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Baltimore Harbor and channels aquatic benthos investigations at the Wolf Trap alternate disposal site in lower Chesapeake Bay : final report

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FINAL REPORT

BALTIMORE HARBOR AND CHANNELS AQUATIC BENTHOS INVESTIGATIONS AT THE WOLF TRAP ALTERNATE DISPOSAL SITE IN LOWER CHESAPEAKE BAY

Prepared For:

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INTRODUCTION

The disposal of dredged material from channel deepening projects is a major anthropogenic process influencing benthic communities of coastal aquatic systems. Such activities are important because benthic subsystems and component organisms play major roles in the functioning of estuarine ecosystems. Benthic invertebrates are major prey items in the diets of fishes and crabs (Arntz and Brunswig 1975, Virnstein 1977, Arntz 1978, Blundon and Kennedy 1982, Lunz and Kendall 1982, Moeller et al. 1985, Pihl et al. 1992). As secondary producers capable of utilizing trophic resources from a variety of sources (e.g. detritus, algae, bacteria), they provide important links to higher trophic levels. From microbes to macrofauna, benthic organisms also have major impacts on the cycling of nutrients (Diaz and Schaffner 1990, Mayer et al. in review), contaminants (Lee and Swartz 1980, Diaz and Schaffner 1990, and Schaffner et al. 1992), and sediments (Rhoads and Boyer 1982, Diaz and Schaffner 1990).

Macrobenthic organisms exhibit many properties that make them good indicators of environmental conditions (e.g. limited mobility, a variety of life histories, a range of physiological tolerances). Numerous studies have demonstrated that spatial and temporal comparisons of the kinds and abundances of benthic organisms are sensitive and important methods for assessing dredge material disposal effects on aquatic systems.

This study documents changes in the structure of lower Chesapeake Bay macrobenthic communities affected by dredged material disposal. The Corps is completing an assessment of changes in benthic resource value at the Wolf Trap Alternate Disposal Site using the *Benthic Resource Assessment Technique* (BRAT).

BACKGROUND

Disturbance is a major process causing mortality of individuals within communities. As a result, disturbance can play an important role in governing the structure and function of communities (Pickett and White 1984). Both natural and anthropogenic disturbances are common in estuarine systems (Boesch 1974, Nichols and Thompson 1985). For soft-sediment estuarine, as well as marine and freshwater communities, initial modes of recolonization and successional changes following disturbance events have been documented (Rhoads et al. 1978, Pearson and Rosenberg 1978, Soster and McCall 1990). However, the mechanisms governing these changes, especially the relative importance of abiotic vs. biotic factors, and their effects on rates of community recovery are not well known (Whitlatch and Zajac 1985).

In some estuarine habitats (e.g. shallow areas subject to wave agitation, low salinity regions, areas that frequently are subjected to hypoxia or anoxia) opportunistic species dominate the ambient community and recovery rates following disturbance tend to be

rapid (weeks to months) (Boesch 1974, Boesch et al. 1976, Santos and Simon 1980 a,b, Zajac and Whitlatch 1982a,b). Recolonization patterns and subsequent dynamics are greatly influenced by habitat conditions, especially as they influence spatial and temporal variability of the ambient community. The timing and spatial extent of the disturbance relative to the availability of larval and post-larval recruits are of primary importance for rates of recovery (Santos and Simon 1980 a,b, Zajac and Whitlatch 1982 a,b, Santos and Bloom 1983, Whitlatch and Zajac 1985, Smith and Brumsickle 1989). Species interactions occur, but are overshadowed by the effects of environment and recruitment processes (Zajac and Whitlatch 1982b, Whitlatch and Zajac 1985).

Deep subtidal, high salinity estuarine and marine soft-bottom habitats are often dominated by more diverse assemblages (Remane 1971, Boesch 1977, Schaffner 1990). Following disturbance, successional progression from initial dominance by small, shallow-dwelling opportunists to later dominance by large or deeper-dwelling infauna in these communities proceeds over months to years (Boesch et al. 1976, McCall 1977, Pearson and Rosenberg 1978, Rhoads et al. 1978). Although the relative importance of abiotic and biotic processes governing succession in these communities are generally not known, the potential roles of environmental tolerance, species life histories, and biotic interactions have been emphasized. Effects of environmental factors such as seasonal timing, magnitude and extent of disturbance have not yet been evaluated in structurally and functionally diverse estuarine or marine communities.

MAJOR OBJECTIVES

This study describes the responses of a subtidal estuarine macrobenthic community to two large-scale disturbance events associated with the disposal of dredged material. Effects of timing and magnitude of disturbance on successional patterns and rates of recovery for component species and the total community are evaluated. Comparisons with results of previous studies are used to extend our knowledge of successional processes and rates along estuarine salinity and depth gradients.

STUDY AREA

The study area is in the 'Wolf Trap' region of lower Chesapeake Bay (Figure 1). The Chesapeake Bay estuary is warm temperate with seasonal fluctuations in temperature, salinity and dissolved oxygen (Figure 2). Salinity at the study area ranges between ca. 20 and 25 ppt. Bottom water column dissolved oxygen typically does not fall below 2 mg l^{-1}. The study area lies within a broad, relatively flat expanse of subtidal (> 10m) silt and fine sand bottom bounded by channels or shoals, termed the bay-stem plains by Wright et al. (1987). In this plains region, physical agitation of bottom sediments below the upper centimeter appears to be minimal (Schaffner et al. 1987a, Wright et al. 1992) Ambient deep subtidal regions of the polyhaline Bay are characterized by communities comprised of a high diversity of infauna, commensal and epifaunal species (Boesch 1972,

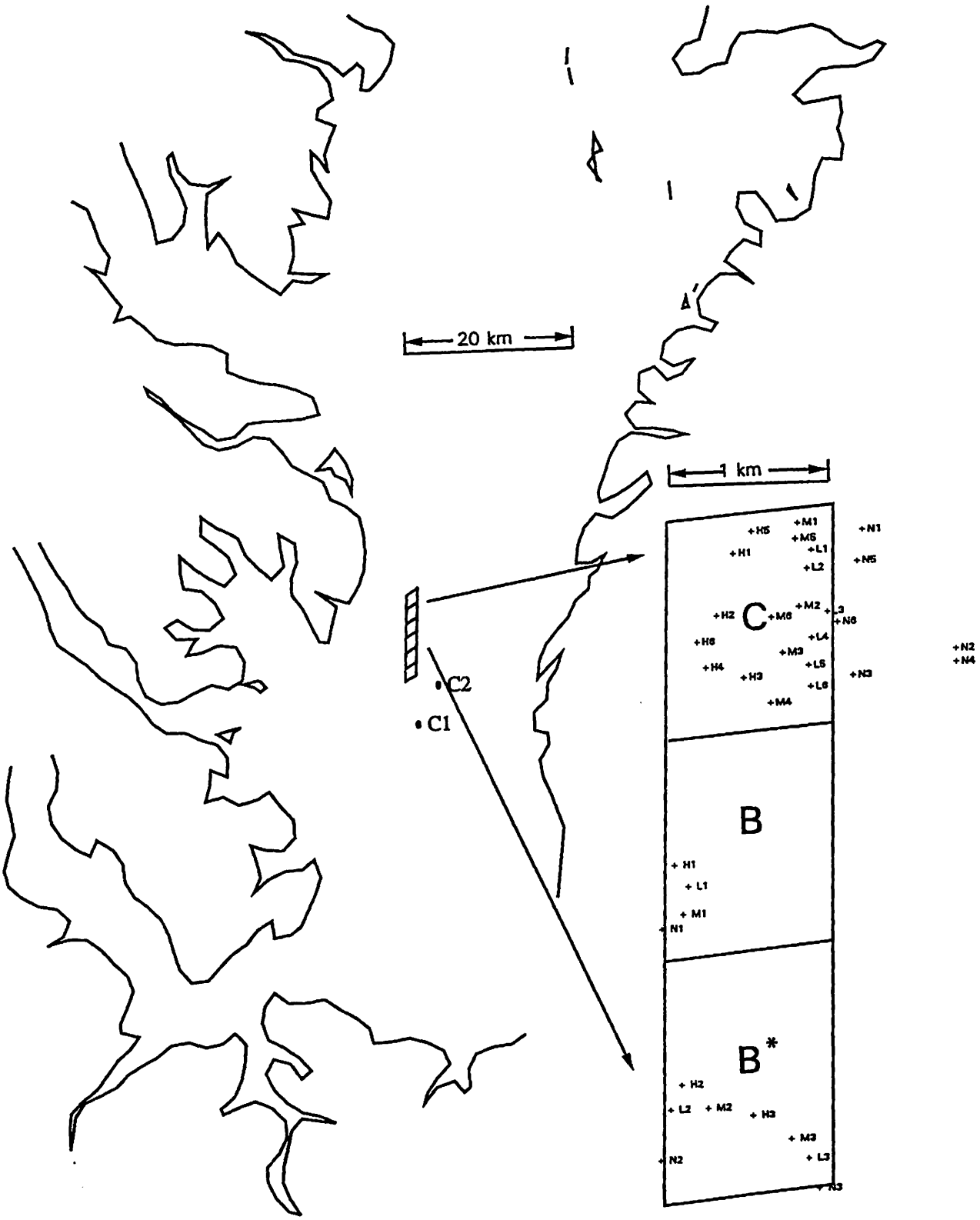

Figure 1. The Wolf Trap Alternate Disposal site and surrounding study region in lower Chesapeake Bay. Locations for ambient community stations C1 and C2, Cell B and Cell C are shown.

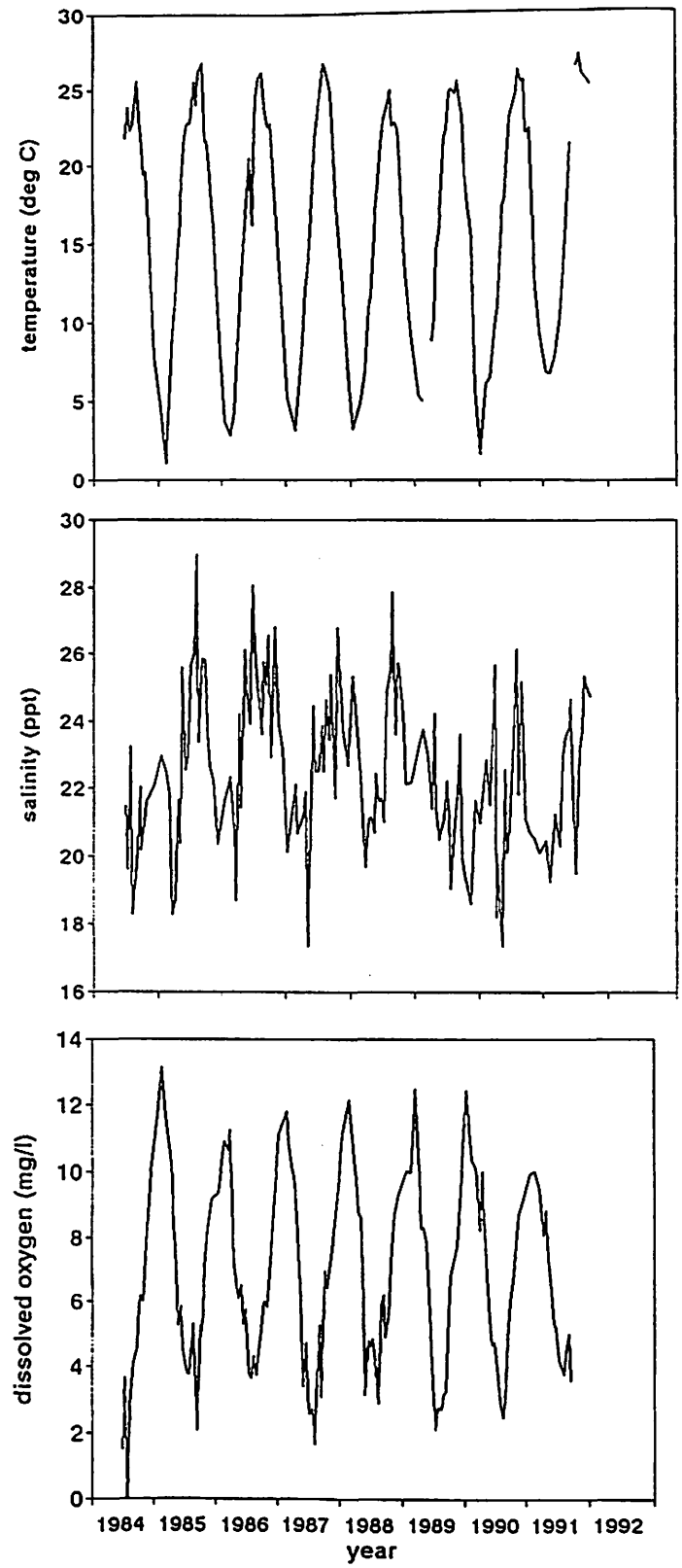

Figure 2. Water quality parameters for the Wolf Trap study region of lower Chesapeake Bay (from Neilson et al. unpublished).

Schaffner 1990, Dauer et al. 1984, 1987). Small, relatively opportunistic species, such as polychaetes in the families Spionidae and Capitellidae are present as numerical dominants, but larger organisms such as burrowing ophiuroids, hemichordates, head-down feeding maldanid polychaetes and tubicolous chaetopterid and terebellid polychaetes are present and often comprise a large portion of the biomass (Schaffner 1990, Mayer et al. in review). Biogenic sediment structuring is a prominent and persistent feature of surface and subsurface sediments (Schaffner et al. 1987a, Schaffner 1990).

METHODS

Sampling design and station locations

Macrobenthic community and sediment data were collected following two disposal events at different locations (Cell B and Cell C, respectively) within a site designated the "Wolf Trap Alternate Disposal Site" (Figure 1). For these experiments, dredged material (DM) was placed into an existing natural trough at the western boundary of the broad bay-stem plains region of the lower bay (Figure 3). The intent was to create areas bathymetrically similar to the adjacent plains region. A total of 5,889,000 cubic yards of material was placed into Cell B (area = 3.16 km^2) between 3 April and 18 October 1987. Cell C (area = 1.58 km^2) received a total of 2,577,482 cubic yards of material between 19 May 1988 and 19 March 1989. The history of disposal in each cell is shown in Figure 4.

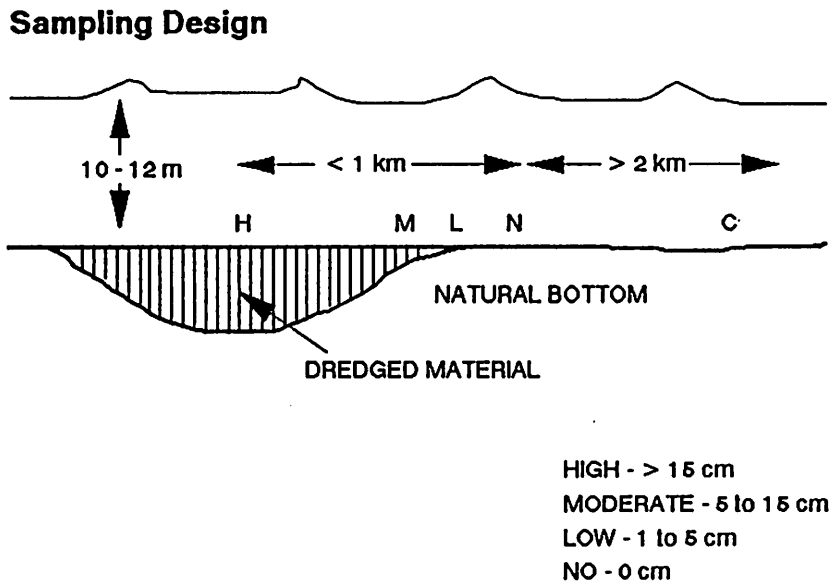

Figure 3. Schematic diagram showing placement of dredged material and station positioning relative to dredged material overburdens.

For each cell, samples were collected as soon as practicable (always within the same season) following the cessation of dredged material disposal. Sampling proceeded for four quarters (winter, spring, summer, fall) during the first year and then was limited to successive spring quarters for a total of 6 sampling dates for each cell. The final distribution of sampling dates varied depending on the time that sampling for each experiment was initiated.

At the initiation of sampling in each cell, DM thickness was determined by mapping the sediment-water interface with a sediment profile camera. Sampling positions for Cell B box core stations were haphazardly set along random transects for high ($\geq$ 15 cm, HDM), moderate (ca. 5 - 15 cm, MDM), low (ca. 1 - 5 cm, LDM), and no (0 cm, NDM), DM overburden levels (Figure 1). The NDM stations were located near the disposal cell (generally within 1 km), but did not receive dredged material. Thus, NDM stations serve as controls for assessing the effects of DM overburden following each disposal event. Once identified, station locations were fixed for the remainder of the study. Thus, on each sampling date there were 3 station locations for each DM overburden level.

The sampling design was altered slightly for Cell C. The number of samples collected was also increased based on preliminary examination of species abundance patterns in collections from Cell B. After mapping was used to identify DM overburden patterns, the cell was stratified on the basis of DM thickness and 6 stations were randomly

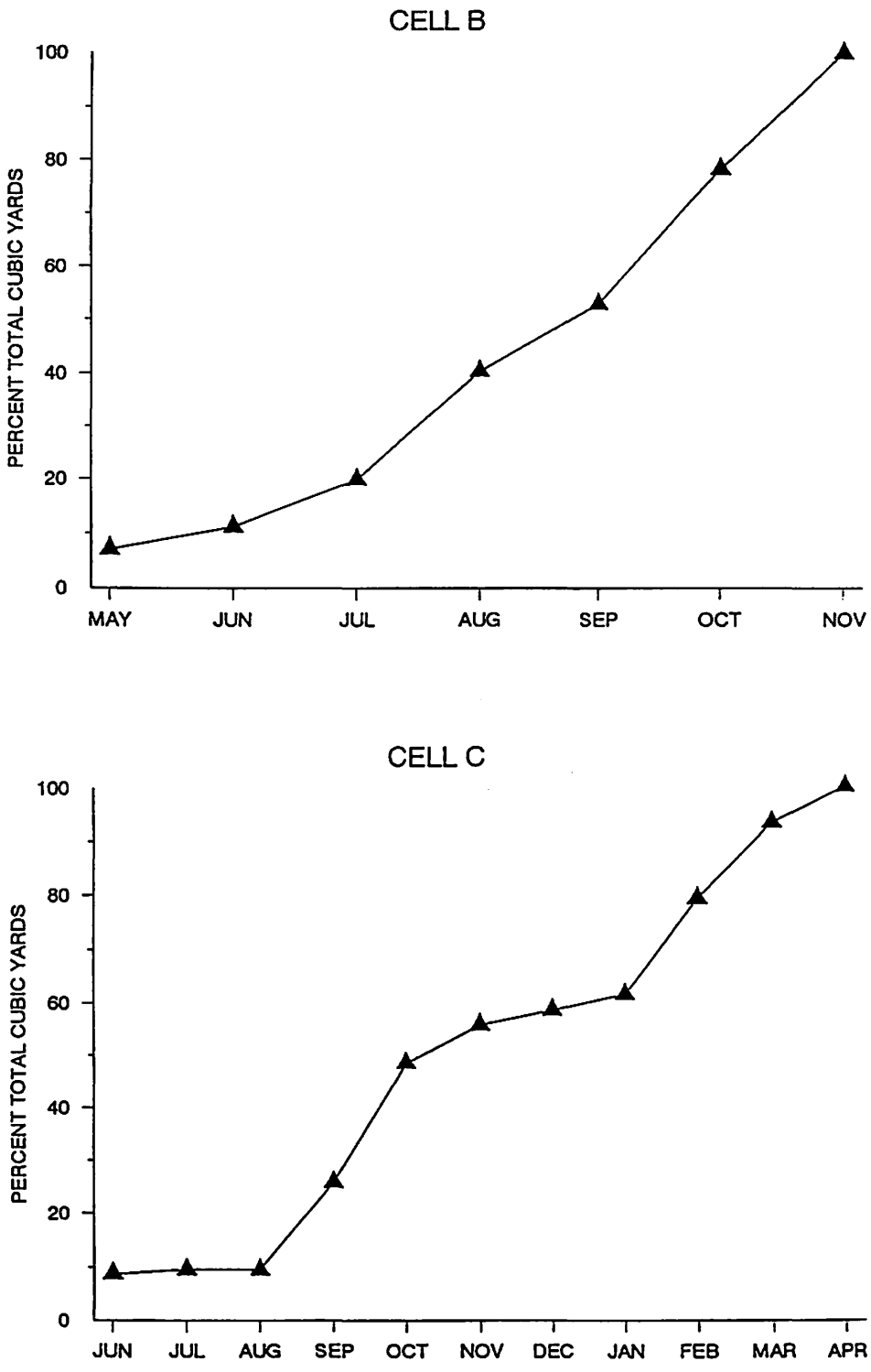

Figure 4. Disposal history for each cell.

identified within each stratum (Figure 1). Again, these stations remained fixed for the duration of the study.

Two additional stations, C1 and C2, were used to follow the ambient community of the bay-stem plains region of lower Chesapeake Bay (Figure 1). Placement for these stations was determined based on previous studies of the area (Diaz et al. 1985) which showed that these locations have macrobenthic communities that are representative of the bay-stem plains environment. Thus, these stations provided a point of reference for comparisons between assemblages at the disposal cells and representative communities of the lower bay.

All station positions were recorded and subsequently relocated using LORAN C navigation. Accuracy of station location was within $\pm$ 20 meters.

Field procedures

All benthic samples were collected using a U.S. Naval Electronics Laboratory Spade Box Corer with a surface area of 0.06 m^2. The box corer is capable of penetrating up to 60 cm in unconsolidated sediment, but only the upper 15 cm of the sediment column in each sample was retained for this study, because this fraction contains > 95 % of the macrofauna by numbers and weight (Schaffner 1987) and because the consolidated sediments below 15 cm are very labor intensive to process. On each sampling date a single box core was collected at each sampling location within disposal cells. Three box

cores were haphazardly collected at each control station location. For each core date, time, disposal cell, station number and core penetration depth were recorded and observations regarding fauna, presence or asbsence of dredged material, sediment layering, color and consistency, presence of clasts, etc. were noted. If any evidence of sample disturbance (e.g. 'wash out') was apparent upon collection, samples were discarded and the location was resampled. Small sediment cores (2 cm i.d.) for sediment analyses were removed from surface and subsurface regions of each core (see below) prior to further processing.

Most cores were sieved in their entirety on 500 μm mesh screen (core type 'A'). Animals and residual material retained on the screen were fixed in 10% buffered seawater formalin made with water collected at the site. Rose Bengal (ca. 0.2%) was added to aid in subsequent sorting of fauna.

Some cores were subdivided to allow study of faunal vertical distribution patterns (core type 'D') for the BRAT study. At Cell B and ambient community stations, one core for each DM level (randomly selected) was subdivided into vertical sections 0-2 cm, 2-5 cm, 5-10 cm and 10-15 cm on each sampling date. At Cell C stations, two cores per DM level (randomly selected) were subdivided on each sampling date. Each vertical section was processed as above, except that the 0-2 cm fraction was sieved on 250 μm mesh screen.

Small core samples for grain size and organic carbon analyses were removed from 0-5 cm and 5-10 cm depth intervals in each core. In the field, these samples were stored under refrigeration. Upon return to the laboratory, samples for grain size analysis were stored under refrigeration, while carbon samples were frozen, until processed.

Laboratory procedures

Each faunal sample was drained and rinsed to remove excess formalin. Organisms retained in each sample were then sorted in water to major taxon (Annelida, Crustacea, Gastropoda, Pelecypoda, etc.). Wet weight biomass values for blotted samples were obtained for each group. For A cores, organisms were then identified to the lowest possible taxonomic level. For D cores, most organism were identified to family level only.

Sediment grain size analysis was performed using a combination of settling tube analysis for the sand fraction and Coulter Counter analysis for the silt and clay fraction as described in Diaz et al. (1985). Total carbon analysis was performed using a Carlo-Erba NA1500 Analyzer following procedures outlined in Hedges and Stern (1984).

Data analyses

All parametric statistics were computed using SAS software on the VIMS Prime computer. Data transformations were performed when necessary to meet the assumptions for analysis of variance. These are discussed further in the approporaite text sections.

For community analyses, patterns of collection similarity and species distributions were determined using numerical classification and reciprocal averaging ordination. Numerical classification attempts to optimally group entities whereas ordination develops a spatial model of the relationships among entities (Clifford and Stephenson 1975, Pielou 1975). Thus, different aspects of the data sets were emphasized during analyses; results of analyses were compared as a means of identifying the most robust patterns.

Prior to some community analyses, data sets were reduced to a subset of the species originally collected. This was necessary to eliminate some rare species for which insufficient collections made interpretation of distribution patterns impossible. Species were eliminated on the basis of frequency of occurence. These reductions resulted in elimination of ca. 40-50 % of the species collected.

Normal classifications of collections and inverse classifications of species were produced using COMPAH (VIMS, unpublished). Algorithms used were standardization based on species maximum densities, interentity resemblance expressed by the Bray-Curtis similarity measure and either group-average or flexible sorting (Clifford and Stephenson 1975, Boesch 1977). Standardization of species abundances by maximum density was used to reduce the effects of absolute species abundances on resemblance measures. Group-average sorting was employed for station classification because chaining onto nuclear groups was not a problem. The space-dilating flexible sorting strategy (β = -0.25) was used to induce discrete groupings in inverse analysis of species patterns.

Normal and inverse classifications were cross-related in order that collection groups might be described in terms of their characteristic species and species groups in terms of the patterns of occurence over collections. Results of these comparisons, termed nodal analysis, are expressed in nodal diagrams (Boesch 1977) using the program NODAL (VIMS, unpublished). Coincidence is expressed in terms of nodal constancy, fidelity and abundance concentration.

Constancy is the degree to which a species is consistently found in a habitat. Constancy of a species group within a collection group was computed as:

$$c_{ij} = a_{ij}/(n_i n_j)$$

where a_{ij} is the actual number of occurences of members of species group i in the collection group j and n_i and n_j are the numbers of entities in the respective groups. The index takes a value of 1 when all species are in all collections in the group and 0 when none of the species occured in the collection group.

Fidelity reflects the degree to which a species selects or is restricted to a habitat. Species with high fidelity are found rarely outside their preferred habitat. Group fidelity refers to the average fidelity of species in a species group within a collection group. The fidelity of species group i in collection group j was defined as:

$$F_{ij} = \frac{a_{ij} \sum_{j}^{0} n_j}{n_j \sum_{j}^{0} a_{ij}}$$

using the same terms as the constancy index. This index is unity when the constancy of a species group in a collection group is equivalent to its overall constancy, greater than 1 when its constancy in that collection group is greater than that overall and less than 1 when its constancy is less than its overall constancy. The significance of the deviation of the number of occurences of members of a species group from that expected within a collection group assuming even distribution was tested by applying a chi-square test.

Some species may have high constancy in a range of collection groups, and thus low fidelity, but be much more abundant in one collection group than elsewhere. To describe this aspect of distribution, abundance concentration was measured. Abundance concentration is computed for each species in each collection group by dividing the mean abundance of the species in the collection group by its mean abundance overall. These ratios are averaged over all species in the species group.

Reciprocal averaging ordination (Hill 1973) was employed on reduced sets of standardized data (species maximum). The program ORDIFLEX of the Cornell Ecology Program Series (Gauch 1977) was used to produce normal (collections) and inverse (species) ordinations.

RESULTS

Sampling commenced on 9 November 1987 and continued through 8 May 1991 according to the schedule presented in Table 1. Sampling of Cell B stations began in fall 1987 and continued through spring 1990. Sampling at Cell C stations commenced in spring 1989 and continued through spring 1991. As described previously, station locations were determined after an inital mapping of DM overburdens at the sediment-water interface with a sediment profile camera. In most cases, the dredged material was distinguishable from the natural sediments on the basis of textural differences, color, layering characteristics and the presences of clasts. The distribution of DM within each cell is shown in Figures 5 and 6. Actual DM overburdens observed in box cores collected on the first visit to each disposal cell are given in Table 2. A full listing of station locations for this study is presented in Appendix 1.

Physical characteristics of the sites

Water depths at stations sampled for macrobenthos ranged between 10 and 13 meters

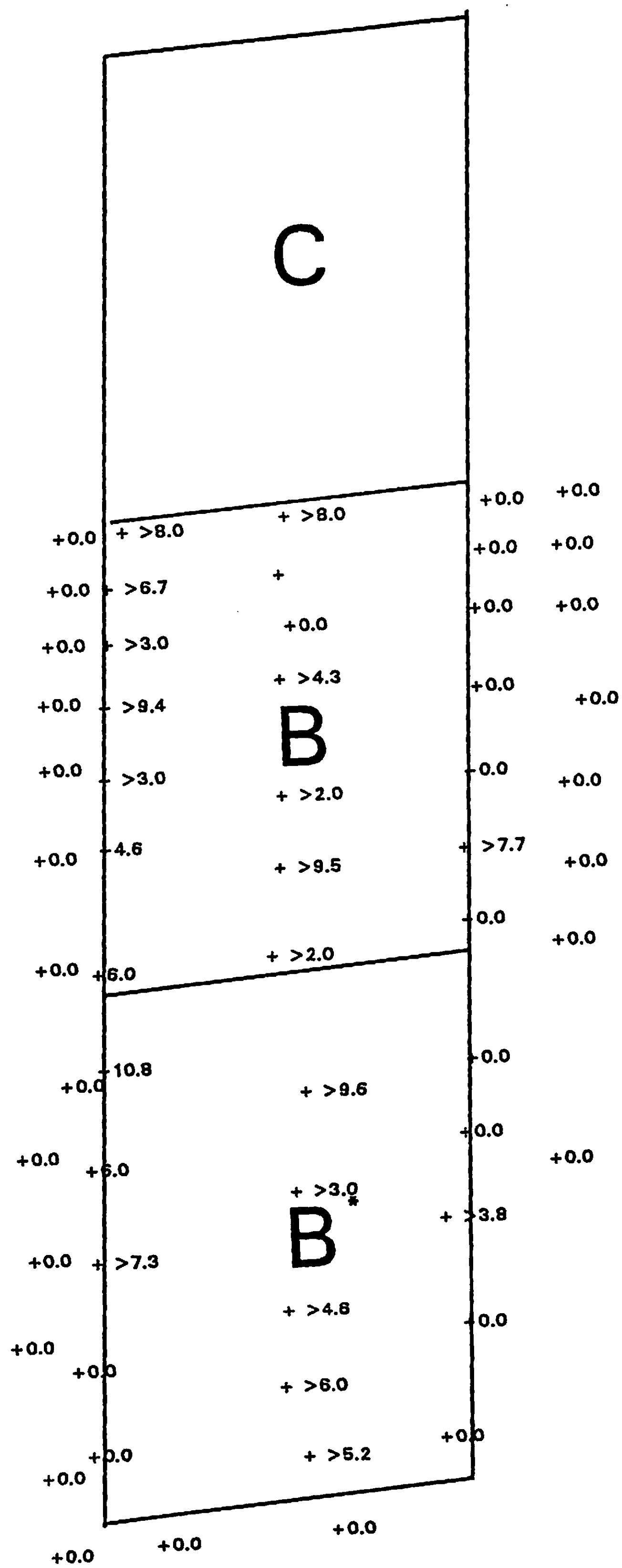

Figure 5. Dredged material overburden thickness in cm for Cell B determined by mapping the sediment-water interface with a sediment profile camera, November 1987. Note: Cell B is equivalent to Cells 3 and 4 (B*) as originally designated by the Corps.

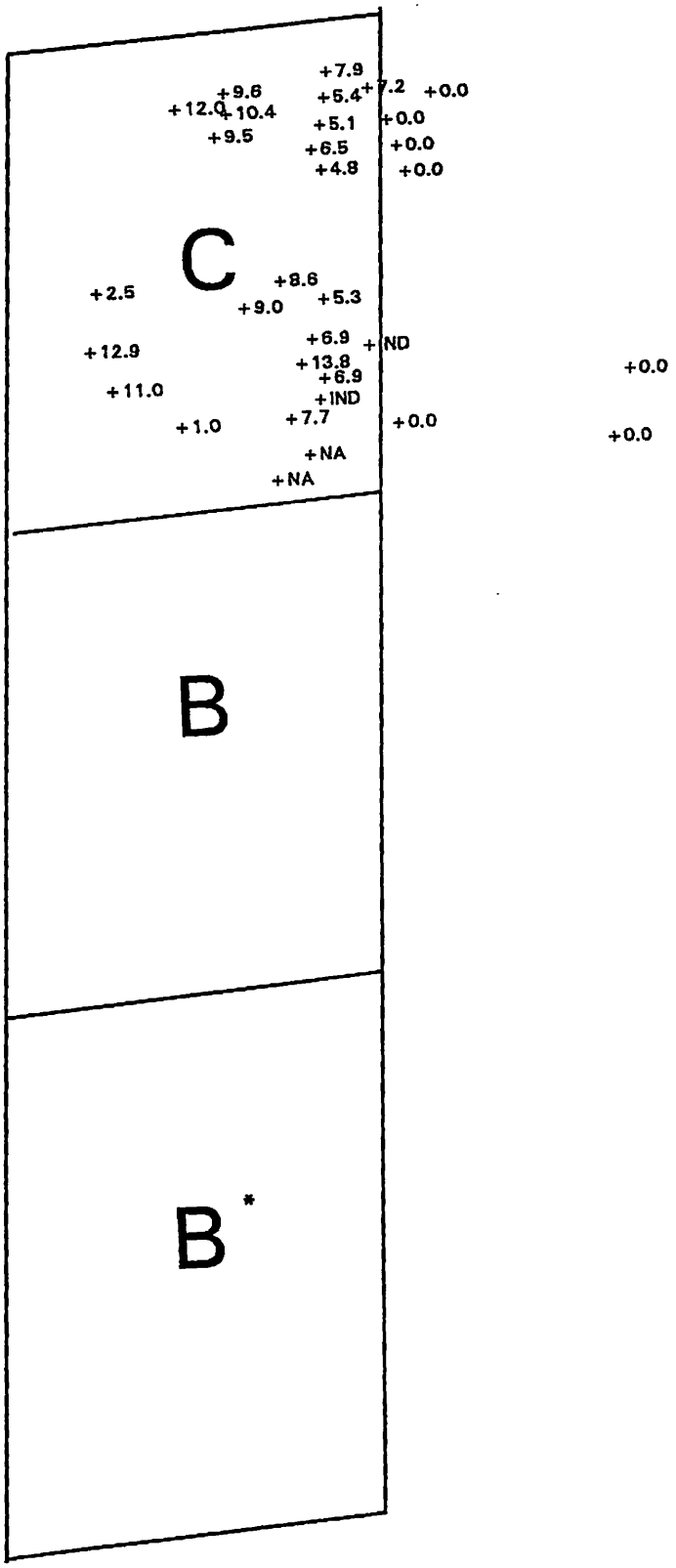

Figure 6. Dredged material overburden thickness in cm for Cell C determined by mapping the sediment-water interface with a sediment profile camera, May 1989. Note: Cell C is equivalent to Cell 2 as originally designated by the Corps.

Table 1. Sampling schedule for Cell B, Cell C and ambient community stations C1 and C2.

Year		1988				1989				1990				1991	
Quarter	F	W	SP	SU	F	W	SP	SU	F	W	SP	S	F	W	SP
Cruise	02	03	04	05	06	07	08	09	10	11	12				13
Cell B	X	X	X	X			X				X				
Cell C							X	X	X	X	X				X
C1 and C2	X	X	X	X	X	X	X	X	X	X	X				X

Table 2. Summary of dredged material overburdens observed in box cores from the Wolf Trap Alternate Disposal Site.

Date	Disposal Cell	Station	DM thickness (cm)
November 1987	B	HDM-1	19
		HDM-2	20
		MDM-1	7
		MDM-2	7
		LDM-1	5
		LDM-2	3
		NDM-1	0
		NDM-2	0
May 1989	C	HDM-1	27
		HDM-2	13
		HDM-3	15
		HDM-4	15
		MDM-1	15
		MDM-2	10
		MDM-3	8
		MDM-4	6
		LDM-1	5-8
		LDM-2	5
		LDM-3	5
		LDM-4	5
		NDM-1	0
		NDM-2	0
		NDM-3	0
		NDM-4	0

Table 3. Ranges for water depths and sediment median grain size (phi) at stations sampled for macrobenthos.

Station	Depth (m)	Median Grain Size
C1	10 - 12	3.5 - 4.0
C2	10 - 12	3.8 - 4.2
Cell B		
HDM	11 - 13	2.2 - 4.5
MDM	11 - 13	2.5 - 4.9
LDM	11 - 13	3.9 - 4.7
NDM	11 - 13	3.2 - 5.5
Cell C		
HDM	10 - 12	3.2 - 3.5
MDM	10 - 12	3.2 - 3.6
LDM	10 - 12	3.0 - 3.5
NDM	10 - 12	2.7 - 3.2

(Table 3). At ambient community stations C1 and C2, bottom sediments were composed of mixtures of fine sands (ca. 40-50 %), silts (ca. 30-40 %) and clays (ca. 10-15 %) (Table 3, Figures 7 and 8). Median grain size (phi) ranged between 3.5 and 4.2 with no evidence of seasonal variation during the study period. Total carbon content was generally less than 1% (Appendix 2).

The DM deposited in Cell B initially was coarser and had a lower mud content (silt + clay) than sediments at C1 and C2 (Figures 7 and 8). These differences were most apparent for HDM stations and persisted through the first sampling year, after which HDM sediments were similar to those observed at the ambient community stations. The NDM control stations had sediments that were, on average, slightly finer than those sampled at C1 and C2. Analyses of sediment samples from spring 1987 indicate that the DM deposited in Cell C initially was similar, or only slightly coarser than the sediments sampled at C1 and C2. Water depths were comparable to those at C1 and C2 (Table 3). Total carbon content of all DM station sediments was generally less than 1% (Appendix 2).

Composition of the fauna

A full listing of all organisms collected during the study is presented in Appendix 3. Biomass values for 'A' type cores are presented in Appendix 4. An analysis of biomass patterns in 'D' type cores will be presented by the Corps in conjunction with the BRAT study.

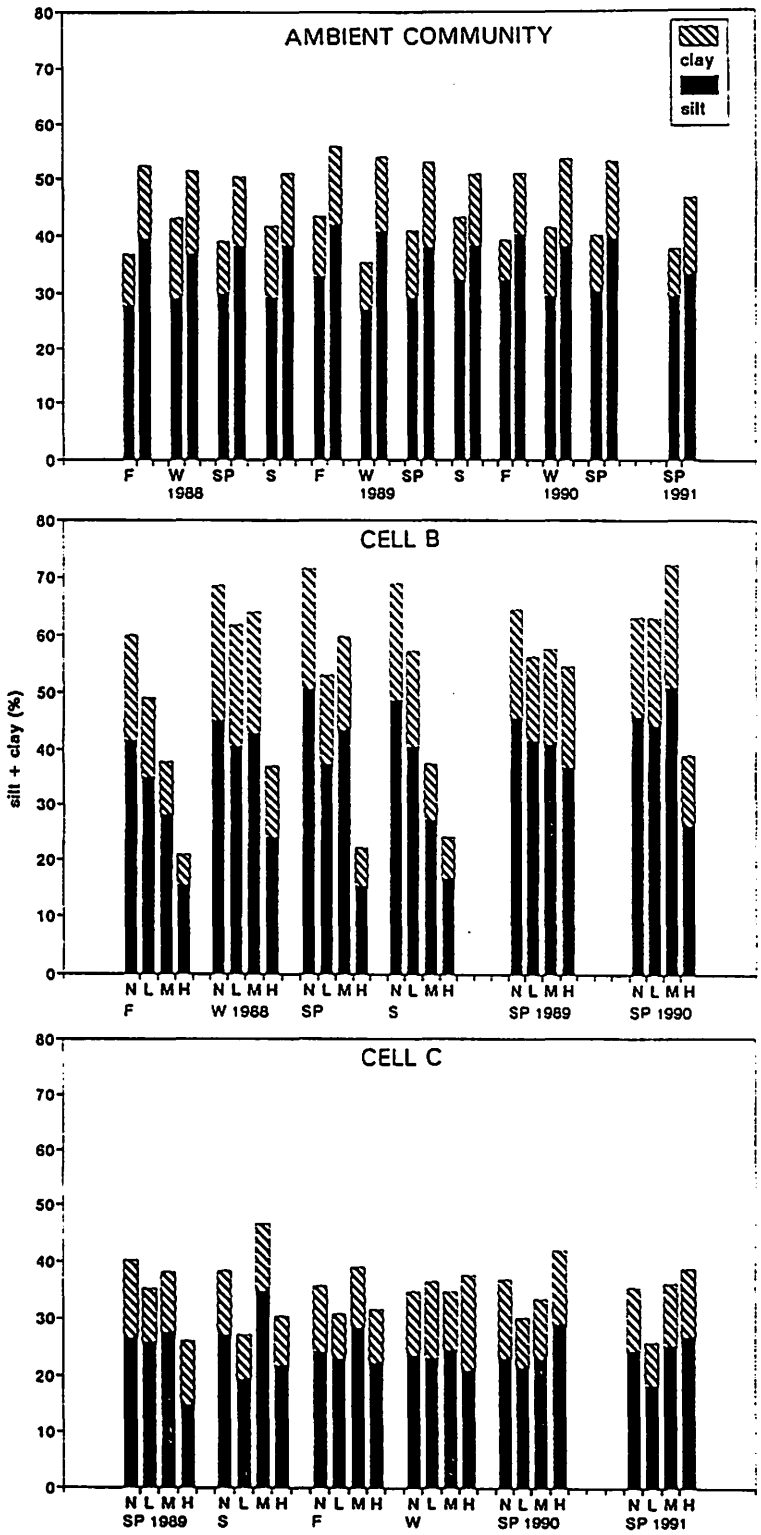

Figure 7. Percent silt+clay at ambient community stations C1 and C2, Cell B and Cell C stations.

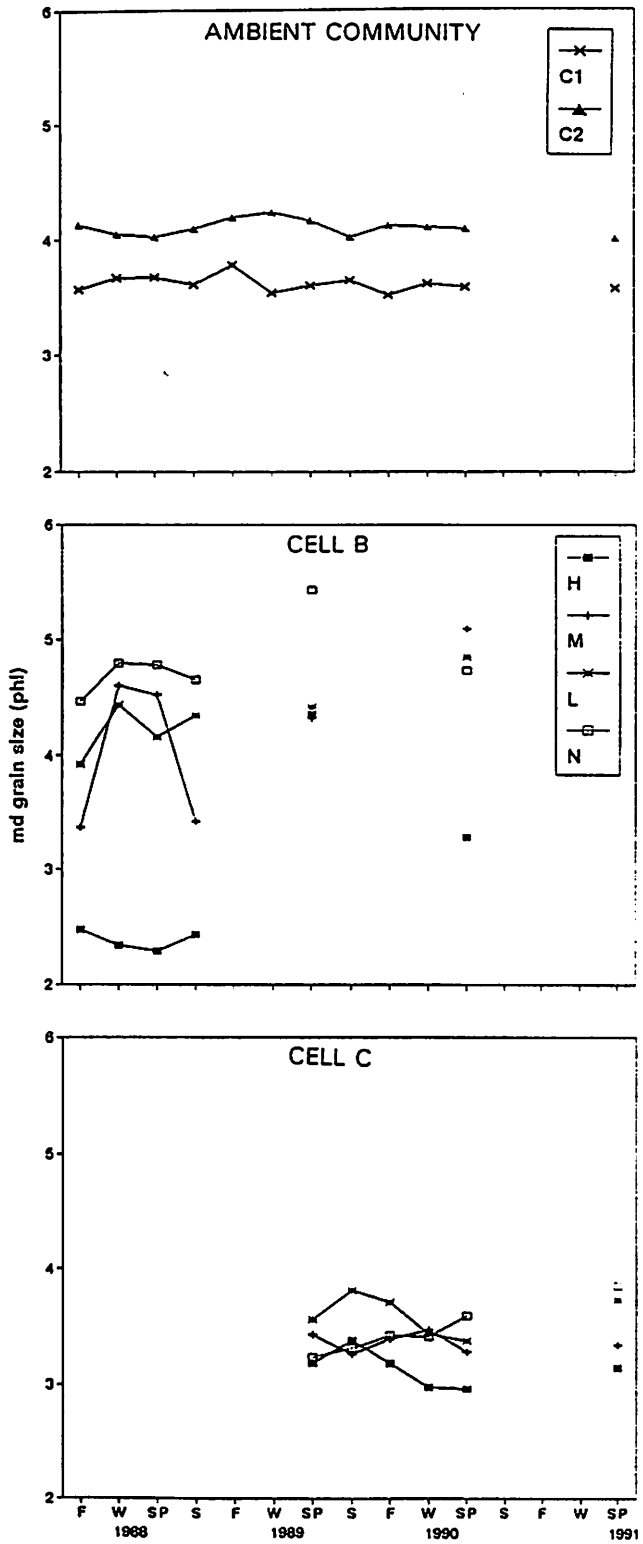

Figure 8. Median grain size (phi) at ambient community stations C1 and C2, Cell B and Cell C.

A total of 128 taxa collected at the 2 ambient community stations (C1, C2; 48 box core collections, total) were identified to the species level. Of these 46 % were annelids, 24 % were mollusks and 20 % were crustaceans. The remaining 11 % included Anthozoa (2 spp.), Platyhelminthes (2 spp.), Nemertea (4 spp.), Phoronida (1 spp.), Echinodermata (2 spp.), Hemichordata (1 spp.) and Urochordata (1 spp.).

A total of 110 taxa were identified to species in collections from Cell B (48 box core collections, total). Of these 46 % were annelids, 22 % were mollusks and 21 % were crustaceans. The remaining 11 % included Anthozoa (3 spp.), Platyhelminthes (2 spp.), Nemertea (3 spp.), Phoronida (1 sp.), Echinodermata (1 sp.), and Hemichordata (1 sp.). Thus, composition at the major taxon level was similar to what was observed in the ambient community despite the potential influence of a disturbance event.

A total of 167 taxa were identified to species in collections from within Cell C (96 box core collections, total). Of these 42 % were annelids, 25 % were mollusks and 21 % were crustaceans. The remaining 11 % included Anthozoa (5 spp.), Platyhelminthes (4 spp.), Nemertea (5 spp.), Phoronida (1 sp.), Echinodermata (2 sp.), and Hemichordata (1 sp.), Urochordata (1 sp.), Priapulidae (1 sp.) and Chordata (1 sp.). Again, this composition at the major taxon level was similar to what was observed in the ambient community and in the first experiment, despite the disturbance event and a significant increase in the total number of taxa collected at this cell as a result of increased sampling effort.

Patterns of community structure

For the ambient community of the Wolf Trap study region, time of sampling was a significant factor influencing the number of individuals ($\log_{10}$ x+1) and number of species (stations C1 and C2), but there was no significant influence of site, no significant interactions and no significant trends in biomass ($\log_{10}$ x+1) (Table 4). Densities were highest during the spring sampling periods and during winter 1990 (Figure 9). Mean number of species (averaged over both sites) increased from a low of 27 per core in the fall of 1987 to a high of 49 per core in spring 1990 and a strong seasonal effect was not apparent (Figure 10). Biomass was highly variable at these sites (Figure 11), presumably due in part to small sample size, but mean densities for the entire study period were comparable (6.3 and 5.2 grams wet weight per core at C1 and C2, respectively).

Dredged material overburden level, but not time of sampling was a significant factor influencing the number of individuals ($\log_{10}$ x+1) at Cell B stations and there was no significant interaction (Table 5). During the first four quarters of sampling, densities were lower at HDM stations than at other DM levels. There were no significant differences between MDM, LDM and NDM collections. When all 6 sampling dates are included the interaction term is significant. Mean densities at HDM stations were comparable to densities at other DM levels, including NDM, by spring 1989 (Figure 9). A peak in organism density at MDM stations in spring 1988 was due to high denisities of the epifaunal bivalve *Mytilus edulis* (see below). Overall, patterns of abundance at

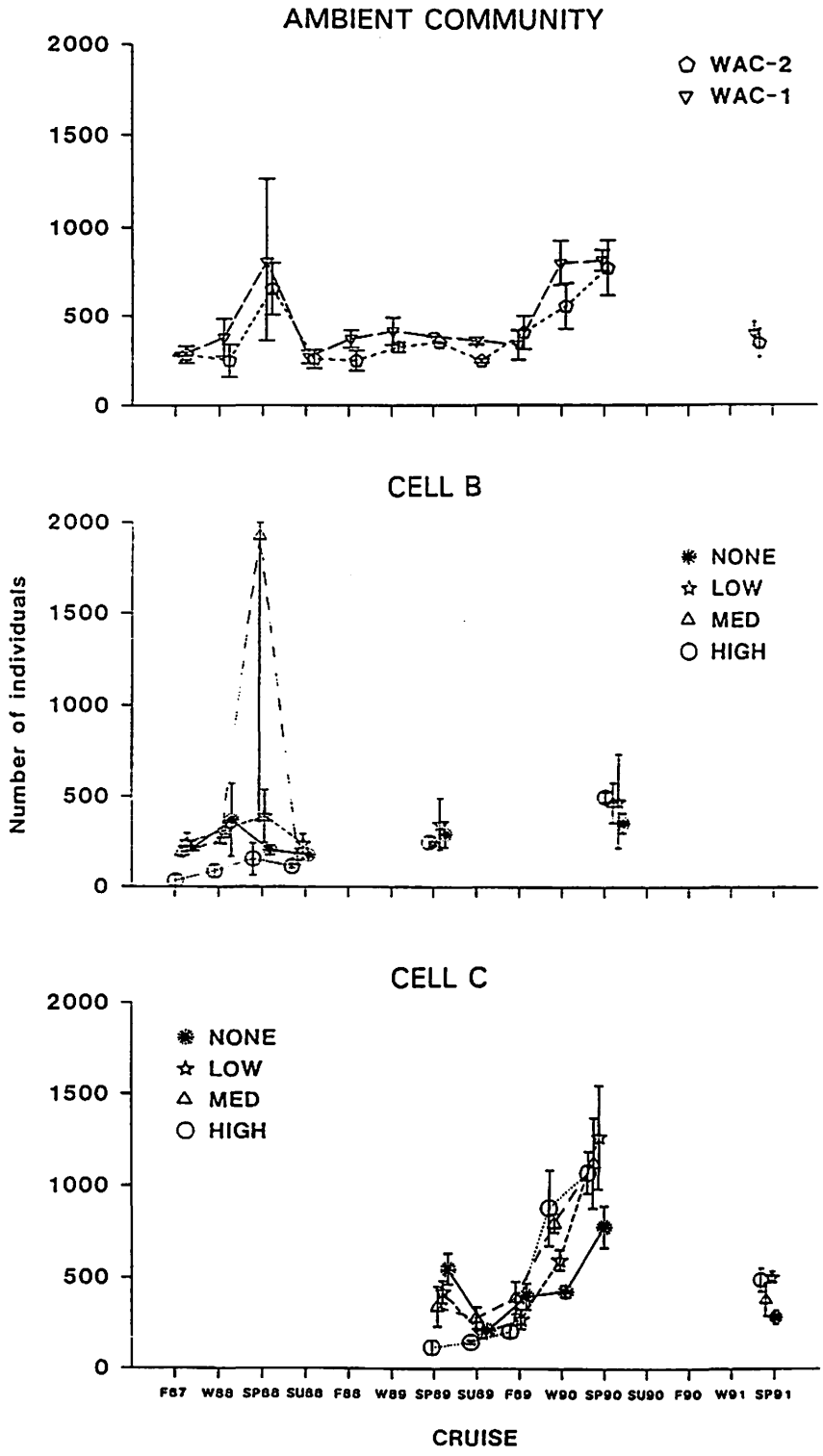

Figure 9. Total organism abundance per $0.06m^2$ versus time for ambient community, Cell B and Cell C stations.

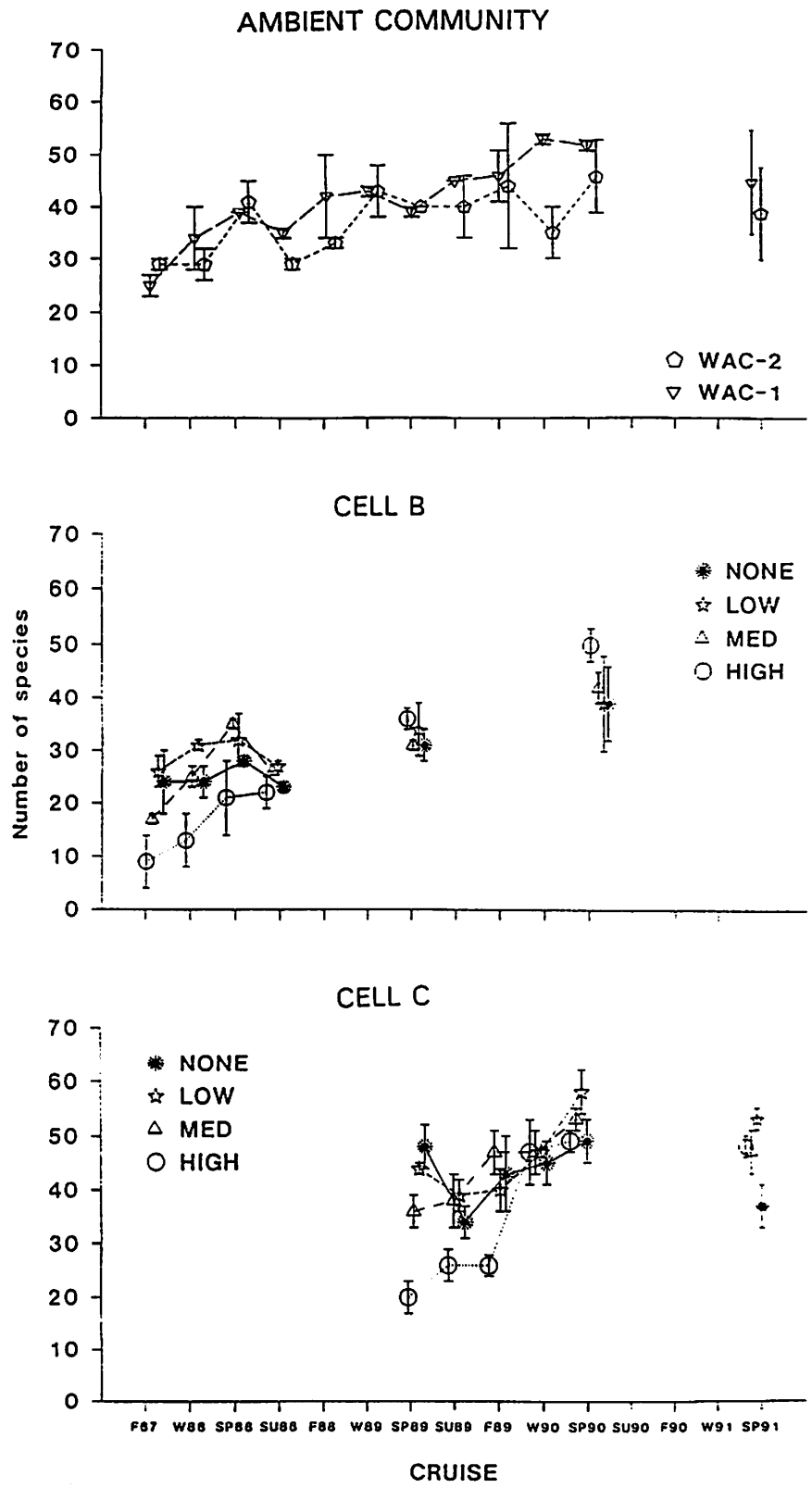

Figure 10. Number of species per 0.06m^2 versus time for ambient community, Cell B and Cell C stations.

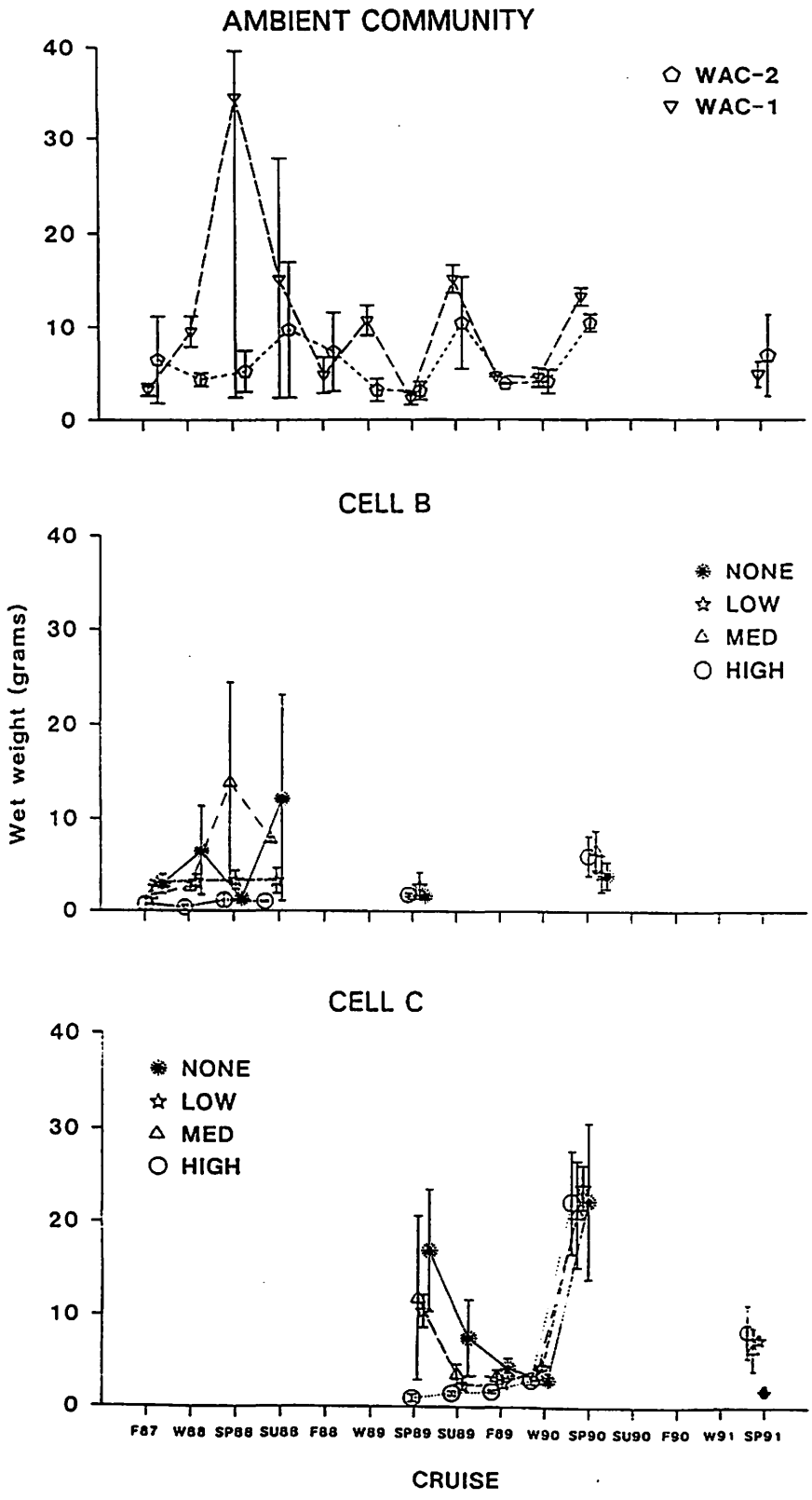

Figure 11. Total wet weight biomass per 0.06m^2 versus time for ambient community, Cell B and Cell C stations.

Table 4. ANOVA table for number of individuals, number of species and total biomass at ambient community stations C1 and C2. Experimental design is 2 stations x 12 sampling dates x 2 cores per station/date combination. For ns, $P > 0.05$. Ryan Multiple F Test used for *a posteriori* contrasts. Collections that are not significantly different at alpha = 0.05 are underlined.

Source of variation	df	F	Prob.	*a posteriori* comparison
Number of Individuals				
Station	1	3.6	ns	
Date	11	5.6	.0002	S88 F87 W88 S89 F88 F89 SP91 W89 SP89 W90 SP88 SP90
Station x Date	11	0.4	ns	
Number of Species				
Station	1	4.6	ns	
Date	11	3.4	.006	S88 F87 W88 S89 F88 F89 SP91 W89 SP89 W90 SP88 SP90
Station x Date	11	0.7	ns	
Total Biomass				
Station	1	0.5	ns	
Date	11	1.2	ns	
Station x Date	11	0.3	ns	

Table 5. ANOVA table for number of individuals, number of species and total biomass at Cell B Stations. Experimental design is 4 DM overburden levels x 4 or 6 sampling dates x 2 cores per DM level/date combination. For ns, $P > 0.05$. Ryan Multiple F Test used for *a posteriori* contrasts. Collections that are not significantly different at alpha = 0.05 are underlined.

Source of variation	df	F	Prob.	*a posteriori* comparison
Fall 1987 - Summer 1988 only				
Number of Individuals				
DM Level	3	7.7	.002	H N L M
Date	3	2.8	ns	
DM Level x Date	9	1.2	ns	
Number of Species				
DM Level	3	9.6	.0007	H N L M
Date	3	5.7	.008	F87 W88 S88 SP88
DM Level x Date	9	1.1	ns	
Total Biomass				
DM level	3	5.8	.007	H N L M
Date	3	1.1	ns	
DM Level x Date	9	0.6	ns	
Fall 1987 - Spring 1990				
Number of Individuals				
DM Level	3	6.3	.002	H N M L
Date	5	4.3	.006	F87 S88 W88 SP89 SP88 SP90
DM Level x Date	15	1.7	ns	
Number of Species				
DM Level	3	2.6	ns	ns
Date	5	18.5	.0001	F87 W88 F88 SP88 SP89 SP90
DM Level x Date	15	2.0	ns	
Total Biomass				
DM level	3	5.1	.007	H N M L
Date	5	1.8	ns	
DM Level x Date	15	1.1	ns	

Cell B stations (excluding HDM in the first year) were similar to those observed at ambient community stations (Figure 9).

When only the first year of data is considered, both DM level and time of sampling had significant effects on the mean number of species collected per sample at Cell B stations, with no interaction (Table 5). The number of species was significantly reduced at HDM stations relative to other DM levels (Figure 10). For all stations, samples from spring 1988 had significantly more species than those from fall 1987, but collections from other sampling dates during the first year (winter, summer 1988) were intermediate. When all sampling dates are included only time of sampling had a significant effect, with highest number of species being collected in spring 1988, 1989, 1990. Again, this mirrors the gradual trend of increases in mean number of species collected from the ambient community.

Wet weight biomass ($\log_{10} x+1$) was significantly reduced for Cell B HDM relative to other DM levels. There was no significant influence of sampling date and no significant interaction (Table 5). This pattern was apparent for both the first year of data and all sampling dates combined, but Figure 11 shows that mean biomass levels in HDM collections were comparable to those at other DM levels and within the ranges observed for control stations by spring 1989 .

Dredged material overburden level, time of sampling and interactions between these factors had significant effects on the number of individuals ($\log_{10} x+1$) at Cell C stations making it impossible to interprete significant patterns (Table 6). A depression of mean densities at HDM stations on the first sampling date is apparent in Figure 9, but this pattern is obscured by winter 1990. High densities of organisms at all Cell C stations during winter and spring 1990 were primarily due to a high settlement of the bivalve *Ensis directus* (see below).

When only the first year of data is considered, both DM level and time of sampling had significant effects on the mean number of species collected per sample in Cell C, with no interaction (Table 6). The number of species was significantly reduced in HDM samples relative to other DM levels through the first 3 quarters of sampling (Figure 10). Samples from winter 1990 had significantly more species than those from spring, summer and fall 1989, consistent with the trends observed at the control stations and disposal Cell B. When all sampling dates are included time of sampling, DM level and the interaction term are all highly significant (Table 6).

When comparisons are limited to collections made during the first four sampling quarters, wet weight biomass ($\log_{10} x+1$) was significantly reduced for HDM stations in Cell C relative to other DM levels. There was no significant influence of sampling date and no significant interaction (Table 6). When all samples are included date of sampling, DM level and the interaction term are significant. Figure 11 shows that mean

Table 6. ANOVA table for number of individuals, number of species and total biomass at Cell C Stations. Experimental design is 4 DM overburden levels x 4 or 6 sampling dates x 4 cores per DM level/date combination. For ns, $P > 0.05$. Ryan Multiple F Test used for *a posteriori* contrasts. Collections that are not significantly different at alpha = 0.05 are underlined.

Source of variation	df	F	Prob.	*a posteriori* comparison
Spring 1989 - Winter 1990 only				
Number of Individuals				
DM Level	3	8.0	.0002	H L N M
Date	3	29.6	.0001	S89 SP89 F89 W90
DM Level x Date	9	5.3	.0001	
Number of Species				
DM Level	3	10.4	.0001	H M L N
Date	3	6.7	.0007	S89 SP89 F89 W90
DM Level x Date	9	2.4	ns	
Total Biomass				
DM level	3	8.9	.0001	H M L N
Date	3	1.9	ns	
DM Level x Date	9	2.6	ns	
Spring 1989 - Spring 1991				
Number of Individuals				
DM Level	3	4.1	.009	H N L M
Date	5	45.3	.0001	S89 SP89 F89 SP91 W90 SP90
DM Level x Date	15	5.0	.0001	
Number of Species				
DM Level	3	9.8	.0001	H N M L
Date	5	13.1	.0001	S89 SP89 F89 SP91 W90 SP90
DM Level x Date	15	2.9	.0012	
Total Biomass				
DM level	3	4.9	.004	H M N L
Date	5	19.4	.0001	S89 F89 W90 SP91 SP89 SP90
DM Level x Date	15	3.7	.0001	

biomass levels in HDM collections were comparable to those at other DM levels and the ambient community by winter 1990.

Community composition: patterns in space and time

When only collections from the ambient community stations C1 and C2 are considered, 8 major collection groups that reflect both long-term changes in the assemblages at these stations and the strong effects of recruitment events, particularly during spring, can be identified using normal classification techniques (Figure 12). Eight species groups are formed by the 69 species included in the inverse classification (Figure 13, Table 7). The distributional characteristics of these species groups among site groups are indicated in the nodal analyses represented in Figure 14.

Species in Group 1 were most common and abundant from the initiation of sampling through May 1989, while species in Group 2 were ubiquitous and abundant through the entire study period. Members of these groups included the polychaetes *Paraprionospio pinnata, Nephtys cryptomma, Sigambra tentaculata, Bhawania heteroseta, Loimia medusa* and *Glycera americana* previously reported as dominants for this region of Chesapeake Bay (Schaffner 1990). Species in Group 3 were less common, but were found in collection groups throughout the study. The species forming Groups 4-6 tended to be most common and abundant in summer collections and collections from August 1989 through May 1990. Species in Groups 7 and 8 were most abundant in spring and winter collections.

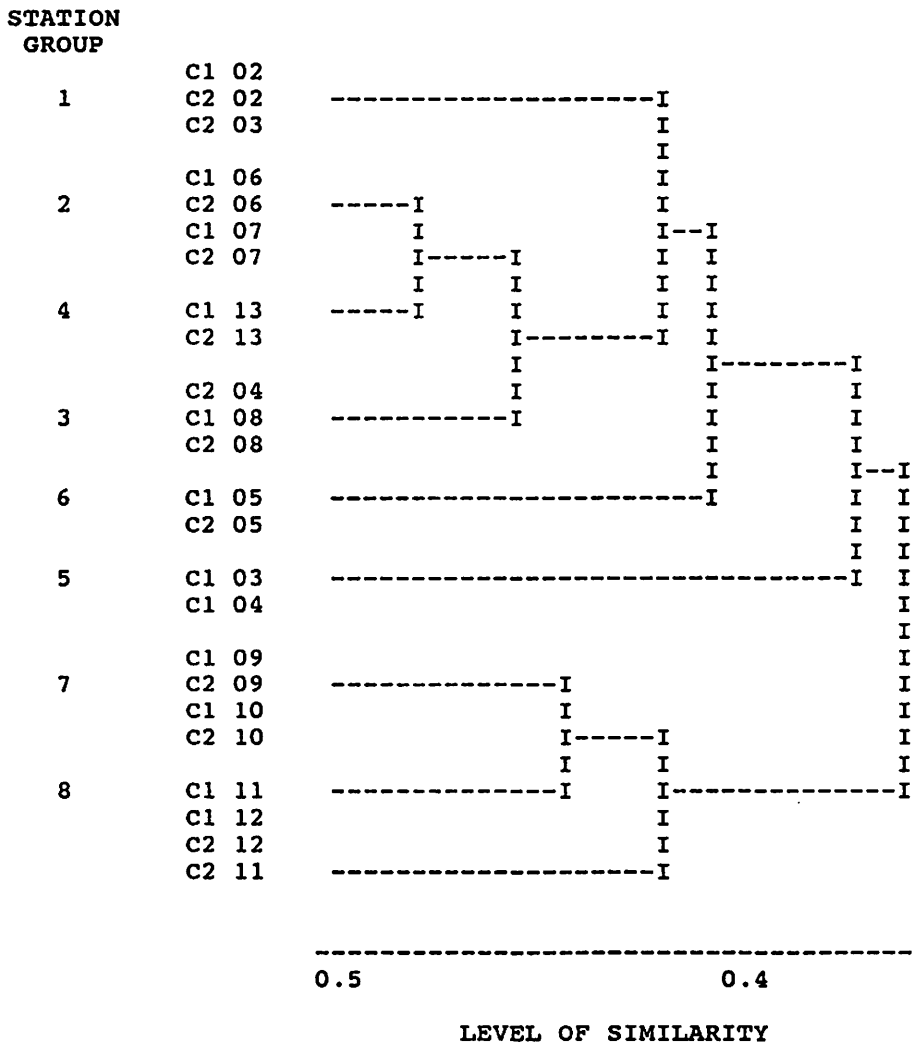

Figure 12. Hierarchies resulting from normal classification of collections of macrobenthos made on a seasonal basis at ambient community stations C1 and C2.

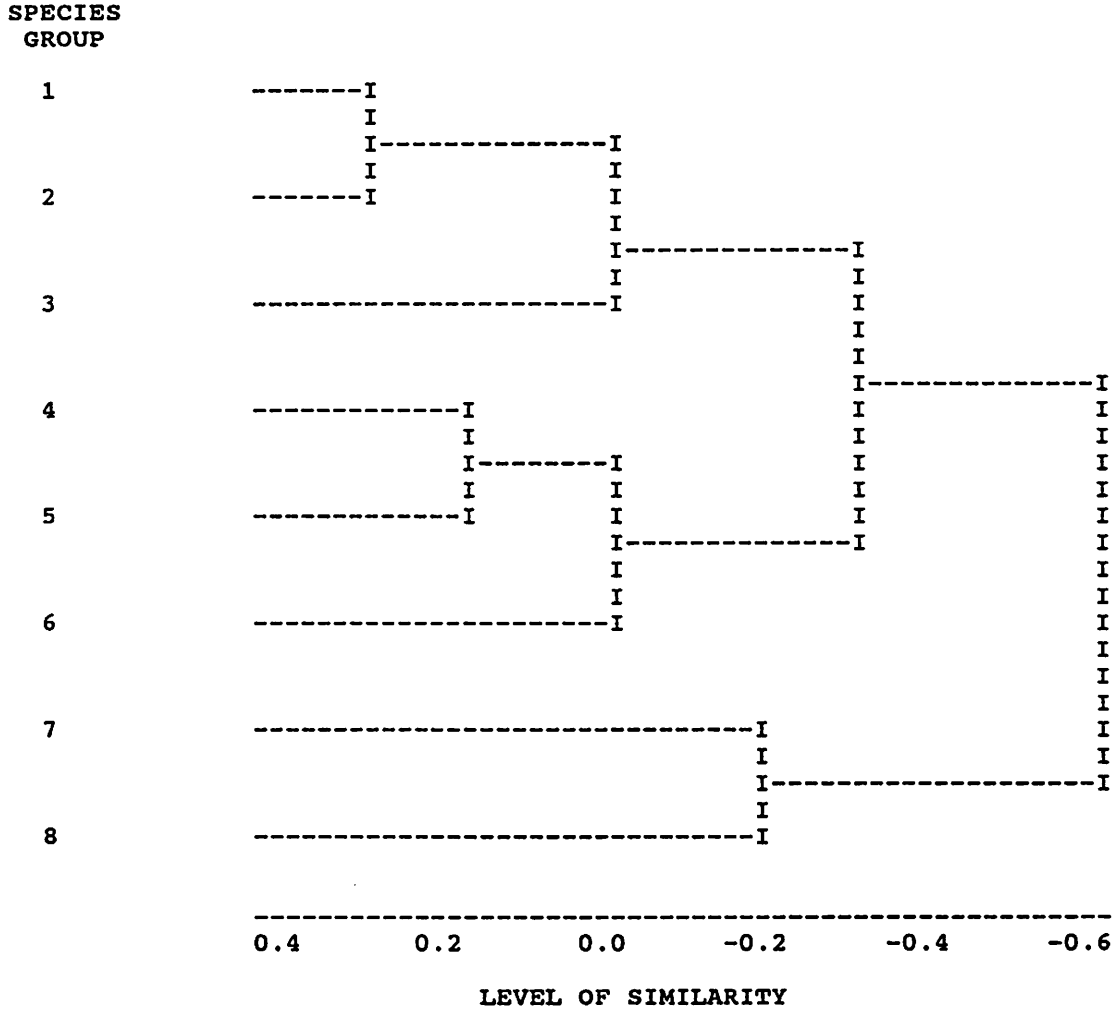

Figure 13. Hierarchies resulting from inverse classification of collections of macrobenthos made on a seasonal basis at ambient community stations C1 and C2.

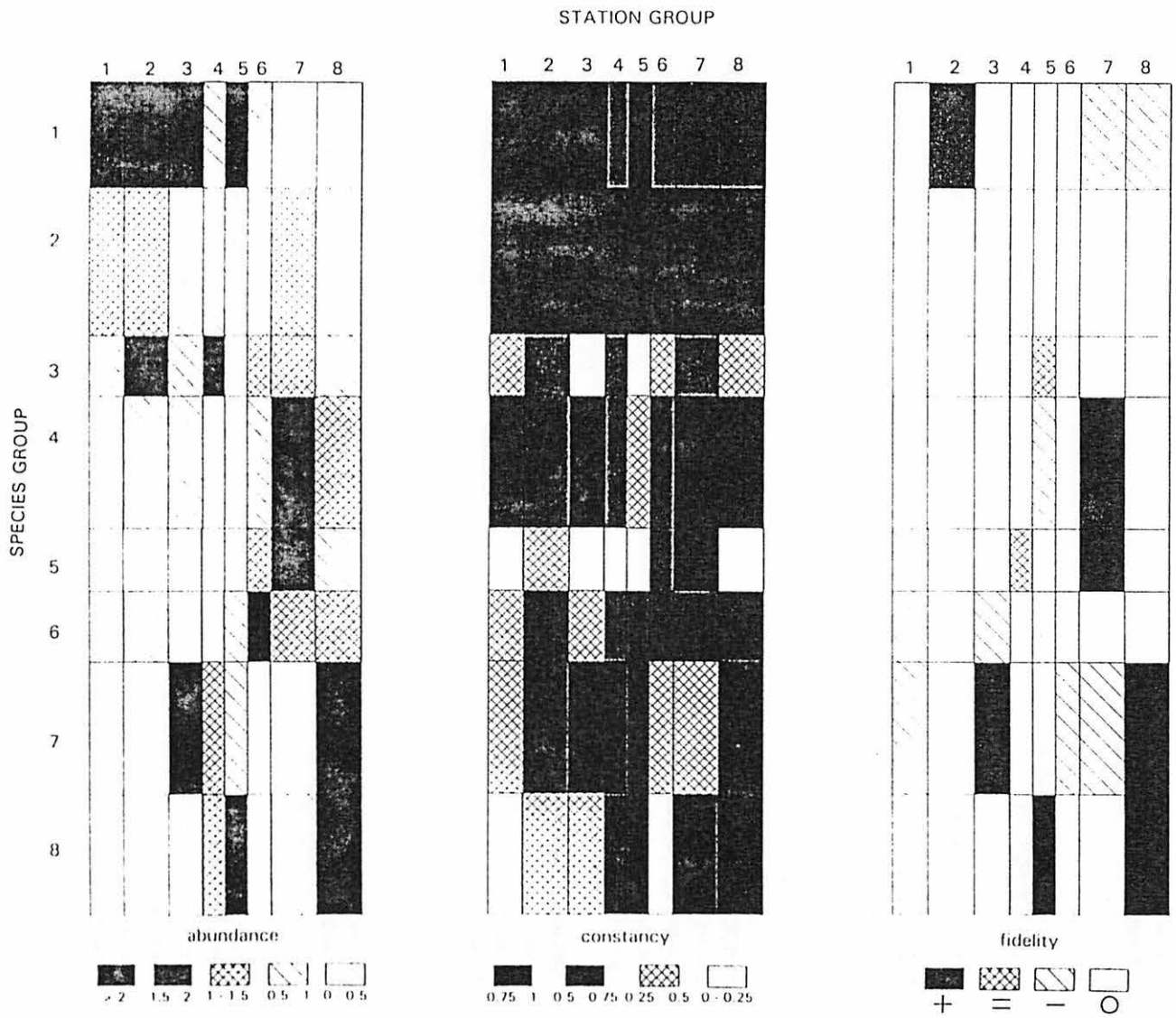

Figure 14. Nodal diagrams depicting the relationships between species groups and collection groups for ambient community stations C1 and C2.

Table 7. Species groups selected from numerical classification of macrobenthos collected at ambient community stations C1 and C2 between November 1987 and May 1991.

Species Group 1
Amphiporus bioculatus
Cylichnella bidentata
Nereis grayi
Natica pusilla
Prionospio perkinsi
Saccoglossus kowalewskii
Nephtys cryptomma
Pseudeurythoe paucibranchiata
Anachis lafresnayi

Species Group 2
Turbonilla interrupta
Loimia medusa
Phoronis sp.
Bhawania heteroseta
Sigambra tentaculata
Micrura rubra
Tubulanus pellucidus
Paraprionospio pinnata
Cabira incerta
Glycera americana
Idunella barnardi
Ogyrides alphaerostris

Species Group 3
Lepidametria commensalis
Chaetopterus variopedatus
Monticellina baptistaea
Edwardsia elegans
Asychis elongata

Species Group 4
Odostomia engonia
Owenia fusiformis
Macoma tenta
Glycinde solitaria
Acteocina canaliculata
Pectinaria gouldii
Microphiopholis atra
Malmgreniella lunulata
Podarkeopsis levifuscina
Sabellaria vulgaris
Turbonilla stricta

Species Group 5
Molgula manhattensis
Stylochus ellipticus
Acteon punctostriatus
Periploma sp.
Spiochaetopterus oculatus

Species Group 6
Diopatra cuprea
Nereis succinea
Cirriformia grandis
Ceriantheopsis americanus
Vitrinellidae
Paracaprella tenuis

Species Group 7
Yoldia limatula
Ampelisca abdita
Asabellides oculata
Macroclymene zonalis
Notomastus sp.
Streblospio benedicti
Lyonsia hyalina
Tellina agilis
Oligochaeta spp.
Oxyurostylis smithi
Mediomastus ambiseta

Species Group 8
Scolelepis sp.
Polydora cornuta
Corophium tuberculatum
Spiophanes bombyx
Erichthonius brasiliensis
Photis pugnator
Phyllodoce arenae
Eteone heteropoda
Mulinia lateralis
Ensis directus

The effects of seasonal changes in faunal patterns and longer-term temporal changes during the course of the study are clearly evident in the ordination of collections from these stations (Figure 15). The first axis separates collections from different seasons while the second axis separates collections made early in the study from those made late in the study. The arrangement of species within ordination space (Figure 16) is consistent with the patterns observed in the inverse classification. For example, members of species Group 2 are arrayed at nearly the center of ordination space reflecting their ubiquitous and abundant distribution throughout the study. Species found primarily in the spring (e.g. species group 7) have low scores on axis 1 and varying scores on axis 2, while species found primarily during the early portion of the study (e.g. species group 1) have high scores on axis 2. Seven major collection groups are identified via normal classification when collections from Cell B stations and from C1 and C2 stations for the corresponding sampling quarters are included (Figure 17). Resultant groups are defined on the basis of season of collection and DM overburden. Collections from the first 4 quarters of sampling at HDM stations cluster into separate groups (Groups 6 and 7), having low similarity (<0.3) to most other collections (Groups 1-5). By spring 1989, 18 months after sampling at Cell B began, the HDM station collection was indistinguishable from ambient community collections and other collections from Cell B.

Eight species groups are formed by the 66 species included in the inverse classification (Figure 18, Table 8). The distributional characteristics of these species groups are indicated in the nodal analyses represented in Figure 19. Species in Group 1 were most

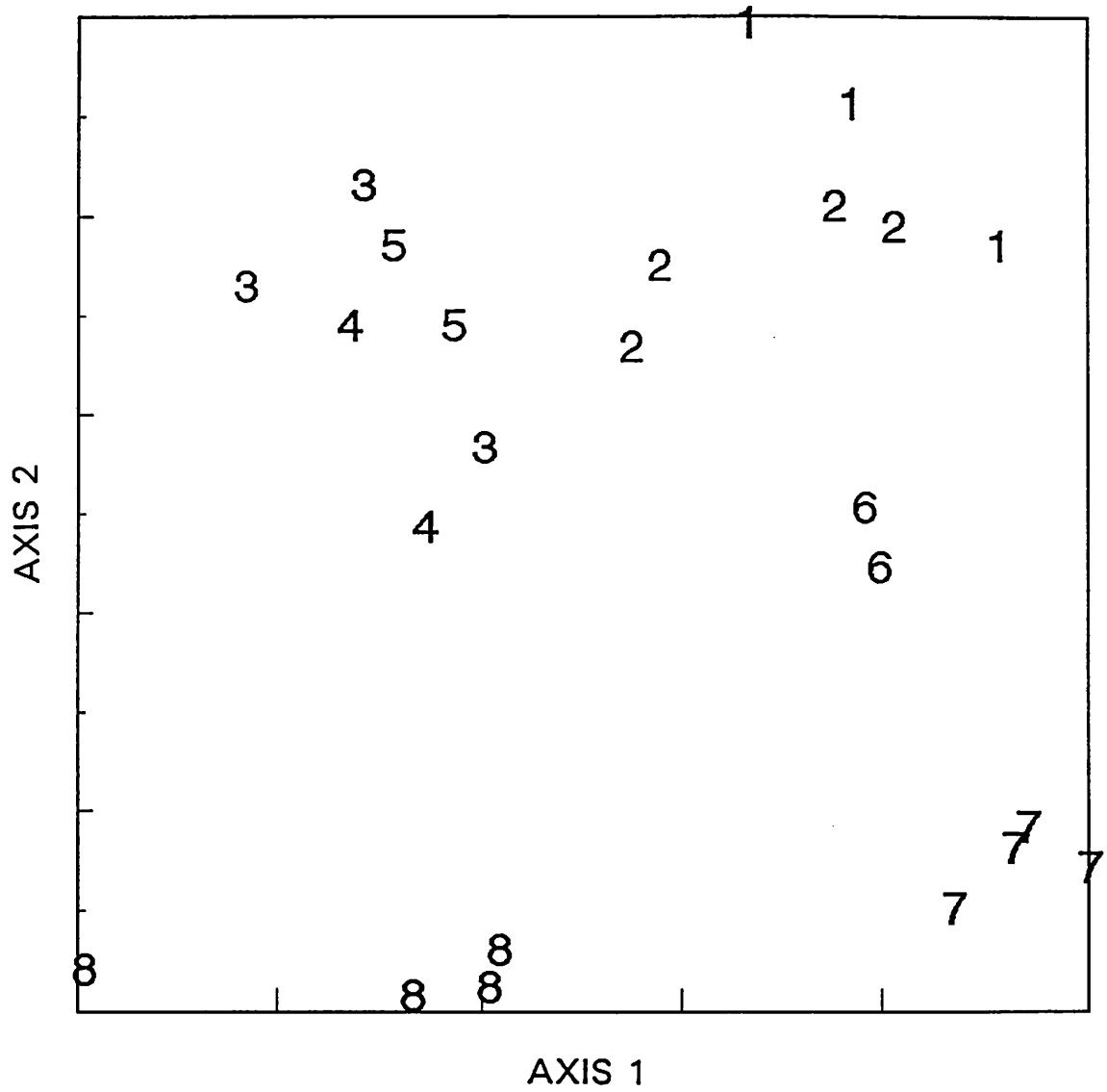

Figure 15. Reciprocal averaging ordination of collections of macrobenthos made seasonally at ambient community stations C1 and C2. Groups memberships are from normal classification (see Figure 12).

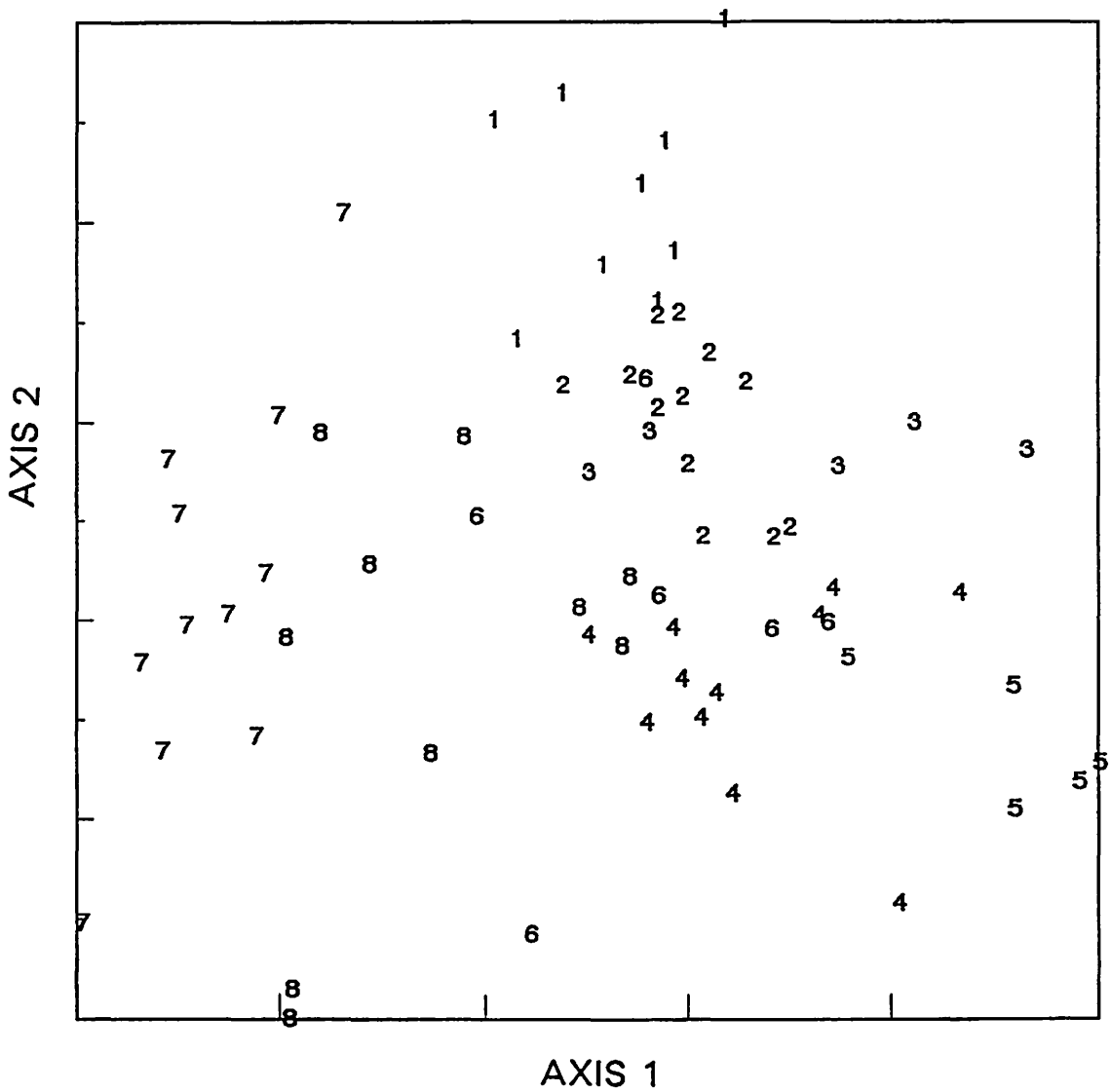

Figure 16. Reciprocal averaging ordination of species from collections of macrobenthos made seasonally at ambient community stations C1 and C2. Group memberships are from inverse classification (see Table 7).

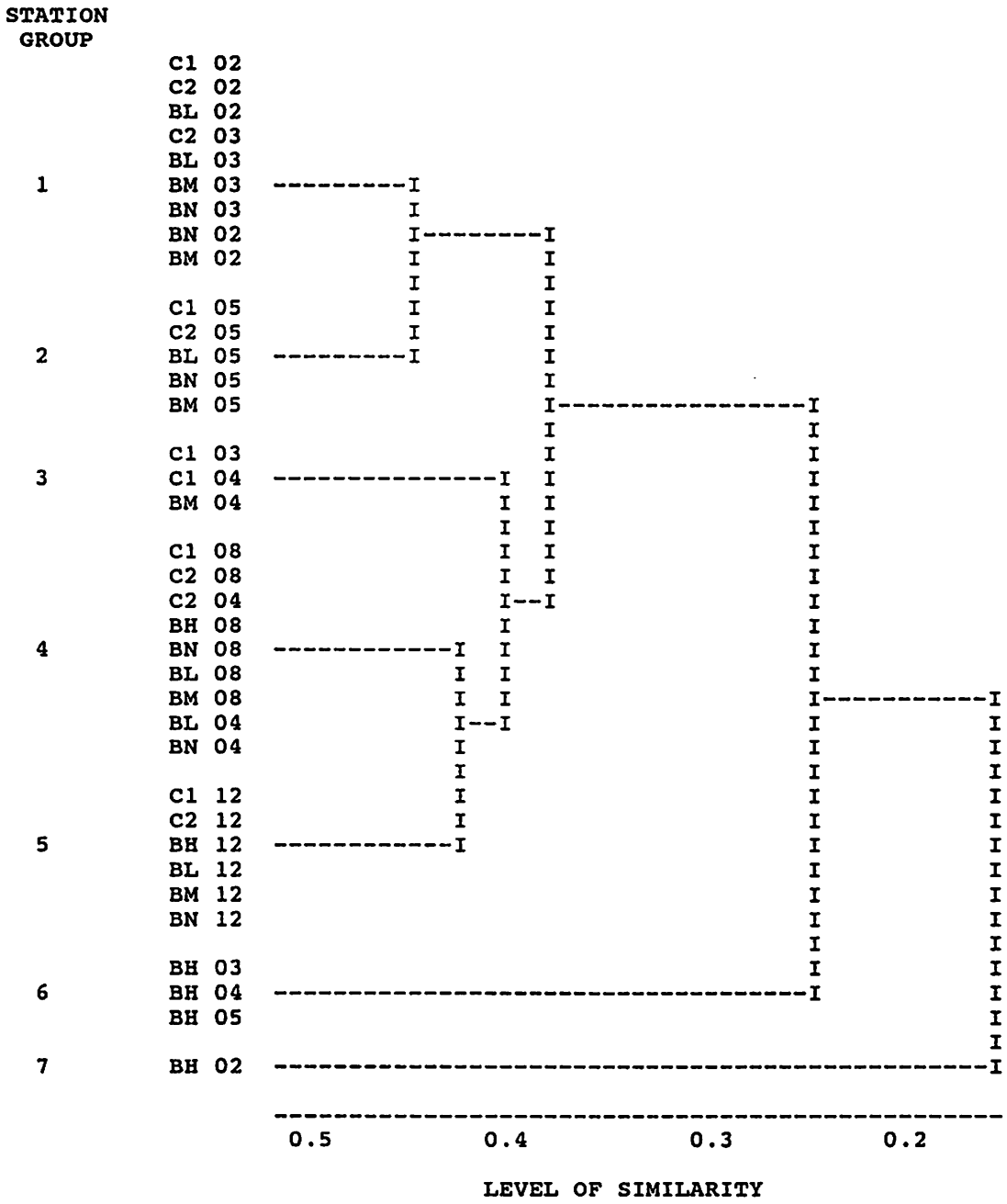

Figure 17. Hierarchies resulting from normal classification of collections of macrobenthos made on a seasonal basis at Cell B and ambient community stations.

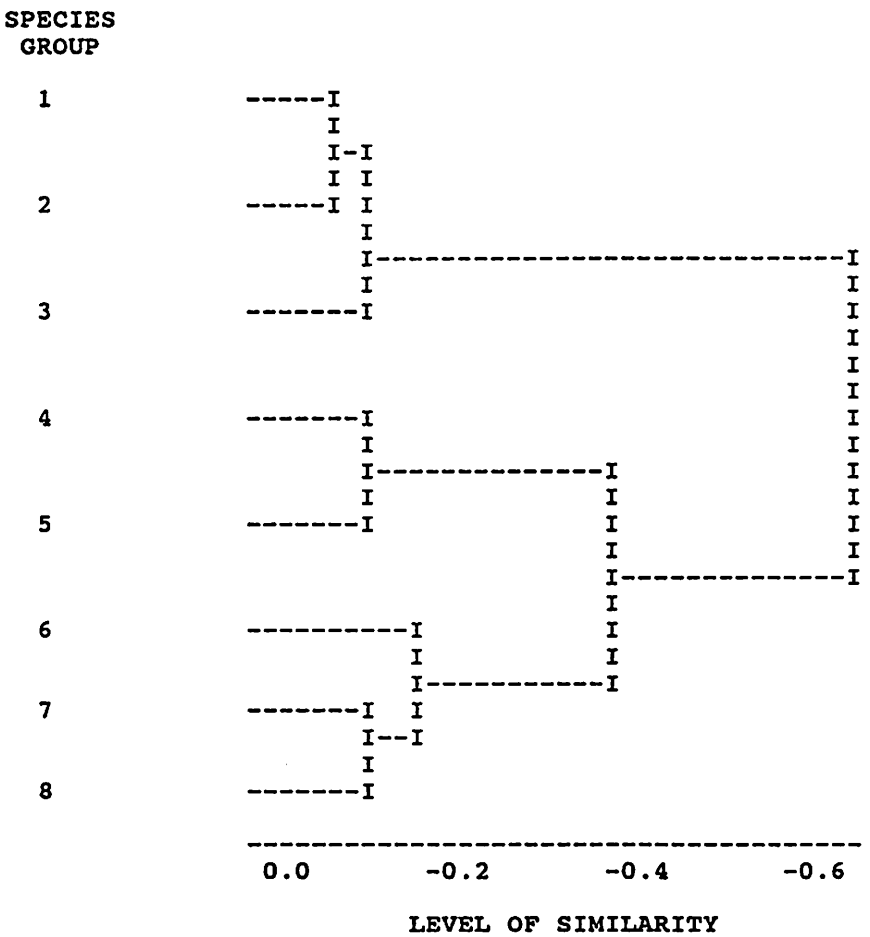

Figure 18. Hierarchies resulting from inverse classification of collections of macrobenthos made on a seasonal basis at Cell B and ambient community stations.

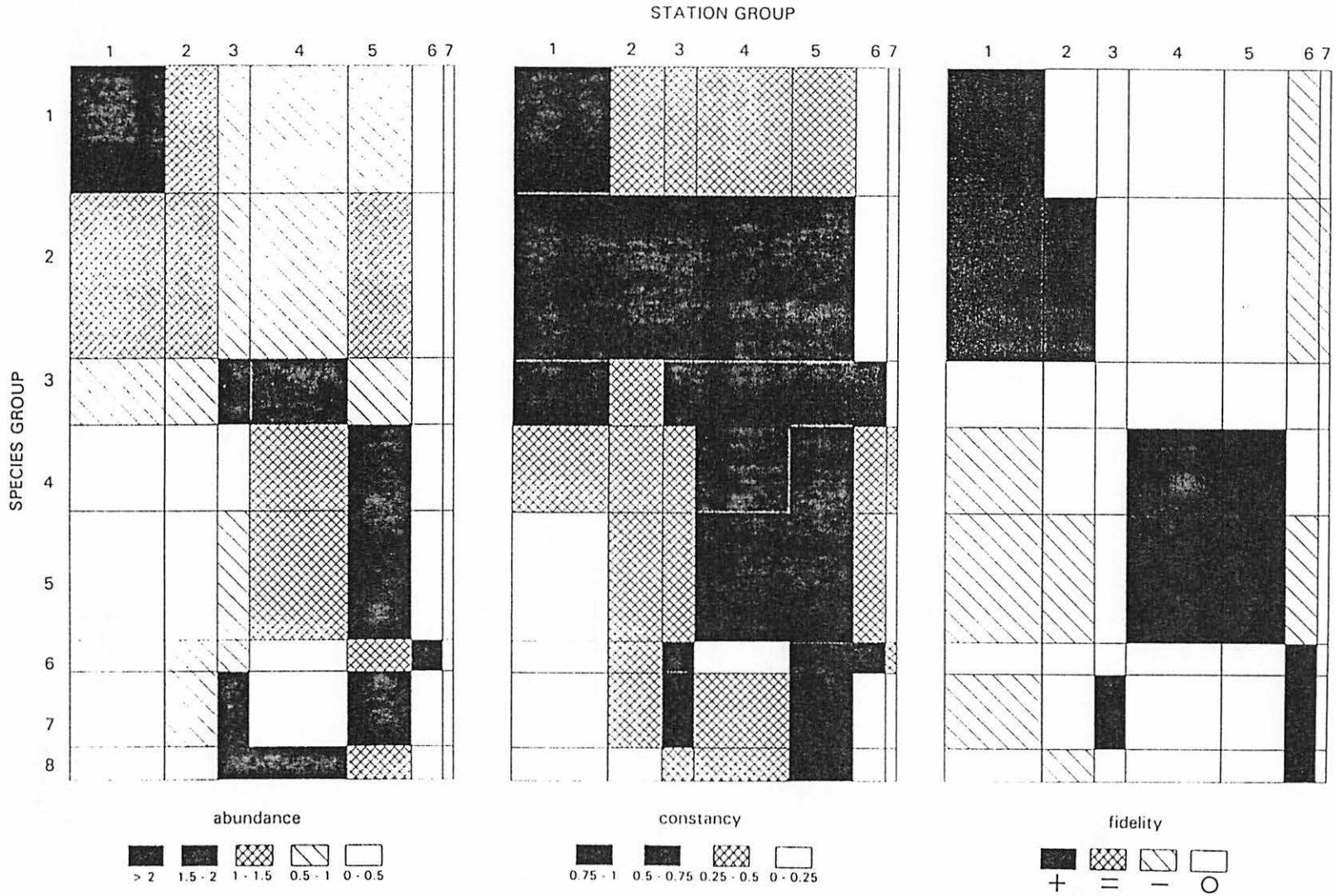

Figure 19. Nodal diagrams depicting the relationships between species groups and collection groups for Cell B and ambient community stations.

Table 8. Species groups selected from numerical classification of macrobenthos collected at Cell B and corresponding C1 and C2 collections between November 1987 and May 1990.

Species Group 1
Amphiporus bioculatus
Phyllodoce arenae
Idunella barnardi
Microphiopholis atra
Malmgreniella lunulata
Lepidametria commensalis
Natica pusilla
Cylichnella bidentata
Vitrinellidae
Anachis lafresnayi
Monticellina baptistaea
Diopatra cuprea

Species Group 2
Prionospio perkinsi
Tubulanus pellucidus
Sigambra tentaculata
Turbonilla interrupta
Loimia medusa
Saccoglossus kowalewskii
Phoronis sp.
Bhawania heteroseta
Pseudeurythoe paucibranchiata
Paraprionospio pinnata
Glycera americana
Ogyrides alphaerostris
Pectinaria gouldii
Podarkeopsis levifuscina
Nereis succinea

Species Group 3
Nephtys cryptomma
Micrura rubra
Scolelepis sp.
Oligochaeta spp.
Cabira incerta
Nereis grayi

Species Group 4
Odostomia engonia
Glycinde solitaria
Acteocina canaliculata
Leucon americanus
Leitoscoloplos sp.
Flatworm sp. A
Mulinia lateralis
Clymenella torquata

Species Group 5
Yoldia limatula
Ampelisca abdita
Oxyurostylis smithi
Macoma tenta
Asabellides oculata
Owenia fusiformis
Macroclymene zonalis
Notomastus sp.
Tellina agilis
Lyonsia hyalina
Mediomastus ambiseta
Streblospio benedicti

Species Group 6
Spiophanes bombyx
Eteone heteropoda
Acteon punctostriatus

Species Group 7
Cirriformia grandis
Molgula manhattensis
Polydora cornuta
Corophium tuberculatum
Harmothoe extenuata
Ceriantheopsis americanus
Ensis directus

Species Group 8
Erichthonius brasiliensis
Paracaprella tenuis
Turbonilla stricta

common and abundant during fall 1987 and winter 1988. Included in this group were numerous gastropods, the brittlestar *Microphiopholis atra* and its commensal polychaete *Malmgreniella lunulata*. Species in Group 2 were ubiquitous and abundant through the entire study period and included the polychaetes *Paraprionospio pinnata, Pseudeurythoe paucibranchiata, Sigambra tentaculata, Bhawania heteroseta, Loimia medusa* and *Glycera americana*. They are important components of the ambient community (see above and Schaffner 1990). Most were rare at HDM stations during the first year.

Species in Groups 3 to 8 tended to be most common and abundant in spring collections. These groups were distinguished primarily by the years in which component species exhibited maximum or minimum abundances (e.g. 1988, 1989 or 1990) and patterns of distribution relative to HDM collections. Only Group 6 species exhibited highest abundances in HDM. Species in Groups 7 and 8, although common and abundant throughout the study, exhibited high fidelity to HDM stations during winter through summer 1988.

The effects both of season and DM overburden are apparent in the ordination of collections from Cell B, and corresponding collections from C1 and C2 (Figure 20). The first axis separates collections from different seasons and, within seasons, collections made in different years. The second axis separates HDM collections from all other collections. The arrangement of species within ordination space (Figure 21) is consistent with the patterns observed in the inverse classification. For example, members of

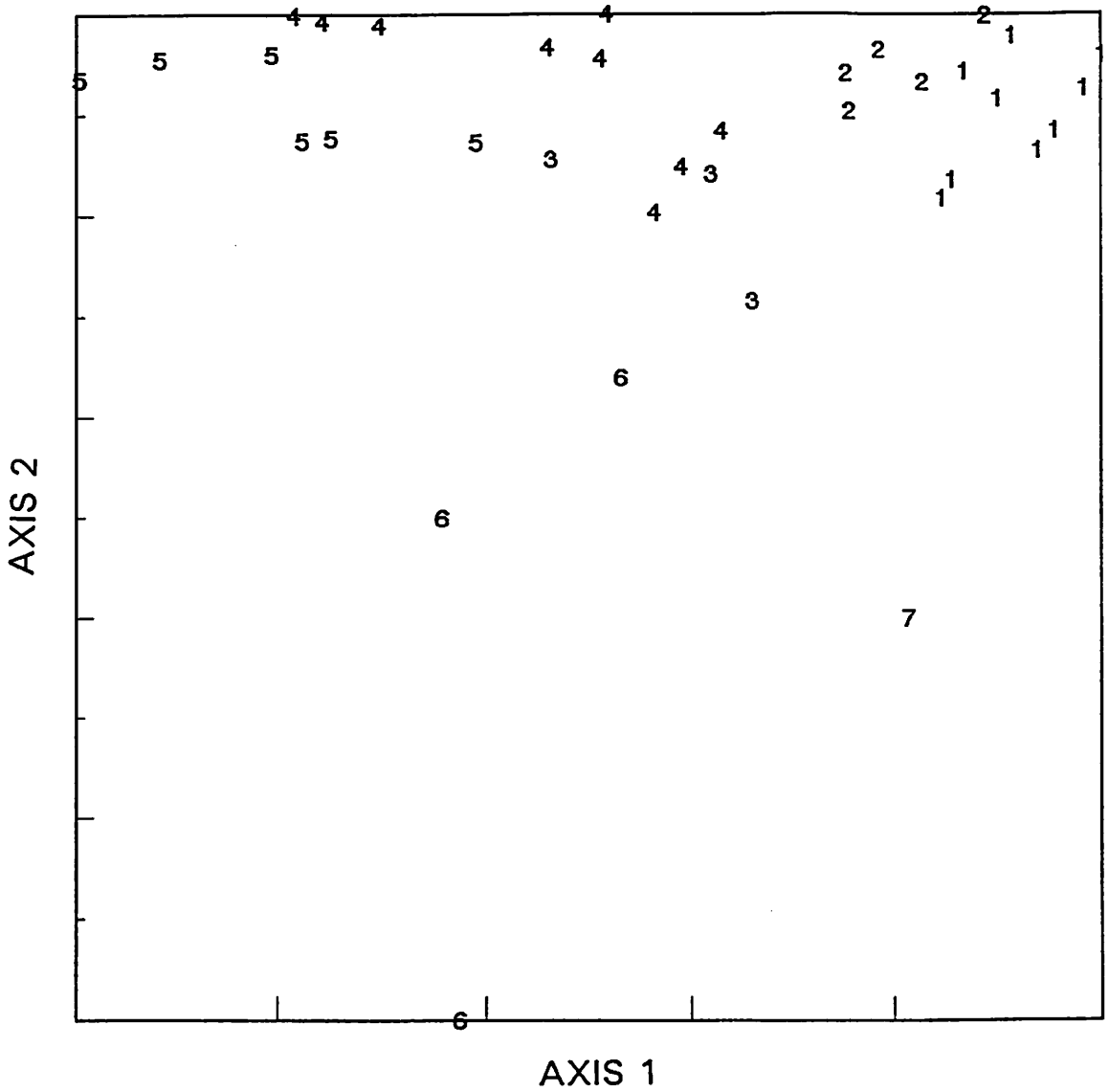

Figure 20. Reciprocal averaging ordination of collections of macrobenthos made seasonally at Cell B and ambient community stations. Group memberships are from normal classification (see Figure 17).

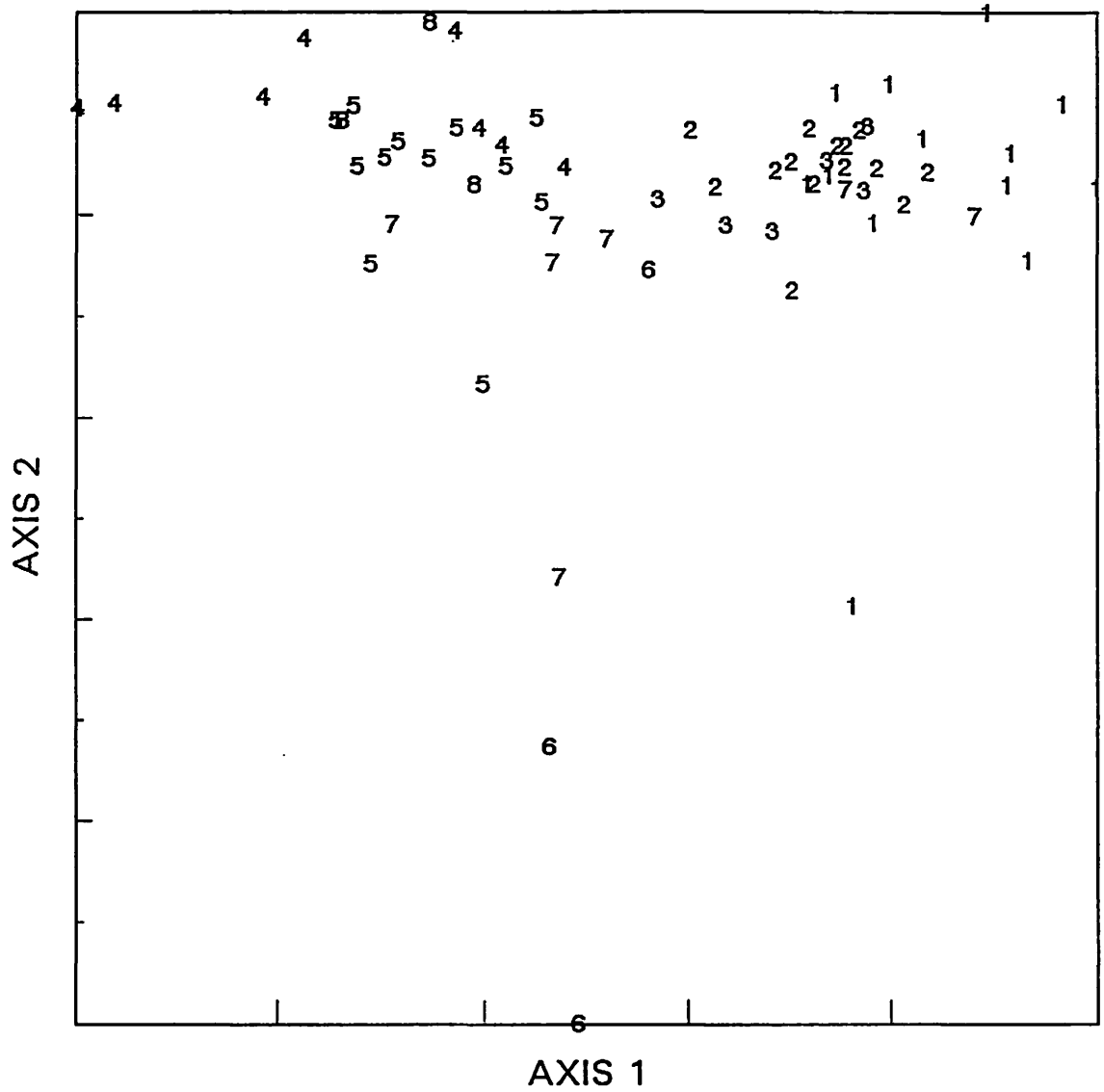

Figure 21. Reciprocal averaging ordination of species from collections of macrobenthos made seasonally at Cell B and ambient community stations. Group memberships are from inverse classification (see Table 8).

Species Groups 1 and 2 have high scores on axes 1 and 2, consistent with their patterns of higher abundance in collections made during fall 1987 and winter 1988. Members of Species Group 6 have the lowest scores on axis 2 and are characteristic of HDM station collections. Only 1 species, the polychaete *Phyllodoce arenae*, is positioned within ordination space at a point roughly corresponding to the position of the HDM collections from fall 1987.

When collections from Cell C and corresponding C1 and C2 collections are considered, 8 major collection groups are identified by normal classification (Figure 22). Resultant groups are defined primarily on the basis of season of collection. Effects of DM overburden are far less apparent than they were for Cell B comparisons. Of all collections made at DM stations, only the collection from the first sampling quarter at HDM overburden had a similarity level less than 0.3 relative to other collections. HDM collections from the second and third quarters (i.e. summer and fall 1989) (Group 5) showed some distinction from the ambient community and other DM stations from the same seasons (Groups 3 and 4), but this was at a higher level of similarity (Figure 22). Spring collections from 1989 and 1991 clustered together, but spring collections from 1990 exhibited greater similarities to collections from winter 1990.

Nine species groups were formed by the 87 species included in the inverse classification of these collections (Figure 23, Table 9). The distributional characteristics of these species groups are indicated in the nodal analyses represented in Figure 24.

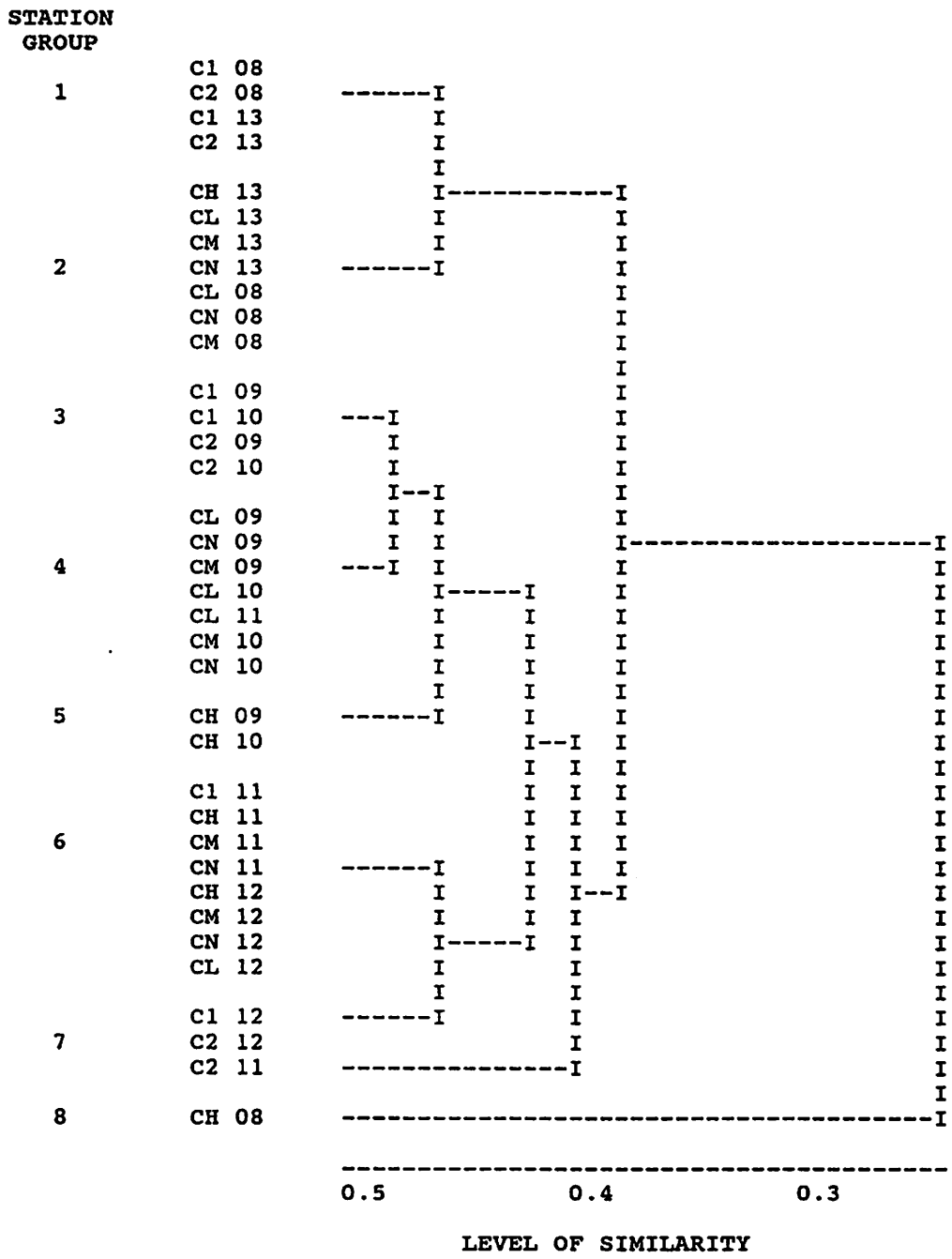

Figure 22. Hierarchies resulting from normal classification of collections of macrobenthos made on a seasonal basis at Cell C and ambient community stations.

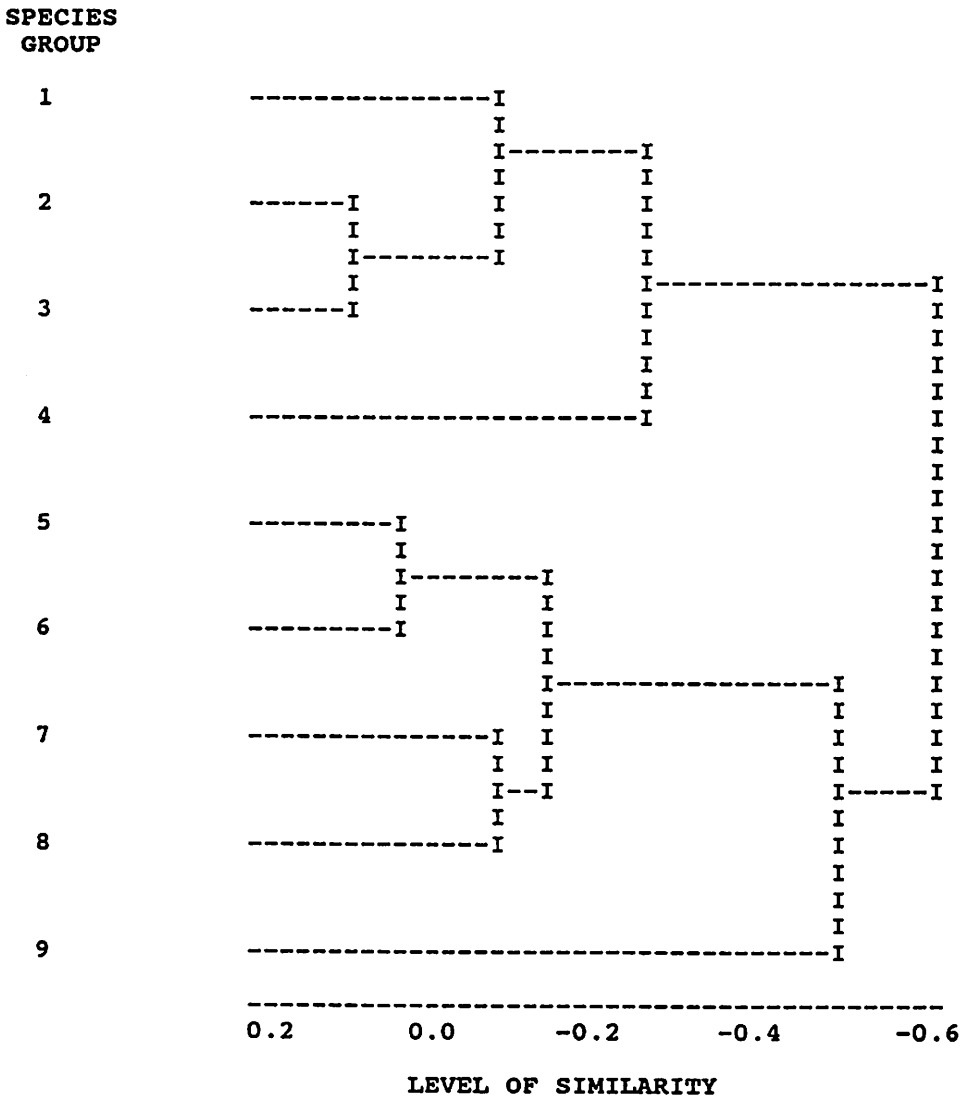

Figure 23. Hierarchies resulting from inverse classification of collections of macrobenthos made on a seasonal basis at Cell C and ambient community stations.

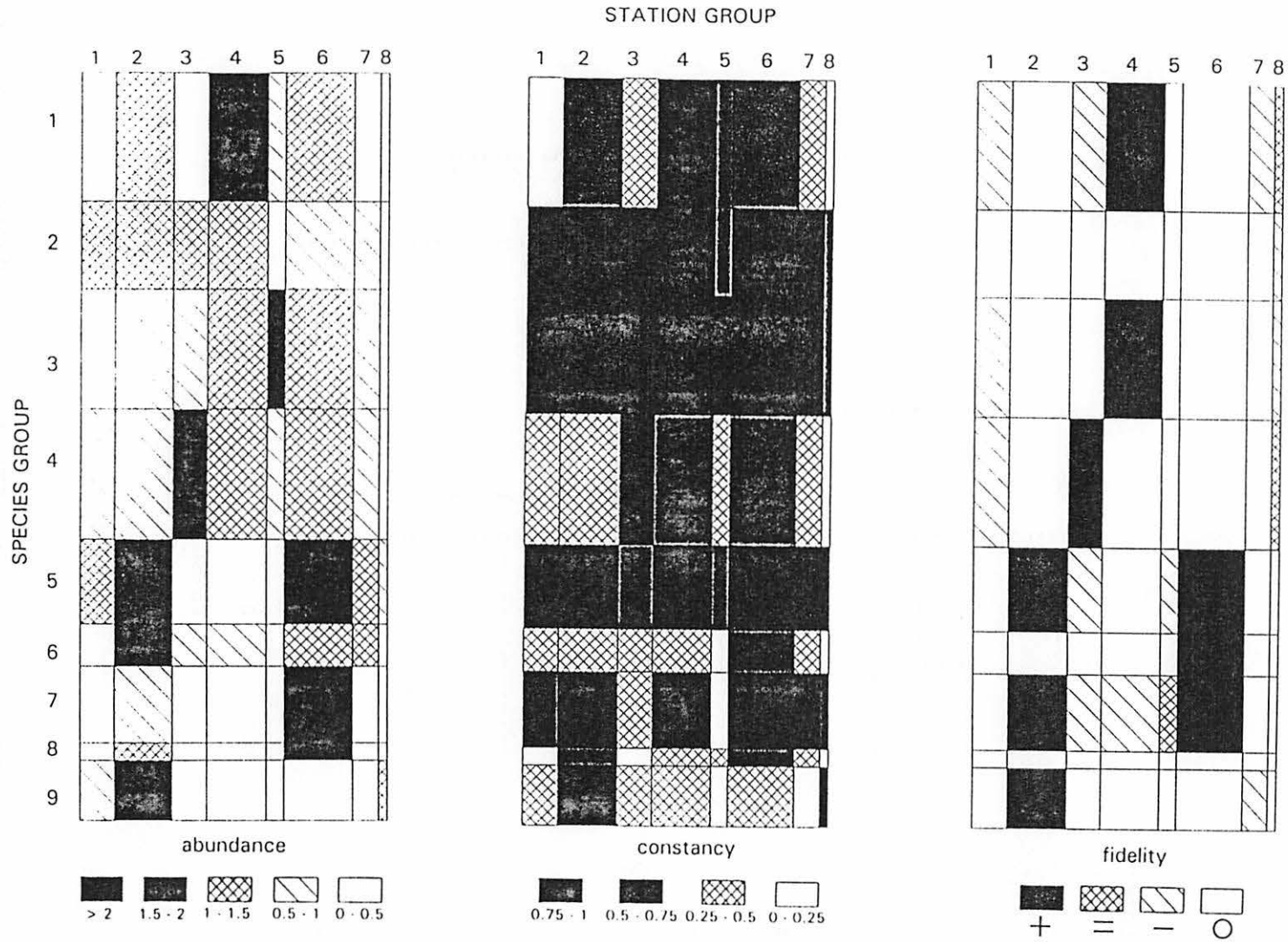

Figure 24. Nodal diagrams depicting the relationships between species groups and collection groups for Cell C and ambient community stations.

Table 9. Species groups selected from numerical classification of macrobenthos collected at Cell C and corresponding C1 and C2 collections between May 1989 and May 1991.

Species Group 1
Amphiporus bioculatus
Nucula proxima
Edwardsia elegans
Ceriantheopsis americanus
Aglaophamus verrilli
Magelona sp.
Nereis succinea
Sabellaria vulgaris
Lucina multilineata
Ampelisca verrilli
Ptilanthura tenuis
Phyllodoce arenae
Idunella barnardi
Scolelepis sp.
Scoloplos rubra

Species Group 2
Cabira incerta
Pseudeurythoe paucibranchiata
Tubulanus pellucidus
Monticellina baptistaea
Loimia medusa
Podarkeopsis levifuscina
Bhawania heteroseta
Prionospio perkinsi
Sigambra tentaculata
Ogyrides alphaerostris

Species Group 3
Glycera americana
Phoronis sp.
Nephtys cryptomma
Odostomia engonia
Paraprionospio pinnata
Owenia fusiformis
Glycinde solitaria
Macoma tenta
Pectinaria gouldii
Turbonilla interrupta
Anachis lafresnayi
Spiochaetopterus oculatus
Acteocina canaliculata
Acteon punctostriatus

Species Group 4
Malmgreniella lunulata
Microphiopholis atra
Micrura rubra
Photis pugnator
Diopatra cuprea
Periploma sp.
Vitrinellidae
Parametopella cypris
Stylochus ellipticus
Batea catharinensis
Turbonilla stricta
Anadara transversa
Molgula manhattensis
Cylichnella bidentata
Asychis elongata

Species Group 5
Notomastus sp.
Macroclymene zonalis
Mediomastus ambiseta
Asabellides oculata
Tellina agilis
Yoldia limatula
Saccoglossus kowalewskii
Ampelisca abdita
Streblospio benedicti
Oligochaeta spp.

Species Group 6
Cirriformia grandis
Caprella penantis
Lepidametria commensalis
Epitonium rupicolum
Oxyurostylis smithi

Species Group 7
Corophium tuberculatum
Polydora cornuta
Erichthonius brasiliensis
Paracaprella tenuis
Lyonsia hyalina
Ensis directus
Mulinia lateralis
Eteone heteropoda
Spio sp.

Species Group 8
Balanus sp.
Clymenella torquata

Species Group 9
Nereis grayi
Leitoscoloplos sp.
Spiophanes bombyx
Heteromastus filiformis
Flatworm sp. A
Tharyx sp. A
Idunella clymenellae

Species in Groups 2 and 3 were ubiquitous and abundant through the entire study period at most stations. They were found in the HDM collections from spring 1989, but were less abundant and exhibited lower fidelity in those collections. These are the groups that contained the core species that characterize the Wolf Trap study region, as discussed previously. Group 4 species were found in most station collections, but were most abundant between summer 1989 and spring 1990. These species were absent from HDM stations during spring 1989. Species in Group 5 were ubiquitous, but were most abundant during the winter and spring sampling quarters. They also were found with high constancy and moderate abundance in HDM collections from spring 1989. Group 7 species were most abundant during winter and spring 1990 and were rare in summer and fall 1989.

Species in Groups 1, 6, 8 and 9 were characteristic of collections from the disposal cell. Species in Group 1 were most common and abundant in the disposal cell, but were rare in HDM collections from spring 1989. Members of Groups 6 and 8 were generally rare, but also tended to have greatest abundance, constancy and fidelity to stations within the disposal cell. Group 9 species were most abundant within the disposal cell and exhibited moderate densities and constancy in the collections from HDM made during spring 1989 (Station Group 8). Among the members of these groups are included a wide variety of species representing various functional groups.

As was observed for the ambient community, the effects of seasonal changes in faunal patterns and longer-term temporal changes were apparent in the ordination of collections from Cell C stations (Figure 25). Together, the first and second axes separate collections from different seasons and reflect continual change in the community through time. The patterns of similarity among spring collections revealed in the cluster analysis are also apparent in the ordination results. Separation of the unique spring 1989 HDM collection from other collections is along axis 1. The arrangement of species within ordination space (Figure 26) is consistent with the patterns observed in the inverse classification. Most species are arrayed with moderate scores on both axes, an indication of their widespread distributions. Species characterizing the collections from winter and spring 1990 have high scores on axis 2. Species with low scores on axis 1 were found in spring 1989 collections from HDM.

Dominant Species

The foregoing analyses of distributional patterns were based on a consideration of a large number of species for each set of comparisons, thus it was advantageous to employ multivariate analyses. However, consideration of abundance patterns of dominant species in station groups formed by normal classification provides additional insight into differences with respect to community composition. The top 10 species ranked by overall mean abundance for each station group, are listed in Tables 10 and 11. The feeding types and living positions of each species are also given.

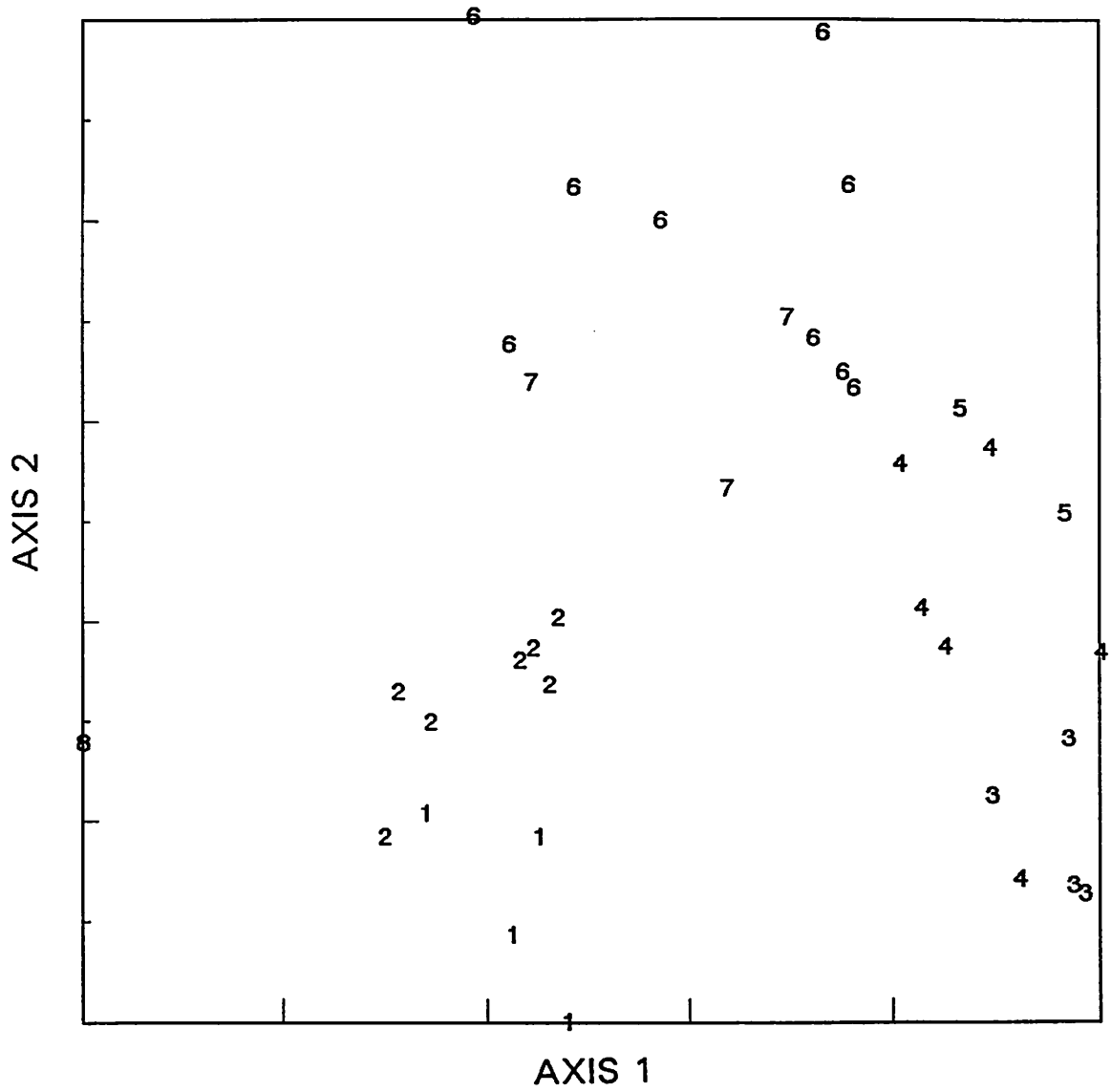

Figure 25. Reciprocal averaging ordination of collections of macrobenthos made seasonally at Cell C and ambient community stations. Group memberships are from normal classification (see Figure 22).

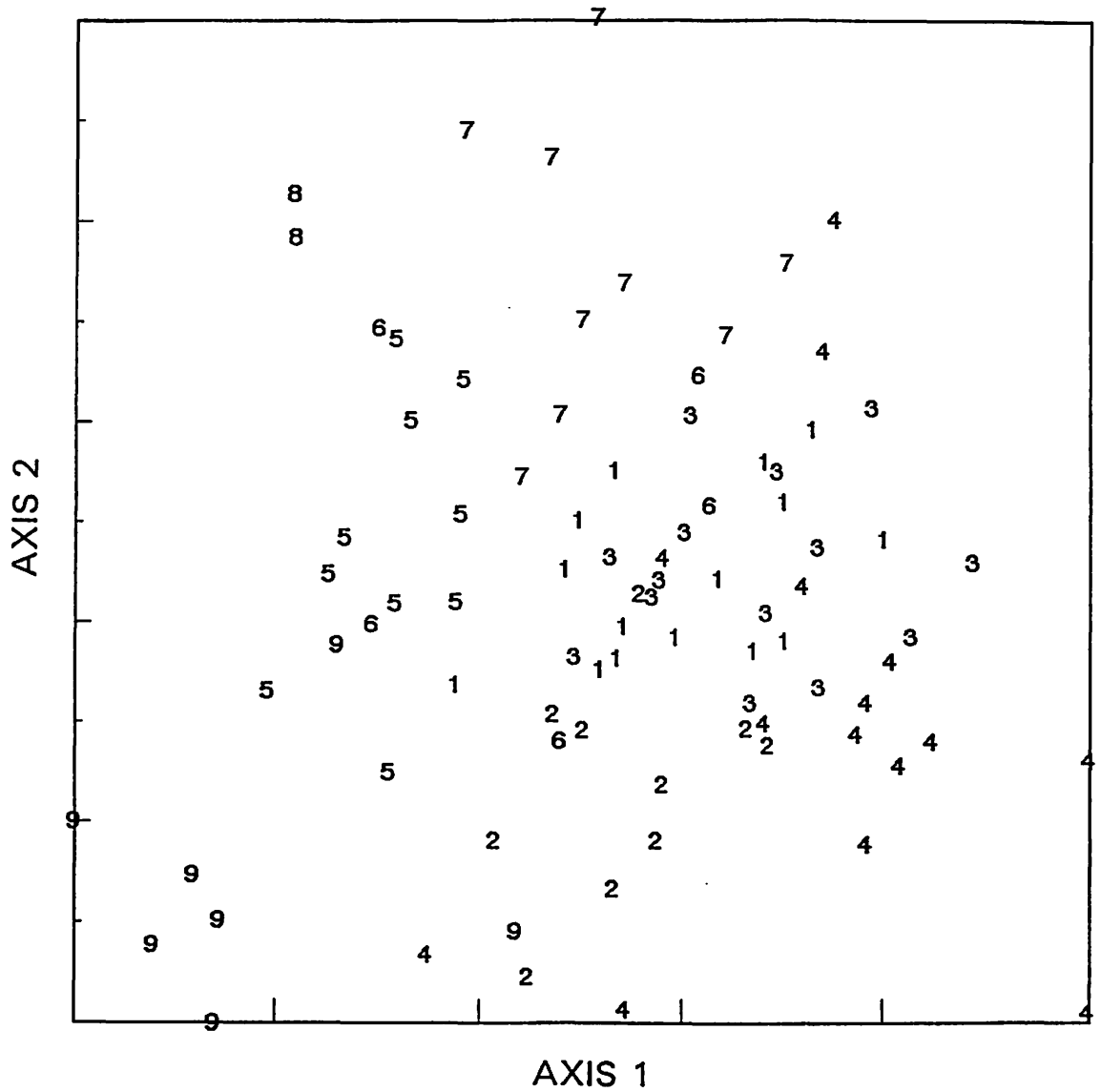

Figure 26. Reciprocal averaging ordination of species from collections of macrobenthos made seasonally at Cell C and ambient community stations. Group memberships are from inverse classification (see Table 9).

Table 10. Dominant species identified in site groups from Cell B and corresponding collections at stations C1 and C2. Mean densities are number of individuals per 0.12 m^2 (summed box cores). Standard errors (SE), frequency of occurence (FR) within the station groups, feeding type (FT) and living position (LP) are also given. For station group membership refer to Figure 17. P - Polychaeta, B - Bivalvia, G - Gastropoda, A - Amphipoda, N - Nemertea. For feeding type: I - interface, C-O - carnivore-omnivore, F - filter, SB - subsurface deposit. For living position: T - tubicolous, FL - free-living, I - infaunal, E - epifaunal.

Taxon	Rank	mean	SE	FR	FT	LP
Station Group 1						
Paraprionospio pinnata (P)	1	241	16	100	I	T-I
Anachis lafresnayi (G)	2	89	38	100	C-O	FL-E
Pseudeurythoe paucibranchiata (P)	3	33	7	100	C-O	FL-I
Nephtys cf. *cryptomma* (P)	4	23	4	100	C-O	FL-I
Sigambra tentaculata (P)	5.5	14	4	100	C-O	FL-I
Bhawania heteroseta (P)	5.5	14	5	100	C-O	FL-I
Phoronis sp. (P)	7	13	3	100	F	T-I
Turbonilla interrupta (G)	8	12	3	100	C-O	FL-E
Prionospio perkinsi (P)	9	9	5	100	I?	T?-I
Tubulanus pellucidus (N)	10	8	2	89	C-O	FL-E
Station Group 2						
Paraprionospio pinnata (P)	1	123	13	100	I	T-I
Pseudeurythoe paucibranchiata (P)	2	36	8	100	C-O	FL-I
Prionospio perkinsi (P)	3	28	7	100	I?	T?-I
Sigambra tentaculata (P)	4	24	6	100	C-O	FL-I
Bhawania heteroseta (P)	5	20	9	100	C-O	FL-I
Nephtys cf. *cryptomma* (P)	6.5	19	5	100	C-O	FL-I
Odostomia engonia (G)	6.5	19	4	100	C-O	FL-E
Anachis lafresnayi (G)	8	15	3	100	C-O	FL-E
Cirriformia grandis (P)	9	14	11	100	SB	FL-I
Mediomastus ambiseta (P)	10	12	8	80	SB	T-I

Table 10. cont.

Taxon	Rank	mean	SE	FR	FT	LP
Station Group 3						
Paraprionospio pinnata (P)	1	182	19	100	I	T-I
Nephtys cf. *cryptomma* (P)	2	69	7	100	C-O	FL-I
Polydora cornuta (P)	3	60	30	100	I	T-E
Yoldia limatula (B)	4	54	26	100	I-SB	FL-I
Anachis lafresnayi (G)	5	48	24	100	C-O	FL-E
Oligochaeta spp.	6	32	16	100	SB	FL-I
Mediomastus ambiseta (P)	7	23	15	66	SB	T-I
Cirriformia grandis (P)	8.5	17	8	100	SB	FL-I
Pseudeurythoe paucibranchiata (P)	8.5	17	10	100	C-O	FL-I
Corophium tuberculatum (A)	10	16	5	100	I	T-E
Station Group 4						
Paraprionospio pinnata (P)	1	196	17	100	I	T-I
Yoldia limatula (B)	2	49	6	100	I-SB	FL-I
Mediomastus ambiseta (P)	3	47	18	100	SB	T-I
Oligochaeta	4	37	19	100	SB	FL-I
Nephtys cf. *cryptomma* (P)	5	35	13	100	C-O	FL-I
Pseudeurythoe paucibranchiata (P)	6	27	7	100	C-O	FL-I
Ampelisca abdita (A)	7	24	7	100	I	T-I
Tubulanus pellucidus (N)	8.5	23	3	100	C-O	FL-E
Sigambra tentaculata (P)	8.5	23	4	100	C-O	FL-I
Prionospio perkinsi (P)	10	19	5	100	I?	T?-I
Station Group 5						
Paraprionospio pinnata (P)	1	178	22	100	I	T-I
Ensis directus (B)	2	172	101	100	F	FL-I
Mediomastus ambiseta (P)	3	147	45	100	SB	T-I
Mulinia lateralis (B)	4	67	33	100	F	FL-I
Tellina agilis (B)	5	42	16	100	I	FL-I
Odostomia engonia (G)	6	38	10	100	C-O	FL-E
Macroclymene zonalis (P)	7	36	16	100	SB	T-I
Asabellides oculata (P)	8	33	6	100	I	T-I
Polydora cornuta (P)	9	30	10	83	I	T-E
Yoldia limatula (B)	10	29	10	100	I-SB	FL-I

Table 10. cont.

Taxon	Rank	mean	SE	FR	FT	LP
Station Group 6						
Paraprionospio pinnata (P)	1	45	23	66	I	T-I
Spiophanes bombyx (P)	2	39	7	100	I	T-I
Polydora cornuta (P)	3	33	32	66	I	T-E
Yoldia limatula (B)	4	17	17	33	I-SB	T-I
Mediomastus ambiseta (P)	5	11	8	100	SB	T-I
Nephtys cf. *cryptomma* (P)	6	10	3	100	C-O	FL-I
Eteone heteropoda (P)	7.5	7	5	67	C-O	FL-E
Ensis directus (B)	7.5	7	6	67	F	FL-I
Odostomia engonia (G)	9.5	6	3	100	C-O	FL-E
Anachis lafresnayi (G)	9.5	6	4	100	C-O	FL-E
Station Group 7						
Paraprionospio pinnata (P)	1	22		100	I	T-I
Anachis lafresnayi (G)	2	19		100	C-O	FL-E
Sigambra tentaculata (P)	3	5		100	C-O	FL-I
Odostomia engonia (G)	5	3		100	C-O	FL-E
Mediomastus ambiseta (P)	5	3		100	SB	T-I
Polydora cornuta (P)	5	3		100	I	T-E
Phyllodoce arenae (P)	8.5	2		100	C-O	FL-E
Glycinde solitaria (P)	8.5	2		100	C-O	FL-I
Macroclymene zonalis (P)	8.5	2		100	SB	T-I
Spiophanes bombyx (P)	8.5	2		100	I	T-I

Table 11. Dominant species identified in site groups from Cell C and corresponding collection at stations C1 and C2. Mean densities are number of individuals per 0.12 m^2 (summed box cores, divided by 2 for Cell C collections). Standard errors (SE), frequency of occurence (FR) within the station groups, feeding type (FT) and living position (LP) are also given. For station group membership refer to Figure 23. P - Polychaeta, B - Bivalvia, G - Gastropoda, A - Amphipoda, N - Nemertea, U - Urochordata, Ph - Phoronida. For feeding type: I - interface, C-O - carnivore-omnivore, F - filter, SB - subsurface deposit. For living position: T - tubicolous, FL - free-living, S - attached sessile, I - infaunal, E - epifaunal.

Taxon	Rank	mean	SE	FR	FT	LP
Station Group 1						
Paraprionospio pinnata (P)	1	160	12	100	I	T-I
Macroclymene zonalis (P)	2	41	13	100	SB	T-I
Yoldia limatula (B)	3	38	16	100	I-SB	FL-I
Nephtys cf. *cryptomma* (P)	4	35	6	100	C-O	FL-I
Tubulanus pellucidus (N)	6	33	1	100	C-O	FL-E
Oligochaeta	6	33	9	100	SB	FL-I
Polydora cornuta (P)	6	33	16	100	I	T-E
Pseudeurythoe paucibranchiata (P)	8	31	12	100	C-O	FL-I
Mediomastus ambiseta (P)	9	31	13	100	SB	T-I
Bhawania heteroseta (P)	10	24	3	100	C-O	FL-I
Station Group 2						
Paraprionospio pinnata (P)	1	134	14	100	I	T-I
Polydora cornuta (P)	2	62	18	100	I	T-E
Mediomastus ambiseta (P)	3	58	6	100	SB	T-I
Spiophanes bombyx (P)	4	51	17	100	I	T-I
Pseudeurythoe paucibranchiata (P)	5	44	9	100	C-O	FL-I
Corophium tuberculatum (A)	6	33	9	100	I	T-E
Nephtys cf. *cryptomma* (P)	7	29	3	100	C-O	FL-I
Bhawania heteroseta (P)	8	22	7	100	C-O	FL-I
Macroclymene zonalis (P)	9	21	7	100	SB	T-I
Tubulanus pellucidus (N)	10.5	18	2	100	C-O	FL-E
Odostomia engonia (G)	10.5	18	3	100	C-O	FL-E

Table 11. cont.

Taxon	Rank	mean	SE	FR	FT	LP
Station Group 3						
Paraprionospio pinnata (P)	1	142	12	100	I	T-I
Bhawania heteroseta (P)	2	40	2	100	C-O	FL-I
Phoronis sp. (Ph)	3	37	1	100	F	T-I
Odostomia engonia (G)	4	36	3	100	C-O	FL-E
Molgula manhattensis (U)	5	27	4	100	F	S-E
Pseudeurythoe paucibranchiata (P)	6	24	2	100	C-O	FL-I
Macoma tenta (B)	7	23	2	100	I	FL-I
Turbonilla interrupta (G)	8	22	1	100	C-O	FL-E
Pectinaria gouldii (P)	9	21	1	100	SB	T-I
Sigambra tentaculata (P)	10	18	3	100	C-O	FL-I
Station Group 4						
Paraprionospio pinnata (P)	1	119	31	100	I	T-I
Ensis directus (B)	2	54	54	57	F	FL-I
Sabellaria vulgaris (P)	3	42	18	100	F	T-E
Polydora cornuta (P)	4	41	17	100	I	T-E
Phoronis sp. (Ph)	5	29	3	100	F	T-I
Pseudeurythoe paucibranchiata (P)	6	27	5	100	C-O	FL-I
Bhawania heteroseta (P)	7	25	7	100	C-O	FL-I
Macoma tenta (B)	8	24	5	100	I	FL-I
Odostomia engonia (G)	9	23	4	100	C-O	FL-E
Molgula manhattensis (U)	10	22	11	100	F	S-E
Station Group 5						
Paraprionospio pinnata (P)	1	107	81	100	I	T-I
Acteocina canaliculata (G)	2	54	7	100	C-O	FL-E
Phoronis sp. (Ph)	3	28	1	100	F	T-I
Odostomia engonia (G)	4	20	5	100	C-O	FL-E
Pectinaria gouldii (P)	5.5	14	9	100	SB	T-I
Turbonilla interrupta (G)	5.5	14	6	100	C-O	FL-E
Mediomastus ambiseta (P)	6	12	2	100	SB	T-I
Glycinde solitaria (P)	7	11	5	100	C-O	FL-I
Nephtys cf. *cryptomma* (P)	9	10	3	100	C-O	FL-I
Macoma tenta (B)	9	10	3	100	I	FL-I
Vitrinellidae (G)	9	10	5	100	C-O?	FL-E

Table 11. cont.

Taxon	Rank	mean	SE	FR	FT	LP
Station Group 6						
Ensis directus (B)	1	578	91	100	F	FL-I
Paraprionospio pinnata (P)	2	177	11	100	I	T-I
Polydora cornuta (P)	3	114	20	100	I	T-E
Mulinia lateralis (B)	4	106	33	100	F	FL-I
Mediomastus ambiseta (P)	5	101	34	100	SB	T-I
Tellina agilis (B)	6	53	15	100	I	FL-I
Odostomia engonia (G)	7	37	5	100	C-O	FL-E
Asabellides oculata (P)	8	35	5	100	I	T-I
Corophium tuberculatum (A)	9	33	8	100	I	T-E
Paracaprella tenuis (A)	10	32	12	100	C-O	FL-E
Station Group 7						
Ensis directus (B)	1	442	104	100	F	FL-I
Paraprionospio pinnata (P)	2	159	47	100	I	T-I
Mediomastus ambiseta (P)	3	111	68	100	SB	T-I
Tellina agilis (B)	4	61	30	100	I	FL-I
Macroclymene zonalis (P)	5	57	28	67	SB	T-I
Polydora cornuta (P)	6	51	10	100	I	T-E
Yoldia limatula (B)	7.5	36	6	100	I-SB	FL-I
Asabellides oculata (P)	7.5	39	11	100	I	T-I
Nephtys cf. *cryptomma* (P)	9	34	6	100	C-O	FL-I
Odostomia engonia (G)	10	31	8	100	C-O	FL-E
Station Group 8						
Paraprionospio pinnata (P)	1	54		100	I	T-I
Tellina agilis (B)	2	34		100	I	FL-I
Yoldia limatula (B)	3	19		100	I-SB	FL-I
Leitoscoloplos sp. (P)	4	13		100	SB	FL-I
Streblospio benedicti (P)	5	13		100	I	T-I
Ensis directus (B)	6	10		100	F	FL-I
Nephtys cf. *cryptomma* (P)	7.5	8		100	C-O	FL-I
Asabellides oculata (P)	7.5	8		100	I	T-I
Pseudeurythoe paucibranchiata (P)	9.5	7		100	C-O	FL-I
Mediomastus ambiseta (P)	9.5	7		100	SB	T-I

As suggested earlier, changes in community composition were due primarily to quantitative changes in species abundance rather than qualitative changes in species composition. This is apparent when the dominant species for each station group are compared. For example, the small spionid polychaete *Paraprionospio pinnata* was the most abundant and ubiquitous species collected throughout the study. It ranked number 1 in all station groups for Cell B and the corresponding collections from the ambient community and was the highest ranked species in 6 out of 8 site groups identified for Cell C and corresponding samples from C1 and C2. The polychaetes *Nephtys* cf. *cryptomma* and *Pseudeurythoe paucibranchiata* were dominants in more than half of the stations groups from each comparison. Many species were among the dominants for more than 1 station group.

Station groups formed from collections made at DM stations generally were characterized by comparable or lower abundances of dominant species then were observed for other station groups. Relative to other station groups, there were no major changes in the composition of dominant species. Station groups comprised of HDM collections from the first quarter of sampling at each disposal cell (Cell B - Group 7, Cell C -Group 8) had overall reduced densities of dominant species.

Temporal Trends in the Community

Measures of collection similarity computed by station type for each disposal cell and the corresponding ambient community collections from C1 and C2 were used to assess the

relative persistence (sensu Boesch 1974) of the composition and abundance relationships within the community. Bray-Curtis measures were computed between all pairs of collections (summed replicates, untransformed abundances) for each DM overburden level or control stations sampled during the same quarters as the disposal cell stations (i.e. HDM, MDM, LDM, NDM, C1, C2). The means of these similarity measures were interpreted as indices of community persistence.

Persistence indices for the ambient community remained at ca. 0.4 for the duration of the study (compare values for collections corresponding to Cell B sampling quarters with values for collections corresponding to Cell C sampling quarters) (Figure 27). The index for Cell B - NDM was slightly higher, while the index for Cell C - NDM was slightly lower. For Cell B, both LDM and MDM stations collections also had persistence indices exceeding 0.4, with the index for MDM approaching 0.6, a higher value than was observed for any other station collection comparison. For Cell C, persistence indices for LDM and MDM were nearly 0.4. The lowest community persistence observed was for Cell B - HDM.

Temporal Trends of Dominant Species

An evaluation of temporal trends of 24 of the 36 dominant species listed in Tables 10 and 11 provides insight regarding the effects of DM overburden and other processes such as recruitment. Four major patterns with respect to periods of peak density and response to DM overburden were observed.

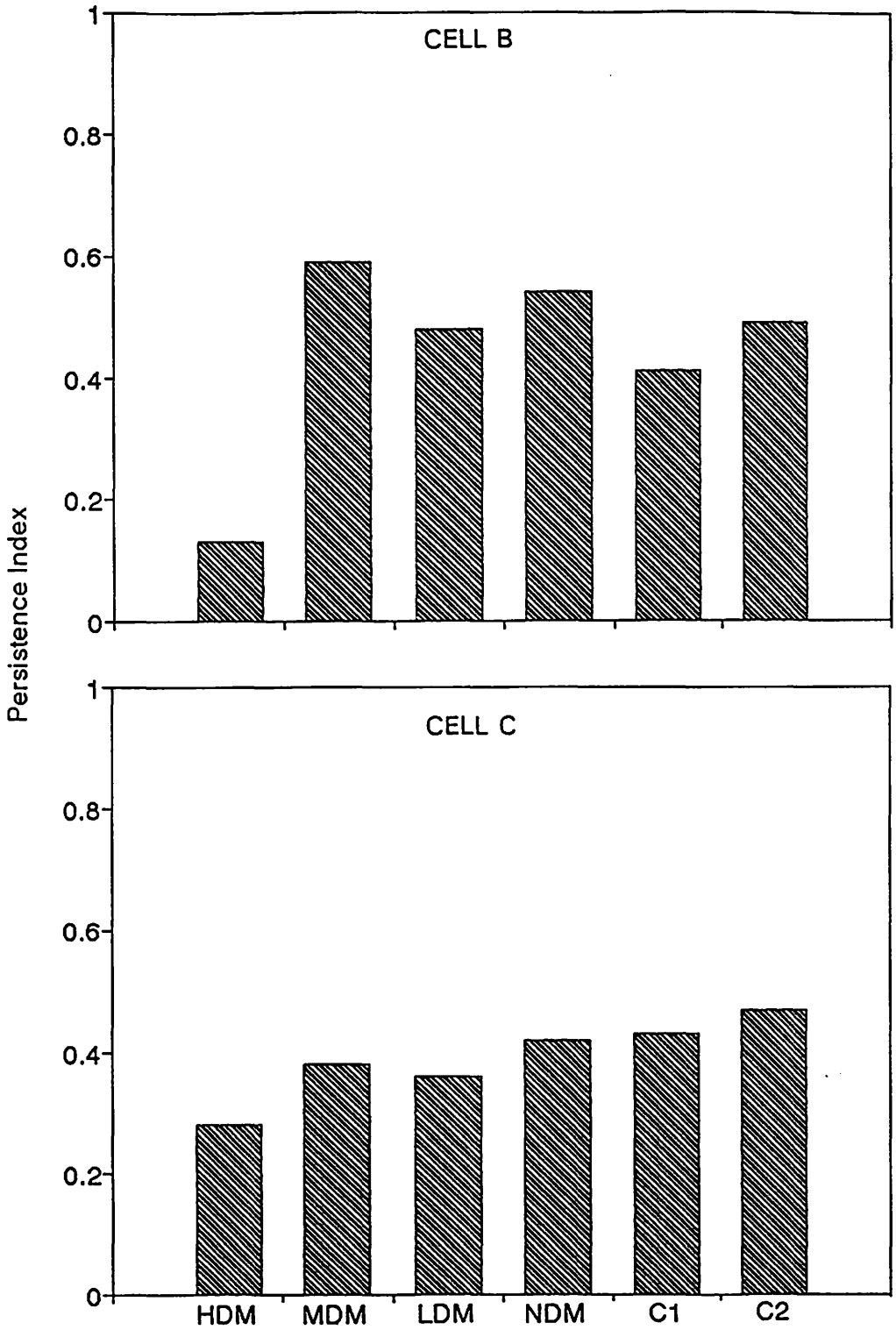

Figure 27. Persistence index of macrobenthos for disposal cell stations and corresponding ambient community station collections.

Four species, the polychaetes *Macroclymene zonalis* and *Mediomastus ambiseta*, the bivalves *Tellina agilis* and *Mytilus edulis* and Oligochaeta were abundant in the ambient community and at disposal cell stations during spring sampling quarters, but were rare during other quarters (Figures 28 to 32). There were no apparent effects of DM overburden on these species.

The bivalves *Yoldia limatula*, *Ensis directus*, *Mulinia lateralis*, amphipod *Corophium tuberculatum* and polychaete *Polydora cornuta*, exhibited peak abundances during the winter to spring quarters (Figures 33 to 37) and, in general, showed no consistent patterns of enhancement or repression in association with DM overburdens. The exception was the small opportunistic bivalve *Mulinia lateralis*. It had highest abundances in association with HDM or MDM overburden levels, particularly at disposal Cell C.

Two other species, the polychaete *Spiophanes bombyx* and gastropod *Acteocina canaliculata*, exhibited some evidence of enhanced densities in association with HDM (Figures 38 and 39). *Spiophanes bombyx* was abundant in HDM collections from Cell B stations but was rare or absent from MDM, LDM and NDM stations and the ambient community during the same quarters. The species was also abundant at Cell C stations, particularly after fall 1989, but it was also present at stations C1 and C2 during these quarters. *Acteocina canaliculata* was most abundant at Cell C HDM stations between

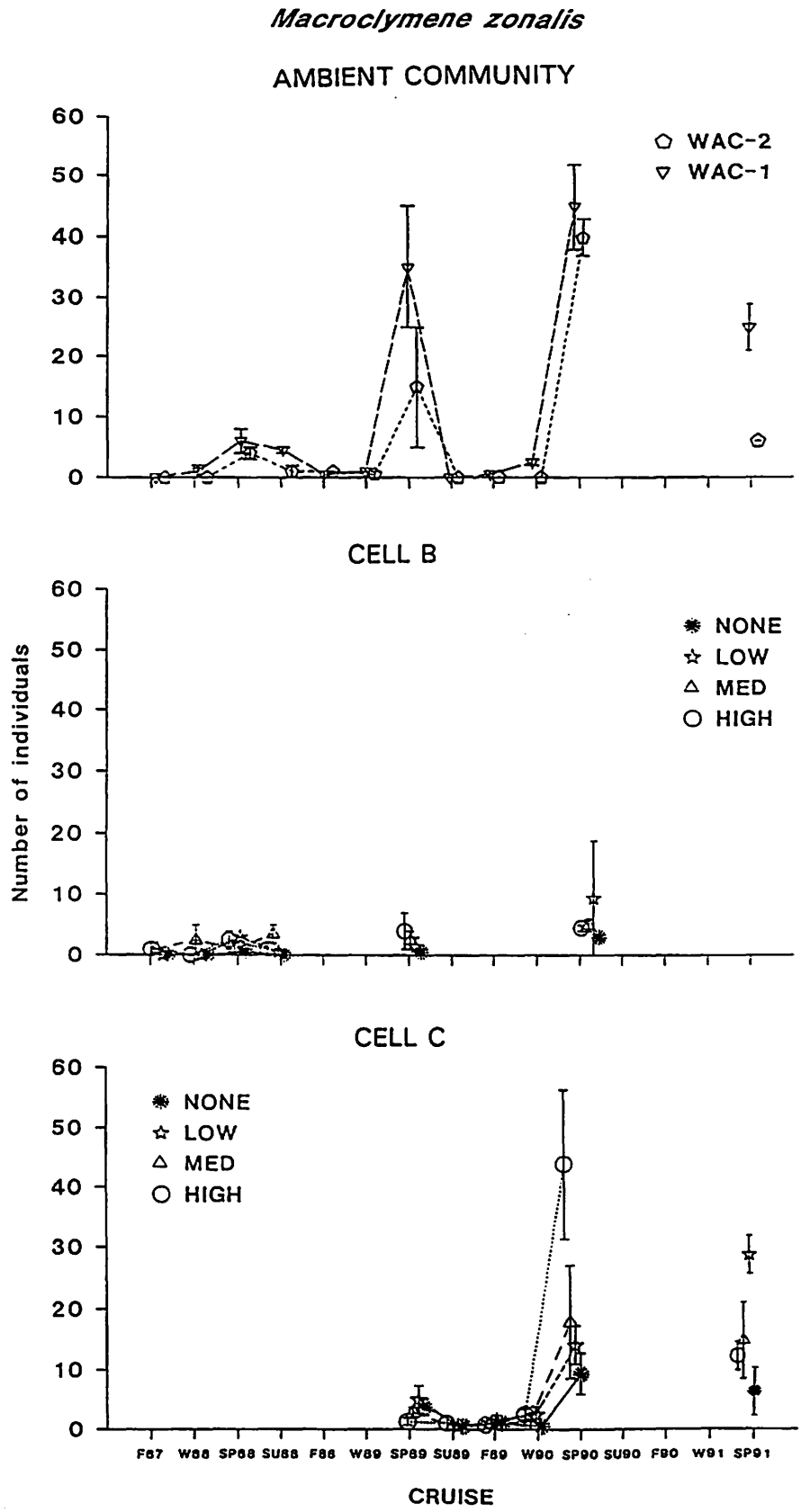

Figure 28. Temporal variation in population densities of the polychaete *Macroclymene zonalis* at ambient community, Cell B, and Cell C stations.

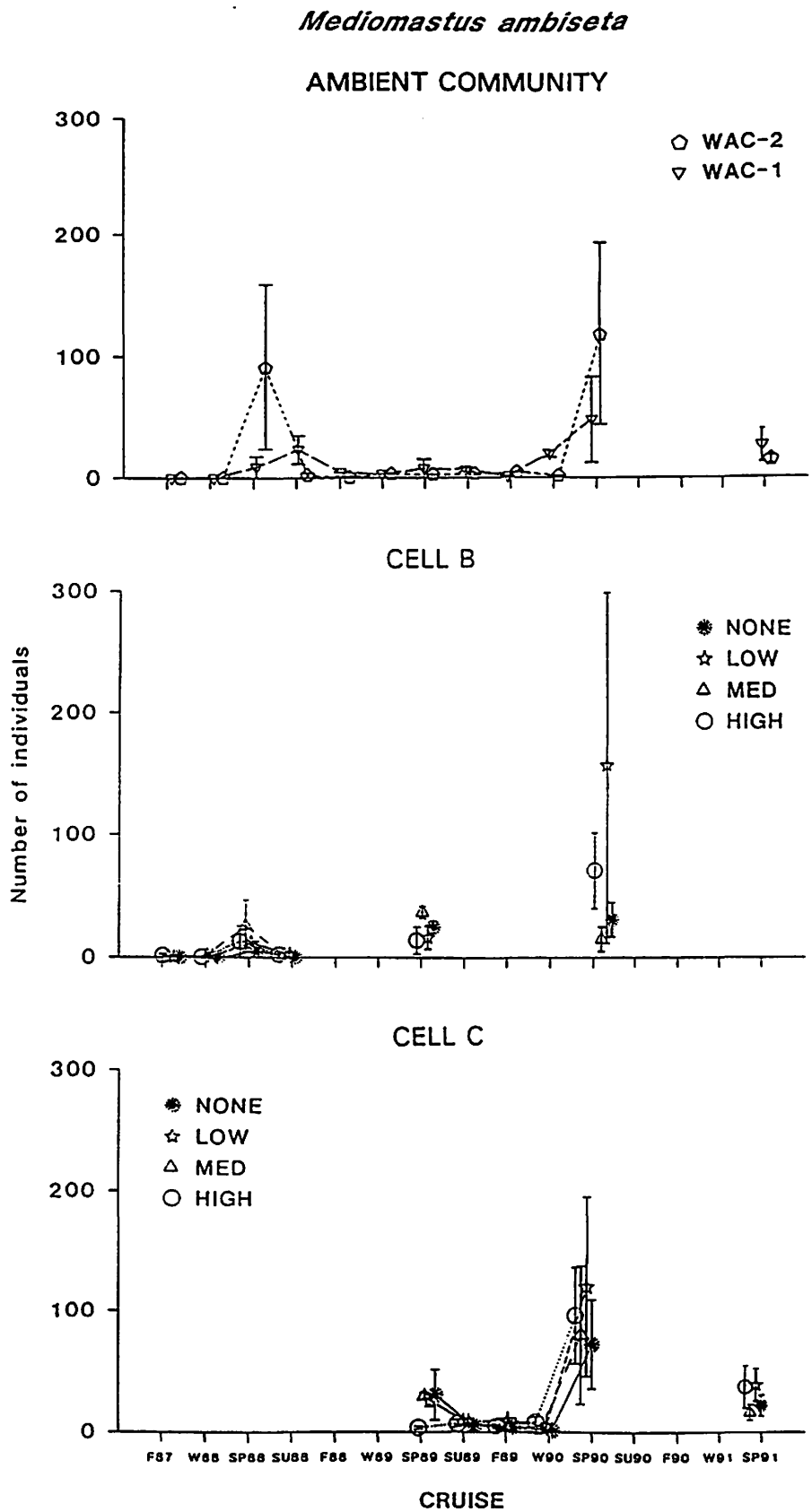

Figure 29. Temporal variation in population densities of the polychaete *Mediomastus ambiseta* at ambient community, Cell B, and Cell C stations.

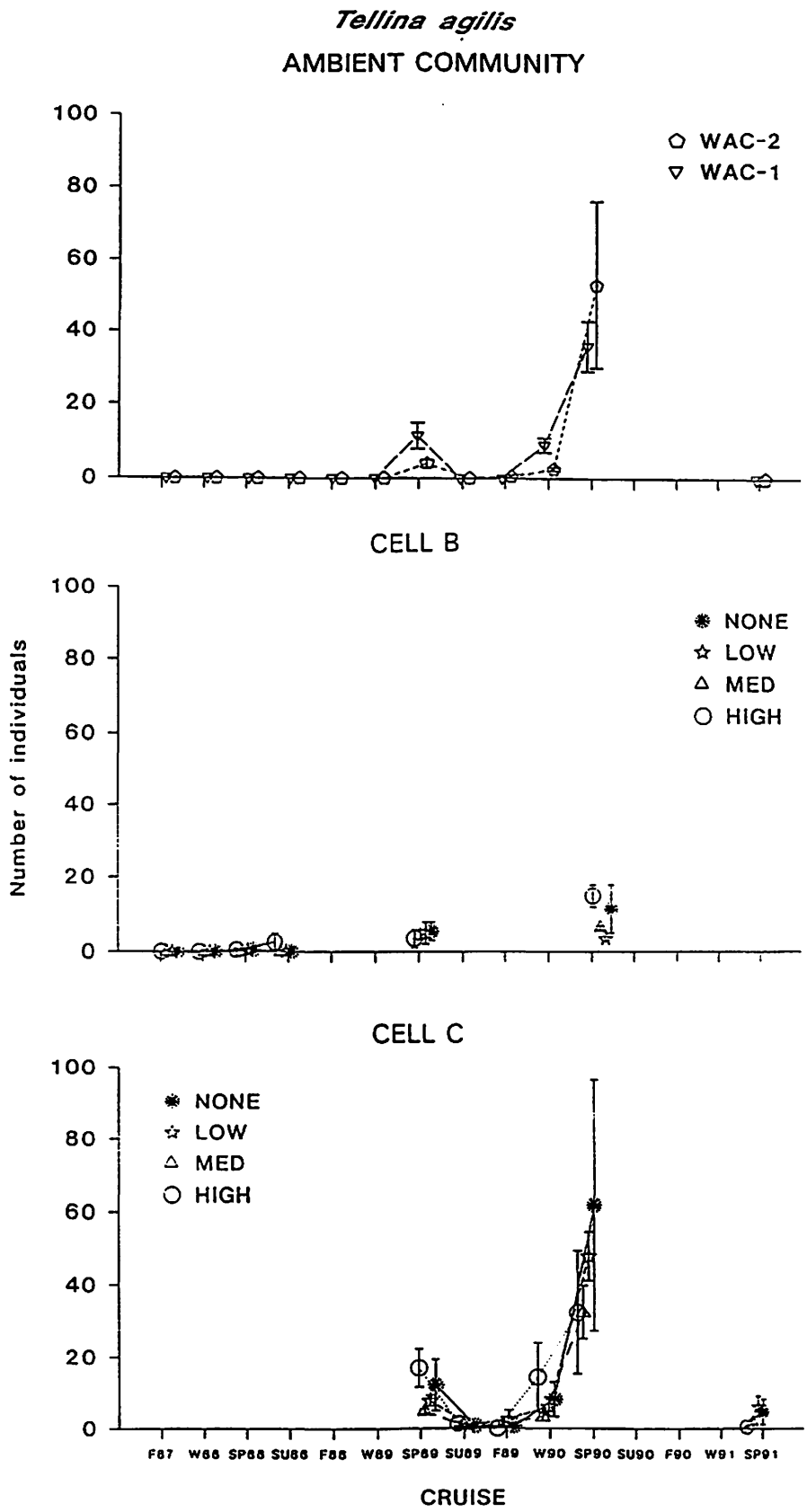

Figure 30. Temporal variation in population densities of the bivalve *Tellina agilis* at ambient community, Cell B, and Cell C stations.

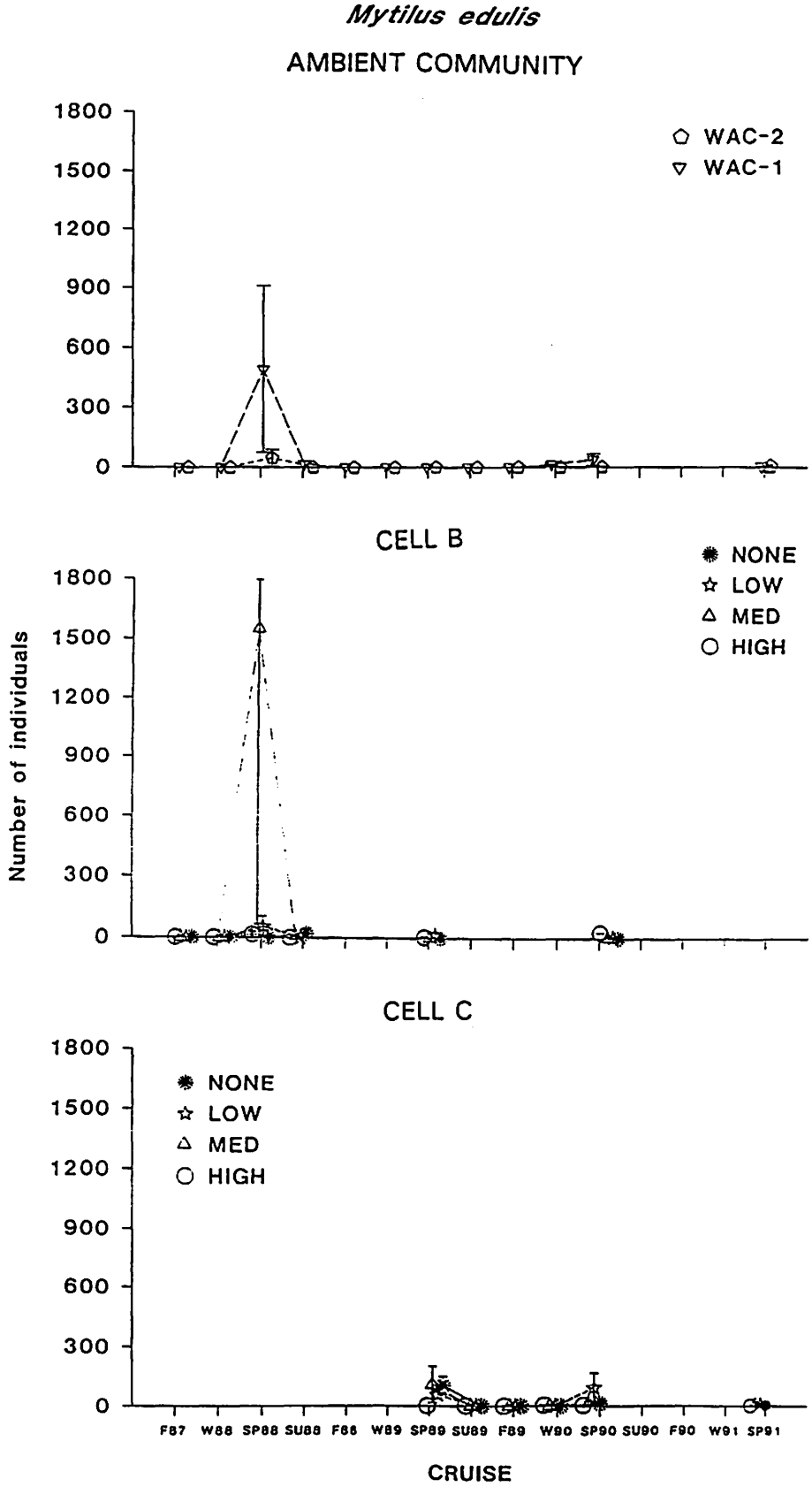

Figure 31. Temporal variation in population densities of the bivalve *Mytilus edulis* at ambient community, Cell B, and Cell C stations.

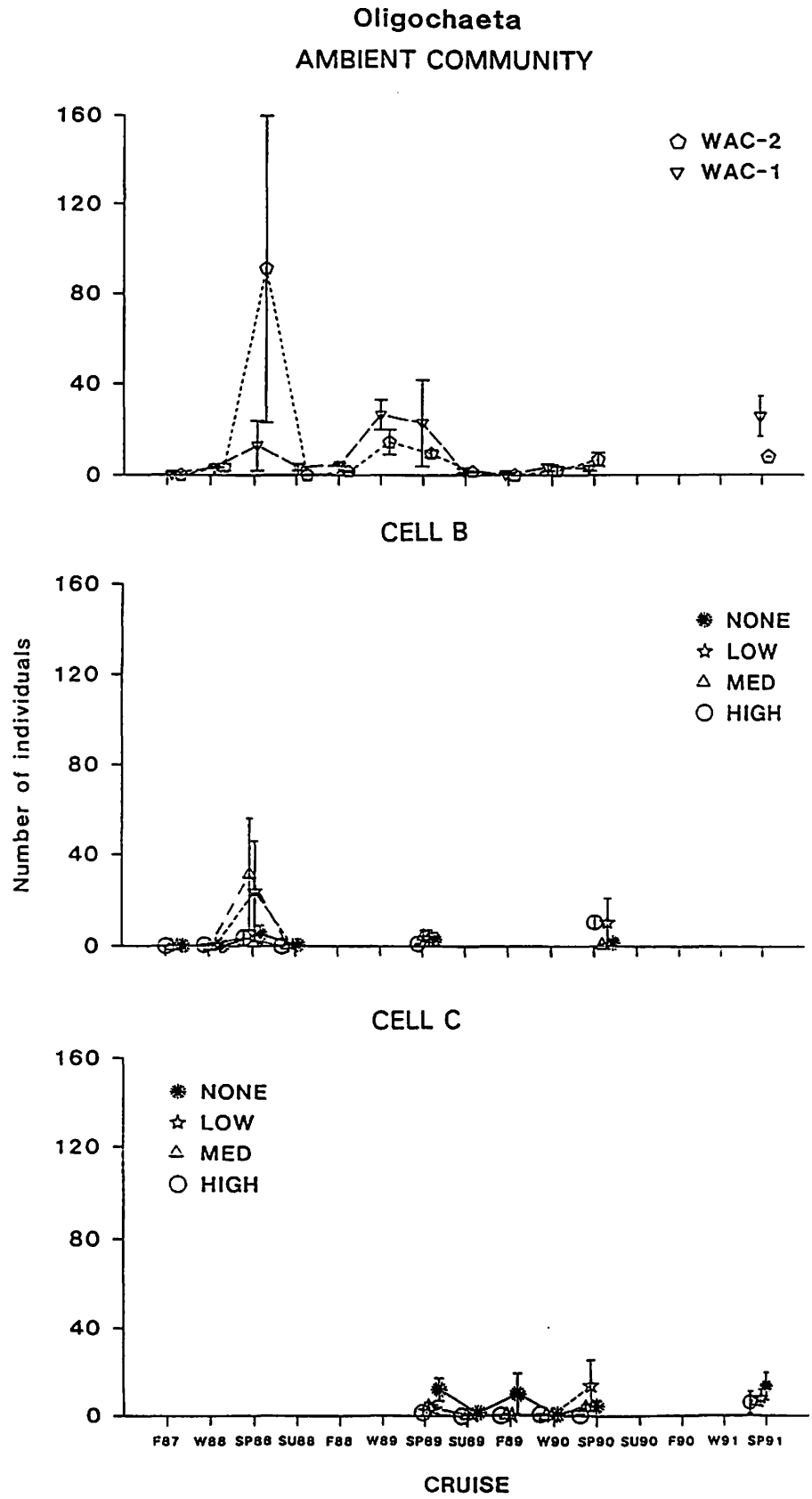

Figure 32. Temporal variation in population densities of *Oligochaeta* at ambient community, Cell B, and Cell C stations.

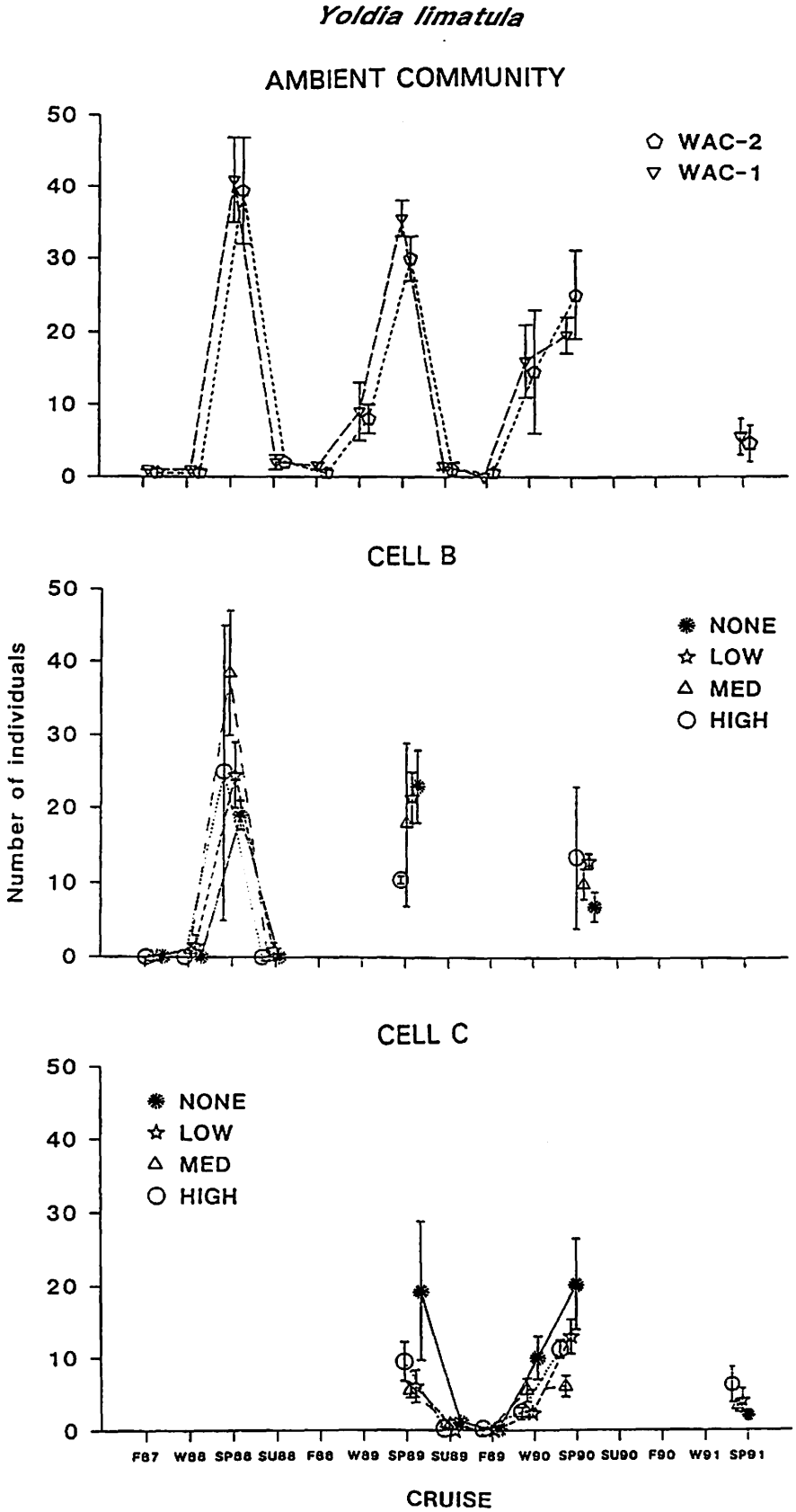

Figure 33. Temporal variation in population densities of the bivalve *Yoldia limatula* at ambient community, Cell B, and Cell C stations.

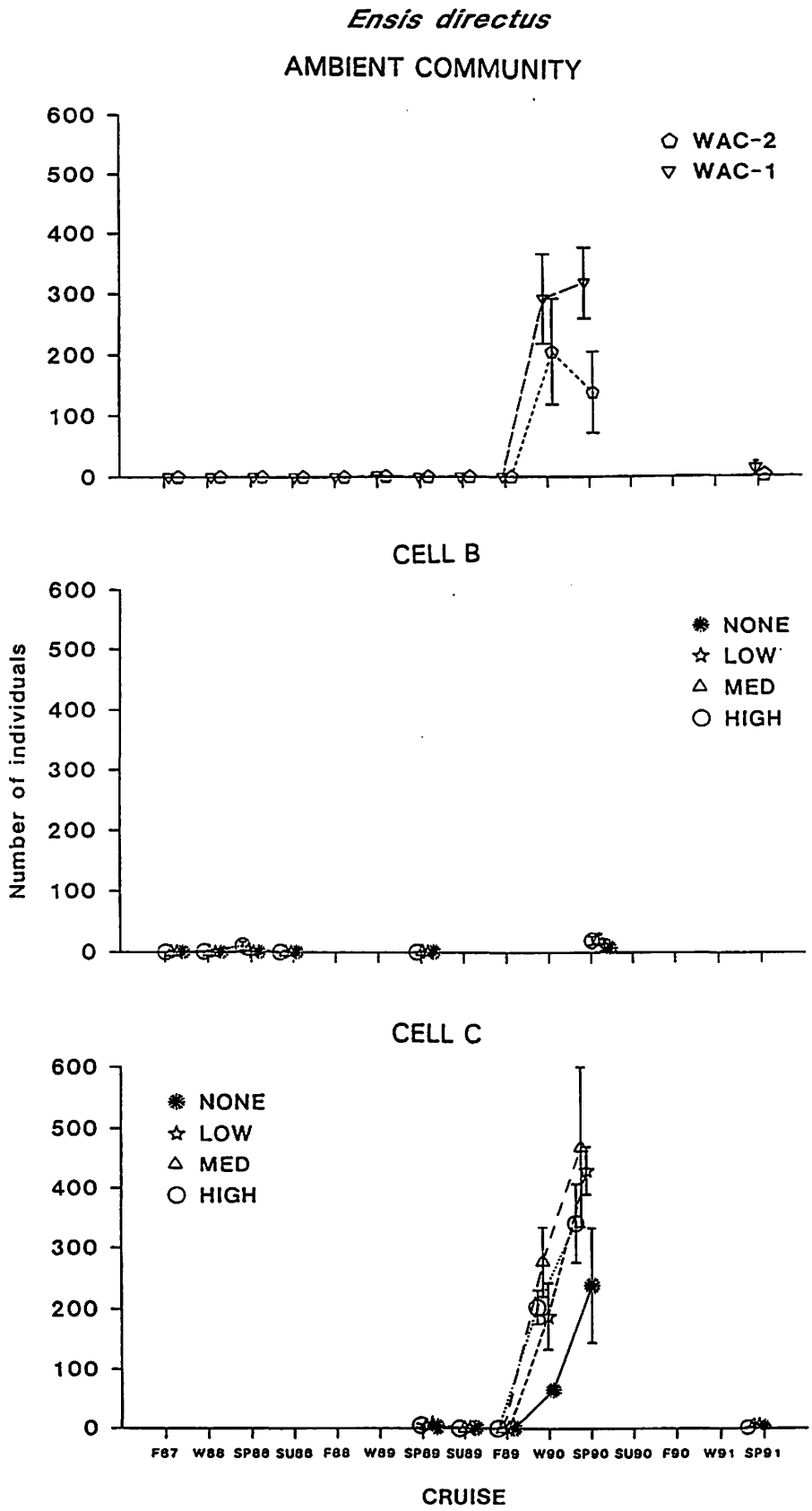

Figure 34. Temporal variation in population densities of the bivalve *Ensis directus* at ambient community, Cell B, and Cell C stations.

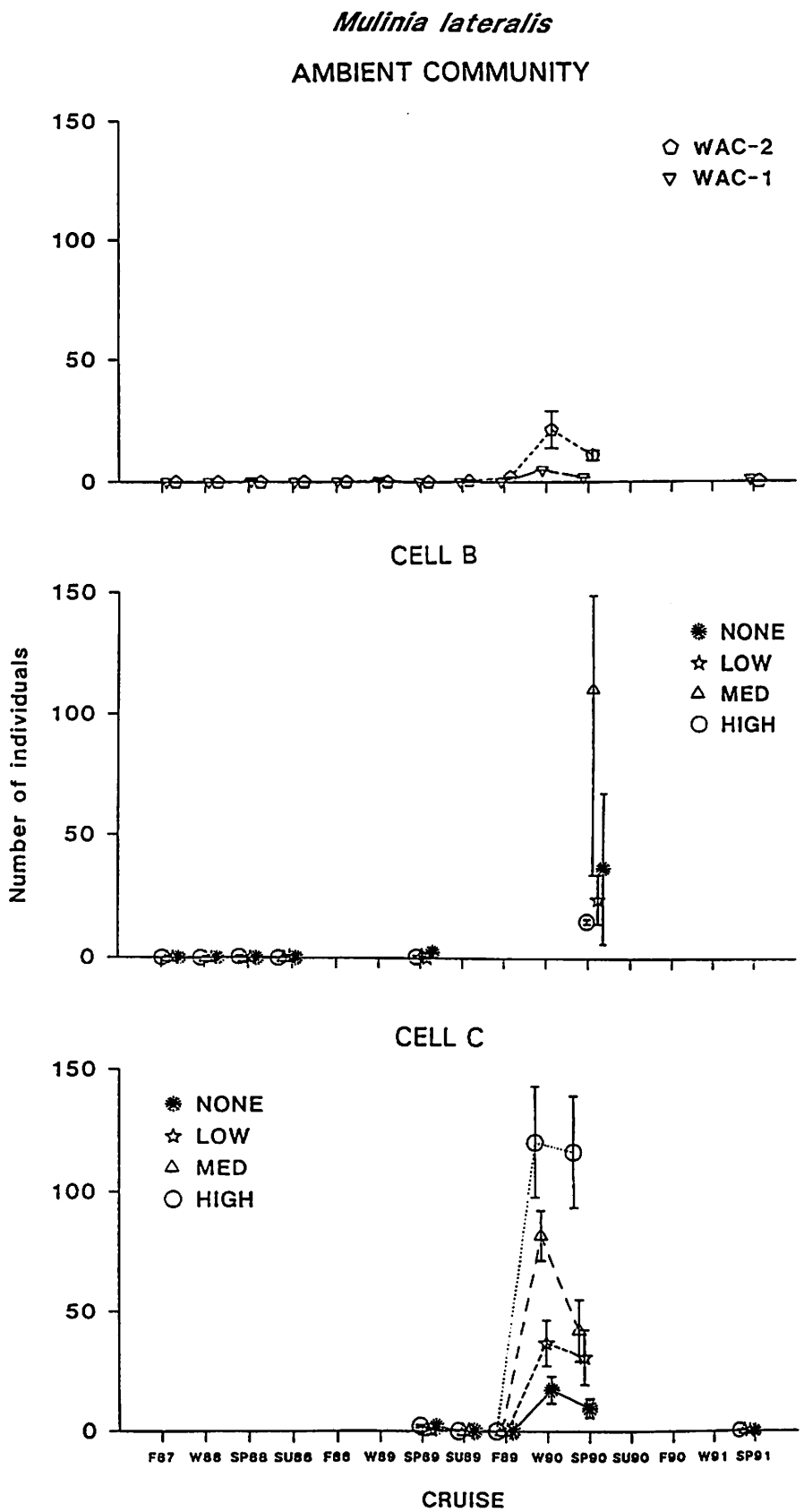

Figure 35. Temporal variation in population densities of the bivalve *Mulinia lateralis* at ambient community, Cell B, and Cell C stations.

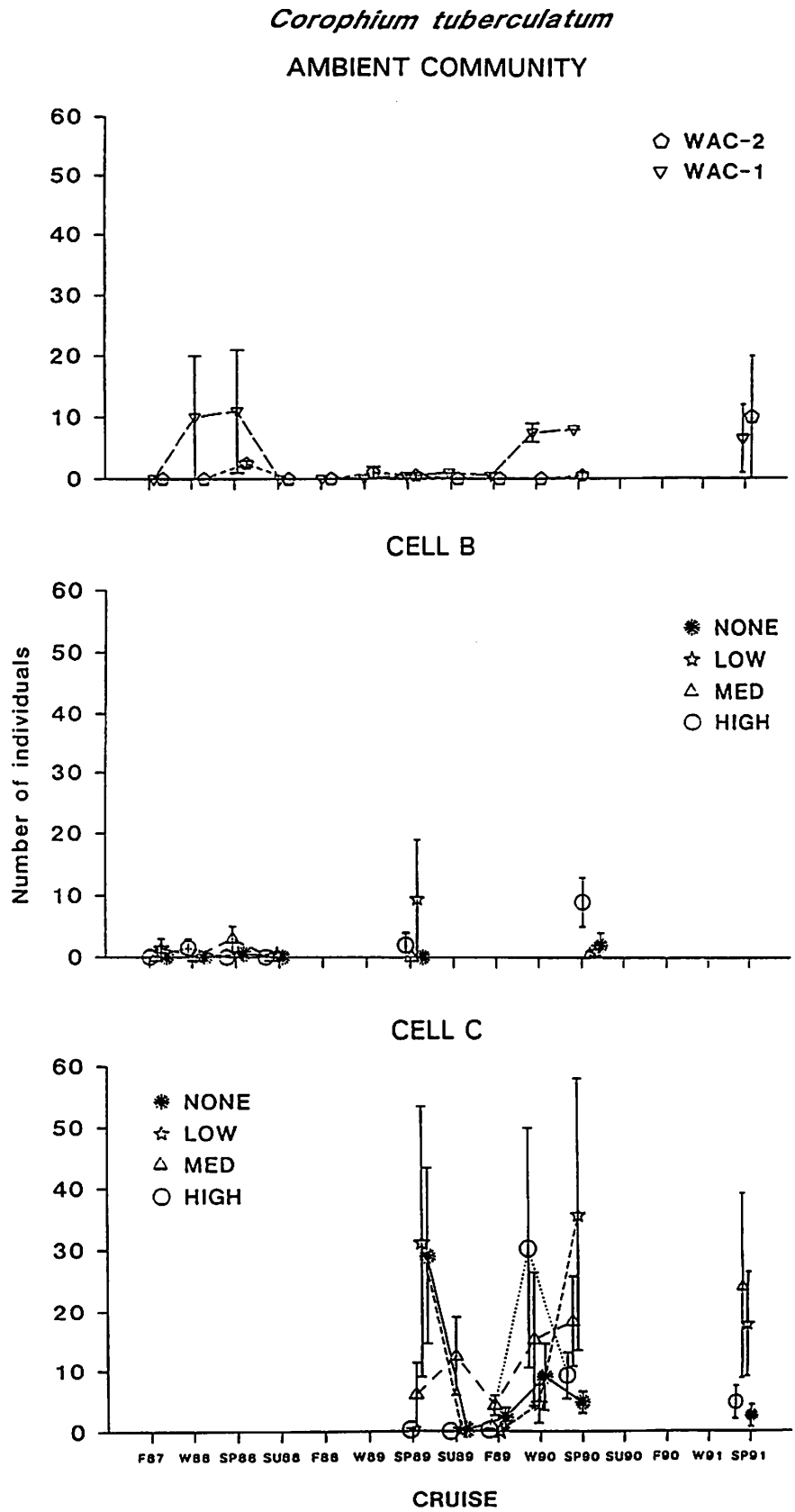

Figure 36. Temporal variation in population densities of the amphipod *Corophium tuberculatum* at ambient community, Cell B, and Cell C stations.

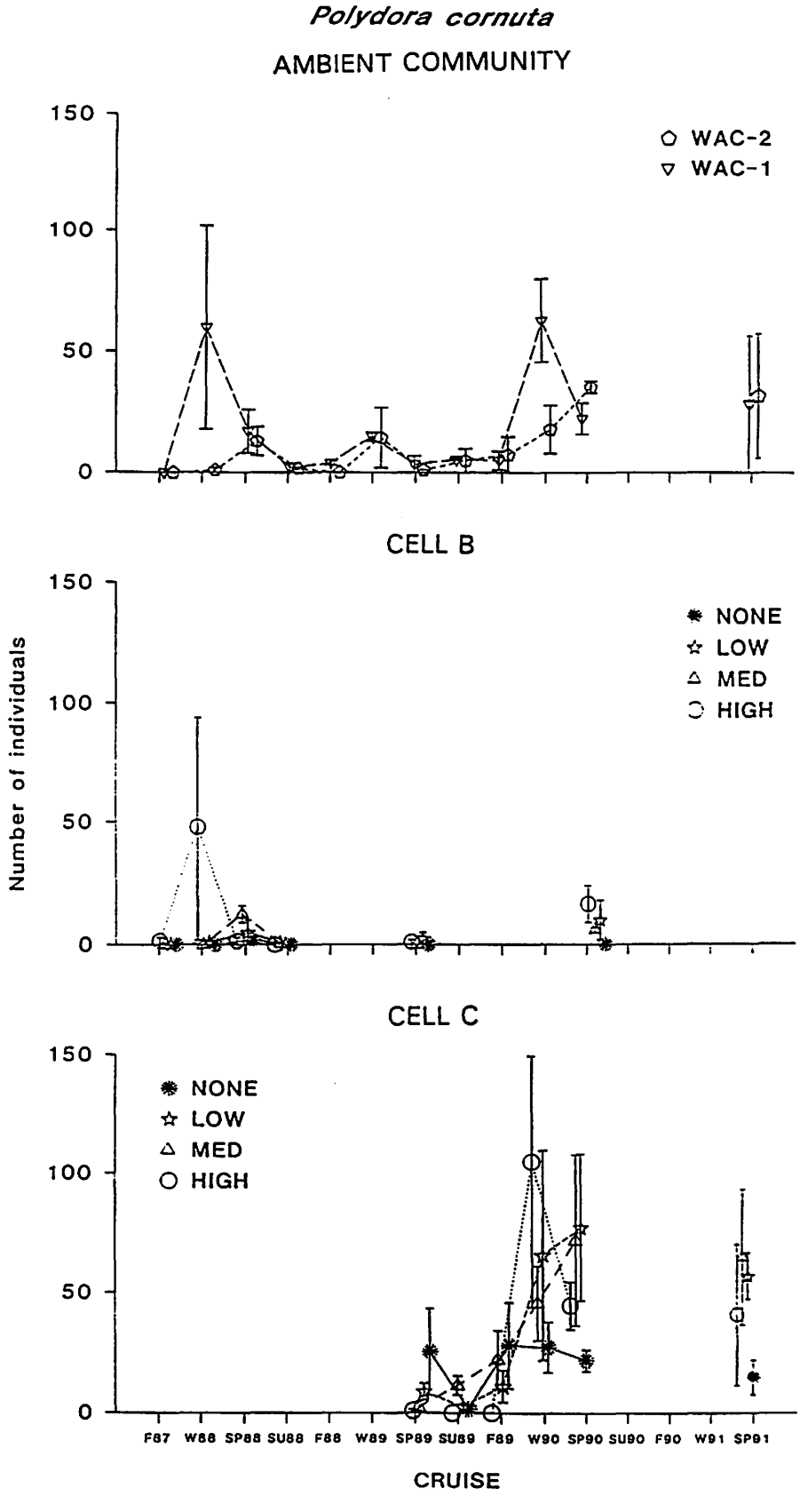

Figure 37. Temporal variation in population densities of the polychaete *Polydora cornuta* at ambient community, Cell B, and Cell C stations.

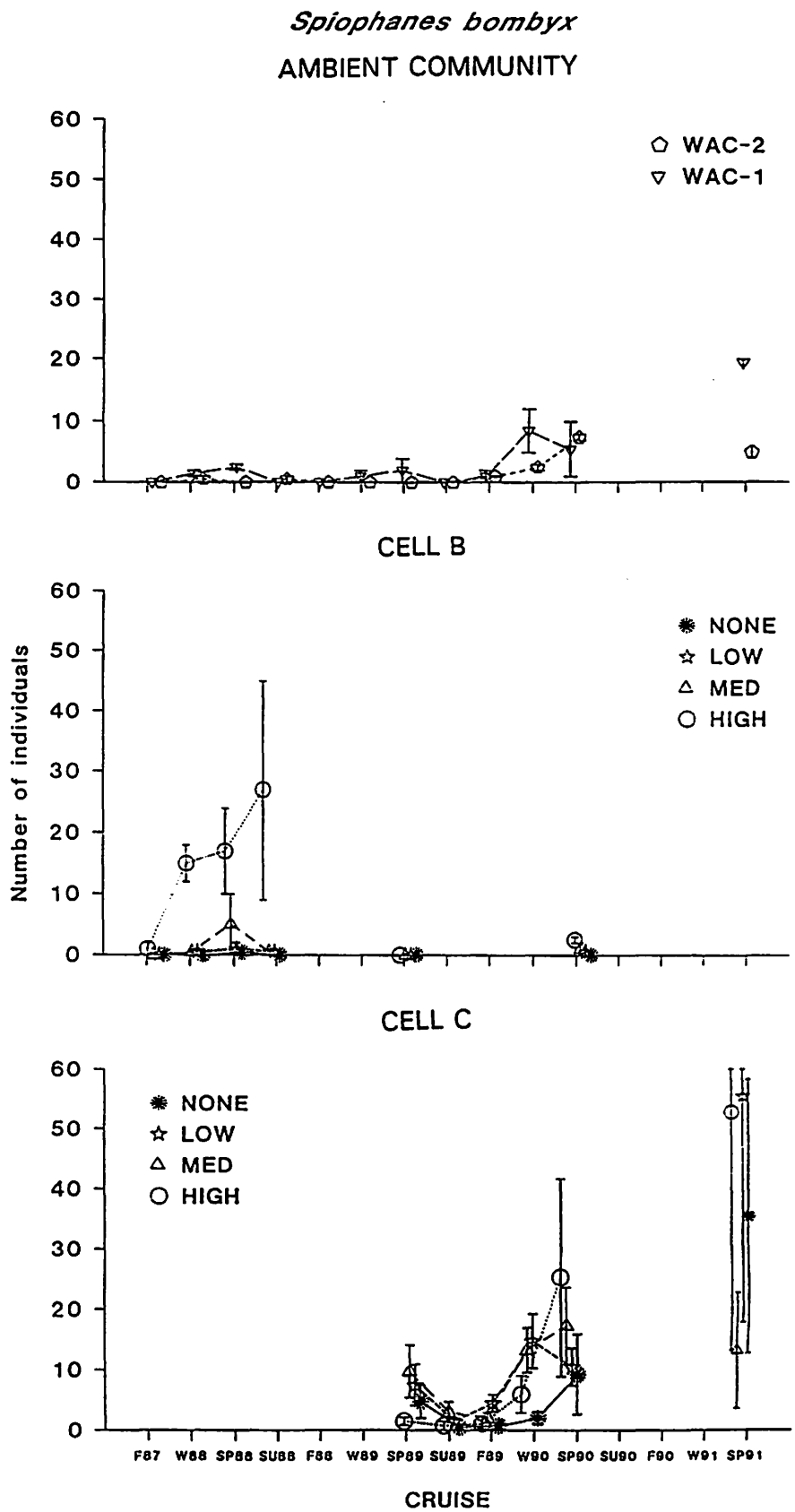

Figure 38. Temporal variation in population densities of the polychaete *Spiophanes bombyx* at ambient community, Cell B, and Cell C stations.

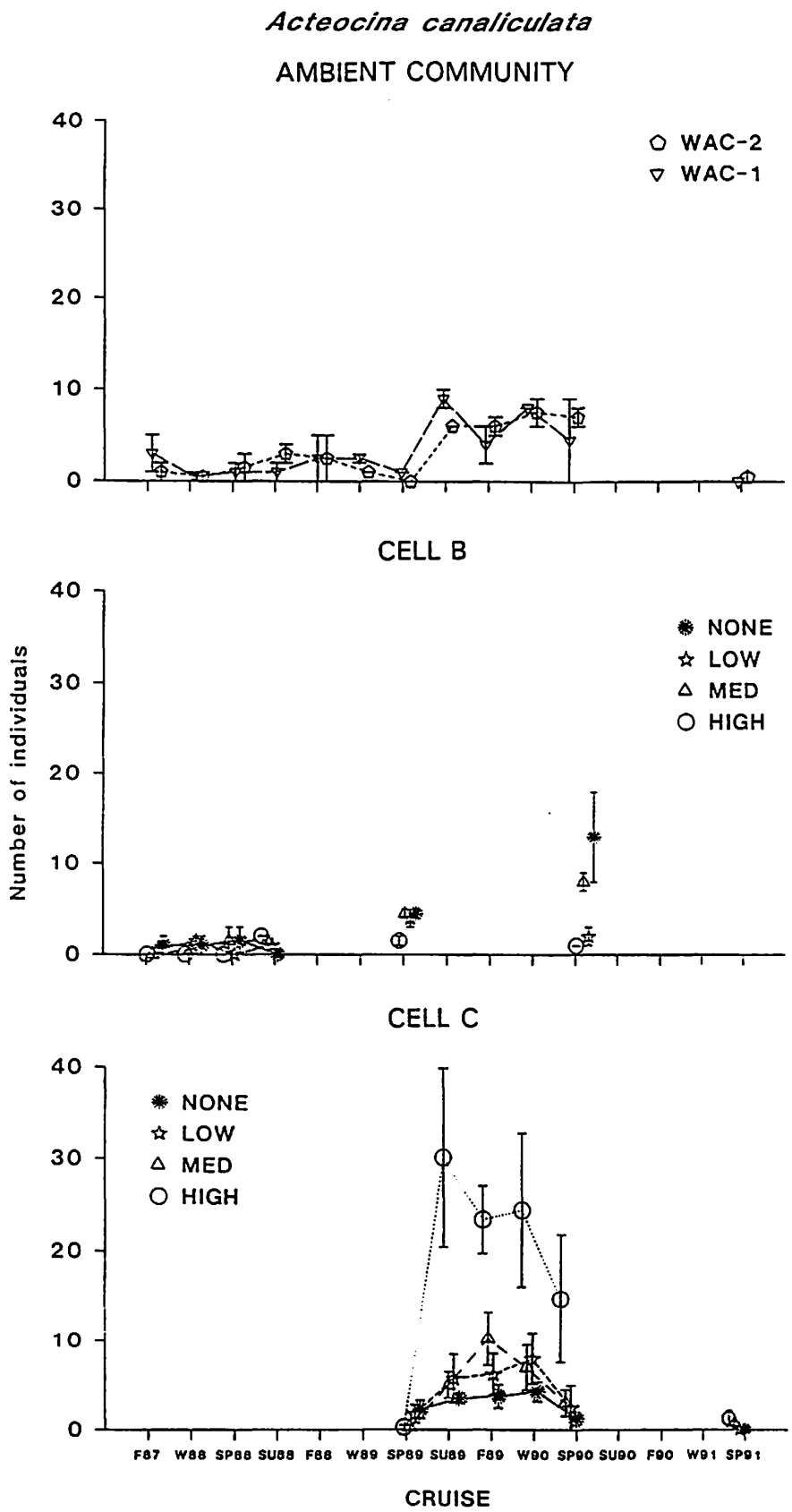

Figure 39. Temporal variation in population densities of the gastropod *Acteocina canaliculata* at ambient community, Cell B, and Cell C stations.

summer 1989 and spring 1990. The polychaete *Sabellaria vulagaris* was present, but had highly variable densities at all Cell C stations. It was rare or absent in the ambient community and at Cell B stations (Figure 40).

A large group of species were present in the ambient community throughout the course of the study. These included the polychaetes *Paraprionospio pinnata, Nephtys* cf. *cryptomma, Prionospio perkinsii, Bhawania heteroseta, Pseudeurythoe paucibranchiata* and *Sigambra tentaculata*, the gastropods *Anachis lafresnayi* and *Turbonilla interrupta*, the phoronid *Phoronis* sp., and nemertean *Tubulanus pellucidus* (Figures 41 to 50). Their abundances at MDM, LDM and NDM stations in both disposal cells generally were comparable to those observed at the stations C1 and C2. However, most of these species exhibited reduced densities at HDM stations for 1 or more quarters of sampling beginning at the initiation of sampling for each disposal cell. The gastropod *Odostomia engonia* also was abundant in the ambient community, but exhibited no patterns of enhancement or repression with respect to DM overburden (Figure 51).

Dynamics at the Functional Group Level

As indicated in the BACKGROUND section, a number of studies in marine and freshwater environments have demonstrated predictable succesional progressions following disturbance events. Communities first are dominated by small, shallow-dwelling infauna and these organisms are gradually replaced by large or deep-dwelling infauna. Based on living position and size, Schaffner (1990) previously identified 5

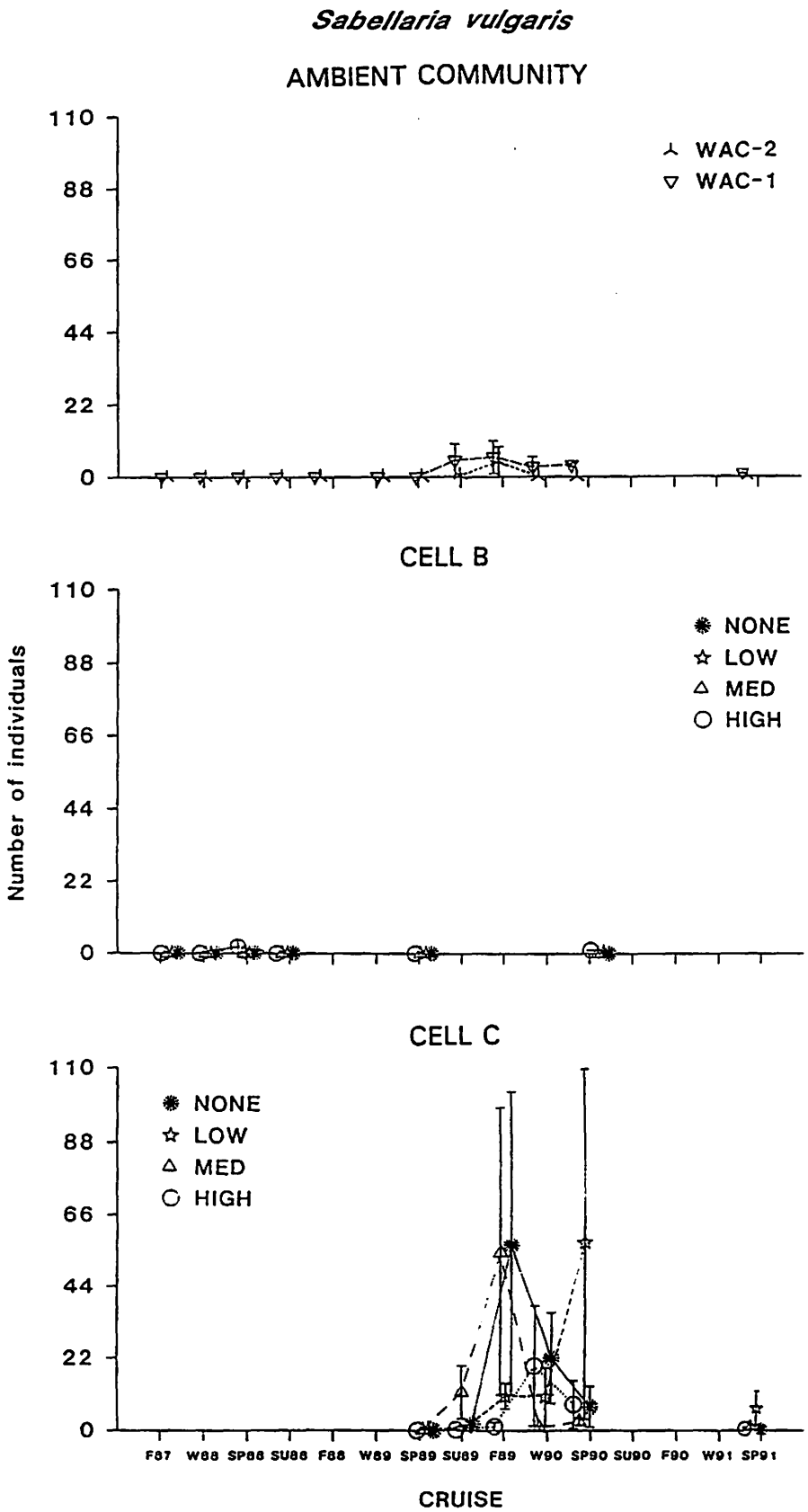

Figure 40. Temporal variation in population densities of the polychaete *Sabellaria vulgaris* at ambient community, Cell B, and Cell C stations.

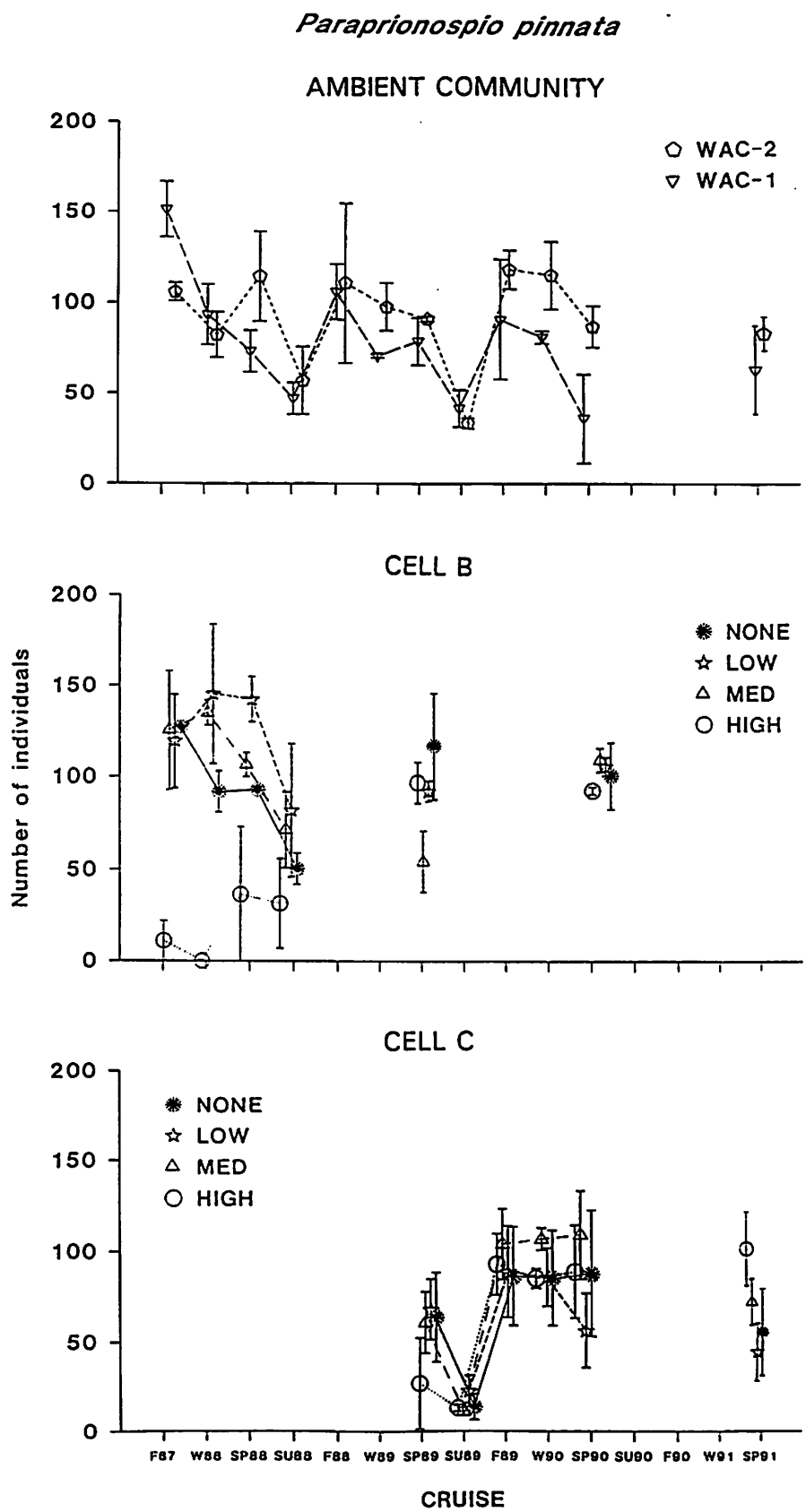

Figure 41. Temporal variation in population densities of the polychaete *Paraprionospio pinnata* at ambient community, Cell B, and Cell C stations.

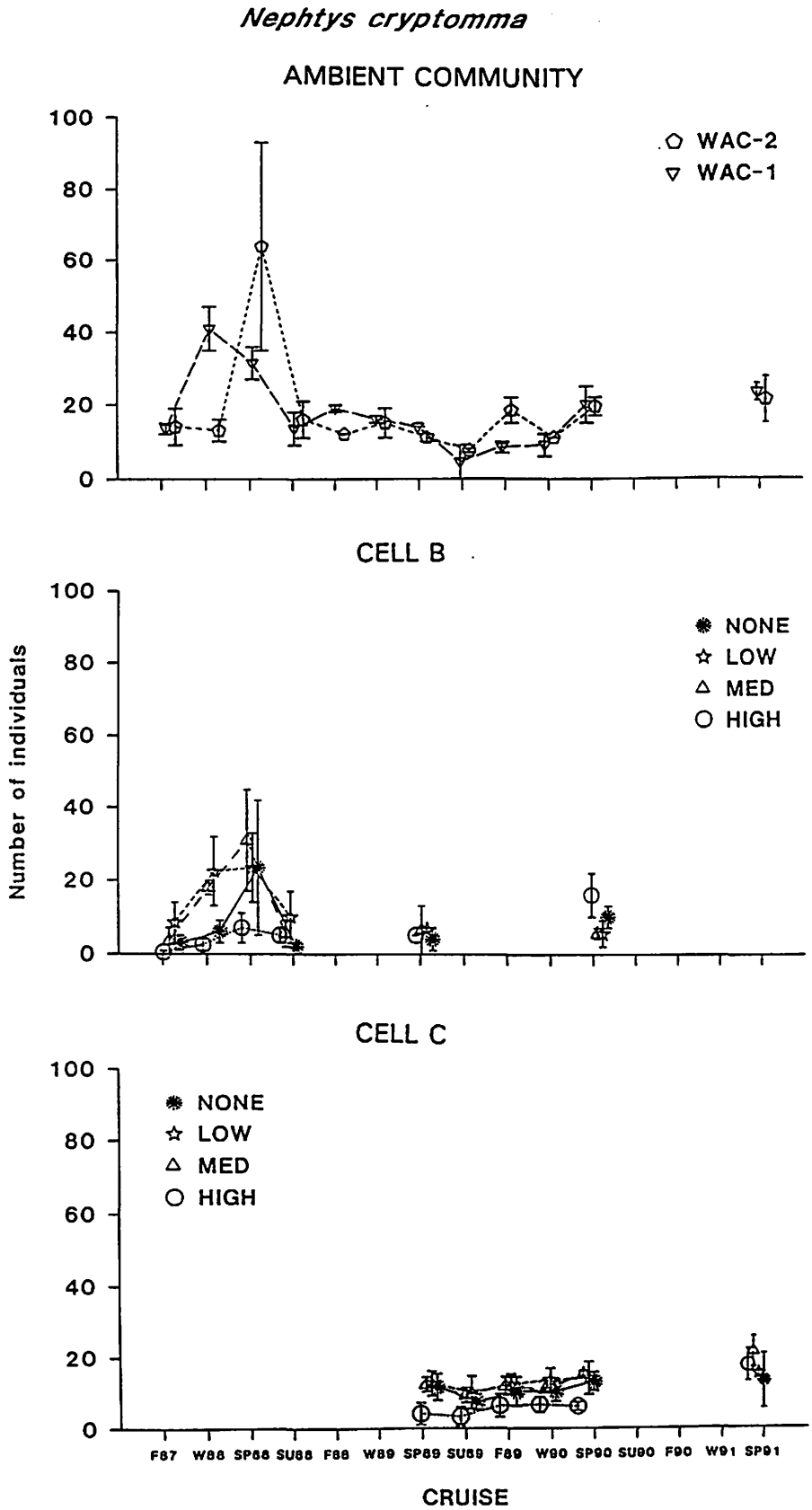

Figure 42. Temporal variation in population densities of the polychaete *Nephtys cryptomma (picta)* at ambient community, Cell B, and Cell C stations.

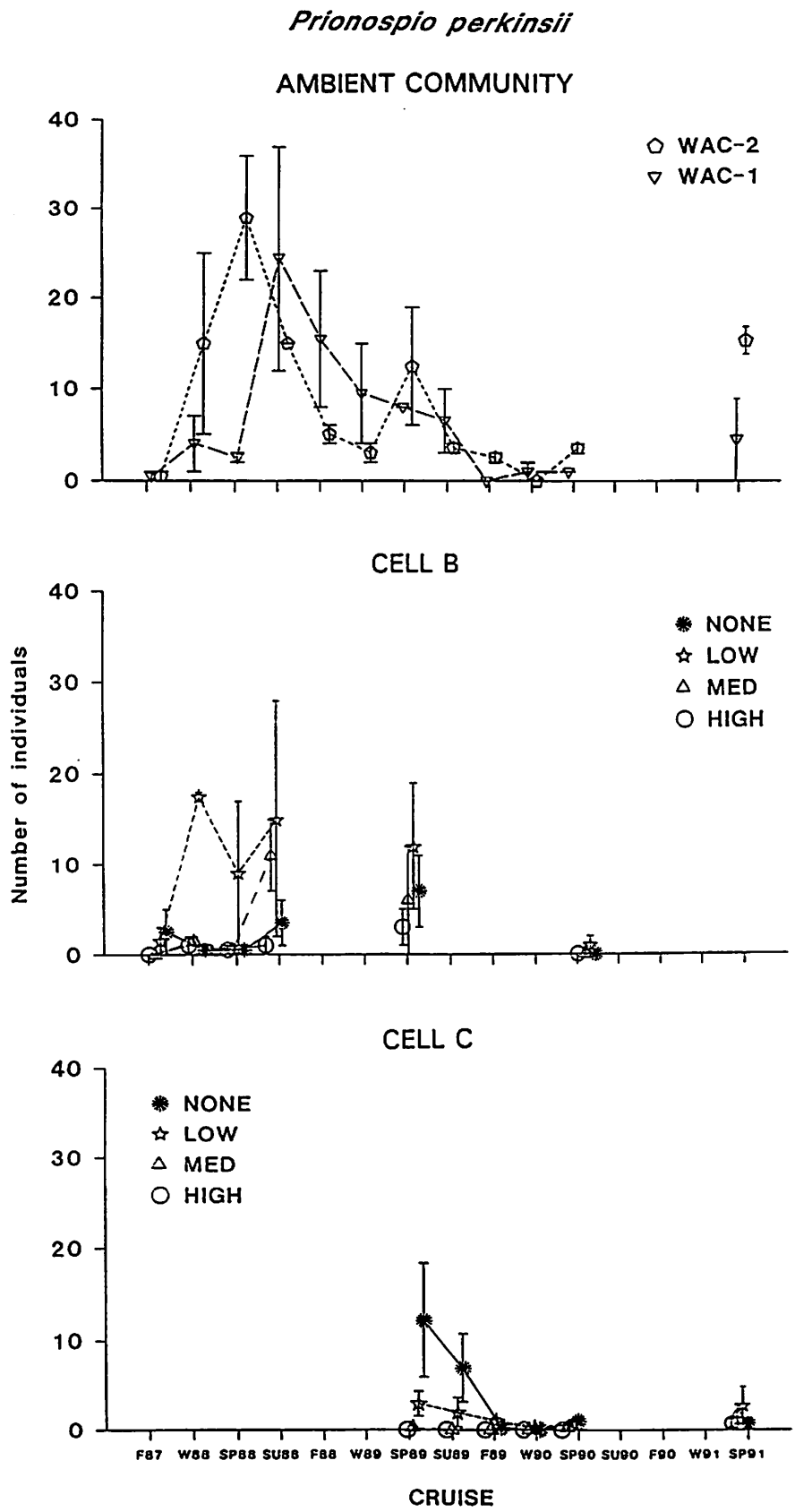

Figure 43. Temporal variation in population densities of the polychaete *Prionospio perkinsii* at ambient community, Cell B, and Cell C stations.

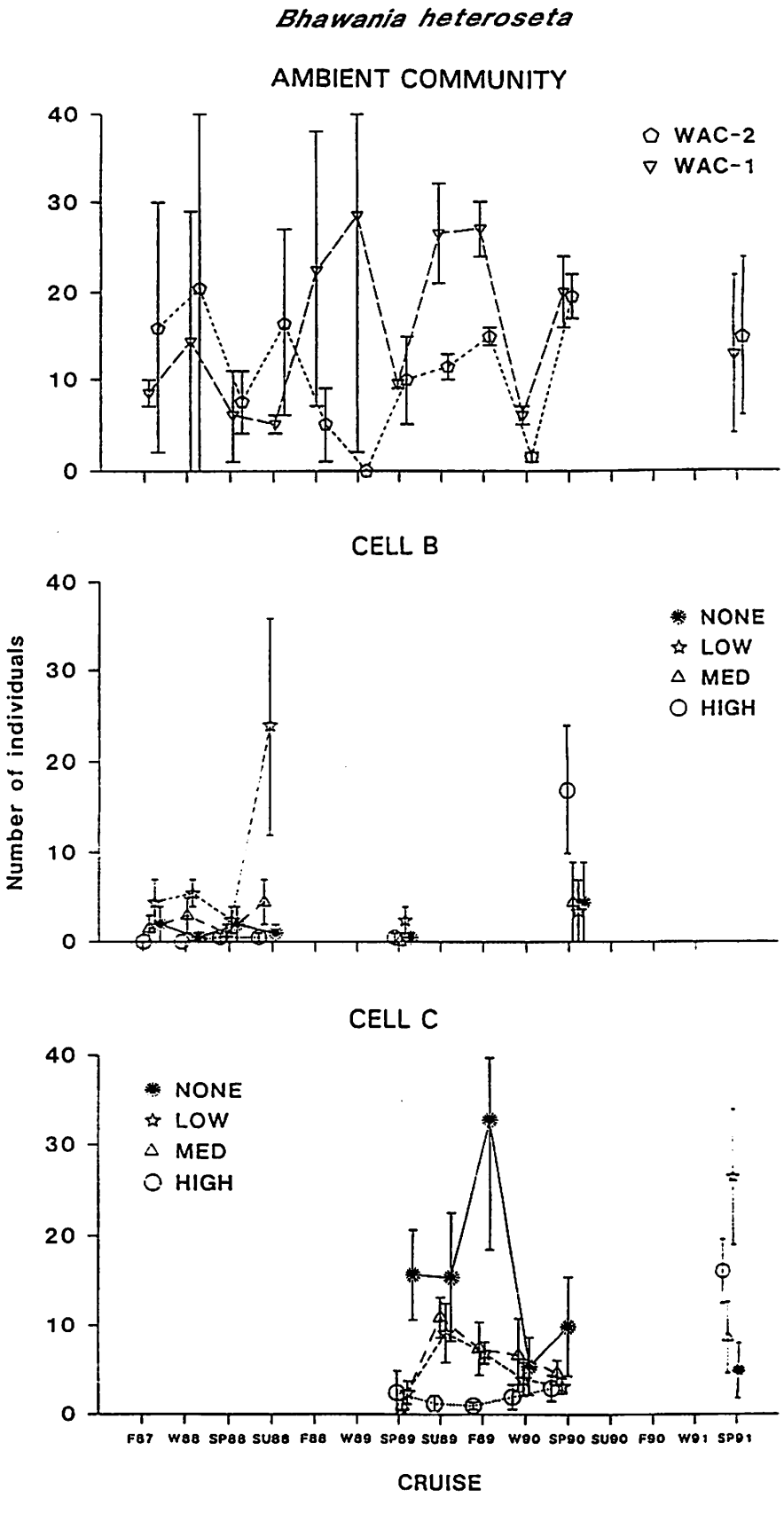

Figure 44. Temporal variation in population densities of the polychaete *Bhawania heteroseta* at ambient community, Cell B, and Cell C stations.

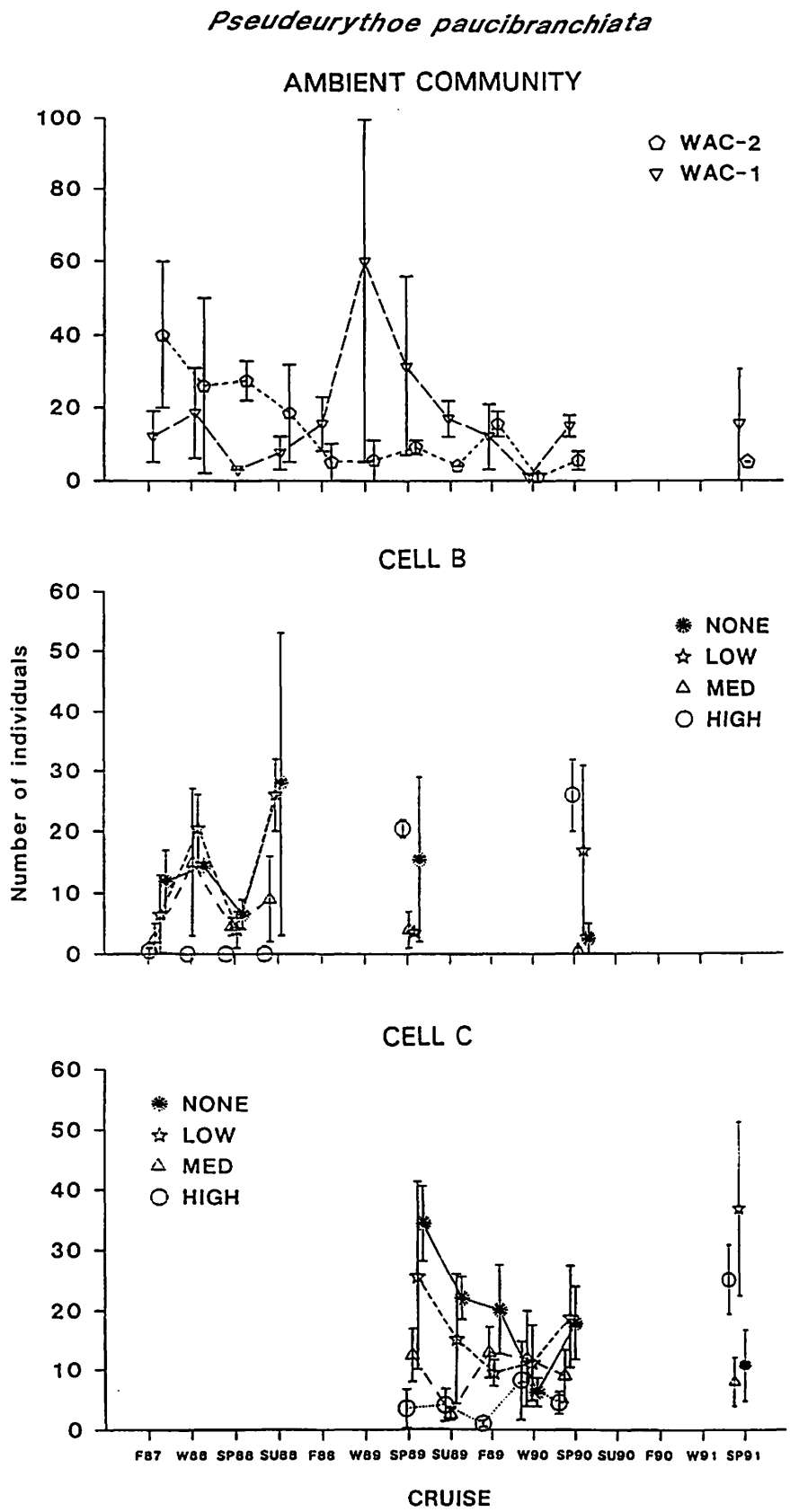

Figure 45. Temporal variation in population densities of the polychaete *Pseudeurythoe paucibranchiata* at ambient community, Cell B, and Cell C stations.

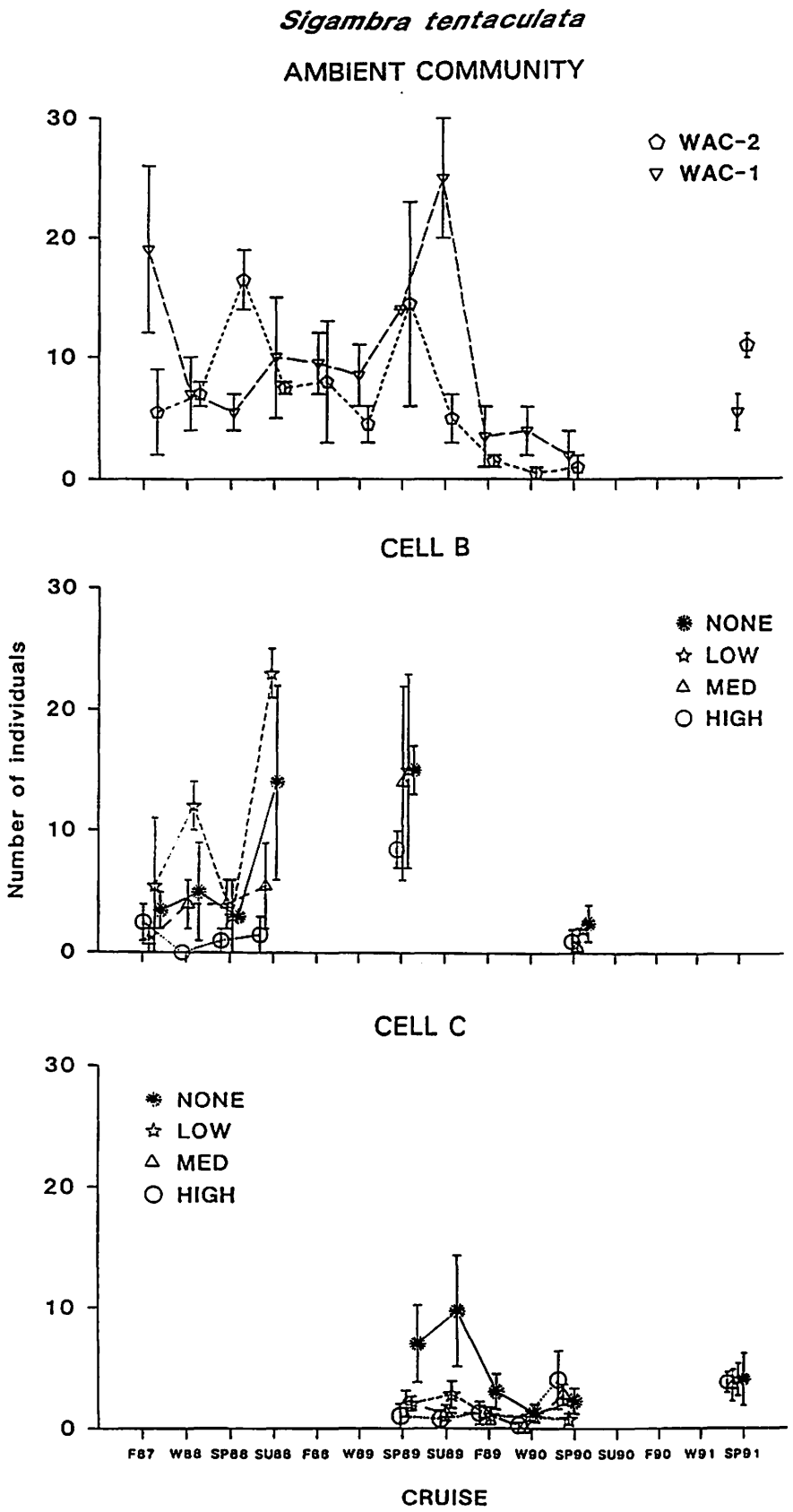

Figure 46. Temporal variation in population densities of the polychaete *Sigambra tentaculata* at ambient community, Cell B, and Cell C stations.

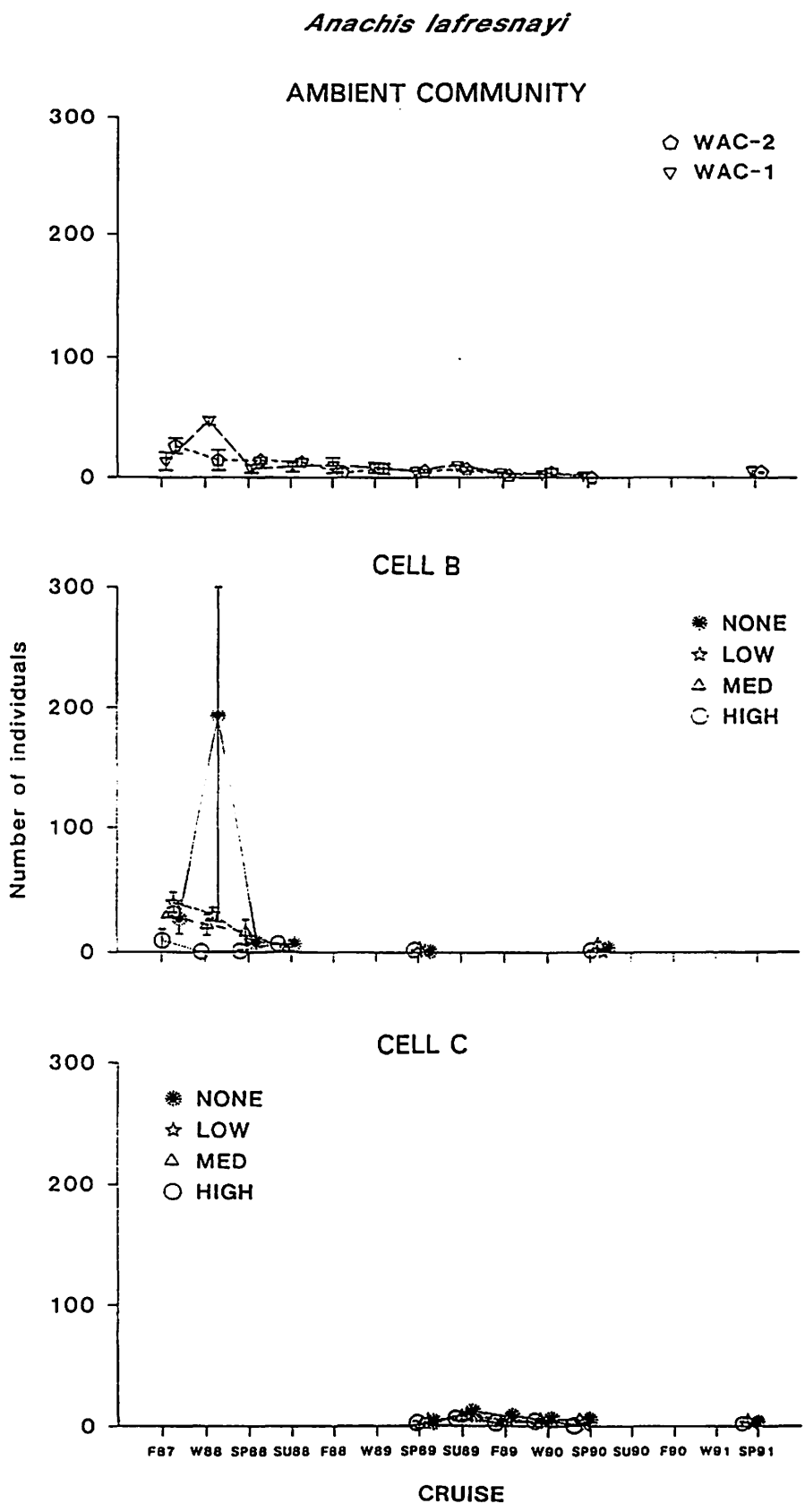

Figure 47. Temporal variation in population densities of the gastropod *Anachis lafresnayi* at ambient community, Cell B, and Cell C stations.

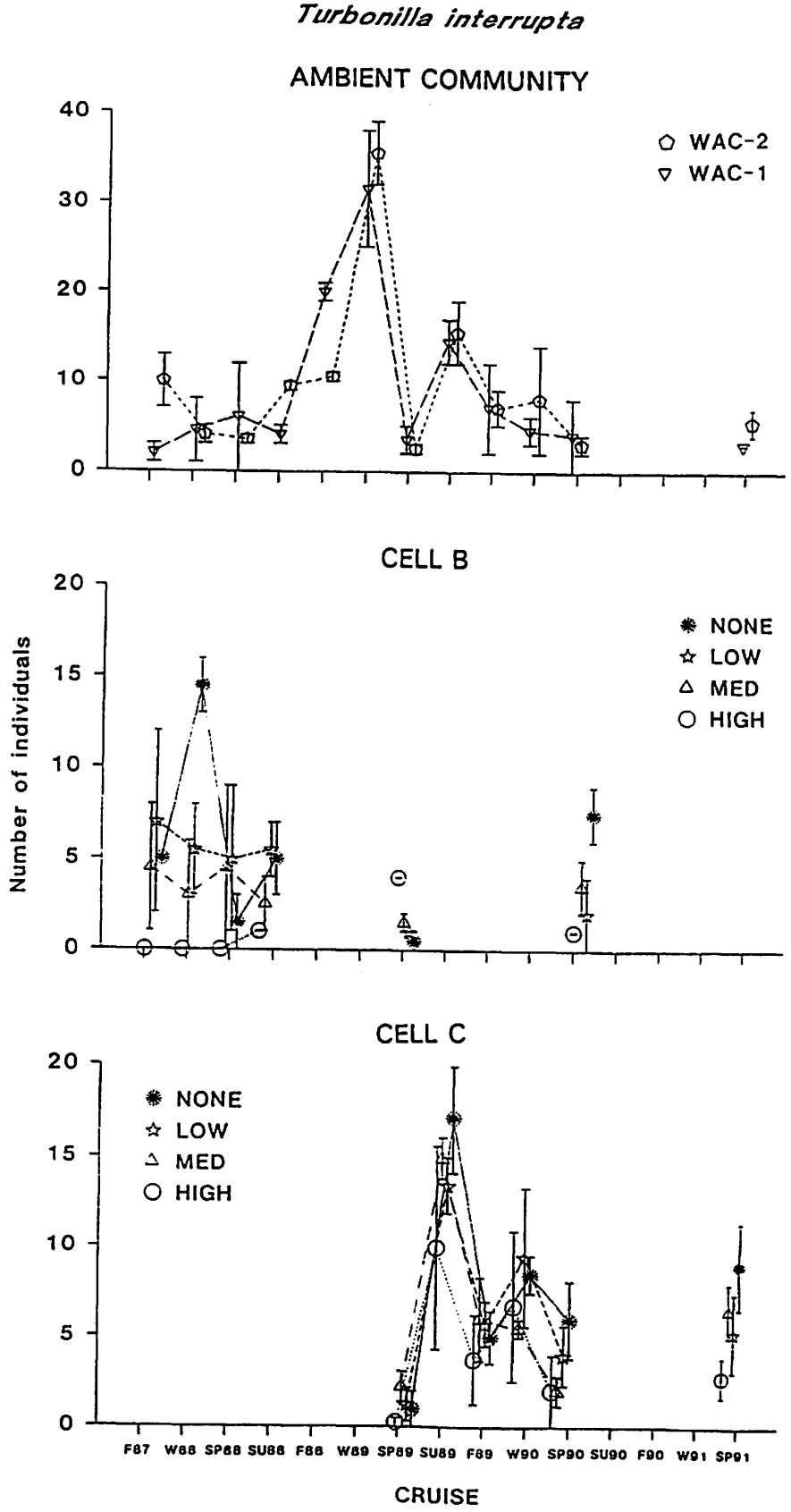

Figure 48. Temporal variation in population densities of the gastropod *Turbonilla interrupta* at ambient community, Cell B, and Cell C stations.

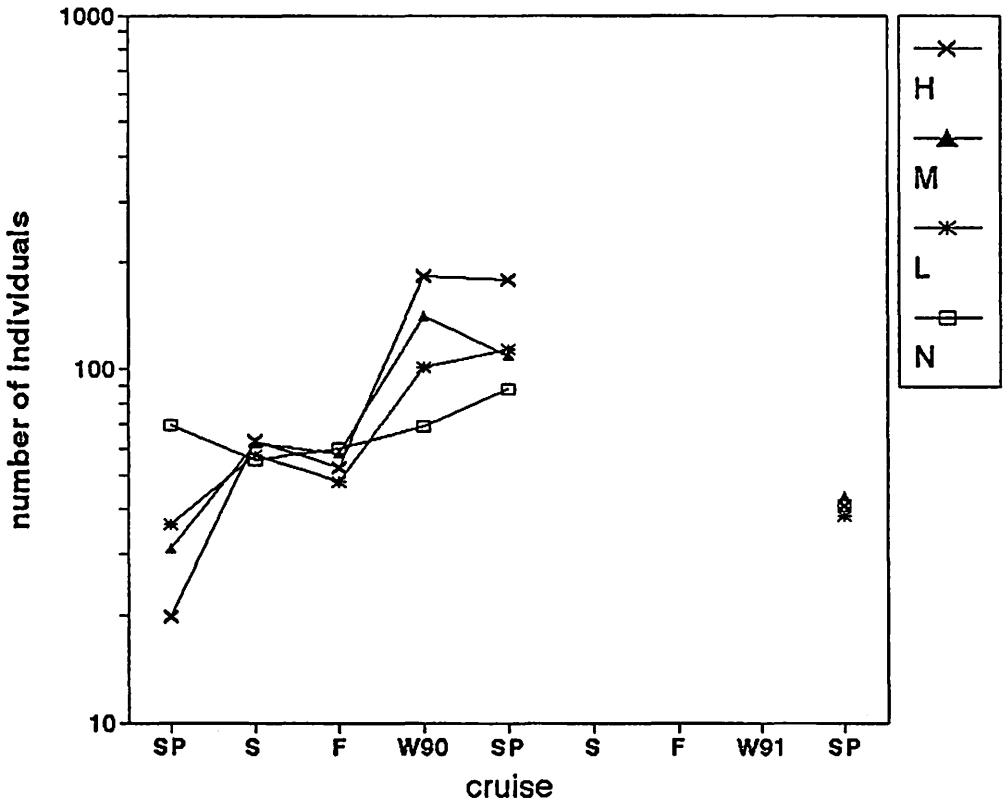

Figure 57. Abundance of shallow burrowers (per 0.06 m^2) at Cell C versus time.

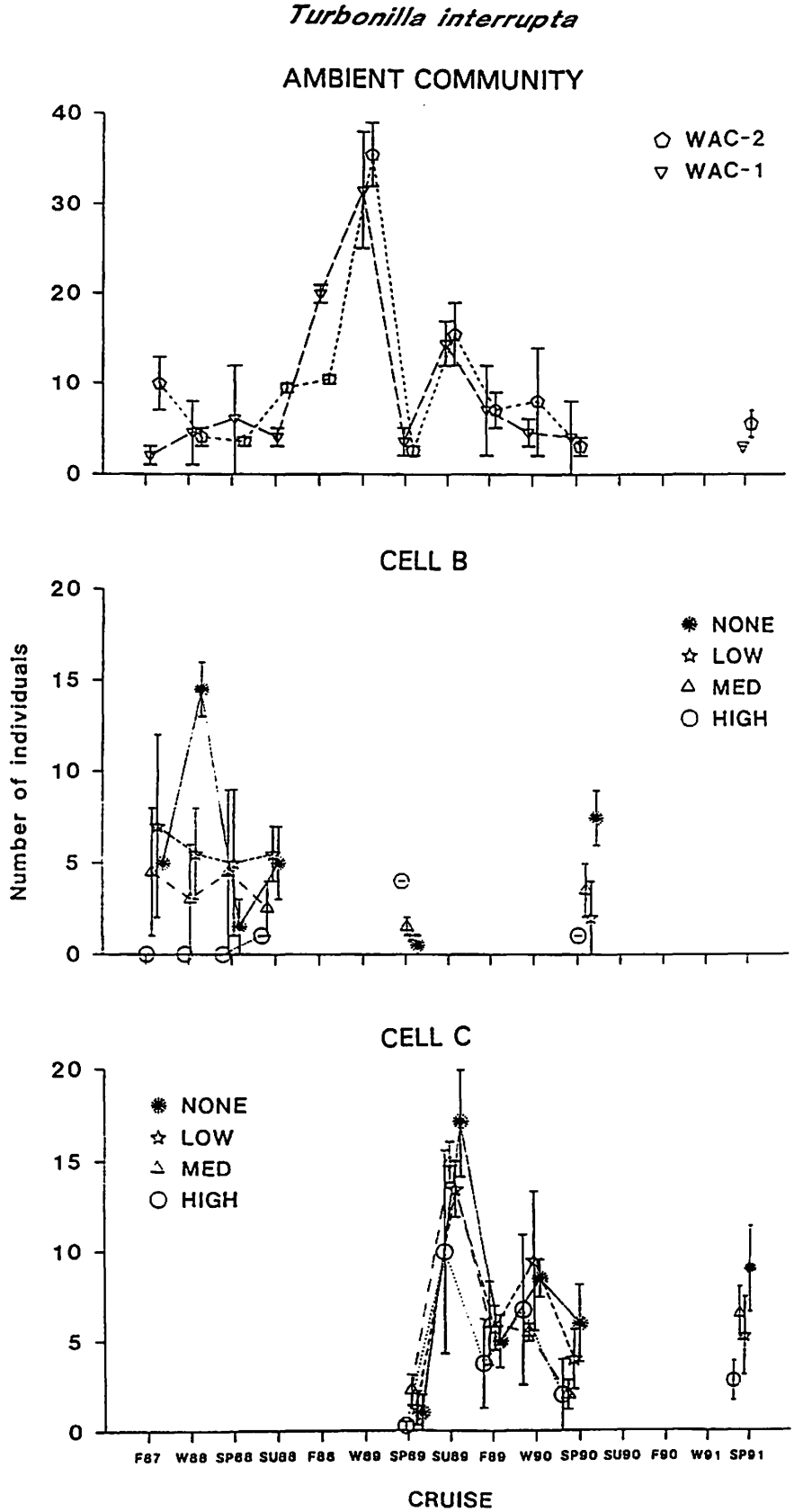

Figure 48. Temporal variation in population densities of the gastropod *Turbonilla interrupta* at ambient community, Cell B, and Cell C stations.

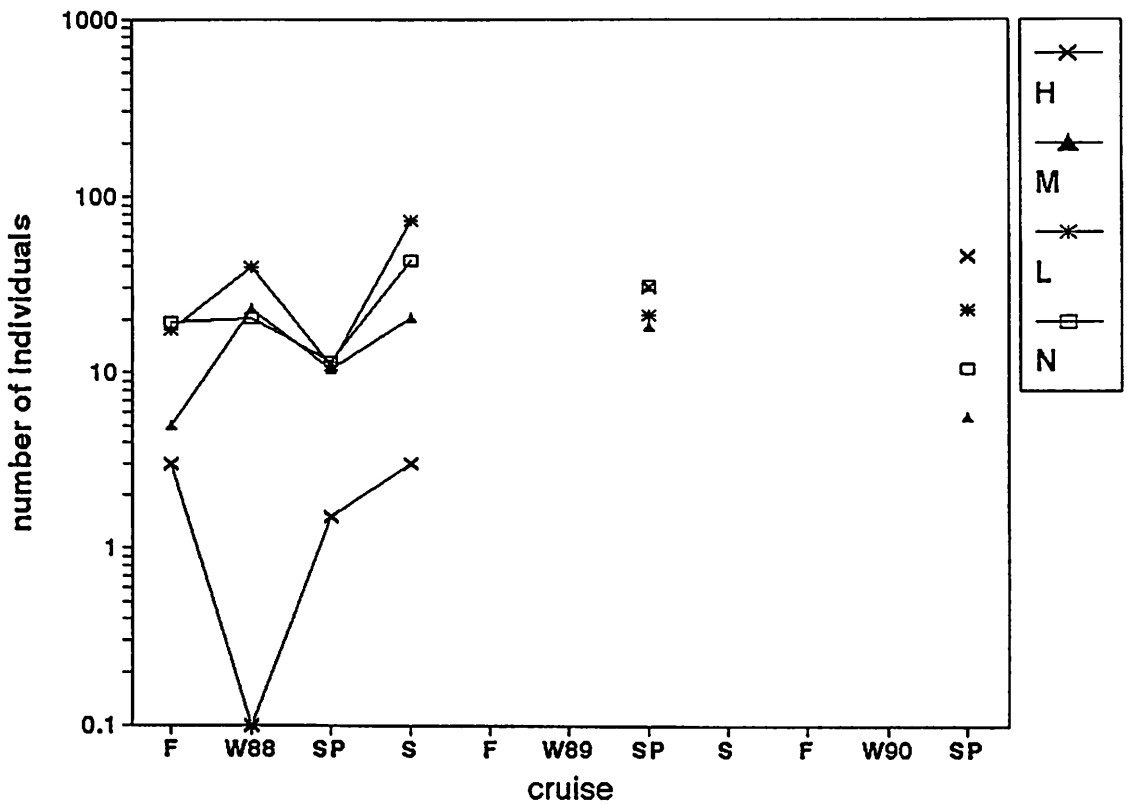

Figure 55. Abundance of deep burrowers (per 0.06 m^2) at Cell B versus time.

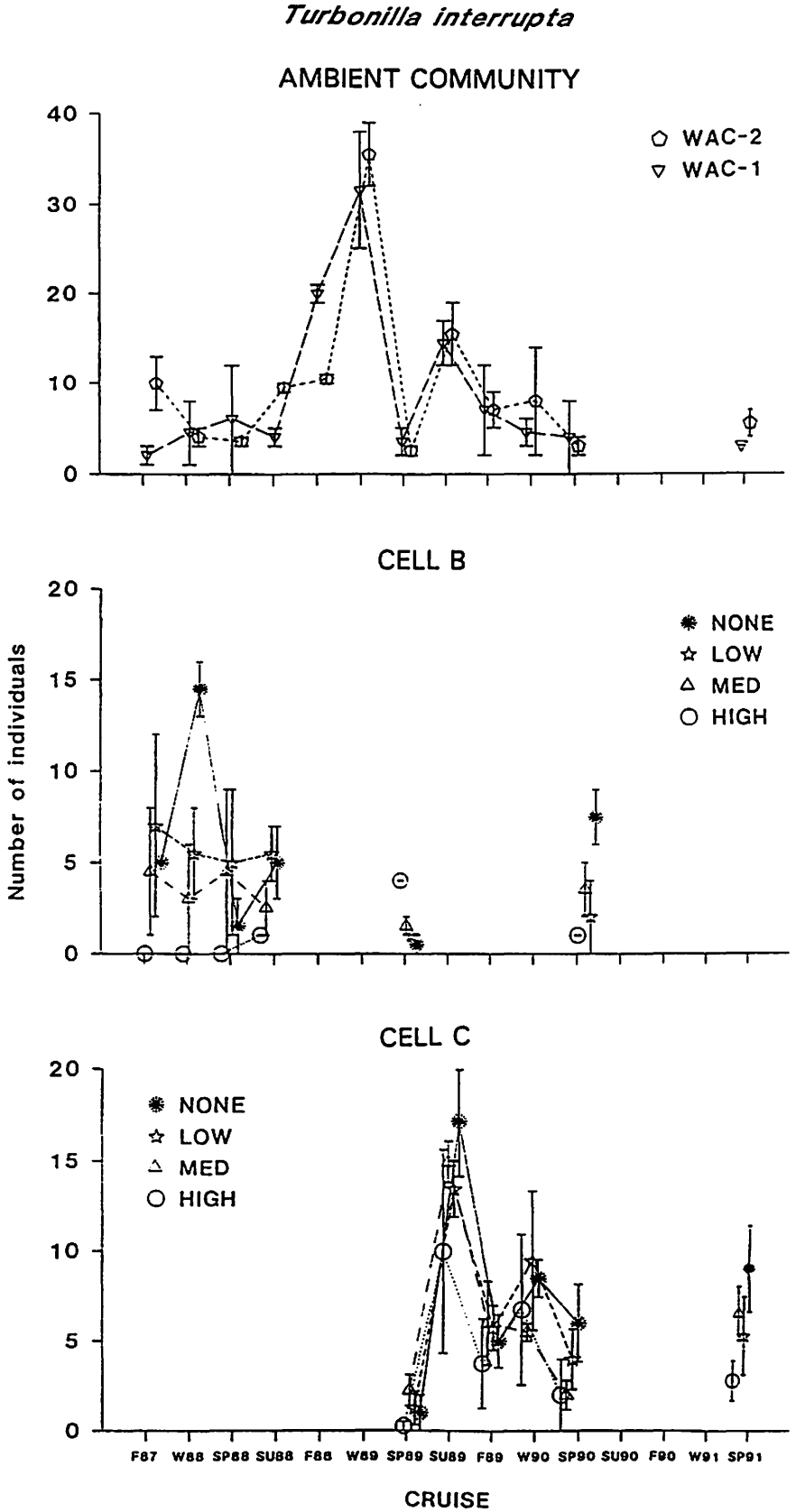

Figure 48. Temporal variation in population densities of the gastropod *Turbonilla interrupta* at ambient community, Cell B, and Cell C stations.

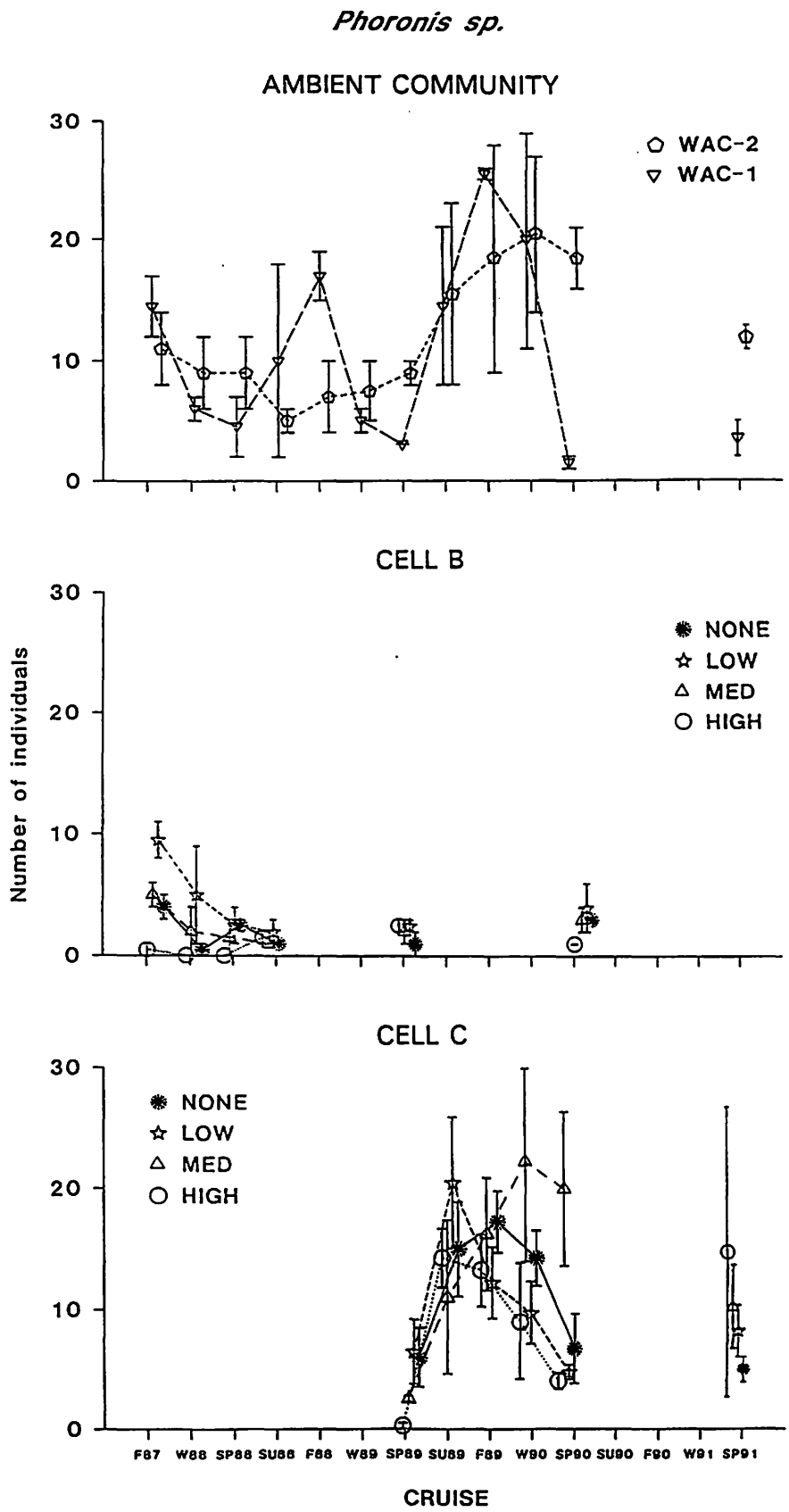

Figure 49. Temporal variation in population densities of the phoronid *Phoronis* sp. at ambient community, Cell B, and Cell C stations.

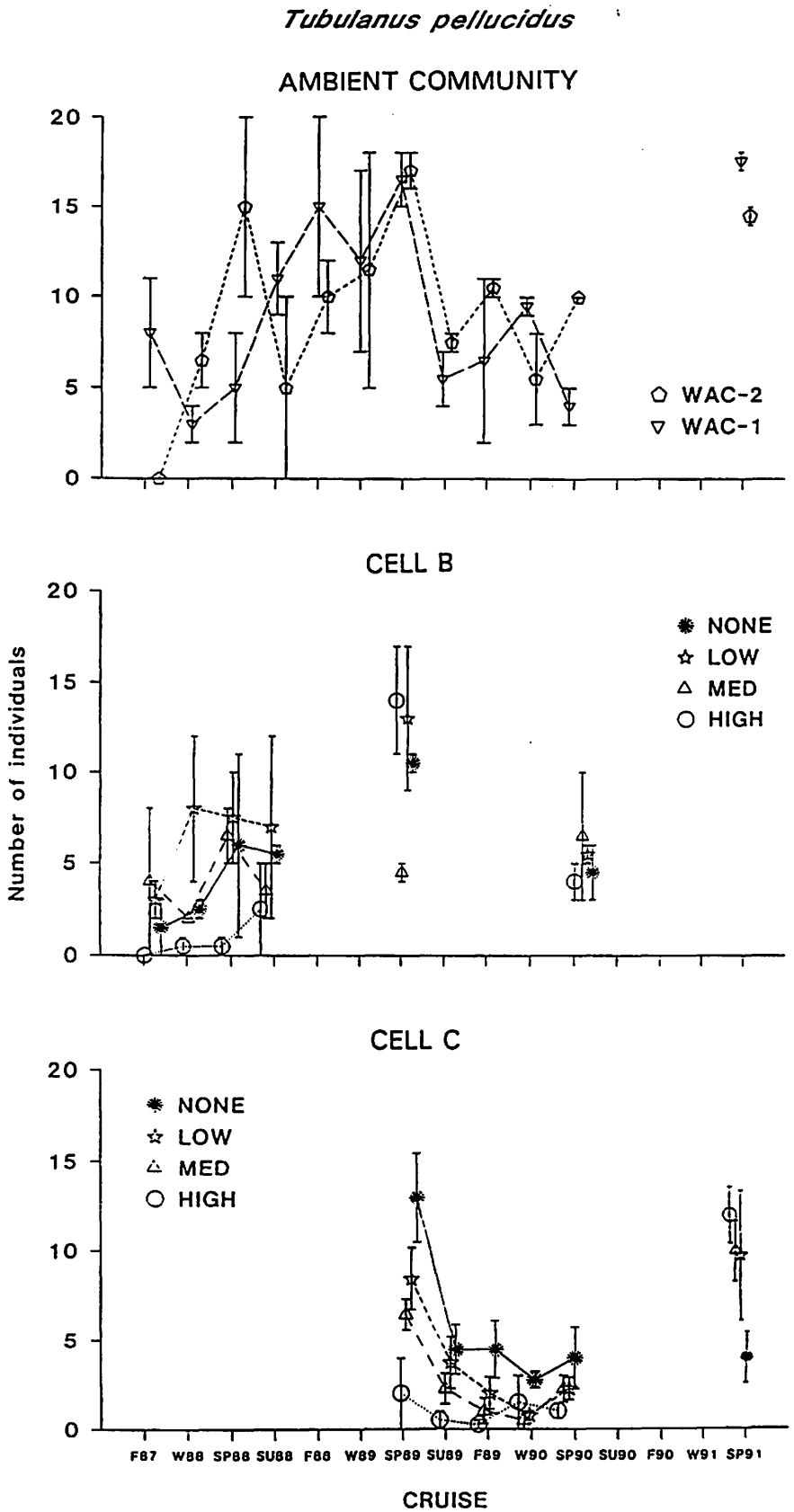

Figure 50. Temporal variation in population densities of the nemertean *Tubulanus pellucidus* at ambient community, Cell B, and Cell C stations.

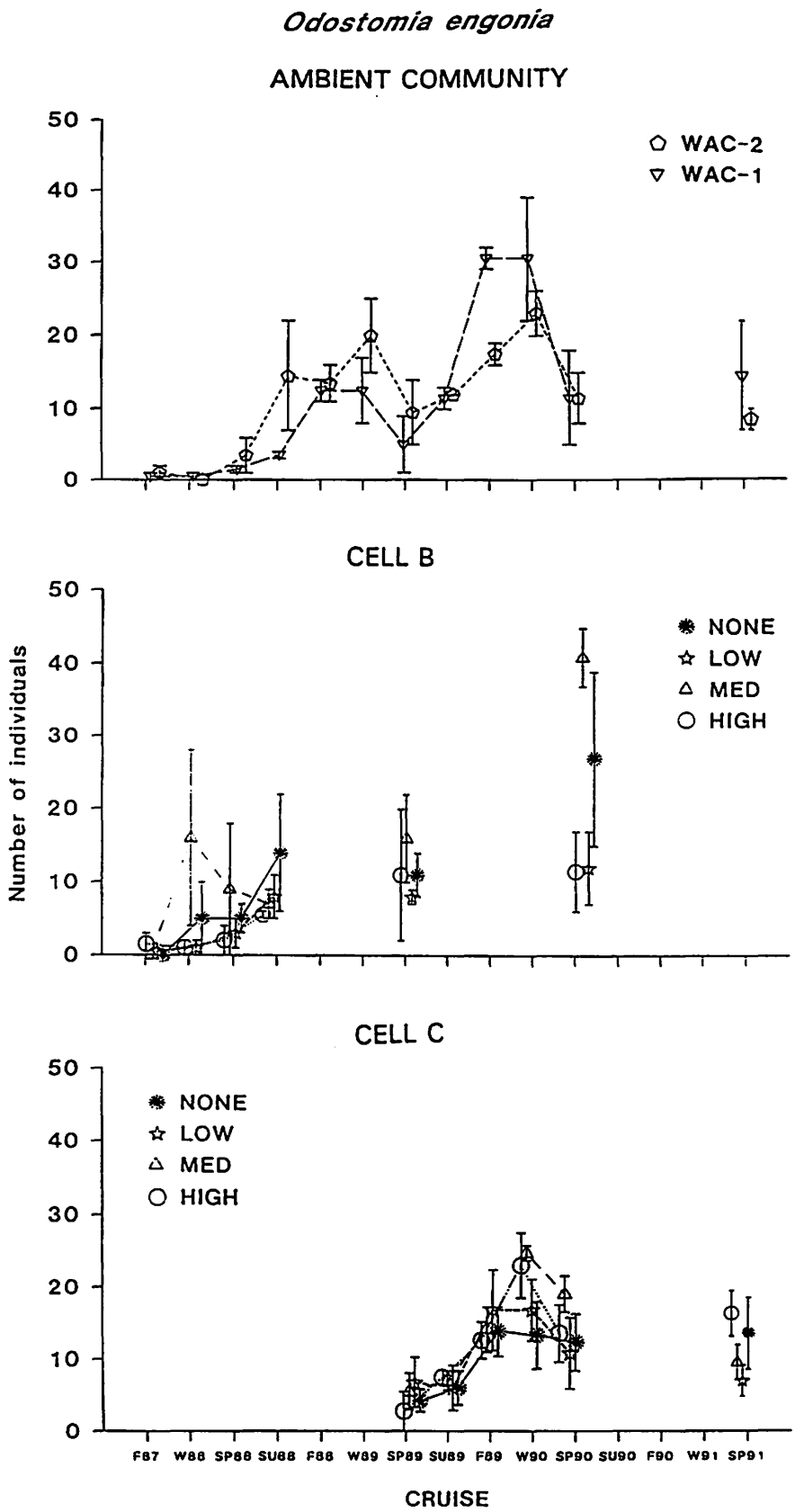

Figure 51. Temporal variation in population densities of the gastropod *Odostomia engonia* at ambient community, Cell B, and Cell C stations.

major functional groups among the dominant species characterizing the ambient community of the Wolf Trap study region. These included 1) small tube and burrow builders, 2) shallow free-living burrowers, 3) large tube and burrow builders, 4) deep free-living burrowers, and 5) epifaunal and commensal species. Species comprising the first four groups were extracted from the data sets for Cell B and Cell C stations and their per core abundances were then summed by functional group as indicated in Table 12. Plots of functional group abundance versus time for each disposal event are presented in Figures 52 through 55 for Cell B and Figures 56 through 59 for Cell C.

At Cell B, abundances of small tube and burrow builders, shallow burrowers and large tube and burrow builders were depressed at HDM stations relative to other stations during fall 1987 and winter 1988 (Figures 52 to 54). These differences were obscured by spring 1988. Abundances of deep burrowers appear to have been depressed through summer 1988 at HDM stations, but were similar to levels observed at other stations by spring 1989 (Figure 55).

At Cell C, abundances of small tube and burrow builders, shallow burrowers and large tube and burrow builders were depressed at HDM stations relative to other stations during spring 1989 (Figures 56 to 58). These differences were obscured by the next sampling quarter, summer 1988. Abundances of deep burrowers appear to have been depressed through fall 1989 HDM stations, but were similar to levels observed at other

Table 12. Functional group assignments for species collected at Cell B stations as presented in Figures 52 through 55 and Cell C stations as presented in Figures 56 through 59. P - Polychaeta, A - Amphipoda, An - Anthozoa, E - Echinodermata, H - Hemichordata, G - Gastropoda, B - Bivalvia, Ph - Phoronida, N - Nemertea. See text for further explanation.

Small tube builders

Ampelisca abdita (A)
Ampelisca verrilli (A)
Asabellides oculata (P)
Mediomastus ambiseta (P)
Owenia fusiformis (P)
Paraprionospio pinnata (P)
Phoronis sp. (Ph)
Spiophanes bombyx (P)
Streblospio benedicti (P)

Large tube and burrow builders

Asychis elongata (P)
Ceriantheopsis americanus (An)
Chaetopterus variopedatus (P)
Clymenella torquata (P)
Loimia medusa (P)
Macroclymene zonalis (P)
Microphiopholis atra (E)
Notomastus sp. A (P)
Saccoglossus kowalewskii (H)

Shallow burrowers

Acteocina canaliculata (G)
Glycera americana (P)
Glycinde solitaria (P)
Macoma tenta (B)
Micrura sp. (N)
Mulinia lateralis (B)
Nepthys cf. *cryptomma* (P)
Oligochaeta
Pectinaria gouldii (P)
Prionospio perkinsii (P)
Turbonilla interrupta (G)
Yolidia limatula (B)

Deep burrowers

Bhawania heteroseta (P)
Cabira incerta (P)
Cirratulidae (P)
Gyptis vittata (P)
Podarkeopsis levifuscina (P)
Pseudeurythoe paucibranchiata (P)
Sigambra tentaculata (P)

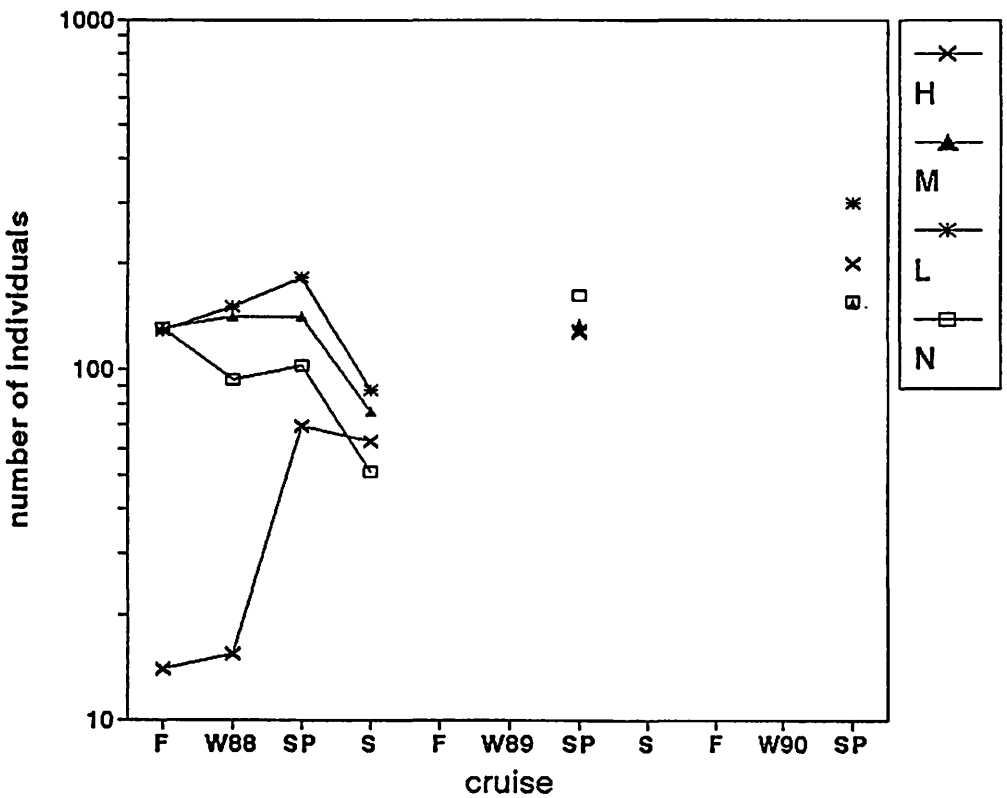

Figure 52. Abundance of small tube builders (per 0.06 m^2) at Cell B versus time.

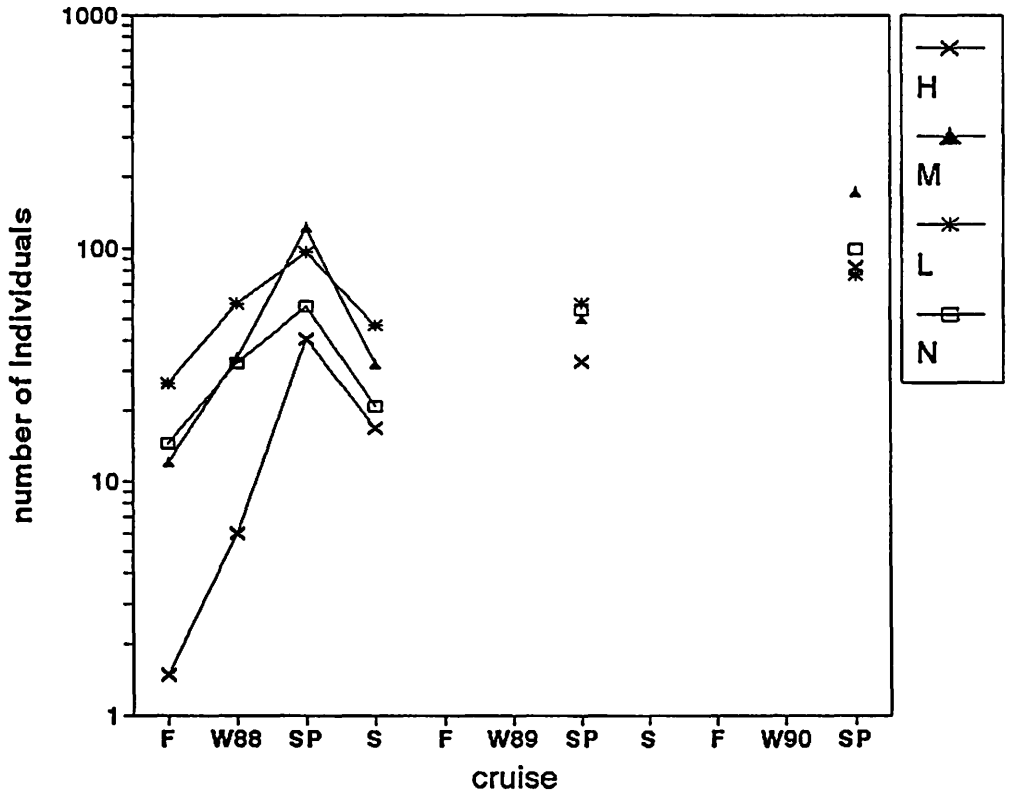

Figure 53. Abundance of shallow burrowers (per 0.06 m^2) at Cell B versus time.

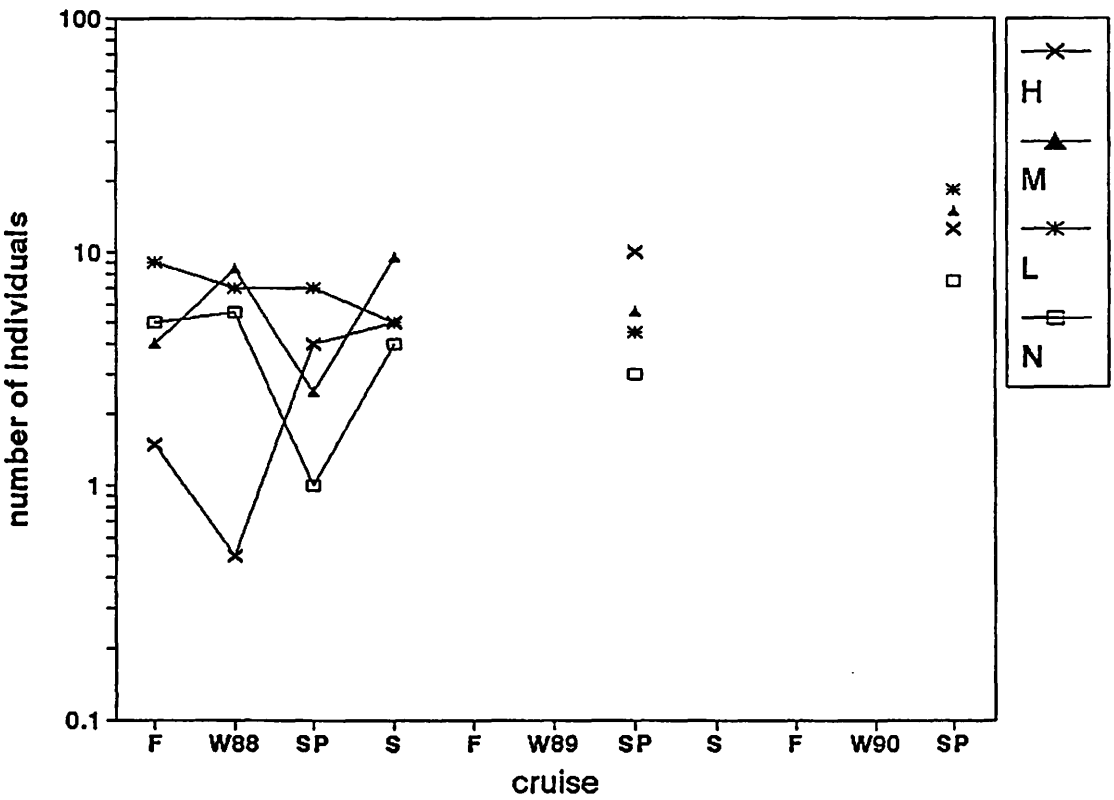

Figure 54. Abundance of large tube and burrow builders (per 0.06 m^2) at Cell B versus time.

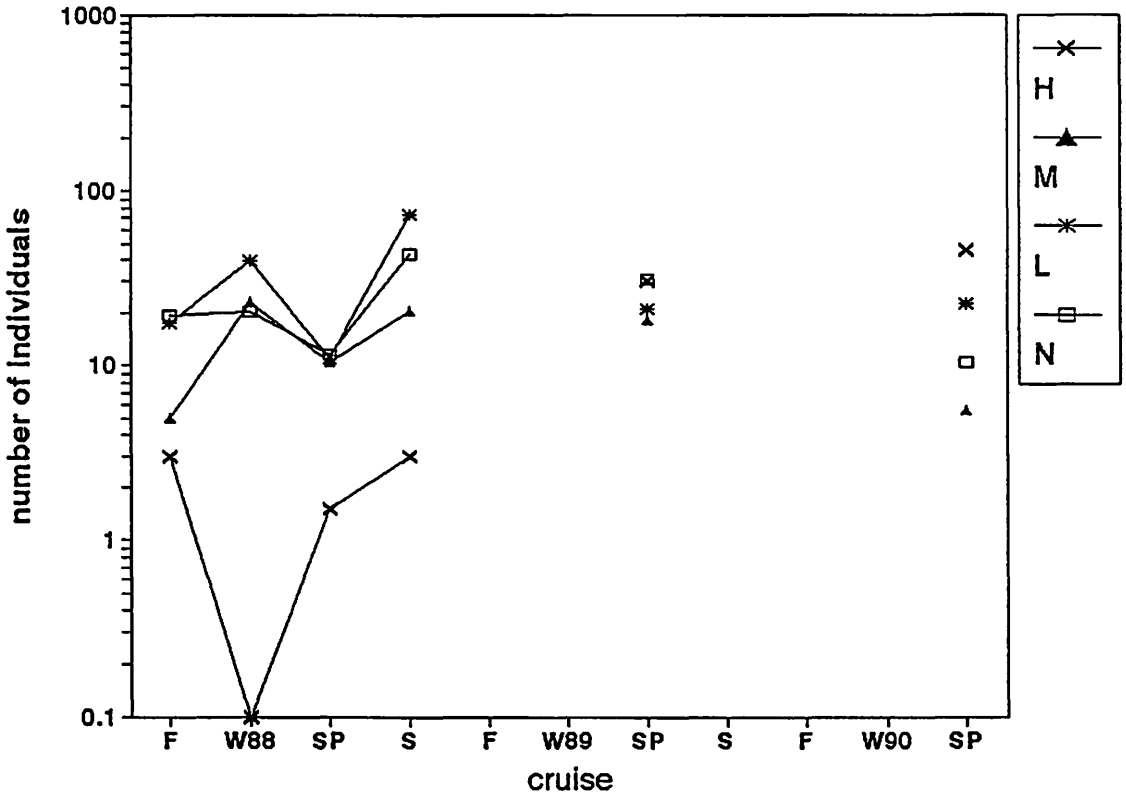

Figure 55. Abundance of deep burrowers (per 0.06 m^2) at Cell B versus time.

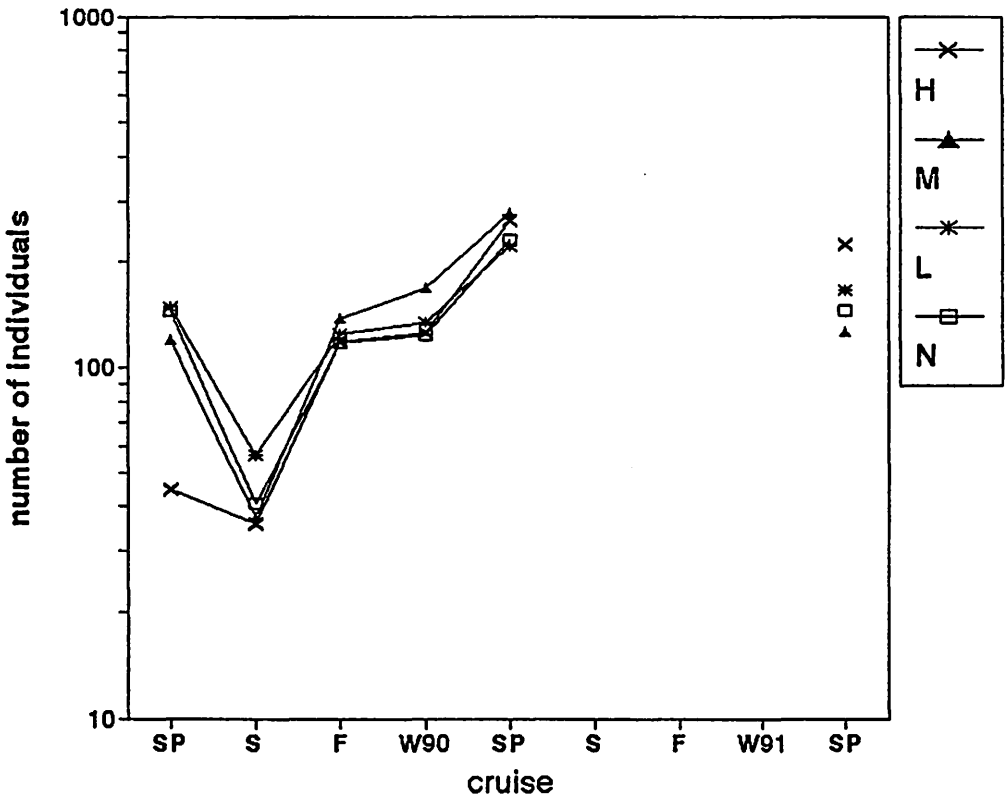

Figure 56. Abundance of small tube builders (per 0.06 m^2) at Cell C versus time.

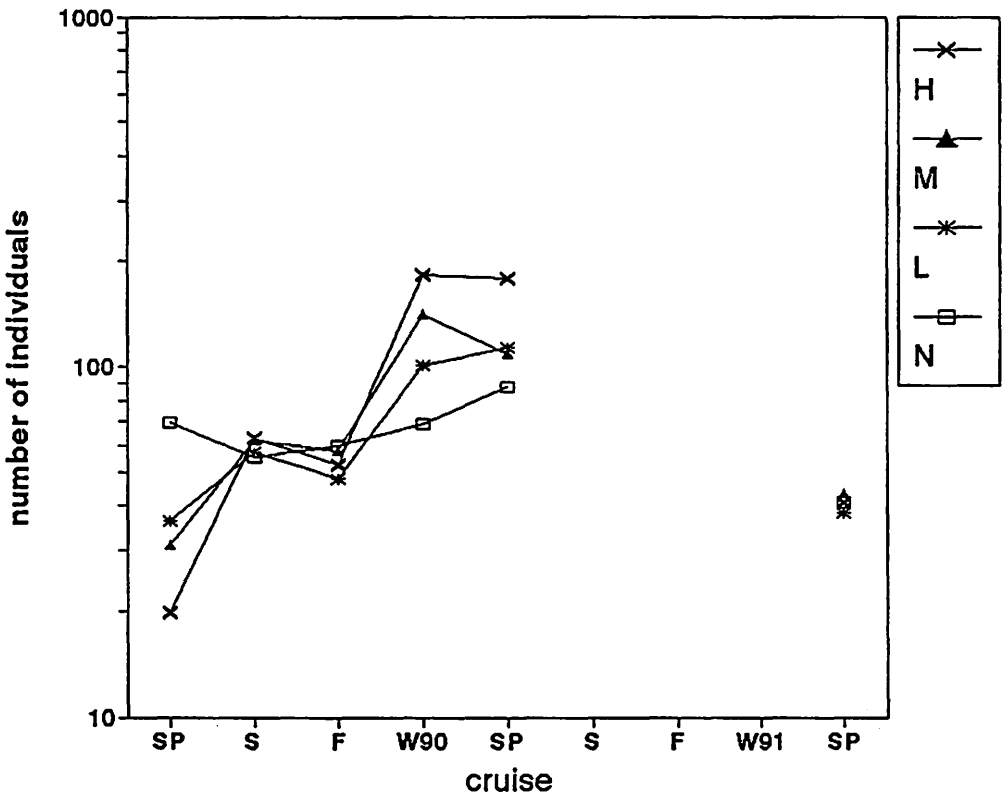

Figure 57. Abundance of shallow burrowers (per 0.06 m^2) at Cell C versus time.

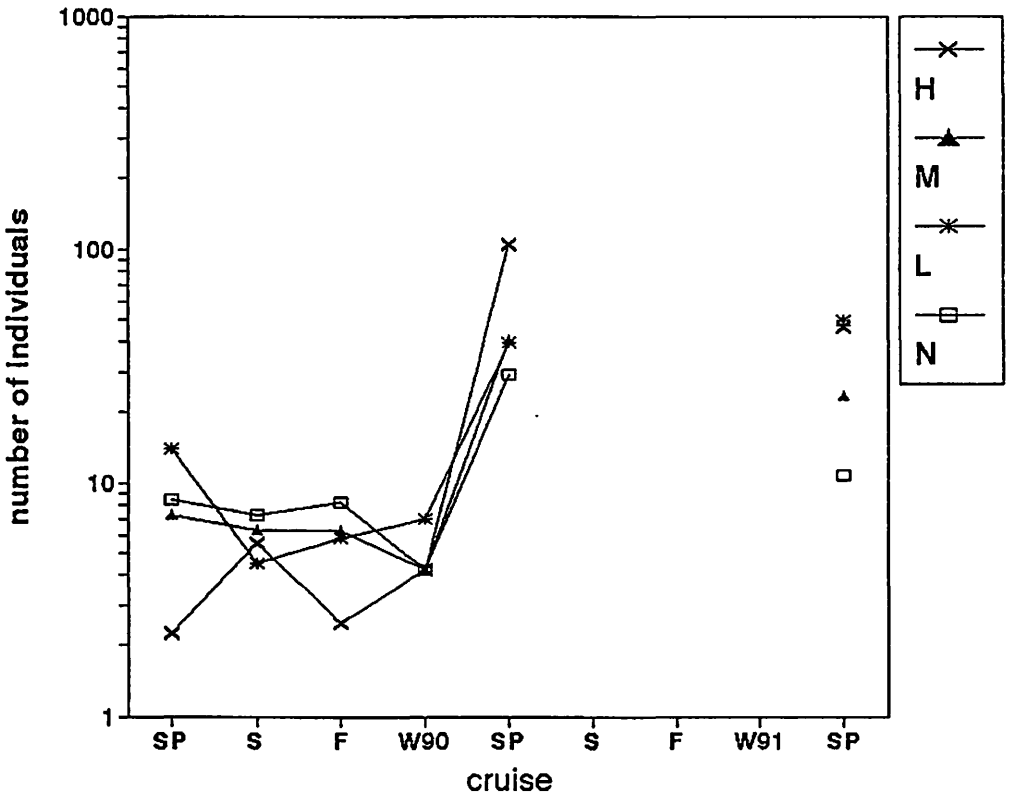

Figure 58. Abundance of large tube and burrow builders (per 0.06 m^2) at Cell C versus time.

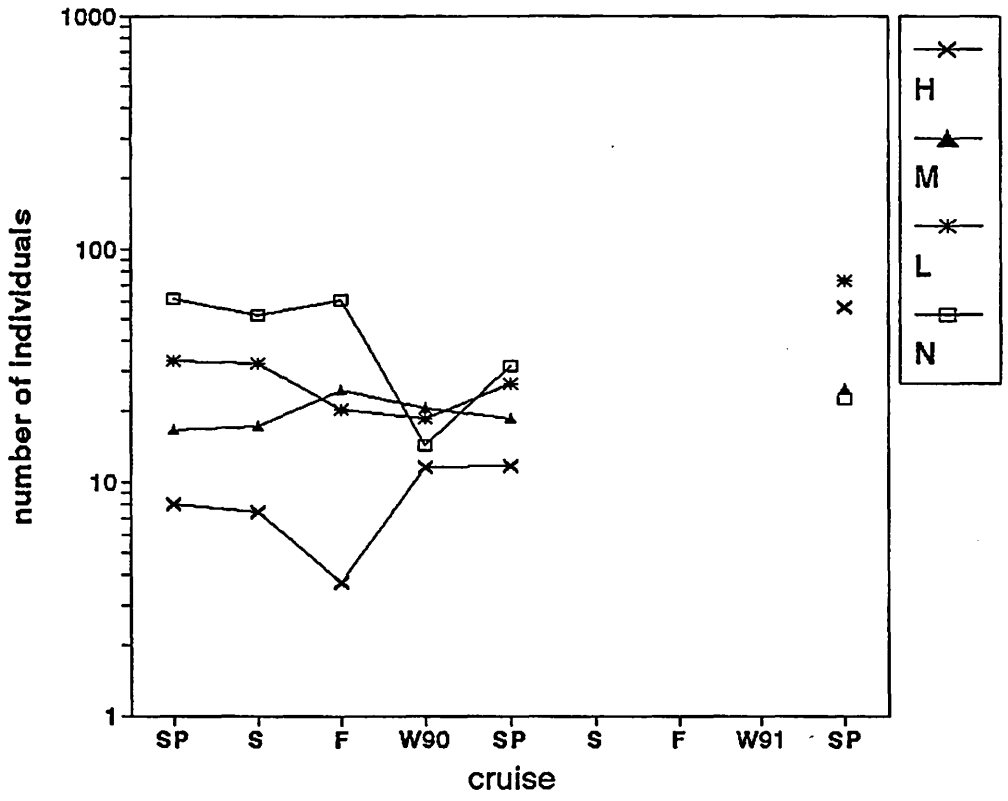

Figure 59. Abundance of deep burrowers (per 0.06 m^2) at Cell C versus time.

stations by winter 1990 (Figure 59). For this functional group there is some evidence for an overburden level-related effect on abundance during the first 3 sampling quarters.

DISCUSSION

The major effects of dredged material disposal at the Wolf Trap Alternate Disposal site were in the form of reduced faunal densities, biomass and species richness rather than major changes in the composition of dominant species. For both disposal cells, there was evidence during the first year of sampling for significant reductions in organism numerical density, biomass and species richness at stations receiving high dredged material overburdens (> 15 cm), but not at stations receiving lower overburdens. After the first sampling year these differences were obscured by natural variability.

For the most part, long term trends in abundance and species richness in the ambient community were mirrored by similar trends at the disposal sites. Thus, organism densities and species richness tended to be higher for Cell C station collections than for Cell B station collections, reflecting the patterns observed at stations C1 and C2. This suggests that the 'state' of the ambient community at the time of the disturbance event may have a major influence on the absolute levels of measured organism density and species richness following disturbance events.

Community analyses of similarity patterns indicate that faunal collections at stations receiving high dredged material overburdens converged with collections at stations that did not receive dredged material within less than 2 years. Recovery at the community level was more rapid for Cell C (less than 6 mo.) than for Cell B (less than 18 mo.). Stations receiving lower dredged material overburdens were not greatly affected at the community level. It should be noted, however, that these stations (i.e. MDM and LDM) were located nearer to the edges of the disposal areas than were the HDM stations. Closer proximity to the ambient community may facilitate recolonzation by juvenile and adult forms, thereby enhancing rates of community recovery.

There was no compelling evidence for successional progressions in dominant species composition following the disposal of dredged material. Analyses of dominant species composition for station groups identified in community analyses showed that effects of dredged material disposal were primarily due to changes in the relative abundances of dominant species, rather than shifts in community composition. Few species exhibited opportunistic responses to the disturbance caused by dredged material disposal. Only the bivalve *Mulinia lateralis*, polychaete *Spiophanes bombyx* and gastropod *Acteocina caniculata* exhibited high abundances at high, or in some cases moderate, dredged material overburden sites at times when they were rare at other sites.

The core group of species that were common in the ambient community (NDM, C1 and C2 stations) throughout most of the study were negatively impacted by high dredged

material overburdens for at least the first quarter, and often for up to a year, following the initiation of sampling at each disposal cell. The species in this group represented a diversity of taxa and functional types including epifauna and infauna, surface and subsurface deposit feeders and carnivore-omnivores, but most were relatively small. For the most part, the mechanisms by which these species were excluded from the disposal cells (e.g. recruitment processes, lack of appropriate habitat) can not be assessed in the present study.

When functional group responses to each disposal event were examined, again, the evidence for successional progression in the community is equivocal. Both small, surface-dwelling fauna and large infaunal tube and burrow builders exhibited similar response patterns following disturbance. But, consistent with predictions based on earlier studies, the deep burrowing functional group had slower recovery rates at both cells. Although the life histories and general ecology of most of the organisms in this latter group are poorly known, Schaffner (1990) suggested that they may live in association with subsurface biogenic structure. Thus, they may have been limited from high dredged material overburden sites by loss of suitable subsurface habitat.

The results of this study indicate that benthic communities of the Wolf Trap region of lower Chesapeake Bay recover from major disturbance events associated with the disposal of dredged material within less than 2 years following the cessation of disposal activity. However, given the existing evidence, it is difficult to determine why rates of

community recovery were greater for Cell C than for Cell B. The duration of disposal period for Cell C was longer (ca. 10 months) than it was for Cell B (6 months). Thus, it seems possible that there was more recolonization of Cell C prior to the initiation of monitoring in May 1989. Additionally, the cessation of disposal into Cell C was in the early spring, a period of high recruitment in Chesapeake Bay. This may have enhanced the potential for recolonization of Cell C via larval recruitment. Disposal into Cell B ceased in the late fall, a time of relatively low reproduction and low larval recruitment potential for many Chesapeake Bay species.

Comparisons With Results of Camera Profile Surveys

Results of profile camera surveys to the Wolf Trap Alternate Disposal Site were previously reported by Schaffner et al. (1987b, 1988 a,b,c, 1990 and 1991). A summary of these results is presented in Appendix 5 of this report. In this section the major findings are summarized for comparison with the faunal surveys.

As indicated earlier, the profile camera system was useful for mapping the distribution of dredged material at the disposal site. The relatively coarse material placed in Cell B was easily recognized on the basis of textural and color differences. Coarse sands, gravel and grey clays were observed. These sediments were readily distinguished from the very fine sand and silt sediments characteristic of the Wolf Trap area. Dredged material placed in Cell C consisted of fine sands, silts and light grey clays. It was recognized at high overburden stations where distinct contacts with underlying Wolf Trap

sediments were observed, but was more difficult to identify at moderate and low overburden levels. There was some evidence, even on the first visit to Cell C, for biological reworking of this material at MDM and LDM stations.

Over the course of the study the gradual reworking of dredged material by physical and biological processes was observed. By the spring of 1989, 18 months after monitoring of Cell B began, a dredged material signature was still present at HDM stations, but the signature was obscure at MDM and LDM stations. There was some evidence in profile photographs and box core observations for the deposition of additional new sediment similar to ambient Wolf Trap sediments on top of coarser dredged material. This may have resulted via natural resuspension and sediment transport processes, or from winnowing and reworking of dredged material. By spring 1990 the dredged material signature was lost at most stations, including HDM.

By the winter and spring of 1990, within a year after monitoring of Cell C began, there was evidence of extensive biological, and possibly physical, reworking of dredged material. The distinct layering of sediments was no longer visible, even at some stations that had received high dredged material overburdens. By spring 1991 there was no DM signature observed at any Cell C stations.

The profile monitoring of benthic community changes was less successful. As indicated earlier, the major changes documented in the faunal surveys of the disposal cells were

changes in the abundances of dominant species and species richness, rather than major shifts in community composition and functional groups. In particular, there was no major progression from assemblages dominated by small surface deposit feeders to large bioturbating infauna. Results of the camera survey indicate that disposal event-induced faunal changes had a lower 'signal-to-noise' ratio than did faunal changes associated with other factors such as seasonal shifts in temperature. Thus, in terms of biogenic features observable in profile photographs, seasonal effects and high spatial variability made it difficult, in most cases, to clearly identify DM-induced changes in the community.

ACKNOWLEDGEMENTS

This study could not have been completed without the dedicated efforts and teamwork of the many people who piloted the research vessels, operated the winches, hauled and sieved the tons of bottom sediments, performed the tedious sorting and counting of benthos, analyzed the sediment characteristics and participated in the data analysis and preparation of this report. To all of them I extend my sincere thanks for jobs well done.

Jeff McKee, Robert Blama, Gene Batty, Brian Walls and others at the Corps of Engineers Baltimore and Norfolk District Offices provided guidance through this major project. I especially appreciate their understanding and support through the final months of preparation of this report.

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