Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Final Report

Injury to Deep Benthos

Subtidal Study Number 2B
(Air/Water Study Number 2)
Final Report

Howard M. Feder
University of Alaska Fairbanks
Institute of Marine Sciences

for:

Alaska Department of Fish and Game
Habitat and Restoration Division
333 Raspberry Road
Anchorage, Alaska 99518-1599

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Study History: Subtidal Study Number 2B was initiated as part of a detailed study plan in 1989 under Air/Water Study Number 2 (Petroleum Hydrocarbon-Induced Injury to Subtidal Marine Sediment Resources). In 1991, the project was reclassified as Subtidal Study Number 2 and renamed (Injury to Benthic Communities) and had distinct shallow tidal and deep tidal project objectives. In 1992, the two elements were split into separate project numbers 2A (Injury to Shallow Benthic Communities and 2B (Deep Water Benthos). Two previously reviewed status reports in 1991 and 1993 (both entitled Injury to Deep Benthos) contributed to the development of this final report.

Abstract: This study was designed to assess the possible injury by petroleum, derived from the *Exxon Valdez* oil spill to benthic infaunal resources within Prince William Sound in water deeper than 20 m. The sampling plan was developed to coordinate with several other concurrent programs within Prince William Sound. Analyses of benthic biological data collected from 14 bays in Prince William Sound in 1990 at 40, 100 and >100 m, by univariate and multivariate techniques, demonstrated no obvious disturbance effects on the benthic biota 16 months after the oil spill. In all multivariate analyses, the major environmental variables related to the composition of benthic assemblages were sediment parameters such as percent silt, clay, mud, percent water and amount of nitrogen and carbon in sediment. Although limited amounts of petroleum hydrocarbons and presence of hydrocarbon degrading bacteria were detected at some sites at 40 and 100 m in 1989 and 1990, minor or no impact was sustained by benthic fauna of the deep benthos within the Sound. It is apparent that the current speed within Prince William Sound during the oil spill was sufficient to flush out toxic fractions of the oil spill before they could damage the fauna within the deep benthos.

Key Words: Community structure, benthic organisms, deep benthos, *Exxon Valdez* oil spill, infauna, multivariate analysis, Prince William Sound, univariate analysis.

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EXECUTIVE SUMMARY

This study addressed the program element Subtidal Study Number 2B (Air/Water Study Number 2) (Injury to Deep Water [$\geq$40 meters]) Benthic Infaunal Resources from Petroleum Hydrocarbons) for benthic biota located within Prince William Sound. The objective of the investigation was to determine if any effects on the benthos were observable 16 months after the *Exxon Valdez* oil spill (EVOS). The benthos was sampled, at depths of approximately 40, 100 and >100 m, at a series of sites within and outside the EVOS trajectory. All sites were located in the vicinity of shores with established sea-grass (*Zostera marina)* beds. The benthic biological sampling plan was developed to coordinate with the group responsible for collection and hydrocarbon analysis of sediment samples (the NOAA Technical Services Task Force, Analytical Chemistry Group (TSTF-ACG), NOAA/NMFS, Auke Bay, Alaska). Fourteen sites were sampled 1-23 July 1990. Five replicate biological samples and one sediment sample were collected with a 0.1m^2 van Veen grab at each of three depths within seven sites potentially exposed to the EVOS and three depths within seven sites identified as potentially uncontaminated by the EVOS. Sites within the EVOS trajectory (OT) were Northwest Bay, Disk Island, Herring Bay, Bay of Isles, Snug harbor, Chenega Bay and Sleepy Bay. Sites outside of the EVOS trajectory (R) were West Bay, Rocky Bay, Zaikof Bay, MacLeod Harbor, Lower Herring Bay, Moose Lips and Drier Bays. Biological material from each grab was washed through 1.0 and 0.5 mm nested stainless steel screens.

Sediment samples were analyzed for grain-size parameters, water content, organic carbon and nitrogen. OC/N values were computed. Stable carbon isotopic ratios (δ^{13}C) were determined. Petroleum hydrocarbon analysis was accomplished by the TSTF-ACG for samples collected at 40 and 100 m. Petroleum hydrocarbon data are reported as polycyclic aromatic hydrocarbons (PAHs). Shannon diversity, Simpson dominance and species richness values for benthic biota were calculated. Data, based on taxon abundance values, were used for classification and ordination of stations. Station groups were identified by hierarchical cluster analysis. Principal coordinate analysis (PCA) and non-metric multi-dimensional scaling (MDS) were used as aids for interpretation of station groups. Stepwise multiple discriminant (MDA) and MDS analyses were applied to biological abundance data from 40 and 100 m to correlate station group separation with environmental variables. Following division into station groups by multivariate techniques, the taxa having the greatest contribution to this division were determined using the SIMPER program.

Analyses of sediments from 40 and 100 m for 1990 demonstrated that oil (derived from EVOS and/or other sources) was not detectable or was present in extremely low concentrations. Another indication of absence or low levels of hydrocarbons within deep subtidal sediments was demonstrated by assessment of δ^{13}C values in sediments. A comparison of δ^{13}C values of sediment from sites in 1990, at all depths (within and outside the EVOS trajectory), with pre-EVOS sediment samples from 1979, 1980 and 1981 indicated no significant differences in values between time periods.

At all stations occupied at 40 m, polychaetous annelids were dominant in abundance. High or low faunal abundance, biomass and species richness values occurred at stations within and outside of the EVOS trajectory. Some of the lowest values for abundance, biomass and species richness occurred at stations outside of the EVOS trajectory (i.e., reference stations). Shannon diversity values were generally similar at all stations but some of the lowest values occurred at stations outside the oil trajectory. Simpson dominance values were low at most stations (indicating no dominance by any taxa) with highest values (indicating dominance and possible disturbance) often recorded at reference stations. Taxa characteristic of disturbance (e.g., capitellid polychaetes) were never restricted to stations within the EVOS trajectory. In fact, at all stations with high faunal abundance values, within and outside the EVOS trajectory, taxa characteristic of disturbance were present, Multivariate analyses of abundance data from 40 m identified two groups of stations: Group I (Zaikof Bay, West Bay and Drier Bay--all out of the EVOS trajectory) and Group II (MacLeod Harbor, Rocky Bay, Moose Lips Bay, Zaikof Bay-out of the EVOS trajectory and Disk Island, Northwest Bay, Sleepy Bay, Herring Bay and Bay of Isles- within the EVOS trajectory). Three stations (Lower Herring Bay (R), Snug Harbor (OT) and Chenega Bay (OT) did not join a group. MDA separated Station Group I from Group II and Chenega Bay by the higher percentage of silt and amount of Nitrogen in sediments of Group I. Application of MDS to the biological and environmental data also resulted in separation of station groups and stations by percent silt and Nitrogen in sediments but also by the PAH C_4 Naphthalene (these three variables resulted in the best match between the MDS abundance plot and the environmental variables). C_4 Naphthalene occurred at stations within and outside of the EVOS trajectory, and, in fact, occurred at its highest concentrations at two reference stations, Lower Herring Bay and Drier Bay. The latter finding indicates that although C_4 Naphthalene may have been derived from the EVOS, it was also a hydrocarbon constituent resulting from other oil sources in the Sound. High benthic faunal abundance at stations within Group II and Chenega Bay, with relatively low sediment nitrogen and carbon values, suggests the advection of particulate organic carbon (POC) to fauna here from external sources.

All comments made concerning fauna (i.e., dominance of polychaetes, abundance, biomass, species richness, Shannon diversity, species richness, taxa characteristic of disturbance) at stations at 40 m applies to benthic biota at 100m. Multivariate analysis of abundance data from 100 m divided stations into four station groups with one station (MacLeod Harbor: R) that did not join a group. Three of the station groups comprised a mixture of stations within and outside of the EVOS trajectory. MDA clearly separated stations of Group II (two stations within and two outside of the EVOS trajectory) from all other stations based on higher Nitrogen content and concentration of C_3 Dibenzothiophene at stations of Group II. MDS separated stations based on higher nitrogen and C_3 Dibenzothiophene but also by percent water in sediment and percent mud. These variables show the best correlation with the biological similarities in the MDS plot of biological data, and "explain" the separation of stations into groups. The presence of a hydrocarbon considered to be a PAH analyte of EVOS, C_3 Dibenzothiophene, at stations within and outside of the EVOS trajectory suggests that this hydrocarbon is not related to the oil spill. As suggested for fauna at 40 m, high abundance values at three of the four stations within Group IV (Mooselips Bay: R, Sleepy

Bay and Herring Bay: OT) in sediments with relatively low carbon and nitrogen values suggest advection of POC to fauna here from external sources.

Multivariate analysis, particularly MDS, of abundance data from >100 m separated stations into three groups. The largest group (Group I) comprised a mixture of stations within and outside the EVOS trajectory. The other groups consisted of stations outside of the EVOS trajectory. Separation of stations by MDA and MDS resulted in percent water, nitrogen, carbon and percent clay separating the stations. No oil data were available for stations at this depth. Stations within Group I had the highest abundance values of all stations sampled. Higher abundance values for the latter group appear related to an apparent greater input of allochthonous POC compared to the other stations.

Analyses of benthic biological, sediment and hydrocarbon data collected at sites within the trajectory of the EVOS, at depths of 40 and 100 m within Prince William Sound, by univariate and multivariate techniques, demonstrated no obvious disturbance effects on benthic biota 16 months after the oil spill. At all sites, the major environmental variables related to composition of benthic biological assemblages were sediment parameters (i.e., percent silt, clay, mud, water and amount of nitrogen and carbon in sediment. Two polycyclic aromatic hydrocarbons (C_4 naphthalene and C_3 dibenzothiophene) added additional structure to the MDS plots of environmental variables and aided in the interpretation of spatial dispersion of stations in the biotic plots (i.e., increased similarity of environmental plots to the biotic plots). However, these hydrocarbons (analytes that could represent the presence of *Exxon Valdez* oil) were present at sites within the EVOS trajectory as well as outside of that trajectory. In fact, in some cases, these hydrocarbons were in higher concentrations at reference sites.

In the summer of 1989, shortly after the EVOS, the numbers of hydrocarbon degrading bacteria in sediments at depths >40 m were below detection limits. However, measurable numbers of hydrocarbon degrading bacteria were present, in 1990, at 40 and 100 m at some sites within the EVOS trajectory. The latter finding suggested mobilization of limited amounts of residual labile hydrocarbons to sediments at these sites. *Exxon Valdez* oil was generally not detected (or was present in extremely low concentrations) in sediments at depths >40 m immediately after the EVOS and for the years following the spill. Thus, it is probable that the limited flux of oil to the bottom in the months immediately after the EVOS resulted in minor, or no, impact on deep benthic fauna throughout Prince William Sound. Assessment of the physical-oceanographic dynamics within the Sound explain the absence or low levels of oil in sediments at depths >40m as well as absence of disturbance signals within the benthic fauna in 1990, approximately 16 months after the EVOS. The general circulation pattern within the Sound is related to the westward flowing Alaska Coastal Current (ACC) of the Gulf of Alaska that enters Prince William Sound through Hinchinbrook Entrance, transits the Sound from east to west and exits through Montague Strait into the Gulf. The coastal circulation within Prince William Sound served as a conduit for oil spilled from the *Exxon Valdez*. Immediately after the EVOS it was considered probable, based on the high suspended sediment load typically found within the ACC, that the oil would adhere

to suspended sediments within the water column and sink to the bottom. However, the ACC is affected by freshwater discharge which was at a record low at the time of the EVOS. Thus, under conditions of lower fresh water discharge, the amount of suspended sediment carried by the current was probably below normal, and the probability of bonding of oil with suspended particles was greatly decreased. Nevertheless, despite the relative slowness of the ACC in 1989, it was believed that current speeds throughout the Sound, several months after the spill, were high enough to continue to flush the waters of the Sound. It is assumed that some of the oil accumulated within some intertidal sediments within the Sound will leach out for a number of years. However, such oil, if deposited subtidally, would not be expected to comprise toxic hydrocarbon components, but might become an energy source for bacteria which in turn could serve as a food source for benthic fauna.

High faunal abundance values were recorded at many stations at sites within and outside the EVOS trajectory in 1990. These values were considerably higher than those recorded on the shelf of the northeastern Gulf of Alaska from 1974-76 and two bays in Prince William Sound in 1982. Based on a fourteen-year data set for the Port Valdez (a fjordic embayment of Prince William Sound) benthos, extreme interannual fluctuations in abundance are characteristic of benthic fauna there, and such changes are probably characteristic of benthos throughout the Sound. The high abundance values at many sites within the Sound in 1990 confuses the assessment of effects of the EVOS on the deep benthos. Thus, if high benthic abundance represented faunal enhancement as a response to an increased food source derived from the EVOS and associated hydrocarbon-degrading bacteria, it would not be possible to separate these effects from natural events occurring during the same period. However, a biological occurrence documented for the Sound in 1990 may explain, in part, the high abundance values at some deep benthic stations. Prince William Sound is a pelagic system in which carbon in the water column (POC) is decoupled from the benthos with most POC flowing through pelagic trophic links. Zooplankton abundance levels were low in 1990, suggesting that a greater flux of POC, as ungrazed phytoplankton, to the benthos would be expected that year. The high benthic faunal abundance levels in 1990 and presence of large numbers of opportunistic taxa appear to reflect the flux of unusual amounts of carbon, available as food, to the bottom. It is also possible that some high faunal abundance values at stations within the EVOS trajectory might have resulted, in part, from a synergistic relationship between the small amounts of oil that settled to the bottom, the hydrocarbon degrading bacteria present and the increased POC that fluxed to the bottom as ungrazed phytoplankton.

In conclusion, regardless of the origin of carbon on the bottom in 1990, the benthic system in Prince William Sound within sites examined at >40 m was a species rich and diverse one 16 months after the EVOS. It is apparent that the current speed within the Sound was sufficient to flush out toxic fractions of the EVOS so that little or no damage occurred to the fauna within the deep benthos.

INTRODUCTION

Small macrobenthos that live on and within subtidal sediments (e.g., infaunal organisms such as polychaetous annelids, bivalve mollusks) represent good *in situ* monitors for measuring effects of oil fluxing to the bottom (for example see Cabioch et al., 1978; Kineman et al., 1980; and Sanders et al., 1980). These organisms are mostly sedentary or relatively slow moving, generally remain close to the site of larval settlement, and, consequently, are able to respond to localized conditions. Thus, the particular assemblages of macrobenthic organisms present at a site can be viewed as an integrated response to the environmental conditions at that site (Bilyard, 1987; Gee et al., 1992). Marine benthic macrofauna has been successfully used at various locations throughout the industrial world as a tool to measure effects of pollutants on the bottom (e.g., see Pearson, 1975; Cabioch et al., 1978; Pearson and Rosenberg, 1978; Gray and Mirza, 1979; Sanders et al., 1980; Kineman et al., 1980; Gray, 1982; Gray and Pearson, 1982; Warwick, 1986; Warwick et al., 1987; Gray et al., 1988; Gray, 1989; Kroncke et al., 1992).

It was expected that a certain proportion of oil derived from the *Exxon Valdez* oil spill (EVOS) in March 1989 would reach the bottom as a result of physical and biological processes. Benthic data collected elsewhere suggest that changes in species number, abundance, biomass, and diversity can be expected if sizable amounts of oil settle to the bottom. Changes in bottom fauna within Prince William Sound would have serious trophic implications since subtidal benthic invertebrates are important food resources for bottom-feeding species (Feder and Jewett, 1986; also see Jewett, 1978, Jewett and Feder, 1983, and Smith et al., 1978, for feeding habits of Tanner crab, and bottom fishes in the northeast Gulf of Alaska that are also common in Prince William Sound). Further, larvae of most benthic organisms in Prince William Sound move into the water column from March through June and are utilized as food by large zooplankters and larval and juvenile stages of pelagic fishes, salmon fry, and herring. Thus, damage to the benthic system by hydrocarbon contamination could affect feeding interactions of organisms on the bottom as well as in the water column.

This study addressed the program element AIR/WATER STUDY NUMBER 2 (Injury to Deep Water [>20 meters] Benthic Infaunal Resources from Petroleum Hydrocarbons) for benthic biota located within Prince William Sound. The objective of the investigation was to determine if any effects on the benthos were observable 16 months after the *Exxon Valdez* oil spill. The benthos was sampled, at depths of approximately 40, 100 and >100 m, at a series of sites within the EVOS trajectory and outside of that trajectory. All sites were located in the vicinity of shores with established sea-grass (*Zostera marina*) beds. Sites, where possible, were to be adjacent to study areas examined by S. Jewett and associates within sea-grass beds (see Final Report by Jewett et al., 1993a).

OBJECTIVES

The original objectives of this study were:

1. To determine if disturbance occurred in the benthos at oiled sites as assessed by comparing taxon (primarily determined at the Family level, abundance and biomass, diversity and richness, and trophic composition of benthic biota living on similar substrate at approximately 40, 100, and >100 m below sea grass beds at oiled and unoiled sites.

2. To determine if changes occurred in the benthos as determined by comparing taxon (primarily determined at the Family level) abundance and biomass, diversity and richness, and trophic composition of benthic biota living on similar substrate at approximately 40, 100, and >100 m below sea grass beds in oiled and unoiled bays on an annual basis for at least five years.

3. If changes were detected in the faunal components of the benthic system, to determine the time required for the benthos to recover to an undisturbed or relatively stable assemblage of taxa.

4. If changes were detected in the benthic fauna, to examine the relationship between the accumulation and retention of hydrocarbons in sediments and the effect on the benthic biota.

Due to termination of the project after the first year of sample collection and analyses, the temporal component of five years did not apply.

METHODS

Sampling

The benthic biological Sampling Plan was developed to coordinate with other concurrent programs within Prince William Sound. Fourteen bays (sites) were sampled (Figure 1) from 1-23 July 1990 on the NOAA ship *Davidson*. Sediment samples for hydrocarbon analysis were collected by the NOAA Technical Services Task Force, Analytical Chemistry Group [TSTF-ACG], NOAA/NMFS, Auke Bay, Alaska. Additional sediment samples were taken by Institute of Marine Science, University of Alaska Fairbanks personnel at each station for sediment analysis. Five replicate biological samples were collected with a 0.1 m^2 van Veen grab at each of three stations within seven sites identified as potentially oil-exposed (i.e., within the EVOS trajectory) and three stations within seven sites identified as potentially uncontaminated (not within the EVOS trajectory). All stations were at approximate depths of 40, 100, and >100m on a transect extending below seagrass (*Zostera*) beds within each of the identified sites. A total of 42 deep stations x 5 replicates were collected in conjunction with the microbiological and hydrocarbon sampling projects underway on the same ship

platform. Benthic samples at oil-exposed (i.e., within the EVOS oil trajectory) and unexposed (i.e., not within the EVOS oil trajectory) sites were collected on bottoms that were as physically similar as possible, based on chart data and some preliminary grab samples accomplished before actual sampling occurred. As noted later in this Report, sediment type at some of the stations within sites was dissimilar. At a few of the sites it was not possible to find a suitable substrate at the deepest stations of the transects; in these cases stations >100 m were not occupied. The seven sites within the EVOS trajectory (noted as OT sites through this report) were Northwest Bay (NB), Disk Island (DI), Herring Bay (HB), Bay of Isles (BI), Snug Harbor (SH), Chenega Bay (CB) and Sleepy Bay (SB). The seven unexposed sites (noted as R for reference sites throughout the report) sampled were West Bay (WB), Rocky Bay (RB), Zaikof Bay (ZB), MacLeod Harbor (MH), Lower Herring Bay (LB), Moose Lips (MB) and Drier Bays (DB) (Figure 1).

Biological material from each grab was washed, on shipboard, through 1.0 mm and 0.5 mm nested stainless steel screens and preserved in 10% formalin-seawater solution buffered with hexamine.

Analysis and Processing of Data

Bottom sediment samples were analyzed for grain-size parameters according to Folk (1980). Water content, by weight, in gross sediments was estimated. Organic carbon and nitrogen were analyzed on carbonate-free samples of bottom sediments, using a Perkin-Elmer Model 240B CHN analyzer. OC/N values were computed on a weight to weight basis. Carbonate-free samples were analyzed for stable carbon isotopes $\delta^{12}C$ and $\delta^{13}C$ with a VG 602E mass spectrometer (see Naidu et al., 1993a). Stable carbon isotopic ratios ($\delta^{13}C$) calculated from these values are expressed relative to a PDB Standard, with a precision of 0.2%.

Sediment samples collected for petroleum hydrocarbon analysis were analyzed by NOAA Technical Services Task Force, Analytical Chemistry Group [TSTF-ACG], NOAA/NMFS, Auke Bay, Alaska.

In most benthic biological studies, as well as this study, organisms collected by grab and subsequently used in analyses include infaunal macrofauna, slow-moving macrofaunal surface dwellers, and small, sessile epifauna. Highly motile epifauna such as large gastropods, shrimps, crabs, and sea stars (except the infaunal sea star *Ctenodiscus crispatus*) are not adequately collected by a grab and, consequently, are usually excluded from analyses. The latter types of organisms were deleted from the present study as well. Meiofaunal organisms (e.g., nematodes, ostracods and harpacticoid copepods) were excluded from all analyses. The remaining organisms were identified to the Family level. Generic and specific designations were included in raw data sheets and computer printouts whenever these categories were known. Data were analyzed utilizing Family or higher taxonomic categories. Warwick (1988), Warwick (1993), and other papers (Rosenberg, 1972; Heip et al., 1988) indicate that better resolution of multivariate data often emerge when taxonomic levels higher than species are used.

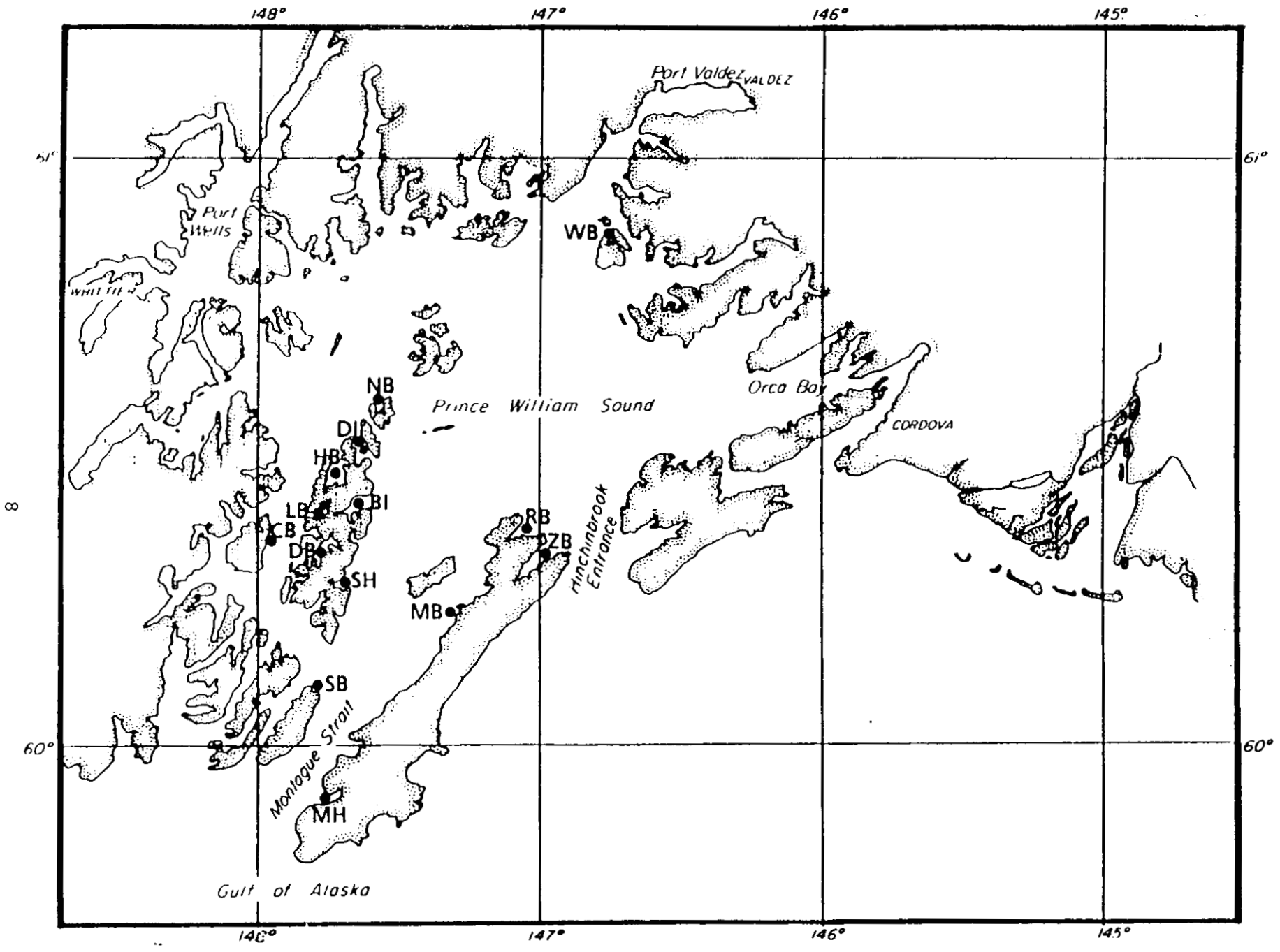

Figure 1. Sites sampled for benthos at 40, 100 and >100 m in Prince William Sound in July 1990. See text (pg. 4) for station symbols.

Data were recorded on data sheets, entered on magnetic tape and processed with the VAX computer at the University of Alaska Fairbanks. Previously written programs for comparisons of number of taxa, rank abundance and biomass, and diversity of taxa were used.

Statistical Procedures

Univariate Analyses

Various measures of diversity were calculated. The number of taxa and diversity are based on identifications to Family level or higher. Indices presented are: Shannon diversity (measures total diversity; weighted in favor of rare taxa), Simpson dominance (useful for identifying dominance by one or a few taxa at a station), and Species Richness. The methodologies used for univariate measures are included in Appendix I (also see Bayne et al., 1988, for review of univariate techniques).

Multivariate Analyses

Station groups (based on taxon abundance) were tentatively identified using hierarchical cluster analysis. Principal coordinate analysis was then used as an aid in interpretation of the cluster analyses and for identifying misclassifications of stations by cluster analysis. (see Appendix I for details of methodology). An additional ordination procedure, non-metric multi-dimensional scaling (MDS), was applied to the abundance data (Kruskal and Wish, 1978; Clarke and Green, 1988). This procedure is a multivariate method used extensively for assessing disturbances resulting from anthropogenic impacts to the environment (e.g., Gray et al., 1988, 1990; Warwick and Clark, 1991; Gee et al., 1992; Agard et al., 1993; Clarke, 1993; Nicolaidou et al., 1993; Olsgard and Hasle, 1993). As described by Gray et al. (1988) "...MDS attempts to construct a 'map' [in ordinal space] of the sites in which the more similar...samples, ...in terms of species abundances, are nearer to each other on the 'map'." The extent to which the relations can be adequately represented in a two dimensional map is summarized by a 'stress coefficient (should be $\leq$_0.15 [Clarke and Ainsworth, 1993]). Following division into station groups by classification and ordination analyses, the taxa having the greatest contribution to this division were determined using the SIMPER program (Warwick et al., 1990).

Stepwise multiple discriminant analysis (MDA), using the BMDP7M program, was applied to biological data at 40 and 100 m to correlate station group separation with environmental variables. Analyses were performed using sediment variables and hydrocarbon polycyclic aromatic hydrocarbons (PAHs). When variables were highly correlated, only one of the correlated pair was chosen for inclusion in the analysis (see discussion in Clarke and Ainsworth, 1993). Percentage values for sediment variables were arcsine transformed. MDA has been used elsewhere to test a biological model (e.g., benthic station groups) with environmental parameters (Flint, 1981; Shin, 1982; Weston, 1988: Feder et al., 1994). No hydrocarbon data were available for sediments at sites $\geq$100 m; consequently, MDA was not applied to biological station group data for this depth.

The relationship between environmental variables and community structure was also assessed

with the BIO-ENV technique of Clarke and Ainsworth (1993). Prior to analysis appropriate data transformations of environmental variables were performed. The BIO-ENV technique computes a rank correlation coefficient (a weighted Spearman coefficient: P^w) of all the elements of the similarity matrices underlying the ordinations of environmental variables and biota. All combinations of measured environmental variables are examined. There is a natural stopping rule for variable selection: the combination of variables which best 'explain' the community structure is that giving highest rank correlation coefficient-adding further variables reduces the correlation (Gee et al., 1992). MDS ordination plots are then constructed relating biotic variables to those combinations of abiotic variables which showed the highest correlation (see methodology in Clarke and Ainsworth, 1993). Programs used for MDS routines, SIMPER and BIO-ENV techniques are from a test version of PRIMER V3.1 kindly furnished by Dr. K. R. Clarke, Plymouth Laboratory, Plymouth, England.

RESULTS

Throughout this report, at all depths, stations selected on shipboard as within the *Exxon Valdez* oil spill trajectory are termed "within the EVOS trajectory" or "within the oil trajectory" or "OT." Stations not within the oil spill trajectory are termed "out of the EVOS trajectory" or "out of the oil trajectory" or "R" for Reference station.

Taxa identified to higher taxonomic levels collected at 40, 100 and $\geq$100 m at sites in Prince William Sound in 1990 are listed in Appendix II.

Data from Sites at 40 m

Sediment Parameters

Sediment grain size, and organic carbon, nitrogen, C/N and $\delta^{13}C$ values in sediment are included in Table 1.

Laboratory Observations of Oil in Samples Collected in July 1990

Some oil residues were observed in sorting dishes containing samples prepared in the laboratory for identification of biota. Oil droplets were detected in variable numbers of replicates of stations for six of the seven sites within the EVOS trajectory (Table 2). No oil was detected in samples from Sleepy Bay (OT) at 40 m. No oil was observed in samples from stations at sites out of the oil trajectory.

Sediment Oil Analyses

Petroleum hydrocarbon data (presented as polycyclic aromatic hydrocarbons [PAHs]) for sediments, as reported by NOAA (Technical Services Task Force: Analytical Chemistry Group:TSTF), are included in Table 3. The estimated polycyclic aromatic hydrocarbons (PAHs in ng/g) presented in this table are those considered by TSTF as present in *Exxon Valdez* crude oil (analytes) (Appendix III; also, see Jewett et al., 1993a, for further comments on EVOS analytes in sediment). Data in Table 3 suggest that PAH's indicative of EVOS were present at most sites, including those within the EVOS trajectory and those chosen as reference sites.

Table 1. Sediment grain size and other parameters for the 14 sites and three depths sampled in Prince William Sound in 1990. A "*" indicates that a station was located within the oil trajectory. See text for site abbreviations.

Site	Depth	% Grav	% Sand	% Silt	% Clay	% Mud	% Wat.	Mean	Sort.	Skew.	Kurt.	Carb.	Nitr.	C/N	$\delta^{13}C$
BI *	40	36.81	48.88	13.60	0.71	14.31	33.95	-0.2	2.9	0.6	1.0	0.92	0.11	8.28	-21.7
CN *	40	27.70	56.82	8.72	6.77	15.49	39.02	-0.3	3.5	0.7	1.4	1.59	0.19	8.56	-22.7
DI *	40	1.80	62.84	30.06	5.24	35.30	43.60	3.7	2.8	0.0	1.8	0.84	0.10	8.03	-21.9
HB *	40	34.14	49.02	15.75	1.10	16.85	39.60	0.7	3.0	0.1	0.6	1.17	0.12	9.35	-21.9
NB *	40	9.40	63.37	24.79	2.44	27.23	44.82	1.9	2.9	-0.1	1.0	1.56	0.14	11.26	-23.3
SB *	40	4.98	70.87	21.19	2.96	24.15	30.86	1.0	3.0	0.6	0.8	0.38	0.07	5.65	-22.5
SH *	40	0.00	63.23	35.50	1.27	36.77	32.63	2.9	2.3	-0.3	0.9	0.65	0.08	8.21	-22.7
DB	40	26.52	41.39	24.26	7.83	32.09	48.21	2.1	3.8	-0.2	0.7	2.32	0.26	8.79	-21.1
LH	40	1.99	57.89	36.11	4.00	40.11	59.34	3.7	1.5	0.0	3.1	6.44	0.54	12.01	-21.5
MB	40	13.11	49.36	23.44	14.10	37.53	35.70	2.8	4.2	0.2	1.0	0.80	0.13	6.29	-20.4
MH	40	0.00	52.19	29.32	18.51	47.82	31.50	5.6	3.2	0.7	1.2	0.55	0.09	6.11	-22.8
RB	40	0.00	64.49	28.28	7.23	35.51	39.22	4.2	2.0	0.6	1.5	0.75	0.10	7.80	-21.9
WB	40	0.00	25.57	66.18	8.25	74.43	51.60	5.1	1.7	0.5	1.3	1.75	0.23	7.73	-20.8
ZB	40	0.00	7.97	63.54	28.49	92.03	61.07	7.2	2.3	0.2	1.1	1.51	0.18	8.44	-22.0
BI *	100	3.12	29.88	47.87	19.13	67.00	71.77	5.6	3.2	-0.3	1.0	3.69	0.42	8.73	-21.7
CN *	100	26.10	50.90	13.45	9.55	23.00	33.80	1.3	4.4	0.4	1.7	0.49	0.08	6.23	-22.3
DI *	100	2.32	42.55	39.06	16.07	55.13	43.72	4.0	3.8	-0.1	0.8	0.60	0.09	6.99	-21.6
HB *	100	1.48	53.29	37.53	7.70	45.23	46.23	3.4	3.2	-0.1	0.9	0.93	0.11	8.40	-21.6
NB *	100	33.53	9.55	47.72	9.20	56.92	46.13	2.2	4.3	-0.5	0.6	1.11	0.14	8.02	-21.4
SB *	100	6.14	41.55	33.43	18.89	52.32	41.62	4.3	4.0	0.1	1.0	0.69	0.10	6.96	-21.7
SH *	100	0.00	8.24	54.92	36.84	91.76	62.20	6.7	2.1	-0.1	0.7	1.39	0.17	8.00	-21.5
DB	100	6.60	35.49	44.28	13.64	57.92	72.49	4.5	3.1	-0.2	1.3	2.71	0.33	8.11	-21.1
LH	100	12.28	43.66	29.93	14.13	44.06	52.57	3.3	4.1	0.0	1.0	2.24	0.26	8.81	-21.1
MB	100	3.60	37.76	42.76	15.88	58.64	31.82	4.9	4.3	0.2	1.0	0.54	0.09	6.16	-22.2
MH	100	0.00	92.36	0.33	7.31	7.64	26.06	2.1	2.0	0.0	3.4	0.21	0.07	2.79	-22.0
RB	100	0.00	4.53	61.15	34.33	95.47	51.61	7.4	2.7	0.2	1.0	0.91	0.13	7.06	-21.4
WB	100	0.00	4.04	51.60	44.38	95.98	52.58	8.1	2.4	0.2	1.2	0.73	0.12	6.11	-21.4
ZB	100	1.45	17.28	62.22	19.06	81.28	40.47	6.0	2.5	0.6	1.0	0.47	0.06	7.38	-22.5
BI *	>100	0.00	5.07	55.88	39.06	94.94	62.72	7.3	2.5	-0.1	1.3	1.18	0.15	7.97	-22.2
CN *	>100	3.05	78.62	9.39	8.94	18.33	29.80	2.6	2.9	0.4	2.0	0.43	0.07	6.12	-22.3
HB *	>100	0.00	30.15	47.66	22.19	69.85	56.38	5.7	2.8	0.1	0.9	1.39	0.17	8.12	-21.4
NB *	>100	0.00	11.53	39.12	49.35	88.47	46.86	7.3	2.7	-0.2	0.9	0.69	0.10	7.21	-21.8
SB *	>100	1.05	50.31	34.60	14.05	48.65	33.25	3.7	3.7	0.0	0.8	0.51	0.07	7.35	-21.7
DB	>100	0.00	28.50	48.65	22.87	71.52	74.66	5.6	3.1	-0.2	0.9	2.64	0.35	7.59	-20.9
LH	>100	0.00	34.34	41.88	23.79	65.67	72.09	5.1	3.3	0.0	0.8	3.07	0.37	8.34	-21.0
MH	>100	0.00	68.96	25.04	6.02	31.06	28.10	3.5	1.8	0.2	2.1	0.33	0.08	4.10	-22.1
RB	>100	0.00	14.39	55.11	30.50	85.61	47.69	7.0	2.8	0.3	0.9	0.60	0.09	6.92	-21.9
WB	>100	0.00	3.29	45.95	50.77	96.72	61.56	8.4	1.6	0.1	1.6	0.72	0.11	6.32	-21.3
ZB	>100	7.42	39.29	40.31	12.98	53.29	23.70	4.2	3.4	0.0	1.2	0.19	0.05	3.71	-23.7

Table 2. Laboratory observations of oil in samples at 40 m at sites in Prince William Sound, July 1990.

Station	Comments
Oiled Sites	
Disk Island	Oil droplets noted in two replicates of the 1.0 mm fraction and two replicates of the 0.5 mm fraction. Faint odor of H_2S.
Northwest Bay	Oil droplets in one replicate of the 1.0 mm fraction and two replicates of the 0.5 mm fraction. Strong H_2S odor in some replicates.
Bay of Isles	No oil in 1.0 mm fraction. Oil droplets in 0.5 mm fraction.
Herring Bay	No notes for 1.0 mm fraction. oil droplets in 0.5 mm fraction.
Sleepy Bay	No oil observed.
Chenega Bay	Oil droplets in one replicate of 1.0 mm fraction.
Snug Harbor	Oil droplets in two replicates of the 1.0 mm fraction. and one replicate of 0.5 mm fraction.
Unoiled Sites	
No oil observed at any site.	

Table 3a. Selected hydrocarbon concentrations for the 14 sites and three depths sampled in Prince William Sound in 1990. The selected hydrocarbons represent those analytes that indicate EVOS oil. See text for site and Appendix IV for abbreviations used for the hydrocarbons. A "*" indicates that a station was located within the oil trajectory.

Site	Depth	Naph	MeNap2	MeNap1	C1Naph	C2Naph	C3Naph	C4Naph	Biphenyl	Fluor	C1Fluor
BI *	40	28.859	32.731	32.851	65.581	30.371	30.294	0.001	26.194	27.761	0.001
CN *	40	6.821	3.381	2.321	5.701	2.361	1.381	0.001	1.141	0.651	0.001
DI *	40	33.871	35.941	42.321	78.261	44.674	39.444	7.634	28.911	27.094	0.001
HB *	40	2.756	3.006	2.016	5.021	5.826	6.436	2.036	1.706	1.311	0.001
NB *	40	3.071	2.386	1.501	3.886	3.166	1.971	0.001	0.966	1.186	0.001
SB *	40	17.786	9.651	6.441	16.091	23.231	46.136	31.066	4.511	5.736	9.451
SH *	40	12.626	8.776	6.126	14.901	33.691	61.791	46.266	5.671	6.961	17.251
DB	40	25.951	9.396	7.041	16.436	21.586	90.966	78.891	4.126	6.296	18.471
LH	40	19.651	5.951	4.496	10.446	21.381	55.316	54.866	2.861	3.921	11.476
MB	40	49.454	49.674	44.528	94.201	60.394	81.084	38.548	39.801	42.731	10.291
MH	40	49.344	46.631	43.724	90.354	56.844	67.331	27.714	34.074	43.928	15.804
RB	40	35.574	35.944	34.351	70.294	47.394	40.441	8.121	36.534	31.138	6.674
WB	40	2.456	4.661	2.916	7.576	13.866	12.676	8.706	1.986	2.156	0.001
ZB	40	6.256	14.146	8.941	23.086	29.521	26.511	14.701	5.601	6.221	10.026
BI *	100	3.211	5.104	3.308	8.411	11.011	10.648	6.508	2.148	2.538	4.511
CN *	100	6.901	6.621	4.181	10.801	10.561	9.061	6.941	1.981	1.861	0.001
DI *	100	7.601	10.636	6.951	17.586	27.526	26.616	15.151	3.491	3.896	7.421
HB *	100	3.616	5.946	3.886	9.831	13.466	11.881	6.371	2.141	2.316	4.001
NB *	100	39.348	52.321	48.644	100.964	55.531	45.494	8.838	35.331	30.794	6.181
SB *	100	8.476	11.871	8.196	20.066	21.121	21.676	9.421	3.356	4.596	7.346
SH *	100	13.291	12.126	7.701	19.826	25.281	29.786	21.036	5.126	5.346	11.086
DB	100	10.241	11.401	7.196	18.596	18.741	19.546	14.546	3.761	4.341	8.351
LH	100	41.786	14.466	10.541	25.006	45.096	98.401	85.196	6.051	8.541	23.356
MH	100	18.001	16.296	6.356	22.651	22.131	26.751	18.066	6.596	10.831	8.601
RB	100	6.191	12.436	8.176	20.611	21.671	18.431	12.191	4.291	4.391	7.731
WB	100	5.196	8.561	5.366	13.926	19.011	16.991	11.291	3.071	3.216	6.071
ZB	100	5.961	13.506	8.356	21.861	29.861	26.396	15.061	4.641	4.396	8.221

Table 3b. Selected hydrocarbon concentrations for the 14 sites and three depths sampled in Prince William Sound in 1990. The selected hydrocarbons represent those analytes that indicate EVOS oil. See text for site and Appendix IV for abbreviations used for the hydrocarbons. A "*" indicates that a station was located within the oil trajectory.

Site	Depth	C2Fl	C3Fl	Dith	C1Dith	C2dith	C3dith	Phen	C1Phen	C2Phen	C3Phen	C4Phen	C1Fl	Chry	C1CH	C2CH
BI *	40	0.001	0.001	20.211	0.196	0.404	0.644	34.546	32.196	3.509	1.064	0.639	0.001	27.276	0.001	0.001
CN *	40	0.001	6.651	0.251	0.001	0.001	0.001	2.861	5.821	8.731	5.441	4.281	0.001	1.841	0.001	0.001
DI *	40	7.074	6.414	31.021	0.001	1.798	1.394	37.881	42.514	10.521	6.591	2.188	4.564	29.898	6.378	7.684
HB *	40	0.001	0.001	0.611	0.001	0.001	0.001	4.956	8.161	8.671	4.811	0.001	2.376	3.961	4.231	5.776
NB *	40	0.001	0.001	0.541	0.001	0.001	5.416	3.441	5.851	6.076	7.346	6.211	6.081	4.906	8.971	14.816
SB *	40	12.256	8.081	6.346	8.911	4.851	0.001	16.416	20.251	15.526	3.206	0.001	2.656	4.451	4.331	4.556
SH *	40	25.606	22.211	10.641	14.091	15.011	10.491	26.616	34.211	27.251	14.236	9.491	11.146	8.436	16.236	13.351
DB	40	18.746	8.316	10.641	16.151	11.351	3.251	20.096	24.381	15.166	3.326	0.001	5.201	5.266	0.001	0.001
LH	40	14.621	8.741	6.811	10.861	6.121	0.001	11.796	15.206	9.626	0.001	0.001	0.001	1.166	0.001	0.001
MB	40	11.744	8.768	38.528	6.571	6.691	5.644	46.381	51.781	13.844	8.868	5.448	4.881	42.028	2.954	1.774
MH	40	23.121	16.858	32.408	6.618	6.328	2.454	60.054	75.848	25.094	14.678	7.921	14.598	40.678	11.074	10.268
RB	40	10.291	6.964	30.991	0.001	0.001	0.001	48.148	46.014	11.088	7.008	2.318	5.988	33.001	3.108	2.484
WB	40	7.861	6.836	0.911	0.001	0.001	0.001	6.691	12.186	10.436	0.001	0.001	0.001	2.576	0.001	0.001
ZB	40	13.991	9.751	2.066	0.001	0.001	0.001	19.691	29.921	24.761	12.636	6.481	12.526	5.746	9.531	9.796
BI *	100	6.668	5.888	0.998	1.184	3.358	3.948	7.558	13.861	13.061	7.761	4.358	5.888	4.371	5.311	6.491
CN *	100	7.501	8.651	0.741	0.001	0.001	0.001	8.461	13.231	15.841	7.301	4.651	5.741	4.011	6.711	5.671
DI *	100	11.801	9.726	1.616	0.001	0.001	0.001	15.236	24.471	22.821	14.186	7.366	11.016	7.141	12.556	11.931
HB *	100	5.961	4.661	1.091	0.001	0.001	0.001	9.111	14.471	13.176	7.146	2.621	5.966	5.596	6.406	7.071
NB *	100	10.728	8.608	32.144	2.504	3.594	3.491	45.671	49.604	15.068	10.564	5.841	9.918	33.768	9.251	13.168
SB *	100	10.046	11.191	1.966	0.001	0.001	0.001	32.256	33.006	33.686	15.331	2.816	17.591	10.261	11.996	10.321
SH *	100	17.151	16.831	3.331	4.036	8.106	8.366	21.806	34.321	35.566	18.076	10.076	13.566	8.911	13.056	12.316
DB	100	15.271	16.806	1.631	2.896	5.431	4.896	16.666	28.706	31.476	14.291	8.141	13.156	10.126	14.651	10.866
LH	100	26.546	13.761	11.201	19.376	13.986	5.961	27.191	38.066	25.046	9.701	0.001	6.596	5.366	5.241	6.171
MH	100	10.731	7.196	4.381	3.981	3.946	0.001	39.561	29.141	15.001	7.266	4.066	7.981	10.481	7.286	6.106
RB	100	10.756	7.346	1.321	2.501	3.136	2.756	13.831	22.526	18.056	12.776	6.091	11.161	4.956	9.926	11.481
WB	100	11.161	8.956	1.456	0.001	0.001	0.001	12.101	19.791	16.466	10.801	2.736	8.091	4.076	7.551	8.886
ZB	100	13.521	10.221	1.781	4.616	4.451	4.406	15.056	23.611	20.206	13.111	6.561	4.641	4.201	4.631	4.926

Faunal Assessment of Data from Stations Sampled July 1990 at 40 m

Composition and Diversity at Stations Based on Values for Higher Taxa

At all stations, polychaetous annelids were dominant in abundance. The abundance, biomass, number of taxa and diversity of benthic fauna for the 14 stations sampled at this depth are tabulated in Table 4. Abundance values at sites within the EVOS trajectory varied between 1044 (Snug Harbor) and 5124 (Bay of Isles) and for sites out of the oil trajectory 386 (Lower Herring Bay) and 7340 (MacLeod Harbor) indiv. m^{-2}. Wet-weight biomass at sites within the oil trajectory varied between 16 (Herring Bay) and 69 (Bay of Isles) g m^{-2} and for sites outside of the oil trajectory between 7 (West Bay) and 397 (MacLeod Harbor) g m^{-2}. The high values for biomass at Rocky Bay and MacLeod Harbor (157 and 397 g m^{-2}, respectively, were mainly a result of large numbers of venerid clams in the former site and many venerid and tellinid clams at the latter site. Number of taxa at sites within the oil trajectory varied between 49 (Snug Harbor) and 79 (Chenega Bay) and at sites outside of the oil trajectory between 29 (Lower Herring Bay) and 90 (Moose Lips Bay). Shannon diversity values were roughly similar at most stations within and outside of the oil trajectory. However, Simpson Dominance was relatively high at three of the stations outside of the oil trajectory--MacLeod Harbor, and Rocky and Zaikof Bays. Dominance at the three sites was a result of high numbers of bivalve mollusks. Species richness at stations within the oil trajectory varied between 7.5 (Bay of Isles) and 10.9 (Chenega Bay) and at stations outside the oil trajectory from 5.5 (Lower Herring Bay) to 11.1 (Moose Lips Bay).

The rank abundance of the dominant fauna collected at all stations occupied is tabulated in Table 5. Differences in taxa between stations can be seen in this table. Stations assumed to be within the EVOS trajectory are designated as [OT] and those out of the trajectory as [R].

Multivariate Analysis

A normal cluster analysis of *ln*-transformed abundance data of biological data from 40 m suggests the presence of three station groups with two stations not joining a group (Figure 2). The three station groups suggested by cluster analysis are tentatively named: Group 1-Stations in Zaikof Bay [R], West Bay [R], Snug Harbor [OT] and Drier Bay [R], Group 2-Sleepy Bay [OT], Moose Lips Bay [R], Northwest Bay [OT], Disk Island [OT], Herring Bay [OT] and Bay of Isles [OT], and Group 3-Rocky Bay [R] and MacLeod Harbor [R]. The two stations not joining a group are Lower Herring Bay [R] and Chenega Bay [OT]. However, assessment of the two ordination plots (in particular the non-metric multi-dimensional scaling [MDS] plot of abundance data) (Figures 3 and 4) and the SIMPER output (Appendix IV-I, Table 2e) indicate that Snug Harbor is misclassified and should be separated from Zaikof Bay, West Bay and Drier Bay. Also, examination of the two ordination plots (particularly, the MDS plot) indicates that Rocky Bay and MacLeod Harbor show strong affinities with the stations in Cluster Group 2 and should be part of this group. Station group ranking by abundance (Appendix IV-I Table 1), SIMPER output (Appendix IV-I, Tables 2a and 2j) and the ordination plots (Figures 3 and 4) indicate that Lower Herring Bay and Chenega Bay should remain separate from the other stations. Thus, at 40 m two groups of stations can be distinguished (Group I: Zaikof Bay, West Bay and Drier Bay--all stations out of the EVOS

[Text continued on page 25.]

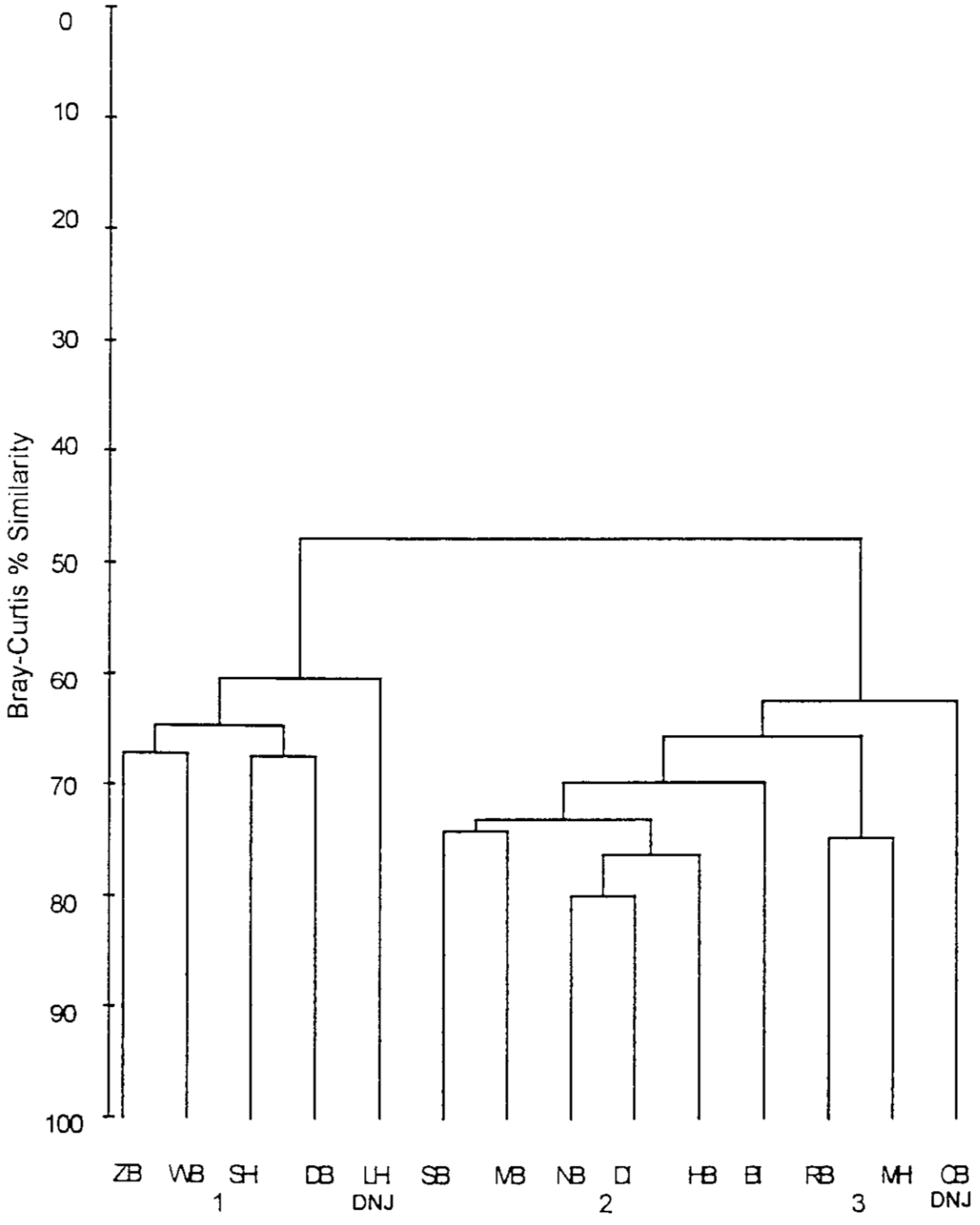

Figure 2. Cluster diagram of *ln*-transformed abundance data for 14 sites at 40m from Prince William Sound collected in 1990. BI = Bay of Isles, CB = Chenega Bay, DB = Drier Bay, DI = Disk Island, HB = Herring Bay, LH = Lower Herring Bay, MB = Moose Lips Bay, MH = MacLeod Harbor, NB = Northwest Bay, RB = Rocky Bay, SB = Sleepy Bay, SH = Snug Harbor, WB = West Bay and ZB = Zaikof Bay. DNJ = stations that did not join a group.

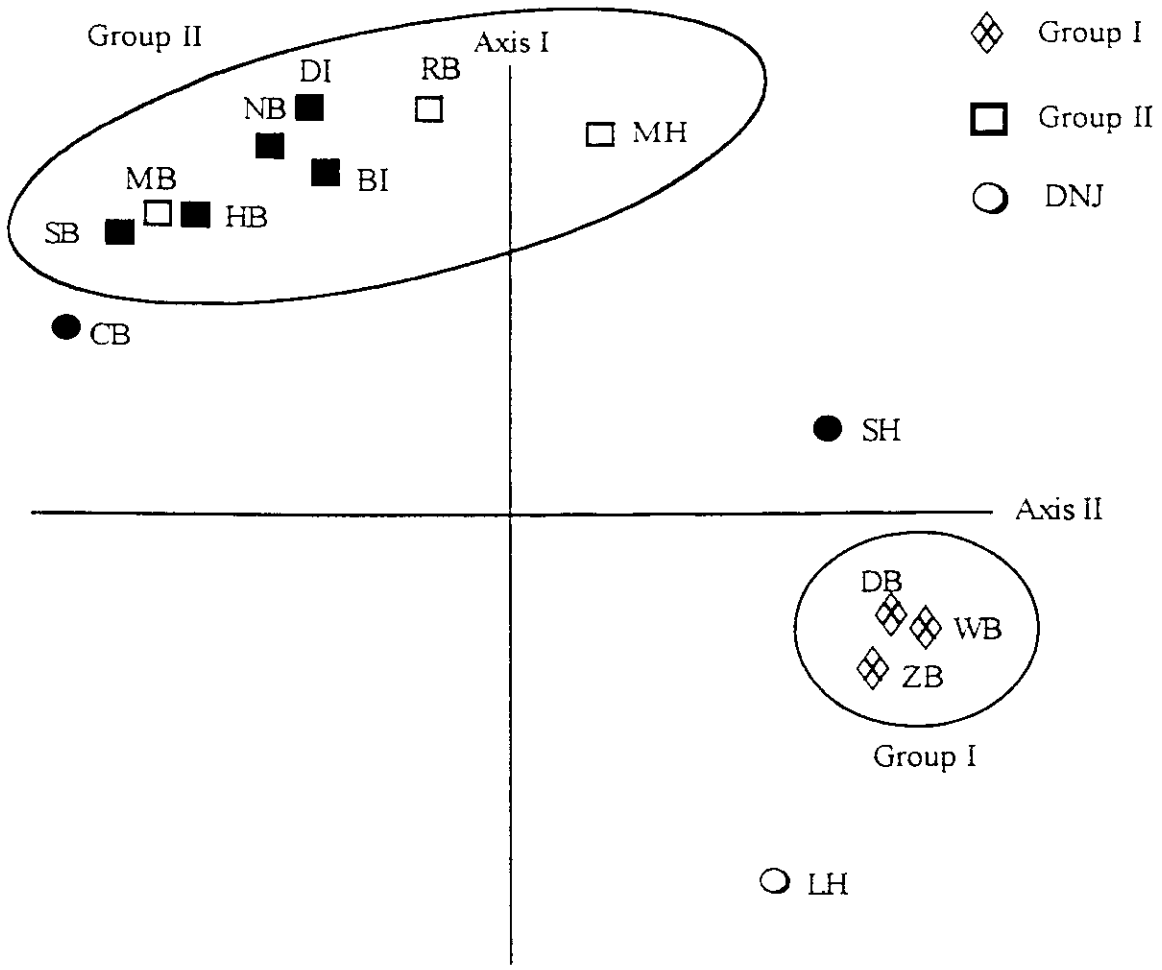

Figure 3. Plot of the first two coordinate axes of a principal coordinate analysis of *ln* - transformed abundance data from 40 m collected during July 1990 at sites within Prince William Sound. Station Groups are circled. Station symbols are identified in Figure 2. Black symbols indicate stations within the EVOS trajectory.

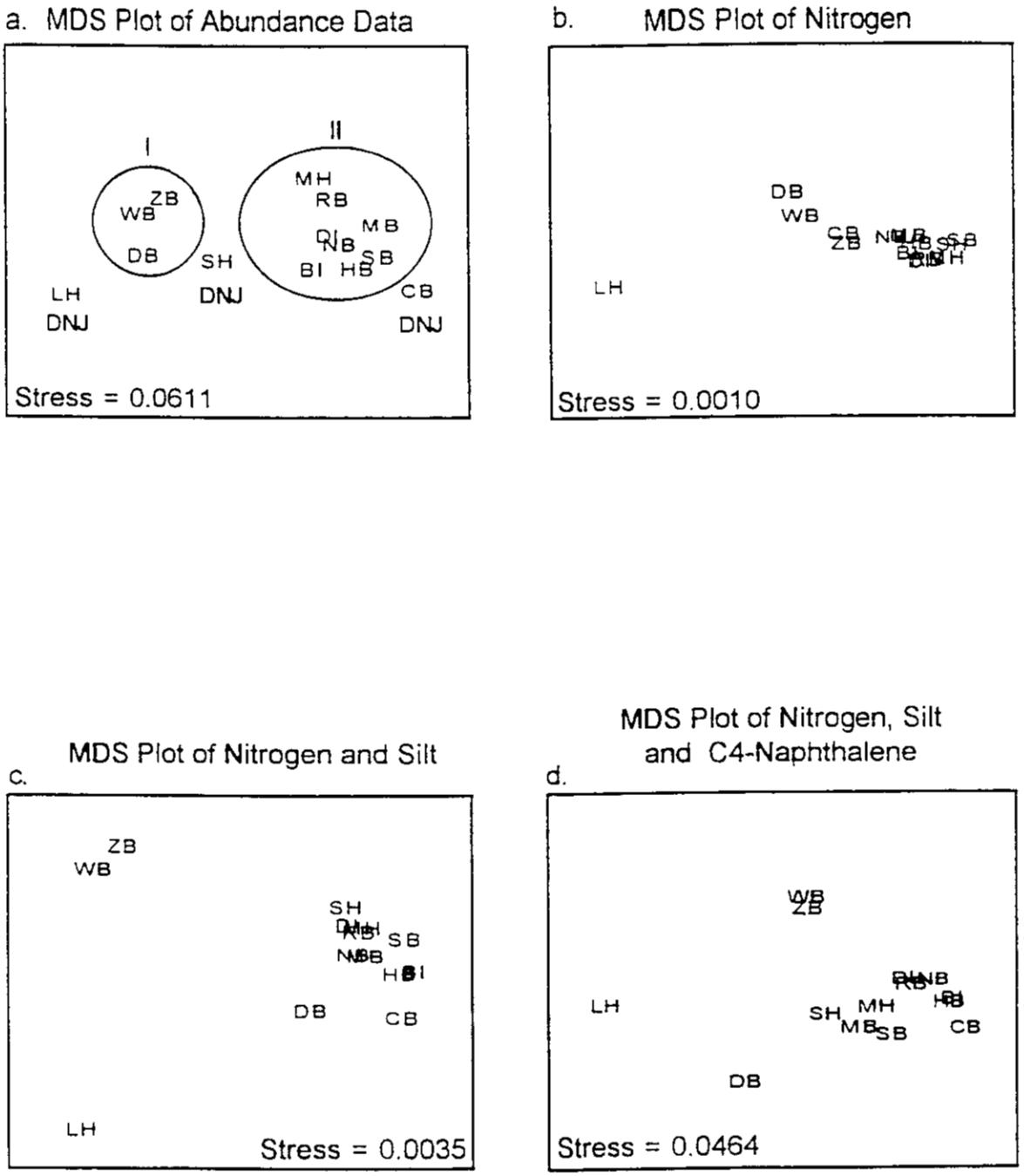

Figure 4. Non-metric multi-dimensional scaling ordinations of abundance and environmental data at 40m for 14 sites throughout Prince William Sound in 1990. The station groupings identified by ordination are circled on the abundance plot. DNJ = does not join. See caption for Fig. 2 for station symbols.

Table 4. Population statistics and diversity values for 14 stations and three depths from Prince William Sound in 1990. Abun. = Abundance (ind. m^{-2}), SR = Species Richness, D = Simpson Dominance and H' = Shannon Diversity. See text for site abbreviations. A "*" indicates that a station was located within the oil trajectory. Sites DI, SH and MB were not sampled at the ≥100m depth.

Depth	Station	Abun.	Biomass	No. Taxa	SR	D	H'
40	BI *	5124	69.2	59	7.52	0.08	2.99
	CB *	2980	42.6	79	10.89	0.06	3.45
	DI *	3618	63.6	61	8.15	0.05	3.32
	HB *	2892	16.0	63	8.69	0.07	3.14
	NB *	2586	69.6	73	10.25	0.06	3.41
	SB *	4182	47.7	70	9.19	0.05	3.37
	SH *	1044	29.3	49	7.85	0.06	3.17
	DB	1330	32.8	40	6.13	0.08	2.90
	LH	386	22.8	29	5.47	0.07	2.96
	MB	6966	97.4	90	11.10	0.08	3.13
	MH	7340	397.1	64	7.81	0.18	2.67
	RB	6744	156.6	81	10.02	0.10	3.12
	WB	732	6.6	41	6.94	0.05	3.19
	ZB	1868	54.9	43	6.27	0.12	2.66
100	BI *	3180	493.9	39	5.26	0.15	2.30
	CB *	2018	7.6	52	7.53	0.06	3.14
	DI *	3220	14.0	54	7.32	0.10	2.84
	HB *	3792	26.8	58	7.70	0.06	3.11
	NB *	2404	19.4	49	6.91	0.13	2.70
	SB *	4942	48.0	66	8.47	0.06	3.15
	SH *	1306	20.5	45	6.94	0.08	2.90
	DB	1644	6.9	40	5.94	0.12	2.60
	LH	1974	26.7	36	5.18	0.10	2.63
	MB	4618	32.7	65	8.42	0.08	2.95
	MH	2204	19.4	80	11.51	0.06	3.40
	RB	1184	113.7	44	6.89	0.09	2.93
	WB	1554	11.1	52	7.83	0.12	2.78
	ZB	2118	82.3	51	7.33	0.06	3.15

Table 4. Continued.

Depth	Station	Abun.	Biomass	No. Taxa	SR	D	H'
>100	BI *	1100	9.7	40	6.32	0.07	2.92
	CB *	2906	14.5	63	8.68	0.09	3.02
	DI*	Not Sampled					
	HB *	4448	38.2	63	8.19	0.09	2.97
	NB *	2682	6.8	49	6.80	0.15	2.59
	SB *	3562	26.3	69	9.26	0.08	3.15
	SH*	Not Sampled					
	DB	554	13.7	21	3.65	0.17	2.17
	LH	548	22.4	25	4.39	0.15	2.28
	MB	Not Sampled					
	MH	2294	21.0	62	8.84	0.11	2.89
	RB	6638	24.1	74	9.16	0.13	2.79
	WB	684	5.2	37	6.32	0.13	2.57
	ZB	4648	132.0	81	10.51	0.04	3.52

Table 5. Rank abundance (indiv. m^{-2}) of dominant taxa by family and higher taxa for all stations at 40 m for data collected in Prince William Sound, July 1990. OT=within oil trajectory[1]. R=outside of oil trajectory[2].

Station	Condition	Dominant Taxa	Abundance (indiv. m^{-2})
BI	OT	Paraonidae	858
		Capitellidae	656
		Polyodontidae	500
		Bivalvia	394
		Cirratulidae	292
		Maldanidae	264
		Lumbrineridae	236
		Leuconidae	230
		Sigalionidae	226
		Syllidae	190
		Nephtyidae	140
CB	OT	Syllidae	464
		Polyodontidae	372
		Spirorbidae	234
		Ophiuroidea	194
		Onuphidae	130
		Ampharetidae	106
		Caecidae	102
		Serpulidae	100
		Bivalvia	92
		Sabellidae	78
DI	OT	Golfingiidae	446
		Cirratulidae	368
		Bivalvia	274
		Paraonidae	266
		Maldanidae	220
		Lumbrineridae	218
		Owenidae	200
		Thyasiridae	172
		Capitellidae	102
		Sabellidae	86
HB	OT	Cirratulidae	406
		Bivalvia	296
		Lumbrineridae	280
		Polyodontidae	226

Table 5. Continued.

Station	Condition	Dominant Taxa	Abundance (indiv. m^{-2})
		Paraonidae	212
		Syllidae	176
		Golfingiidae	170
		Maldanidae	144
		Capitellidae	122
		Ampharetidae	66
		Sabellidae	60
NB	OT	Cirratulidae	436
		Lumbrineridae	212
		Paraonidae	200
		Owenidae	146
		Leuconidae	106
		Maldanidae	106
		Bivalvia	94
		Capitellidae	90
		Syllidae	78
SB	OT	Mytilidae	432
		Bivalvia	402
		Cirratulidae	306
		Syllidae	276
		Golfingiidae	242
		Sigalionidae	238
		Polyodontidae	236
		Maldanidae	224
		Capitellidae	190
		Lumbrineridae	166
		Limidae	148
SH	OT	Capitellidae	104
		Spionidae	100
		Nuculidae	96
		Paraonidae	66
		Cirratulidae	62
		Owenidae	46
		Leuconidae	40
		Lucinidae	34
		Nephtyidae	32
DB	R	Bivalvia	186
		Nephtyidae	178

Table 5. Continued.

Station	Condition	Dominant Taxa	Abundance (indiv. m^{-2})
		Lucinidae	146
		Paraonidae	130
		Nuculidae	112
		Tellinidae	84
		Lumbrineridae	54
		Ophiuroidea	48
		Rhynchocoela	38
LH	R	Lucinidae	48
		Orbiniidae	46
		Paraonidae	44
		Capitellidae	26
		Tellinidae	26
		Sigalionidae	22
		Cirratulidae	20
		Nephtyidae	18
MB	R	Cirratulidae	1466
		Owenidae	766
		Ampeliscidae	678
		Bivalvia	456
		Capitellidae	338
		Golfingiidae	316
		Balanidae	312
		Syllidae	262
		Paraonidae	256
		Phoxocephalidae	244
		Ophiuroidea	212
MH	R	Owenidae	2950
		Bivalvia	508
		Sternaspidae	414
		Paraonidae	408
		Magelonidae	298
		Maldanidae	220
		Thyasiridae	188
		Scaphandridae	184
		Lumbrineridae	184
		Capitellidae	174
		Cirratulidae	174
RB	R	Spionidae	1742
		Capitellidae	830

Table 5. Continued.

Station	Condition	Dominant Taxa	Abundance (indiv. m^{-2})
		Golfingiidae	498
		Bivalvia	316
		Lumbrineridae	264
		Paraonidae	246
		Maldanidae	210
		Thyasiridae	206
		Owenidae	178
		Magelonidae	154
		Cirratulidae	112
WB	R	Capitellidae	84
		Bivalvia	56
		Nephtyidae	52
		Lumbrineridae	52
		Spionidae	50
		Rhynchocoela	42
		Nuculanidae	42
		Sternaspidae	42
		Cirratulidae	40
ZB	R	Nephtyidae	522
		Paraonidae	228
		Bivalvia	178
		Spionidae	136
		Nuculanidae	134
		Pyrenidae	92
		Cirratulidae	78
		Lumbrineridae	74
		Chaetodermatidae	50

[1] Stations within the oil trajectory (OT):
NB=Northwest Bay; DI=Disk Island; HB=Herring Bay; SB=Sleepy Bay; BI=Bay of Isles; SH=Snug Harbor; CB=Chenega Bay;

[2] Stations outside of the oil trajectory (R=reference station)
WB=West Bay; RB=Rocky Bay; ZB=Zaikof Bay; MH=MacLeod Harbor; LH=Lower Herring Bay; DB=Drier Bay

trajectory [R], Group II: MacLeod Harbor, Rocky Bay, Moose Lips Bay, Zaikof Bay--out of the EVOS trajectory [R]; and Disk Island, Northwest Bay, Sleepy Bay, Herring Bay, Bay of Isles--within the EVOS trajectory [OT]), and three stations that did not join a group (Lower Herring Bay [R], Snug Harbor [OT] and Chenega Bay [OT]). Faunal differences between station groups and stations are shown by the Simper analysis (Appendix IV-I, Table 2a through 2h).

The two station groups and the three unclassified stations are 'explained' (in a statistical sense) by Stepwise Multiple Discriminant Analysis by two sediment parameters (Figure 5). Discriminant function (DF) 1 contributes 97% of the total separation among station groups. A total of 79% of the stations were correctly grouped by the jackknife classification into station groups by the two variables that form the discriminant functions. The two negative values along DF 1 are due to percent silt and nitrogen concentration in sediment. The standardized coefficients for these variables are -0.71 (% silt) and -1.17 (nitrogen in sediment). The position of Lower Herring Bay [R] is distinct from the two station groups and the other two unclassified stations along the axis of DF 1. The centroid of Group I (West, Drier and Zaikof Bays [R]) is separated from Station Group II and the other two unclassified stations on DF 1. The position of Chenega Bay [OT] is distinct from the centroid of Station Group II and Snug Harbor [OT]. The separation of Lower Herring Bay from the other stations and station groups is the result of the higher percentage of silt and amount of nitrogen within that site. The higher percentage of silt and amount of nitrogen within Station Group I results in its separation from Group II and the other two unclassified stations. Chenega Bay is separated from Group II and Snug Harbor, on DF 1, based on its higher nitrogen content.

The results of the BIO-ENV analysis of benthic biota and environmental variables are summarized in Table 6 and plotted in Figures 4b-4d. This table lists the combinations of environmental variables which produced the highest rank correlation coefficients for a given number of variable. The best fit between the biota and a single environmental variables is achieved with nitrogen (P_s = 0.644) (P_s = standard Spearman coefficient; Figures 4a, b). Table 1 and Figure 4b show that Lower Herring Bay [R] had the highest nitrogen value compared to all of the other stations. Superimposing nitrogen on the faunal MDS reflects the magnitude of this variable at Lower Herring Bay compared to the other stations (Figures 4 and 6; procedure after Field et al., 1982). The fit between the biota and the environmental variables is improved with the addition of percent silt (P_w = 0.759). Addition of the latter variable separates Zaikof Bay (R) and West Bay (R) from the group of stations to the right of the plot. Superimposing percent silt on the faunal MDS indicates that four of the five stations to the left on the MDS plot have higher amounts of silt (Table 1; Figure 7) The best three-variable combination retains the above two variables and adds one PAH analyte (C4-Naphthalene) which only improves the P_w value slightly to 0.763. Addition of the latter variable moves Zaikof Bay [R] and West Bay [R] to the right so that they are in approximately the same horizontal position on the MDS plot as Drier Bay (R), the other member of Station Group I. Lower Herring Bay (LH) (R) is slightly to the left of all of the other stations but all of the other stations in this MDS plot (stations within and outside of

[Text continued on page 30.]

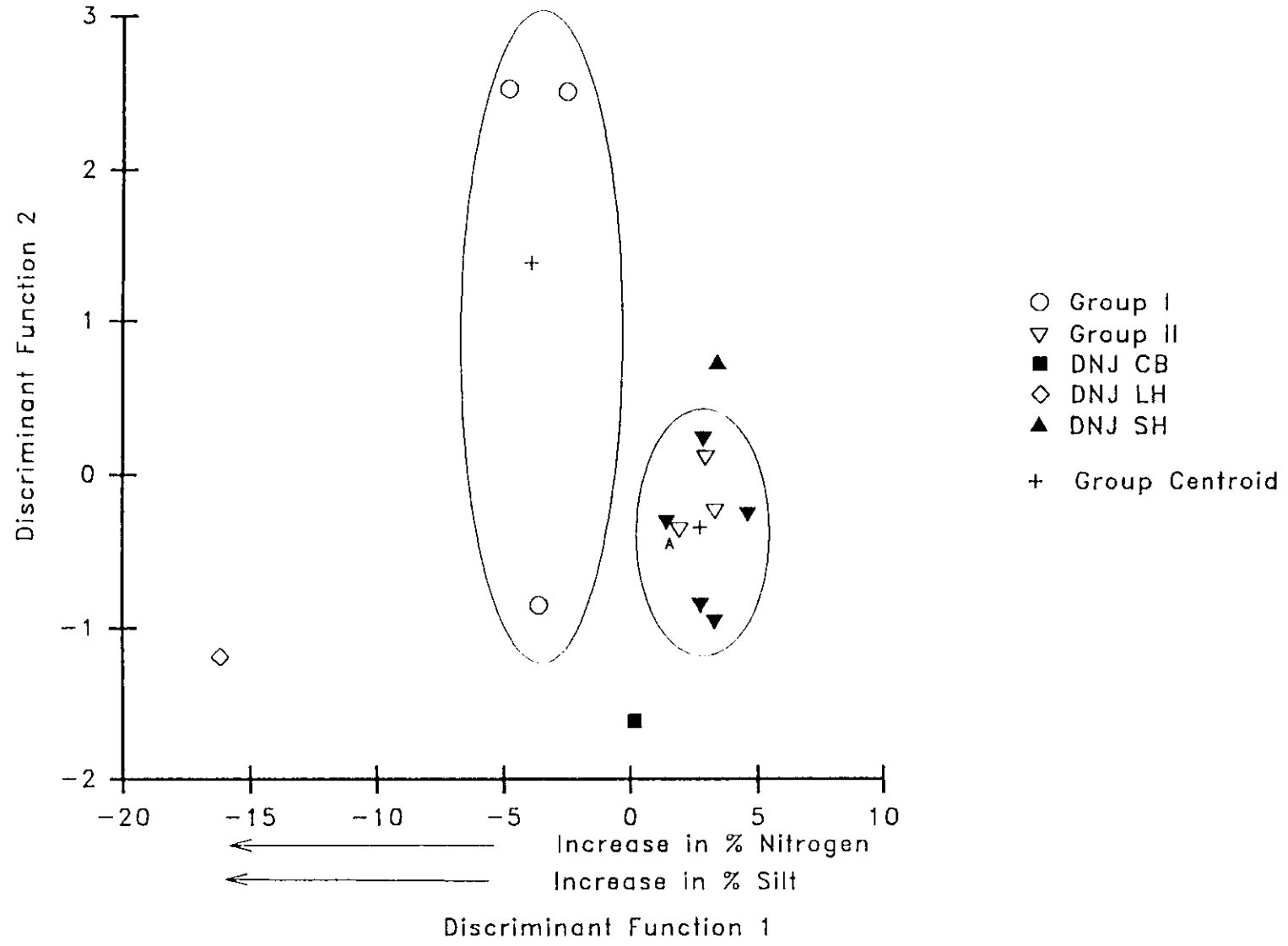

Figure 5. Station group and station plot from stepwise multiple discriminant analysis of infaunal abundance data from 40m utilizing environmental variables. A "+" indicates the group centroid. Dark symbols indicate sites within the EVOS trajectory. DNJ indicates stations that did not join a group. Station symbols are identified in the caption of Figure 2.

Table 6. Correlation analyses of biotic and environmental similarity matrices using the BIO-ENV routine* for 40 m data from 14 sites in Prince William Sound collected in 1990. Similarity matrices for biota, sediment and selected PAH analyte data were compared using the Spearman rank correlation (see Methods and Clarke and Ainsworth [1993] for description of procedure and program output) to determine the combination of variables giving the best correlation coefficient between the biotic and environmental data. P_s = standard Spearman coefficient. "..." indicates succeeding combinations not shown. Correlation coefficients are given in parentheses. Best variable combinations are shown in bold type.

Number of variables	Variable combinations (P_s)	
1.	Nitrogen (0.644), % Water (0.519), Carbon (0.488),	...
2.	Nitrogen, % Silt (0.759), Carbon, % Silt (0.718),	...
3.	**Nitrogen, % Silt, C-4 naphthalenes (0.763)**, Carbon, % Silt, C-4 naphthalenes (0.755),	...

* The BIO-ENV program is one routine in the PRIMER statistical package provided courtesy of Dr. Clarke, Plymouth Laboratories.

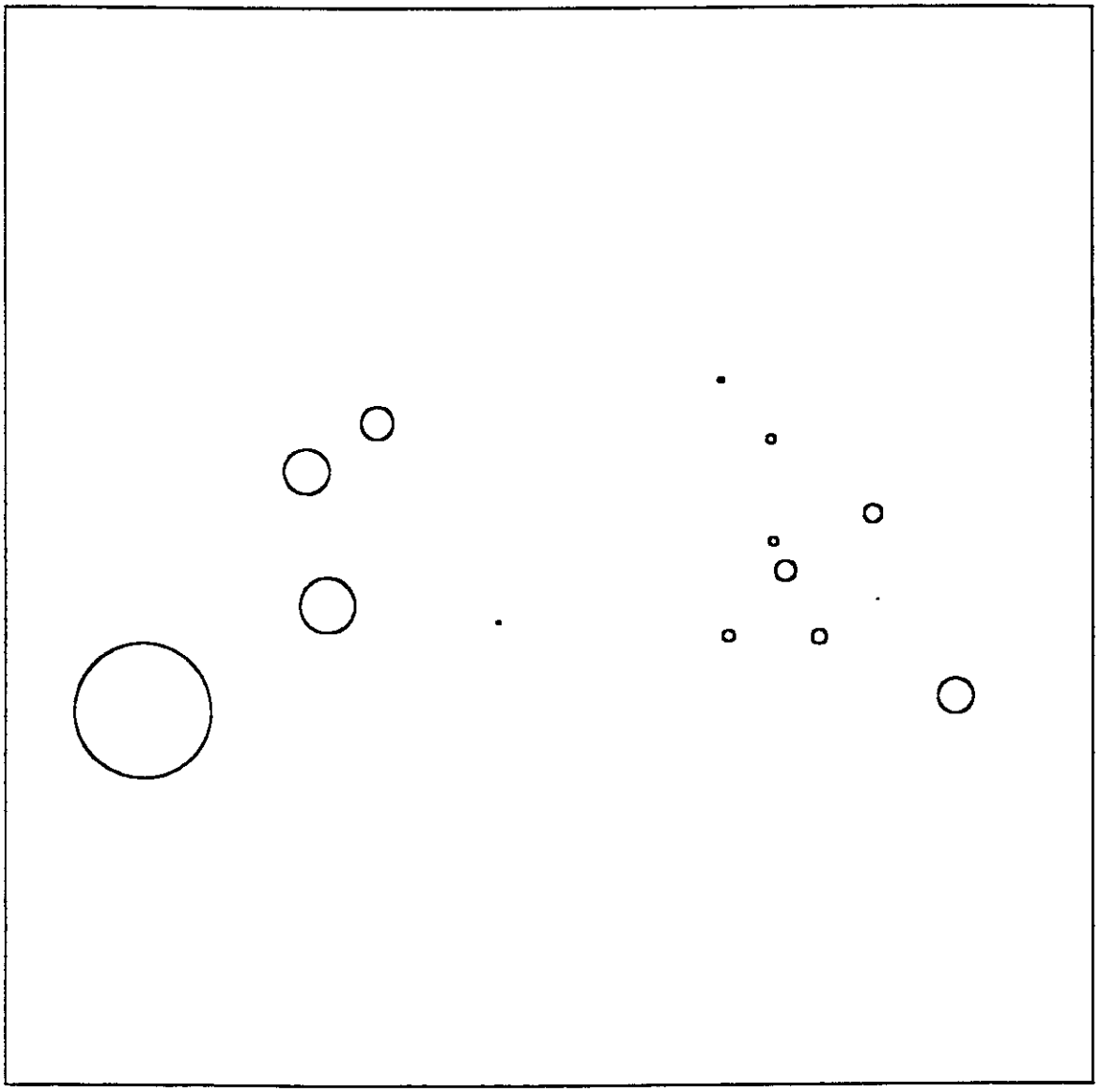

Figure 6. Relation of stations to sediment nitrogen at 40m to the MDS ordination of stations based on faunal abundance. Stations are delineated as in Figure 4a. At each Station enclosures proportional in diameter to the nitrogen concentration are superimposed.

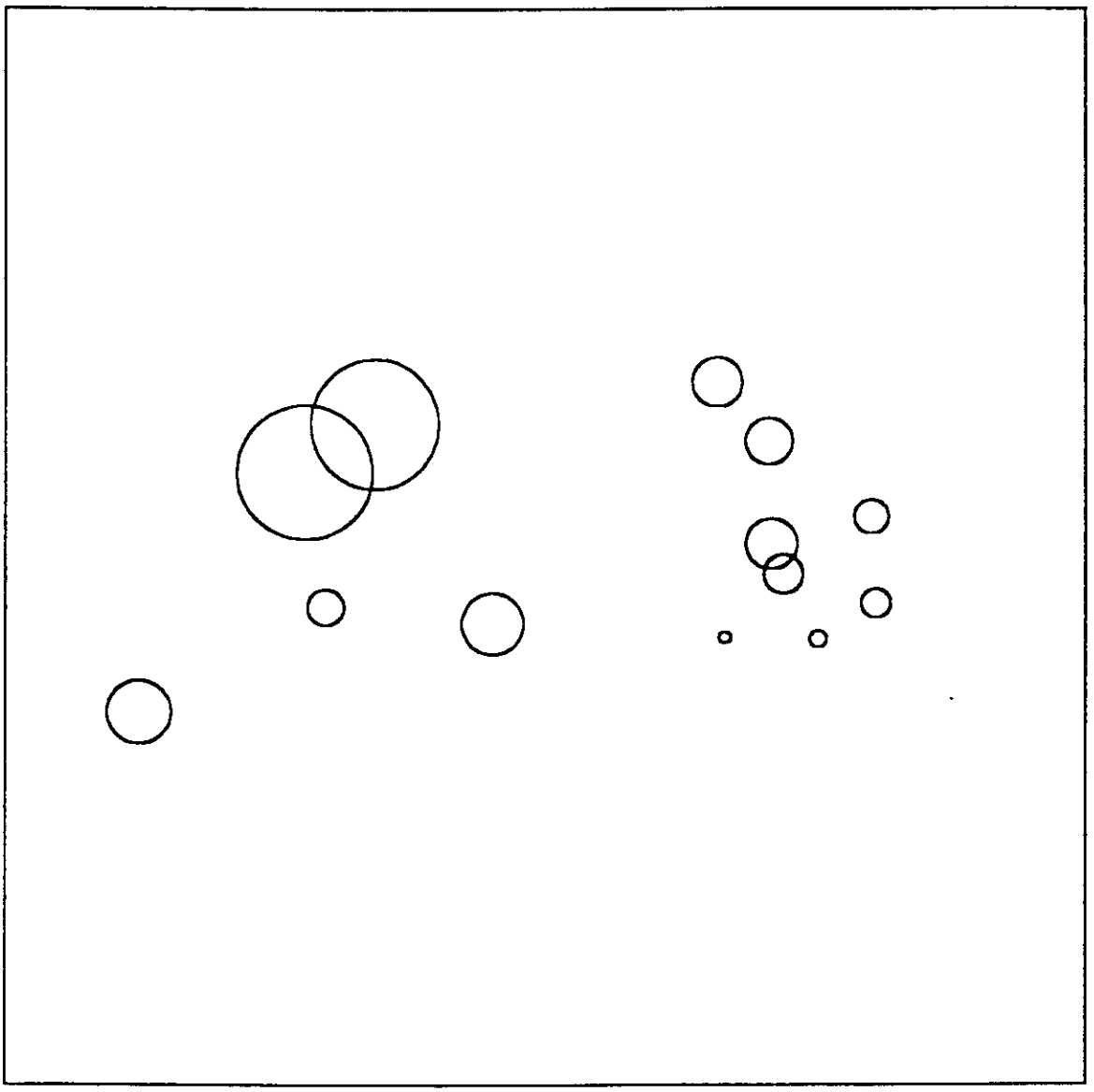

Figure 7. Relation of stations to silt content at 40m to the MDS ordination of stations based on faunal abundance. Stations are delineated as in Figure 4a. At each Station enclosures proportional in diameter to the percentage of silt are superimposed.

the EVOS trajectory) are grouped together, implying that they all basically share the same relationships to the three environmental parameters. A plot superimposing concentration of C-4 naphthalene (Figure 8) demonstrates that this analyte is generally randomly distributed between stations within and outside of the EVOS trajectory. However, the two stations with the highest levels of C4-Naphthalene are Lower Herring Bay and Drier Bay, both considered to be outside of the EVOS trajectory. The 'vertical' separation of Zaikof Bay and West Bay from the other stations in the MDS plots shown in Figures 4b and 4c may be related to the high percentage of silt at these stations (see Figures 4a and 7).

Data from Sites at 100 m

Sediment Analyses

Sediment parameters, and organic carbon, nitrogen, C/N and $\delta^{13}C$ values in sediment are included in Table 1.

Laboratory Observations of Oil in Samples Collected in July 1990

No oil was observed in the biological samples collected at 100 m.

Sediment Oil Analyses

Petroleum hydrocarbon data reported by NOAA (Technical Services Task Force: Analytical Chemistry Group:TSTF) are included in Table 3. The estimated polycyclic aromatic hydrocarbons (PAHs in ng/g) presented in this table are possibly derived from the EVOS (see Jewett et al., 1993a, for further comments on EVOS analytes in sediment).

Faunal Assessment of Data from Stations Sampled July 1990 at 100 m

Composition and Diversity at Stations Based on Values for Higher Taxa

At all 100 m stations, as at 40 m, polychaetous annelids were dominant in abundance. The abundance, biomass, number of taxa and diversity of benthic fauna for the stations sampled at this depth are tabulated in Table 4. Abundance values at sites within the EVOS trajectory varied between 1184 (Rocky Bay) and 4942 (Sleepy Bay) indiv. m^{-2}. and for sites outside of the EVOS trajectory between 1184 (Rocky Bay) and 4618 (Moose Lips Bay) indiv. m^{-2}. Wet-weight biomass at sites within the oil trajectory varied between 8 (Chenega Bay) and 494 (Bay of Isles: result of dominance by tellinid bivalves) g m^{-2}; wet weight at sites outside of the oil trajectory varied between 7 (Drier Bay) and 114 (Rocky Bay: result of dominance by tellinid and nuculanid bivalves) g m^{-2}. Number of taxa at stations within the oil trajectory varied between 40 (Bay of Isles) and 66 (Sleepy Bay); at stations outside of the trajectory taxa varied between 36 (Lower Herring Bay) and 80 (MacLeod Harbor). Shannon diversity values were roughly similar at most stations. A few lower values were recorded at stations within and outside the EVOS trajectory (i.e., Bay of Isles, Northwest Bay:OT; Drier Bay, Lower Herring Bay, West Bay:R). Simpson dominance values were higher at all of the latter stations. Species Richness at stations within the EVOS trajectory varied between 2.30 (Bay of Isles) and 3.15 (Sleepy Bay); at stations out of the EVOS trajectory species richness varied from 2.60 (Drier Bay) to 3.40 (MacLeod Harbor).

The rank abundance of the dominant fauna collected at all stations occupied at 100 m are

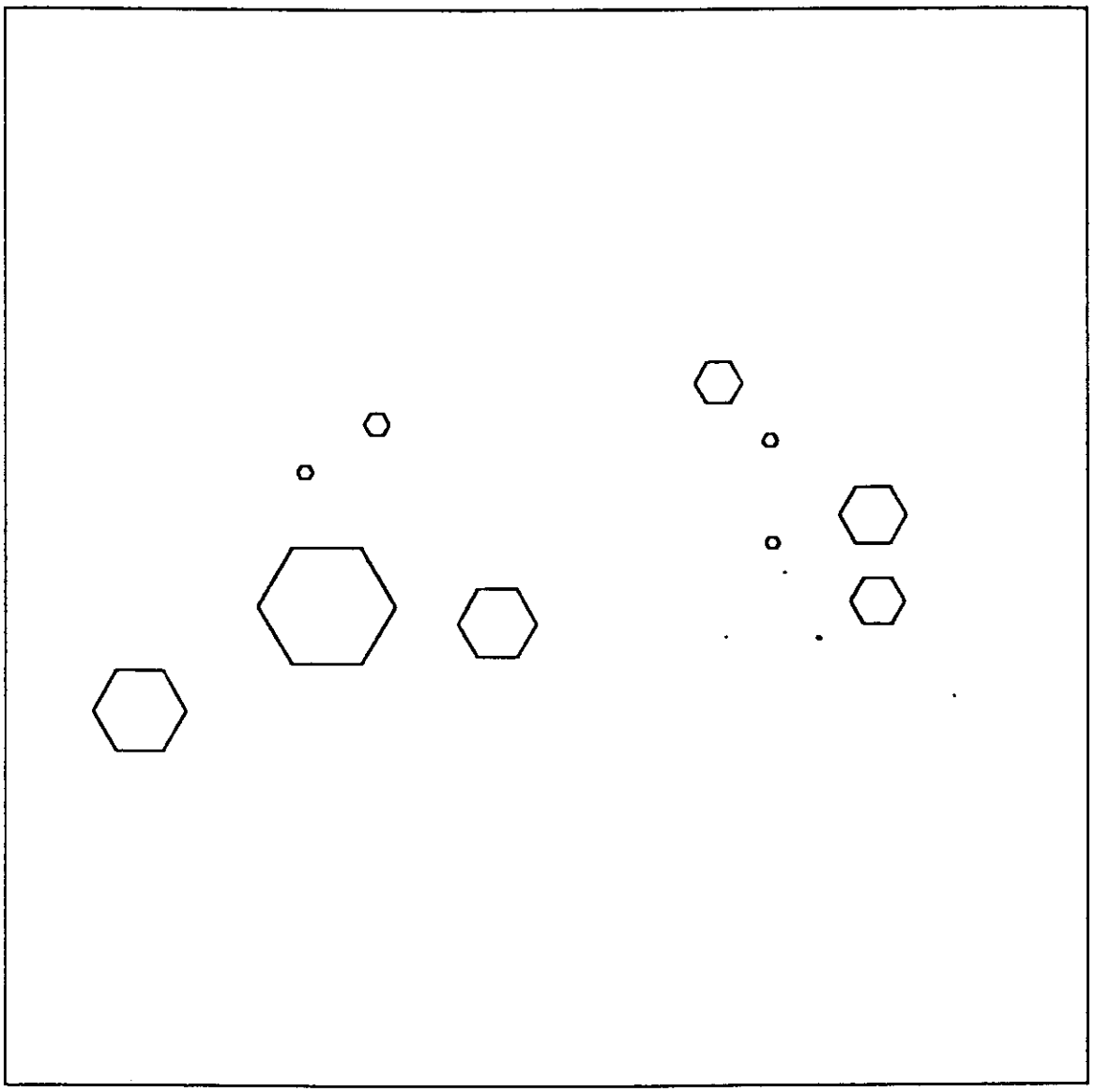

Figure 8. Relation of stations to the concentration of C-4 naphthalenes at 40m to the MDS ordination of stations based on faunal abundance. Stations are delineated as in Figure 4a. At each Station enclosures proportional in diameter to the concentration of C-4 naphthalenes are superimposed.

tabulated in Table 7. Differences in taxa between stations can be seen in this table.

Multivariate Analysis

A normal cluster analysis of *ln*-transformed abundance data and two ordination procedures (Principal Coordinate Analysis, Non-Metric Multi-dimensional Scaling) and SIMPER output of biological data for 100 m indicate the presence of four cluster groups and one station that did not join a group (Figures 9-11; Appendix IV-II). The groups are as follows: Group I-Zaikof and Rocky Bays: both out of the oil trajectory [R], Group II-Snug Harbor and Bay of Isles [both OT], and Lower Herring Bay and Drier Bay [both R], Group III-West Bay [R], Northwest Bay and Disk Island [both OT], and Group IV-Moose Lips Bay [R], Sleepy Bay, Herring Bay and Chenega Bay [all OT]. MacLeod Harbor [R] did not join a group.

The four station groups and the one unclassified station were 'explained' (in a statistical sense) by Stepwise Multiple Discriminant Analysis by a number of variables (Figure 12). Discriminant function (DF) 1 contributes 88% of the total separation among station groups. A total of 69% of the stations were correctly grouped by the jackknife classification into stations and station groups by the variables that form the discriminant functions. Group II (comprised of two stations within the EVOS trajectory and two stations outside the EVOS trajectory) is well separated from all of the other stations on DF 1 by its higher concentration of Nitrogen and C-3 dibenzothiophene. MacLeod Harbor (R) is well separated from all of the other stations on DF 1 by its very low percent silt and high percent sand (see Table 1) and low C-3 dibenzothiophene concentration (Table 3; Figure 12). MacLeod Harbor and Station Groups I, III, and IV are characterized by medium to relatively high fluorene values with Northwest Bay (OT) and MacLeod Harbor (R) having the highest values (Table 3).

The results of the BIO-ENV analysis of similarity matrices of the benthic biota and environmental variables are summarized in Table 8 and plotted in Figures 13a-13d. The table lists the combinations of environmental variables which produced the highest rank correlation coefficients for a given number of variables. The best fit between the biota and a single environmental variable is achieved with % water (P_s = 0.494; P_s = standard Spearman coefficient) (Figure 13a). Table 1 shows that Drier Bay (R) and Bay of Isles (OT) have the highest percent water in sediment compared to all other stations. The fit is improved with the two variables percent mud and carbon (P_s = 0.669) (Figure 13b). These variables bring Zaikof Bay (R) and Rocky Bay (R) of Station Group I closer together, and Lower Herring Bay (R) together with Drier Bay and Bay of Isles of Station Group II. The best three variable combination of percent mud, nitrogen and C-3 dithiobenzene (P 0.682) further improves the fit for most of the station groups (Figure 13c). The best four variable combination (P_s = 0.689) only slightly improves the fit (Figure 13d). Northwest Bay (OT) moves to the right and is closer to the other stations in Group III. In the last three MDS BIO-ENV plots MacLeod Harbor (R; the station with the highest percent sand: 92%) is furthest to the right of all stations, indicating its difference with low values for the four variables. Stations within Station Group II (comprised of mixed stations within and outside of the oil trajectory), located to the left on the MDS plot, are distinguished by their high values for the four variables. The remaining stations (a mixture of stations within and outside of the EVOS

[Text continued on page 42.]

Table 7. Rank abundance (no. m^{-2}) by families and higher taxa for all stations at 100 m for data collected in Prince William Sound, July 1990.

Stat	Cond	Taxa	(no. m^{-2})	Stat	Cond	Taxa	(no. m^{-2})
DI	OT	Golfingiidae	754	NWB	OT	Bivalvia	708
		Bivalvia	512			Lumbrineridae	276
		Cossuridae	240			Cirratulidae	216
		Lumbrineridae	202			Golfingiidae	172
		Thyasiridae	160			Paraonidae	144
		Cirratulidae	148			Sabellidae	120
		Paraonidae	140			Capitellidae	116
		Owenidae	134			Spionidae	90
		Sabellidae	130			Nephtyidae	52
		Capitellidae	92			Cossuridae	46
		Nephtyidae	82			Maldanidae	38
		Nuculanidae	64			Dentaliidae	36
		Syllidae	54			Owenidae	34
		Maldanidae	52			Syllidae	30
		Spionidae	42			Polyodontidae	30
						Phoxocephalidae	30
HB	OT						
		Golfingiidae	412	SH	OT	Nephtyidae	192
		Paraonidae	352			Leuconidae	190
		Bivalvia	334			Paraonidae	162
		Cirratulidae	326			Bivalvia	110
		Lumbrineridae	326			Lumbrineridae	106
		Syllidae	302			Spionidae	84
		Maldanidae	232			Cirratulidae	50
		Capitellidae	188			Scaphandridae	42
		Phoxocephalidae	162			Gastropoda	36
		Spionidae	138			Nuculanidae	34
		Sabellidae	134			Cossuridae	34
		Owenidae	94			Capitellidae	30
		Ampharetidae	92			Hesionidae	28
		Cossuridae	48			Nuculidae	26
		Terebellidae	48			Ophiuroidea	20
SLB	OT	Golfingiidae	642	CN	OT	Sabellidae	284
		Sabellidae	528			Golfingiidae	186
		Bivalvia	520			Paraonidae	144
		Syllidae	420			Ampharetidae	132
		Paraonidae	296			Syllidae	126
		Owenidae	266			Onuphidae	108
		Cirratulidae	266			Cirratulidae	92
		Polyodontidae	210			Owenidae	90
		Phoxocephalidae	190			Archaeogastropoda	68
		Maldanidae	132			Lumbrineridae	62
		Lumbrineridae	132			Maldanidae	58
		Gnathiidae	128			Spionidae	48
		Ampharetidae	116			Capitellidae	44
		Ampeliscidae	106			Dentaliidae	42
		Capitellidae	98			Astartidae	40

Table 7. Continued.

Stat	Cond	Taxa	(no. m^{-2})	Stat	Cond	Taxa	(no. m^{-2})
		Terebellidae	82				
		Sigalionidae	72	BI	OT	Tellinidae	910
		Spionidae	68			Cirratulidae	498
		Gastropoda	62			Lumbrineridae	472
		Tanaidacea	58			Spionidae	312
		Montacutidae	44			Hesionidae	212
		Nephtyidae	44			Nephtyidae	202
		Dentaliidae	42			Capitellidae	168
						Polynoidae	70
						Paraonidae	58
						Cossuridae	30
						Nuculidae	28
						Bivalvia	28
BI		Nuculanidae	24	MCH		Bivalvia	86
I		Thyasiridae	22			Phoxocephalidae	72
		Phyllodocidae	20			Terebellidae	66
		Oedicerotidae	20			Mytilidae	64
						Pyrenidae	62
						Gnathiidae	46
DB	R	Nephtyidae	388			Paraonidae	42
		Bivalvia	310				
		Paraonidae	152	MLB	R	Capitellidae	666
		Lumbrineridae	134			Spionidae	588
		Leuconidae	114			Polyodontidae	578
		Orbiniidae	82			Cirratulidae	522
		Nuculidae	72			Syllidae	420
		Cossuridae	64			Bivalvia	188
		Nuculanidae	52			Phoxocephalidae	160
		Spionidae	40			Maldanidae	152
		Cirratulidae	34			Paraonidae	144
						Sabellaridae	124
ZB	R	Cirratulidae	278			Owenidae	114
		Sternaspidae	266			*Lumbrineridae*	112
		Lumbrineridae	172			Sabellidae	82
		Nuculanidae	172			Laqueidae	62
		Leuconidae	142			Ampharetidae	58
		Thyasiridae	92			*Terebellidae*	50
		Tellinidae	92			Anthozoa	42
		Amphiuridae	78			Golfingiidae	42
		Capitellidae	70			Nuculidae	40
		Nephtyidae	68			Ophiuroidea	40
		Bivalvia	66				
		Spionidae	60	LH	R	Paraonidae	312
		Owenidae	50			Bivalvia	264
		Paraonidae	46			Nephtyidae	260
		Dentaliidae	42			Cirratulidae	246
		Orbiniidae	42			Lumbrineridae	238
						Spionidae	142
RB	R	Nephtyidae	256			Capitellidae	82
		Nuculanidae	152			Leuconidae	72
		Tellinidae	94			Orbiniidae	40

Table 7. Contined.

Stat	Cond	Taxa	(no. m^{-2})	Stat	Cond	Taxa	(no. m^{-2})
		Nuculidae	72			Nuculanidae	40
		Paraonidae	64			Phoxocephalidae	36
		Thyasiridae	50			Maldanidae	32
		Spionidae	48			Gastropoda	28
		Lumbrineridae	42			Opheliidae	24
		Leuconidae	40			Hesionidae	20
		Capitellidae	38			Rhynchocoela	20
		Sternaspidae	36				
		Owenidae	36	WB	R	Bivalvia	420
		Scaphandridae	26			Lumbrineridae	248
		Gastropoda	24			Nephtyidae	104
		Hesiondae	24			Golfingiidae	84
		Pyrenidae	24			Dentaliidae	70
		Bivalvia	20			Owenidae	68
		Amphiuridae	20			Paraonidae	66
						Cirratulidae	64
MCH	R	Owenidae	424			Sternaspidae	42
		Polyodontidae	152			Leuconidae	38
		Syllidae	122			Capitellidae	34
		Maldanidae	118			Montacutidae	32
		Golfingiidae	96			Thyasiridae	32
		Capitellidae	90			Spionidae	30
		Spionidae	90			Onuphidae	24
		Cirratulidae	90				

Table 8. Correlation analyses of biotic and environmental similarity matrices using the BIO-ENV routine* for 100 m data from 14 sites in Prince William Sound collected in 1990. Similarity matrices for biota, sediment and selected PAH analyte data were compared using the Spearman rank correlation (see Methods and Clarke and Ainsworth [1993] for description of procedure and program output) to determine the combination of variables giving the best correlation coefficient between the biotic and environmental data. P_s = standard Spearman coefficient. "..." indicates succeeding combinations not shown. Correlation coefficients are given in parentheses. Best variable combinations are shown in bold type.

Number of variables	*Variable combinations* (P_s)
1.	% Water (0.494), Nitrogen (0.396), Carbon (0.376),...
2.	Carbon, % Mud (0.669), Nitrogen, % Mud (0.660),...
3.	Nitrogen, % Mud, C-3 dibenzothiophenes (0.682), Carbon, % Mud, C-3 dibenzothiophenes (0.680),...
4.	**% Water, Nitrogen, % Mud, C-3 dibenzothiophenes (0.689)**, ...

* The BIO-ENV program is one routine in the PRIMER statistical package provided courtesy of Dr. Clarke, Plymouth Laboratories.

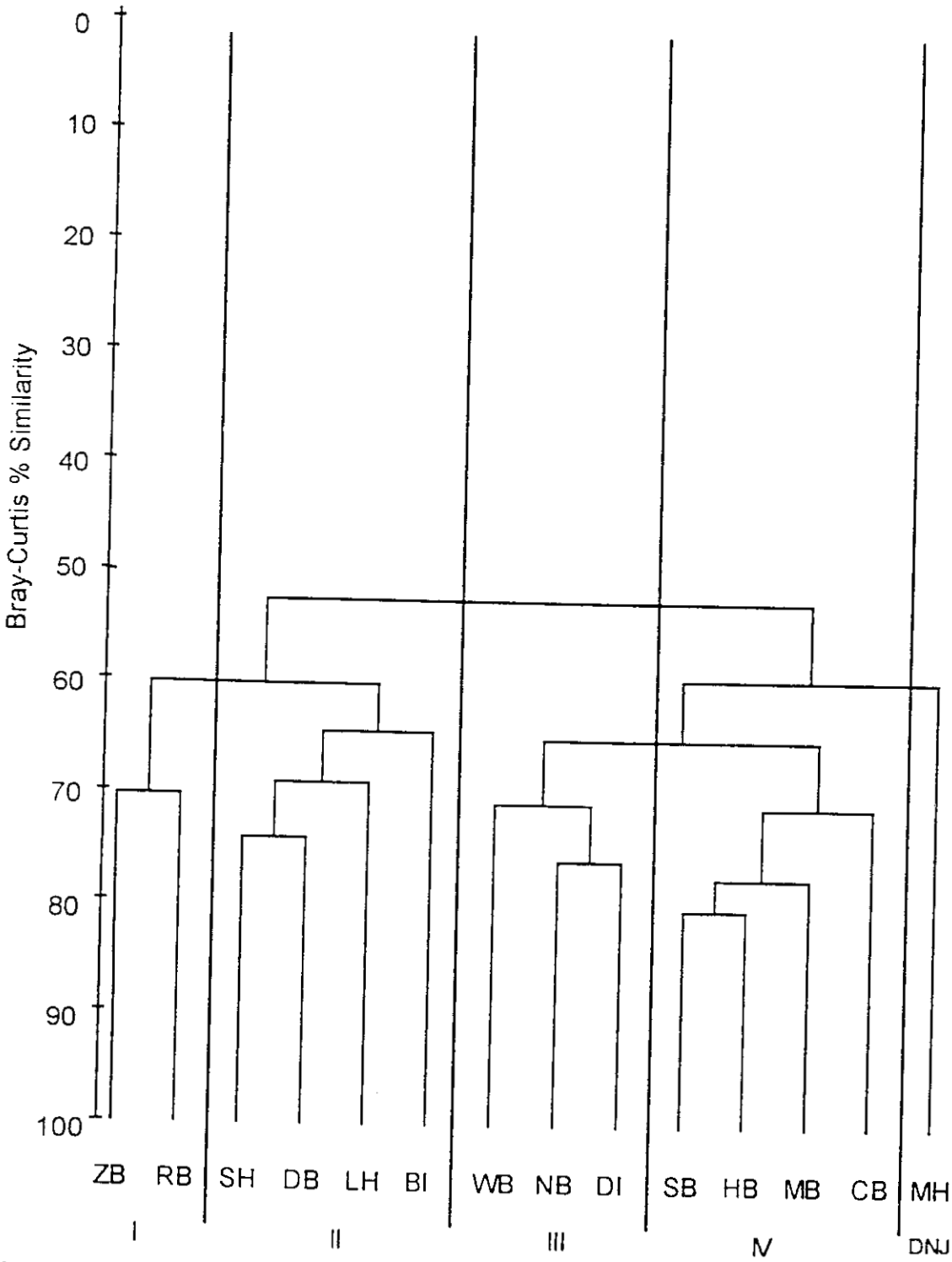

Figure 9. Cluster diagram of *ln*-transformed abundance data for 14 sites throughout Prince William Sound in 1990 from 100m showing the four station groups. See caption of Figure 2 for symbols.

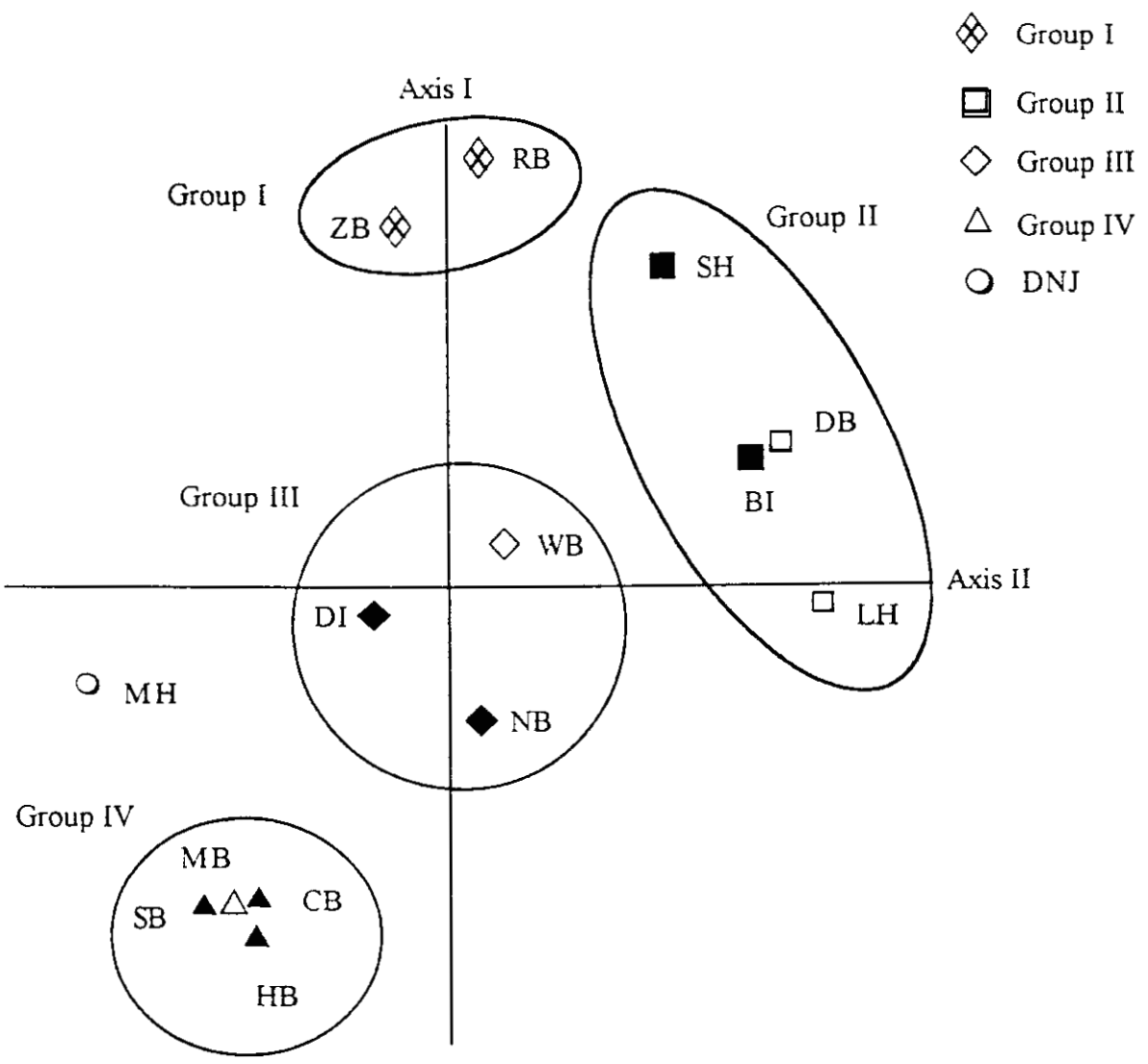

Figure 10. Plot of the first two coordinate axes of a principal coordinate analysis of *ln* - transformed abundance data from 100 m collected during July 1990 at sites within Prince William Sound. Station Groups are circled. Station symbols are identified in Figure 2. Black symbols indicate stations within the EVOS trajectory.

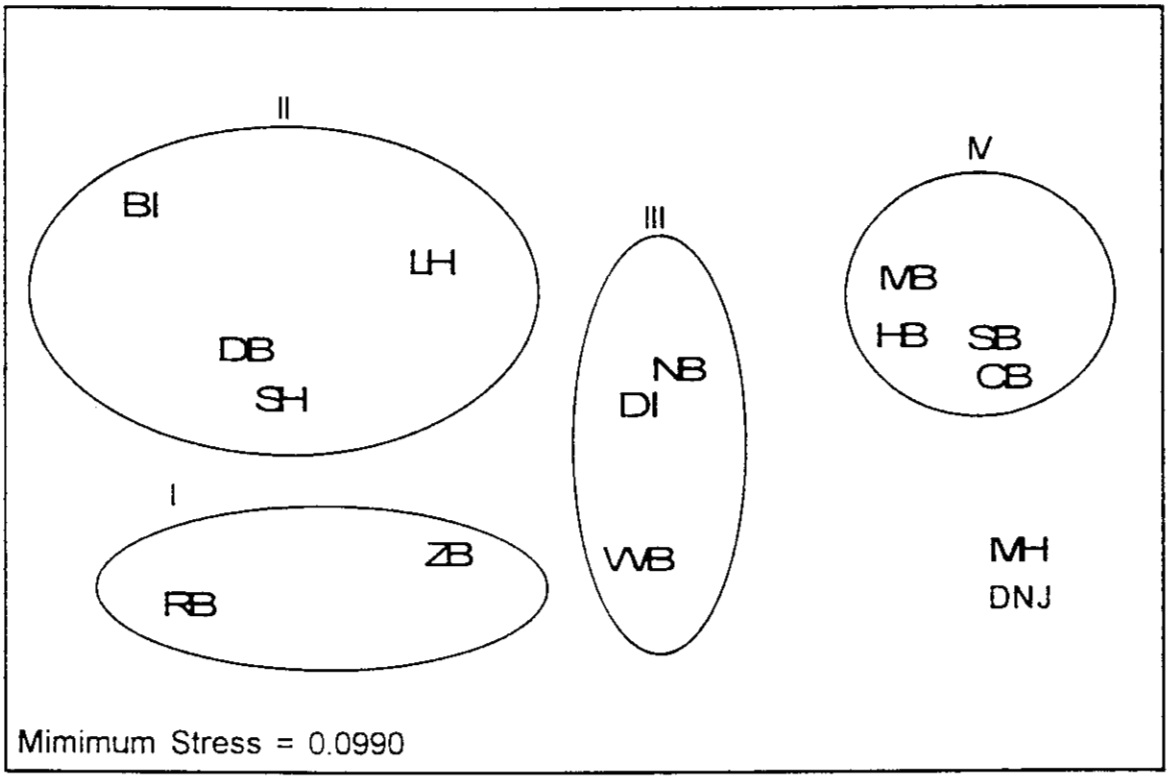

Figure 11. Non-metric muilti-dimensional scaling ordination of abundance data at 100m for 14 sites throughout Prince William Sound in 1990. See caption for Figure 2 for station symbols. Station groups identified by ordination are circled. DNJ = station that did not join a group.

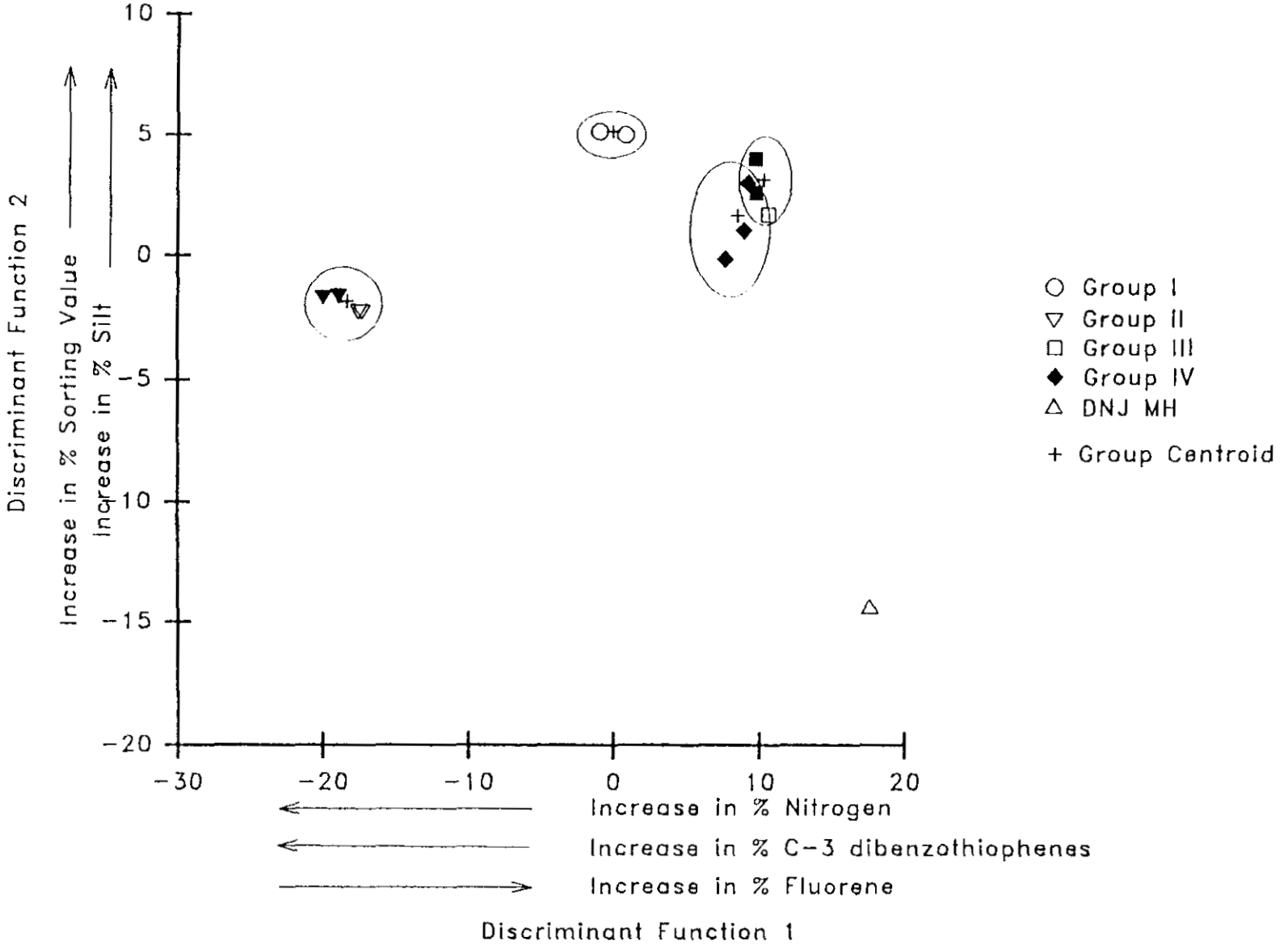

Figure 12. Station group and station plot from stepwise multiple discriminant analysis of infaunal abundance data from 100m utilizing environmental variables. A "+" indicates the group centroid. Dark symbols indicate sites within the EVOS trajectory. DNJ indicates stations that did not join a group. Station symbols are identified in the caption of Figure 2.

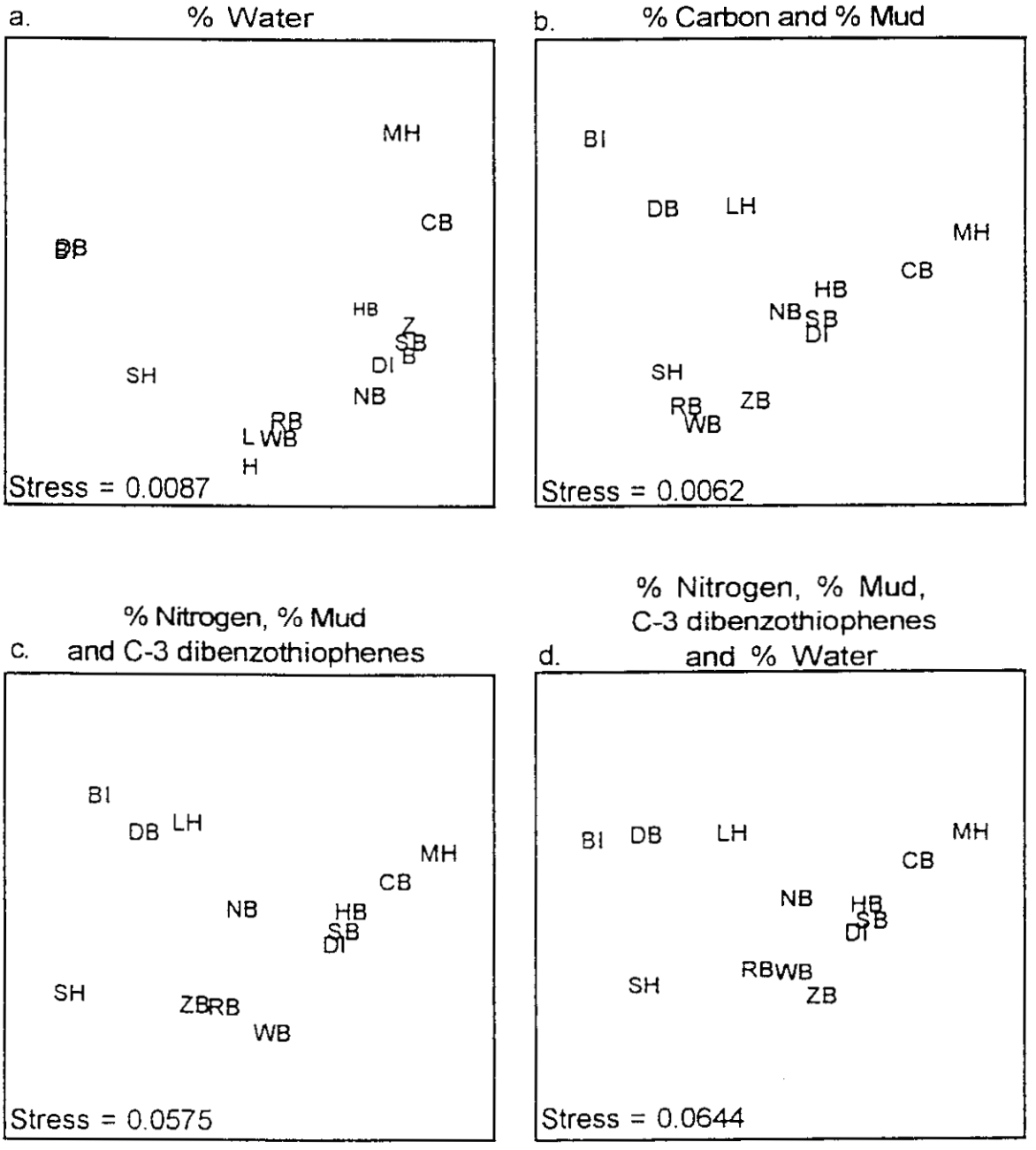

Figure 13. MDS plots of environmental variables for samples collected at 100m for the 14 sites from Prince William Sound in 1990. See caption for Figure 2 for station symbols.

trajectory; Zaikof, Rocky, West, Northwest, Sleepy, Herring, Moose Lips and Chenega Bays, and Disk Island) are mostly intermediate in position in the final MDS plot (Figure 13d), implying that these stations basically have the same relationships to the four environmental parameters. Fluorene was not an important variable in the MDS BIO-ENV analysis.

Data from Sites at >100 m

The bathymetry at some of the study sites at >100 m made it impossible to obtain samples there. Sites not sampled were Moose Lips Bay (R), Disk Island (OT) and Snug Harbor (OT). Thus, only eleven stations were occupied at this depth.

Sediment Analyses

Sediment parameters, and organic carbon, nitrogen, C/N and d13C values in sediment are included in Table 1.

Sediment Oil Analyses

No oil samples were collected by NOAA at >100 m. No other Damage-Assessment projects sampled sediment for presence of petroleum hydrocarbons at this depth.

Laboratory Observations of Oil in Samples Collected in July 1990

No oil was observed in any of the biological samples collected at >100 m.

Faunal Assessment of Data from Stations Sampled July 1990 at >100 m

Composition and Diversity at Stations Based on Values for Higher Taxa

At most stations polychaetous annelids were dominant. However, at stations at six sites sipunculids (Golfingiidae, *Golfingia margaritacea*) were also very abundant: Herring Bay (OT), Sleepy Bay (OT), Northwest Bay (OT), Chenega Bay (OT), Zaikof Bay (R), and Rocky Bay (R). Additionally, at a few sites (Herring Bay, Sleepy Bay, Bay of Isles (OT), West Bay (R) and Rocky Bay) small bivalves were abundant. The abundance, biomass, number of taxa and diversity of fauna for stations sampled at this depth are included in Table 4.

Abundance values within the EVOS trajectory varied between 1100 (Bay of Isles) and 4448 (Herring Bay) indiv. m^{-2} and for sites outside of the EVOS trajectory between 548 and 554 (Lower Herring and Drier Bay, respectively) and 6638 (Rocky Bay) indiv. m^{-2}. Wet-weight biomass within the EVOS trajectory varied between 6.8 (Northwest Bay) and 38.2 (Herring Bay) g m^{-2}; wet weight at sites outside of the EVOS trajectory varied between 5.2 (West Bay) and 132.0 (Zaikof Bay: high biomass primarily a result of presence of ophiuroids and astartid bivalves) g m^{-2}. The number of taxa at stations within the EVOS trajectory varied between 40 (Bay of Isles) and 69 (Sleepy Bay; taxa outside of the EVOS trajectory varied between 21 (Drier Bay) and 81 (Zaikof Bay). Most of the Shannon Diversity values were relatively high and similar between stations within and outside of the EVOS trajectory. Lower diversity values occurred at Drier Bay (R; 2.2), and Northwest Bay (OT) and West Bay (R) (both 2.6). Dominance by some polychaetes, sipunculids and bivalves is reflected by

relatively high Simpson dominance values at some stations, within and outside of the EVOS trajectory: Northwest Bay (0.15: within the EVOS trajectory) and Drier Bay (0.17), Lower Herring Bay (0.15), MacLeod Harbor (0.11), Rocky Bay (0.13), and West Bay (0.13) (all outside the EVOS trajectory. Species Richness (SR) at stations within the EVOS trajectory ranged between 6.8 (Northwest Bay) and 9.3 (Sleepy Bay); SR outside of the EVOS trajectory varied between 3.7 (Drier Bay) and 9.2 (Rocky Bay). The rank abundance of the dominant fauna collected at all stations occupied at >100 m are tabulated in Table 9. Differences in taxa between stations can be seen in this table.

Multivariate Analysis

Cluster and principal coordinate analyses of faunal abundance data from >100 m (Figures 14 and 15) suggest the presence of four station groups. However, the MDS biotic plot clearly segregates three station groups (Figure 16): Group I-Zaikof Bay, Chenega Bay (OT), Sleepy Bay (OT), Herring Bay (OT), Northwest Bay (OT), Rocky Bay (R) and MacLeod Harbor (R), Group II-West Bay (R) and Bay of Isles (OT) and Group III-Drier Bay (R) and Lower Herring Bay (R).

Results of the BIO-ENV analysis of the similarity matrices of benthic biota and environmental variables are summarized in Table 10 and plotted in Figure 17. The best fit between the biota and a single environmental variable is achieved with nitrogen ($P_s = 0.640$; P_s = standard Spearman coefficient (Figures 16 and 17a). Table 1 and Figure 17a show that Drier Bay [R] and Lower Herring Bay [R] have the highest nitrogen values compared to the other stations. Although the highest Spearman coefficient is with the two variables nitrogen and percent water ($P_s = 0.734$; P_s = standard Spearman coefficient), the fit is not improved with these two variables (Figure 17b). The MDS plot demonstrates the wide separation of Drier Bay and Lower Herring Bay from all of the other stations; the latter two stations have the highest N and percent water of all stations occupied at this depth (see Table 1). The best fit between the MDS plots of the biota and environmental variables (although far from a perfect fit) is with four variables ($P_s = 0.716$)-percent clay, percent water, nitrogen and carbon (Figures 16 and 17d). The latter four variables clearly separate the stations to the left in Figure 17d (Zaikof Bay [R], MacLeod Harbor [R], Sleepy Bay [OT], and Chenega Bay [OT]) from Drier and Lower Herring Bays to the right of the plot. The former sites are distinguished by the low percent values for nitrogen and carbon, and percent water while Drier and Lower Herring Bays had the highest values for these three variables. The other stations have intermediate values for the three variables. The addition of percent clay resulted in a vertical separation of Northwest Bay (OT), Bay of Isles (OT) and West Bay (R) stations from the other stations; stations at the former three sites had the highest percent clay within sediments.

[Text continued on page 51.]

Table 9. Rank abundance (no. m^{-2}) by families and higher taxa for all stations at >100 m for data collected in Prince William Sound, July 1990.

Abundance Stat	Cond	Taxa	Abundance (no. m^{-2})	Stat	Cond	Taxa	Abundance (no. m^{-2})
DI	OT	Not sampled		SH	OT	Not sampled	
HB	OT	Golfingiidae	1026	CB	OT	Golfingiidae	682
		Bivalvia	492			Owenidae	384
		Cirratulidae	290			Anthozoa	282
		Lumbrineridae	256			Syllidae	248
		Spionidae	246			Sabellidae	202
		Maldanidae	244			Ampharetidae	176
		Paraonidae	236			Ascidiacea	118
		Phoxocephalidae	198			Bivalvia	98
		Sabellidae	184			Cirratulidae	86
		Owenidae	146			Capitellidae	74
		Syllidae	144			Sigalionidae	70
		Capitellidae	126			Archaeogastropoda	64
		Ampharetidae	112			Phoxocephalidae	54
		Polyodontidae	72			Gnathiidae	52
		Cossuridae	58			Leuconidae	46
		Dentaliidae	50			Paraonidae	46
		Terebellidae	44			Polyodontidae	46
		Nephtyidae	44			Ophiuroidea	46
						Arabellidae	42
SB	OT	Golfingiidae	570				
		Sabellidae	564	BI	OT	Paraonidae	156
		Bivalvia	294			Bivalvia	142
		Paraonidae	218			Nuculanidae	104
		Cirratulidae	214			Nephtyidae	104
		Syllidae	208			Lumbrineridae	70
		Owenidae	148			Leuconidae	64
		Lumbrineridae	126			Spionidae	64
		Spionidae	96			Gastropoda	54
		Montacutidae	82			Cirratulidae	46
		Phoxocephalidae	68			Scaphandridae	42
		Dentaliidae	68			Cossuridae	36
		Capitellidae	62			Thyasiridae	26
		Maldanidae	58			Capitellidae	24
		Nephtyidae	54			Nuculidae	22
		Polyodontidae	50			Sternaspidae	
		Ampharetidae	48			Tellinidae	18
		Gastropoda	44			Glyceridae	26
		Gnathiidae	42				14
		Onuphidae	40	DB	R	Nephtyidae	148
						Cossuridae	144
NB	OT	Golfingiidae	888			Paraonidae	66
		Spionidae	386			Orbiniidae	40
		Cirratulidae	176			Nuculidae	30
		Bivalvia	172			Leuconidae	30
		Syllidae	152			Spionidae	28
		Maldanidae	110			Trichbranchidae	14
		Sabellidae.	108			Nuculanidae	8
		Lumbrineridae	80			Ampharetidae	8
		Phoxocephalidae	78			Bivalvia	8
		Ampharetidae	46			Cirratulidae	6

Table 9. Continued.

Stat	Cond	Taxa	(no. m^{-2})	Stat	Cond	Taxa	(no. m^{-2})
		Nephtyidae	40				
		Terebellidae	36				
		Lysianassidae	36				
		Serpulidae	32				
		Paraonidae	32				
		Capitellidae	30				
ZB	R	Cirratulidae	460	MH	R	Owenidae	646
		Golfingiidae	320			Capitellidae	224
		Capitellidae	282			Spionidae	208
		Balanomorpha	276			Phoxocephalidae	168
		Spionidae	272			Bivalvia	162
		Polyodontidae	258			Golfingiidae	108
		Carditidae	238			Gnathiidae	64
		Owenidae	228			Paraonidae	58
		Syllidae	210			Leuconidae	42
		Bivalvia	196			Orbiniidae	40
		Paraonidae	176			Maldanidae	38
		Sabellidae	120			Veneridae	38
		Diastylidae	104			Rhynchocoela	34
		Tanaidacea	100			Cirratulidae	32
		Ophiuroidea	98			Terebellidae	30
		Echinoida	96			Glyceridae	30
		Phoxocephalidae	90			Ophiuridae	30
		Lumbrineridae	76				
		Ampharetidae	70				
		Ophiuridae	62	MB	R	Not sampled	
		Maldanidae	62				
		Mytilidae	62	LH	R	Nephtyidae	148
						Leuconidae	108
RB	R	Golfingiidae	2050			Paraonidae	52
		Owenidae	892			Spionidae	36
		Bivalvia	514			Bivalvia	30
		Sabellidae	386			Cirratulidae	22
		Lumbrineridae	336			Hesionidae	14
		Spionidae	296			Gastropoda	10
		Paraonidae	180			Rhynchocoela	6
		Nephtyidae	164			Cossuridae	6
		Maldanidae	154			*Amphipoda*	
		Thyasiridae	152			*gammaroida*	6
		Dentaliidae	132				
		Leuconidae	130	WB	R	Bivalvia	156
		Cirratulidae	128			Lumbrineridae	146
		Capitellidae	100			Nephtyidae	92
		Gastropoda	72			Leuconidae	40
		Amphictenidae	68			Cirratulidae	38
		Sternaspidae	58			Dentaliidae	32
		Rhynchocoela	58			Sternaspidae	24
		Nuculanidae	56			Onuphidae	12
		Ophiuroidea	56			Montacutidae	12
		Terebellidae	56			Spionidae	10
		Trichbranchidae	50			Nuculidae	10
		Mytilidae	44				

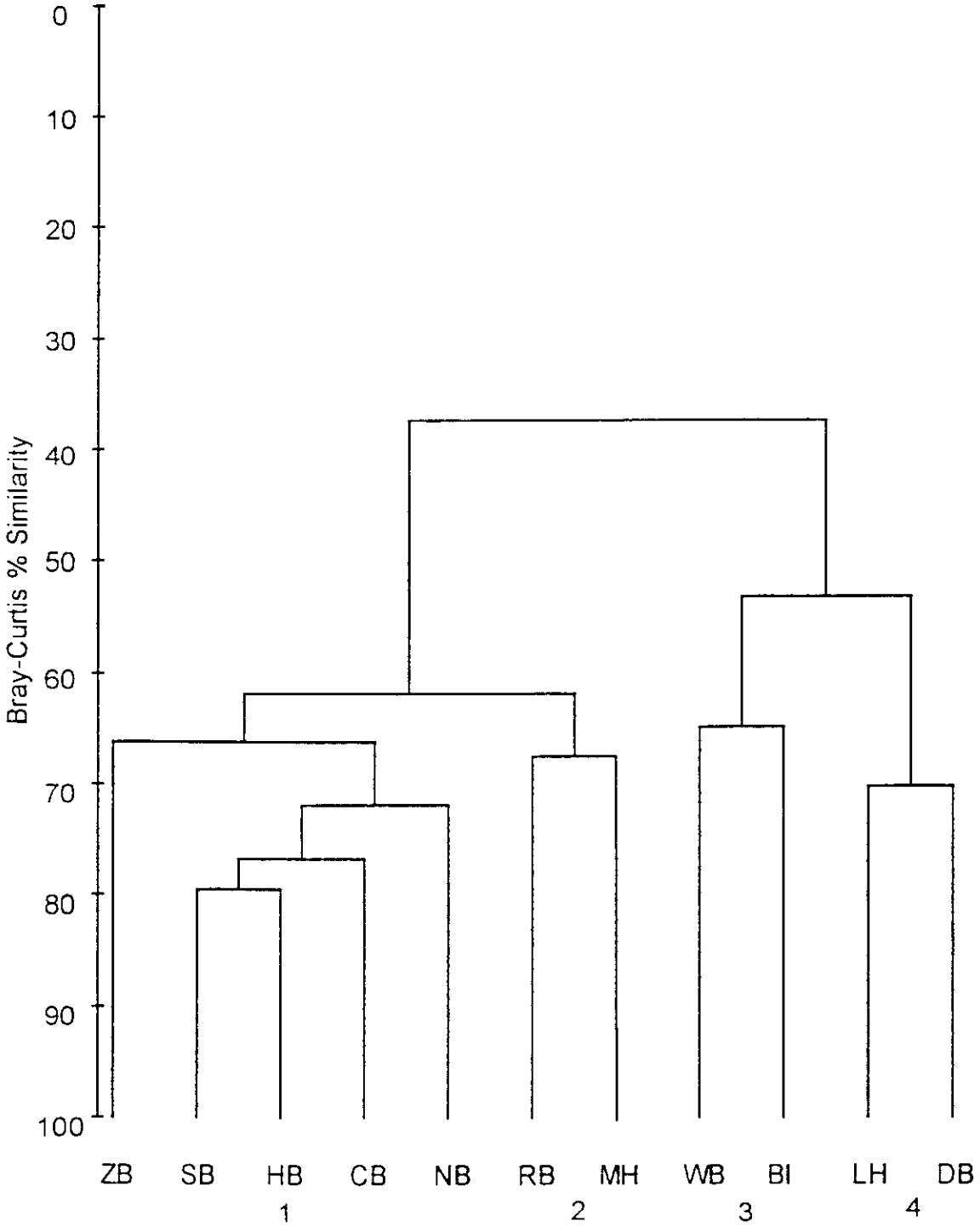

Figure 14. Cluster diagram of *ln*-transformed abundance data for 11 sites throughout Prince William Sound collected in 1990 from >100 m. Station Groups suggested by this analysis are Groups 1-4. Symbols are identified in the caption for Figure 2.

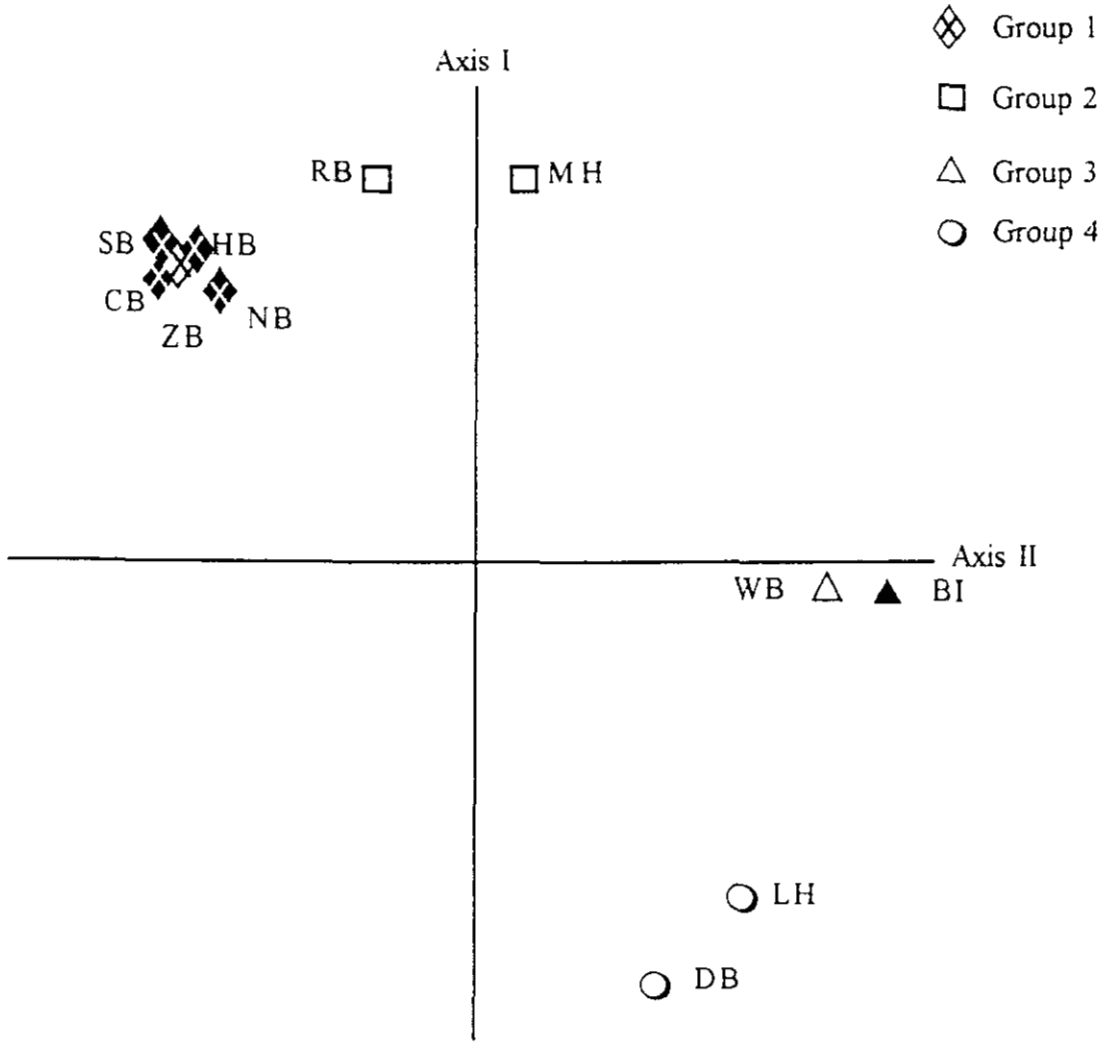

Figure 15. Plot of the first two coordinate axes of a principal coordinate analysis of *ln* - transformed abundance data from >100 m collected in 1990 at sites within Prince William Sound. Station symbols are identified in Figure 2. Black symbols indicate stations within the EVOS trajectory.

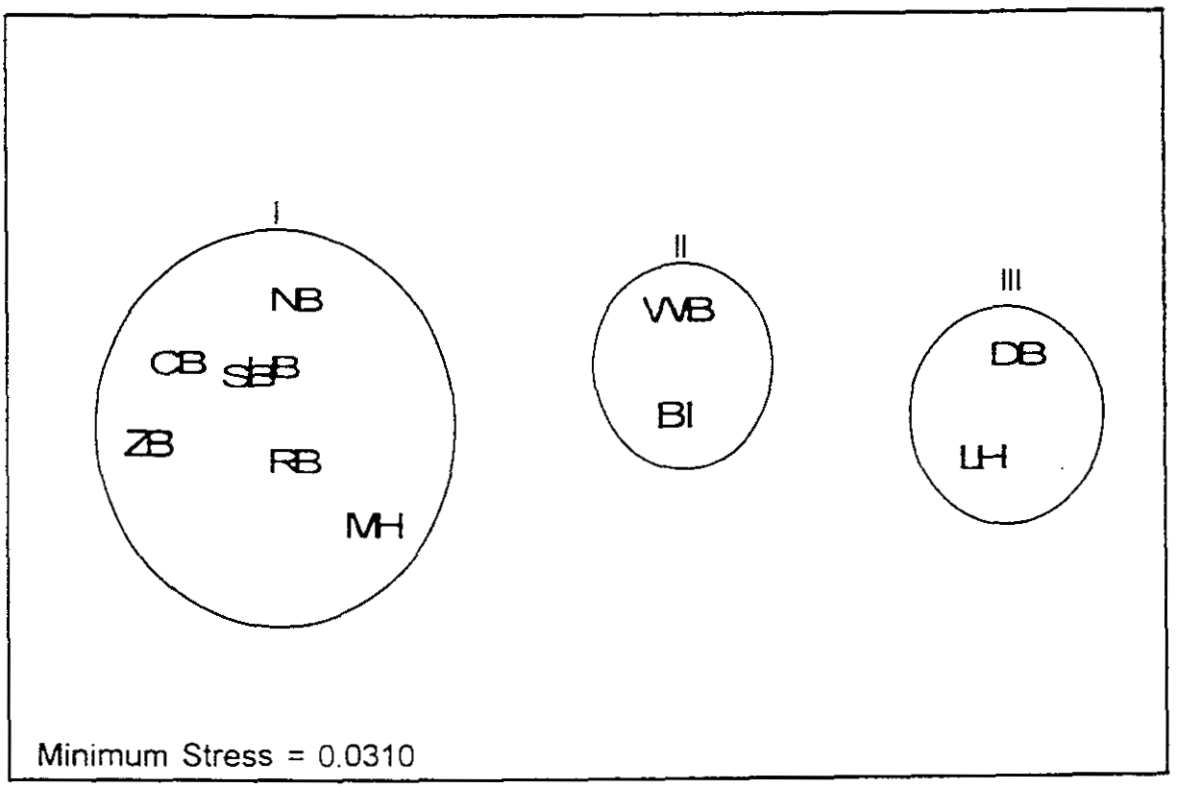

Figure 16. Non-metric mulit-dimensional scaling ordination of abundance data at >100m for 11 sites throughout Prince William Sound in 1990. Station groups identified by ordination are circled. See caption for Figure 2 for station symbols.

Table 10. Correlation analyses of biotic and environmental similarity matrices using the BIO-ENV routine* for >100 m data from 11 sites in Prince William Sound collected in 1990. Similarity matrices for biota, sediment and selected PAH analyte data were compared using the Spearman rank correlation (see Methods and Clarke and Ainsworth [1993] for description of procedure and program output) to determine the combination of variables giving the best correlation coefficient between the biotic and environmental data. P_s = standard Spearman coefficient. "..." indicates succeeding combinations not shown. Correlation coefficients are given in parentheses. Best variable combinations are shown in bold type.

Number of variables	Variable combinations (P_s)	
1.	Nitrogen (0.640), % Water (0.635), Carbon (0.611),	...
2.	**Nitrogen, % Water (0.734)**, % Water, Carbon, (0.715),	...
3.	% Water, Nitrogen, † Carbon (0.713),	
	% Water, Nitrogen, % Clay (0.692),	...
4.	% Water, Nitrogen, Carbon, % Clay (0.716),	...

* The BIO-ENV program is one routine in the PRIMER statistical package provided courtesy of Dr. Clarke, Plymouth Laboratories.

† Nitrogen and Carbon were highly correlated (r = 0.9-, using Pearson's Product Moment Correlation method)

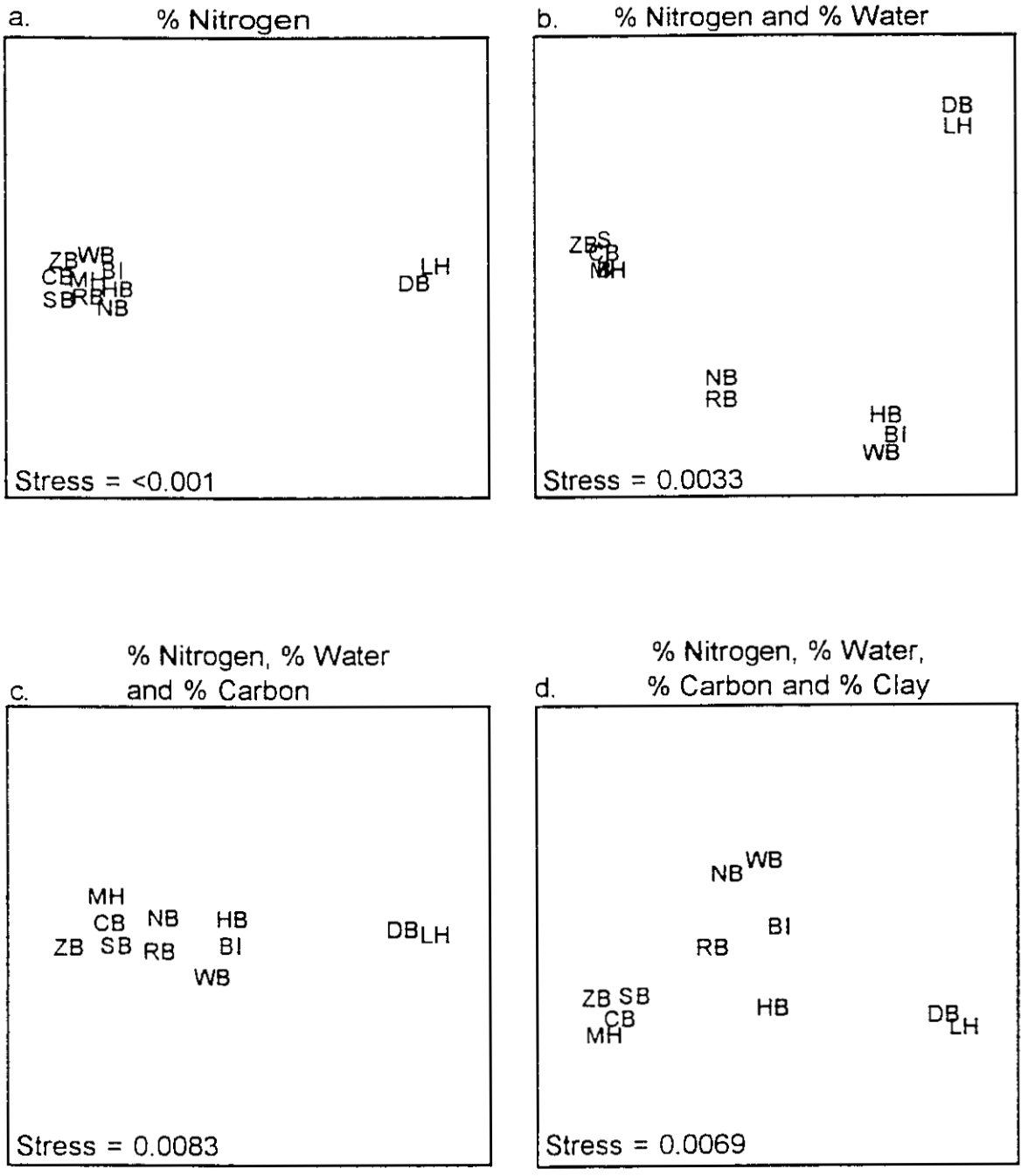

Figure 17. MDS plots of environmental variables for samples collected at >100m for the 14 sites from Prince William Sound in 1990. See caption for Figure 2 for station symbols.

DISCUSSION

General

Based on literature documenting oil spills in marine waters (e.g., see reviews in Teal and Howarth, 1984, and Spies, 1987), it was expected that a certain proportion of oil derived from the *Exxon Valdez* oil spill (EVOS) would reach the bottom as a result of physical and biological processes (also see reviews in Boesch and Rabalais, 1987, Kuiper and Van Den Brink, 1987). For example, after Teal and Howarth (1984) reviewed data from seven oil spills they stated that in all of the spills"... there is evidence either that oil was transported to the sediments (that is, it was detected in the sediments themselves or in the benthic animals) or that a mechanism for such transport was present." Benthic data collected in oil-impacted marine waterselsewhere suggest that changes in species number, abundance, biomass, diversity and species richness can be expected if sizable amounts of oil settle to the bottom (e.g., see Dauvin, 1982, and Glemarec and Hussenot, 1982). In Prince William Sound there was concern that changes in bottom fauna might have serious trophic implications since subtidal benthic invertebrates are important food resources for bottom-feeding species there (Feder and Paul, 1977; Feder and Hoberg, 1980; Feder and Jewett, 1988). Also see comments in Jewett (1978), Smith et al. (1978), Rice et al. (1980), Feder and Paul (1980), Feder and Jewett (1981), and Jewett and Feder (1983) for feeding habits of pandalid shrimps, Tanner and Dungeness crabs, and bottom fishes (all species common in Prince William Sound) in Cook Inlet, Kodiak bays and the shelf of the northeast Gulf of Alaska. Further, since larvae of most benthic organisms in Prince William Sound move into the water column from March through June, where they are utilized as food by large zooplankters and larval and juvenile stages of pelagic fishes, salmon fry, and herring (Feder and Paul, 1977; Feder, 1979; Feder, unpub., R. T. Cooney, Person. commun., S. C. Jewett, Person. commun.), this important trophic link could have been at risk following the EVOS. Thus, damage to the benthic system by hydrocarbon contamination was expected to affect feeding interactions of organisms on the bottom and in the water column. However, unexpectedly, benthic biological data from seven embayments within the EVOS trajectory collected 16 months after the spill (this Report) demonstrated no indications of ecological effects such as those still in evidence after this time period at some sites following the *Amoco Cadiz* spill in France (Dauvin, 1982; Glemarec and Hussenot, 1982). In fact, the benthic biota at most of the sites within the EVOS trajectory at 40, 100 and >100 m demonstrated high abundance and relatively high species richness values. None of the univariate measures indicated disturbance at these sites, and multivariate analyses did not relate faunal composition and associations at stations within the oil trajectory to hydrocarbons derived from the EVOS.

The following discussion considers and assesses data collected in July 1990 at fourteen sites within Prince William Sound at depths of 40, 100 and ≥100 m.

Sites at 40 m

The presence of oil residues in all biological samples within sorting dishes at six of the seven sites within the EVOS trajectory (OT; Table 2; Appendix III) suggests that (1) oil was still

present as a result of the oil spill and/or (2) oil was moving into deeper water from oil-contaminated beaches (Wolfe et al., 1993), and/or (3) petroleum hydrocarbons were present from other oil-spill events in the past (e.g., see Kvenvolden et al., 1993) or from seeps in the eastern Gulf of Alaska (Page et al., 1993; see discussion in Braddock et al., in press). No oil was observed in sample dishes from the reference sites (R). Thus, the hydrocarbon data for sediment samples presented in Table 3 are difficult to interpret since some of the polycyclic aromatic hydrocarbon analytes (PAHs) were at relatively high levels at stations within sites both outside of and within the EVOS trajectory. Jewett et al. (1993a) working in the shallow subtidal to 20 m states that "... the data... suggest that oil was present in many (if not all) of our control sites... It appears that the effects of oil may not have been restricted to our "oiled" sites, but may have occurred to a lesser degree throughout the Sound. O'Clair et al. (1993), summarizing the NOAA TSTF data, indicate that "Sediments collected at 40 m ... were for the most part not contaminated with *Exxon Valdez* oil. Although oil concentrations in subtidal sediments were probably not acutely toxic to most organisms, the low level oil concentrations...would be a source of chronic exposure to subtidal communities." Rice et al. (1993) state that sediments at "... 40 m sometimes had low levels of hydrocarbon contamination, but the analyte profiles were not always similar to *Exxon Valdez* crude oil." Wolfe et al. (1993) indicate that "Near some heavily oiled areas, low concentrations of residual petroleum hydrocarbons and associated concentrations of microbial hydrocarbon-degraders ... were detectable during the summer of 1990 in deeper (40-100 m)...sediments where no activity had been detected in 1989." (also see Braddock et al., 1995). Fluorescence data on sediments at wave lengths for phenanthrene and naphthalene demonstrated fluorescence at all of the oiled sites except Chenega Bay; no fluorescence was detected at any of the unoiled sites (Wolfe, Status Report and Person. Commun.). Also, at some sites Collier et al. (1993) detected fluorescent aromatic compounds in fish bile of several species of flatfishes. The preceding reports and papers indicate that oil (derived from EVOS and/or other sources) was present at 40 m but that the levels of hydrocarbons were very low.

Examination of stable carbon isotope ratios ($\delta^{13}C$) elsewhere demonstrate that this approach can be useful in identifying marine regions contaminated with petroleum (e.g., see Spies and DesMarais, 1983). The premise in previous investigations was that carbon derived from various organic pools has a characteristic $\delta^{13}C$ value. In principle, the $\delta^{13}C$ of marine sediments could help to estimate the proportion in the sediment of organic matter derived from various natural and anthropogenic pools. Based on the above premise Naidu et al. (1993b) examined the possibility of subtidal sediment contamination by EVOS oil ($\delta^{13}C$=-30 ‰) in Prince William Sound. They compared $\delta^{13}C$ values of sediment samples from sites in 1990 (those within and outside the EVOS trajectory) with pre-EVOS sediment samples from 1979, 1980 and 1981, and could detect no significant differences in the values. They concluded that sediments at sites within the EVOS trajectory were not markedly contaminated with oil, a conclusion that supports the low levels of hydrocarbons detected at 40 m by the other techniques noted above. As discussed above, observations of oil in biological sample dishes and hydrocarbon data for 1990 suggest that low levels of oil were present at 40 m at some sites within the EVOS trajectory. However, there is no indication that these oil residues

adversely influenced the benthic fauna at stations within that trajectory. High and low faunal abundance, biomass and species richness values occurred at stations within and outside of the EVOS trajectory (Table 4). In fact, some of the lowest values for abundance, biomass and species richness occurred at stations outside the oil trajectory (i.e., the reference stations). Shannon Diversity was similar at all stations with lowest values often occurring at reference stations. Simpson dominance values were low at most stations (indicating no dominance) with the highest values (indicating dominance and possible disturbance) often recorded at reference stations (see Boesch and Rosenberg, 1981, Zajac and Whitlatch, 1982, and Sousa, 1984, for definition and discussion of 'disturbance'). Taxa characteristic of disturbance (e.g., see Pearson and Rosenberg, 1978) were not restricted to stations within the EVOS. In fact, at all stations with high faunal abundance values (within and outside of the EVOS trajectory) surface-deposit and suspension-feeding taxa were present, some of which may occur at disturbed sites (for examples, see Fauchald and Jumars, 1979, for polychaete feeding types; Pearson and Rosenberg, 1978). Multivariate techniques divided stations into two groups, with three stations not joining a group. The largest group (Group II: Figures 3 and 4) comprises a mixture of stations within and outside of the EVOS trajectory; all of the stations within this group had high abundance values. The Chenega Bay station (OT), one that did not join a group but showed the greatest similarity to Group II, also had a high abundance value. The other station group (Group I) consisted of three stations, all outside of the EVOS trajectory, had low abundance values. The other two stations that did not join a group, Lower Herring Bay (R) and Snug Harbor (OT), were most similar to Group I, and these stations also had low abundance values (Figure 18).

Stepwise Multiple Discriminant Analysis applied to the two station groups and the three stations that did not join these groups separated Station Group I (Lower Herring Bay and Snug Harbor) from Group II and Chenega Bay by the higher percentage of silt and amount of Nitrogen in sediment of the former stations (Figures 5, 6 and 7). Application of Non-Metric Multidimensional Scaling (MDS) to the biological and environmental data resulted in nitrogen and per cent silt separating the stations in a similar relationship to the biological MDS (i.e., the best match of the environmental correlations with the MDS ordination; see interpretation of this technique by Clarke and Ainsworth, 1993). However, addition of the hydrocarbon PAH analyte C4-Naphthalene to the analysis resulted in the best match between the MDS abundance plot and the environmental variables (Table 6). However, C4-Naphthalene occurred at stations within and outside of the EVOS trajectory. In fact, this analyte had its highest concentrations at two of the reference stations (Lower Herring Bay and Drier Bay; Table 3a; Figures 4 and 8) which indicates that C4-Naphthalene may have been derived from *Exxon Valdez* oil but was apparently also a hydrocarbon constituent resulting from other oil sources in the Sound. Thus, although the addition of C4-Naphthalene to Nitrogen and percent silt results in the best match with the biological ordination, it is obvious that this hydrocarbon does not necessarily reflect the effect of oil from the EVOS. The high benthic abundance values at stations within Group II and Chenega Bay (Figure 18), stations with relatively low sediment nitrogen and carbon values, are associated with the presence of coarse sediments as compared to the other stations (Table 1; Figures 4, 5, 7 and 18). Such sediment characteristics suggest the presence of greater turbulence and/or bottom

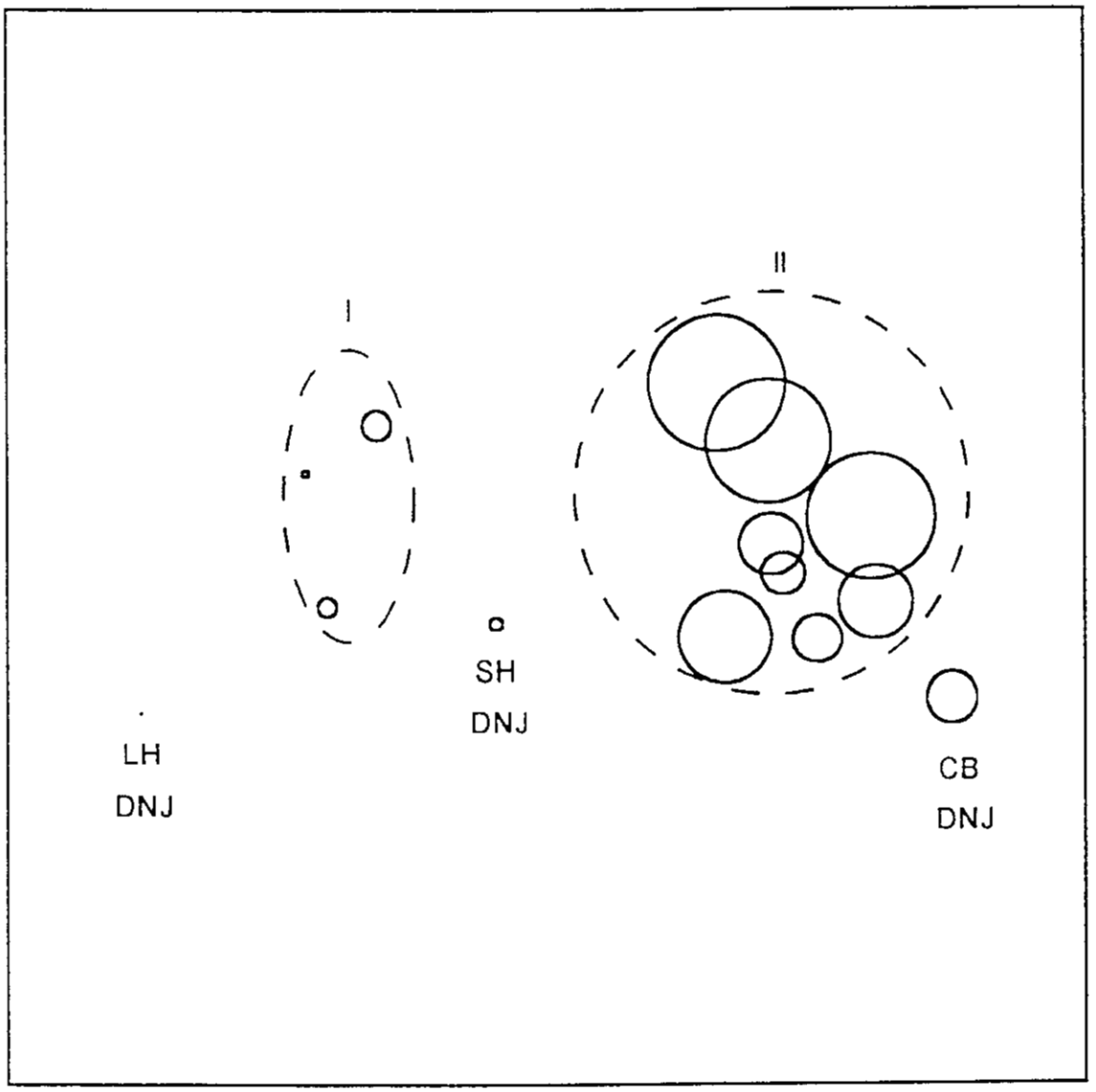

Figure 18. Relation of stations and station groups to faunal abundance values at 40m. MDS plot based on infaunal abundance with groupings delineated as in Figure 4. At each station, circles proportional in diameter to faunal abundance are superimposed. Station groups determined by ordination in Figure 4a are enclosed by dashed lines and identified by Roman numerals. DNJ = stations that did not join a group.

currents, conditions usually associated with increased availability of particulate organic carbon for organisms feeding at the benthic interface or benthic boundary layer (see McCave, 1976, for comments on the benthic boundary layer).

Sites at 100 m

No oil was observed in biological samples within any of the sorting dishes from any of the sites. As for oil data (i.e., EVOS PAH analytes listed in Table 3; Appendix III) from sediment samples at this depth, the data for 100 m are as difficult to interpret as those from 40 m. Again, some of the PAHs were at relatively high levels at stations within sites both outside of and within the EVOS trajectory. O'Clair et al. (1993), summarizing the NOAA TSTF data, indicate that "Sediments collected at ... 100 m were for the most part not contaminated with *Exxon Valdez* oil. Although oil concentrations in subtidal sediments were probably not acutely toxic to most organisms, the low level oil concentrations...would be a source of chronic exposure to subtidal communities." Rice et al. (1993) state that sediments at "...100 m sometimes had low levels of hydrocarbon contamination, but the analyte profiles were not always similar to *Exxon Valdez* crude oil." They also state that "By 1990 there was some indication at some of the heavily contaminated sites that hydrocarbon levels at depth increased." Wolfe et al. (1993) indicate that "Near some heavily oiled areas, low concentrations of residual petroleum hydrocarbons and associated concentrations of microbial hydrocarbon degraders...were detectable during the summer of 1990 in deeper (40-100 m)... sediments where no activity had been detected in 1989 (also see Braddock et al., 1993; Braddock et al., 1995). As also noted for 40 m sediment samples, Naidu et al. (1993b) concluded, based on assessment of $\delta^{13}C$ data, that sediments at sites [inclusive of those at 100m] within the EVOS trajectory were not markedly contaminated with oil. The preceding comments indicate that oil (derived from the EVOS and/or other sources) was present at 100 m in 1990 but that the levels of these hydrocarbons were very low.

As discussed for stations at 40 m, there are no indications that the low levels of oil at 100 m influenced the benthic fauna here. All comments made above concerning fauna at 40 m applies to the benthic biota at 100 m.

Multivariate analyses divided stations into four station groups with one station (MacLeod Harbor: outside of the EVOS trajectory) that did not join a group (Figures 9, 10, 11; Appendix IV-III). Station Groups II, III and IV comprised a mixture of stations within and outside of the EVOS trajectory). Highest abundance values occurred within three of the Group IV stations (Moose Lips Bay [R], Herring Bay [OT], Sleepy Bay [OT]) with coarse and poorly sorted sediments (Table 1; Figure 19). Benthic abundance values at MacLeod Harbor were intermediate; sediments were sandy and relatively well sorted at this station. Low abundance values were generally characteristic of Groups I and II; sediments were very muddy at stations within these groups.

Stepwise Multiple Discriminant Analysis (Figure 12) clearly separated stations within Group II (consisting of two stations within and two outside the EVOS trajectory) from all other stations based on higher Nitrogen content and concentration of C3 Dibenzothiophene at

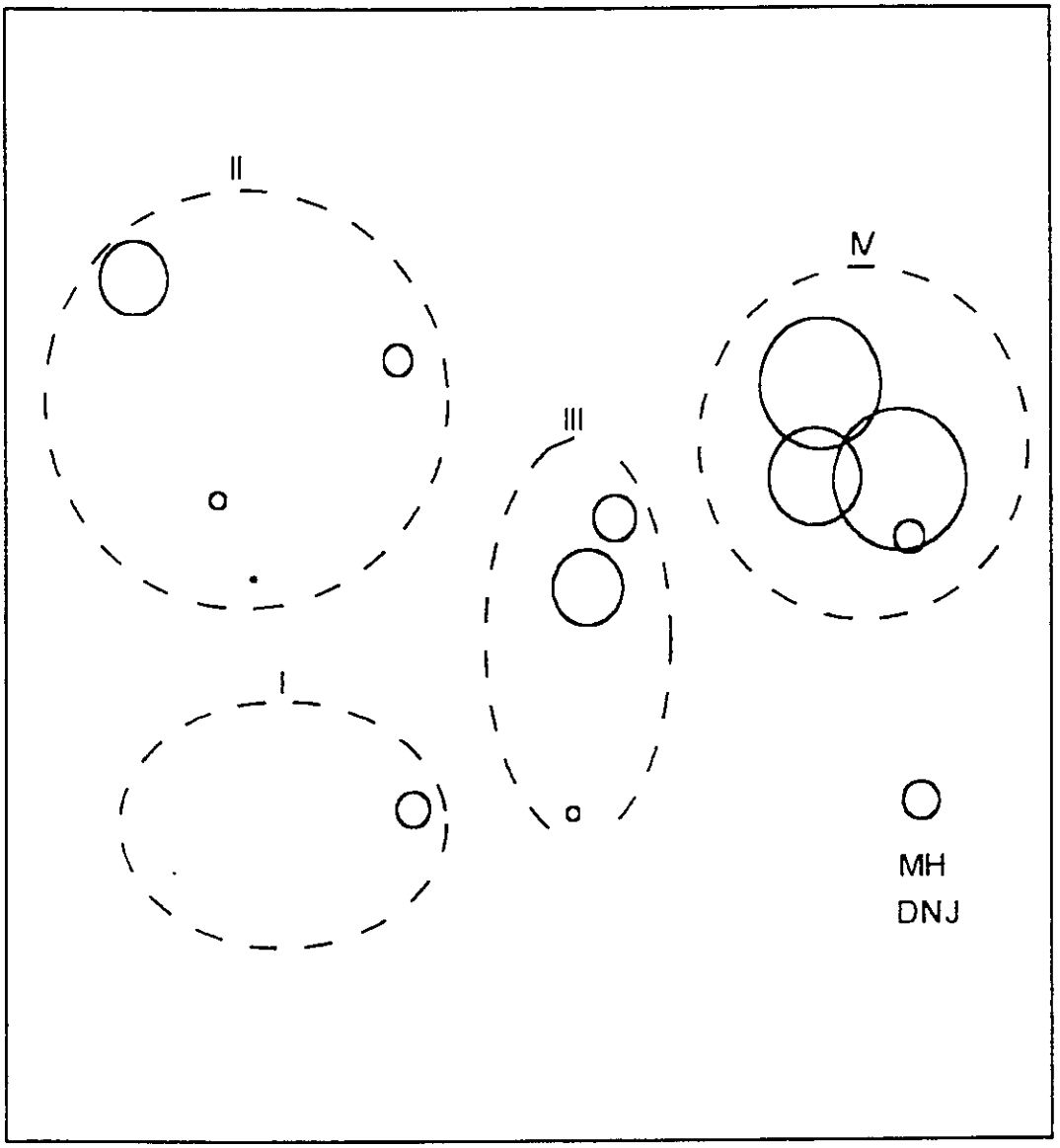

Figure 19. Relation of stations and station groups to faunal abundance values at 100m. MDS plot based on infaunal abundance with groupings delineated as in Figure 11. At each station, circles proportional in diameter to faunal abundance are superimposed. Station groups determined in Figure 11 are enclosed by dashed lines and identified by Roman numerals. DNJ = station that did not join a group.

stations of Group II. Relatively higher fluorene values were found within Station Groups I, III, IV and MacLeod Harbor, a mixture of stations within and outside the EVOS trajectory. The non-metric multi-dimensional scaling (MDS) BIO-ENV program separated stations based on higher nitrogen and C3 Dibenzothiophene but also by percent water in sediment and percent mud. These four variables show the best correlation with the biological similarities in the MDS plot of biological data, and seem to explain the separation of the stations into groups (Table 8; Figures 11 and 13; see Clarke and Ainsworth, 1993, for interpretation of BIO-ENV output). Fluorene was unimportant as a variable in the BIO-ENV analysis of the 100 m benthic biological data. The presence of a hydrocarbon considered to be a PAH analyte of the EVOS, C3 Dibenzothiophene, at stations within and outside of the trajectory of the EVOS indicates that this hydrocarbon is not related to the spill. However, the presence of the highest concentrations of this analyte at Snug Harbor (within the EVOS trajectory) at 40 and 100 m (Table 3b: "C3dith") suggests that this analyte may, at this site, be related to the EVOS. However, none of the univariate measures at either depth at Snug Harbor suggest disturbance responses by the benthic biota that might be related to oil toxicity. Fluorene was present at a mixture of stations within and outside the EVOS trajectory. The highest value was at Northwest Bay (OT) and next highest at MacLeod Harbor (R). However, fluorene concentration at Northwest Bay (OT) at 40 m was very low but very high at MacLeod Harbor (R). Also, the highest values for fluorene at 40 m were at three of the Reference stations (Table 3). Thus, the presence of this hydrocarbon analyte does not appear to be related to the EVOS. As suggested for fauna at 40 m, the high abundance values at three of the four stations within Group IV (Moose Lips Bay: reference station; Sleepy Bay and Herring Bay: within the EVOS trajectory) in sediments with relatively low carbon and nitrogen values suggest advection of POC to fauna here from external sources (Table 1; Figures 11, 12, 13 and 19).

Sites at >100 m

No oil was observed in biological sample dishes at this depth at any sites. No sediment samples for hydrocarbon analysis were collected at this depth. However, based on the low level of hydrocarbons reported for sediment from 100 m (O'Clair et al., 1993, Rice et al., 1993, Wolfe et al., 1993), it is unlikely that detectable levels of petroleum hydrocarbons derived from the EVOS would occur at this deeper depth. There are no indications, based on 1990 data, that the benthic fauna at >100 m was affected by input of a stressing agent, such as petroleum hydrocarbons from the EVOS. All comments made above concerning faunal characteristics at 40 m apply to the benthic biota at >100 m.

Non-metric multi-dimensional scaling clearly separated stations at this depth into three groups (Figure 16). The largest group (Group I) comprises a mixture of stations within (OT) and outside (R) the oil trajectory (Northwest Bay, Herring Bay, Sleepy Bay, Chenega Bay: OT; Zaikof Bay, Rocky Bay and Macleod Harbor: R), Group II consists of two stations (Bay of Isles: OT, and West Bay: R), and Group III with two stations outside the EVOS trajectory. Stations within Group I had the highest abundance values of all stations sampled (Table 4: Figures 16 and 20).

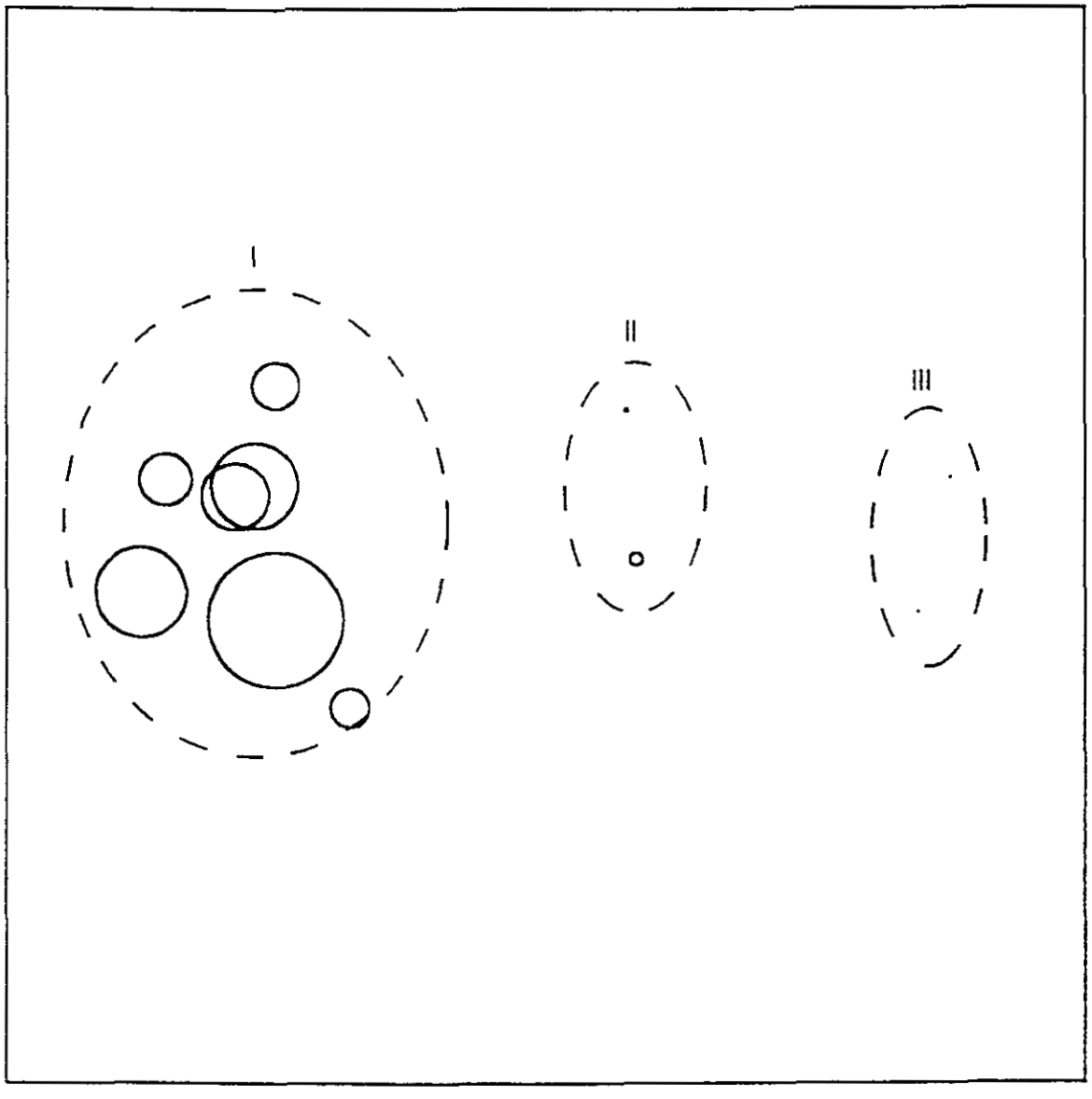

Figure 20. Relation of stations and station groups to faunal abundance values at >100m. MDS plot based on infaunal abundance with groupings delineated as in Figure 16. At each station, circles proportional in diameter to faunal abundance are superimposed. Station groups determined in Figure 16 are enclosed by dashed lines and identified by Roman numerals. DNJ = station that did not join a group.

Application of Non-Metric Multidimensional Scaling (MDS) to the biological and environmental data resulted in percent water, nitrogen, carbon and percent clay separating the stations in a similar relationship to the biological MDS (i.e., the best match of the environmental correlations with the MDS ordination; Figures 16 and 17; see interpretation of this technique by Clarke and Ainsworth, 1993). Drier Bay and Lower Herring Bay (both out of the EVOS trajectory) are separated from the other stations by their high values for nitrogen and carbon, and high percentage of water in sediment (Table 1; Figures 16 and 17). Decreased stability of sediments here are reflected by the higher numbers of motile taxa present (Table 9; e.g. nephtyid polychaetes; see polychaete motility types listed in Fauchald and Jumars, 1979).

Also, the dominance of the motile polychaete group Nephtyidae at both stations reflects the high organic carbon present (Table 1). Various species of *Nephtys* are reported elsewhere in organically enriched sediments (Lizaraga-Partida, 1974; Pearson and Rosenberg, 1978). Jewett et al. (1993b) indicates that shallow benthic communities in silled fjords in Prince William Sound were dominated by *N. cornuta* when the bottom was organically enriched andoxygen levels were low. The higher abundance values at stations in Group I (Figure 20) appear related to the greater stability of the sediment and presumably greater input of allochthonous POC to the bottom compared to all other stations. Greater sediment stability at stations within Group I could be attributed to the lower percent water in sediments here relative to Groups II and III (Figure 17; Tables 1, 10). The relationship of high sediment stability/cohesiveness with decreased water content within sediment is discussed in detail in Postma (1967). The addition of percent clay to the BIOENV analysis (Table 10) resulted in a vertical separation of Northwest Bay (OT), Bay of Isles (OT), Rocky Bay (R) and West Bay (R) from all of the other stations; these four stations had the highest percentage of clay within sediments (Table 1). The ecological significance of this high percentage of clay is not clear. As noted by Clarke and Ainsworth (1993), "...there can be no guarantee that..." a particular variable "... is directly *causal* in the shaping of community structure; it may be simply collinear with unmeasured characteristics."

CONCLUSIONS

Analyses of benthic biological, sediment and hydrocarbon data collected in bays in Prince William Sound in 1990 at 40 and 100 m, by univariate and multivariate techniques, demonstrate no obvious disturbance effects on the benthic biota 16 months after the *Exxon Valdez* oil spill. In all cases, the major environmental variables that were related to the composition of benthic assemblages (at various depths) were sediment parameters such as percent silt, clay, mud, percent water, and amount of nitrogen and carbon in sediment. Two polycyclic aromatic hydrocarbons (C-4 naphthalene and C-3 dibenzothiophene; analytes that could be represented by presence of *Exxon Valdez* oil) added additional structure to the MDS plots of environmental variables and aided in the interpretation of spatial dispersion of stations in the biotic plots (i.e., increased similarity of environmental plots to the biotic plots (see theoretical discussion in Clarke and Ainsworth, 1993). However, these hydrocarbon compounds were present at sites within (OT) and outside (R) the EVOS trajectory, and, in

some cases, were in higher concentrations at reference sites.

Braddock et al. (1993, 1995), O'Clair et al. (1993), Rice et al. (1993) and Wolfe et al. (1993, 1994) detected limited amounts of petroleum hydrocarbons and the presence of hydrocarbon degrading bacteria in 1990 at 40 and 100 m at some sites in Prince William Sound within the EVOS trajectory. However, it is probable that little oil fluxed to the bottom at $\geq$ 40 m after the EVOS in 1989 and that only minor, or no, impact was sustained by the benthic fauna of the deep benthos throughout the Sound. This conclusion is based on knowledge of the physical oceanographic dynamics of waters of the Gulf of Alaska and Prince William Sound (Royer et al., 1990; Niebauer et al., 1994). "The general circulation pattern is defined by a portion of the westward flowing Alaska Coastal Current on the Gulf of Alaska shelf that enters Prince William Sound through Hinchinbrook Entrance and transits the Sound from east to west before exiting through Montague Strait..." (Niebauer et al., in press). "The coastal circulation of the northwest Gulf and Prince William Sound served as a conduit for oil spilled from the ...*Exxon Valdez*" (Royer et al., 1990). The Prudhoe Bay crude oil spilled by the *Exxon Valdez* has a relatively low density (Anonymous, 1985) and to settle to the bottom it had to increase its specific gravity. Thus, the oil had to adhere to suspended sediments within the water column in order to sink. This was initially (i.e., immediately after the *Exxon Valdez* spill) considered probable based on the very high suspended sediment load typically found within the Alaska Coastal Current which enters Prince William Sound (Burbank, 1974; Feely et al., 1979). The Alaska coastal current is affected by freshwater discharge which according to Royer et al. (1990) was at a record low at the time of the EVOS in March 1989. Carlson and Kvenvolde (1993) suggest that under the "... conditions of lower discharge, the amount of suspended sediment carried by streams draining the large glaciers bordering the Gulf of Alaska was probably below normal... If the amount of particulate matter (in the water column) [was] low, the probability of bonding (of crude oil with suspended particles) decreases." They felt that this process might explain the absence of EVOS oil in deep-water samples in 1989. Carlson and Kvenvolde (1993) also speculated that if the lower freshwater discharge in 1989 caused water movement through the Sound to be slowed, the oil would have more time to attach to sediment particles. However, the general absence of oil in deep sediment after the spill indicated to them that their first suggestion (noted above) was the likely one. Nevertheless, despite the relative slowness of the Alaska Coastal Current in 1989 immediately following the EVOS, Royer et al. (1990) felt that current speeds throughout the Sound were high enough by June 1989 (approximately three months after the EVOS) to "...reduce the concentration of any potentially oiled sediments..." They state that "The swift Alaska Coastal Current has and will continue to flush the waters of Prince William Sound..." Thus, the physical-oceanographic dynamics within the Sound explain the lack of low levels of oil in sediments at depths $\geq$40 m as well as the absence of disturbance signals within the benthic biota in 1990, approximately 16 months after the EVOS. An alternate possible source of sediment bonding with oil could be the oiled sediments on beaches and adjacent shallow waters. However, the absence or very low concentrations of oil in deeper sediments ($\geq$40 m)indicates that the deep subtidal region was not a major depot site for these oiled sediments.

Hyland and Schneider (1976) suggested that recovery of benthic marine systems in open estuarine areas and embayments (such as many of the sites examined in Prince William Sound) from the effects of an oil spill is dependent on the flushing characteristics of the body of water. In assessing the impact of the Amoco Cadiz oil spill on the benthos, Cabioch et al. (1978) noted the tendency for accumulation of oil, and the resulting benthic perturbation, in fine sediments but not in coarse sediments. They state that "...hydrodynamics [in turbulent areas] will discourage the persistence of particulate oil..." while simultaneously ...facilitating its breakdown by good oxygenation..." Dauvin (1982) indicates that levels of hydrocarbons after the Amoco Cadiz spill were at background levels within a year at a site with fine sand bottom. As indicated previously, little or no oil from the EVOS probably settled subtidally to 40-100 m as a result of hydrodynamic conditions present (Royer et al., 1990) and toxic levels of oil when present intertidally never occurred subtidally (O'Clair et al., 1993). Nevertheless, it is assumed that some oil will continue to leach out of oil contaminated intertidal areas in Prince William Sound and might reach the deep subtidal region intermittently for a number of years. "However, any such oil deposited subtidally would result in sediment concentrations of total PAHs that are not acutely toxic, but may in fact become an energy source for bacteria... (S.D. Rice and J. W. Short, Person. Commun. to S. Jewett; also see comments on microbial utilization of oil in Spies, 1987).

High abundance values were recorded at many stations at sites within and outside of the EVOS trajectory in 1990 (Table 4). These values were considerably higher than those recorded on the shelf of the northeastern Gulf of Alaska from 1974-76 (Feder and Matheke, 1980; Feder and Jewett, 1986) and within Rocky and Zaikof Bays within Prince William Sound in 1982 (Hoberg, 1986). The Prince William Sound benthic system is a complex one that would be difficult to interpret even if a long-term data base were available prior to the EVOS. Based on a fourteen-year data set for the Port Valdez (a fjordic embayment of Prince William Sound) benthic system, extending from 1971-1993, extreme interannual fluctuations in abundance of benthic fauna are characteristic there (Feder and Matheke, 1979; Feder and Jewett, 1988; Feder and Shaw, 1995; Feder and Blanchard, 1994), and such changes are probably characteristic of the benthos throughout the Sound. For example, abundance values at 40 m for Zaikof and Rocky Bays in 1982 (both sites occupied in the present study) were 117 and 917 indiv. m^{-2}, respectively, as compared to 1868 and 6744 indiv. m^{-2} for these sites, respectively, in 1990 (Table 4; Hoberg, 1986). The very high abundance values at many sites in the Sound in 1990 confuse the interpretation of effects of the EVOS on the deep benthos. Thus, if the high benthic abundance represented faunal enhancement, as a response to an increased food source derived from the EVOS and associated hydrocarbon-degrading bacteria, it would not be possible to separate these effects from natural events occurring at the same time. However, a recent biological occurrence, documented for the Sound in 1990 by Dr. T. Cooney (Person. commun.), may explain, in part, the high abundance values at some of the deep benthic stations. Prince William Sound is typically a pelagic system in which carbon in the water column (POC) is decoupled from the benthos with most POC flowing through pelagic trophic links (T. Cooney, unpub. and Person. Commun.; also see discussion in Cooney and Coyle, 1988). However, zooplankton populations within the Sound were at low levels in 1990 (T. Cooney, unpub.), suggesting

that a greater flux of POC, as ungrazed phytoplankton, to the benthos might be expected that year. High benthic faunal abundance in the Sound in 1990, higher than values reported previously for the shelf of the northeastern Gulf of Alaska (Feder and Jewett, 1986), as well as the presence of high abundance values for taxa often considered opportunistic (Tables 5, 7 and 9: Pearson and Rosenberg, 1978), appear to reflect a flux of unusual amounts of carbon, available as food, to the bottom. It is also possible that some high faunal abundance values at stations within the EVOS trajectory in 1990 might have resulted, in part, from a synergistic relationship between the small amounts of oil that settled to the bottom, the hydrocarbon degrading bacteria present and the increased POC that fluxed to the bottom as ungrazed phytoplankters.

In conclusion, regardless of the origin of the carbon that fluxed to the bottom in 1990, the benthic system in Prince William Sound, within sites examined at 40 to >100 m, was a species rich, diverse one 16 months after the *Exxon Valdez* oil spill. It is apparent that the current speed within Prince William Sound (described by Royer et al., 1990, and Niebauer et al., 1994) was sufficient to flush out toxic fractions of the EVOS so that little or no damage occurred to the fauna within the deep benthos. This conclusion for the deep benthos is supported in a review by Dicks and White (1992) that considers the effects of oil-spill events elsewhere. They state that "Studies so far tend to confirm the absence of significant effects from oil spills on deep water communities." However, they indicate that "The potential impacts of a spill increase in shallow coastal waters because of a higher chance of contact between oil dispersions and organisms. For example, benthic community changes, such as mortality of amphipods, were clearly shown after the *Amoco Cadiz* spill [at 20m]." Effects of the EVOS on benthic biota in shallow waters (<20 m) were also demonstrated by Jewett et al. (1993a).

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Appendix I

Sample Collection and Analysis Protocol

I. COLLECTION APPARATUS AND METHOD OF SAMPLE HANDLING

Collection Device.
Samples were collected with a 0.1 m^{-2} van Veen grab with bottom penetration facilitated by addition of 31.7 kg of lead. The van Veen grab is available from the Seward Marine Center, University of Alaska. A discussion of the effectiveness of the van Veen grab as a quantitative instrument is included in Feder et al. (1973). The benthic samples were collected using the same methods recommended by Baltic Sea biologists for examining benthos following a major oil spill by the Tsesis (Kineman et al. 1980) and the methods previously used in Prince William Sound and the Gulf of Alaska by Feder and associates (Feder and Matheke, 1980; see Feder and Jewett, 1986, for pertinent references and discussion). Samples were washed on 1.0 mm stainless steel screen and retained organisms removed by means of forceps and placed in sample bags.

Sample Containers.
Specimens from each replicate grab sample were placed in a separate Whirlpak bag. A label (Rite-in-the-Rain paper was used) was placed in each bag, and sufficient hexamine-buffered 10% formalin placed in each bag so as to cover the specimen. Each bag was then enclosed in another Whirlpak bag. All replicates from each station were then placed in a large plastic bag which was then sealed. Each bag from each station was placed in a five-gallon container for transportation to Fairbanks (see Chain of Custody protocol included in the Technical Study Plan).

Sample Analysis.
In the laboratory all organisms were identified, counted, and weighed after excess moisture was removed with an absorbent towel. All data were entered on code sheets and submitted to IMS Data Management for data entry into the computer.

II. DATA ANALYSIS

Multivariate Analysis.
Station groups and taxon assemblages for each year and for the combined data collected on all future surveys were identified using the technique of hierarchical cluster analysis (Field and MacFarlane 1968; Field 1969, 1970, 1971; Day et al 1971). The procedure consists of three steps:

1. Calculation of a measure of similarity between entities to be classified.
2. Sorting through a matrix of similarity coefficients to arrange the entities in a hierarchy or dendrogram.
3. Recognition of station classes or groups within the hierarchy.

The Czekanowski coefficient was used to calculate similarity matrices for cluster analysis routines. The Czekanowski coefficient is synonymous with the Motyka (Mueller-Dombois and Ellenberg, 1974) and Bray-Curtis (Clifford and Stephenson 1975) coefficients and is defined by:

$$C_{cz1,2} = \frac{2W}{A+B}$$

where A = the sum of the measures of attributes of entity one
B = the sum of the measures of attributes of entity two
W = the sum of the lesser measures of attributes shared by entities one and two.

The Czekanowski coefficient emphasizes the effect of dominant species on the classification and was used with a base 10 logarithm transformation, $Y = ln(X + 1)$, which reduces the influence of dominant species on the similarity determination. Dendrograms were constructed from the similarity matrices using a group-average agglomerative hierarchical cluster analysis (Lance and Williams 1966).

Principal coordinate analysis (Gower 1967, 1969) was used as an aid in interpreting the results of the cluster analysis of the data (Stephenson and Williams 1971, Boesch 1973) and identifying misclassification of stations by cluster analysis. Misclassifications in an agglomerative cluster analysis can occur by the early fusion of two stations and their subsequent incorporation into a group whose stations have a high similarity to only one member of the original pair (Boesch 1973). In principal coordinate analysis an interstation similarity matrix generated can be conceived of as a multidimensional space in which the stations are arranged in such a way that they are separated from one another according to their similarities. An ordination is then performed on the matrix to extract axes from this multidimensional space. The first axis extracted coincides with the longest axis and accounts for the largest amount of variation in the similarity matrix. Subsequent axes account for successively smaller amounts of variation in the data.

An additional ordination procedure, non-metric multi-dimensional scaling (MDS), was used (Kruskal and Wish, 1978; Clarke and Green, 1988). This is a multivariate method that has been used extensively recently for assessing disturbances resulting from anthropomorphic impacts to the environment (e.g., Gray et al., 1988, 1990; Warwick and Clarke, 1991, Agard et al., 1993; Clarke, 1993; Olsgard and Hasle, 1993). As described by Gray et al. (1988) "...MDS attempts to construct a 'map' of the sites in which the more similar ...samples, ...in terms of species abundances, are nearer to each other on the 'map'." The extent to which the relations can be adequately represented in a two (rather than three or higher) dimensional map is summarized by a 'stress' coefficient (should be $\leq$_0.15 [Clarke and Ainsworth, 1993]). MDS is perhaps the most robust ordination technique available, using only rank order information of the form Sample 1 is more similar to Sample 2 than it is to Sample 3. In addition, it has been argued that non-metric ordinations are more robust to aberrant values (for example, a species with an exceptionally high abundance at a site in one year) and , hence, are likely to be more consistent in repeated samples from year to year (Digby and Kempton, 1987. Programs used to MDS are routines from a test version of PRIMER V3.1 furnished by Dr. K. R. Clarke of the Plymouth Marine Laboratory.

MDS ordination plots were constructed for the biotic variables and those combinations of abiotic variables which show the highest correlation (Clarke and Ainsworth, 1993).

Following the division of abundance data into station groups by classification and ordination analysis,

the taxa having the greatest contribution to this division were determined using the similarity percentages program SIMPER (Warwick *et al.*, 1990).

Diversity.

Species diversity can be thought of as a measurable attribute of a collection or a natural assemblage of species and consists of two components: the number of species or "species richness" and the relative abundance of each species or "evenness." The two most widely used measures of diversity which include species richness and evenness were the Brillouin (Brillouin 1962) and Shannon (Shannon and Weaver 1963) information measures of diversity (Nybakken, 1978). There is still disagreement on the applicability of these indices, and the results are often difficult to interpret (Sager and Hasler 1969, Hurlbert 1971, Fager 1972, Peet 1974, Pielou 1966a, b). Pielou (1966a, b) has outlined some of the conditions under which these indices are appropriate.

The Shannon function was calculated as:

$$H' = -_i\Sigma\, p_i \log p_i \text{ where } p_i \frac{n_i}{N}$$

where n_i = number of individuals in the i^{th} species

N = total number of species.

Species richness (Margalef, 1958) was calculated as:

$$SR = \frac{(S-1)}{\ln N}$$

where S = the number of species

N = the total number of individuals.

The Simpson dominance index (Simpson, 1949; Odum, 1975) was also calculated:

$$S = \sum \frac{n_i(n_i-1)}{N(N-1)}$$

where ni = number of individuals in the i^{th} species

N = total number of individuals.

Diversity indices were calculated for all stations.

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[1]See Reference section in the main body of the text for additional references not included in this Appendix Reference section.

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Appendix II

Taxa Identified to Higher Taxonomic Levels Collected at 40, 100, >100 m Stations at Sites in Prince William Sound

TAXA AT HIGHER TAXONOMIC LEVELS COLLECTED IN JULY 1990 AT ALL 40 M STATIONS WITHIN PRINCE WILLIAM SOUND

PROTOZOA
Foraminiferida
PORIFERA
CNIDARIA
Hydrozoa
Anthozoa
Alcyonacea
Pennatulacea
Virgulariidae
Caryophylliidae
PLATYHELMENTHES
RHYNCHOCOELA
Lineidae
NEMATODA
ANNELIDA
Polychaeta
Aphroditidae
Polynoidae
Polyodontidae
Sigalionidae
Chrysopetalidae
Euphrosinidae
Phyllodocidae
Hesionidae
Syllidae
Nereidae
Nephtyidae
Sphaerodoridae
Glyceridae
Goniadidae
Onuphidae
Eunicidae
Lumbrineridae
Arabellidae
Dorvilleidae
Orbiniidae
Paraonidae
Apistobranchidae
Spionidae
Magelonidae
Chaetopteridae
Cirratulidae
Cossuridae
Flabelligeridae
Scalibregmidae
Opheliidae
Sternaspidae
Capitellidae
Arenicolidae
Maldanidae
Owenidae
Sabellaridae
Amphictenidae
Ampharetidae
Terebellidae
Trichbranchidae
Sabellidae
Serpulidae
Spirorbidae
Oligochaeta
MOLLUSCA
Gastropoda
Archaeogastropoda
Acmaeidae
Lepetidae
Cocculinidae
Trochidae
Turbinidae
Rissoidae
Vitrinellidae
Turritellidae
Caecidae
Cerithiidae
Eulimidae
Calyptraeidae
Naticidae
Cymatiidae
Muricidae
Pyrenidae
Turridae
Pyramidellidae
Cephalaspidea
Scaphandridae
Diaphanidae
Retusidae
Onchidoridide
Polyplacophora
Lepidopleuridae
Ischnochitonidae
Mopaliidae
Aplacophora
Chaetodermatidae
Bivalvia
Nuculidae
Nuculanidae
Mytilidae
Limidae
Lucinidae
Thyasiridae
Kelliidae
Montacutidae
Carditidae
Astartidae
Cardiidae
Mactridae
Tellinidae
Veneridae
Myidae
Hiatellidae
Pandoridae
Lyonsiidae
Thraciidae
Cuspidariidae
Scaphopoda
Dentaliidae
ARTHROPODA
Acarida
Crustacea
Ostracoda
Harpacticoida
Cirripedia
Balanidae
Archaeobalanidae
Leptostraca
Nebaliidae
Cumacea
Lampropidae
Leuconidae
Diastylidae
Campylaspid
Nannastacida
Bodotriidae
Tanaidacea
Isopoda
Gnathiidae
Anthuridae
Janiridae
Jaeropsidae
Munnidae
Amphipoda
Ampeliscidae
Corophidae
Dexaminidae
Gammaridae
Isaeidae
Ischyrocerid
Lysianassidae
Oedicerotidae
Pardaliscidae
Phoxocephalidae
Stenothoidae
Synopiidae
Caprellidea
Caprellidae
Decapoda
Pinnotheridae
SIPUNCULA
Golfingiidae
ECHIURA
Echiuridae
PRIAPULIDA
TARDIGRADA
PHORONIDA
BRYOZOA
BRACHIOPODA
Cancellothyridae
Dallinidae
Laqueidae
ECHINODERMATA
Ophiuroidea
Ophiuridae
Amphiuridae
Echinoida
Holothuroidea
Cucumariidae
UROCHORDATA
Ascidiacea
Ascidiidae

TAXA AT HIGHER TAXONOMIC LEVELS COLLECTED IN JULY 1990 AT ALL 100 M STATIONS WITHIN PRINCE WILLIAM SOUND

PROTOZOA
Foraminiferida
PORIFERA
Hydrozoa
Anthozoa
Virgulariidae
Actiniaria
Caryophylliidae
PLATYHELMENTHES
RHYNCHOCOELA
NEMATODA
ANNELIDA
Polychaeta
Polynoidae
Polyodontidae
Sigalionidae
Chrysopetalidae
Euphrosinidae
Phyllodocidae
Hesionidae
Syllidae
Nereidae
Nephtyidae
Sphaerodoridae
Glyceridae
Goniadidae
Onuphidae
Eunicidae
Lumbrineridae
Arabellidae
Dorvilleidae
Orbiniidae
Paraonidae
Apistobranchidae
Spionidae
Magelonidae
Trochochaetidae
Chaetopteridae
Cirratulidae
Cossuridae
Flabelligeridae
Scalibregmidae
Opheliidae
Sternaspidae
Capitellidae
Maldanidae
Owenidae
Sabellaridae
Amphictenidae
Ampharetidae
Terebellidae
Trichbranchidae
Sabellidae
Serpulidae
Spirorbidae
Oligochaeta
MOLLUSCA
Gastropoda
Archaeogastropoda
Fissurellidae
Lepetidae
Trochidae
Rissoidae
Caecidae
Epitoniidae
Calyptraeidae
Naticidae
Pyrenidae
Olividae
Mitridae
Turridae
Pyramidellidae
Scaphandridae
Retusidae
Polyplacophora
Lepidopleuridae
Ischnochitonidae
Mopaliidae
Aplacophora
Chaetodermatidae
Bivalvia
Nuculidae
Nuculanidae
Mytilidae
Limidae
Lucinidae
Thyasiridae
Montacutidae
Carditidae
Astartidae
Cardiidae
Tellinidae
Veneridae
Hiatellidae
Periplomatidae
Thraciidae
Dentaliidae
ARTHROPODA
Acarida
Pycnogonida
Crustacea
Ostracoda
Harpacticoida
Cirripedia
Cumacea
Lampropidae
Leuconidae
Diastylidae
Campylaspidae
Nannastacidae
Bodotriidae
Tanaidacea
Isopoda
Gnathiidae
Anthuridae
Aegidae
Jaeropsidae
Munnidae
Amphipoda
Acanthonotozomatidae
Ampeliscidae
Corophidae
Dexaminidae
Eusiridae
Gammaridae
Haustoriidae
Isaeidae
Ischyroceridae
Lysianassidae
Oedicerotidae
Pardaliscidae
Phoxocephalidae
Stenothoidae
Synopiidae
Caprellidea
Pinnotheridae
Golfingiidae
TARDIGRADA
PHORONIDA
BRYOZOA
BRACHIOPODA
Cancellothyridae
Laqueidae
ECHINODERMATA
Asteroidea
Porcellanasteridae
Ophiuroidea
Amphiuridae
Echinoidea
Dendrasteridae
Holothuroidea
Cucumariidae
UROCHORDATA
Ascidiacea

TAXA AT HIGHER TAXONOMIC LEVELS COLLECTED IN JULY 1990 AT ALL > 100 M STATIONS WITHIN PRINCE WILLIAM SOUND

PROTOZOA
Foraminiferida
PORIFERA
Hydrozoa
Anthozoa
Pennatulacea
Virgulariidae
Caryophylliidae
RHYNCHOCOELA
NEMATODA
ANNELIDA
Polychaeta
Aphroditidae
Polynoidae
Polyodontidae
Sigalionidae
Phyllodocidae
Hesionidae
Syllidae
Nereidae
Nephtyidae
Sphaerodoridae
Glyceridae
Goniadidae
Onuphidae
Eunicidae
Lumbrineridae
Arabellidae
Dorvilleidae
Orbiniidae
Paraonidae
Apistobranchidae
Spionidae
Magelonidae
Chaetopteridae
Cirratulidae
Acrocirridae
Cossuridae
Flabelligeridae
Scalibregmidae
Opheliidae
Sternaspidae
Capitellidae
Maldanidae
Owenidae
Sabellaridae
Amphictenidae
Ampharetidae
Terebellidae
Trichbranchidae
Sabellidae
Serpulidae
Spirorbidae
Oligochaeta
MOLLUSCA
Gastropoda
Archaeogastropoda
Fissurellidae
Trochidae
Rissoidae
Trichotropidae
Naticidae
Pyrenidae
Mitridae
Turridae
Pyramidellidae
Scaphandridae
Retusidae
Polyplacophora
Lepidopleuridae
Aplacophora
Chaetodermatidae
Bivalvia
Nuculidae
Nuculanidae
Mytilidae
Limidae
Thyasiridae
Montacutidae
Carditidae
Astartidae
Cardiidae
Tellinidae
Veneridae
Hiatellidae
Lyonsiidae
Cuspidariidae
Dentaliidae
ARTHROPODA
Acarida
Pycnogonida
Crustacea
Ostracoda
Harpacticoida
Lepadidae
Balanomorpha
Cumacea
Lampropidae
Leuconidae
Diastylidae
Pseudocumidae
Campylaspidae
Bodotriidae
Tanaidacea
Isopoda
Gnathiidae
Idoteidae
Janiridae
Jaeropsidae
Munnidae
Ampeliscidae
Calliopiidae
Corophiidae
Dexaminidae
Eusiridae
Gammaridae
Haustoriidae
Isaeidae
Ischyroceridae
Lysianassidae
Oedicerotidae
Pardaliscidae
Phoxocephalidae
Pleustidae
Podoceridae
Stenothoidae
Synopiidae
Hyperiidae
Caprellidea
SIPUNCULA
Golfingiidae
PHORONIDA
BRYOZOA
BRACHIOPODA
Cancellothyridae
Dallinidae
Laqueidae
ECHINODERMATA
Ophiuroidea
Ophiuridae
Amphiuridae
Echinoida
Holothuroidea
Psolidae
Cucumariidae
Molpadiidae
UROCHORDATA
Ascidiacea
Corellidae

Appendix III

Aromatic Hydrocarbons Analyzed as Present in *Exxon Valdez* Crude Oil

Appendix III-1. Polycyclic aromatic hydrocarbons analyzed as present in EXXON VALDEZ crude oil and included in the estimation of concentrations of EXXON VALDEZ PAHs (Jewett, *et al.*, 1993b).

Abbreviations	Compound
Naph	naphthalene
MeNap2	2-methylnaphthalene
MeNap1	1-methlynaphthalene
C1Naph*	C-1 naphthalenes
C2Naph	C-2 naphthalenes
C3Naph	C-3 naphthalenes
C4Naph	C-4 naphthalenes
Biphenyl	biphenyl
Fluor	fluorene
C1Fluor	C-1 fluorene
C2Fluor	C-2 fluorene
C3Fluor	C-3 fluorene
Dith	dibenzothiophenes
C1Dith	C-1 dibenzothiophenes
C2Dith	C-2 dibenzothiophenes
C3Dith	C-3 dibenzothiophenes
Phen	phenanthrene
C1Phen	C-1 phenanthrenes/anthracenes
C2Phen	C-2 phenanthrenes/anthracenes
C3Phen	C-3 phenanthrenes/anthracenes
C4Phen	C-4 phenanthrenes/anthracenes
C1Fl	C-1 fluoranthenes/pyrenes
Chry	chrysene
C1Ch	C-1 chrysenes
C2Ch	C-2 chrysenes

* was used in analyses but not included in list of EVOS analytes.

Appendix IV-I

Station Group Rankings for Stations at 40m Depth by Abundance and Contribution to Station Group Dissimilarities (SIMPER)*

DNJ LH
Group I = DB, WB, ZB
DNJ SH
Group II = BI, DI, HB, MB, MH, NB, RB, SB
DNJ CB

* Abundance values presented in the SIMPER tables should be multiplied by two to obtain comparable values to the station group rankings.

The following station abbreviations are used in Appendices IV-I, IV-II and IV-III:

BI	=	Bay of Isles
CB	=	Chenega Bay
DB	=	Drier Bay
DI	=	Disk Island
HB	=	Herring Bay
LH	=	Lower Herring Bay
MB	=	Moose Lips Bay
MH	=	MacLeod Harbor
NB	=	Northwest Bay
RB	=	Rocky Bay
SB	=	Sleepy Bay
SH	=	Snug Harbor
WB	=	West Bay
ZB	=	Zaikoff Bay

Table IV-I 1. Ranking by abundance (ind. m^{-2}) for stations and station groups of the 14 stations sampled at 40m in Prince William Sound in 1990.

ST	Taxa	Abundance (ind. m^{-2})	Frequency (%)
DNJ	Nephtyidae	522	100
(LH)	Paraonidae	228	100
	Bivalvia	178	100
	Spionidae	136	100
	Nuculanidae	134	100
	Pyrenidae	92	100
	Cirratulidae	78	100
	Lumbrineridae	74	100
	Chaetodermatidae	50	100
	Leuconidae	40	100
	Rhynchocoela	40	100
	Capitellidae	38	100
	Sigalionidae	32	100
	Scaphandridae	28	100
	Hesionidae	22	100
	Tellinidae	20	100
	Thyasiridae	18	100
	Orbiniidae	16	100
	Phoxocephalidae	14	100
	Nuculidae	12	100
	Pyramidellidae	12	100
I	Bivalvia	85	100
(DB, WB,	Nephtyidae	83	100
ZB)	Lucinidae	69	100
	Paraonidae	69	100
	Capitellidae	48	100
	Nuculidae	47	100
	Sternaspidae	42	33
	Lumbrineridae	39	100
	Tellinidae	38	100
	Rhynchocoela	31	100
	Cirratulidae	28	100
	Sigalionidae	27	100
	Spionidae	27	100
	Nuculanidae	25	100
	Pandoridae	22	33
	Orbiniidae	21	100
	Scaphandridae	19	100

Table IV-I 1. Continued.

St	Taxa	Abundance (Ind. m^{-2})	Frequency (%)
	Thyasiridae	18	100
	Maldanidae	17	67
	Gastropoda	14	67
DNJ	Spionidae	144	100
(SH)	Capitellidae	118	100
	Nuculidae	96	100
	Paraonidae	66	100
	Cirratulidae	62	100
	Maldanidae	54	100
	Owenidae	46	100
	Leuconidae	40	100
	Lucinidae	34	100
	Bivalvia	32	100
	Nephtyidae	32	100
	Polyodontidae	30	100
	Amphictenidae	26	100
	Orbiniidae	26	100
	Cossuridae	18	100
	Lumbrineridae	18	100
	Rhynchocoela	18	100
	Sigalionidae	18	100
	Thyasiridae	18	100
	Tellinidae	16	100
II	Owenidae	548	100
(BI, DI, HB,	Cirratulidae	445	100
MB, MH,	Bivalvia	343	100
NB, RB,	Paraonidae	315	100
SB)	Capitellidae	313	100
	Spionidae	277	100
	Golfingiidae	219	100
	Lumbrineridae	207	100
	Maldanidae	188	100
	Polyodontidae	187	88
	Sternaspidae	161	38
	Syllidae	154	100
	Balanidae	107	38
	Ampeliscidae	105	100
	Sigalionidae	99	100
	Magelonidae	97	88
	Thyasiridae	95	100

Table IV-I 1. Continued.

St	Taxa	Abundance (Ind. m^{-2})	Frequency (%)
	Leuconidae	86	88
	Mytilidae	78	100
	Phoxocephalidae	68	100
DNJ (CB)	Syllidae	464	100
	Polyodontidae	372	100
	Spirorbidae	234	100
	Onuphidae	130	100
	Ampharetidae	106	100
	Caecidae	102	100
	Serpulidae	100	100
	Bivalvia	92	100
	Sabellidae	78	100
	Astartidae	76	100
	Golfingiidae	70	100
	Hiatellidae	70	100
	Thyasiridae	70	100
	Sigalionidae	68	100
	Cirratulidae	64	100
	Dallinidae	56	100
	Maldanidae	50	100
	Paraonidae	46	100
	Dorvilleidae	40	100
	Gastropoda	40	100

Table IV-I 2a. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups LH and I = 35.69 and the standard deviation = 3.62.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	LH		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Pyrenidae	46.00	0.00	3.67	3.21	1.81	0.62	5.08
Chaetodermatidae	25.00	0.00	1.33	1.53	1.81	0.47	5.08
Lucinidae	1.00	0.00	34.67	34.27	1.77	0.73	4.96
Nephtyidae	261.00	0.00	41.33	42.15	1.61	0.95	4.52
Nuculanidae	67.00	0.00	12.67	10.41	1.49	1.14	4.18
Phoxocephalidae	7.00	0.00	0.00	0.00	1.47	0.16	4.13
Leuconidae	20.00	0.00	3.00	2.65	1.41	0.88	3.94
Spionidae	68.00	0.00	13.67	10.02	1.23	0.58	3.44
Veneridae	6.00	0.00	0.67	1.15	1.13	0.50	3.17
Pyramidellidae	6.00	0.00	0.67	0.58	1.07	0.41	3.01
Chaetopteridae	3.00	0.00	0.00	0.00	0.98	0.11	2.76
Paraonidae	114.00	0.00	34.33	26.73	0.98	0.54	2.75
Maldanidae	0.00	0.00	5.67	5.51	0.98	0.86	2.75
Sternaspidae	1.00	0.00	7.00	12.12	0.88	0.65	2.46
Glyceridae	3.00	0.00	0.33	0.58	0.83	0.34	2.33
Cirratulidae	39.00	0.00	14.00	5.29	0.73	0.29	2.05
Polyodontidae	0.00	0.00	2.00	1.73	0.67	0.59	1.87
Tellinidae	10.00	0.00	19.00	20.66	0.65	0.40	1.83
Lumbrineridae	37.00	0.00	19.33	12.42	0.63	0.72	1.78
Owenidae	1.00	0.00	3.67	4.73	0.63	0.39	1.75

Table IV-I 2b. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between stations LH and SH = 38.33 and the standard deviation was not calculated as there was only one station in each of the station groups.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	LH		SH				
Species	Abun	SD	Abun	SD	δ	SD	%

Comparisons not performed due to the single station in these two groups.

Table IV-I 2c. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups LH and II = 48.80 and the standard deviation = 3.65.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	LH		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Maldanidae	0.00	0.00	93.75	29.30	1.94	0.25	3.98
Golfingiidae	0.00	0.00	109.50	95.25	1.70	0.69	3.49
Owenidae	1.00	0.00	274.13	499.45	1.63	0.54	3.34
Polyodontidae	0.00	0.00	81.75	82.57	1.58	0.87	3.23
Syllidae	1.00	0.00	76.75	42.40	1.52	0.30	3.12
Sabellidae	0.00	0.00	21.00	12.21	1.25	0.40	2.56
Magelonidae	0.00	0.00	42.63	50.94	1.24	0.68	2.53
Ampharetidae	0.00	0.00	20.00	12.05	1.22	0.36	2.49
Mytilidae	0.00	0.00	38.75	72.07	1.20	0.64	2.46
Trichbranchidae	0.00	0.00	18.00	12.32	1.20	0.30	2.45
Ampeliscidae	0.00	0.00	52.63	115.96	1.15	0.56	2.35
Terebellidae	0.00	0.00	10.63	3.29	1.04	0.15	2.13
Gnathiidae	0.00	0.00	19.12	15.76	1.04	0.60	2.13
Phyllodocidae	0.00	0.00	12.50	8.93	1.02	0.27	2.09
Pyrenidae	46.00	0.00	10.63	12.37	1.01	0.72	2.06
Nephtyidae	261.00	0.00	31.25	19.83	0.97	0.28	1.98
Astartidae	0.00	0.00	11.50	15.02	0.89	0.42	1.83
Onuphidae	1.00	0.00	16.25	12.83	0.80	0.36	1.63
Nuculanidae	67.00	0.00	16.38	14.56	0.79	0.49	1.61
Chaetodermatidae	25.00	0.00	5.25	5.12	0.78	0.43	1.59

Table IV-I 2d. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between stations LH and CB = 58.03 and the standard deviation was not calculated as there was only one station in each of the station groups.

Abun = $\bar{X}$ abundance, *SD* = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	LH		CB				
Species	Abun	SD	Abun	SD	δ	SD	%

Comparisons not performed due to the single station in these two groups.

Table IV-I 2e. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups SH and I = 36.85 and the standard deviation = 4.80.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	SH		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Owenidae	23.00	0.00	3.67	4.73	1.47	0.96	4.00
Leuconidae	20.00	0.00	3.00	2.65	1.38	0.86	3.74
Maldanidae	27.00	0.00	5.67	5.51	1.35	1.09	3.67
Polyodontidae	15.00	0.00	2.00	1.73	1.27	0.51	3.45
Phoxocephalidae	5.00	0.00	0.00	0.00	1.25	0.13	3.38
Spionidae	72.00	0.00	13.67	10.02	1.24	0.57	3.37
Ampharetidae	7.00	0.00	1.00	1.00	1.05	0.50	2.86
Golfingiidae	4.00	0.00	0.33	0.58	0.97	0.35	2.64
Glyceridae	4.00	0.00	0.33	0.58	0.97	0.35	2.64
Nuculanidae	2.00	0.00	12.67	10.41	0.92	0.53	2.49
Nuculidae	48.00	0.00	23.67	28.04	0.89	0.72	2.42
Syllidae	7.00	0.00	1.67	2.08	0.88	0.51	2.39
Sternaspidae	1.00	0.00	7.00	12.12	0.86	0.64	2.34
Hesionidae	1.00	0.00	6.33	2.52	0.86	0.16	2.33
Amphictenidae	13.00	0.00	4.33	4.16	0.86	0.65	2.32
Dentaliidae	0.00	0.00	3.33	4.04	0.82	0.57	2.22
Cossuridae	9.00	0.00	2.33	1.53	0.81	0.30	2.20
Phyllodocidae	2.00	0.00	0.00	0.00	0.76	0.08	2.07
Astartidae	2.00	0.00	0.00	0.00	0.76	0.08	2.07
Pyrenidae	1.00	0.00	3.67	3.21	0.71	0.23	1.93

Table IV-I 2f. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups II and I = 55.47 and the standard deviation = 6.47.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group II		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Golfingiidae	109.50	95.25	0.33	0.58	1.75	0.76	3.15
Syllidae	76.75	42.40	1.67	2.08	1.60	0.41	2.89
Owenidae	274.13	499.45	3.67	4.73	1.58	0.78	2.86
Phoxocephalidae	33.75	38.32	0.00	0.00	1.48	0.41	2.68
Maldanidae	93.75	29.30	5.67	5.51	1.45	0.66	2.61
Polyodontidae	81.75	82.57	2.00	1.73	1.38	0.75	2.49
Glyceridae	23.63	7.37	0.33	0.58	1.37	0.24	2.48
Mytilidae	38.75	72.07	0.00	0.00	1.31	0.67	2.35
Sabellidae	21.00	12.21	0.33	0.58	1.25	0.46	2.26
Ampeliscidae	52.63	115.96	0.00	0.00	1.24	0.58	2.24
Chaetopteridae	13.38	8.57	0.00	0.00	1.18	0.41	2.13
Cirratulidae	222.50	213.56	14.00	5.29	1.16	0.38	2.10
Gnathiidae	19.12	15.76	0.00	0.00	1.13	0.63	2.03
Phyllodocidae	12.50	8.93	0.00	0.00	1.11	0.28	1.99
Magelonidae	42.63	50.94	2.00	2.65	1.07	0.67	1.93
Leuconidae	37.50	36.02	3.00	2.65	1.06	0.63	1.92
Ampharetidae	20.00	12.05	1.00	1.00	1.05	0.47	1.89
Trichbranchidae	18.00	12.32	1.00	1.00	1.03	0.41	1.86
Terebellidae	10.63	3.29	0.33	0.58	1.03	0.25	1.85
Lucinidae	11.88	16.95	34.67	34.27	0.98	0.66	1.77

Table IV-I 2g. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups CB and I = 63.49 and the standard deviation = 4.96.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	CB		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Spirorbidae	117.00	0.00	0.00	0.00	2.22	0.15	3.49
Syllidae	232.00	0.00	1.67	2.08	2.16	0.28	3.41
Polyodontidae	186.00	0.00	2.00	1.73	2.00	0.34	3.15
Caecidae	51.00	0.00	0.00	0.00	1.84	0.13	2.89
Serpulidae	50.00	0.00	0.00	0.00	1.83	0.13	2.88
Onuphidae	65.00	0.00	0.67	0.58	1.74	0.31	2.74
Astartidae	38.00	0.00	0.00	0.00	1.70	0.12	2.68
Hiatellidae	35.00	0.00	0.00	0.00	1.67	0.12	2.62
Sabellidae	39.00	0.00	0.33	0.58	1.61	0.25	2.54
Ampharetidae	53.00	0.00	1.00	1.00	1.59	0.36	2.50
Golfingiidae	35.00	0.00	0.33	0.58	1.56	0.27	2.46
Dorvilleidae	20.00	0.00	0.00	0.00	1.42	0.10	2.23
Turridae	18.00	0.00	0.00	0.00	1.37	0.10	2.16
Mytilidae	17.00	0.00	0.00	0.00	1.34	0.09	2.12
Lucinidae	1.00	0.00	34.67	34.27	1.16	0.49	1.83
Tellinidae	0.00	0.00	19.00	20.66	1.16	0.60	1.83
Terebellidae	13.00	0.00	0.33	0.58	1.13	0.24	1.77
Bodotriidae	10.00	0.00	0.00	0.00	1.11	0.08	1.76
Gnathiidae	10.00	0.00	0.00	0.00	1.11	0.08	1.76
Chaetopteridae	8.00	0.00	0.00	0.00	1.02	0.07	1.61

Table IV-I 2h. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups SH and II = 40.92 and the standard deviation = 2.58.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	SH		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Golfingiidae	4.00	0.00	109.50	95.25	1.09	0.49	2.67
Dentaliidae	0.00	0.00	14.25	9.35	1.08	0.19	2.64
Chaetopteridae	0.00	0.00	13.38	8.57	1.08	0.37	2.63
Polynoidae	0.00	0.00	17.25	20.08	1.06	0.43	2.59
Onuphidae	0.00	0.00	16.25	12.83	1.00	0.50	2.45
Lumbrineridae	9.00	0.00	103.50	29.34	0.99	0.20	2.41
Sabellidae	1.00	0.00	21.00	12.21	0.94	0.38	2.30
Syllidae	7.00	0.00	76.75	42.40	0.91	0.27	2.23
Mytilidae	1.00	0.00	38.75	72.07	0.89	0.62	2.18
Ampeliscidae	1.00	0.00	52.63	115.96	0.84	0.56	2.05
Gnathiidae	1.00	0.00	19.12	15.76	0.81	0.46	1.99
Lucinidae	17.00	0.00	11.88	16.95	0.75	0.53	1.84
Polyodontidae	15.00	0.00	81.75	82.57	0.75	0.37	1.83
Terebellidae	1.00	0.00	10.63	3.29	0.73	0.13	1.79
Cirratulidae	31.00	0.00	222.50	213.56	0.71	0.30	1.75
Trichbranchidae	2.00	0.00	18.00	12.32	0.71	0.28	1.75
Magelonidae	5.00	0.00	42.63	50.94	0.68	0.46	1.66
Nuculidae	48.00	0.00	22.63	27.66	0.68	0.51	1.65
Pyramidellidae	1.00	0.00	12.00	15.04	0.66	0.33	1.62

Table IV-I 2i. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between stations SH and CB = 50.20 and the standard deviation was not calculated as there were only one station in each of these two groups.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	SH		CB				
Species	Abun	SD	Abun	SD	δ	SD	%

Comparisons not performed due to the single station in these two groups.

Table IV-I 2j. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 40m depth from Prince William Sound in 1990. The average dissimilarity between groups CB and II = 37.59 and the standard deviation = 6.72.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	CB		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Spirorbidae	117.00	0.00	1.50	3.21	1.41	0.30	3.74
Caecidae	51.00	0.00	0.50	1.07	1.21	0.20	3.21
Serpulidae	50.00	0.00	0.88	1.81	1.17	0.26	3.11
Hiatellidae	35.00	0.00	0.38	0.52	1.09	0.14	2.89
Magelonidae	0.00	0.00	42.63	50.94	0.94	0.52	2.51
Lumbrineridae	8.00	0.00	103.50	29.34	0.79	0.15	2.10
Capitellidae	9.00	0.00	156.38	140.25	0.79	0.24	2.09
Turridae	18.00	0.00	2.63	3.70	0.71	0.36	1.88
Leuconidae	3.00	0.00	37.50	36.02	0.67	0.27	1.78
Bodotriidae	10.00	0.00	1.00	1.85	0.66	0.26	1.74
Dentaliidae	1.00	0.00	14.25	9.35	0.60	0.16	1.61
Onuphidae	65.00	0.00	16.25	12.83	0.60	0.44	1.58
Dorvilleidae	20.00	0.00	6.13	8.68	0.59	0.39	1.57
Owenidae	15.00	0.00	274.13	499.45	0.56	0.45	1.49
Paraonidae	23.00	0.00	157.63	118.79	0.55	0.24	1.47
Phyllodocidae	1.00	0.00	12.50	8.93	0.55	0.21	1.46
Thraciidae	5.00	0.00	0.25	0.71	0.55	0.14	1.45
Polyodontidae	186.00	0.00	81.75	82.57	0.55	0.54	1.45
Astartidae	38.00	0.00	11.50	15.02	0.54	0.29	1.43
Cirratulidae	32.00	0.00	222.50	213.56	0.54	0.23	1.43

Appendix IV-II

Station Group Rankings for Stations at 100m Depth by Abundance and Contribution to Station Group Dissimilarities (SIMPER)*

Group I = RB, ZB
Group II = BI, DB, LH, SH
Group III = DI, NB, WB
Group IV = CB, HB, MB, SB
DNJ MH

* Abundance values presented in the SIMPER tables should be multiplied by two to obtain comparable values to the station group rankings.

Table IV-II 1. Ranking by abundance (ind. m^{-2}) for station groups of the 14 stations sampled at 100m in Prince William Sound in 1990.

ST	Taxa	Abundance (ind. m^{-2})	Frequency (%)
I	Nephtyidae	162	100
(RB, ZB)	Nuculanidae	162	100
	Sternaspidae	151	100
	Cirratulidae	145	100
	Lumbrineridae	107	100
	Tellinidae	93	100
	Leuconidae	91	100
	Thyasiridae	71	100
	Paraonidae	55	100
	Capitellidae	54	100
	Spionidae	54	100
	Amphiuridae	49	100
	Nuculidae	47	100
	Bivalvia	43	100
	Owenidae	43	100
	Maldanidae	30	50
	Orbiniidae	24	100
	Sigalionidae	23	100
	Dentaliidae	22	100
	Scaphandridae	22	100
II	Nephtyidae	261	100
(BI, DB,	Lumbrineridae	238	100
LH, SH)	Tellinidae	238	100
	Cirratulidae	207	100
	Bivalvia	178	100
	Paraonidae	171	100
	Spionidae	145	100
	Leuconidae	125	75
	Capitellidae	73	100
	Hesionidae	68	100
	Nuculidae	42	75
	Nuculanidae	38	100
	Cossuridae	35	100
	Orbiniidae	35	100
	Gastropoda	22	100
	Scaphandridae	20	75
	Polynoidae	20	100
	Thyasiridae	16	75

Table IV-II 1. Continued.

ST	Taxa	Abundance (ind. m^{-2})	Frequency (%)
	Maldanidae	15	75
	Opheliidae	15	75
	Phoxocephalidae	15	100
III	Bivalvia	547	100
(DI, NB,	Golfingiidae	337	100
WB)	Lumbrineridae	242	100
	Cirratulidae	143	100
	Paraonidae	117	100
	Cossuridae	97	100
	Thyasiridae	96	67
	Sabellidae	89	100
	Capitellidae	81	100
	Nephtyidae	79	100
	Owenidae	79	100
	Spionidae	54	100
	Dentaliidae	48	100
	Maldanidae	33	100
	Syllidae	29	100
	Nuculanidae	29	100
	Gastropoda	25	100
	Leuconidae	25	100
	Onuphidae	21	100
	Sternaspidae	20	100
	Montacutidae	18	67
IV	Golfingiidae	321	100
(CB, HB,	Syllidae	317	100
MB, SB)	Bivalvia	308	100
	Cirratulidae	302	100
	Capitellidae	249	100
	Sabellidae	247	100
	Polyodontidae	241	100
	Paraonidae	234	100
	Spionidae	210	100
	Lumbrineridae	158	100
	Maldanidae	144	100
	Owenidae	141	100
	Phoxocephalidae	134	100
	Ampharetidae	96	100
	Gnathiidae	58	100
	Sabellaridae	52	75

Table IV-II 1. Continued.

ST	Taxa	Abundance (ind. m^{-2})	Frequency (%)
	Terebellidae	48	100
	Ampeliscidae	38	75
	Sigalionidae	38	100
	Onuphidae	36	100
	Gastropoda	34	100
DNJ	Owenidae	424	100
(MH)	Polyodontidae	152	100
	Syllidae	122	100
	Maldanidae	118	100
	Golfingiidae	96	100
	Capitellidae	90	100
	Cirratulidae	90	100
	Spionidae	90	100
	Bivalvia	86	100
	Phoxocephalidae	72	100
	Terebellidae	66	100
	Mytilidae	64	100
	Pyrenidae	62	100
	Gnathiidae	46	100
	Paraonidae	42	100
	Magelonidae	32	100
	Scaphandridae	32	100
	Nannastacidae	26	100
	Amphiuridae	24	100
	Gastropoda	24	100
	Isaeidae	24	100

Table IV-II 2a. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups II and I = 39.76 and the standard deviation = 6.43.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group II		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Sternaspidae	0.00	0.00	75.50	81.32	2.28	0.39	5.73
Cossuridae	17.50	10.79	0.00	0.00	1.65	0.40	4.16
Amphiuridae	0.50	1.00	24.50	20.51	1.61	0.40	4.06
Owenidae	2.00	1.63	21.50	4.95	1.28	0.40	3.21
Pyrenidae	0.75	1.50	9.50	3.54	1.19	0.48	3.00
Tellinidae	118.75	224.18	46.50	0.71	1.18	0.28	2.98
Thyasiridae	6.00	4.69	35.50	14.85	1.14	0.64	2.87
Cirratulidae	103.50	108.31	72.50	94.05	1.00	0.75	2.52
Golfingiidae	1.00	0.82	9.50	7.78	0.91	0.39	2.28
Nuculanidae	18.75	5.85	81.00	7.07	0.86	0.16	2.16
Dentaliidae	0.75	0.96	11.00	14.14	0.86	0.65	2.16
Leuconidae	47.00	39.72	45.50	36.06	0.85	0.81	2.15
Glyceridae	0.25	0.50	5.00	4.24	0.85	0.33	2.13
Onuphidae	1.50	1.91	9.50	9.19	0.85	0.52	2.13
Opheliidae	5.50	5.92	0.00	0.00	0.84	0.71	2.11
Maldanidae	5.50	7.33	7.50	10.61	0.83	0.68	2.09
Phoxocephalidae	7.25	7.18	2.50	3.54	0.75	0.63	1.87
Rissoidae	1.50	3.00	4.50	6.36	0.72	0.73	1.82
Nuculidae	15.75	14.93	23.50	17.68	0.72	0.80	1.81
Sphaerodoridae	0.25	0.50	3.00	0.00	0.72	0.20	1.81
Polynoidae	9.75	16.84	1.00	1.41	0.71	0.74	1.77

Table IV-II 2b. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups III and I = 40.86 and the standard deviation = 5.39.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group III		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Cossuridae	48.67	62.58	0.00	0.00	1.61	0.71	3.94
Amphiuridae	0.00	0.00	24.50	20.51	1.59	0.25	3.88
Sabellidae	44.33	31.56	1.50	0.71	1.37	0.54	3.34
Tellinidae	3.67	3.79	46.50	0.71	1.36	0.45	3.33
Golfingiidae	168.33	182.04	9.50	7.78	1.34	0.62	3.27
Nuculanidae	14.33	15.70	81.00	7.07	1.15	0.65	2.80
Pyrenidae	0.33	0.58	9.50	3.54	1.13	0.35	2.76
Scaphandridae	1.00	1.73	11.00	2.83	1.09	0.48	2.67
Terebellidae	7.00	2.65	0.00	0.00	1.07	0.16	2.62
Opheliidae	5.33	3.51	0.00	0.00	0.93	0.36	2.29
Maldanidae	16.67	10.69	7.50	10.61	0.90	0.73	2.21
Thyasiridae	32.00	42.33	35.50	14.85	0.90	0.78	2.21
Sternaspidae	10.00	9.54	75.50	81.32	0.90	0.54	2.20
Gnathiidae	6.33	6.66	0.00	0.00	0.90	0.35	2.20
Cirratulidae	71.33	38.07	72.50	94.05	0.82	0.56	2.02
Sigalionidae	1.67	2.08	11.50	10.61	0.80	0.52	1.95
Dentaliidae	24.00	9.54	11.00	14.14	0.78	0.75	1.90
Syllidae	14.67	12.50	1.50	0.71	0.76	0.52	1.86
Pyramidellidae	0.00	0.00	5.00	5.66	0.76	0.40	1.86
Chaetopteridae	5.33	6.66	0.00	0.00	0.76	0.43	1.85
Phoxocephalidae	9.00	5.20	2.50	3.54	0.74	0.63	1.82

Table IV-II 2c. *Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups III and II = 41.23 and the standard deviation = 5.13.*

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group III		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Golfingiidae	168.33	182.04	1.00	0.82	2.36	0.46	5.72
Dentaliidae	24.00	9.54	0.75	0.96	1.60	0.40	3.88
Owenidae	39.33	25.42	2.00	1.63	1.51	0.47	3.67
Sabellidae	44.33	31.56	3.00	2.16	1.31	0.65	3.17
Sternaspidae	10.00	9.54	0.00	0.00	1.29	0.49	3.12
Glyceridae	6.67	1.53	0.25	0.50	1.08	0.21	2.61
Thyasiridae	32.00	42.33	6.00	4.69	1.07	0.68	2.59
Tellinidae	3.67	3.79	118.75	224.18	1.05	1.09	2.55
Onuphidae	10.67	2.31	1.50	1.91	1.04	0.46	2.51
Leuconidae	12.33	5.77	47.00	39.72	1.03	0.38	2.51
Gnathiidae	6.33	6.66	0.00	0.00	0.99	0.35	2.39
Orbiniidae	1.33	0.58	17.25	17.56	0.98	0.61	2.38
Terebellidae	7.00	2.65	0.75	0.96	0.92	0.32	2.22
Hesionidae	3.33	2.08	34.00	48.11	0.91	0.69	2.20
Polynoidae	0.00	0.00	9.75	16.84	0.88	0.71	2.12
Maldanidae	16.67	10.69	5.50	7.33	0.87	0.59	2.12
Syllidae	14.67	12.50	1.50	0.58	0.84	0.55	2.04
Scaphandridae	1.00	1.73	7.50	9.26	0.82	0.65	1.99
Montacutidae	6.00	8.72	0.00	0.00	0.81	0.77	1.96
Nuculidae	7.67	5.86	15.75	14.93	0.78	0.63	1.88
Cossuridae	48.67	62.58	17.50	10.79	0.76	0.45	1.84

Table IV-II 2d. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average *dissimilarity between groups* IV and I = 51.60 and the standard deviation = 6.86.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group IV		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Syllidae	158.50	69.48	1.50	0.71	1.85	0.12	3.59
Polyodontidae	120.50	117.74	0.50	0.71	1.85	0.50	3.58
Tellinidae	0.00	0.00	46.50	0.71	1.78	0.21	3.44
Sternaspidae	0.00	0.00	75.50	81.32	1.77	0.37	3.43
Sabellidae	123.50	104.47	1.50	0.71	1.68	0.46	3.26
Gnathiidae	29.00	23.45	0.00	0.00	1.47	0.25	2.85
Phoxocephalidae	67.00	37.30	2.50	3.54	1.42	0.63	2.75
Thyasiridae	1.00	1.41	35.50	14.85	1.39	0.34	2.70
Terebellidae	24.00	14.31	0.00	0.00	1.37	0.25	2.66
Ampharetidae	47.75	17.17	1.50	0.71	1.36	0.32	2.64
Maldanidae	71.75	35.76	7.50	10.61	1.32	0.80	2.55
Nuculanidae	8.50	8.58	81.00	7.07	1.21	0.57	2.34
Golfingiidae	160.25	131.46	9.50	7.78	1.16	0.60	2.24
Scalibregmidae	10.25	4.03	0.00	0.00	1.09	0.16	2.11
Pyrenidae	0.25	0.50	9.50	3.54	1.00	0.27	1.94
Amphiuridae	2.00	1.83	24.50	20.51	0.98	0.46	1.89
Sabellaridae	19.50	28.59	0.00	0.00	0.94	0.71	1.83
Scaphandridae	0.75	0.96	11.00	2.83	0.94	0.31	1.82
Astartidae	8.25	8.34	0.00	0.00	0.89	0.50	1.72
Leuconidae	5.75	3.30	45.50	36.06	0.88	0.46	1.70
Cirratulidae	150.75	88.68	72.50	94.05	0.82	0.68	1.58

Table IV-II 2e. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average *dissimilarity between groups* IV and II = 50.50 and the standard deviation = 5.40.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group IV		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Golfingiidae	160.25	131.46	1.00	0.82	2.02	0.54	4.01
Syllidae	158.50	69.48	1.50	0.58	2.02	0.13	3.99
Polyodontidae	120.50	117.74	2.00	1.83	1.71	0.54	3.38
Sabellidae	123.50	104.47	3.00	2.16	1.67	0.54	3.30
Gnathiidae	29.00	23.45	0.00	0.00	1.60	0.24	3.16
Owenidae	70.25	42.19	2.00	1.63	1.60	0.36	3.16
Tellinidae	0.00	0.00	118.75	224.18	1.49	0.93	2.95
Maldanidae	71.75	35.76	5.50	7.33	1.40	0.57	2.78
Terebellidae	24.00	14.31	0.75	0.96	1.27	0.35	2.51
Ampharetidae	47.75	17.17	3.75	2.22	1.19	0.33	2.37
Glyceridae	12.25	3.10	0.25	0.50	1.19	0.18	2.35
Leuconidae	5.75	3.30	47.00	39.72	1.10	0.48	2.19
Dentaliidae	15.25	8.02	0.75	0.96	1.10	0.43	2.18
Nephtyidae	15.00	7.07	130.25	45.07	1.10	0.38	2.18
Phoxocephalidae	67.00	37.30	7.25	7.18	1.04	0.42	2.06
Sabellaridae	19.50	28.59	0.00	0.00	1.02	0.74	2.02
Orbiniidae	1.50	2.38	17.25	17.56	0.98	0.63	1.94
Astartidae	8.25	8.34	0.00	0.00	0.97	0.52	1.91
Arabellidae	6.00	2.83	0.00	0.00	0.95	0.20	1.88
Scalibregmidae	10.25	4.03	1.00	1.41	0.93	0.33	1.83
Onuphidae	17.75	24.51	1.50	1.91	0.90	0.70	1.78

Table IV-II 2f. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups IV and III = 34.94 and the standard deviation = 6.12.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group IV		Group III				
Species	Abun	SD	Abun	SD	δ	SD	%
Polyodontidae	120.50	117.74	6.00	7.94	1.35	0.71	3.86
Syllidae	158.50	69.48	14.67	12.50	1.17	0.54	3.35
Thyasiridae	1.00	1.41	32.00	42.33	1.00	0.68	2.85
Sternaspidae	0.00	0.00	10.00	9.54	1.00	0.38	2.85
Cossuridae	6.75	11.53	48.67	62.58	0.96	0.64	2.75
Sigalionidae	19.00	12.19	1.67	2.08	0.95	0.40	2.72
Ampharetidae	47.75	17.17	6.33	4.04	0.91	0.37	2.62
Polynoidae	7.75	5.32	0.00	0.00	0.91	0.30	2.60
Sabellaridae	19.50	28.59	0.33	0.58	0.88	0.62	2.53
Arabellidae	6.00	2.83	0.00	0.00	0.86	0.18	2.46
Phoxocephalidae	67.00	37.30	9.00	5.20	0.79	0.37	2.25
Astartidae	8.25	8.34	0.67	1.15	0.75	0.50	2.14
Gnathiidae	29.00	23.45	6.33	6.66	0.68	0.42	1.94
Maldanidae	71.75	35.76	16.67	10.69	0.67	0.40	1.93
Nereidae	7.50	5.32	1.00	1.00	0.62	0.35	1.76
Montacutidae	6.00	10.71	6.00	8.72	0.61	0.52	1.75
Tellinidae	0.00	0.00	3.67	3.79	0.59	0.27	1.69
Sabellidae	123.50	104.47	44.33	31.56	0.59	0.48	1.68
Ampeliscidae	14.25	25.86	1.67	1.53	0.56	0.52	1.60
Phyllodocidae	4.25	1.71	1.00	1.73	0.55	0.31	1.57
Scalibregmidae	10.25	4.03	2.33	0.58	0.54	0.16	1.53

Table IV-II 2g. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups MH and I = 46.87 and the standard deviation = 7.35.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	MH		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Polyodontidae	76.00	0.00	0.50	0.71	1.76	0.38	3.75
Tellinidae	0.00	0.00	46.50	0.71	1.69	0.17	3.60
Sternaspidae	0.00	0.00	75.50	81.32	1.68	0.44	3.59
Terebellidae	33.00	0.00	0.00	0.00	1.54	0.15	3.29
Nuculanidae	2.00	0.00	81.00	7.07	1.44	0.10	3.08
Syllidae	61.00	0.00	1.50	0.71	1.41	0.01	3.00
Gnathiidae	23.00	0.00	0.00	0.00	1.39	0.13	2.96
Mytilidae	32.00	0.00	0.50	0.71	1.37	0.08	2.91
Nephtyidae	3.00	0.00	81.00	66.47	1.25	0.52	2.67
Maldanidae	59.00	0.00	7.50	10.61	1.22	0.97	2.61
Phoxocephalidae	36.00	0.00	2.50	3.54	1.21	0.67	2.59
Nannastacidae	13.00	0.00	0.00	0.00	1.15	0.11	2.46
Isaeidae	12.00	0.00	0.00	0.00	1.12	0.11	2.39
Thyasiridae	2.00	0.00	35.50	14.85	1.06	0.08	2.27
Ampeliscidae	10.00	0.00	0.00	0.00	1.05	0.10	2.24
Oedicerotidae	10.00	0.00	0.00	0.00	1.05	0.10	2.24
Ischyroceridae	9.00	0.00	0.00	0.00	1.01	0.10	2.15
Owenidae	212.00	0.00	21.50	4.95	0.99	0.19	2.12
Leuconidae	3.00	0.00	45.50	36.06	0.98	0.29	2.08
Astartidae	8.00	0.00	0.00	0.00	0.96	0.09	2.05
Goniadidae	9.00	0.00	0.50	0.71	0.86	0.30	1.85

Table IV-II 2h. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups MH and II = 55.52 and the standard deviation = 2.24.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	MH		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Owenidae	212.00	0.00	2.00	1.63	2.09	0.35	3.76
Nephtyidae	3.00	0.00	130.25	45.07	1.63	0.18	2.94
Polyodontidae	76.00	0.00	2.00	1.83	1.62	0.36	2.92
Golfingiidae	48.00	0.00	1.00	0.82	1.55	0.24	2.79
Syllidae	61.00	0.00	1.50	0.58	1.53	0.08	2.75
Gnathiidae	23.00	0.00	0.00	0.00	1.50	0.03	2.71
Pyrenidae	31.00	0.00	0.75	1.50	1.48	0.34	2.66
Terebellidae	33.00	0.00	0.75	0.96	1.46	0.26	2.62
Tellinidae	0.00	0.00	118.75	224.18	1.41	0.97	2.53
Mytilidae	32.00	0.00	1.25	1.89	1.38	0.35	2.48
Magelonidae	16.00	0.00	0.00	0.00	1.34	0.03	2.41
Cossuridae	0.00	0.00	17.50	10.79	1.31	0.31	2.37
Maldanidae	59.00	0.00	5.50	7.33	1.30	0.57	2.34
Nannastacidae	13.00	0.00	0.00	0.00	1.25	0.02	2.25
Isaeidae	12.00	0.00	0.00	0.00	1.21	0.02	2.18
Lumbrineridae	8.00	0.00	118.75	83.16	1.14	0.30	2.06
Ampeliscidae	10.00	0.00	0.00	0.00	1.13	0.02	2.04
Leuconidae	3.00	0.00	47.00	39.72	1.12	0.36	2.02
Glyceridae	11.00	0.00	0.25	0.50	1.09	0.17	1.97
Ischyroceridae	9.00	0.00	0.00	0.00	1.09	0.02	1.96
Goniadidae	9.00	0.00	0.00	0.00	1.09	0.02	1.96

Table IV-II 2i. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups MH and III = 44.34 and the standard deviation = 3.59.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	MH		Group III				
Species	Abun	SD	Abun	SD	δ	SD	%
Pyrenidae	31.00	0.00	0.33	0.58	1.40	0.25	3.16
Cossuridae	0.00	0.00	48.67	62.58	1.32	0.65	2.97
Polyodontidae	76.00	0.00	6.00	7.94	1.28	0.65	2.90
Magelonidae	16.00	0.00	0.00	0.00	1.22	0.08	2.76
Nannastacidae	13.00	0.00	0.00	0.00	1.14	0.07	2.57
Lumbrineridae	8.00	0.00	121.00	18.68	1.12	0.13	2.53
Amphiuridae	12.00	0.00	0.00	0.00	1.11	0.07	2.49
Isaeidae	12.00	0.00	0.00	0.00	1.11	0.07	2.49
Mytilidae	32.00	0.00	1.67	0.58	1.09	0.13	2.46
Scaphandridae	16.00	0.00	1.00	1.73	1.04	0.39	2.34
Oedicerotidae	10.00	0.00	0.00	0.00	1.03	0.06	2.33
Sabellidae	2.00	0.00	44.33	31.56	1.02	0.45	2.30
Ischyroceridae	9.00	0.00	0.00	0.00	0.99	0.06	2.24
Nephtyidae	3.00	0.00	39.67	13.05	0.98	0.18	2.22
Sternaspidae	0.00	0.00	10.00	9.54	0.95	0.41	2.13
Goniadidae	9.00	0.00	0.33	0.58	0.89	0.14	2.00
Thyasiridae	2.00	0.00	32.00	42.33	0.86	0.43	1.95
Lucinidae	6.00	0.00	0.00	0.00	0.84	0.05	1.89
Astartidae	8.00	0.00	0.67	1.15	0.80	0.31	1.80
Owenidae	212.00	0.00	39.33	25.42	0.79	0.31	1.77
Syllidae	61.00	0.00	14.67	12.50	0.76	0.55	1.72

Table IV-II 2j. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 14 stations sampled at the 100m depth from Prince William Sound in 1990. The average dissimilarity between groups MH and IV = 37.33 and the standard deviation = 2.84.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	MH		Group IV				
Species	Abun	SD	Abun	SD	δ	SD	%
Sabellidae	2.00	0.00	123.50	104.47	1.32	0.35	3.54
Pyrenidae	31.00	0.00	0.25	0.50	1.26	0.18	3.39
Magelonidae	16.00	0.00	0.00	0.00	1.09	0.08	2.91
Mytilidae	32.00	0.00	1.25	0.50	1.03	0.03	2.77
Nannastacidae	13.00	0.00	0.00	0.00	1.01	0.08	2.71
Isaeidae	12.00	0.00	0.00	0.00	0.98	0.07	2.64
Scaphandridae	16.00	0.00	0.75	0.96	0.92	0.24	2.46
Scalibregmidae	0.00	0.00	10.25	4.03	0.91	0.12	2.44
Ischyroceridae	9.00	0.00	0.00	0.00	0.88	0.07	2.37
Oedicerotidae	10.00	0.00	0.25	0.50	0.85	0.16	2.29
Sabellaridae	0.00	0.00	19.50	28.59	0.79	0.64	2.12
Goniadidae	9.00	0.00	0.50	1.00	0.78	0.23	2.09
Lumbrineridae	8.00	0.00	79.00	57.90	0.76	0.23	2.04
Lucinidae	6.00	0.00	0.00	0.00	0.75	0.06	2.00
Ampharetidae	6.00	0.00	47.75	17.17	0.73	0.18	1.95
Arabellidae	0.00	0.00	6.00	2.83	0.73	0.16	1.95
Trichbranchidae	1.00	0.00	11.75	3.59	0.70	0.09	1.87
Amphiuridae	12.00	0.00	2.00	1.83	0.64	0.33	1.73
Ampeliscidae	10.00	0.00	14.25	25.86	0.64	0.22	1.73
Veneridae	4.00	0.00	0.00	0.00	0.62	0.05	1.65

Appendix IV-III

Station Group Rankings for Stations at >100m Depth by Abundance and Contribution to Station Group Dissimilarities

Group I = CB, HB, MH, NB, RB, SB, ZB
Group II = BI, WB
Group III = DB, LH

Table IV-III 1. Ranking by abundance (ind. m^{-2}) for station groups of the 11 stations sampled at > 100m in Prince William Sound in 1990.

ST	Taxa	Abundance (ind. m^{-2})	Frequency (%)
I	Golfingiidae	806	100
(CB, HB,	Owenidae	353	100
MH, NB,	Balanomorpha	276	14
RB, SB,	Bivalvia	275	100
ZB)	Sabellidae	261	86
	Spionidae	219	100
	Cirratulidae	198	100
	Syllidae	145	100
	Paraonidae	135	100
	Lumbrineridae	132	100
	Capitellidae	128	100
	Maldanidae	100	100
	Phoxocephalidae	97	100
	Polyodontidae	87	71
	Ampharetidae	73	100
	Nephtyidae	51	100
	Carditidae	51	71
	Leuconidae	47	100
	Pleustidae	42	14
	Dentaliidae	42	100
II	Bivalvia	149	100
(BI, WB)	Lumbrineridae	108	100
	Nephtyidae	98	100
	Paraonidae	87	100
	Nuculanidae	53	100
	Leuconidae	52	100
	Cirratulidae	42	100
	Scaphandridae	42	50
	Spionidae	37	100
	Gastropoda	31	100
	Cossuridae	22	100
	Dentaliidae	22	100
	Sternaspidae	21	100
	Capitellidae	16	100
	Nuculidae	16	100
	Thyasiridae	14	100
	Montacutidae	12	50
	Onuphidae	12	50

Table IV-III 1. Continued.

ST	Taxa	Abundance (ind. m^{-2})	Frequency (%)
	Pyramidellidae	10	50
	Tellinidae	9	100
III (DB, LH)	Nephtyidae	148	100
	Cossuridae	75	100
	Paraonidae	71	100
	Leuconidae	69	100
	Orbiniidae	46	100
	Spionidae	32	100
	Nuculidae	30	50
	Bivalvia	19	100
	Cirratulidae	14	100
	Hesionidae	9	100
	Trichbranchidae	9	100
	Gastropoda	6	100
	Nuculanidae	6	100
	Ampharetidae	5	100
	Rhynchocoela	5	100
	Chaetodermatidae	4	50
	Scaphandridae	4	100
	Sipuncula	4	50
	Tellinidae	4	50
	Capitellidae	2	50

Table IV-III 2a. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 11 stations sampled at the >100m depth from Prince William Sound in 1990. The average dissimilarity between groups II and I = 55.89 and the standard deviation = 5.19.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group II		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Golfingiidae	0.50	0.71	403.14	316.04	2.84	0.67	5.08
Sabellidae	0.00	0.00	111.71	95.39	2.09	0.95	3.74
Owenidae	2.00	1.41	176.43	156.09	1.91	0.55	3.42
Syllidae	1.00	0.00	72.29	44.57	1.76	0.57	3.15
Terebellidae	0.00	0.00	17.29	6.05	1.52	0.28	2.72
Gnathiidae	0.00	0.00	17.71	9.45	1.49	0.35	2.67
Ampharetidae	1.00	0.00	36.43	27.02	1.44	0.40	2.58
Maldanidae	2.50	2.12	50.14	38.13	1.34	0.43	2.41
Phoxocephalidae	2.50	0.71	48.43	31.60	1.32	0.44	2.37
Polyodontidae	0.00	0.00	31.00	45.42	1.20	0.86	2.14
Spionidae	18.50	19.09	109.71	60.41	1.05	0.64	1.88
Sternaspidae	10.50	2.12	5.43	10.92	1.01	0.55	1.81
Ampeliscidae	0.00	0.00	8.29	5.38	1.00	0.47	1.78
Amphictenidae	0.00	0.00	9.29	11.51	0.98	0.42	1.76
Capitellidae	8.00	5.66	64.14	45.91	0.97	0.47	1.74
Sigalionidae	0.50	0.71	12.57	13.13	0.92	0.55	1.65
Nuculanidae	26.50	36.06	7.00	9.56	0.92	0.66	1.64
Nuculidae	8.00	4.24	4.71	10.29	0.85	0.37	1.51
Arabellidae	0.50	0.71	7.57	6.80	0.84	0.53	1.50
Trichbranchidae	0.00	0.00	6.57	8.70	0.81	0.40	1.45
Onuphidae	3.00	4.24	11.00	7.66	0.81	0.54	1.45

Table IV-III 2b. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 11 stations sampled at the > 100m depth from Prince William Sound in 1990. The average dissimilarity between groups III and I = 69.70 and the standard deviation = 3.23.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group III		Group I				
Species	Abun	SD	Abun	SD	δ	SD	%
Golfingiidae	0.50	0.71	403.14	316.04	3.25	0.74	4.66
Owenidae	0.50	0.71	176.43	156.09	2.62	0.65	3.76
Syllidae	0.00	0.00	72.29	44.57	2.44	0.71	3.51
Sabellidae	0.00	0.00	111.71	95.39	2.39	1.09	3.43
Phoxocephalidae	0.00	0.00	48.43	31.60	2.29	0.62	3.28
Maldanidae	0.00	0.00	50.14	38.13	2.26	0.53	3.24
Capitellidae	0.50	0.71	64.14	45.91	2.16	0.45	3.10
Lumbrineridae	1.00	0.00	65.86	59.94	1.86	0.53	2.67
Gnathiidae	0.00	0.00	17.71	9.45	1.71	0.40	2.45
Glyceridae	0.00	0.00	13.86	6.82	1.58	0.27	2.26
Terebellidae	0.50	0.71	17.29	6.05	1.54	0.38	2.20
Cirratulidae	7.00	5.66	99.00	71.54	1.44	0.59	2.06
Ampharetidae	2.50	2.12	36.43	27.02	1.37	0.53	1.97
Polyodontidae	0.00	0.00	31.00	45.42	1.37	0.97	1.96
Dentaliidae	0.50	0.71	20.86	23.29	1.30	0.65	1.86
Onuphidae	0.00	0.00	11.00	7.66	1.29	0.72	1.85
Orbiniidae	23.00	4.24	4.43	7.14	1.28	0.80	1.84
Sigalionidae	0.00	0.00	12.57	13.13	1.27	0.59	1.83
Arabellidae	0.00	0.00	7.57	6.80	1.16	0.57	1.67
Ampeliscidae	0.00	0.00	8.29	5.38	1.13	0.53	1.63
Scalibregmidae	0.00	0.00	6.00	3.06	1.13	0.32	1.62

Table IV-III 2c. Ranking of taxa using the SIMPER routine by their contribution to the dissimilarity between station groupings for the 11 stations sampled at the >100m depth from Prince William Sound in 1990. The average dissimilarity between groups III and II = 46.89 and the standard deviation = 4.63.

Abun = $\bar{X}$ abundance, SD = standard deviation, δ = contribution to the dissimilarity between the two groups and % = the percentage of the total dissimilarity.

	Group III		Group II				
Species	Abun	SD	Abun	SD	δ	SD	%
Lumbrineridae	1.00	0.00	54.00	26.87	3.48	0.82	7.42
Sternaspidae	0.00	0.00	10.50	2.12	2.59	0.44	5.53
Dentaliidae	0.50	0.71	11.00	7.07	2.21	0.89	4.71
Orbiniidae	23.00	4.24	2.50	2.12	2.19	0.81	4.66
Capitellidae	0.50	0.71	8.00	5.66	1.80	0.58	3.83
Trichbranchidae	4.50	3.54	0.00	0.00	1.68	0.62	3.59
Nuculanidae	3.00	1.41	26.50	36.06	1.64	1.05	3.49
Scaphandridae	2.00	0.00	10.50	14.85	1.59	0.37	3.40
Cossuridae	37.50	48.79	11.00	9.90	1.54	1.18	3.28
Nuculidae	7.50	10.61	8.00	4.24	1.47	0.96	3.14
Glyceridae	0.00	0.00	4.00	4.24	1.40	0.69	2.98
Phoxocephalidae	0.00	0.00	2.50	0.71	1.33	0.32	2.84
Thyasiridae	0.50	0.71	7.00	8.49	1.30	1.12	2.77
Maldanidae	0.00	0.00	2.50	2.12	1.27	0.69	2.70
Cirratulidae	7.00	5.66	21.00	2.83	1.21	0.67	2.58
Veneridae	0.00	0.00	2.50	2.12	1.17	0.43	2.50
Onuphidae	0.00	0.00	3.00	4.24	1.13	1.30	2.41
Montacutidae	0.00	0.00	3.00	4.24	1.13	1.30	2.41
Paraonidae	35.50	3.54	43.50	48.79	1.12	0.45	2.39
Tellinidae	1.00	1.41	4.50	4.95	1.11	0.70	2.36
Goniadidae	0.00	0.00	1.50	0.71	0.93	0.14	1.98