1991

Community Structure of the Macrobenthos in Back Bay, Virginia

Michael F. Lane
Old Dominion University

Daniel M. Dauer
Old Dominion University

Community Structure of the Macrobenthos in Back Bay, Virginia

Michael F. Lane
and
Daniel M. Dauer

Department of Biological Sciences
Old Dominion University
Norfolk, Virginia

Abstract: A study of the subtidal macrobenthos in Back Bay, Virginia was conducted to examine community structure in relation to sedimentary and water quality characteristics. Samples were collected in August and November of 1987 and February and May of 1988 at ten stations.

From a cluster analysis of ten collection stations, three site groups were identified. Species composition between site groups was relatively homogeneous. Discriminant analysis indicated that eight species accounted for most of the variation between site groups. A comparison of plots of the biological and environmental variables in discriminant space suggested that variation in the biological data between site groups was related in part to silt-clay content, organic content, and particle size of the sediment.

Three temporal groups were identified from a second cluster analysis of data averaged over all collection stations by collection date. Discriminant analysis indicated that six species accounted for most of the variation between temporal groups. Temporal variation in macrobenthic community structure was the result of reproductive and recruitment events of these six species.

Species diversity indices were similar to values obtained in oligohaline regions of the Chesapeake Bay (Dauer 1988; 1989). Community density was higher and community biomass was lower than values found in the Chesapeake Bay oligohaline areas (Dauer, 1988; 1989). Major changes in total community density and biomass were related to spatial and temporal changes in two dominant species: *Chironomus riparius* (Insecta) and *Scolecolepides viridis* (Polychaeta).

Introduction

Benthic macrofauna are an important component of marine and estuarine systems. These organisms are a food source for higher trophic levels (Holland et al. 1980; Dauer et al. 1982; Virstein 1977), affect both the physical and chemical properties of the sediment and the overlying water column (e.g. Aller 1978, 1980; Rhoads 1973; Rhoads and Young 1970) and influence nutrient cycling (Flint and Kamykowski 1984; Rowe et. al 1975; Zeiteschel 1980). These characteristics suggest that monitoring of the benthos should provide important information for making management decisions in marine systems (Bilyard 1987). Also, the life span and sedentary nature of these organisms make them good indicators of water quality and the effects of man-made disturbances on aquatic systems (Bilyard 1987; Reish 1973).

Studies of the macrobenthos in the state of Virginia have focused primarily on the Chesapeake Bay and its tributaries (Boesch 1972, 1973, 1977a, Boesch et al. 1976a, 1976b; Dauer et al. 1984; Dauer et al. 1989; Hawthorne and Dauer 1983; Tourtellote and Dauer 1983). Back Bay an area just south of Chesapeake Bay has received little attention. It is an important commercial and recreational fishery, as well as, a major wetlands area and feeding ground for waterfowl. Only two unpublished studies of the benthos have been conducted in Back Bay (Robinson 1978; Wollitz 1962).

The purpose of this study was to describe the macrobenthic communities in Back Bay and examine possible relationships between macrobenthic community structure and sedimentary characteristics. Temporal patterns in community structure over a one year period were also examined.

Description of Study Area

Back Bay is a large shallow estuary located in the southern sector of the city of Virginia Beach. It is the northernmost body of a chain of similar embayments which are separated from the Atlantic Ocean by the Outer Banks - Cape Hatteras barrier island chain. The Bay extends approximately 17.7 km from Sandbridge to Currituck Sound (Fig. 1). Width of the Bay ranges from 3.2 km at the northern end to 8 km at the southern end.

Back Bay consists of approximately 9950 hectares of open water and has a total drainage basin of approximately 270 km2. Several small creeks drain into Back Bay. Average depth of the bay is 1.3 m with a maximum depth of 3 m. Lunar tidal amplitude is estimated to be 0.7 m; however, wind driven tides virtually eliminate the influence and periodicity of lunar tides (Mann 1983).

Methods and Materials

Sampling procedures

A total of 120 benthic samples were collected at 10 stations during August and November of 1987 and February and May of 1988. The collection dates will be referred to as Summer (August), Fall (November), Winter (February) and Spring (May). Locations of the sampling stations are shown in Figure 1.

Three replicate samples were taken at each station using a hand-held coring device. The core had a length of 22.9 cm, an internal diameter of 7.6 cm, and sampled a total surface area of 45.4 cm^2. During the last three sampling events, an additional core was taken at each station from which an aliquot of sediment was removed for particle size analysis and volatile solids content analysis. Temperature, dissolved oxygen levels, and salinity were recorded at each station using a Hydrolab SVR-2.

Benthic samples were sieved through a 0.5 mm sieve screen and the material retained on the screen was washed into prelabeled cloth bags. Specimens were relaxed in dilute isopropyl alcohol and preserved in a 10% solution of formalin and rose bengal.

Benthic Sample Processing

Benthic samples were sorted in white enamel pans with the aid of fiber optic illuminators. Organisms were counted and identified to the lowest possible taxon. Biomass estimates of the major taxa were recorded as ash-free dry weight (AFDW) biomass. AFDW biomass was determined by drying each major taxon for 24 hours at 60°C and then ashing the sample at 550°C and taking the difference between the dry and ashed weights. AFDW Biomass values less than 1 mg were recorded as 1 mg.

Sediment Analysis

Silt-clay and sand fractions of the sediment were separated by wet sieving the sediment through a 63 um sieve screen. The sand fraction was transferred into culture dishes, placed in a drying oven at 65°C for 24 hours, and divided into whole phi intervals by sieving through a series of Wentworth graded screens. Each fraction was transferred to a pre-tared plastic pan and weighed using a Sartorius analytical balance.

Particle size distribution of the silt-clay fraction was determined using pipette analysis (Folk 1974). The percentage of sand and silt-clay, mean grain size, and sorting coefficients were calculated using a computer program designed by Darby and Wobus (1976). Volatile solids content of the sediment was calculated as the ash-free dry weight (AFDW) of the sediment divided by the dry weight of the sediment expressed as a percentage.

Data Analysis

A one-way ANOVA was used to determine significant differences in log-transformed abundances, biomass and diversity indices between stations, site groups, and temporal groups. Duncan's range test was used to determine specific differences between stations, site groups, and temporal groups (Sokal and Rohlf 1981).

Species diversity was calculated using the Shannon-Weaver index:

$$H' = -\sum_{i=1}^{s} pilog2pi$$

where pi is the proportion of the i-th species and s is the number of species (Pielou 1966). Species richness was calculated using Margelef's index:

$$SR = (S - 1)/lnN$$

where S is the total number of species and N is the total number of individuals collected at the station. Evenness was measured using Pielou's index:

$$J = H'/log2S.$$

Stations and collection times were classified into spatial groups and temporal groups using log transformed abundance data. The variance between sites and times was obtained by calculating the Euclidean distance between sites and times (over all species) after sites and times were centered to their respective means. The variance estimates were then used as a measure of dissimalarity for cluster analyses to determine the spatial and temporal groups (Williams and Stephenson 1973). A flexible sorting strategy was used with a cluster intensity coefficient of -0.25 (Boesch 1977b).

The mean variance between sites (over all times) and between times (over all stations) was determined by calculating the variance attributable to the species over all inter-site and inter-time comparisons, and then finding the mean of these values. The means were examined to determine the relative importance sites and times had on the variation in the data (Williams and Stephenson 1973).

Multivariate analysis of variance (MANOVA) was used to determine if there were significant differences in centroids between spatial and temporal groups. Plots of the site and time groups on the major discriminant functions were used to determine which species provided the best discrimination between groups. Those species with high loadings and significant ANOVAs were used as axis labels for the discriminant functions. Three species (the cumacean *Almyracuma proximoculi*, the isopod *Edotea triloba* and the chironomid *Djalmebatista pulcher*) occurred only once during the entire study and were eliminated from all analyses.

A second discriminant analysis was conducted using the water quality and sedimentary variables. Plots of the site groups and the environmental variables in discriminant space were compared to determine if the separation between site groups was influenced by the environmental parameters (Green 1979).

Results

Water quality data

No significant differences were found in any of the water quality parameters between stations ($p<0.05$). Salinity values were oligohaline with a baywide average of 2.4 ppt. Mean baywide salinity declined from 2.9 ppt in the summer to 1.9 ppt in the spring (Fig. 2A). Temperature showed a typical seasonal pattern with only small variations between stations. Dissolved oxygen values were generally high throughout the bay and were highest during the fall and winter when temperatures were lowest (Fig. 2B). Station means were all above 9.0 mg/l and anoxic conditions were never observed during this study. A minimum dissolved oxygen value of 5.5 mg/l was recorded at Station 2 during the summer.

Sedimentary data

Sediments at Stations 1, 2, 4, and 10 had high percentages of silt-clay and mean grain sizes ranging from medium to coarse silts (Folk 1974). The sediments at these stations were poorly sorted and organic content ranged from 4.10% to 6.52%. Stations 3 and 6 had intermediate values for silt-clay, were poorly sorted, and had a mean grain size in the coarse silt range (Folk 1974). Four stations (5, 7, 8, 9) had sediments consisting of well sorted fine sands (Folk 1974). Sand content at these stations ranged from 90% to 99% and organic content was very low ranging from 0.64% to 1.20%.

General community description

A total of 2803 individuals representing 20 invertebrate taxa (Table 1) was collected. Annelids comprised 48.4% of the total number of individuals collected, insects 48.2%, other arthropods 2.5% and molluscs less than 1%.

Larvae of the insect *Chironomus riparius* represented the most abundant species and accounted for 45.5% of total number of individuals and 28.2% of the biomass (AFDW) collected. The spionid polychaete *Scolecolepides viridis* accounted for 33.0% of the specimens recorded and 56.5% of the biomass (AFDW).

Density ranged from 7973 ind/m^2 (Station 2) to 3747 ind/m^2 (Station 7). However, there were no significant differences in mean density between stations ($p>0.05$). Biomass (AFDW) ranged from 4611 mg/m^2 at Station 7 to 1376 mg/m^2 at Station 10. There was a significant difference in mean community biomass between stations ($p<0.05$). The number of species per replicate, species richness, and species diversity was highest at Station 5. There were no significant differences in any of the diversity indices between stations ($p>0.05$).

Spatial patterns in community structure

On the basis of the classification analysis, three site groups were recognized: 1) the Mud Site Group - composed of those stations with the highest silt-clay and organic content (Stations 1, 2, 10), 2) the Mixed Site Group - comprised of Stations 3 and 6 with an intermediate silt-clay content, and Station 8 which had a low silt-clay and organic content, and 3) the Sand Site Group composed of the remaining stations with a high sand content and low organic content (Stations 5, 7, 9) and Station 4 (Fig. 3).

Table 2 presents the top density dominants for each of the three site groups. Density dominants were those species which accounted for a minimum of 1% of the number of individuals collected at each site group. Species composition between site groups was relatively homogeneous and major differences between site groups were due primarily to differences in the abundance of dominant species.

Abundance of *C. riparius* was significantly higher at the Mud site group than the Sand Site Group but not significantly different at the Mixed Site Group (Table 3). Biomass of *C. riparius* was significantly higher at the Mud Site Group (Table 4). Abundance and biomass of the chironomid *Clinotanypus pinguis* were significantly higher at the Mud Site Group (Tables 3-4). The oligochaete *Tubificoides heterochaetus* and the amphipod *Leptocheirus plumulosus* had significantly higher abundances and biomass at the Mixed Site Group (Table 3-4). Abundance and biomass of the polychaetes *S. viridis* and *Hobsonia florida*, the chironomid *Polypedilium convictum*, and the bivalve *Rangia cuneata* were significantly higher at the Sand Site Group (Tables 3-4). There were no significant differences in density or biomass between site groups for the oligochaete *Limnodrilus* spp., or the amphipods *Gammarus daiberi* and *Monoculodes edwardsi* (Table 3-4).

The MANOVA indicated a significant difference between the centroids of the site groups. There was a significant separation between site groups with respect to the first (DF-1) and second (DF-2) discriminant functions. DF-1 accounted for 52% of the variance and DF-2 explained 48% of the variance. Separation of the site groups occurred along both DF-1 and DF-2 (Fig. 4). The Sand Site Group can be characterized as having higher abundances of *S. viridis, H. florida, P. convictum* and *R. cuneata* (Fig. 5A-D), while the Mud Site Group had higher densities of *C. riparius* and *C. pinguis* (Fig. 6A-B). The Mixed Site Group had higher densities of *T. heterochaetus* and *L. plumulosus* (Fig. 6C-D).

Table 5 lists the mean community parameters for each of the site groups. Total community density was slightly higher at the Mud and Mixed sites although there was no significant difference in community density between site groups (Table 5). Total community biomass was significantly higher at the Sand Site Group (Table 5). There were no significant differences in any of the diversity indices between site groups (Table 5).

There was a significant difference in centroids between site groups with respect to the physical parameters. There was a significant separation between site groups with respect to the first discriminant function (DF-1), which explained 97% of the variance. The Mud and Sand sites appear to separate well in relation to silt-clay content, volatile solids and mean phi size ; however, there was some overlap between these two sites groups and the Mixed Site Group (Fig. 7). Mean values of the physical and sedimentary parameters for each site group are presented in Table 6.

Figure 8 shows the mean values of silt-clay, organic content, and mean phi for each station. Sediments at Station 8 were similar to those of the Sand Site Group while those at Station 4 more closely resembled those of the Mud Site Group. Stations 3 and 6 of the Mixed Site Group had intermediate values for silt-clay, organic content, and mean phi. This could explain the degree of overlap between site groups in relation to the physical parameters.

Temporal trends in community structure

The second classification analysis identified three temporal groups: 1) Summer 2) Fall and 3) Winter-Spring (Fig. 9).

Abundance and biomass of *C. riparius, P. convictum*, and *R. cuneata* were significantly higher during the Summer (Table 7-8). Abundance and biomass of the amphipods *Gammarus daiberi* and *Monoculodes edwardsi* were highest during the Winter-Spring temporal periods (Tables 7-8). Abundance of *S. viridis* was significantly higher during the Winter-Spring season (Table 7); however, there was no significant difference in biomass between temporal groups for this species (Table 8). There were no significant differences in abundance or biomass of *T. heterochaetus, Limnodrilus* spp., *H. florida, L. plumulosus*, and *C. pinguis* between temporal groups (Table 7-8).

Multivariate analysis of variance indicated a significant difference between the centroids of the temporal groups. There was a significant separation between temporal groups in relation both the first (DF-1) and second (DF-2) discriminant functions, which explained 93% and 7% of the variance, respectively. The Fall and the Winter-Spring group separated from the Summer group along DF-1 (Fig. 10). This separation reflects a drastic decline in abundance of *C. riparius, P. convictum*, and *R. cuneata* which occurred during the Fall and continued into the Winter-Spring (Fig 11 A-C). Abundances of *G. daiberi* and *M. edwardsi* increased during these two time periods (Fig. 11D-E). The Winter-Spring group separated from the Fall group along DF-2 and was due primarily to recruitment of *S. viridis* (Fig. 11F).

All site groups showed a dramatic decline in total community density from the Summer to the Fall followed by an increase in density during the Winter-Spring (Table 9). This was due to a precipitous decline in abundance of *C. riparius* during the Fall followed by heavy recruitment of *S. viridis* during the Winter-Spring (Fig. 12-14A).

Total community biomass at the Mud and Mixed Site Groups showed a similar decline from the Summer to the Fall and continued to decrease during the Winter-Spring (Table 9). Changes in total community biomass at these two site groups primarily reflected changes in biomass of *C. riparius* (Fig. 12-13B). Total community biomass at the Sand Site Group increased from the Summer to the Fall and decreased slightly during the Winter-Spring period (Table 9). These changes were the result of changes in biomass of *S. viridis* (Fig. 14b).

The Mud and Mixed Site Group showed a drop in the number of species per replicate from the Summer to Fall followed by an increase during the Winter-Spring temporal period. The number of species per replicate at the Sand Site Group also decreased during the Fall but only slightly increased during the Winter-Spring period (Table 9). Species richness, species diversity, and evenness gradually increased from the Summer to the Winter-Spring at the Mud site groups (Table 9). The Mixed Site Group showed a decline in all of the diversity indices during the Fall followed by an increase during the Winter-Spring temporal period. These indices declined from the Summer to the Winter-Spring at the Sand sites (Table 9). The variance in macrobenthic community structure was primarily associated with temporal effects (76.2%). Spatial effects accounted for 19.3% of the variance while the interaction between site and time groups accounted for less than 5% of the variance.

Discussion

General Patterns

Few studies of macrobenthic communities have focused on the tidal freshwater or oligohaline portions of estuarine systems (Crumb 1977; Dean and Haskin 1964; Jordan and Sutton 1984). In the Chesapeake Bay, oligohaline-tidal freshwater regions have been studied for the purpose of examining general trends in the benthos in relation to the estuarine gradient (Boesch 1972, 1977; Boesch et al. 1976a; Dauer et al. 1989; Holland et al. 1988). Back Bay can be classified as an oligohaline estuary. Oligohaline estuaries of the Southeastern United States tend to be dominated by the tubificid oligochaete *Tubificoides heterochaetus*, the spionid polychaete *Scolecolepides viridis*, the bivalve *Rangia cuneata*, the isopod *Cyathura polita*, the amphipods *Leptocheirus plumulosus* and *Gammarus daiberi*, and the chironomid *Clinotanypus pinguis* (Boesch 1976; Boesch 1977; Dauer et al. 1988; Diaz 1980; Holland et al. 1988; Jordan and Sutton 1984; Tenore 1972). Tidal freshwater areas are characterized by tubificid oligochaetes of the genus *Limnodrilus*, the chaoborid larva *Chaoborus punctipenis*, and the chironomid larva *Chironomus* sp., *Cryptochironomus* sp., and *Polypedilium* sp.(Crumb 1977; Dauer et al. 1988; Dean and Haskin 1964; Diaz 1980; Holland et al. 1988; Wass 1972). Species composition of the macrofauna in Back Bay can be characterized as being a mixture of oligohaline and tidal freshwater species.

Community density values for Back Bay were higher than those obtained in the Chesapeake Bay while community biomass values were lower (Dauer et al. 1988, 1989). This difference was related to the absence of adult *R. cuneata* which accounts for most of the biomass in oligohaline areas of this estuary (Dauer et al. 1988). Although *R. cuneata* was collected, the individuals were small juveniles ranging in size from 1 to 3 mm.

Values for the number of species per replicate and the species diversity indices obtained in Back Bay were typical for oligohaline estuaries (Boesch 1972; Dauer et al. 1988). In general, species diversity tends to be much lower in the oligohaline portion of an estuary because polyhaline and estuarine endemic species are unable to colonize areas with reduced salinities and freshwater species cannot acclimate to an increase in salinity due to osmotic stress (Boesch 1977a; Remane and Schlieper 1971). Changes in hydrochemical propeties such as calcium content, chlorinity and ion ratios associated with decreasing salintiy may also produce a physiological barrier to freshwater and marine species (Kinne 1971).

Spatial patterns in community structure

Three spatial groups were identified by the cluster analysis and confirmed by the MANOVA and discrimnant analyses. A comparison between the plots of discriminant functions of the biological and environmental parameters indicated that the Mud and Sand Site Groups separated well in relation sedimentary parameters but the Mixed Site Group showed some overlap between both of these site groups.

The discriminant analysis identified eight species which accounted for most of the variation between site groups. Distribution patterns of several of the species identified by the discriminant analysis seem to correspond to previously demonstrated sedimentary preferences.

C. riparius, is found in a wide range of aquatic habitats and is primarily associated with fine grained sediments with a high organic content (Crumb 1977; Davies and Hawkes 1981; Gower and Buckland 1978; Rasmussen 1984a and 1984b). Rasmussen (1984b) found that gut contents of *C. riparius* consisted mainly of silt, microdetritus, and benthic diatoms indicating that this species was a deposit feeder. This species preference for fine-grained sediments is probably related to its deposit feeding life style.

C. pinguis is a ubiquitous species found in habitats ranging from small ponds to large rivers and also prefers soft mud bottoms (Roback 1976).

S. viridis is primarily found in sediments characterized by a high sand fraction of the sediment (Dauer et al. 1981; Kinner and Maurer 1978; Robinson 1978;). This species depends on a high sediment permeability in order to maintain an efficient respiratory current (Dauer 1985).

The distribution pattern of *P. convictum* could be related to its feeding mode. The larvae of this species are filter-feeders (Simpson and Bode 1980). Infaunal suspension feeders require contact with the sediment surface in order to feed (Sanders 1960). Areas with high silt-clay content may have a sediment surface which is too unstable to enable suspension feeders to maintain a connection with the overlying water.

R. cuneata is found in a wide variety of sediment types, however; a high silt-clay and organic content of the sediment has been shown to adversely affect growth and mortality in this species (Tenore et al. 1968). This could explain the lower densities of and small size of individuals obtained at the Mud Site Group.

H. florida is often found in sandy, or muddy sand sediments and is often associated with plant detritus (Pettibone 1977).

L. plumulosus has been described as prefering muddy sediments (Sanders et al. 1965); however, Feeley and Wass (1976) indicate that this species is found in many substrate types. Results of this study agree with those of Feeley and Wass (1976).

T. heterochaetus is found in a wide variety of sediment types but is most abundant in substrates characterized by fine grained sediments with a high organic content (Diaz 1980). The results of this study do not support previously reported sedimentary preferences for this species.

Differences in sediment type seem to influence distribution patterns of certain species but they do not fully explain the groupings produced by the cluster analyses. Several other factors, discussed below, may influence community structure of the macrobenthos in Back Bay.

Several of the stations on the western side of Back Bay were located near incoming freshwater streams. High numbers of insect larvae found at these stations may be carried there by currents from these streams.

Robinson (1978) found that distribution patterns of nearshore macrofauna in Back Bay were related to vegetation patterns. Adult migration from nearshore populations may influence distribution patterns in offshore areas. Several of the species collected in Back Bay (i.e. chironomids, *L. plumulosus, M. edwardsi* and *S. viridis*) have good powers of dispersal (Dauer 1980; Dauer et al. 1982; Mundie, 1959). As such, variations in nearshore plant communities could indirectly effect community structure of some offshore areas.

Alden (1989) has examined temporal and spatial patterns in water quality in Back Bay. Results of his study indicted that certain areas of Back Bay, notably several of the small tributary creeks, had elevated levels of nutrients. These areas had high levels of nitrogen (NH_3 and NO_3) and phosphorus (TP and OPO4) probably as a result of agricultural and residential runoff. Several of the benthic sampling stations (Stations 1, 2, 3, and 10) were located at or close to the mouths of these creeks. The top density dominant at all of these stations was *C. riparius*. This species has often been described as being an indicator of organic pollution (Gower and Buckland 1978; Simpson and Bode 1980; Davies and Hawkes 1981). The absence of adult *R. cuneata* could also be related to the high nitrogen and phosphorus levels in Back Bay. Tenore et al. (1968) reported that elevated levels of nitrogen and phosphorus in sediments adversely effected growth rates and mortality of *R. cuneata*.

Interspecific interactions may also influence community structure in Back Bay. Burrowing and feeding activities of chironomid larvae are known to disturb feeding and respiratory activities of tubificid oligochaetes (McCall and Tevesz 1982). This could explain why *T. hetreochaetus* was not found in high densities at the Mud Site Group where *C. riparius* was the dominant species.

Temporal patterns in community structure

Three temporal groups were defined in the cluster analyses and were confirmed by MANOVA and discriminant analyses. The discriminant analysis identified six species which accounted for most of the variation between the temporal groups. Temporal changes in the abundance of these species seem to correspond to known reproduction and recruitment events.

The life cycle of *C. riparius* is characterized as multivoltine i.e. several generations per year (Gower and Buckland 1978; Davies and Hawkes 1981). Larval densities are highest during late summer and early autumn and decline dramatically later in the fall as adults emerge. Some larvae overwinter and adults emerge again during the spring (Davies and Hawkes 1981; Gower and Buckland 1978). *C. riparius* in Back Bay exhibited a similar pattern of high densities during the summer followed by a precipitous decline during the fall.

Reproduction and recruitment of *S. viridis* occur during winter and early spring (Boesch et al. 1976b; Dauer et al. 1982; George 1966). Recruitment results in denser spring populations which gradually decline throughout the year (Boesch et al. 1976b). Densities of S. viridis in Back Bay followed this pattern declining from the Summer to the Fall followed by an increase during the Winter-Spring due to recruitment of many small individuals.

The amphipods *G. daiberi* and *M. edwardsi* reproduce throughout the year; however, reproduction peaks during the early spring (Feeley and Wass 1969). This could explain the higher abundances of these two species obtained during the Winter-Spring temporal period.

P. convictum showed a seasonal pattern similar to *C. riparius*. The decrease in abundance during the Fall was probably the result of emergence of adults sometime during the late summer suggesting a similar life history to that of *C. riparius*.

Newly recruited *R. cuneata* were found almost exclusively during the Summer. This species has two peaks in recruitment; one during the late summer and early fall and the second during midwinter (Cain 1975; Jordan and Sutton 1984). The presence of *R. cuneata* juveniles during the Summer temporal period is probably the result of the summer reproductive event.

The comparison of mean variance attributable to site and time groups indicated that most of variance in macrofaunal abundance was due to temporal effects. This seems reasonable since most of the species collected have annual life cycles. Previous studies suggest that species composition of oligohaline macrofaunal communities tend to be qualitatively persistent over time but the dominant species exhibit wide seasonal fluctuations in abundance (Boesch et al. 1976b; Jordan and Sutton 1984). Results of this study seem to confirm this general trend.

High seasonal variability may overshadow some subtle spatial patterns in community structure. Further investigations of the macrofauna in Back Bay should have more frequent temporal sampling so that seasonal variations can be more clearly defined and their effects on spatial patterns elucidated.

Acknowledgements
The staff of the Pocahontus-Trojan Wildlife Refuge and Ronald Southwick and Mitchell Norman of the Virginia Game and Inland Fisheries Commission allowed us to use their boats during this study. Larry White of the Old Dominion University Applied Marine Research Laboratory collected the water quality data. Special thanks go to Lynn Mize for piloting the boats and his aid in sample collection. Dr. James Matta helped identify the insect larvae. We thank Dr. Raymond W. Alden for his suggestions for statistical analyses. We thank Rodney Bertelsen, Cheryl Hess, John Kressel, Anthony Rodi, and John Seibel for their help with computer work and data analysis.

Literature Cited

Alden, R.W., 1989. Multivariate analyses of spatiotemporal water quality patterns of Back Bay, Virginia. Applied Marine Research Laboratory Technical Report No. 707. 59 pp.

Aller, R.C., 1978. Experimental studies on changes produced by deposit feeders on pore water, sediment and overlying water chemistry. Amer J. Sci. 278:1185-1234.

Aller, R.C., 1980. Relationships of tube-dwelling benthos with sediment and overlying water chemistry. pp. 285-308, In Marine Benthic Dynamics, K.R. Tenore and B.C. Coull, eds., University of South Carolina Press, Columbia S.C.

Bilyard, G.R., 1987. The value of benthic infauna in marine pollution monitoring studies. Mar. Poll. Bull. 18:581-585.

Boesch, D.F., 1972. Species diversity of the marine macrobenthos in the Virginia area. Chesapeake Sci. 13: 206-211.

Boesch, D.F., 1973. Classification and community structure of the macrobenthos in the Hampton Roads area, Virginia. Mar. Biol. 21:226-224.

Boesch, D.F., 1977a. A new look at zonation of the benthos along the estuarine gradient. pp. 285-308, In Marine Benthic Dynamics, K.R. Tenore and B.C. Coull, eds., University of South Carolina Press, Columbia S.C.

Boesch, D.F., 1977b. Application of numerical classification in ecological investigations of water pollution. EPA Report 600/3-77-033, U.S. Environmental Protection Agency, Cornvallis, 115 pp.

Boesch, D.F., R.J. Diaz, and R.W. Virstein, 1976a. Effects of tropical storm Agnes on soft-bottom communities of the James and York estuaries and the lower Chesapeake Bay. Ches. Sci. 17:246-259.

Boesch, D.F., M.L. Wass, and R.W. Virnstein, 1976b. The dynamics of estuarine benthic communities. pp. 442-487, In Estuarine Processes, Vol I., M. Wiley, ed., Academic Press, New York.

Cain, T.D., 1975. Reproduction and recruitment of the brackish water clam *Rangea cuneata* in the James River, Virginia. Fish. Bull. 76:

Crumb, S.E., 1977. Macrobenthos of the tidal Delaware River system between Trenton and Burlington, New Jersey. Ches. Sci. 18: 253-265.

Darby, D.A. and H.B. Wobus, 1976. A versatile computer program for sediment size analysis. Technical Report PGS-TR-GE-76-25. Old Dominion University Research Foundation, Norfolk, Va.

Dauer, D.M., 1985. Functional morphology and feeding beahvior of *Paraprinospio pinnata* (Polychaeta:Spionidae). Mar. Biol. 85:143-151.

Dauer, D.M., R.M. Ewing, and J.A. Ranasinghe, 1988. Macrobenthic communities of the Lower Chesapeake Bay. Chesapeake Bay Program. March 1985 - June 1987. Old Dominion University Research Foundation Technical Report, 310 pp.

Dauer, D.M., R.M. Ewing, J.A. Ranasinghe, and A.J., Rodi, 1989. Macrobenthic communities of the Lower Chesapeake Bay. Chesapeake Bay Program. March 1985 - June 1988. Old Dominion University Research Foundation Technical Report, 295 pp.

Dauer, D.M., R.M. Ewing, J.W. Sourbeer, W.T. Harlan, and T.L. Stokes, Jr. 1982. Nocturnal movements of the macrobenthos of the Lafayette River, Virginia. Int. Revue ges. Hydrobiol. 67: 761-775.

Dauer, D.M., R.M. Ewing, G.H. Tourtellotte, and H.R. Barker Jr., 1980. Nocturnal swimming of *Scolecolepides viridis*. Estuaries 7: 148-149.

Dauer, D.M., R.M. Ewing, G. Tourtellotte, and W. Harlan. 1982. Predation, resource limitation and the structure of benthic infaunal communities of the Lower Chesapeake Bay. Int. Revue ges. Hydrobiol., 67:477-489.

Dauer, D.M., C.A. Maybury and R.M. Ewing, 1981. Feeding behavior and general ecology of several spionid polychaetes from the Chesapeake Bay. J. exp. mar. Biol. Ecol. 54:21-38.

Dauer D.M., T.L. Stokes, Jr., H.R. Barker, Jr. R.M. Ewing, and J.W. Sourbeer, 1984. Macrobenthic communities of the lower Chesapeake Bay. IV. Bay-wide transects and the lower inner continental shelf. Int. Revue ges. Hydrobiol. 69:1-22

Davies, L.J. and H.A. Hawkes, 1981. Some effects of organic pollution on the distribution and seasonal incidence of Chironomidae in riffles in the River Cole. Freshwater Biol. 11:549-559.

Dean D, and H.H. Haskin, 1964. Benthic repopulation of the Raritan River estuary following pollution abatement. Limnol. Oceanogr. 9:551-563.

Diaz, R.J., 1980. Ecology of tidal freshwater and estuarine Tubificidae (Oligochaeta). p. 319-330, In Aquatic Oligochaete Biology R.O. Brinkhurst and D.G. Cooks eds. Plenum Press, New York.

Ewing, R.M. and D.M. Dauer, 1982. Macrobenthic communities of the lower Chesapeake Bay. I. Plantation Flats, Old Plantation Creek, Kings Creek and Cherrrystone Inlet. Int. Revue ges. Hydrobiol. 67:777-791

Feeley, J.B. and M.L. Wass, 1971. The distribution and ecology of the Gammaridea (Crustacea:Amphipoda) of the lower Chesapeake estuaries. Special papers in Marine Science No. 2. Virginia Institute of Marine Science.

Flint, R.W. and D. Kamykowski, 1978. Benthic nutrient regeneration in south Texas coastal waters. Estuar. Coast. Shelf Sci. 18: 221-230.

Folk, R.L., 1974. Petrology of sedimentary rocks. Hemphil Publishing Co., Austin, TX.

George, D.J., 1966. Reproduction and developement of the spionid polychaete *Scoleoclepidis viridis* (Verril) Biol. Bull. 130:76-93.

Gower, A.M. and P.J. Buckland, 1978. Water quality and the occurrence of *Chironomus riparius* Meigen (Diptera: Chironomidae) in a stream receiveing sewage effluent. Freshwater Biol. 8:153-164.

Green, R.H., 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York, NY. 257 pp.

Hawthorne, S.D. and D.M. Dauer, 1983. Macrobenthic communities of the lower Chesapeake Bay. III. Southern branch of the Elizabeth River. Int. Revue ges. Hydrobiol. 68:193-205.

Holland, A., N. Mountford, M. Heigel, D. Cargo, and J. Mihursky, 1980. Influence of predation on infaunal abundance in the upper Chesapeake Bay. Mar. Biol., 57:221-235.

Holland, A.F., A.T. Shaughnessy, L.C. Scott, V.A. Dickens, J.A. Ranasinghe, and J.K. Summers, 1988. Progress Report: Long- term benthic monitoring and assessment program for the Maryland portion of the Chesapeake Bay (July 1986 - October 1987). Volume I - Text. Versar Inc., ESM Operations, Columbia, Maryland.

Jordan, R.A., and C.E. Sutton, 1984. Oligohaline benthic communities at two Chesapeake Bay power plants. Estuaries 7: 192-212

Kinne, O., 1971. Salinity. Animals-Invertebrates. In Marine Ecology, O. Kinne ed., vol. 1, pp. 821-995. Wiley- Interscience, London.

Kinner, P., and D. Maurer, 1978. Polychaetous annelids of the Delaware Region. Fish. Bull. 76: 209-224.

Kinner, P., D. Maurer, and W. Leathman, 1974. Benthic invertebrates in Delaware Bay: animal-sediment associations of the dominant species. Int. Revue ges Hydrobiol. 59:685-701.

Mann, R. 1983. A management plan for the Back Bay watershed. Roy Mann Associates, Inc. Boston, MA. Margelef, R., 1958. Information theory in ecology. Gen. Syst. 3:36-71.

McCall, P.L. and M.J.S. Tevesz, 1982. The effects of benthos on physical properties of freshwater sediments. pp 105-176 In Animal-Sediment Relations. The Biogenic Alteration of Sediments., P.L. McCall and M.J.S. Tevesz eds. Plenum Press, New York.

Mundie, J.H., 1958. The diurnal activity of the larger invertebrates at the surface of Lac la Ronge, Saskatchewan. Can. J. Zool. 37: 945-956.

Pettibone, M.H., 1977. The synonymy and distribution of the estuarine *Hypaniola florida* (Hartmann) from the east coast of the United States (Polychaeta: Ampharetidae). Proc. Biol. Soc. Wash. 90:205-208.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13:131-144.

Rasmussen J.B., 1984a. The life-history, distribution, and production of *Chrionomus riparius* and *Glycotendipes paripes* in a prairie pond. Hydrobiol. 119:65-72.

Rasmussen J.B., 1984b. Comparison of gut contents and assimilation efficiency of fourth instar larvae of two coexisting chironomids, *Chironomus riparius* Meigen and *Glycotendipes paripes* (Edwards). Can J. Zool. 62:1022-1026.

Reish, D., 1973. The use of benthic animals in monitoring the marine environment. J. Environ. Plan. Poll. Cont. 1:32-38.

Rhoads, D.C., 1973. The influence of deposit-feeding benthos on water turbidity an nutrient cycling. Amer. J. Sci. 271:1-22.

Rhoads, D.C. and D.K. Young, 1970. The influence of deposit- feeding organisms on sediment stability and community trophic structure. J. Mar. Res. 28:150-178.

Roback, S.S., 1976. The immature chironomids of the eastern United States. I. Introduction and Tanypodinae-Coelotanypodini. Proc. Acad. Nat. Sci. Phila. 127:147-201.

Robinson, W.W., 1978. A comparison of macroinvertebrate infauna of two non-tidal estuarine sandy substrate communities. M.S. Thesis. Old Dominion University. Norfolk, VA. 101 pp.

Rowe, G.T., C.H. Clifford, K.L. Smith and P.L. Hamilton, 1975. Benthic nutrient regeneration and its coupling to primary productivity in coastal waters. Nature 255:215-217.

Sanders, H.L., 1960. Benthic stuides in Buzzard's Bay. III. The structure of the soft-bottom community. Limnol. Oceanogr. 5:138-152.

Sanders, H.L., P.C. Mangelsdorf, Jr. and G.R. Hampson, 1965. Salinity and faunal distribution in the Pocasset River, Massachusetts. Limnol. Oceangr. 10 (Suppl.): R216-R228.

Simpson K.W. and R.W. Bode, 1980. Common larvae of Chironomidae (Diptera) from New York state streams and Rivers. Bull. N.Y. St. Mus. no. 439. 105 pp.

Sokal, R.R. and F.J. Rohlf, 1981. Biometry. W.H. Freeman and Company, New York, NY. 859 pp.

Tenore, K.R., 1972. Macrobenthos of the Pamlico River estuary, North Carolina. Ecol. Monogr. 42:51-68.

Tenore, K.R., D.B. Horton and T.W. Duke, 1968. Effects of bottom substrate in the brackish water clam Rangea cuneata. Ches. Sci. 9:238-248

Tourtelloute, G.H. and D.M. Dauer, 1983. Macrobenthic communities of the lower Chesapeake Bay. II. Lynnhaven Roads, Lynnhaven River, Broad Bay, and Linkhorn Bay. Int. Revue ges. Hydrobiol. 68:59-72.

Virstein, R.W., 1977. Predation on estuarine infauna: response patterns of component species. Estuaries 2: 69-86.

Wass, M.L. 1972. A check list of the biota of Lower Chesapeake Bay. Special Scientific Report no. 65. Virginia Institue of Marine Science. 290 pp.

Williams, W.T. and W. Stephenson, 1973. The analysis of three- dimensional data (sites x species x times) in marine ecology. J. Exp. Mar. Biol. Ecol. 11:207-277.

Wollitz, R.G. 1962. Virginia's Dingell-Johnson Program. Final report. Virginia Commission of Game and Inland Fisheries.

Zeitzschel, B., 1980. Sediment-water interactions in nutrient dynamics. pp. 195-218. In Marine Benthic Dynamics, K.R. Tenore and B.C. Coull, eds., University of South Carolina Press, Columbia S.C.

Table 1. List of macrobenthic species collected in the Back Bay study area from August, 1987 to May, 1988.

Phylum ANNELIDA

Class Polychaeta
- *Hobsonia florida* (Hartmann)
- *Laeonereis culveri* (Webster)
- *Scolecolepides viridis* (Verrill)

Class Oligochaeta
- *Limnodrilus hoffmeisteri* Claparede
- *Limnodrilus* spp. juveniles
- *Tubicoides heterochaetus* (Michaelson)

Phylum MOLLUSCA

Class Bivalvia
- *Rangia cuneata* Sowerby

Phylum ARTHROPODA

Class Crustacea

Order Isopoda
- *Cyathura polita* (Stimpson)
- *Edotea triloba* (Say)

Order Cumacea
- *Almyracuna proximoculi* (Jones and Burbanck)

Order Amphipoda
- *Corophium lacustre* Vanhoffen
- *Gammarus daiberi* Bousfield
- *Leptocheirus plumulosus* Shoemaker
- *Monoculodes edwardsi* Holmes

Class Insecta

Order Diptera
- *Chironomus attenatus* (Walker)
- *Chironomus riparius* (Meigen)
- *Clinotanypus pinguis* (Loew)
- *Cryptochironomus parafulvus* (Beck and Beck)
- *Djalmabetista pulcher* (Johannsen)
- *Polypedilium convictum* (Walker)

Table 2. Abundance of the dominant species for each site group. Density is expressed in number of individuals per square meter and biomass (AFDW) is given in milligrams per square meter.

Taxon code: A=Amphipoda I=Insecta O=Oligochaeta P=Polychaeta.

Mud Site Group

Species	% Total Abund.	Mean Density	% Total Biomass	Mean Biomass
Chironomus riparius (I)	84.5	4715	71.1	1280
Scolecolepides viridis (P)	5.6	312	8.5	153
Clinotanypus pinguis (I)	3.8	214	6.1	110
Limnodrilus spp. (O)	2.1	116	4.8	86
Tubificoides heterochaetus (O)	1.1	61	1.3	24

Mixed Site Group

Species	% Total Abund.	Mean Density	% Total Biomass	Mean Biomass
Chironomus riparius (I)	38.9	2130	29.3	686
Scolecolepides viridis (P)	27.4	1500	47.5	1114
Tubificoides heterochaetus (O)	22.0	1206	8.4	196
Limnodrilus spp. (O)	3.5	190	3.1	73
Hobsonia florida (P)	2.9	159	2.3	55
Gammarus daiberi (A)	1.2	67	1.6	37
Monoculodes edwardsi (A)	1.0	55	1.3	31
Leptocheirus plumulosus (A)	1.0	55	1.3	31

Sand Site Group

Species	% Total Abund.	Mean Density	% Total Biomass	Mean Biomass
Scolecolepides viridis (P)	63.3	2893	69.9	2553
Chironomus riparius (I)	15.8	721	6.8	248
Hobsonia florida (P)	6.5	299	3.6	133
Tubificoides heterochaetus (O)	4.3	197	2.5	92
Polypedilium convictum (I)	2.0	91	1.0	36
Limnodrilus spp. (O)	1.9	87	<1.0	32
Rangia cuneata (B)	1.8	83	5.1	188
Monoculodes edwardsi (A)	1.2	55	<1.0	27

Table 3. Results of univariate comparisons of log transformed abundance of the dominant species between site groups. Comparisons were made using Duncan's Multiple Range Test. Values in the table not underscored by the same line are significantly different (P<0.05). Values in pararentheses are mean density values for each site group and are expressed in numbers of individuals per square meter. A. Mud Dominants - Species with greatest mean value at the Mud Site Group. B. Mixed Dominants - Species with the greatest mean value at the Mixed Site Group. C. Sand Dominants - Species with the greatest mean value at the Sand Site Group. D. Ubiquitous Species - Species with no mean differences between site groups.

A. Mud Dominants

Chironomus riparius
Mud (4714) Mixed (2130) Sand (721)

Clinotanypus pinguis
Mud (214) Mixed (31) Sand (0)

B. Mixed Dominants

Tubificoides heterocheatus
Mixed (1206) Sand (197) Mud (61)

Leptocheirus plumulosus
Mixed (55) Mud (6) Sand (5)

C. Sand Dominants

Scolecolepides viridis
Sand (2893) Mixed (1500) Mud (312)

Hobsonia florida
Sand (298) Mixed (159) Mud (31)

Polypedilium convictum
Sand (92) Mixed (12) Mud (0)

Rangia cuneata
Sand (83) Mud (18) Mixed (12)

D. Ubiquitous species

Limnodrilus spp. juveniles
Mixed (190) Mud (116) Sand (87)

Gammarus daiberi
Mixed (67) Mud (37) Sand (28)

Monoculodes edwardsi
Mixed Sand Mud

Table 4. Results of univariate comparisons of log transformed biomass of the dominant species between site groups. Comparisons were made using Duncan's Multiple Range Test. Values in the table not underscored by the same line are significantly different (P<0.05). Values in pararentheses are mean biomass values for each site group and are expressed in milligrams (AFDW) per square meter. A. Mud Dominants - Species with greatest mean value at the Mud Site Group. B. Mixed Dominants - Species with the greatest mean value at the Mixed Site Group. C. Sand Dominants - Species with the greatest mean value at the Sand Site Group. D. Ubiquitous Species - Species with no mean differences between site groups

A. Mud Dominants

Chironomus riparius
Mud (1280) Mixed (686) Sand (721)

Clinotanypus pinguis
Mud (110) Mixed (31) Sand (0)

B. Mixed Dominants

Tubificoides heterocheatus
Mixed (196) Sand (92) Mud (24)

Leptocheirus plumulosus
Mixed (31) Mud (12) Sand (5)

C. Sand Dominants

Scolecolepides viridis
Sand (2553) Mixed (1114) Mud (153)

Hobsonia florida
Sand (133) Mixed (55) Mud (24)

Polypedilium convictum
Sand (37) Mixed (6) Mud (0)

Rangia cuneata
Sand (188) Mud (55) Mixed (37)

D. Ubiquitous species

Limnodrilus spp. juveniles
Mixed (190) Mud (116) Sand (87)

Gammarus daiberi
Mixed (67) Mud (37) Sand (28)

Monoculodes edwardsi
Mixed (31) Sand (28) Mud (18)

Table 5. A. Mean values of community parameters by site group. Density is expressed in numbers of individuals per square meter and biomass in milligrams (AFDW) per square meter. B. Results of the univariate comparisons of community parameters between site groups. Comparisons were made using Duncan's Multiple Range Test. Values in the table not underscored by the same line are significantly different ($P<0.05$).

A. Community parameters

Site Group	Density	AFDW Biomass	Species per replicate	H′	J	SR
Mud	5578	1800	2.42	1.23	0.61	1.08
Mixed	5474	2345	3.53	1.50	0.63	1.10
Sand	4570	4629	3.29	1.36	0.61	1.05

B. Univariate comparisons between site groups

Density (ind./m²)

Mud	Mixed	Sand
———	———	———

AFDW Biomass (mg/m²)

Sand	Mixed	Mud
	———	———

Species per replicate

Mixed	Sand	Mud
———	———	———

Diversity (H′)

Mixed	Sand	Mud
———	———	———

Evenness (J′)

Mixed	Sand	Mud
———	———	———

Species Richness (SR)

Mixed	Sand	Mud
———	———	———

Table 6. Mean values of A. physical and B. sedimentary parameters by site group.

A. Physical parameters

Site Group	Salinity o/oo	D.O.	Temp. °C
Mud	2.40	10.24	14.98
Mixed	2.45	10.24	15.08
Sand	2.48	10.72	15.05

B. Sedimentary parameters

Site Group	%Silt-Clay	Mean Phi	Sorting	%Volatile Solids
Mud	84.45	5.39	1.87	5.72
Mixed	34.55	3.77	1.53	3.77
Sand	22.29	3.59	1.21	1.45

Table 7. Results of univariate comparisons of log transformed abundance of the dominant species between temporal groups. Comparisons were made using Duncan's Multiple Range Test. Values in the table not underscored by the same line are significantly different (P<0.05). Values in pararentheses are mean density values for each temporal group expressed in numbers of individuals meter square. (Sum=Summer W-Spr=Winter-Spring). A. Summer Dominants - Species with greatest mean value during the Summer Temproal Group. B. Winter-Spring Dominants - Species with the greatest mean value during the Winter-Spring Temporal Group. C. Species with no seasonal trend - Species with no mean differences between temporal groups.

A. Summer

Chironomus riparius
Sum (8773) Fall (309) W-Spr (143)

Polypedilium convictum
Sum (162) Fall (0) W-Spr (0)

Rangia cuneata
Sum (132) Fall (29) W-Spr (4)

B. Winter-Spring

Gammarus daiberi
W-Spr (70) Fall (29) Sum (0)

Monoculodes edwardsi
W-Spr (96) Fall (15) Sum (0)

Scolecolepides viridis
W-Spr (2936) Sum (523) Fall (411)

Leptochierus plumulosus
W-Spr (29) Fall (15) Sum (7)

Clinotanypus pinguis
Sum (110) W-Spr (73) Fall (37)

C. Species with No Seasonal Trend

Tubificoides heterochaetus
W-Spr (489) Fall (448) Sum (411)

Limnodrilus spp. juveniles
Sum (140) W-Spr (132) Fall (103)

Hobsonia florida
W-Spr (206) Sum (191) Fall (103)

Table 8. Results of univariate comparisons of log transformed biomass of the dominant species between temporal groups. Comparisons were made using Duncan's Multiple Range Test. Values in the table not underscored by the same line are significantly different (P<0.05). Values in pararentheses are mean biomass values for each temporal group expressed in milligrams (AFDW) per meter square. (Sum=Summer W-Spr=Winter-Spring). A. Summer Dominants - Species with greatest mean value during the Summer Temproal Group. B. Winter-Spring Dominants - Species with the greatest mean value during the Winter-Spring Temporal Group. C. Species with no seasonal trend - Species with no mean differences between temporal groups.

A. Summer

Chironomus riparius
Sum (2087) Fall (419) W-Spr (125)

Polypedilium convictum
Sum (66) Fall (0) W-Spr (0)

Rangia cuneata
Sum (330) Fall (66) W-Spr (7)

B. Winter-Spring

Gammarus daiberi
W-Spr (40) Fall (15) Sum (0)

Monoculodes edwardsi
W-Spr (44) Fall (15) Sum (0)

Leptochierus plumulosus
W-Spr (18) Fall (15) Sum (7)

Clinotanypus pinguis
Sum (59) W-Spr (40) Fall (29)

Scolecolepides viridis
Fall (1786) W-Spr (1312) Sum (1198)

C. Species with No Seasonal Trend

Tubificoides heterochaetus
W-Spr (110) Sum (103) Fall (88)

Limnodrilus spp. juveniles
Sum (73) Fall (58) W-Spr (55)

Hobsonia florida
Sum (102) W-Spr (81) Fall (44)

Table 9. Mean values of community parameters of each site group for each temporal group. Density is expressed in numbers of individuals per square meter and biomass in milligrams AFDW per square meter.

A. Mud Site Group

Temporal Group	Density	AFDW Biomass	Species per replicate	H′	J	SR
Summer	18663	4629	2.88	0.35	0.16	0.72
Fall	833	1004	1.56	1.20	0.75	0.98
Winter-Spring	1408	783	2.56	1.67	0.76	1.31

B. Mixed Site Group

Temporal Group	Density	AFDW Biomass	Species per replicate	H′	J	SR
Summer	9895	3943	3.56	1.67	0.77	1.31
Fall	2179	2400	2.67	0.98	0.39	0.96
Winter-Spring	4910	1518	3.94	1.68	0.75	1.20

C. Sand Site Group

Temporal Group	Density	AFDW Biomass	Species per replicate	H′	J	SR
Summer	4996	3943	4.58	1.97	0.73	1.36
Fall	1635	4372	2.83	1.59	0.75	1.10
Winter-Spring	5823	3160	2.88	0.95	0.47	0.87

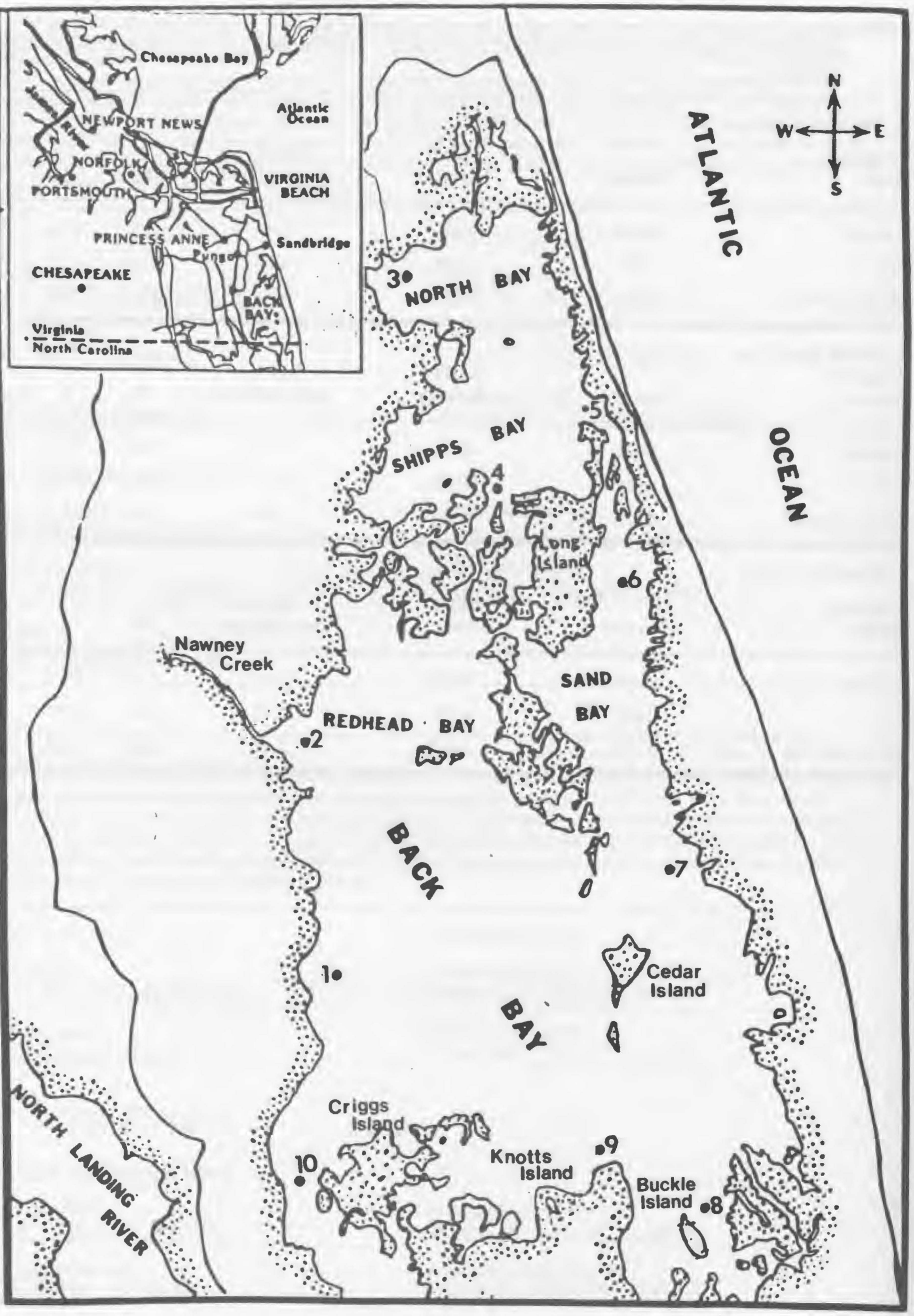
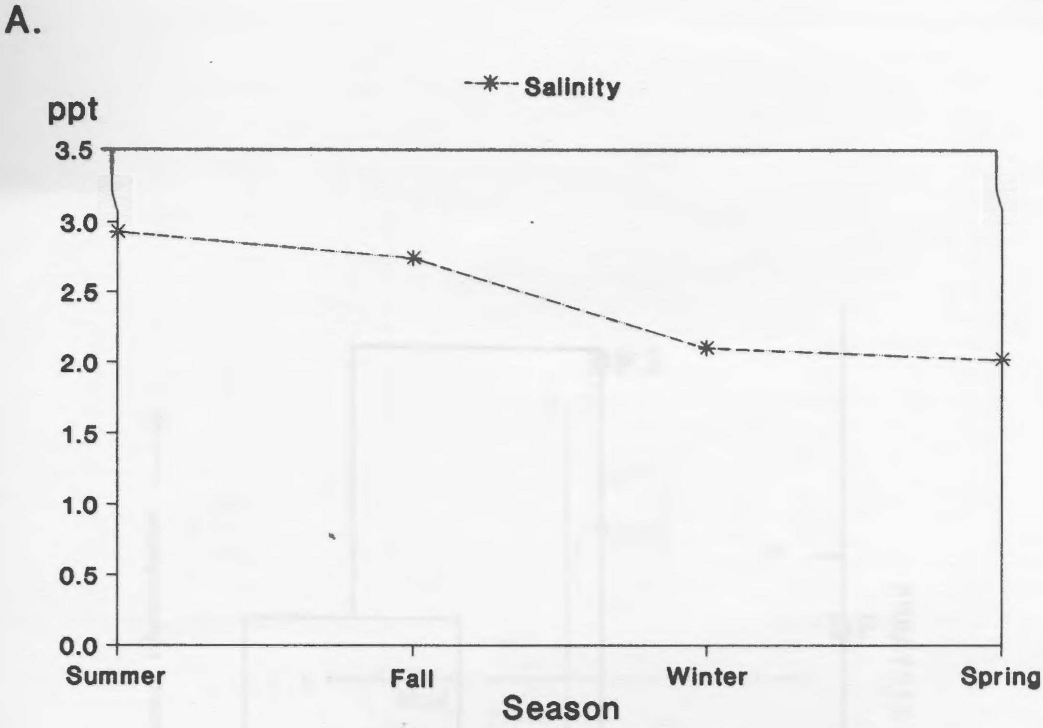


Figure 1. Map showing location of the study area (insert) and the sampling stations.



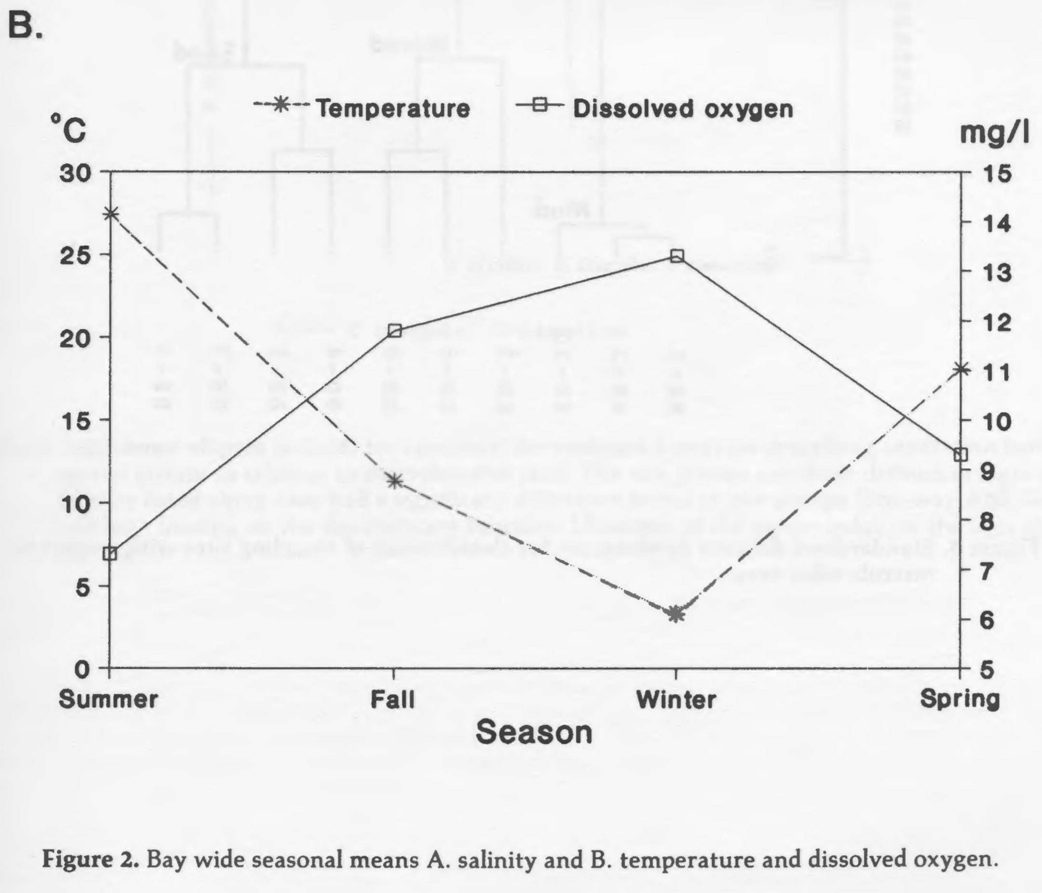


Figure 2. Bay wide seasonal means A. salinity and B. temperature and dissolved oxygen.

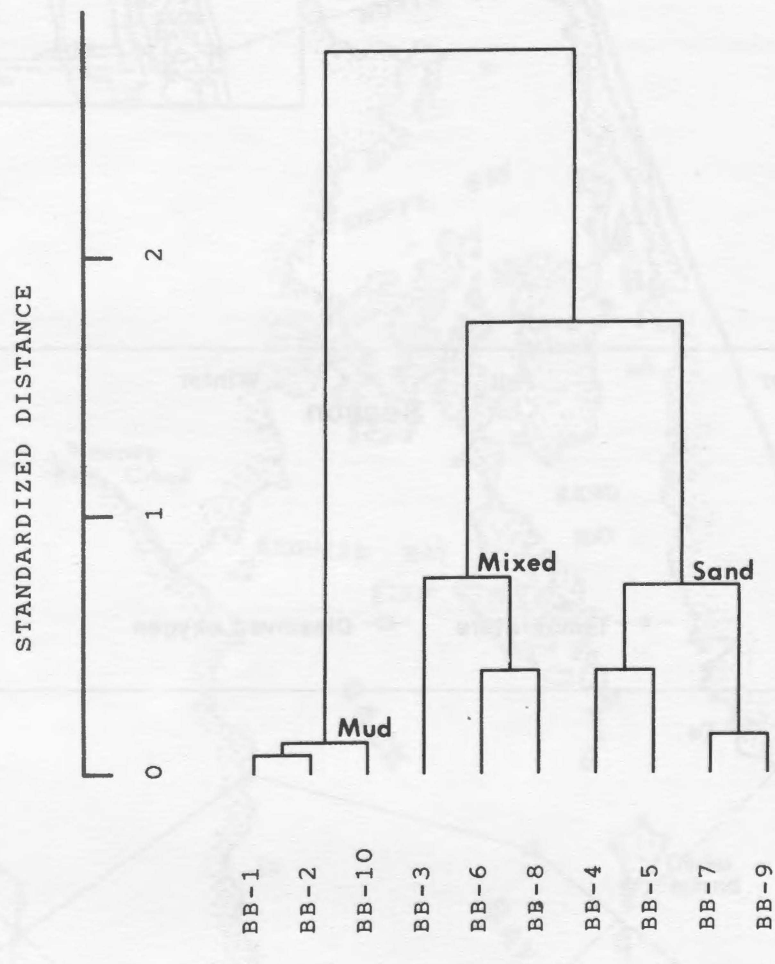


Figure 3. Standardized distance dendrogram for classification of sampling sites with respect to macrobenthic taxa.

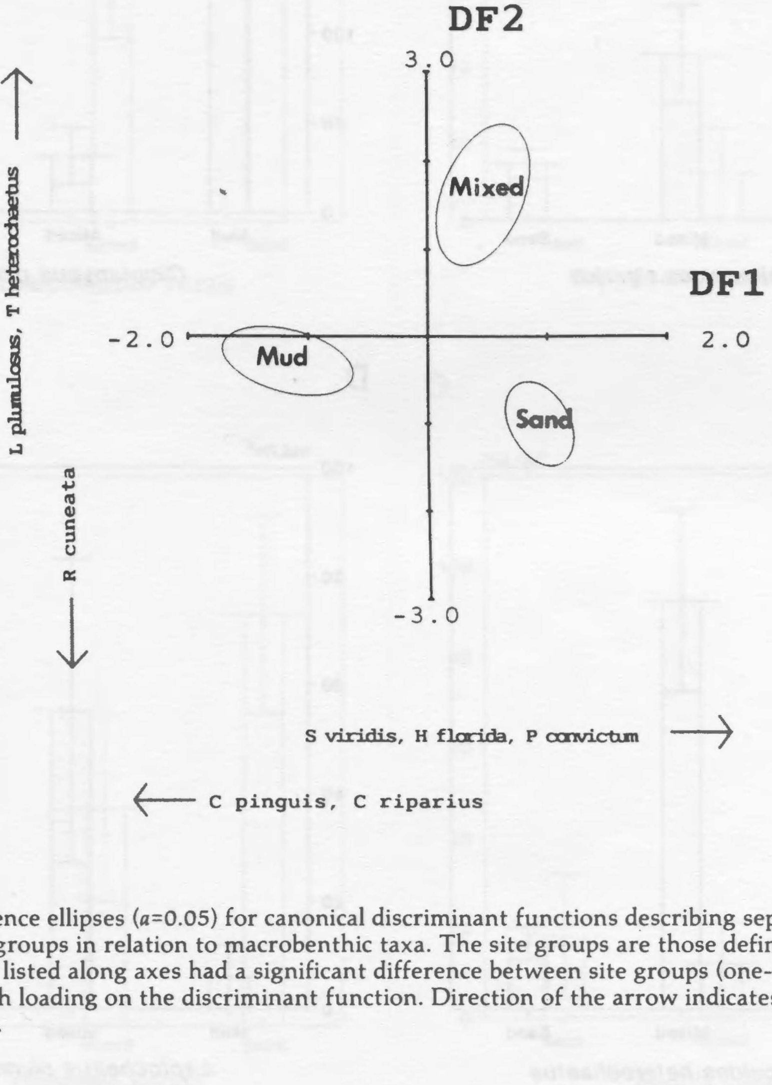


Figure 4. Confidence ellipses (a=0.05) for canonical discriminant functions describing separation between spatial groups in relation to macrobenthic taxa. The site groups are those defined in Figure 3. Species listed along axes had a significant difference between site groups (one-way ANOVA) and high loading on the discriminant function. Direction of the arrow indicates the sign of the loading.

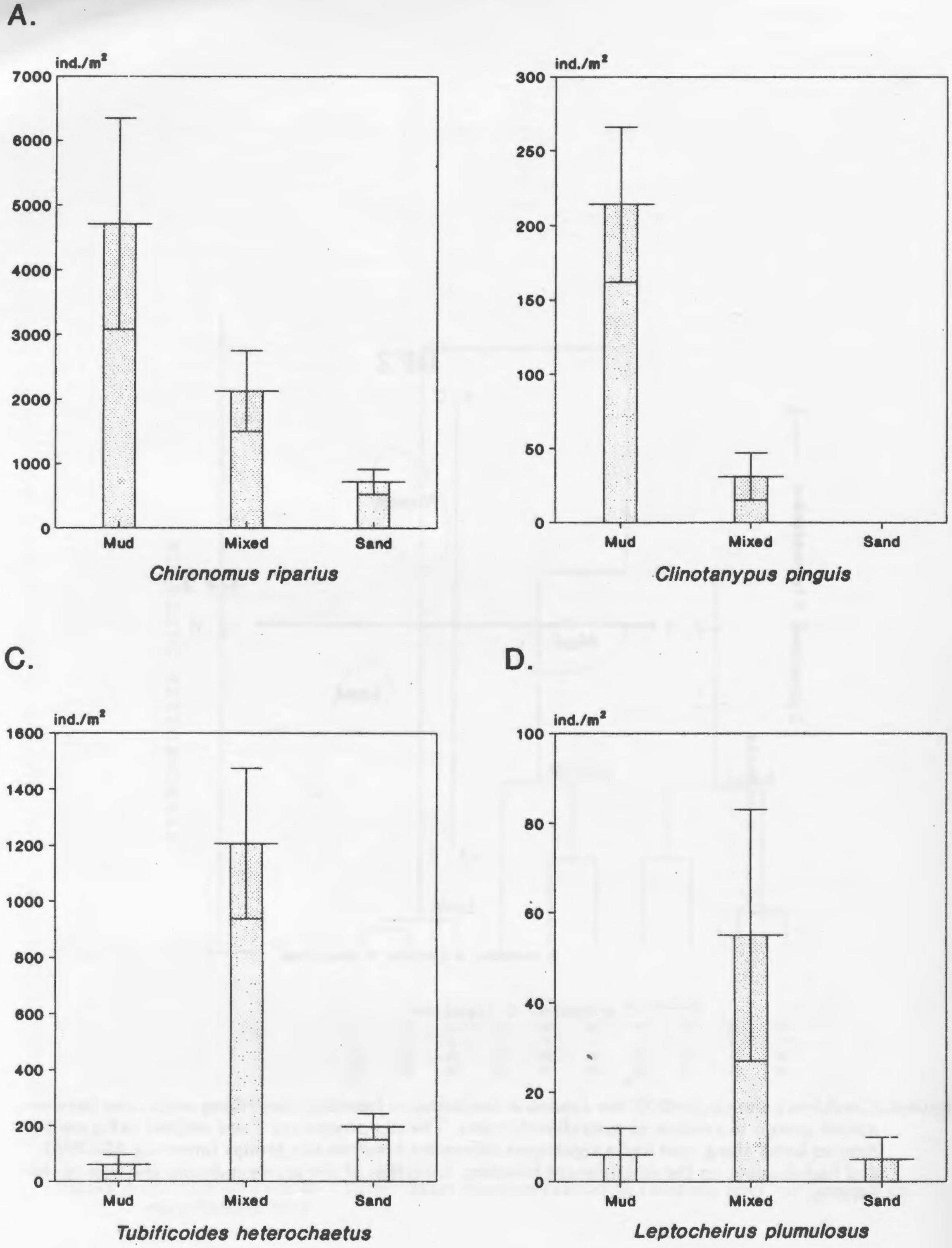


Figure 5. Mean density of dominant species for each site group. Species shown had a significant difference in abundance between site groups (one-way ANOVA). Vertical bars represent /- one standard error of the mean. Density is expressed as the number of individuals per square meter. (A. *Chironomus riparius* B. *Clinotanypus pinguis* C. *Tubificoides heterochaetus* D. *Leptocheirus plumulosus*).

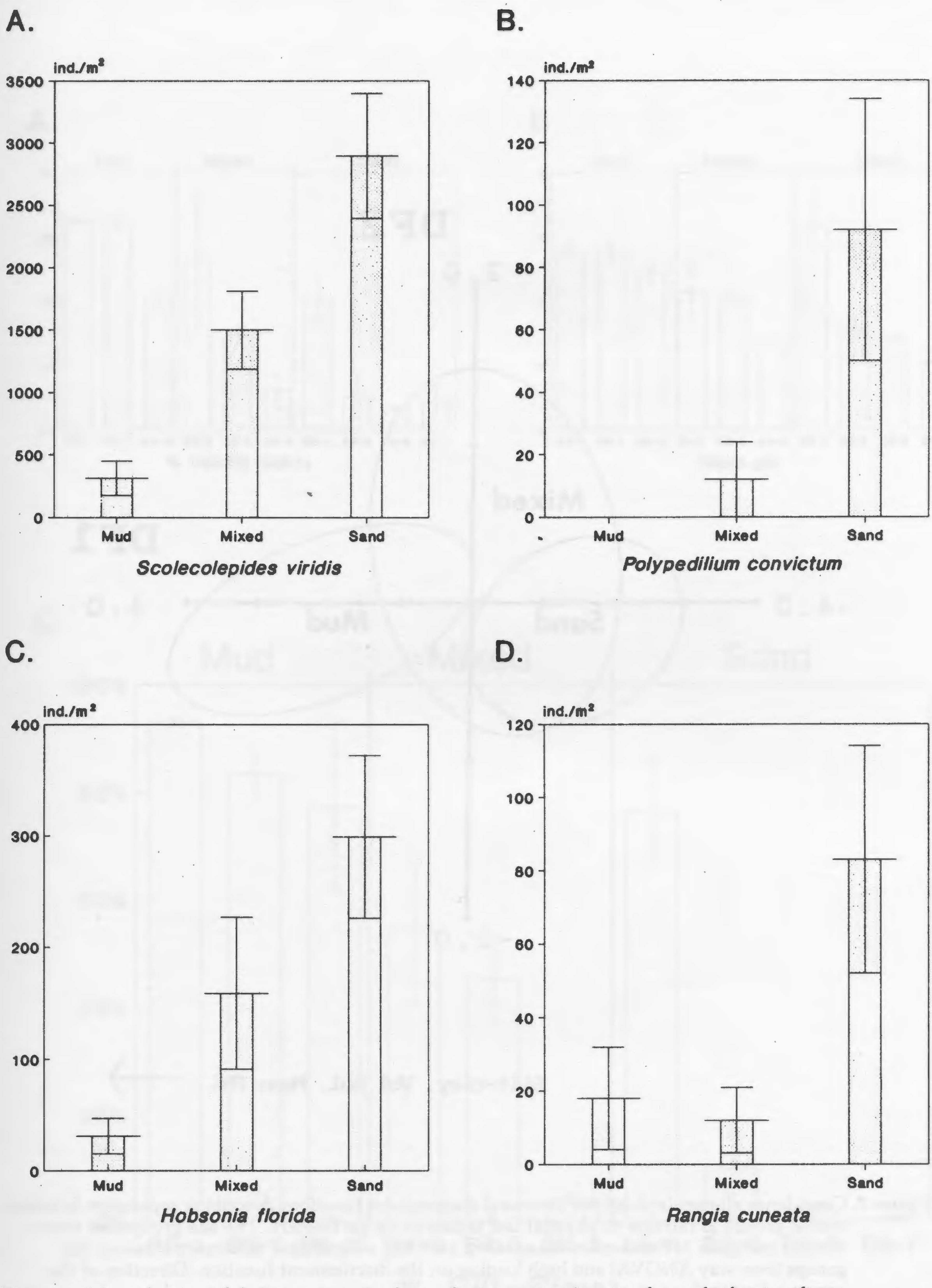


Figure 6. Mean density of dominant species for each site group. Species shown had a significant difference in abundance between site groups (one-way ANOVA). Vertical bars represent + or – one standard error of the mean. Density is expressed as the number of individuals per square meter. (A. *Scoelecolepides viridis* B. *Polypedilium convictum* C. *Hobsonia florida* D. *Rangia cuneata*).

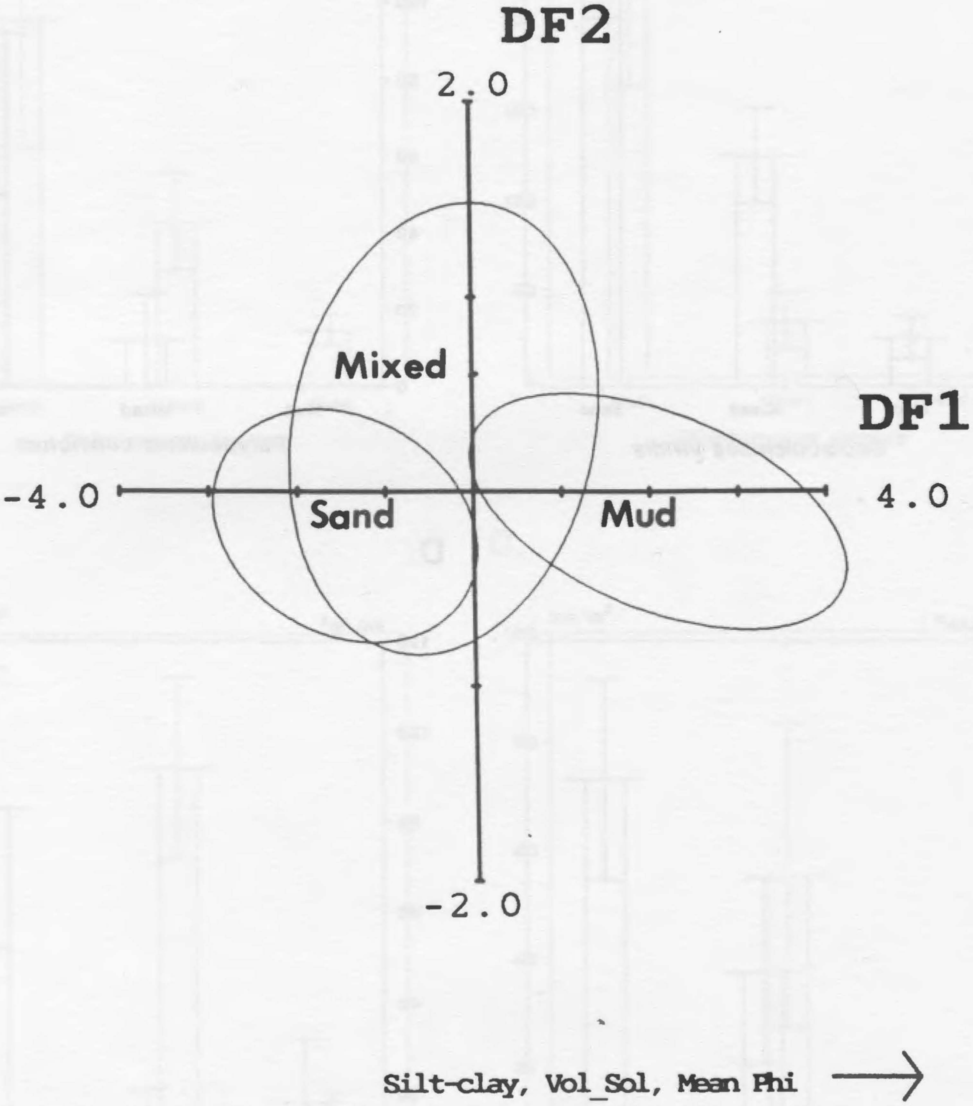


Figure 7. Confidence ellipses (a=0.05) for canonical discriminant functions describing separation between spatial groups in relation to physcial and sedimentary parameters. The site groups are those defined in Figure 3. Parameters listed along axes had a significant difference between site groups (one-way ANOVA) and high loading on the discriminant function. Direction of the arrow indicates the sign of the loading.

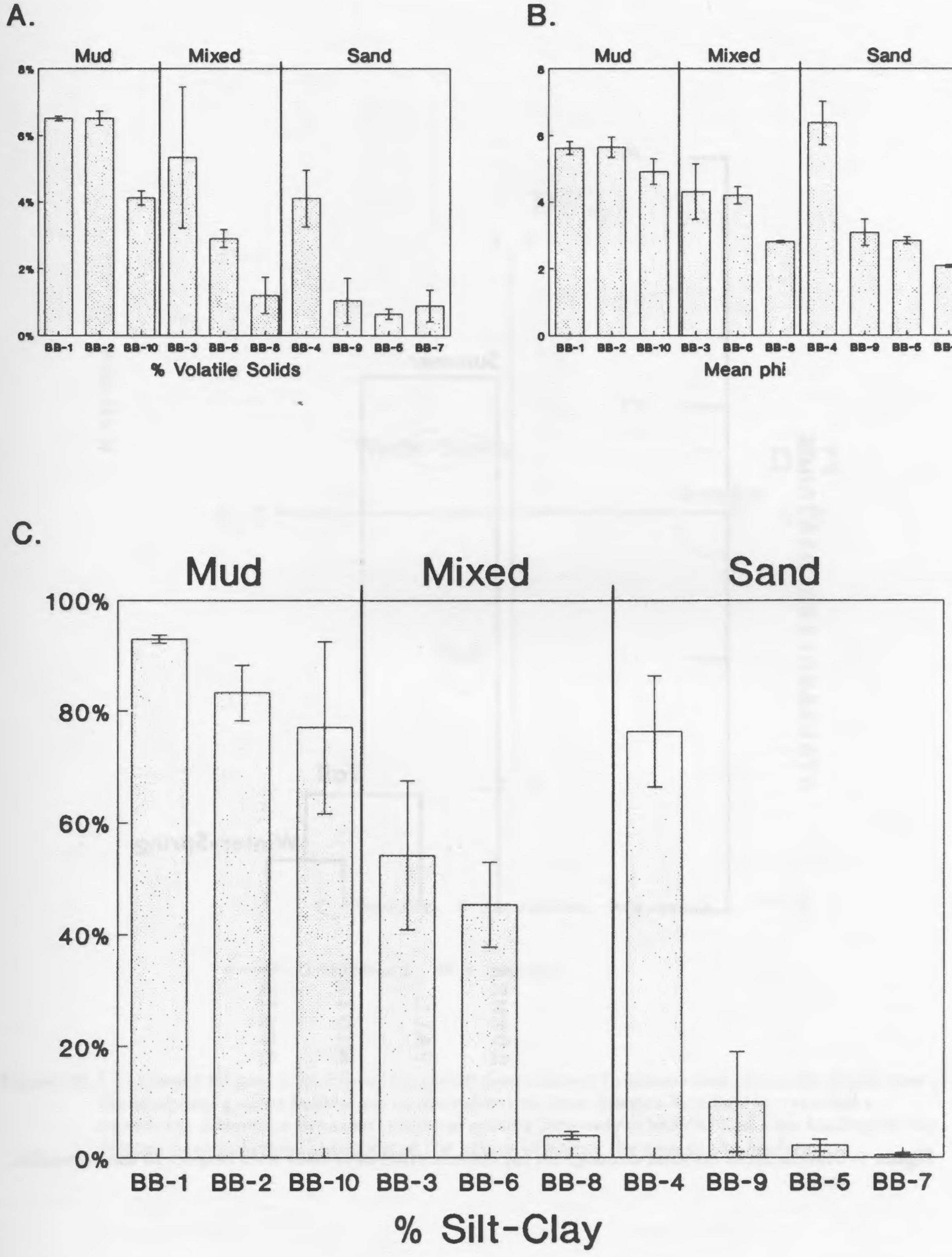


Figure 8. Mean values for A. organic content, B. mean phi, and C. silt-clay for each station. Vertical bars represent + or - one standard error of the mean.

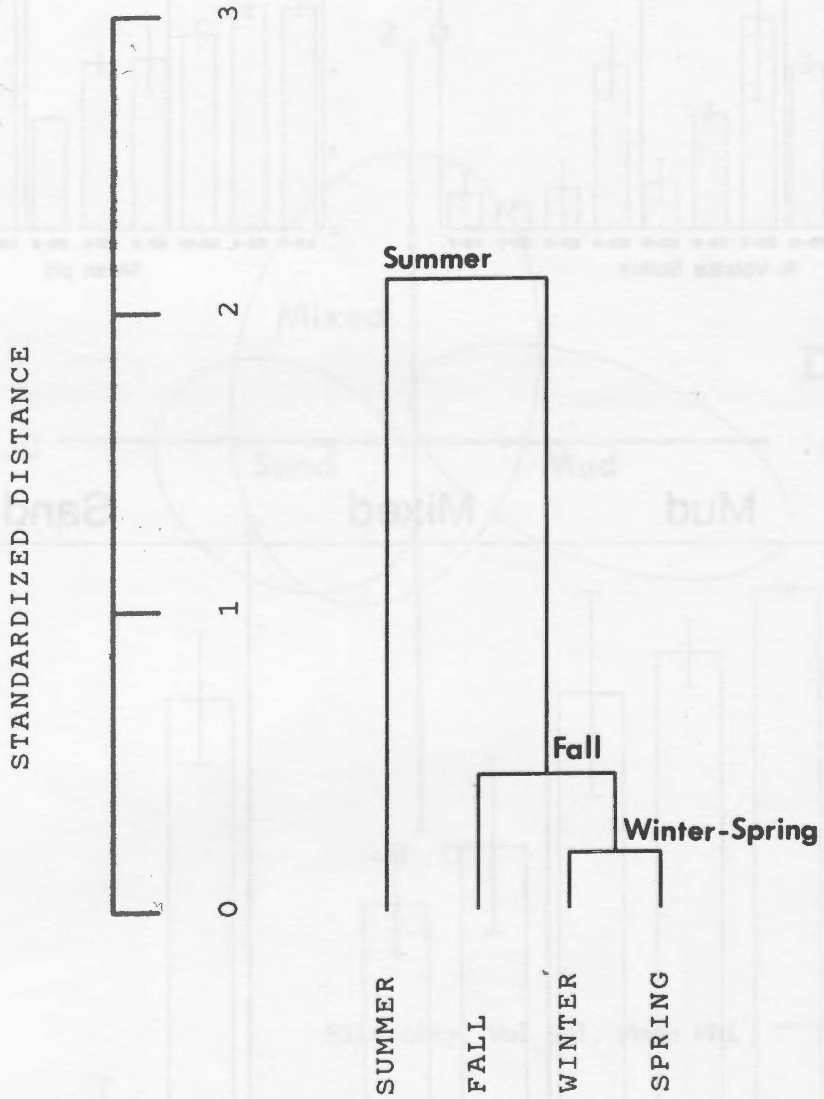


Figure 9. Standardized distance dendogram for classification of cruises with respect to macrobenthic taxa.

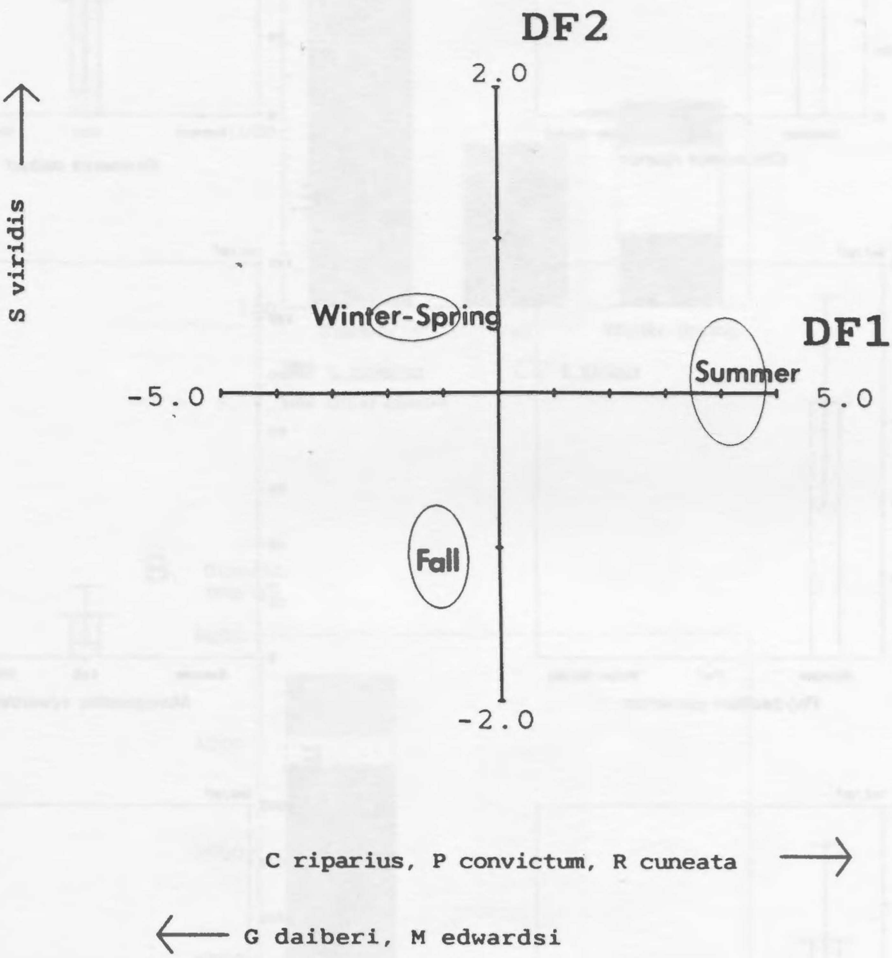


Figure 10. Confidence ellipses (a=0.05) for canonical discriminant functions describing the separation of the temporal groups in relation to macrobenthic taxa. Species listed along axes had a significant difference between temporal groups (one-way ANOVA) and high loading on the discriminant function. Direction of the arrow indicates the sign of the loading.

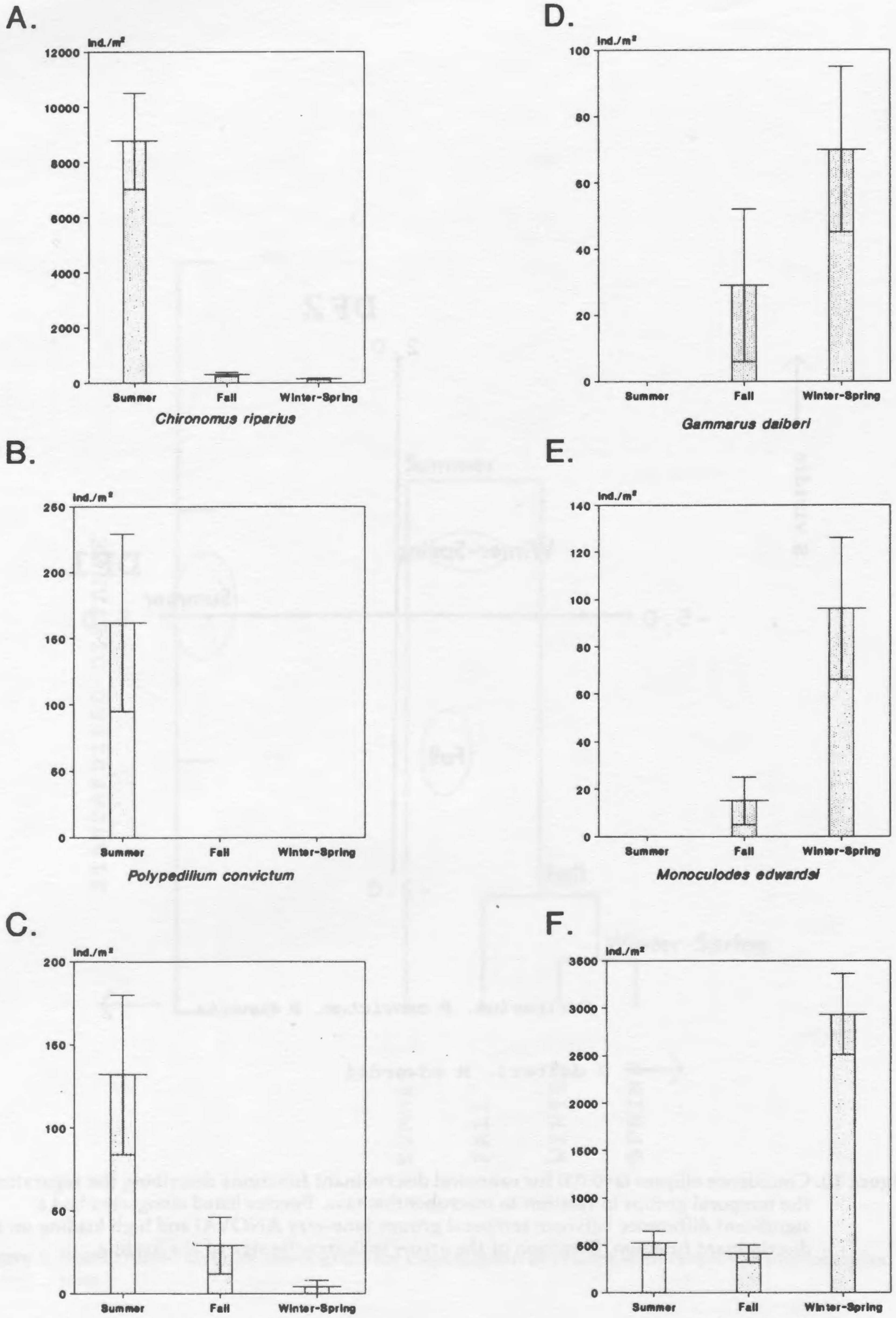


Figure 11. Mean density of the dominant species for each temporal group. Species shown had a significant difference in abundance between temporal groups (one-way ANOVA). Vertical bars represent + or – one standard error of the mean. (A. *Chironomus riparius*, B. *Polypedilium convictum*, C. *Rangia cuneata*, D. *Gammarus daiberi*, E. *Monoculodes edwardsi*, F. *Scolecolepides viridis*).

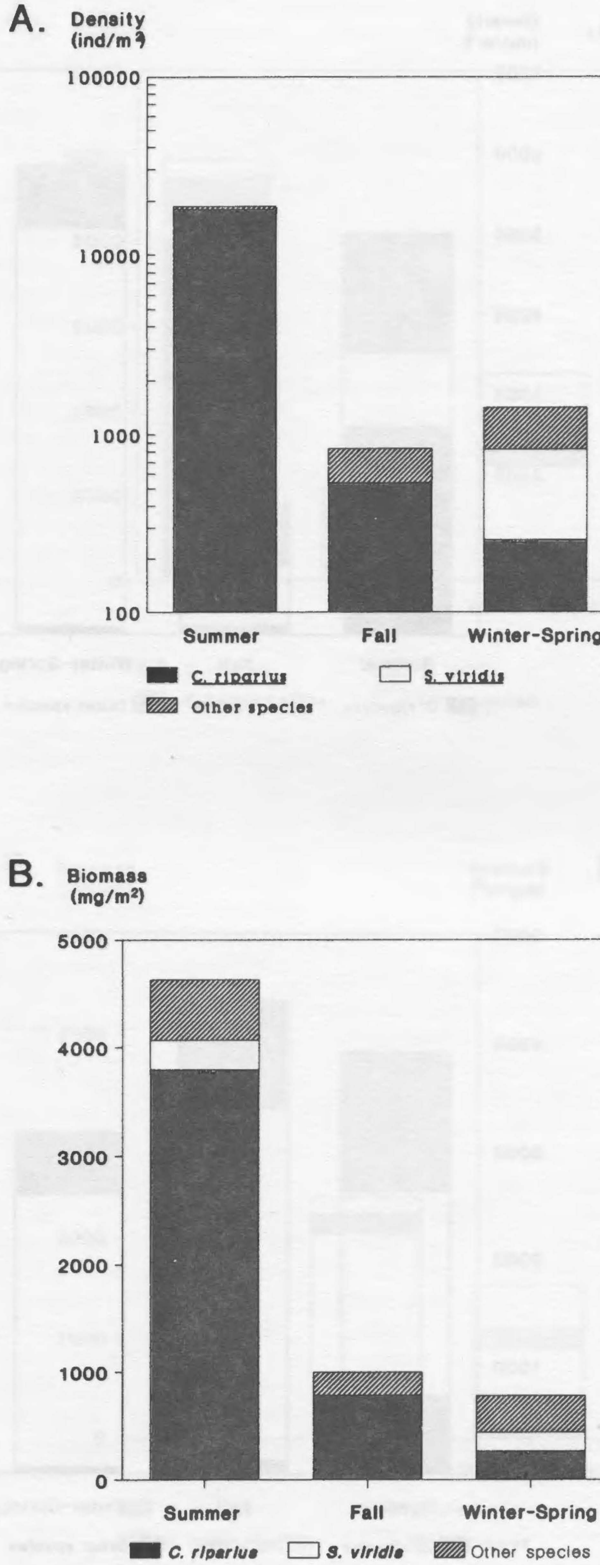


Figure 12. Mean community A. density and B. biomass values for the Mud Site Group for each temporal group. Density is expressed as the number of individuals per square meter and biomass in milligrams (AFDW) per square.

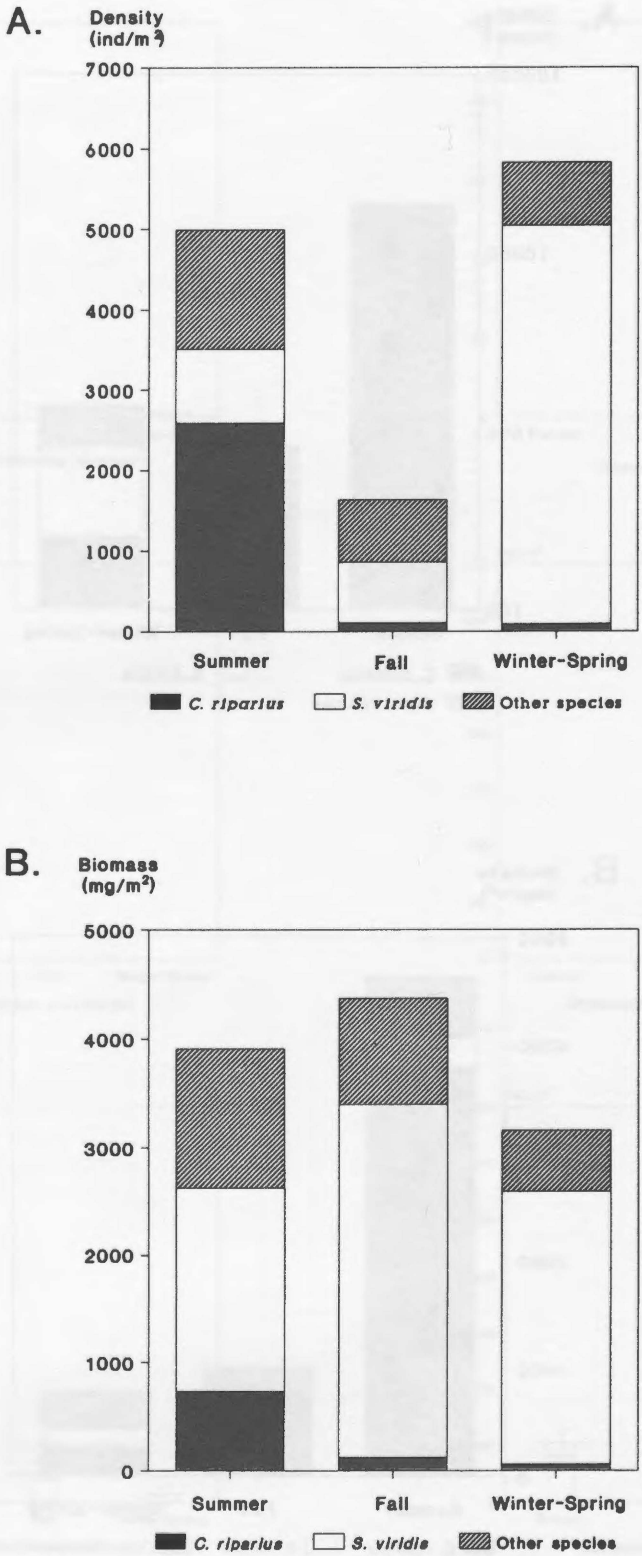


Figure 13. Mean community A. density and B. biomass values for the Mixed Site Group for each temporal group. Density is expressed as the number of individuals per square meter and biomass in milligrams (AFDW) per square meter.

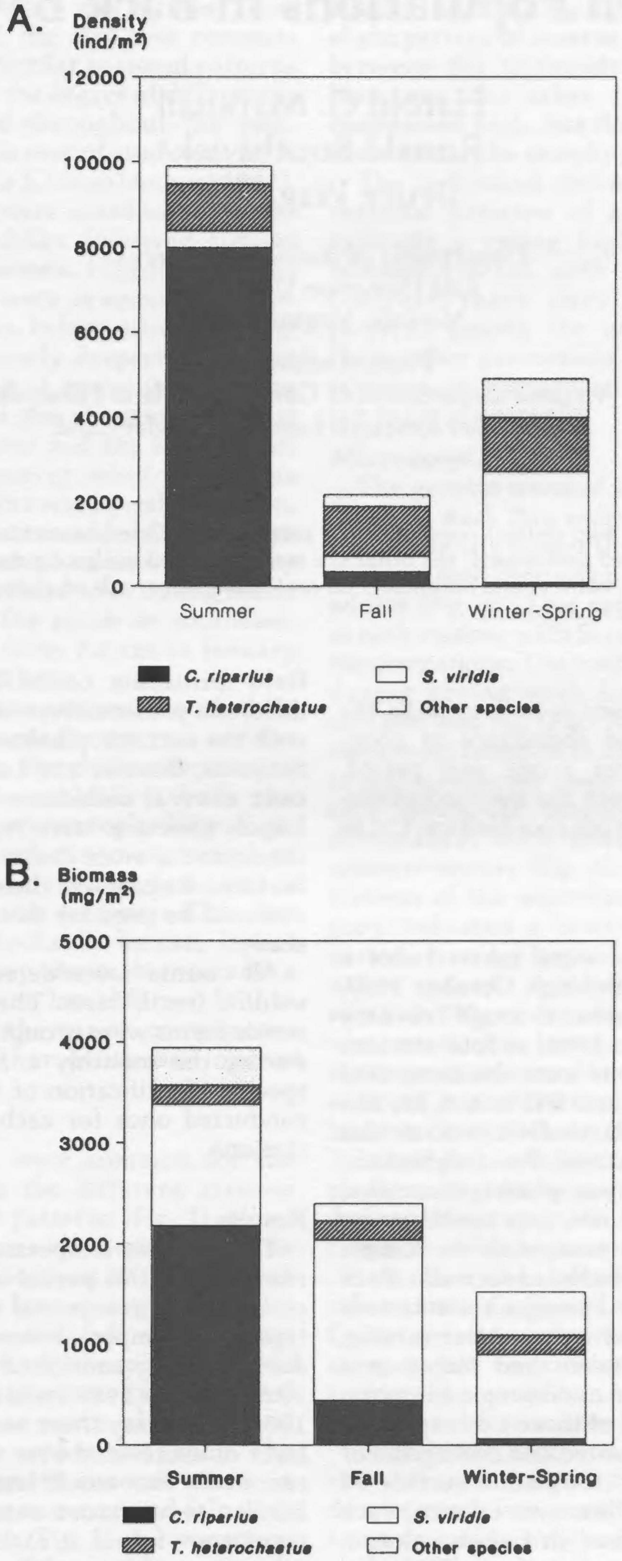


Figure 14. Mean community A. density and B. biomass values for the Sand Site Group for each temporal group. Density is expressed as the number of individuals per square meter and biomass in milligrams (AFDW) per square meter.