H | | | | | | | | | | | | | | |
| Corycaeus sp. | | | | | | | | | X | | | | | | |
| Oithona spp. | | X | X | X | X | | X | | X | X | X | X | X | X | X |
| Harpacticoids | D | | | | | | | | | | | | | | |
| Alteutha depressa | | | | X | X | | | | | X | X | | | | X |
| unid. spp. | | | X | X | X | X | | | | X | X | X | | X | |
| Caligoids | H | | | | | | | | | | | | | | |
| unid. spp. | | | | | | X | | | | | | | | | |
| Branchiura | H | | | | | | | | | | | | | | |
| Argulus sp. | | | | | | X | | | | | | | | | |
| Cirripedia | M | | | | | | | | | | | | | | |
| Barnacle nauplius | | X | X | X | X | X | X | | X | X | X | X | X | X | X |
| Barnacle cypris | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Mysidacea | D | | | | | | | | | | | | | | |
| Heteromysis formosa | | | | | | | | | X | | | | | | |
| Mysidopsis bigelowi | | | | | X | X | X | X | | | | X | | X | |
| Neomysis americana | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Cumacea | D | | | | | | | | | | | | | | |
| Cyclaspis varicans | | X | X | X | X | X | X | X | X | X | | | | X | X |
| Diastylis sp. | | | X | X | X | X | | | | | X | | | | X |
| Leucon americanus | | | | X | | X | X | X | | | X | | | | |
| Mancocuma stellifera | | | | X | | | | | | | | | | X | |
| Oxyurostylis smithi | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Table 3. (continued)

| | | 1979 | | | | | Date Sampled | | | | 1980 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIES | TYPE | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| *Pseudoleptocuma minor* | | | X | X | X | | | | | | X | X | X | X | X |
| | | | | | | | | | | | | | | | |
| Tanaidacea | D | | | | | | | | | | | | | | |
| unid. sp. | | | | X | X | X | X | X | | | | | | | |
| | | | | | | | | | | | | | | | |
| Isopoda | D | | | | | | | | | | | | | | |
| Cymothoid sp. | | | | | X | X | X | X | X | X | | | | | X |
| *Edotea triloba* | | X | X | X | X | X | X | X | | X | X | | | X | |
| *Erichsonella attenuata* | | | | X | X | X | X | X | | X | X | X | | | X |
| *Idotea balthica* | | | | | | | | | X | | X | | X | | X |
| | | | | | | | | | | | | | | | |
| Amphipoda | | | | | | | | | | | | | | | |
| Gammarids | D | | | | | | | | | | | | | | |
| *Ampelisca* spp. | | X | X | X | | X | X | X | | X | | X | | X | X |
| *Ampithoe longimana* | | | | | | X | X | | X | X | X | | | | |
| *Batea catharinensis* | | X | | | | | | | | | | | | X | |
| *Bathyporeia* sp. | | | | X | | | | | | | X | | X | X | |
| *Corophium* spp. | | X | X | | X | | X | X | X | X | X | X | | X | |
| *Cymadusa compta* | | X | | X | X | X | X | X | X | X | X | | X | | X |
| *Gammarus mucronatus* | | X | X | X | X | X | X | | X | X | X | X | X | X | X |
| *Gammarus* sp. | | | X | | | | X | | | X | X | | | X | X |
| unid. Haustorid | | | | | | | X | | | | | | X | X | X |
| *Leptocheirus* sp. | | X | | | | | | | | | X | X | | X | |
| *Listriella barnardi* | | | | | | X | X | X | X | | | | | | |
| *Melita appendiculata* | | | | | | | | | | X | | | | | |
| *Melita nitida* | | X | | X | X | | X | | | | X | | | | |
| *Microprotopus raneyi* | | X | X | X | X | X | X | X | X | X | X | | X | X | |
| *Monoculodes edwardsi* | | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| *Parametopella cypris* | | | | | | | | | | X | X | | | X | |
| *Stenothoe minuta* | | | | | | | | | | | X | X | | | |
| *Unciola irrorata* | | | | X | | | | | | | | | | | |

Table 3. (continued)

| SPECIES | TYPE | 1979 | | | | | | | Date Sampled | | | | | 1980 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| Hyperiids | H | | | | | | | | | | | | | | |
| unid. spp. | | | | | | | | | X | | | | | X | |
| Caprellids | D | | | | | | | | | | | | | | |
| *Caprella equilibra* | | | X | X | X | | | | | X | | | | | X |
| *Caprella penantis* | | | | X | X | X | X | X | X | | | | | X | X |
| *Paracaprella tenuis* | | | X | | | X | X | X | | X | | | | | |
| Stomatopoda | M | | | | | | | | | | | | | | |
| unid. zoea | | | | | | X | X | | | | | | | | |
| Decapoda | M | | | | | | | | | | | | | | |
| *Callianassa* sp. A | | X | | | | X | X | X | | | | | | | |
| *Callianassa* sp. B | | | | | | | X | X | | | | | | | |
| *Callinectes sapidus* | | | | | | X | X | | | | | | | | |
| *Crangon septemspinosa* | | X | X | X | X | | X | | X | X | X | X | X | X | X |
| *Emerita talpoida* | | | | | | | X | | | | | | | | |
| *Euceramus praelongus* | | | | | | | | | X | | | | | | |
| *Libinia* spp. | | | | | X | | X | | | | | | | | |
| *Lucifer* sp. | | | | | | | | | X | | | | | | |
| *Naushonia crangonoides* | | | | | | | X | | | | | | | | |
| *Neopanope texani* | | | | X | X | X | X | | | | | | | | |
| *Ogyrides limicola* | | | | | | | X | | | | | | | | |
| *Pagurus longicarpus* | | X | | X | X | X | X | | | | | | | | X |
| *Pagurus pollicaris* | | | | | | | X | | | | | | | | |
| *Palaemonetes* spp. | | | | X | X | X | X | X | | | | | | | |
| *Panopeus herbstii* | | | | | | X | X | | | | | | | | |
| *Pinnixa chaetopterana* | | | | X | X | X | X | X | | X | | | | | |
| *Pinnixa sayana* | | | | | X | | X | X | X | X | | | | | |
| *Pinnotheres maculatus* | | | | | X | | X | | | | | | | | |
| *Pinnotheres ostreum* | | | | | | | X | | | | | | | | |
| *Sesarma reticulum* | | | | | X | X | X | | | | | | | | |

Table 3. (continued)

| SPECIES | TYPE | 1979 |  |  |  |  |  | Date Sampled |  |  |  |  | 1980 |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| *Uca* spp. |  |  |  | X | X | X | X |  |  |  |  |  |  |  |  |
| *Upogebia affinis* |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
| PHORONIDA | M |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| unid. larvae |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
| CHAETOGNATHA | H |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Sagitta elegans* |  |  |  |  |  |  |  |  |  |  |  |  |  | X |  |
| *Sagitta enflata* |  |  |  |  |  |  | X | X | X |  |  |  | X |  |  |
| *Sagitta hispida* |  |  |  |  |  |  |  | X | X |  |  |  |  |  |  |
| *Sagitta tenuis* |  |  |  |  |  |  | X | X | X |  | X |  |  |  |  |
| *Sagitta* unid. |  |  | X |  |  |  | X |  |  |  |  |  |  |  |  |
| CHORDATA | M |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pisces |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| *Ammodytes* sp. |  | X |  |  |  |  |  |  |  |  |  |  | X | X |  |
| *Anchoa hepsetus* |  |  |  |  |  |  |  |  |  | X |  |  |  |  |  |
| *Anchoa mitchilli* |  |  |  | X | X | X | X | X |  | X | X |  |  |  |  |
| *Brevoortia tyrannus* |  | X | X |  |  |  |  |  |  | X |  | X |  | X |  |
| *Cynoscion regalis* |  |  |  | X | X |  | X |  |  |  |  |  |  |  |  |
| *Gobiosoma* sp. |  |  |  | X | X | X | X | X |  |  |  |  |  |  |  |
| *Hypsoblennius hentzi* |  |  |  |  | X | X | X | X |  |  |  |  |  |  |  |
| *Leiostomus xanthurus* |  |  | X |  |  |  |  |  |  |  |  |  |  |  |  |
| *Membras martinica* |  |  |  | X | X | X | X |  |  |  |  |  |  |  |  |
| *Microgobius thalassinus* |  |  |  |  |  | X |  |  |  |  |  |  |  |  |  |
| *Micropogonias undulatus* |  |  |  |  |  |  |  | X |  | X | X | X |  |  |  |

Table 3. (continued)

| SPECIES | TYPE | 1979 | | | | | Date Sampled | | | | | | 1980 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 |
| *Paralichthys dentatus* | | | | | | | | | | | | | X | | |
| *Peprilus* sp. | | | | | | | X | | | | | | | | |
| *Pseudopleuronectes americanus* | | | | | | | | | | | | | | X | |
| Sciaenidae spp. | | | | X | X | X | X | | | | | | | | X |
| *Scophthalmus aquosus* | | | | | | | | | | | | | X | X | |
| *Syngnathus fuscus* | | | | X | X | X | X | X | | | | | | | |
| *Tautoga onitis* | | | | X | | | | | | | | | | | X |
| *Trinectes maculatus* | | | | | | | X | | | | | | | | |

Figure 6. Monthly relative percentages of holoplankton, meroplankton, and demersal plankton by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand).

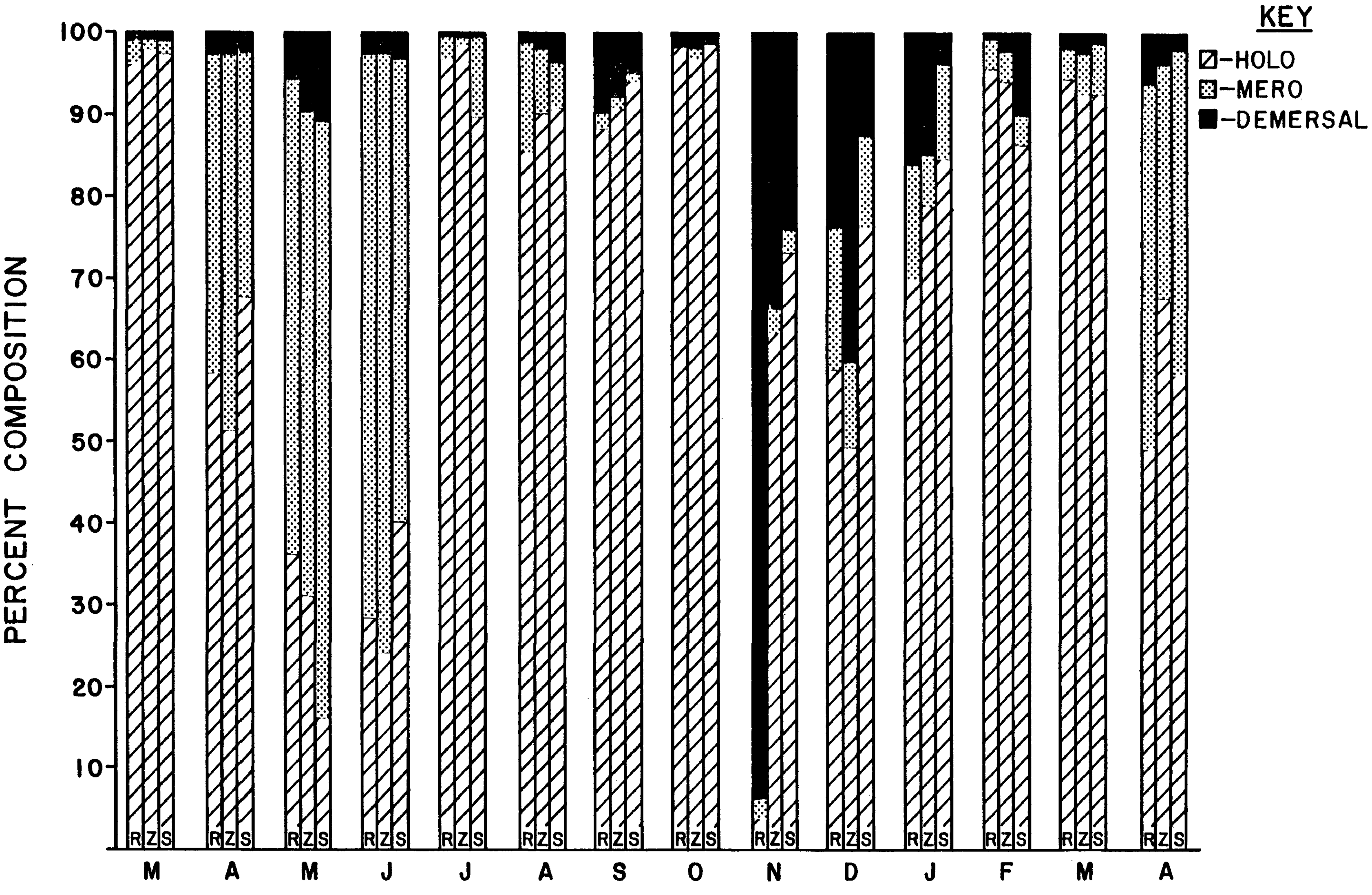

KEY
▨-HOLO
▩-MERO
■-DEMERSAL
PERCENT COMPOSITION
100
90
80
70
60
50
40
30
20
10
R Z S
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 6

Species composition and abundance of each taxonomic group will be presented phylogenetically under the appropriate subheading (i.e. holo-, mero-, demersal plankton).

## Holoplankton

Cnidaria. One species of hydromedusae, Nemopsis bachei, was collected in low numbers May through September 1979 and April 1980. Qualitatively, higher densities were observed at the Ruppia and Zostera stations compared to the Sand station. Two scyphozoan species were recorded during this study. Chrysaora quinquecirrha occurred during summer months while Cyanea capillata was collected during the winter months. Neither species was present in numbers greater than $1/m^3$ at any of the stations.

Ctenophora. Ctenophores disintegrate quickly when placed in formalin, thus no effort was made to quantify their occurrence. Mnemiopsis leidyi was collected May through October 1979. Numbers were greatest during September, as evidenced by filling 50% of the entire volume of the net during a three minute tow. Densities were qualitatively observed to be highest at Ruppia and lowest at the Sand station. Another species, Pleurobrachia pileus, occurred in January 1980 in relatively high numbers.

Rotifera. Rotifers were present in March 1979 and April of both years. An unidentified soft-bodied species comprised 1-4% of the zooplankton total during March ($580/m^3$). The contribution of rotifers to the zooplankton community was probably underestimated as the net mesh used in this study (0.202 mm) was too large to quantitatively sample this group.

*Cladocera*. Two cladoceran species were present in the summer-fall collections. *Podon polyphemoides* occurred in July 1979 with a maximum abundance of $1800/m^3$ (Zostera) representing 4% of the zooplankton total at all three stations. *Evadne tergestina* was observed in low numbers July and August 1979. Another pulse in cladoceran abundance ($500/m^3$) was observed during April 1980 accounting for 7% (Ruppia) to 27% (Sand) of the zooplankton total. *Evadne nordmanni* was the only species recorded in these collections.

*Copepoda*. Copepods were the numerically dominant and most diverse holoplanktonic taxon sampled. A total of eleven calanoid and two cyclopoid species was identified, representing nine families. Calanoids and cyclopoids combined accounted for greater than 85% of the zooplankton numerical total in 7 of the 14 months sampled (Table 4). Copepods comprised less than 50% of the zooplankton total only in May and June 1979 and April 1980.

Abundance of total copepods appeared bimodal over an annual cycle (Figure 7). Densities greater than $10^4$ individuals/$m^3$ were observed in March of both years and throughout the period July - October 1979. These peaks in abundance reflected the seasonal succession pattern in species composition. Two distinct copepod communities were apparent, a winter-spring assemblage and a summer-

Table 4. List of the three numerically dominant taxa and percent of numerical total by station for zooplankton collections March 1979 through April 1980

| | MONTH | STATION | | | | | |
|---|---|---|---|---|---|---|---|
| | | RUPPIA | | ZOSTERA | | SAND | |
| 1979 | MARCH | Copepoda | 93.1 | Copepoda | 96.7 | Copepoda | 97.1 |
| | | Rotifera | 3.6 | Rotifera | 1.5 | Rotifera | 1.0 |
| | | Polychaete larvae | 1.4 | Barnacle larvae | 0.9 | Decapod larvae | 1.0 |
| | APRIL | Copepoda | 59.6 | Copepoda | 51.7 | Copepoda | 68.1 |
| | | Polychaete larvae | 30.1 | Polychaete larvae | 37.8 | Polychaete larvae | 23.2 |
| | | Barnacle larvae | 8.3 | Barnacle larvae | 8.9 | Barnacle larvae | 8.4 |
| | MAY | Copepoda | 35.4 | Polychaete larvae | 33.6 | Barnacle larvae | 39.2 |
| | | Barnacle larvae | 34.5 | Copepoda | 31.8 | Polychaete larvae | 30.3 |
| | | Polychaete larvae | 19.7 | Barnacle larvae | 21.5 | Copepoda | 16.8 |
| | JUNE | Copepoda | 28.2 | Barnacle larvae | 37.5 | Copepoda | 40.5 |
| | | Barnacle larvae | 23.6 | Copepoda | 25.0 | Polychaete larvae | 24.5 |
| | | Polychaete larvae | 21.4 | Gastropod larvae | 17.1 | Barnacle larvae | 16.2 |
| | JULY | Copepoda | 93.3 | Copepoda | 94.5 | Copepoda | 90.5 |
| | | Cladocera | 4.1 | Cladocera | 4.3 | Cladocera | 4.8 |
| | | Decapod larvae | 0.7 | Barnacle larvae | 0.4 | Gastropod larvae | 2.2 |
| | AUGUST | Copepoda | 86.2 | Copepoda | 90.7 | Copepoda | 91.7 |
| | | Pelecypod larvae | 10.4 | Pelecypod larvae | 6.2 | Pelecypod larvae | 3.8 |
| | | Barnacle larvae | 1.9 | Mysidacea | 1.3 | Mysidacea | 3.6 |
| | SEPTEMBER | Copepoda | 87.7 | Copepoda | 89.7 | Copepoda | 94.4 |
| | | Mysidacea | 9.2 | Mysidacea | 7.5 | Mysidacea | 4.9 |
| | | Pelecypod larvae | 1.2 | Pelecypod larvae | 1.0 | Pelecypod larvae | 0.5 |

Table 4. (continued)

| | | STATION | | | | | |
|---|---|---|---|---|---|---|---|
| MONTH | | RUPPIA | | ZOSTERA | | SAND | |
| 1979 | OCTOBER | Copepoda | 99.0 | Copepoda | 97.9 | Copepoda | 99.6 |
| | | Barnacle larvae | 0.5 | Barnacle larvae | 0.3 | Polychaete larvae | 0.1 |
| | | Polychaete larvae | 0.3 | Polychaete larvae | 0.2 | Chaetognatha | 0.1 |
| | NOVEMBER | Mysidacea | 81.2 | Copepoda | 65.0 | Copepoda | 73.9 |
| | | Cumacea | 6.2 | Mysidacea | 26.2 | Mysidacea | 21.7 |
| | | Amphipoda | 5.3 | Harpacticoid | 4.8 | Harpacticoid | 1.6 |
| | DECEMBER | Copepoda | 60.1 | Copepoda | 49.8 | Copepoda | 77.6 |
| | | Polychaete larvae | 15.3 | Mysidacea | 34.8 | Mysidacea | 12.3 |
| | | Mysidacea | 11.9 | Polychaete larvae | 8.4 | Polychaete larvae | 8.1 |
| 1980 | JANUARY | Copepoda | 70.8 | Copepoda | 78.8 | Copepoda | 85.7 |
| | | Mysidacea | 14.7 | Mysidacea | 16.0 | Polychaete larvae | 11.5 |
| | | Polychaete larvae | 13.1 | Polychaete larvae | 4.7 | Mysidacea | 2.6 |
| | FEBRUARY | Copepoda | 96.2 | Copepoda | 94.9 | Copepoda | 86.9 |
| | | Polychaete larvae | 2.8 | Mysidacea | 2.4 | Mysidacea | 9.5 |
| | | Mysidacea | 0.5 | Polychaete larvae | 1.5 | Polychaete larvae | 2.3 |
| | MARCH | Copepoda | 95.7 | Copepoda | 93.7 | Copepoda | 93.6 |
| | | Polychaete larvae | 1.7 | Polychaete larvae | 2.8 | Barnacle larvae | 2.4 |
| | | Barnacle larvae | 1.7 | Barnacle larvae | 2.5 | Polychaete larvae | 1.7 |
| | APRIL | Copepoda | 41.3 | Copepoda | 42.1 | Copepoda | 32.3 |
| | | Polychaete larvae | 18.1 | Cladocera | 25.8 | Cladocera | 27.2 |
| | | Barnacle larvae | 16.9 | Barnacle larvae | 16.5 | Barnacle larvae | 17.8 |

Figure 7. Mean monthly abundance (log [(number per $m^3$) + 1]) of total copepods by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand).

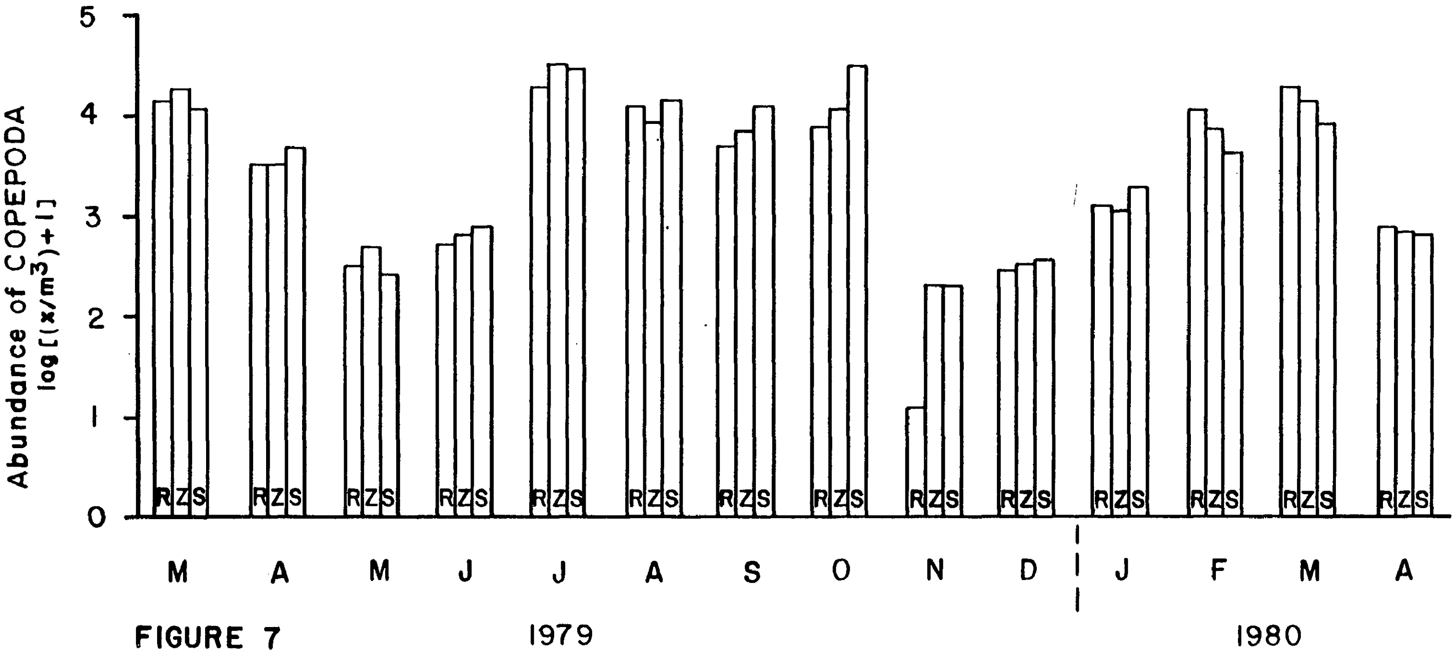

Abundance of COPEPODA
log[(x/m^3)+1]
0
1
2
3
4
5
R Z S
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 7

fall assemblage. Low abundance (<$10^3$ individuals/$m^3$) was characteristic of the transition months between the two seasons, spring to summer (May-June) and fall to winter (November-December). Statistical analysis of mean copepod abundance, using the Wilcoxon test, indicated that no significant difference existed between any station pairs (Ruppia-Zostera, Zostera-Sand, Ruppia-Sand).

Adults outnumbered copepodites in all collections. However this is probably an artifact of sampling error as the mesh size (0.202 mm) used in this study was too large to adequately sample the smaller individuals.

The winter-spring copepod assemblage consisted of *Acartia clausi*, *Acartia* copepodites, *Centropages hamatus*, *Eurytemora affinis*, *Oithona* sp., *Pseudocalanus minutus*, *Temora longicornis*, and *Acartia tonsa*. According to Bradford (1976) North American specimens identified as *A. clausi* (Giesbrecht) may be *A. hudsonica* previously known as *A. clausi hudsonica* (Pinhey). Bradford (1976) revised the subgenus *Acartiura*, elevating *hudsonica* from subspecific to specific status. She determined *A. hudsonica* type locality as Patuxent River, Md and the Gulf of Maine with *A. clausi* type locality as Genoa Harbor, Italy and Riviere de Morlaix, France. However this revision has not been widely-adopted by North American scientists. Throughout this study, the designation *A. clausi* will be maintained.

*Acartia clausi* and *Acartia* spp. copepodites constituted greater than 85% of the March 1979 copepod total. *Acartia tonsa* and *C. hamatus* were present in low numbers (less than 4% of the total each). In March 1980 a numerical peak in total copepod abundance was observed; however, the community structure differed from that of 1979. *Acartia clausi* was not the dominant species nor had *A. tonsa* numbers decreased to the level observed in 1979. *Acartia clausi* represented less than 23% of the total and *A. tonsa* > 27%. In addition, *C. hamatus* and *P. minutus* increased in importance in 1980, reaching 26% and 8% of the numerical total, respectively. Conversely, *Acartia* copepodite numbers decreased from approximately 6000/m$^3$ in 1979 to 1000/m$^3$ in 1980.

Species diversity, in terms of the number of species present, was lower for the summer-fall copepod community. *Acartia tonsa* dominated the summer-fall assemblage, accounting for 60-90% of the copepod total, with a peak abundance of >30,000 individuals/m$^3$ in July. The annual maximum copepod abundance was observed in July, coinciding with the *A. tonsa* peak. *Acartia* copepodites, *Pseudodiaptomus coronatus*, and *Labidocera aestiva* were also present during the summer months, but in relatively low numbers.

*Acartia tonsa* was the only copepod species to occur in 100% of the collections. *Oithona* sp., *P. coronatus*, *P. minutus*, and *Parvocalanus crassirostris* (= *Paracalanus crassirostris*) each occurred in 10 of the 14 sampling months. *Paracalanus* sp., *Corycaeus* sp. and *Centropages typicus* were rare species, collected only during one month each.

Chaetognatha. Chaetognaths were the second most diverse holoplanktonic group sampled; abundance and species composition varied seasonally. This taxon was absent from collections March through July 1979 with the exception of the Zostera station in April ($<0.1/m^3$). The summer-fall chaetognath assemblage was comprised of Sagitta tenuis (95%), Sagitta enflata and low numbers of Sagitta hispida. Densities of $22/m^3$ and $36/m^3$ were observed in September (Zostera) and October (Sand), respectively. A single species was present in the 1980 winter collections. Sagitta elegans was recorded in February and March reaching a peak abundance of $15/m^3$. Chaetognaths never accounted for more than 0.5% of the zooplankton numerical total.

## Meroplankton

Polychaeta. Polychaete larvae contributed in high numbers to the zooplankton assemblage during the transition period spring to summer (Figure 8). This taxon comprised between 15 and 38% of the zooplankton total consistently April through June at all three stations. Maximum densities of $> 10^3$ individuals/$m^3$ were observed in April 1979. Low numbers ($<70/m^3$) of polychaete larvae were characteristic of the summer-fall collections. Statistical analysis demonstrated that no significant difference existed between stations in mean larval polychaete abundance over the 14-month period.

Mollusca. Gastropod larvae were collected June through August 1979 and in April 1980. Maximum abundances were observed in June ($450/m^3$, Zostera) and July ($860/m^3$, Sand), representing between

Figure 8. Mean monthly abundance (log [(number per m$^3$) + 1]) of total polychaete larvae by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

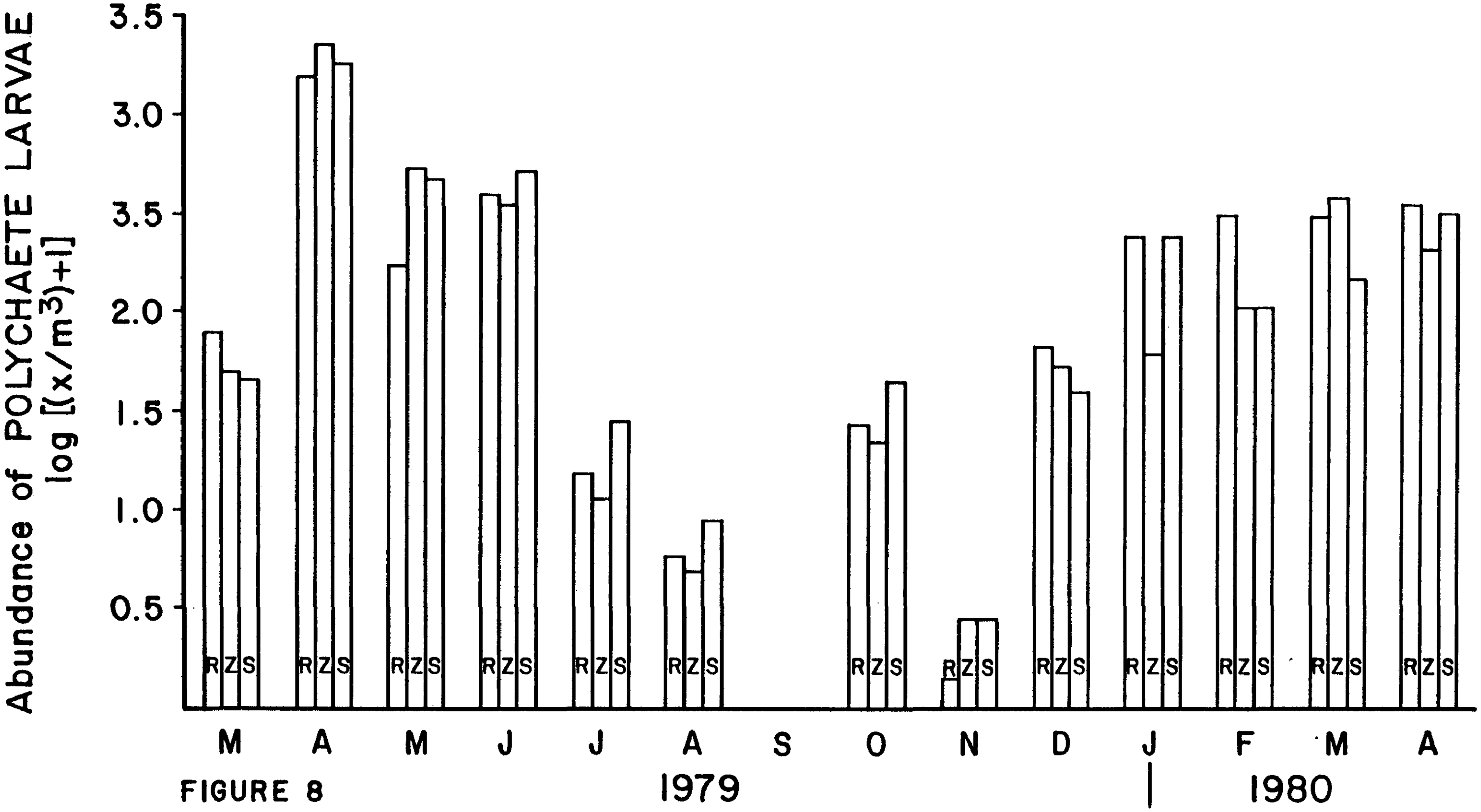

Abundance of POLYCHAETE LARVAE
log [(x/m³)+1]
3.5
3.0
3.5
2.0
1.5
1.0
0.5
RZS
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 8

2-15% of the zooplankton total in these months. Pelecypod larvae were present June through September 1979 and April 1980. Abundance values were less than $150/m^3$ except during August when larval pelecypod density ranged from $600/m^3$ (Ruppia, Zostera) to $1400/m^3$ (Sand). At no time did this group account for more than 10% of the total zooplankton standing stock. A single larval cephalopod, Lolliguncu1us brevis was collected in August at the Sand station.

Cirripedia. Barnacle larvae, both nauplius and cypris stages, were present every month sampled. This taxon was an important constituent of the zooplankton community, April through June, reaching densities > $300/m^3$ at all stations (Figure 9). This time period coincides with the transition between the winter-spring and summer-fall holoplankton assemblages. Barnacle larvae ranked third in numerical abundance in April, constituting 8% of the zooplankton total in 1979 and 16-20% in 1980. In May and June, cirripede larvae represented between 16 and 39% of the numerical total, ranking among the three numerical dominants at all stations (Table 4). Low abundances (<50 individual/$m^3$) were characteristic of collections September through February. Statistical analysis demonstrated that no significant difference in mean barnacle larvae abundance existed between stations over the 14-month period.

Decapoda. Decapod larvae constituted the most diverse group of all the zooplankton taxa sampled during this study. A total of 22 species was identified, most of which occurred solely in summer collections June through August. Zoeal stages accounted for 99% of the decapod larvae; small numbers of megalopae were also encountered.

Figure 9. Mean monthly abundance (log [(number per $m^3$) + 1]) of total barnacle larvae by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

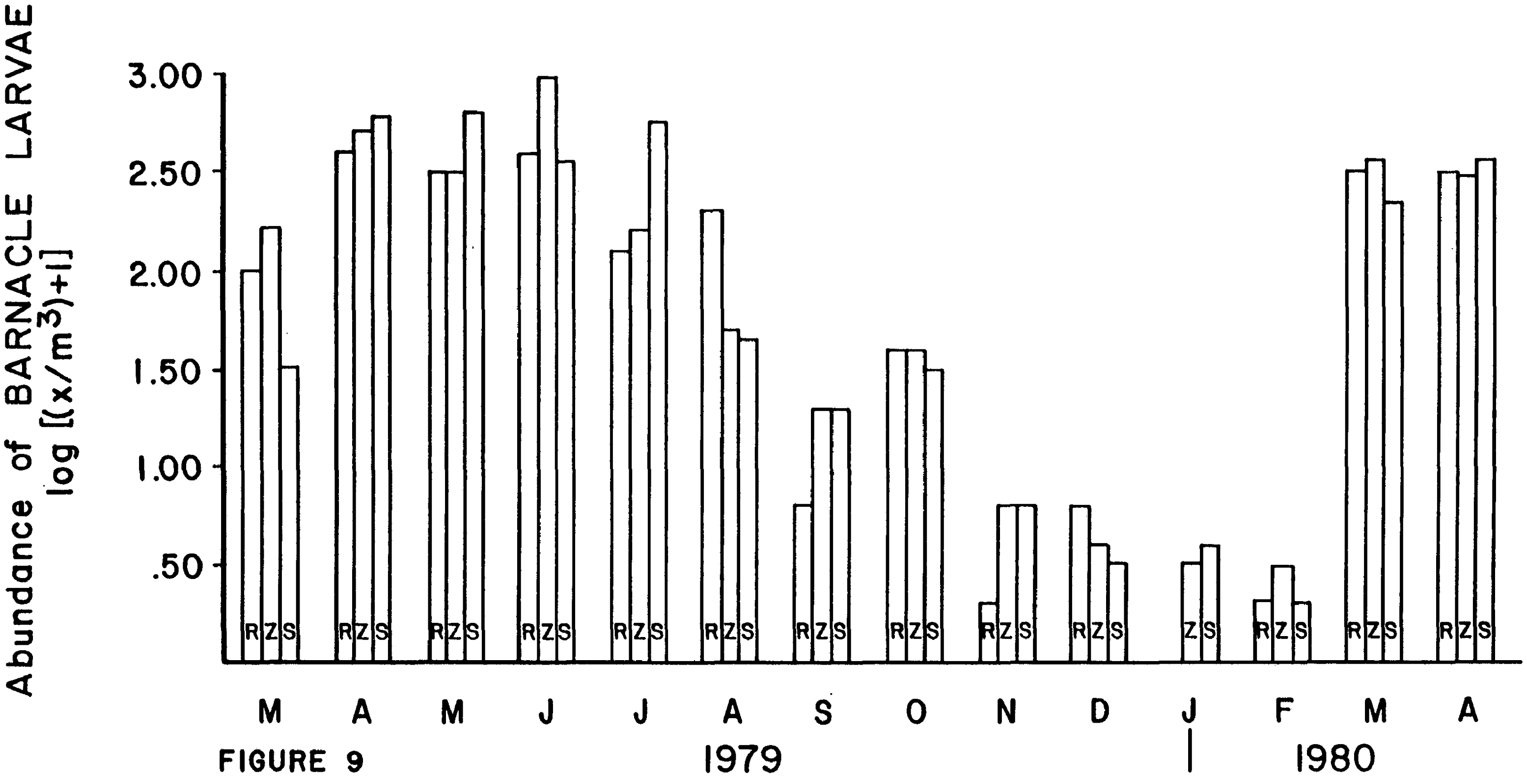

Abundance of BARNACLE LARVAE
log [(x/m$^3$)+1]
3.00
2.50
2.00
1.50
1.00
.50
RZS
ZS
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 9

Decapod abundance was bimodal over an annual cycle (Figure 10). Densities greater than 100 individuals/$m^3$ were observed in March of both years and in June and July 1979. Low numbers ($<10/m^3$) were recorded for seven of the 14 months sampled (April 1979, 1980; September 1979 - January 1980). Spatial variability in decapod abundance was high during the months of peak abundance. However, the difference in abundance between stations was not significant over the 14-month period based on statistical analysis using the Wilcoxon test.

The winter-spring decapod assemblage (December through April) consisted almost entirely (99%) of zoeal *Crangon septemspinosa*. Low numbers of *Callianassa* sp. (= sp. A in Sandifer, 1972) and *Pagurus longicarpus* occurred sporadically in these collections.

The number of species collected per month increased six-fold from March (n=3) to August (n=20). *Palaemonetes* sp. and *C. septemspinosa* predominated during the transition-period (May and June) from spring to summer. *Uca* sp., *P. longicarpus*, *Pinnixa chaetopterana*, *Palaemonetes* sp., *Neopanope texana*, *Sesarma reticulum* and *Upogebia affinis* comprised approximately 85% of the summer decapod assemblage (July and August). In addition, *Callinectes sapidus*, *Emerita talpoida*, *Libinia* sp., *Naushonia crangonoides*, *Ogyrides* sp., *Pagurus pollicaris*, *Panopeus herbstii*, *Pinnixa sayana*, *Pinnotheres maculatus*, and *Pinnotheres ostreum* were present during summer months in densities of less than

Figure 10. Mean monthly abundance (number per $m^3$) of total decapod larvae and number of species by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

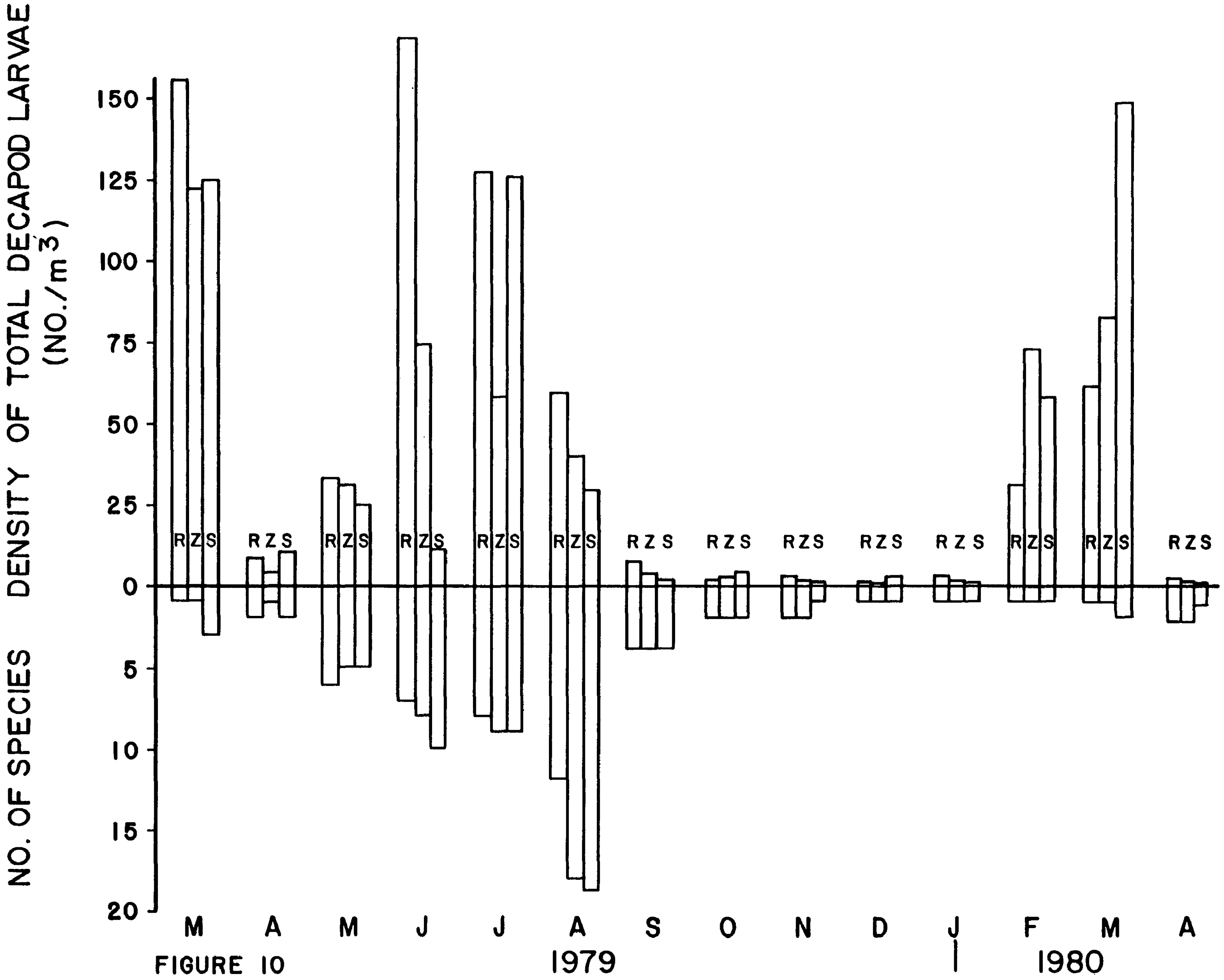

DENSITY OF TOTAL DECAPOD LARVAE
(NO./m3)
NO. OF SPECIES
150
125
100
75
50
25
0
5
10
15
20
RZS
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 10

5 individuals/$m^3$ each. The number of species decreased abruptly from August (n=20) to September (n=4), coinciding with a decrease in total larval decapod abundance.

In general, individual decapod species were distributed uniformly between stations. However, the abundance of _Palaemonetes_ sp. was generally much greater in Ruppia than in the Sand station. For example, in June _Palaemonetes_ density ranged from 142/$m^3$ at Ruppia to less than 1/$m^3$ at the Sand station. _Palaemonetes_ sp. accounted for greater than 85% of the decapod total in Ruppia, May through June, and less than 6% at the Sand station during the same period.

_Phoronida_. Phoronid larvae were present in July 1979 collections. Comprising less than 0.5% of the zooplankton total, phoronid density ranged from 30/$m^3$ at the vegetated stations to 140/$m^3$ at the Sand station.

_Pisces_. Although fish eggs and larvae were the second most diverse meroplanktonic taxa sampled, abundance values were the lowest. However, nets with mouth opening less than 60 cm are not considered effective for quantitative sampling of fish larvae (Wiebe and Holland, 1968; Jacobs and Grant, 1978).

Fish eggs were present during seven of the 14 months sampled but occurred in numbers greater than 1 individual/$m^3$ only in late spring and early summer (May-July). Densities were consistently much lower, by an order of magnitude, at the Ruppia station compared to Sand

(Figure 11A). Anchoa mitchilli and Sciaenidae eggs comprised 99% of the total eggs sampled. Abundances greater than 20 eggs/$m^3$ were observed at the Sand station for A. mitchilli (May and July) and for Sciaenidae (July). Eggs of Membras martinica and Gobiosoma sp. were present in summer collections while Brevoortia tyrannus and Scophthalmus aquosus eggs were collected in the winter. None of these four species reached densities greater than 1 egg/$m^3$ at any of the three stations.

Fish larvae were present in every month sampled, occurring in numbers greater than 1 individual/$m^3$ from June through September (Figure 11B). Gobiosoma sp. accounted for 80% of the total fish larvae during June 1979 with a maximum abundance of 12/$m^3$ (Zostera). Anchoa mitchilli dominated the larval fish assemblage July (68%) and August (85%). Maximum densities of Anchoa larvae were observed in August (30 individuals/$m^3$) at Ruppia and Zostera. Also present in summer collections were low densities of Cynoscion regalis, Syngnathus fuscus, unid. Sciaenidae, M. martinica, Hypsoblennius hentzi, Microgobius thalassinus, Trinectes maculatus and Peprilus alepidotus.

Low abundances of B. tyrannus, Ammodytes sp., Leiostomus xanthurus, Pseudopleuronectes americanus, Tautoga onitis, Micropogonias undulatus, S. aquosus, Anchoa hepsetus, Opisthonema oglinum and Paralichthys dentatus were observed in fall-winter collections, November through April. In most cases, each species occurred during only one month and in densities less than 1 individual/$m^3$.

Figure 11. Mean monthly abundance (number per $m^3$) of total A. Fish eggs B. Fish larvae by station, March 1979 - April 1980 (R = Ruppia, Z = Zostera, S = Sand)

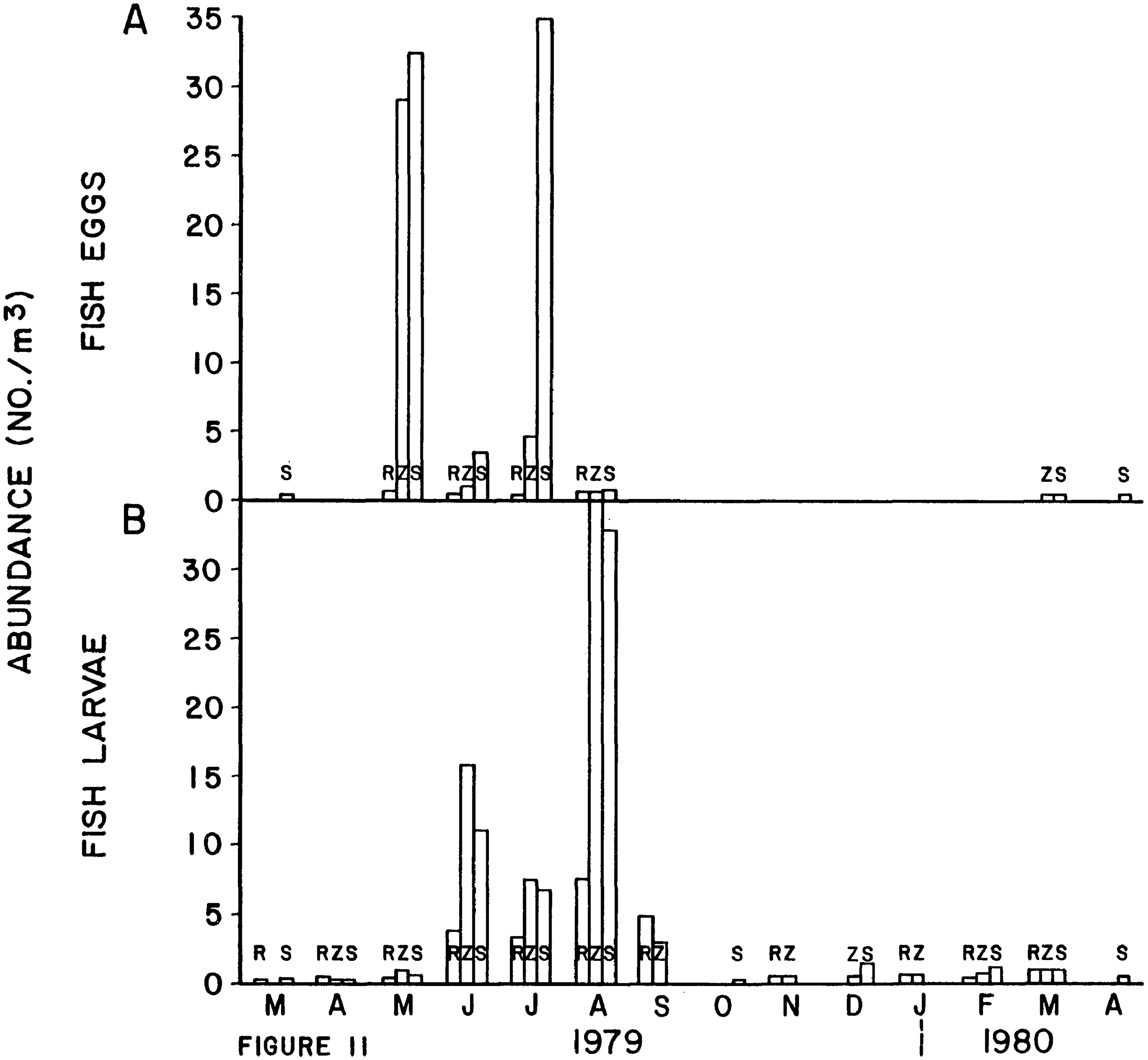

ABUNDANCE (NO./m3)
A
FISH EGGS
B
FISH LARVAE
35
30
25
20
15
10
5
0
R
S
RZS
RZ
ZS
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE II

## Demersal Plankton

*Polychaeta*. Adult polychaetes were the second most diverse demersal taxon collected; a total of 12 species was identified. In general, low abundances ($<2/m^3$) were characteristic of collections October through March (Figure 12). Values $>5/m^3$ were observed for Ruppia and Zostera in April ($17/m^3$) and May ($7/m^3$) and for Sand in July ($8/m^3$) and August ($9/m^3$). Results of the Wilcoxon test, indicated no significant difference in adult polychaete abundance between any station pairs (Ruppia-Zostera, Zostera-Sand, Ruppia-Sand).

*Nereis succinea* was the most common adult polychaete, accounting for 36% of the polychaete total. This species occurred March through September 1979 with a maximum abundance of $14/m^3$ in April. *Scoloplos* sp. was present 8 of 14 months sampled, also peaking in April 1979 ($4/m^3$). *Paraonis fulgens*, *Tharyx setigera*, Spionidae spp, *Eteone heteropoda*, and Terebellidae spp, combined, accounted for 48% of the polychaete total. These species occurred sporadically reaching maximum abundance values between 2 - $8/m^3$.

The following species occurred infrequently, never reaching densities $>1/m^3$: *Autolytus* sp., *Cistena gouldii*, *Eteone lactea*, *Glycera dibranchiata* and *Parahesione* sp.

Figure 12. Mean monthly abundance (number per $m^3$) of total adult polychaetes by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

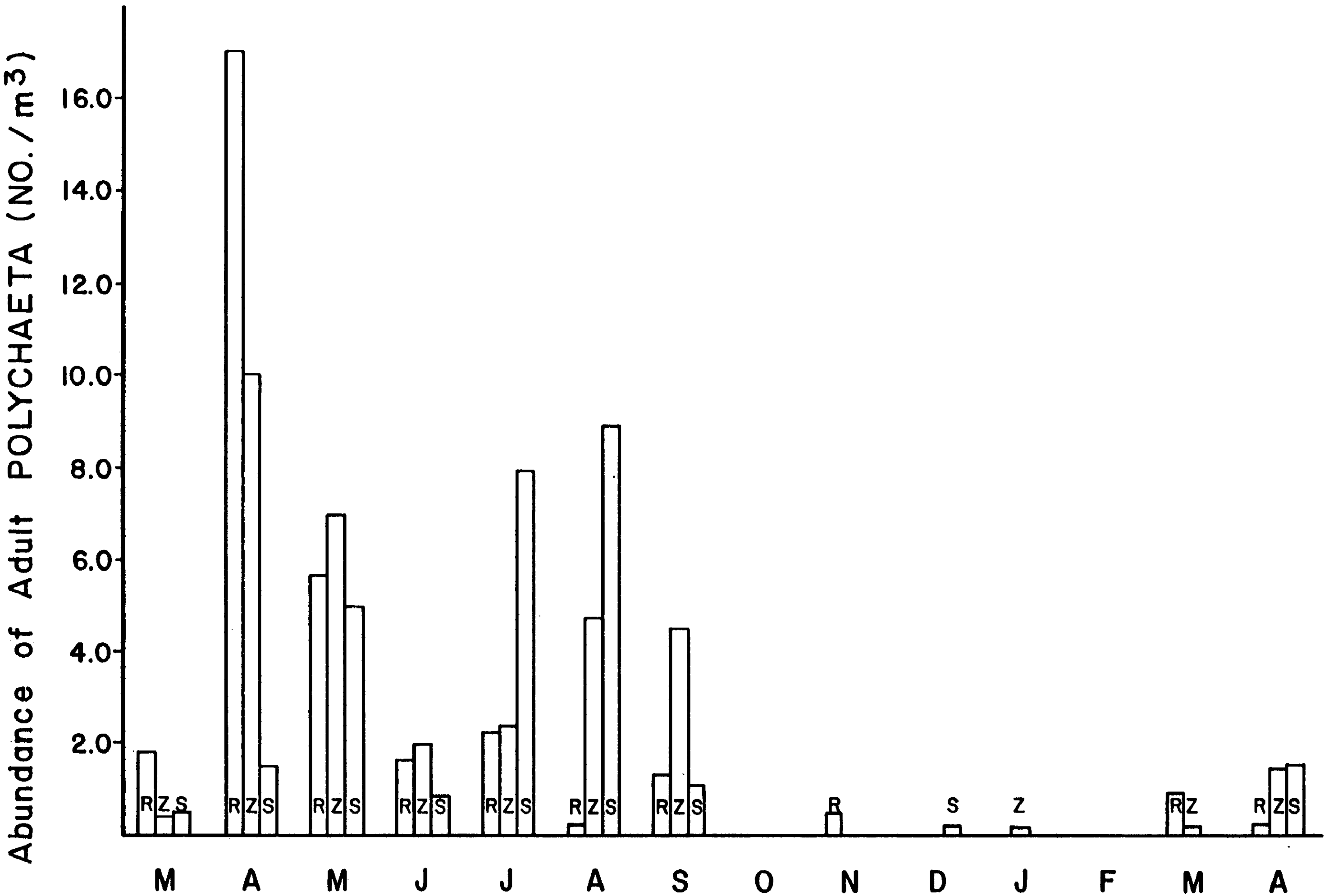

Abundance of Adult POLYCHAETA (NO./m$^3$)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
R Z S
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 12

Harpacticoida. Harpacticoid copepods were an important constituent of the zooplankton assemblage April through June and in November and December. This demersal taxon comprised 3-8% of the zooplankton total in May 1979 and 1-5% in June, November, December 1979 and April 1980. Abundance values $>30/m^3$ were observed in April of both years, May ($134/m^3$), June, July, and March 1980. Abundance varied between stations but no discernable pattern was apparent. This taxon was considered as a group category and no attempt was made to identify individuals to species, except in the case of Alteutha depressa. This relatively large harpacticoid (1.4mm) was present November, December and April through June in numbers $< 15/m^3$. The maximum abundance of A. depressa was observed in May 1979 at the Sand station ($130/m^3$).

Mysidacea. Mysids were the numerically dominant demersal taxon. Abundance values were consistently $>50/m^3$ August through February (Figure 13). Mysids comprised between 5-9% of the zooplankton total in September, 22-81% in November, 12-35% in December, and 3-15% in January. Maximum densities were observed in September 1979 at Ruppia ($494/m^3$), Zostera ($579/m^3$) and Sand ($605/m^3$). Numbers $>400/m^3$ were also collected in August and February at the Sand station. Statistical analysis indicated no significant difference in mysid abundance over the 14-month study period between any station pairs (Ruppia-Zostera, Zostera- Sand, Ruppia-Sand).

Figure 13. Mean monthly abundance (number per $m^3$) of total mysids by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

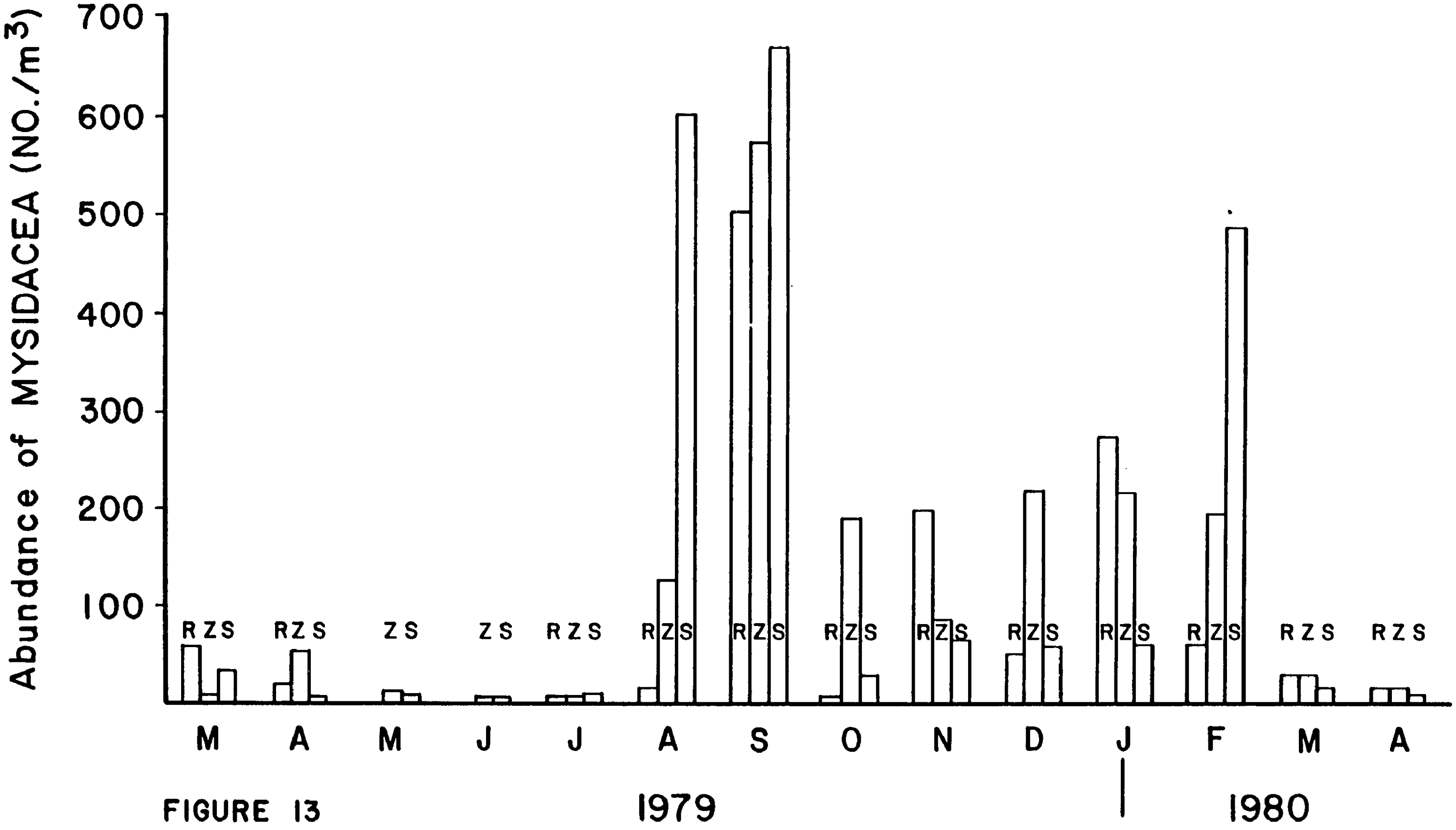

Abundance of MYSIDACEA (NO./m³)
700
600
500
400
300
200
100
R Z S
R Z S
Z S
Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 13

A total of three species of Mysidacea was identified. Neomysis americana accounted for 99% of all the mysids collected. This species occurred in densities $>200/m^3$ for at least one station in August, September, and November through February. Abundance of N. americana varied between stations, however no interstation pattern was evident. Juveniles outnumbered adults August through October comprising 68-94% of the N. americana total. Conversely adults outnumbered juveniles November through February accounting for 66-92% of the total.

Mysidopsis bigelowi was the second most commonly occurring mysid. This species was present July through September 1979 and in January 1980. Abundance of M. bigelowi was $<2/m^3$ throughout the sampling period with the exception of the Sand station in August ($19/m^3$). A third species, Heteromysis formosa, occurred only in October at the Sand station ($<1/m^3$).

Cumacea. Another important demersal taxon, Cumacea, was present in every month sampled and was represented by five species. Abundance of total cumaceans varied between months and between stations (Figure 14); maximum density values were observed in November ($15/m^3$) and December ($20/m^3$), both at the Ruppia station. Abundances $> 4/m^3$ were observed at the Ruppia station 8 of the 14 months sampled, Zostera 5, and the Sand station only once. Statistical analysis of total cumacean abundance using the Wilcoxon test indicated significantly higher numbers at the Ruppia station compared to Zostera and likewise higher numbers at Zostera compared to Sand.

Figure 14. Mean monthly abundance (number per $m^3$) of total cumaceans by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

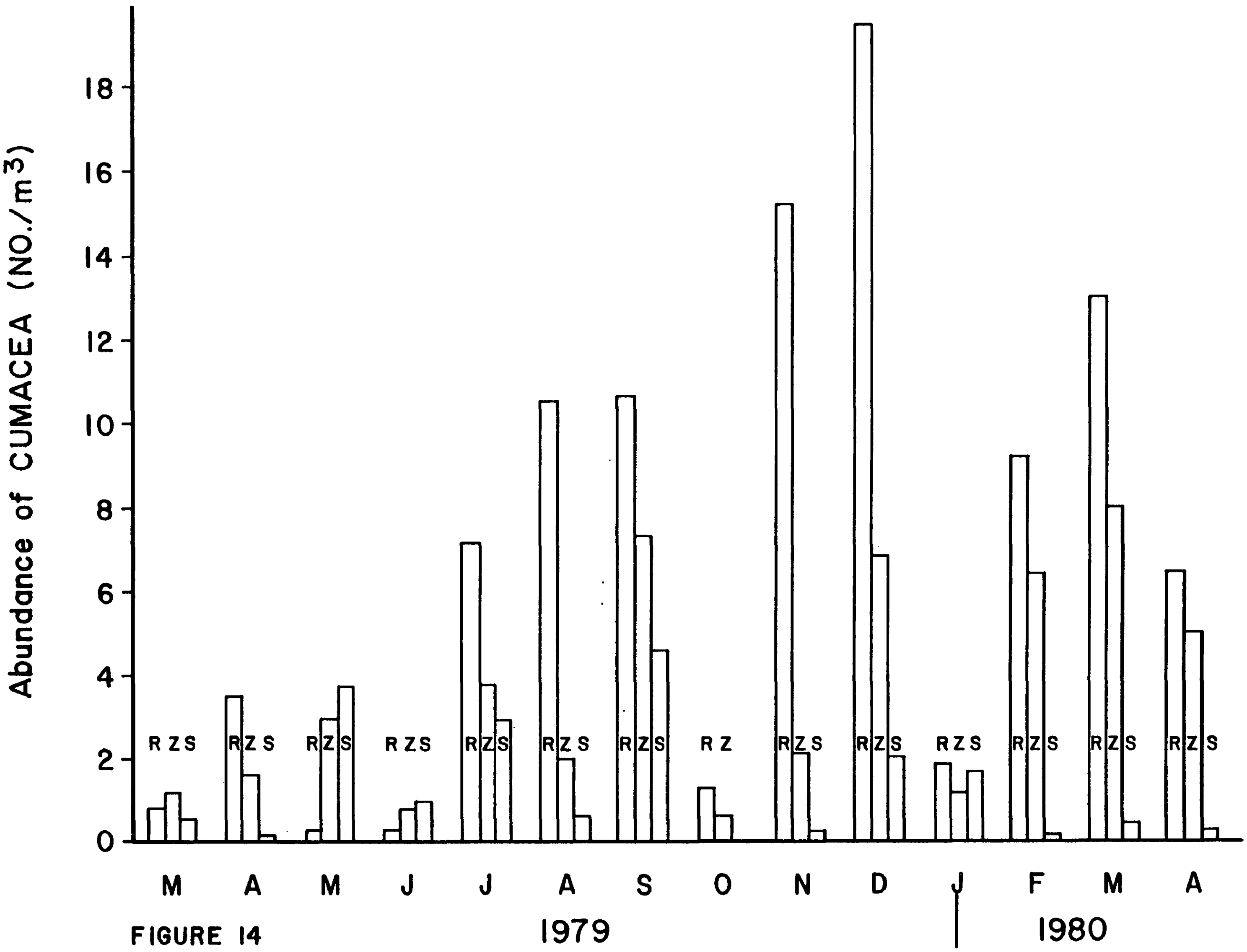

Abundance of CUMACEA (NO./m3)
0
2
4
6
8
10
12
14
16
18
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
R Z
R Z S
R Z S
R Z S
R Z S
R Z S
R Z S
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 14

During November and December 1979, cumaceans comprised between 4-6% of the zooplankton total at the Ruppia station and 1% of the total at Zostera in December. At no other time did cumaceans account for >0.5% of the zooplankton numerical total.

Oxyurostylis smithi was collected during all months sampled. In general this species occurred in low abundances ($<2/m^3$), with the exception of September ($5/m^3$), November ($15/m^3$) and December ($4/m^3$). Cyclaspis varicans was present March through November, dominating the cumacean assemblage, July through September and in March 1980 ($>6/m^3$)). Pseudoleptocuma minor was collected December through June and dominated the cumaceans December through February. At the Ruppia station in December, P. minor abundance was $>15/m^3$, the highest single species density observed for any cumacean.

Diastylis sp. was present during the spring months dominating the cumaceans in April ($2/m^3$). Leucon americanus and Mancocuma stellifera occurred infrequently in numbers $<1/m^3$. In general, abundance values were lowest at the Sand station for each of the five cumacean species.

Tanaidacea. An unidentified tanaid was present in collections, May through September. The maximum abundance ($1.5/m^3$) was observed in May at the Ruppia station. Tanaids were collected at the Sand station only in September ($<0.5/m^3$).

Isopoda. A total of four species of the demersal taxon, Isopoda, was collected during this study. At the Ruppia station, isopods were present in every month sampled. However, this group was absent from Zostera collections 3 months and from Sand collections 7 months. Peak abundance values for each station were observed during July and August: $12/m^3$ Ruppia, $12/m^3$ Zostera, and $5/m^3$ Sand. During all other months, isopod abundance values were $<5/m^3$. Based on statistical analysis (Wilcoxon test), no significant difference in isopod abundance existed between Ruppia and Zostera and likewise between Zostera and Sand. However isopod abundances were significantly lower at the Sand station compared to Ruppia.

Edotea triloba and Erichsonella attenuata were the two dominant isopod species collected. Maximum densities were $10/m^3$ (June) and $8/m^3$ (August) for E. triloba and E. attenuata, respectively. Idotea balthica occurred sporadically October through April in numbers less than $1/m^3$. A parasitic cymothoid species was collected June through November 1979 and April 1980 in numbers $<2/m^3$.

Amphipoda. Amphipoda was the most diverse demersal taxon sampled; eighteen gammarid and three caprellid species were identified. Abundance of total amphipods varied between months and between stations (Figure 15); no distinct seasonal pattern was evident. Amphipods accounted for <1.0% of the zooplankton total, eleven of 14 months.

Figure 15. Mean monthly abundance (number per $m^3$) of total amphipods and number of species by station, March 1979 - April 1980. (R = Ruppia, Z = Zostera, S = Sand)

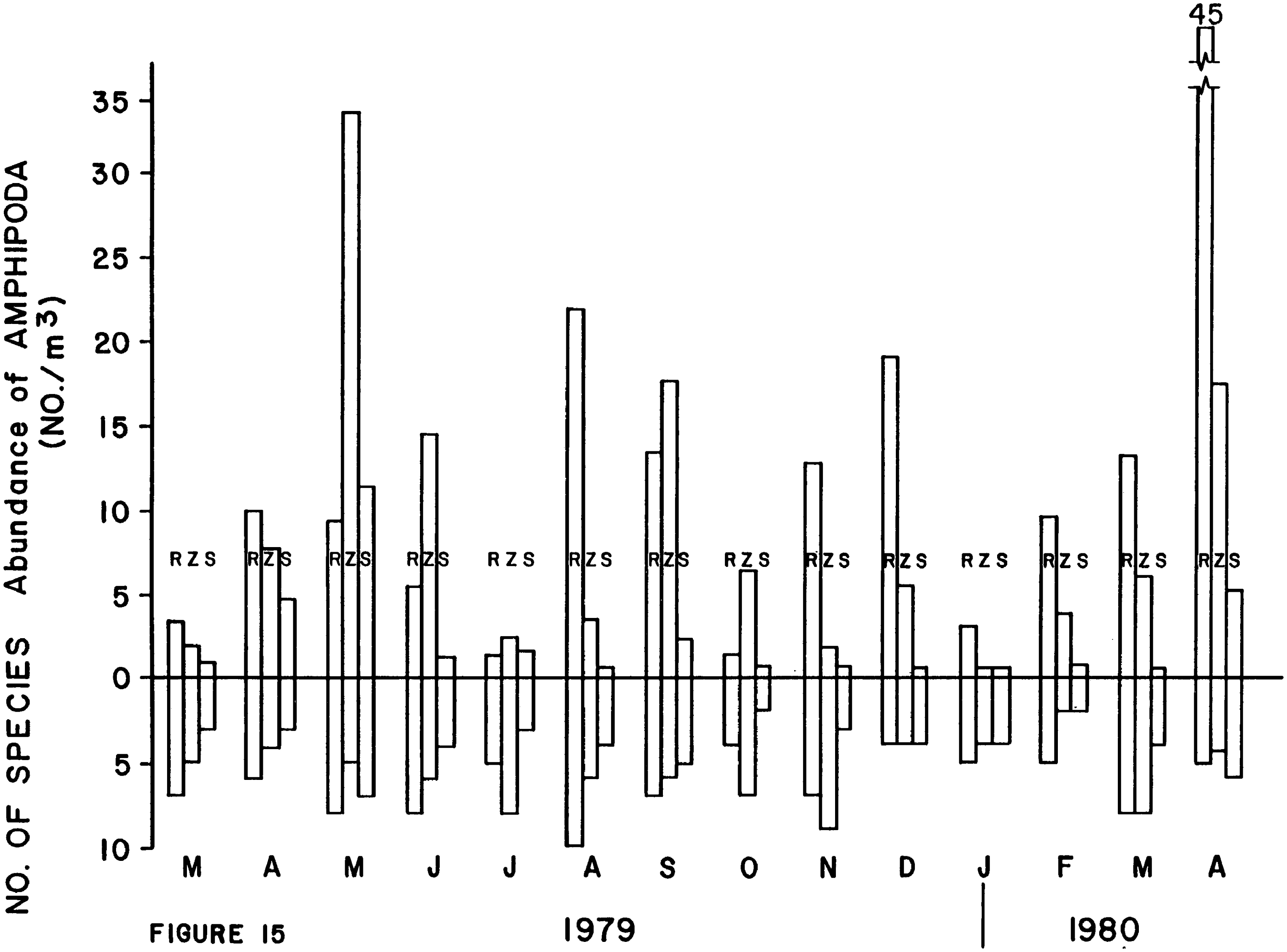

NO. OF SPECIES
Abundance of AMPHIPODA (NO./m$^3$)
35
30
25
20
15
10
5
0
5
10
R Z S
45
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1979
1980

FIGURE 15

During May 1979 and April 1980, this taxon comprised 1-2% of the zooplankton total at both Ruppia and Zostera and 4% at Ruppia in November 1979. At no time did amphipods account for >1.0% of the total at the Sand station. Densities of <5/m$^3$ were observed for the Sand station 12 of 14 months, Zostera 6 of 14, and the Ruppia 4 of 14. The peak amphipod abundance (45/m$^3$) occurred at the Ruppia station in April 1980.

Results of the Wilcoxon test indicated no significant difference in amphipod abundance between the Ruppia and Zostera samples. However, amphipod abundance was significantly lower at the Sand station compared to either Zostera or Ruppia.

*Monoculodes edwardsi*, *Microprotopus raneyi*, and *Gammarus mucronatus*, combined, accounted for 78% of all the amphipods collected. *Monoculodes edwardsi* was present in every month sampled; peak abundances were observed at the Ruppia station in December 1979 (18/m$^3$) and April 1980 (30/m$^3$). Most of these specimens were small young juveniles, probably recently hatched. *Microprotopus raneyi* was present every month except February 1980, with a peak abundance of 25/m$^3$ at the Zostera station in May 1979. *Gammarus mucronatus* was collected in all months except September 1979; young juveniles outnumbered adults for this species, also. Maximum densities of *G. mucronatus* reached 11/m$^3$, in April 1980 at the Zostera station.

Other frequently occuring amphipods included *Cymadusa compta*, *Corophium* sp., *Ampithoe longimana*, and *Ampelisca* sp. These species demonstrated no seasonality in occurrence, except for *A. longimana* which was collected only June through September. At no time did any of these species occur in numbers $>10/m^3$.

The following species occurred sporadically (usually less than 4 of 14 months) never reaching abundances $>1/m^3$: *Batea catharinensis*, *Bathyporeia* sp., *Leptocheirus* sp., *Listriella barnardi*, *Melita appendiculata*, *M. nitida*, *Parametopella cypris*, *Stenothoe minuta*, *Unciola irrorata*, and an unidentified haustorid species.

Of the three caprellid species collected, *Caprella penantis* was the most commonly occurring and most abundant. This species was present March through October, with maximum densities observed in May ($8/m^3$) and June ($7/m^3$). *Caprella equilibra* and *Paracaprella tenuis* were each collected in 5 of 14 months sampled, generally in numbers $<1/m^3$.

### Diel Variability.

Twelve day zooplankton samples were collected, six in May 1979 and six in August 1979. The day collections were made during the high tide either immediately following or preceeding the monthly night sampling.

May night collections were characterized by relatively low numbers of total organisms (900-1600/m$^3$) compared to the other months sampled during this study. Meroplankton dominated the May night assemblage (57-73%) followed by holoplankton (17-37%) and demersal plankton (5-10%). In the May day collections, the number of total organisms (300-1100/m$^3$) was lower than that observed for May night. Meroplankton ranked first numerically during the day, comprising a greater percentage of the total than in the corresponding night samples. The demersal plankton comprised only 1-3% of the zooplankton total during the day in May.

In general, abundances of copepods, polychaete larvae, fish eggs, amphipods, and harpacticoids were lower by an order of magnitude in the day collections compared to the night (Table 5). Three demersal groups (adult polychaetes, cumaceans, and mysids) were present at night in relatively low numbers, <12/m$^3$, but were absent from all day collections. Barnacle larvae comprised 20-40% of the zooplankton total at night and 40-80% during the day. However, this is an artifact of lower daytime holoplankton abundance, as barnacle larvae abundances were similar day vs. night.

The disparity between day and night abundance values varied among stations. At Ruppia and Zostera, the difference between day and night densities was much greater than that observed for the Sand station. Daytime copepod and larval polychaete abundances at the Sand station

Table 5. Day versus night taxon abundance values (no. per $m^3$) by station, May, 1979.

| TAXON | RUPPIA |  | ZOSTERA |  | SAND |  |
|---|---|---|---|---|---|---|
|  | D | N | D | N | D | N |
| Copepoda | 51 | 324 | 25 | 502 | 237 | 273 |
| Barnacle larvae | 267 | 315 | 281 | 339 | 432 | 635 |
| Polychaete larvae | 5 | 180 | 43 | 531 | 377 | 492 |
| Harpacticoida | 4 | 27 | 8 | 85 | 6 | 134 |
| Decapod larvae | 4 | 33 | 6 | 31 | 13 | 24 |
| Fish eggs | <1 | 1 | <1 | 30 | 3 | 33 |
| Amphipoda | <1 | 10 | 3 | 35 | 2 | 12 |
| Cnidaria | 1 | 14 | 1 | 2 | 1 | 2 |
| Adult Polychaeta | 0 | 6 | 0 | 7 | 0 | 5 |
| Cumacea | 0 | <1 | 0 | 3 | 0 | 4 |
| Mysidacea | 0 | 1 | 0 | 13 | 0 | 8 |
| Isopoda | <1 | 2 | <1 | <1 | 0 | <1 |
| TOTAL | 333 | 913 | 367 | 1578 | 1071 | 1622 |

were similar to night Sand values and were an order of magnitude greater than the day values for Ruppia and Zostera.

August night collections were characterized by high numbers of total organisms (9800-16800/m$^3$), dominated by copepods (86-92%). Daytime August samples were also dominated by copepods (74-96%), however, the number of total organisms was lower generally by an order of magnitude than the corresponding night collections (Table 6). Abundances of pelecypod larvae, copepods, fish larvae and mysids were much lower in the daytime than at night. Barnacle larvae, gastropod larvae, decapod larvae, and adult polychaetes exhibited similar densities between night and day collections.

Similar to the May results, the disparity between day and night abundances was greater for the Ruppia and Zostera stations in August. Also, day Sand copepod numbers were an order of magnitude higher than either Ruppia or Zostera day values. The species composition of the zooplankton assemblage did not vary between day and night samples in May or August 1979.

Zooplankton biomass (AFDW) was also generally lower in the daytime than at night (Table 7). Day AFDW values were lower by an order of magnitude in May at Ruppia and Zostera and in August at Zostera coinciding with lower daytime abundances of total zooplankton. Likewise during May and August at Sand, the day AFDW value was

Table 6. Day versus night taxon abundance values (no. per $m^3$) by station, August, 1979.

| TAXON | RUPPIA |  | ZOSTERA |  | SAND |  |
|---|---|---|---|---|---|---|
|  | D | N | D | N | D | N |
| Copepoda | 1604 | 11518 | 555 | 8943 | 9073 | 15367 |
| Pelecypod larvae | 40 | 1389 | 102 | 613 | 195 | 634 |
| Barnacle larvae | 47 | 258 | 49 | 48 | 74 | 42 |
| Gastropod larvae | 20 | 60 | 8 | 37 | 24 | 38 |
| Decapod larvae | 14 | 60 | 19 | 40 | 15 | 30 |
| Polychaete larvae | 4 | 5 | 0 | 4 | 0 | 9 |
| Cnidaria | 119 | 10 | 1 | <1 | 0 | <1 |
| Amphipoda | <1 | 22 | <1 | 4 | <1 | <1 |
| Fish larvae | 1 | 8 | 2 | 37 | 7 | 34 |
| Adult Polychaeta | <1 | <1 | 8 | 5 | 10 | 9 |
| Cumacea | <1 | 11 | 0 | 2 | 0 | <1 |
| Mysidacea | <1 | 16 | 0 | 127 | <1 | 605 |
| Isopoda | 0 | 12 | 0 | <1 | <1 | <1 |
| TOTAL | 1850 | 13369 | 744 | 9856 | 9404 | 16761 |

Table 7. Day versus night zooplankton ash-free dry weight values ($mg/m^3$) by station, May and August 1979.

| Month | | Ruppia | Zostera | Sand |
|---|---|---|---|---|
| May | Day | 55.7 | 21.5 | 51.7 |
| | Night | 397.5 | 132.4 | 118.6 |
| August | Day | 379.8 | 14.9 | 104.6 |
| | Night | 121.3 | 163.9 | 263.5 |

approximately half the night value, also similar to the diel trend in total zooplankton numbers at this station. In contrast, zooplankton biomass was higher during the day at the Ruppia station in August compared to the night biomass. Total zooplankton abundance, however, was lower by an order of magnitude in these day samples.

# DISCUSSION

## Community Seasonality

Previous studies in Middle Atlantic embayments (Cowles, 1930; Sage and Herman, 1972; Allan et al., 1976; Jacobs, 1978; Maurer et al. 1978; and Grant and Olney, 1979) have described several general zooplankton community characteristics:

1) alternation of two distinct semi-annual assemblages;
2) peak periods of zooplankton abundance heavily dominated by copepods, in particular the congeneric pair *Acartia clausi* - *A. tonsa*;
3) occurrence of both estuarine and coastal species;
4) higher diversity and species richness in the summer-fall assemblage; and
5) occasional high abundance of meroplanktonic organisms.

The data presented in this study generally concurred with previous characterizations of estuarine zooplankton. In addition, several community aspects unique to shallow-water seagrass systems were observed.

Two distinct zooplankton communities were identified, a winter-spring assemblage peaking in March and a summer-fall assemblage peaking in August. Holoplankton, primarily calanoid copepods, accounted for 70-90% of the winter-spring (January-March) and 75-95% of the summer-fall (July-October) collections. Characteristic dominant zooplankton species for each assemblage are presented in Table 8. The

Table 8. Characteristic zooplankton species from the two semi-annual assemblages: winter-spring and summer-fall.

| Taxon | Winter-Spring | Summer-Fall |
|---|---|---|
| COPEPODA | *Acartia clausi*<br>*Centropages hamatus*<br>*Temora longicornis* | *Acartia tonsa*<br>*Labidocera aestiva* |
| CLADOCERA | *Evadne nordmanni* | *Podon polyphemoides*<br>*Evadne tergestina* |
| CHAETOGNATHA | *Sagitta elegans* | *Sagitta tenuis* |
| DECAPOD LARVAE | *Crangon septemspinosa* | *Palaemonetes* sp.<br>*Uca* spp.<br>*Pinnixa* spp.<br>Xanthid spp. |
| FISH LARVAE | *Brevoortia tyrannus*<br>*Leiostomus xanthurus* | *Anchoa mitchilli*<br>*Gobiosoma* sp. |
| CUMACEA | *Oxyurostylis smithi*<br>*Pseudoleptocuma minor* | *Cyclaspis varicans* |
| ISOPODA | *Idotea balthica* | *Edotea triloba* |
| AMPHIPODA | *Monoculodes edwardsi* | *Microprotopus raneyi* |

summer-fall community contained a greater number of total species and more individuals per $m^3$ than the winter-spring community.

Total zooplankton abundance was lower by an order of magnitude during the transition months, (April-June and November-December) between the two seasonal communities. Characteristic species from both assemblages were present. Holoplankton generally comprised less than 50% of the numerical total during the transition months. Meroplankton, in particular barnacle and polychaete larvae, dominated (57-73%) the zooplankton in May and June. During November and December total numbers of holoplankton and meroplankton were at an annual low; demersal taxa comprised from 13-93% of the zooplankton total at this time.

## Zooplankton Biomass

Ash-free dry weight estimates of zooplankton biomass fluctuated erratically between successive months, especially at the Ruppia and Zostera stations. These changes do not correlate with increases or decreases in the total number of zooplankters. Analyses of the taxonomic samples indicate that in many cases the temporal biomass variability may be attributed to fluctuations in the abundance of a single taxon. Certain taxa, especially in the demersal category, are characterized by large-bodied robust organisms. These individuals although comparatively rare numerically, may significantly increase the biomass. The September peak in biomass, for example, coincides with the annual peak abundance of Mysidacea. Likewise in January, although the number of total zooplankters was comparatively low, high abundance of ctenophores and mysids resulted in higher biomass (AFDW) values.

Results of the taxonomic analyses are also useful in explaining the monthly spatial variability in biomass. For example, the relatively greater biomass observed at the Zostera station in December and the Sand station in February reflects higher abundance of mysids at these stations.

Jacobs (1978), using a similar net and mesh size, determined zooplankton AFDW from double-oblique tows taken during the day in the open waters of the Chesapeake Bay proper. The AFDW data collected in the present study (29-783 mg/m$^3$) were generally higher and more variable than those observed at Jacob's station closest to Vaucluse Shores (<1-247 mg/m$^3$). Values >200 mg/m$^3$ were observed in 10 of the 13 months for this study compared to 4 of 24 months sampled by Jacobs. The differences observed in zooplankton biomass between the two studies are probably due to fluctuations in 1) large-bodied demersal organisms which migrate into the water column predominantly at night and 2) increased detrital load. One of the inherent problems with using gross community biomass techniques is the inability to separate detritus from living material. Visual examination of the taxonomic samples indicated qualitatively greater amounts of non-living detrital matter in the shallower Ruppia and Zostera stations. Increased wave action associated with wind may resuspend seagrass and _Spartina_ detrital matter in these shallow-water areas.

These results suggest that conventional gross community biomass estimates may not reflect actual trends in spatial or temporal zooplankton distribution within shallow-water estuarine systems. Detritus and transient demersal taxa may significantly distort community biomass values.

## Holoplankton

Of the three major taxonomic components comprising shallow-water zooplankton communities, holoplankton exhibited the least spatial variability throughout this study. Abundance and species composition of the numerically dominant holoplanktonic taxa, Copepoda, were essentially uniform between the three stations. High density aggregations of copepods, indicative of swarming, were not observed at any station during the present study.

Seasonal trends in copepod community structure closely paralleled those observed by Jacobs (1978) and Grant and Olney (1979; 1982) for the lower Chesapeake Bay proper. There was, however, a major discrepancy in the temporal distribution of _Acartia tonsa_ observed in the present study. Semi-annual congeneric species replacement (_A. tonsa_ - _A. clausi_) is a well-documented phenomenon in Middle-Atlantic estuaries (Conover, 1956; Jeffries 1962, 1967; Sage and Herman, 1972; Jacobs, 1978). According to Jacobs (1978), _A. tonsa_ was present year-round in the lower Chesapeake Bay, dominating the zooplankton assemblage August through December. _Acartia clausi_ first appeared in November and dominated the zooplankton February through May. By June, _A. clausi_ was absent from the lower Bay.

The March copepod community in the Chesapeake Bay is generally characterized by a greater abundance, usually by one or two orders of magnitude, of *A. clausi* compared to *A. tonsa* (Table 9). This was the case in the present study for March 1979. However, in 1980 similar numbers of the congeneric pair were observed. *Acartia clausi* was present in numbers comparable to those observed for March in previous years. In contrast, the 1980 *A. tonsa* abundance was an order of magnitude higher than that of 1979. In addition, *Centropages hamatus* and *Pseudocalanus minutus* comprised a relatively greater numerical percent (35% vs 5%) of the 1980 copepod community. A similar phenomenon occurred in 1975 for the Delaware Bay. According to Maurer et al. (1978), *A. clausi* abundance did not exceed that of *A. tonsa*; instead *C. hamatus* and *Temora longicornis* dominated the winter assemblage.

It appears from these data that the congeneric replacement of *A. clausi* - *A. tonsa* may be an annually variable phenomenon in southern Middle Atlantic estuaries or at least it may be spatially limited to certain portions of these estuaries. In March 1980, salinity was roughly 3 ppt higher (17 vs 20 ppt) than in March 1979 at the study site. The greater abundances of typical winter coastal species like *C. hamatus*, *P. minutus*, and *T. longicornis* in 1980, suggests an intrusion of saltier coastal waters along the eastern side of the Bay. *Acartia tonsa* is a year-round resident of both estuarine and coastal waters in the southern Mid-Atlantic Bight, while *A. clausi* is apparently confined to estuarine waters (Grant, 1977a, 1979; Van Engel and Tan, 1965).

Table 9. Average abundance (no. per $m^3$) of adult _Acartia tonsa_ and _Acartia clausi_ in March.

| Investigator | Year | No. of samples | A. clausi | A. tonsa |
|---|---|---|---|---|
| Jacobs | March 1972 | 24 | 21,500 | 410 |
| Jacobs | March 1973 | 24 | 2,603 | 95 |
| Grant and Olney* | March 1978 | 20 | 4,714 | 670 |
| present study | March 1979 | 6 | 7,996 | 532 |
| present study | March 1980 | 6 | 3,063 | 3,808 |

*using 60 cm net (0.202 mm)

Autochthonous populations of A. tonsa in the Chesapeake Bay may be augmented by intrusions of coastal water populations, resulting in higher A. tonsa abundance as was observed in 1980 at the study site. In the middle portions and along the western side of the Bay in 1980, normal congeneric replacement of A. tonsa by A. clausi may have been occurring.

Chaetognath and cladoceran abundance and species composition were also distributed evenly between stations. All species collected in this study, their seasonal distribution and abundance have been previously recorded in the lower Chesapeake Bay (Bryan, 1977; Grant, 1977b).

Two holoplanktonic taxa, hydromedusae and ctenophores, exhibited variability in spatial distribution. Qualitatively higher densities of these organisms were observed at the Ruppia and Zostera stations compared to the Sand station. Ctenophores and hydromedusae may be concentrating or swarming via active orientation in the reduced current velocity water associated with the seagrass systems (assuming they detect currents). As a second possibility, the seagrass blades may act as a sieve to passively concentrate large-bodied spherical particles such as hydromedusae and ctenophores while allowing smaller particles (copepods, cladocerans, etc.) to pass unimpeded.

### Meroplankton

Meroplankton varied spatially to a greater extent than holoplankton, but in general no consistent interstation trends were apparent. Larval barnacle, polychaete and decapod abundances were statistically similar between stations over the fourteen month study period. Only fish eggs exhibited a consistent pattern in spatial distribution. Fish egg abundance was generally an order of magnitude higher at the Sand compared to the Ruppia station. Since fish eggs are considered incapable of independent movement, an active or non-static mechanism may be responsible for this observed distribution. Increased predation by fishes associated with seagrass areas may result in reduced concentration of fish eggs at the Ruppia station. There are no stomach content data, however, to test this hypothesis.

According to Olney (in press) the center of spawning in the lower Chesapeake Bay for Anchoa and Sciaenidae, the two dominant egg types collected in this study, is the mid-channel open Bay waters. The time required for transport to shallow water seagrass areas may be longer than the developmental time of these eggs (Anchoa mitchilli fertilization to hatching = 24 hours at 27°C; Kuntz 1914). Thus, the eggs may hatch before they are transported into the bed, resulting in low egg abundances at the Ruppia station (J. Olney VIMS, pers. comm.).

Meroplankton abundance also varied temporally; well-defined seasonal pulses were apparent for each taxonomic group. High densities of barnacle larvae and polychaete larvae were collected April through June, comprising 30-70% of the zooplankton total. In the Delaware Bay, Maurer et al. (1978) noted occassional numerical dominance by meroplankters at shallow water stations. Jacobs (1978) also noted high densities of barnacle larvae April through June 1972 and 1973 in the lower Chesapeake Bay. Numerical dominance of the zooplankton community by selected meroplankton species coincides with the transition period between the two seasonal holoplankton assemblages.

Larval decapod abundance exhibited two peaks over an annual cycle. Species composition and seasonality of the zoeal assemblage were similar to previous Chesapeake Bay characterizations (Sandifer, 1973; Jacobs, 1978; Grant and Olney, 1979; 1982). The winter decapod community was overwhelmingly dominated by <u>Crangon septemspinosa</u>. Diversity, in terms of the number of species collected, was much higher during the summer and abundances were more evenly distributed between species than in winter collections.

Absolute abundance estimates and relative numerical percentages of selected decapod species differed in the present study from those previously described. Considering annual variability, sampling gear differences, and the limited area sampled in this study, these abundance differences are presumed minor.

Generally, the abundance of individual decapod species was independent of the presence of seagrass. Except for <u>Palaemonetes</u> sp., there was no evidence that spawning by decapod species was restricted to the vegetated areas. Zoeal densities of <u>Palaemonetes</u> were higher at Ruppia compared to the Sand station. Sandifer (1973) also found lower <u>Palaemonetes</u> abundances in open bay than York River collections. Species of <u>Palaemonetes</u> (<u>P</u>. <u>pugio</u>, <u>P</u>. <u>vulgaris</u>, and <u>P</u>. <u>intermedius</u>), commonly known as grass shrimps, predominantly inhabit beds of submerged aquatic vegetation in estuarine systems (Williams, 1965).

Demersal Plankton

Demersal plankton exhibited the greatest spatial variability of the major taxonomic groups analyzed in this study. Significantly higher numbers of specific demersal groups, in particular Amphipoda, Cumacea, and Isopoda were observed at the Ruppia and Zostera stations in comparison to the Sand station. This greater density at the vegetated stations may be attributed to 1) proximity to the seagrass system, a source of benthic organisms or 2) a shallower water column at Ruppia and Zostera.

Alldredge and King (1980) demonstrated that most vertically migrating benthic organisms rise only 1-2 m off the bottom. Sampling at a fixed depth of 1 m from the surface may cause differential capture of demersal plankters between shallow and deep (>2 m) water stations. I do not feel, however, that the variability in demersal abundance observed in this study is solely an artifact of sampling depth. Seagrass systems are considered an important source of food, and protection for numerous benthic invertebrate species (den Hartog, 1977; Heck and Wetstone, 1977; McRoy, 1977). Faunal differences between vegetated and non-vegetated habitats have been well-documented (Santos and Simon, 1974; Orth, 1973; Thayer et al., 1975). In general, the number of species and density of epifaunal and infaunal organisms are considerably lower in non-vegetated habitats. The physical complexity of seagrass increases structural heterogeneity resulting in greater diversity and abundance of fauna in vegetated areas (Orth, 1977; Heck and Orth, 1980).

The density of macrophytic cover may further regulate species composition and abundance. Heck and Wetstone (1977) speculated that the increased species richness observed in seagrass meadows is a function of grass blade density which increases food availability, living space, and protection from predators. Thus, abundance of macrobenthic organisms ($N/m^2$) and species diversity are directly related to mean macrophytic biomass (Stoner, 1980).

Based on these studies, a greater abundance of resident benthic organisms can be expected in areas of submerged aquatic vegetation. In the present study, demersal plankton was more abundant and comprised a greater percentage of the total zooplankton density at vegetated stations in comparison to a non-vegetated station and to previous Chesapeake Bay zooplankton characterizations. Demersal taxa are, therefore, important components of the zooplankton community in shallow shallow-water seagrass systems, more so than in adjacent non-vegetated areas.

The trophic importance of benthic invertebrates to diurnal bottom-feeding fish predators is well known (Carr and Adams, 1973; Stickney et al., 1975; Sheridan, 1978). However, recent studies have illustrated the impact benthic species, which move up into the water column at night, have upon the trophic structure of nocturnal pelagic-feeding fishes (Robertson and Howard, 1978; Hobson and Chess, 1978). A study conducted in the nearshore waters off California

(Hobson and Chess, 1976) correlated diel changes in zooplankton composition with food habits of various fish predators. Diurnal planktivorous fishes consume predominantly holoplanktonic organisms (i.e. copepods and cladocerans), while demersal organisms comprise a large portion of the diet of nocturnal planktivorous fishes.

In Chesapeake Bay seagrass systems, there are at least two nocturnal pelagic-feeding fish species which may benefit from the increased prey input of diel-migrating demersal taxa: *Membras martinica*, the rough silverside and juvenile *Bairdiella chrysoura*, the silver perch. Concurrent with the time period of this study, the food habits of juvenile silver perch in seagrass meadows were investigated at the Vaucluse Shores study site (Brooks et al., 1981). Unfortunately no stomach data were collected for *M. martinica* during this period. Several species collected at night in the zooplankton samples also occurred as prey items in stomachs of juvenile *B. chrysoura*: *Neomysis americana*, *Gammarus mucronatus*, *Caprella penantis*, *Cymadusa compta*, *Corophium* sp., and *Microprotopus raneyi* (Brooks et al., 1981). Juvenile silver perch typically feed at night, in mid-water, consuming prey directly in front of them (Chao and Musick, 1977; H. Brooks, VIMS pers. comm.). The mysid, *N. americana*, was an important food item by number and by weight for silver perch 70-150 mm SL during September, October, and November. This species was also the numerically dominant demersal taxon collected at the Ruppia and Zostera stations during these months (200-500/m$^3$). *Gammarus mucronatus* and *Caprella penantis* are epifaunal amphipods (McCain, 1968; Bousfield, 1973) and may have been consumed directly from their habitat on the seagrass blades. However, M. raneyi, C. compta, and Corophium sp. are tube-building infaunal amphipods (Bousfield, 1973). Since no evidence of benthic feeding (sand or tubes) was observed in the stomachs (Brooks, pers. comm.), juvenile silver perch are probably consuming these prey items as they migrate into the water column at night. Thus, resident demersal zooplankters may represent an important energy source to nocturnal mid-water fishes in Chesapeake Bay seagrass systems.

Several hypotheses have been presented to explain the functional significance of diel migration by benthic invertebrates. Movement into the water column subjects these demersal organisms to increased predator pressure by nocturnal, mid-water fishes; thus, a counter-balancing advantage for vertical migration must exist (Robertson and Howard, 1978).

Historically, the planktonic presence of many demersal taxa has been correlated with feeding habits (Blegvad, 1922). Emery (1968) speculated that many carnivorous benthic invertebrates such as some species of polychaetes, cumaceans and amphipods migrate to forage on holoplankton in the water column. Many omnivorous species of Mysidacea also feed nocturnally on small zooplankton (Hobson and Chess, 1976; Cooper and Goldman, 1980). The mysid, Neomysis americana, collected in this study was observed consistently in large numbers in the water column. Little information exists on the feeding habits of N. americana, however other species of Neomysis are zooplanktivorous

(Murtaugh, 1981; Siegfred and Kopache, 1980). The consistency and large numbers in which *N. americana* appeared in the water column at night indicates feeding as a probable functional advantage of vertical migration in this species.

Most of the other demersal taxa collected in this study, however, are herbivorous. For example, *G. mucronatus*, *M. raneyi*, *Ampelisca* sp., *A. longimona*, *E. triloba* and *E. attennata* feed primarily on epiphytic algae, benthic drift algae or microbial flora associated with detrital particulate matter (Mills, 1967; Nelson, 1980; Zimmerman et al., 1979; Smith et al., 1979; Orth and Boesch, 1979). Migration by these species, thus, is probably unrelated to feeding behavior.

Williams and Bynum (1972) correlated the migratory behavior of many amphipod species with avoidance of nocturnal predation by benthic feeding fishes. Subsequent studies (Hobson and Chess, 1976; Robertson and Howard, 1978) have rejected this hypothesis on the grounds that most benthic feeding occurs during daylight, stimulated by visual cues. In fact, the opposite case appears to exist, with increased predation pressure in the mid-waters at night.

The vertical migration of certain benthic invertebrates has been linked to reproductive strategy. Some polychaete species, for example, synchronously swarm at the surface to spawn (Clark, 1965; Evans, 1911). In this study most of the adult polychaetes were collected in low numbers. No monospecific swarms were observed; sexual epitokes were rare. The amphipod, *Ampelisca* sp., an infaunal tube-builder, enters the water column periodically to mate when sexually mature (Mills, 1967). Several of the gammarid amphipod species collected frequently in this study including *Ampelisca* sp., *Cymadusa compta*, *Corophium* sp., and *Ampithoe longimana*, are infaunal or epifaunal tube-builders (Bousfield, 1973). These organisms may increase the probability of successfully encountering a mate by leaving their tubes and actively searching.

Another possible explanation of demersal vertical migration involves ecdysis. The cumacean, *Diastylis rathkei* was observed by Anger and Valentin (1976) to migrate into the water column at night only during ecdysis in the Baltic Sea. Specimens of *Diastylis* sp. and *Cyclaspis varicans* captured in the present study were undergoing ecdysis as evidenced by partially discarded molts attached to the pleon. No other demersal plankters showed signs of molting.

Another advantage of vertical migration may be the horizontal dispersal of benthic invertebrates via water currents. Alldredge and King (1980) concluded that benthic organisms entering the water column, if only for a brief period of time, may be dispersed over short horizontal distances possibly relocating them to more favorable habitats. A striking feature of the present study was the large number (45/$m^3$) of juvenile amphipods, particularly *G. mucronatus* and *M. edwardsi* collected pelagically. Grant and Olney (1979; 1982) observed higher densities of *G. mucronatus*, *M. raneyi* and *Corophium* sp. in surface waters compared to subsurface waters of the Chesapeake Bay proper. These data suggest that vertical migration may be an important mechanism for horizontal dispersal of selected amphipod species. This behavior may promote rapid recolonization of disturbed sites and reduce competition between juveniles and adults (Robertson and Howard, 1978; Alldredge and King, 1980).

The temporal distribution of demersal taxa collected in this study was highly variable. No consistent seasonal trends were apparent for many of the groups and interannual variation was high for all groups. Demersal taxa exhibit species-specific diel migration patterns, i.e., when they enter the water column and how long they stay. Using artifically darkened emergence traps, Alldredge and King (1980) demonstrated that absence of light is a major cue stimulating migration. In some species, particularly amphipods (Macquart-Moulin, 1976), the timing of migration may also be affected by circadian rhythms. In addition, factors such as age, sex, ecdysis and spawning condition may regulate an individual's migration pattern on a particular night (Alldredge and King, 1980). Thus species composition and abundance of demersal plankton may vary from dusk to dawn and between successive nights.

In this study all night sampling was conducted at high tide, regardless of moon phase or actual time. The temporal distribution of demersal zooplankton abundance observed in this study may be a result of variability in light level, moon phase or internal motivation factors rather than actual temporal changes in numbers of organisms. The high degree of temporal variability must be kept in mind when comparing demersal zooplankton abundance between studies or between stations of the same study when sampled days or even several hours apart.

## Diel Availability

Abundance of obligate and facultative zooplankton also varied temporally on a diel basis. Diel changes in the vertical distribution of zooplankton have been well-documented, especially in oceanic environments (Bary, 1967; Longhurst, 1976, Zaret and Suffern, 1976; Robertson and Howard, 1978). The general pattern of migration exhibited by most species is upward at dusk and downward at dawn, resulting in higher densities near the surface of the water column at night.

In this study, total zooplankton abundance was greater in night collections, usually by an order of magnitude, compared to day collections. In most cases, demersal taxa were absent during daylight or present in very low numbers compared to night levels. The diel variability of demersal zooplankton and its functional significance have been presented previously in this discussion.

Diel changes in the abundance of obligate zooplankton varied among taxa. Larvae of fish, polychaete and pelecypod species exhibited the typical trend of higher abundances in night collections. Uniform abundances of barnacle, gastropod and decapod larvae were observed between day and night.

The most apparent diel change was observed for copepod abundance. At the Ruppia and Zostera stations, copepod numbers decreased by an order of magnitude during daylight. However, copepod abundance at the Sand station was similar or only slightly greater at night compared to day. Copepods undergoing vertical migration downward at dawn may possibly be moving into water deeper than the water flooding the seagrass meadow at high tide. Thus fewer copepods would acutally enter the seagrass bed during the day. Another possible explanation involves increased predation in areas of submerged aquatic vegetation by sight-feeding planktivores. Many species of postlarval and juvenile fish, for example, are more abundant at the Ruppia and Zostera stations (Brooks, et al 1981). Grazing on copepods by these predators may result in lower copepod abundances at the Ruppia and Zostera stations compared to Sand.

The number of diel comparisons analyzed in this study was inadequate to evaluate the validity of this trend in copepod abundance. In fact, other zooplankton data collected during the day at the same stations in conjuction with another study contradicted the diel changes observed above. Using the same pushnet apparatus, zooplankton was collected during the day at Ruppia, Zostera, and Sand approximately every fourth day during April 1980 (Meyer, unpubl. data). Daytime copepod abundance values were similar between vegetated and unvegetated samples (Meyer, unpublished data). April is the month of peak postlarval spot, Leiostomus xanthurus abundance in lower Chesapeake Bay seagrass beds (Merriner and Boehlert, 1979); this species feeds primarily on copepods as a postlarvae (Kjelson et al, 1975). If predation were the cause of the observed spatial variability in copepod abundance, one would expect much lower copepod densities at the vegetated stations during April 1980. However, this trend was not observed (Meyer, unpubl. data).

Additional research on diel changes in the distribution of holoplankton in shallow-water areas is necessary. Such research is desirable in view of recent speculation on the importance of such areas as nursery grounds for a variety of fish species (Reid, 1954; Carr and Adams, 1976; Adams, 1976).

## Summary

Composition, abundance, seasonality and community structure of the holoplanktonic and meroplanktonic assemblages collected in lower Chesapeake Bay seagrass systems closely resemble deeper, open water zooplankton populations of the Bay proper. In contrast, demersal plankton was more abundant than in the Bay, comprising a greater percentage of the zooplankton total at stations associated with submerged aquatic vegetation (SAV).

The source of obligate plankton for SAV beds appears to be adjacent deeper, non-vegetated areas. Zooplankton is transported in and out of the seagrass meadow via flooding and ebbing waters. Thus, there is a potential energy gain to the SAV ecosystem in terms of exogeneous zooplankton imported on a flood tide. The importance of this input to the overall energy flow in highly productive ecosystems such as seagrass beds is poorly known. Regardless of what percentage zooplankton contributes to the overall system production, a number of adult planktivorous fishes and invertebrates rely on plankters as prey items. Seagrass systems are utilized for refuge by a variety of fish species and life history stages. Inputs of zooplankton to seagrass beds on a tidally-replenished basis may represent a significant source of nutrition to such planktivores seeking refuge in an otherwise detrital-based ecosystem.

Resident members of the benthic substrate represent a second source of organisms to zooplankton communities in seagrass systems. These facultative forms or demersal plankton vertically migrate into the water column periodically, especially at night. Demersal taxa play an important trophic role during the day for numerous diurnal benthic-feeding fishes, however, as they migrate up into the water column they become an important food supply for nocturnal pelagic-feeding planktivores. During nightly ebb tides, demersal plankton may be exported from their resident bed in high densities, thus representing an energy loss from the resident SAV ecosystem.

# CONCLUSIONS

1. One hundred twenty-four species were identified from 93 collections over the 14 month study period, March 1979 - April 1980. Two distinct semi-annual assemblages were apparent, a winter-spring assemblage peaking in March and a summer-fall assemblage peaking in August. Peak periods of zooplankton abundance were dominated (70-90%) by copepods, in particular the congeneric pair *Acartia clausi* - *A. tonsa*. During the transitional months between the two seasonal communities, zooplankton abundance was lower by 1-2 orders of magnitude. At these times, meroplankton and demersal taxa comprised a greater percentage of the zooplankton total.

2. Ash-free dry weight estimates of zooplankton biomass ranged from 29-783 mg/m$^3$ and fluctuated erratically between successive months, especially at the vegetated stations. Conventional gross community biomass estimates may not reflect actual trends in spatial or temporal zooplankton distribution within shallow-water seagrass systems. Detritus and transient demersal taxa may significantly distort biomass values in these areas.

3. Diel changes in zooplankton abundance varied among taxa. Copepods, most demersal taxa, and larvae of fish, polychaete and pelecypod species were more abundant at night compared to day collections, usually by 1-2 orders of magnitude. Barnacle, gastropod and decapod larvae abundances were similar between diel periods.

4. Holoplankton exhibited the least spatial variability throughout this study. Abundance and species composition of Copepoda, Cladocera, and Chaetognatha were essentially uniform between stations. Meroplankton varied spatially to a greater extent than holoplankton, but in general no consistent interstation trends were apparent. Abundances of larval barnacles, polychaetes, and decapods were statistically similar between stations. However, fish egg abundance was an order of magnitude lower at the Ruppia compared to the Sand station.

5. Composition, abundance, seasonality and community structure of the holoplanktonic and meroplanktonic assemblages sampled in this study closely resembled characterizations of deeper, open water zooplankton populations in the lower Chesapeake Bay proper. Generally, the abundance of individual species was independent of the presence of seagrass.

6. Demersal plankton was more abundant, comprising a greater percentage of the zooplankton total at stations associated with submerged aquatic vegetation compared to the nonvegetated station and the Bay proper. Significantly higher numbers of specific demersal groups, in particular Amphipoda, Cumacea, and Isopoda were observed at the Ruppia and Zostera stations. The greater density of demersal plankton at the vegetated stations may be attributed to 1) proximity to the seagrass system, a source of benthic organisms, and 2) a shallower water column at the Ruppia and Zostera stations.

7. As resident demersal organisms vertically migrate into the water column at night they become a potentially important energy source to nocturnal mid-water fishes in Chesapeake Bay seagrass systems.

8. Within shallow-water seagrass meadows there are two sources of planktonic organisms. Most obligate plankters originate in deeper Bay waters and are transported into the system via flooding waters. Facultative plankton, however, are resident members of the seagrass meadow benthic-substrate and enter the water column via periodic vertical migration.

# APPENDIX

Primary references for identification of zooplanktonic taxa

| | |
|---|---|
| AMPHIPODA | Bousfield (1973)<br>Fox and Bynum (1975)<br>McCain (1968) |
| CHAETOGNATHA | Grant (1963) |
| CLADOCERA | Della Croce (1974) |
| COPEPODA | Murphy and Cohen (1978)<br>Owre and Foyo (1967)<br>Rose (1933)<br>Sars (1903)<br>Wilson (1937a)<br>Wilson (1937b) |
| CUMACEA | Watling (1979) |
| DECAPODA | Sandifer (1972) |

| | |
|---|---|
| ISOPODA | Schultz (1969) |
| MYSIDACEA | Tattersall (1951) |
| PISCES | U.S. Fish and Wildlife Service (1978) |
| POLYCHAETA | Day (1973)<br>Fauchauld (1977)<br>Gardiner (1976)<br>Pettibone (1963) |
| MISCELLANEOUS | Calder (1971)<br>Gosner (1971) |

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