

AN ABSTRACT OF THE THESIS OF

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The shallow water benthic habitat of the SW Beaufort Sea is frequently gouged by the keels of ice pressure ridges. This natural physical disturbance was hypothesized to be an important factor affecting the structure of the benthic community. Smith-McIntyre grab samples were taken from three discrete gouge axes and from control areas on both sides of each gouge to examine this hypothesis. Significantly lower abundances were noted for total macrofauna and at the major taxa level inside two of the three gouge axes. Diversity and evenness indices increased inside the axes of all three gouges. At the species level, differences existed between gouge areas, but in general lower abundances were also found for many of the dominant species. A few species abundances were significantly higher inside the gouge axes. These differences were not dependent on differences in gouge depth, age or associated sediment parameters. Thus ice gouging is thought to be important in structuring the associated benthic assemblages at

these discrete disturbance sites. The generality of the significance of ice gouging along the entire Beaufort coast is considered.

Comparisons among gouges by cluster analyses of both the species and sediment data each yielded three groups of similar station aggregations suggesting a strong correlation between species distributions and sediment characteristics. However, factors such as water depth and relative gouge age, also correlate with the observed cluster groups. Therefore, one factor alone was unable to account for the observed patterns. Interactions of the many physical factors in this environment are proposed to explain the observed distributions. The physical action of ice gouging directly impacts the benthic assemblages by reducing abundances and indirectly by changing the associated sediment parameters which can influence animal distributions.

The Structure of an Arctic Shallow Water Benthic
Community: Effects of Ice Gouging

by

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THE STRUCTURE OF AN ARCTIC SHALLOW WATER BENTHIC
COMMUNITY: EFFECTS OF ICE GOUGING

INTRODUCTION

Research in the Alaskan Arctic accelerated dramatically in the early 1970's after the announcement of large off-shore petroleum reserves on Alaska's North Slope. The discovery of oil along the Alaskan shelf was a boon to the scientific community. The large influx of money and the need to have baseline information from all disciplines for environmental impact assessments resulted in a massive interdisciplinary effort to characterize the Beaufort environment. Accordingly, most benthic biological studies were directed at elucidating the general distribution and composition of the fauna present in the region (Carey et al, 1974; 1981; Wacasey, 1974; Carey and Ruff, 1977; Bilyard and Carey, 1979). Only recently have more specialized studies been undertaken (Kern and Carey, 1983). Likewise, geologists have studied the importance of, and processes associated with, sea-ice/sediment interactions along the inner continental shelf of the Beaufort Sea (Barnes and Reimnitz, 1974; Kovacs and Mellor, 1974; Reimnitz and Barnes, 1974; Reimnitz et al, 1978; Barnes et al, 1984). Geological studies have revealed that the moving keels of ice-pressure ridges extensively rework the sediments in the nearshore zone (Barnes and Reimnitz, 1974). Ice gouging of the sediments has been implicated in, or suggested to have had significant impacts on, the distribution and community structure of marine benthic invertebrates

by many workers in the Arctic (MacGinitie, 1955; Carey et al, 1974; 1978; Reimnitz and Barnes, 1974), but none of these studies quantitatively investigated the actual disturbance created by ice gouging. In this study, I investigated three discrete ice gouging events to quantitatively determine the impact of sea-ice gouging on the associated benthic communities.

Studies in many communities have shown that physical and biological disturbances are important in governing their structure (Loucks, 1970; Dayton, 1971; Connell, 1978; Paine, 1979; Sousa, 1979). In marine soft-bottom habitats, a variety of phenomena can disturb the sediments. The foraging or movement of animals may remove or displace members of the benthos (Rhoads and Young, 1970; Woodin, 1974; Brenchly, 1981; Reidenauer and Thistle, 1981; VanBlaricom, 1982; Nerini and Oliver, 1983; Oliver et al, 1984). Environmental stresses, such as periodic oxygen depletion (Tulkki, 1965; Santos and Simon, 1980; Arntz and Rumohr, 1982) or salinity reduction (Boesch et al, 1976) can defaunate large areas of the sediments. Severe physical disturbances such as storm-induced surges or dredging (Rees et al, 1977; Dobbs and Vozarik, 1983; McCauley et al, 1977; Rhoads et al, 1978; Bonsdorff, 1980; Swartz et al, 1980) may also have significant effects on community structure.

The frequency, severity and magnitude of disturbances vary greatly with their source. The theoretical studies of Miller (1982), Hastings (1980) and Connell and Slatyer (1977) predict, and the previously cited field studies provide evidence, that the effect of disturbance on community structure may vary dramatically depending on

both the size and frequency of the disturbance. When disturbances are large and relatively infrequent, effects of the disturbance will likely persist for long periods of time providing ample time and space for recruitment of colonizing species. At the other extreme, when the disturbance is small in size and relatively frequent, the disturbed area may not persist long enough for specialized colonizing species to locate and exploit it. Recolonization of small disturbances will be dominated by adult migration (dispersal) or advection from the surrounding area rather than larval recruitment (Miller, 1982; Sousa, 1984). Intermediate degrees of size or frequency of disturbances may result in higher species diversity in benthic communities since the community will consist of a patchwork of areas in different stages of recovery from disturbance (Johnson, 1971; Grassle and Sanders, 1973; Miller, 1982).

The correspondence of specific benthic communities with sediment type was identified by the the earliest ecologists (Petersen, 1913; Thorson, 1957). Much of the subsequent work in the benthos has been devoted to describing and explaining the association between particular organisms and sediment types (Sanders, 1960; Johnson, 1971; Gray, 1974; Rhoads, 1974; Fresi et al, 1983). Some of the more important characteristics of sediments are the grain size (% sand, silt, and clay, mean phi), shear strength, thixotrophy, dilatancy, depth of the redox potential discontinuity (RPD) and the organic content. Among these, grain size and organic content are commonly cited as important structuring forces (Bader, 1954; Longbottom, 1970; Gray, 1974; Parsons et al, 1977). Many studies have

shown that some species, either as larvae or adults, actively select sediment on the basis of grain size (Day and Wilson, 1934; Thorson, 1957; Jansson, 1967; Gray, 1974). However, larval and adult substrate selection is not solely dependent on grain size. Other sediment characteristics, some of which may be correlated with grain size, can be important. Rhoads and Young (1970) demonstrated that an increase in the water content of sediments by deposit feeders resulted in the exclusion of suspension feeders from the area. Rhoads (1974) noted that biologically reworked sediments are more easily resuspended than those sediments not reworked by bioturbation. Gray (1967) performed sediment selection experiments which showed that benthic invertebrates were attracted to particles covered with organic films produced by bacteria. However, other studies have failed to demonstrate correlations between faunal abundances and total organic content (Sanders and Hessler, 1969). All of these sediment parameters may, either individually or in some combination, affect the substrate selection of larvae and adults. Data from the substrate selection studies and descriptive distributional work suggests that sediment type plays a major role in determining the species composition of a community.

Sediment type may be influenced or changed due to the associated hydrodynamic processes. These processes have recently received much attention in the benthic literature (Eckman et al, 1981; Eckman, 1983; Jumars and Nowell, 1984; Nowell and Jumars, 1984). Depending on their strength, currents are able to distribute, redistribute and winnow sediments (Jumars and Nowell, 1984). The

effect on sediments may change the sediment properties enough to influence the distributional patterns of the animals. The speed, direction and duration of currents may also directly influence the settlement patterns of benthic larvae (Hannan, 1982; Eckman, 1983) affecting the community structure.

Relationships between benthic community organization and single environmental variables have been considered here. However, within each principal factor discussed, there are many complex interactions with the other factors which should be considered. For example, VanBlaricom (1982) found that foraging rays created disturbances in the benthic environment. These ray pits preferentially collected an enriched organic layer (changing the sediment parameters) due to the altered flow regime (made by the disturbance). The enriched habitat attracted benthic invertebrates and changed the community structure. Thus, studies of benthic community structure must consider the many inter-relationships between environmental variables.

In this study I was concerned with the effects of the annual ice gouging of the inner continental shelf of the southwestern Beaufort Sea by keels of ice pressure-ridges. Ice gouging has been shown to have a significant impact upon the bottom by reworking and redistributing large amounts of sediment (Barnes and Reimnitz, 1974; Barnes et al, 1984). The study area has been shown to have a very diverse sediment regime (Barnes and Reimnitz, 1974) indicating that ice gouging is potentially very important in structuring the associated benthic communities. The environment seems to be dominated

by physical rather than biotic variables. I tried to elucidate the physical-environmental forces affecting community structure. The main objective of this study was to determine how ice gouging of the sediments affects the benthic community structure. Specific objectives were to determine: 1) the general community structure of three gouge areas (i.e. numerical abundance, species richness and composition, diversity and evenness) and to compare these values with other studies along the Alaskan coast, 2) whether there were different faunal patterns inside gouge axes compared with outside undisturbed stations, 3) if the patterns at one discrete gouge area were similar to other gouged areas, and 4) which, if any, environmental variables can be correlated with the observed patterns and identified as important structuring factors.

STUDY AREA

The Nearshore Beaufort Sea Environment

The study region lies on the inner continental shelf of the southwestern Beaufort Sea off the northern coast of Alaska (Figure 1). The continental shelf can be characterized as a narrow shallow shelf extending 50 to 100 km from the coast to the shelf break. The prominent features of the shelf are broad shallow deltas off the major rivers, sand and gravel island chains parallel to the coast, and a series of sand and gravel shoals in water 10 to 20 m deep (Barnes et al, 1984). Oceanographic processes on the Beaufort Sea shelf are influenced by the circulation patterns of the Arctic Ocean. At the shelf margin, surface currents flow westward due to the influence of the anticyclonic Beaufort Gyre driven by the dominant northeasterly winds (Norton and Weller, 1984; Mountain, 1974). However, the average subsurface motion over the slope and shelf seaward of the 50 m isobath is a strong eastward flow, termed the Beaufort Undercurrent by Aagaard (1984). This undercurrent has been implicated in the distribution patterns of benthic polychaetes (Bilyard and Carey, 1979). A net wind-driven westward coastal current dominates inside the mid-shelf area (Kozo, 1984). This coastal current is variable and can change directions depending on the wind speed and direction.

Sea ice dominates the physical and biological processes along the entire Beaufort Sea shelf. Ice cover is almost 100% nine to ten months a year, forming in September and usually melting in early June (Kovacs and Mellor, 1974). On the inner shelf, seasonal ice can freeze to over 2 m thick in one season while multiyear ice averages 4

Figure 1. Location map showing the transect along which the three studied ice gouges were found. Insert gives overview of Alaskan coast. (Redrawn from Barnes et al. 1977)

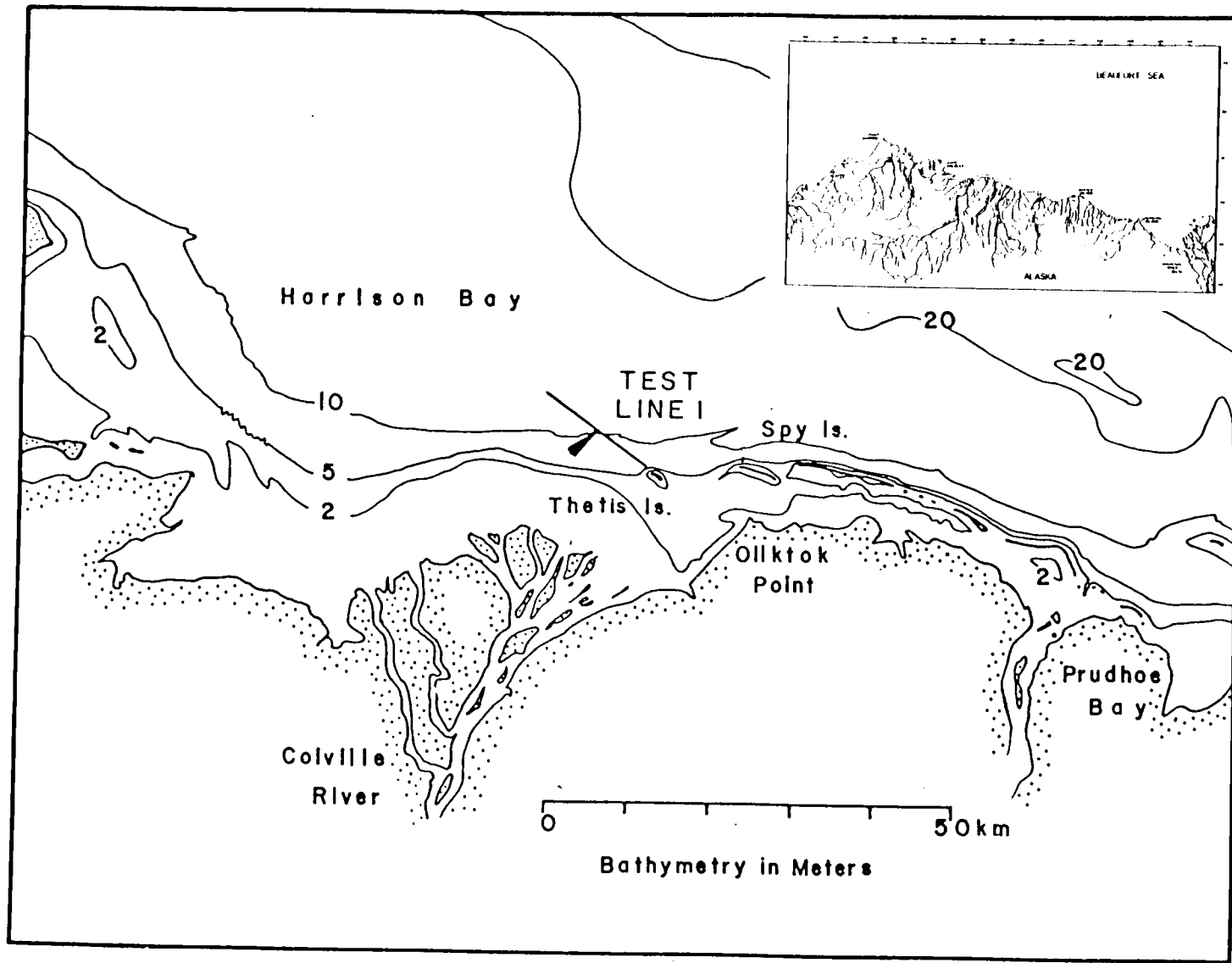


Figure 1.

m in thickness; ice islands and ice ridges probably occur with drafts up to 50 m (Norton and Weller, 1984). Reimnitz et al., (1978) defined different zones of ice on the inner shelf (Figure 2). The first zone, termed bottom fast ice, forms along the coast and freezes directly to the bottom to a depth of about 2 m. The second zone labelled the floating fast ice, is an extension of the fast ice but is not in direct contact with the sediments. This latter zone varies in width from 1 to 50 km, and its seaward edge interacts with the third zone, the *stamukhi* zone. The *stamukhi* zone is an area, usually in 15 to 25 m of water, where the moving polar ice pack and the stationary fast ice zones intersect. The interaction of the polar pack and the landfast ice results in an extensive pressure-ridge system which is commonly aground along the inshore edge. Pressure-ice ridges are prominent features along the Beaufort Sea coast, reaching over 10 m in height with ice keels several tens of meters deep (Tucker et al., 1984). During the season of ice cover the seafloor in the *stamukhi* zone is scoured by dragging pressure-ridge ice keels which form gouges in the sediments (Figures 2 and 3). Areas of intense groundings occur seaward of the barrier islands parallelling the coast. These barrier islands and shoals tend to moderate the influence of the pack ice on the areas inshore of the islands (e.g. Simpson Lagoon). However, in areas such as Harrison Bay where there are no protective islands, large grounded ridges can be found in shallower water (roughly 10 m) (Weeks et al., 1983).

During the open water season, the pack ice is transported away from shore in response to the regional wind stresses. This pattern is variable and occasionally the pack ice can remain adjacent to the

Figure 2. Ice zones in relation to bottom morphology along the inner continental shelf of the Beaufort Sea (modified from Reimnitz et al, 1978).

Figure 2.

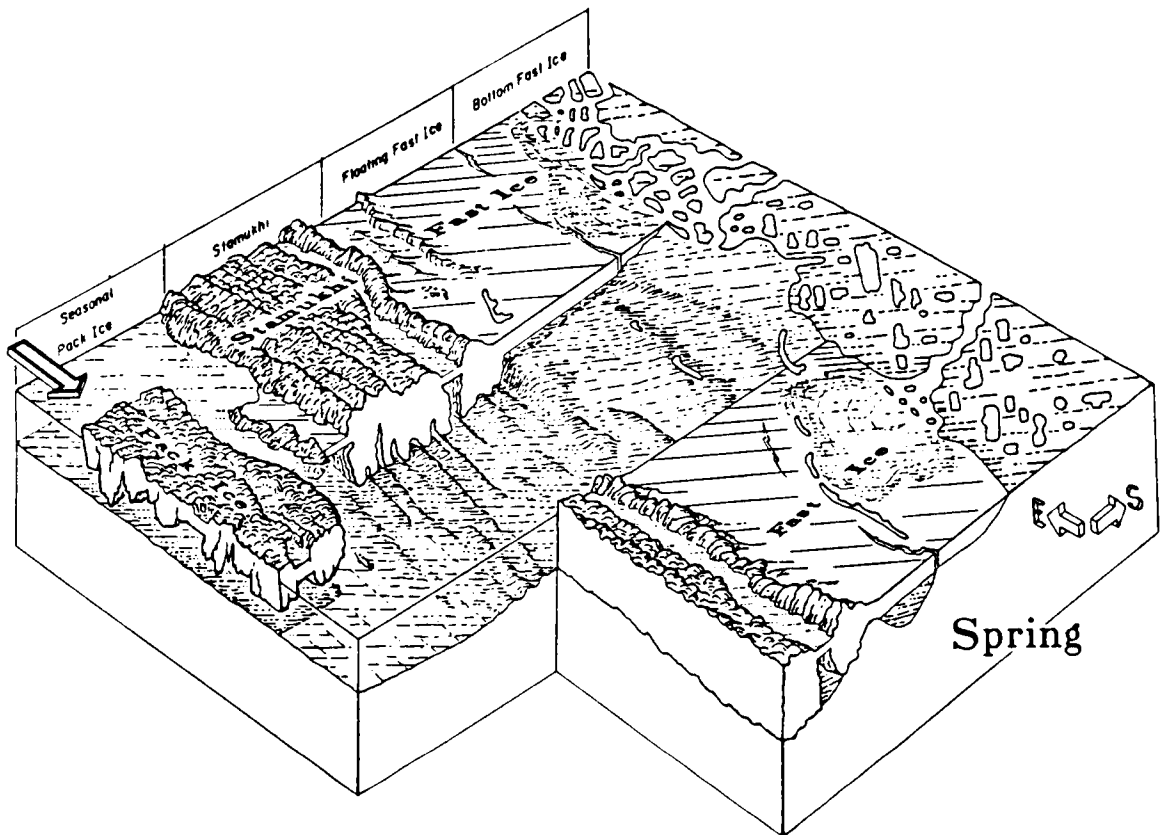
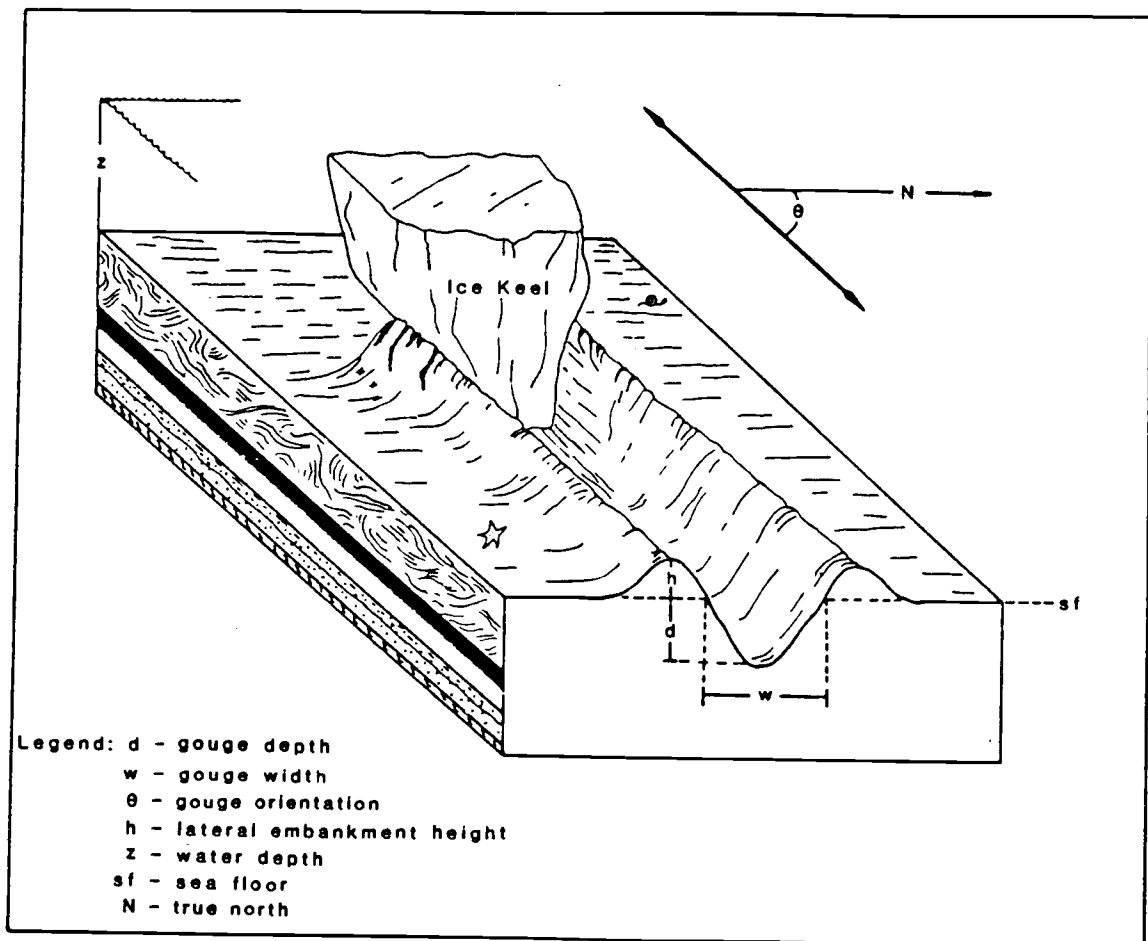


Figure 3. Cross-section of typical ice gouging event by the keel of a floating ice floe. Standard measurements made on ice gouges (after Week et al, 1983).

Figure 3.



coastline the entire season (Kovacs and Mellor, 1974). In the spring, Arctic rivers flood the nearshore ice, hastening the melting and deterioration of the fast ice. As the seasonal ice melts, the bottom fast ice begins to float and allows the nearshore ice to become mobile, facilitating the break up of the seasonal ice. Some of the pressure-ice ridges, though forming massive areas of grounded ridges and rubble of the stamukhi zone, remain grounded through most of the summer (Kovacs, 1976; Barnes and Reimnitz, 1979).

The ice affects the continental shelf directly by redistributing significant portions of surface sediment and disrupting the associated invertebrate fauna when impinging on the bottom. The keels of the sea ice ridges scrape the bottom as they are transported across the shelf by wind and circulation patterns. Sometimes the gouging causes significant disturbance of the benthic environment. Between 7 and 40 meters, ice gouging disturbance may cause reduction of organisms in the path of the ice keels (Barnes and Reimnitz, 1974; Reimnitz and Barnes, 1974; Reimnitz et al., 1978). Surficial bottom sediments reflect these ice interactions by exhibiting both lateral and vertical variability over short distances (Naidu and Mowatt, 1975; Barnes and Reimnitz, 1974). Barnes et al. (1978) noted the absence of lateral continuity over distances of tens of meters, although the vertical character of the cores were remarkably similar, with beds of slightly sandy muds alternating with well-laminated clean sands.

The characteristics, extent and degree of ice gouging on the inner continental shelf have been well studied (Barnes et al., 1984, 1979, 1978; Weeks et al., 1984; Reimnitz et al., 1978, 1977, 1972; Barnes and Reimnitz, 1979, 1974; Reimnitz and Barnes, 1974; Kovacs and

Mellor, 1974; Rearic et al, 1981). In general, the dominant orientation of ice gouges is parallel to the coast (ESE-WNW). Ice gouges in shallow water depths (0-10 m) have a more acute angle of incidence to the coast (71° to 83° T) than do gouges in deeper water (Weeks et al., 1984). The depths and widths of individual gouging events vary from very small (< 0.2 m deep) to very large (67 m wide) (Barnes et al, 1984). Multiple gouging events can have a much greater impact on the benthic environment. Information on the rate of new gouge formation has been studied by Barnes et al. (1978) and Weeks et al. (1984). They found that gouging events were fairly frequent (5.2 gouges/km of trackline/year).

An important aspect of ice gouge dynamics is the rate at which the gouges fill with sediments. Average sedimentation rates, assuming uniform sedimentation, appear to be quite low, 0.06 cm/yr (Reimnitz et al., 1977). With this low amount of sediment deposited, it would take about 1666 years to fill a 1 m deep gouge and 5000 years to fill a 3 m gouge (Weeks et al., 1983). The assumption of uniform sedimentation is probably in error. The bottom morphology due to ice gouging creates differential relief features and local sedimentation rates which can cause large differences in sedimentation over short distances (Weeks et al., 1983). As an ice keel plows through the sediments it creates ridges on both sides which are subject to slumping and sliding back into the gouge axis partially filling it in (Reimnitz and Barnes, 1974). Ridges formed by ice keels are sites of erosion while gouge axes act as sites of accelerated sediment deposition and catchments for algae and other organic debris (Reimnitz and Barnes, 1974; Weeks et al., 1983).

Besides the bottom morphology, high levels of hydrodynamic activity have been shown to be important in rates of gouge infilling in shallow water (Kovacs, 1972; Barnes and Reimnitz, 1974, 1979; Pilkington and Marcellus, 1981). In field observations, Barnes and Reimnitz (1979) showed that storm-induced large waves and wind-generated shelf currents during extensive open water conditions effectively obliterated ice gouges to a water depth of 13 meters. In deeper water these conditions caused pronounced infilling of gouges and ponding of sediments on the up-current side of the gouge ridges. Based on these observations the rates of sediment reworking and redistribution during large storm events are much higher than the average sedimentation rate. Conditions similar to these events occur approximately every 25 years or less (Reimnitz and Maurer, 1978). Events such as these make aging ice gouges much more difficult and virtually impossible without repeated annual observations of specific gouge areas.

METHODS AND MATERIALS

Sampling Procedure

The specific study sites were located along a transect northwest of Thetis Island in Harrison Bay, Alaska (Figure 1). During August of 1980, three ice-gouged areas, of relative, but undetermined ages, were sampled from a small 10.7 m research vessel (RV D.W.Hood). A field camp was established on Thetis Island where an ice-free anchorage existed and salt water was available for sieving operations. Five replicate grab samples were taken from each gouge axis and from the ungouged control sites on both sides of each gouge axis with a 0.1 m² Smith-McIntyre remote grab sampler (Smith and McIntyre, 1954). Most grab sample locations and operations were visually confirmed by SCUBA divers. Two sediment cores (2.8 cm I.D.) were removed from each grab sample and frozen for subsequent particle size and organic carbon analysis. A total of 45 macrofaunal grab samples and 90 sediment cores from 9 stations were obtained. Sample collection required 3 days (August 17, 18, 19, 1980) with one gouge site being sampled each day. Macrofauna samples were sieved at the field camp into two size fractions, 1.0 mm and 0.5 mm, after each daily cruise. Samples were fixed in a 10% formalin and seawater solution buffered with an excess of sodium borate.

Sample Treatment

In the laboratory samples were transferred to 95% ethanol and stained with Rose Bengal (Mason and Yevich, 1967). All samples were initially sorted into major taxonomic groups (e.g. Polychaeta, Pelecypoda, Amphipoda, Cumacea, Isopoda, Tanaidacea, Sipunculida, Priapulida and miscellaneous taxa) using a dissecting microscope and maintaining the separation between the two size fractions. Polychaetes, pelecypods, amphipods, isopods and cumaceans were identified to species and enumerated. Identification of the polychaetes followed the familial and generic classification of Fauchald (1977). The works of Hartman (1969), Uschakov (1955) and Pettibone (1954) were also very useful in the polychaete identifications. Bivalve identifications follow Lubinsky (1980), amphipod taxonomy follows Barnard (1969), Gurjanova (1951) and Sars (1895) and the isopods and cumaceans follow Richardson (1905) and Calman (1912), respectively. The remaining taxa were identified to the lowest taxonomic group possible and then enumerated. Only those taxa consistently retained on a 0.5 mm mesh sieve were included since samples cannot be regarded as being quantitative for the smaller meiofaunal organisms. Data derived from identified species and the remaining taxa were used in subsequent analysis.

Data Analysis

Sediment subsamples from each grab sample were analyzed for sand-silt-clay size fractions using the standard methods of Folk (1974). The sediment statistics of median and mean phi, deviation, skewness and kurtosis were computed following the formulas of Inman (1952) and Folk and Ward (1957). Percent dry weight of organic carbon was determined using a Perkin-Elmer CHN Analyzer. One sediment core was used for grain size, and the other, for organic content.

A one-way analysis of variance was calculated to test for differences between stations in the abundance of total macrofauna at each gouge site (3 stations) (5 replicate grabs / station) and on the dominant species of all taxa ($\geq 1.0\%$ total abundance / station). Multi-variate analysis of variance (Cooley and Lohnes, 1971) was used to test for differences in the density of major taxa between station locations. The Student-Neuman-Keuls (SNK) multiple comparison test (Sokal and Rohlf, 1969) was used to identify the station differences if the ANOVA was found to be significant. Data were $\ln(x+1)$ transformed prior to testing to better meet the assumptions of the parametric tests. Data from each gouge area were analyzed separately, since the specific history of each gouge was unknown.

For the remainder of the analyses, the data from samples gathered at each station (5 replicate 0.1 m^2 grabs) were pooled. Although this method eliminates the within-station variation, the subsequent analyses are directed at comparisons between stations.

Diversity and evenness indices were calculated using the

Shannon-Wiener Index of diversity ($H' = -\sum_{i=1}^S p_i \ln p_i$) and evenness ($J' = H' / \ln S$), where S = number of species and p = the proportion of individuals in species i , for each station at each gouge area (Pielou, 1966). To determine if the rank order of the dominant species was similar between the axis and the outsides of each gouge, Spearman's Rank-order correlation coefficient (r_s) (Spearman, 1904) was calculated. Since this test is for paired comparisons only, the two stations outside of each gouge were initially tested to determine if they were similar. If they were found to be significantly correlated, one side was randomly chosen and compared to the axis of the gouge. The significance level was adjusted to account for the multiple comparisons.

To determine if all three gouge axes could be distinguished from the controls, cluster analyses were performed on the sediment and faunal data. The clustering algorithm (CLUSB) is designed to find clusters of observations in multivariate data (McIntire, 1973). All observations are initially scaled for use throughout the program. All observations are assigned to the first cluster and the mean of the scaled observations calculated. The observation with the largest scaled distance from the cluster mean is selected to start the next cluster; it serves as the new cluster mean. Each point is examined to see whether its distance from the new cluster mean is less than its distance to the old cluster mean. If the distance is less, the point is moved to the new cluster, altering the new cluster mean. For subsequent steps, the observation with the largest distance from its cluster mean initializes the next new cluster, and all points are

examined for reclassification until the desired number of clusters is reached. A discriminant function analysis (DFA) on the resulting clusters was performed to determine the distinctiveness of each cluster. The DFA takes the input groups and maximizes the separation between them. The end result is a plot of the groups in 2 dimensional discriminant space, revealing the relative distinctness of each group.

A cluster analysis followed by a discriminant function analysis was performed on both the sediment and faunal data. For the sediment analysis, the individual grab samples were considered cases and all available sediment parameters were the variables. For the faunal analysis, the 3 stations from each of the 3 gouge areas (9 total) were considered cases, and the 48 most abundant taxa from all 3 gouge areas were used as the variables. The clusters of grab samples (sediment analysis) and stations (faunal analysis) as defined by the cluster analysis were used as the input groups for the DFA. The cluster, DFA and MANOVA analysis were performed with a Control Data Corporation 6000 computer at the Oregon State University computer center using the *CLUSB program and SPSS programs (Nie et al,1975).

RESULTS

Gouge Descriptions

Three discrete ice gouging events were sampled with a remote grab sampler and by diver observations. Measurements of bottom temperature and salinity were taken at each location during the sampling day (Table 1). Measurements of bottom temperature, and salinity show little variation between control and gouged areas. There are slight differences in temperature between gouge areas (Table 1). Since these samples were taken on 3 different days and at slightly different depths, these results are not surprising. Brief descriptions of the locations and characteristics of each gouge follow (see also Figures 1 and 3).

Gouge 1 was located approximately 13,190 m NW of Thetis Island ($70^{\circ}37.3'N$, $150^{\circ}12'W$) in 13 m of water. The gouge axis was variable from 0.5 to 1.0 m deep and trends NE/SW of magnetic north. No information was available on the gouge width. Diver observations made of the gouge axis indicated that this gouge was relatively old and appeared to be silted in. Visual observations of a sediment core sample from one of the grab samples revealed 3 layers: 1) 3-4 cm of unconsolidated silt, 2) 2-3 cm of a dark layer, and 3) a layer of clay; the diver field observations confirm these results.

Gouge 2 was located approximately 4340 m NW of Thetis Island ($70^{\circ}35'N$, $150^{\circ}17'W$) in 8.5 m of water. The depth of the gouge axis varied from 0.6 - 1.1 m and the width was estimated at 4.1 m (Fig. 3). The trend of the axis was noted as NE/SW. According to diver observations, this was a 'new-looking' W-shaped gouge characterized by

Table 1. Bottom temperature, salinity and water depth of outside control stations and inside axis stations from the three gouge areas.

	Gouge 1		Gouge 2		Gouge 3	
	<u>Outside</u>	<u>Axis</u>	<u>Outside</u>	<u>Axis</u>	<u>Outside</u>	<u>Axis</u>
Temperature: (C)	-0.20	-0.09	-0.55	---	-1.03	-1.07
Salinity: (o/oo)	30.18	30.75	30.99	---	31.19	31.58
Depth: (m)	13.0	13.5	8.5	9.2	12.0	12.5

sharp relief and little or no silting. Prior to sampling both the control and the axis sediments appeared similar, however, when disturbed by the sampling process and the action of the divers, the sediment cover inside the gouge axis appeared thinner. Gouge 2 may have been acting as a detritus trap as Laminaria, wood chips and balls of detritus were noted in the axis by the divers.

Gouge 3 was located in 12 m of water approximately 11,390 m NW of Thetis Island ($70^{\circ}36.6'N$, $150^{\circ}24.7'W$). The axis depth was measured at 0.5 m and the trend of the axis was NE/SW. According to diver observations the gouge appeared to be older than Gouge 2, much broader in width with smooth relief and filled with silts. Divers noted very little animal life; an amphipod, an isopod (Saduria sabini), a gastropod and a mysid (Mysis sp.) were observed. Field notes state that there was no detrital build up in the axis. Visual observations from the grab samples noted that within-gouge sediments appeared to consist of loose silt on top of a dense clay which supported the diver observations.

Sediment Parameters

Results of the sediment analyses for Gouges 1 and 2 are found in Table 2; sediment samples and data are missing for Gouge 3.

Comparison of sediment samples from the three stations at Gouge 1 demonstrate that the outside stations are very similar with each other while the axis station is very different. From the sediment statistics (Table 2) the sediment distribution at the outside stations can be characterized as a poorly sorted, highly positively

Table 2. Mean values (± 1 standard deviation) of sediment characteristics from different station locations at Gouges 1 and 2.

Station location	Sediment characteristics										
	% sand	% silt	clay	median phi	mean phi	deviation	skewness	kurtosis	% organic carbon		
Gouge 1	NE	\bar{X} (SD)	86.25 (6.33)	6.81 (3.46)	6.94 (3.37)	3.25 (0.20)	3.37 (0.30)	1.11 (0.4)	0.58 (0.09)	4.65 (1.92)	1.52 (.09)
	Axis	\bar{X} (SD)	14.41 (3.88)	52.67 (6.82)	32.92 (3.36)	6.55 (0.20)	6.87 (0.17)	2.68 (0.31)	0.26 (0.31)	0.80 (0.13)	1.71 (0.30)
	S	\bar{X} (SD)	89.18 (1.99)	5.65 (2.34)	5.18 (1.05)	3.05 (0.03)	3.13 (0.04)	0.96 (0.17)	0.61 (0.03)	5.45 (1.30)	1.05 (0.22)
Gouge 2	NW	\bar{X} (SD)	41.58 (10.03)	44.31 (9.19)	14.12 (1.95)	4.14 (0.32)	5.05 (0.27)	2.16 (0.15)	0.66 (0.08)	1.35 (0.43)	2.50 (0.43)
	Axis	\bar{X} (SD)	46.05 (11.91)	36.48 (8.10)	13.47 (5.21)	3.84 (0.25)	4.57 (0.44)	2.13 (0.33)	0.63 (0.20)	1.83 (0.77)	2.68 (0.14)
	SE	\bar{X} (SD)	64.47 (11.12)	22.68 (13.31)	12.85 (4.03)	3.78 (0.15)	4.97 (0.60)	2.10 (0.36)	0.65 (0.19)	2.58 (1.76)	2.52 (0.23)

skewed, extremely leptokurtic, very fine sand (Royse, 1970). The gouge axis station was characterized as a very poorly sorted, positively skewed, platykurtic, fine silt (Royse, 1970). These data confirm the diver's field observations that the axis of the gouge was filled in with silt, making it a very different sedimentary habitat from the outside stations. The organic carbon content of the axis station is slightly higher than either outside station.

Comparisons among Gouge 2 stations reveal very similar sediment characteristics. The sediment distribution at all 3 stations can be characterized as very poorly sorted, very positively skewed, very leptokurtic, coarse silt (Royse, 1970). There does not seem to be any difference between the outside stations and the axis except that the percent organic carbon content of the axis station is slightly higher than the outside locations (Table 2). The lack of higher silt content in the axis station supported the diver observations that this was a fairly recent gouge without much infilling.

Comparisons of the sediment data between the gouge areas show that the outsides at each location are different. The Gouge 2 sediments were more silty. This spatial variability is common in this shallow water arctic environment (Barnes and Reimnitz, 1974). The differences in the amount of silt in the axes of the gouges reaffirm the relative ages of the gouges. The axis of Gouge 1 appears to be filled in with very poorly sorted silts which are indicative of infilling via some transport mechanism (Reimnitz and Kempema, 1983). The axis of Gouge 2 does not appear to have accumulated much, if any, silt compared to the outside stations. Gouge 2 is, therefore,

presumed to be younger than Gouge 1. The lack of silt in Gouge 2 may be caused by the gouge orientation or shape which may in some manner affect the currents so that silts are preferentially transported out of the axis. However, this explanation seems unlikely since the divers noted various forms of detritus in the axis that suggested the gouge was acting as a detritus trap.

When cluster analysis was applied to the 30 individual grabs, based on sediment parameters, interpretable results were obtained with 3 clusters. Group 1 was composed of all the grabs (15) from Gouge 2 which were characterized as a very poorly sorted coarse silt. Group 2 was composed of the grab samples (5) from the Gouge 1 axis station which were dominated by high silt percentages and Group 3 had the 10 grabs from the sandy outside stations of Gouge 1. The DFA plot showed these groups to be very distinct (Figure 4). Based on the data in Table 2, the cluster analysis and DFA groups make intuitive sense.

General Community Characteristics

A total of 20,974 animals from the three gouge areas were examined and identified to the lowest taxon possible. These animals represented 114 different taxa (Appendix 2). Polychaetes dominated the fauna with 52 species representing 82.4% of the total abundance. Bivalve molluscs were the second most dominant taxon representing 7.2% total abundance. Amphipods (27 species), priapulids and sipunculids were also fairly abundant (2.7%, 2.6%, 1.6% respectively). The remainder of the fauna was made up of cumaceans (0.8%), tanaids (0.8%), isopods (0.1%) and miscellaneous taxa (1.8%)(Table 4). The miscellaneous taxa consisted of oligochaetes, gastropods, nemertean,

Figure 4. Three clusters of grab samples based on sediment characteristics generated by a discriminant function analysis. The stars represent the mean of the group. Composition of the groups is explained in the text.

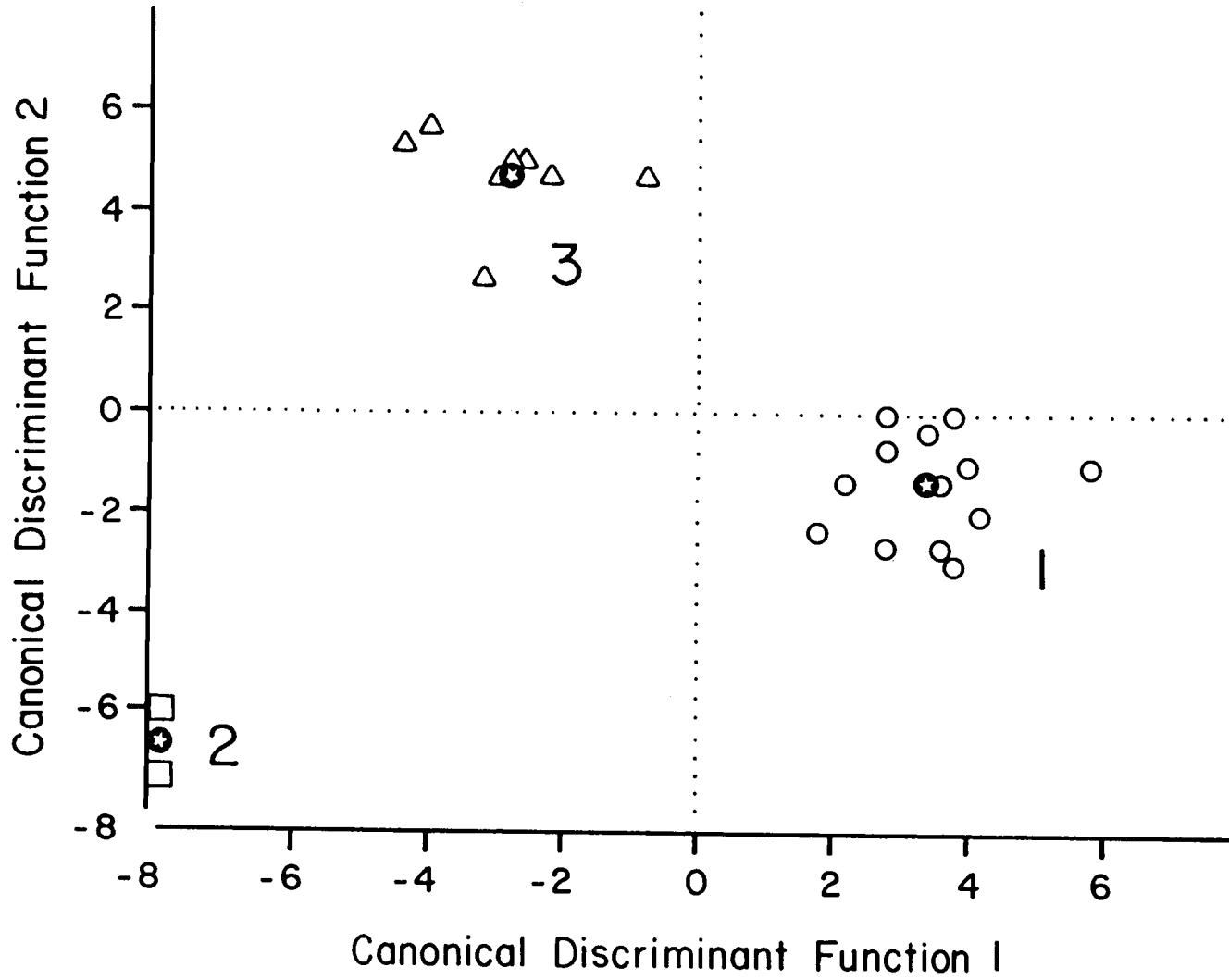


Figure 4.

mysids, miscellaneous crustaceans, fish and unidentified others. Results of the diversity and evenness indices calculations for the total fauna give $H' = 1.92$ and $J' = 0.41$. By pooling all of the data, comparisons of the community structure on the inner shelf region of Harrison Bay can be made with previous studies along the inner shelf of the Beaufort Sea (Carey, 1978; Carey et al, 1974; Wacasey, 1974; Ellis, 1960).

Overall, numerical abundance was highest in the Gouge 1 area ($x = 660.9$ ind/0.1 sq m) and was similar between Gouges 2 and 3 (361.3 ind/0.1 sq m and 376.5 ind/0.1 sq m, respectively) (Table 3) when the three stations at each gouge area are pooled. The number of species present follows the same pattern: Gouge 1 had the most species (96), Gouge 3 had an intermediate number of species (79) and Gouge 2 had the least number of species (66) (Table 4). Polychaetes dominated at all 3 gouge areas; Gouge 1 had the highest percent (87.0%) and Gouge 2 and 3 were similar (79.2% and 77.3% respectively) (Table 4). Bivalve molluscs were the second most abundant taxa at all gouge areas, however in this case, Gouge 2 and 3 had higher percentages (11.4 and 7.8%) than Gouge 1 (4.6%). Amphipods (2.7%), priapulids (1.6%) and sipunculids (1.3%) represented the next most abundant taxa at the Gouge 1 area. The next three dominant taxa of Gouge areas 2 and 3 had similar ranks (priapulids, 3.3% and 3.5%; amphipods, 2.2% and 3.2% and sipunculids, 1.7% and 2.1% respectively) (Table 4).

There are differences in the values of the diversity and evenness indices (computed by pooling the three stations at each gouge area) between the gouge areas (Table 4). The Gouge 1 area has the lowest diversity and the lowest evenness ($H' = 1.60$, $J' = 0.35$)

Table 3. Means, standard deviations and ranges of the total number of individuals per 0.1 sq. meter and per 1.0 sq. meter from the three gouge areas (3 stations combined - 15 grab samples).

	No. of individuals/ 0.1 sq. m	No. of individuals/ 1.0 sq. m
Gouge 1	$\bar{x} = 660.9 \pm 282.6$ range 203 - 1142	$\bar{x} = 6609 \pm 2826$ range 2030 - 11,420
Gouge 2	$\bar{x} = 361.3 \pm 187.9$ range 66 - 832	$\bar{x} = 3613 \pm 1879$ range 660 - 8320
Gouge 3	$\bar{x} = 376.5 \pm 117.3$ range 110 - 555	$\bar{x} = 3765 \pm 1173$ range 1100 - 5550

Table 4. Combined community characteristics - major taxa abundances and percent composition from the three gouge areas.

Major taxa	Number	% composition	
<u>All stations combined</u>			
Polychaeta	17284	82.4	
Pelecypoda	1518	7.2	
Amphipoda	568	2.7	
Priapulida	535	2.6	
Spiunculida	340	1.6	
Tanaidacea	173	0.8	
Cumacea	161	0.8	
Isopoda	28	0.1	
Miscellaneous*	376	1.8	
Total	20,980		
Total no. species	114	H' = 1.92	J' = 0.41
<u>Gouge 1</u>			
Polychaeta	8625	87.0	
Pelecypoda	459	4.6	
Amphipoda	268	2.7	
Priapulida	159	1.6	
Tanaidacea	130	1.3	
Sipunculida	129	1.3	
Cumacea	60	0.6	
Isopoda	5	0.05	
Miscellaneous*	78	0.8	
Total	9913		
Total no. species	99	H' = 1.60	J' = 0.35
<u>Gouge 2</u>			
Polychaeata	4295	79.2	
Pelecypoda	617	11.4	
Priapulida	180	3.3	
Amphipoda	121	2.2	
Sipunculida	90	1.7	
Cumacea	44	0.8	
Isopoda	15	0.3	
Tanaidacea	11	0.2	
Miscellaneous*	47	0.9	
Total	5420		
Total no. species	66	H' = 2.01	J' = 0.48

Table 4 (cont.)

Major taxa	Number	% composition	
<u>Gouge 3</u>			
Polychaeta	4364	77.3	
Pelecypoda	442	7.8	
Priapulida	196	3.5	
Amphipoda	179	3.2	
Sipunculida	121	2.1	
Cumacea	57	1.0	
Tanaidacea	32	0.6	
Isopoda	8	0.1	
Miscellaneous*	251	4.4	
Total	5647		
Total no. species	79	H' = 2.10	J' = 0.48

indicating that this area is more dominated by a few species than either of the other areas. Gouge areas 2 and 3 had very similar diversity ($H' = 2.01$ and 2.10) and evenness indices ($J' = 0.48$ and 0.48).

Distinct Patterns at Each Gouge Area

In general, fewer animals were found inside gouges than outside. Comparisons by ANOVA of the total numerical abundance between the outside control stations and the gouge axis station showed significantly fewer individuals inside the gouges than outside at Gouges 1 ($F_{2,12} = 4.552$, $P < 0.05$) and 2 ($F_{2,12} = 9.572$, $P < 0.01$). There was no significant difference in the number of individuals between the outside stations and the axis station at Gouge 3 ($F_{2,12} = 1.720$, $P > 0.05$) (Figure 5). The two outside stations at all three gouge areas were never significantly different.

Comparison of the abundances of the major taxa among the three stations at each gouge resulted in highly significant differences (Gouge 1: $F_{10,24} = 8.65$, $P < .001$; Gouge 2: $F_{10,24} = 3.89$, $P < .005$; Gouge 3: $F_{10,24} = 3.83$, $P < .005$). Results of the individual ANOVAs identified the polychaetes and the molluscs as significantly different among stations at Gouges 1 (polychaetes, $F_{2,12} = 5.01$, $P < .025$; bivalves, $F_{2,12} = 8.83$, $P < .005$) and 2 (polychaetes, $F_{2,12} = 10.44$, $P < .005$; bivalves, $F_{2,12} = 6.36$, $P < .025$). Use of the SNK multiple comparisons test and plotting of the abundances of the polychaetes and molluscs from the three gouge sites (Figure 6A,B), demonstrates that the abundances are decreased in the axis stations for Gouges 1 and 2. In contrast, no individual major taxa at Gouge 3 showed a significant

Figure 5. Total mean number of individuals per 0.1 sq m at each station (± 1 standard deviation) from all three gouge areas (A = Gouge 1, B = Gouge 2, C = Gouge 3). Note that the abundance is significantly lower at the axis stations from Gouges 1 and 2 (station designations are directions relative to gouge axes).

Figure 5.

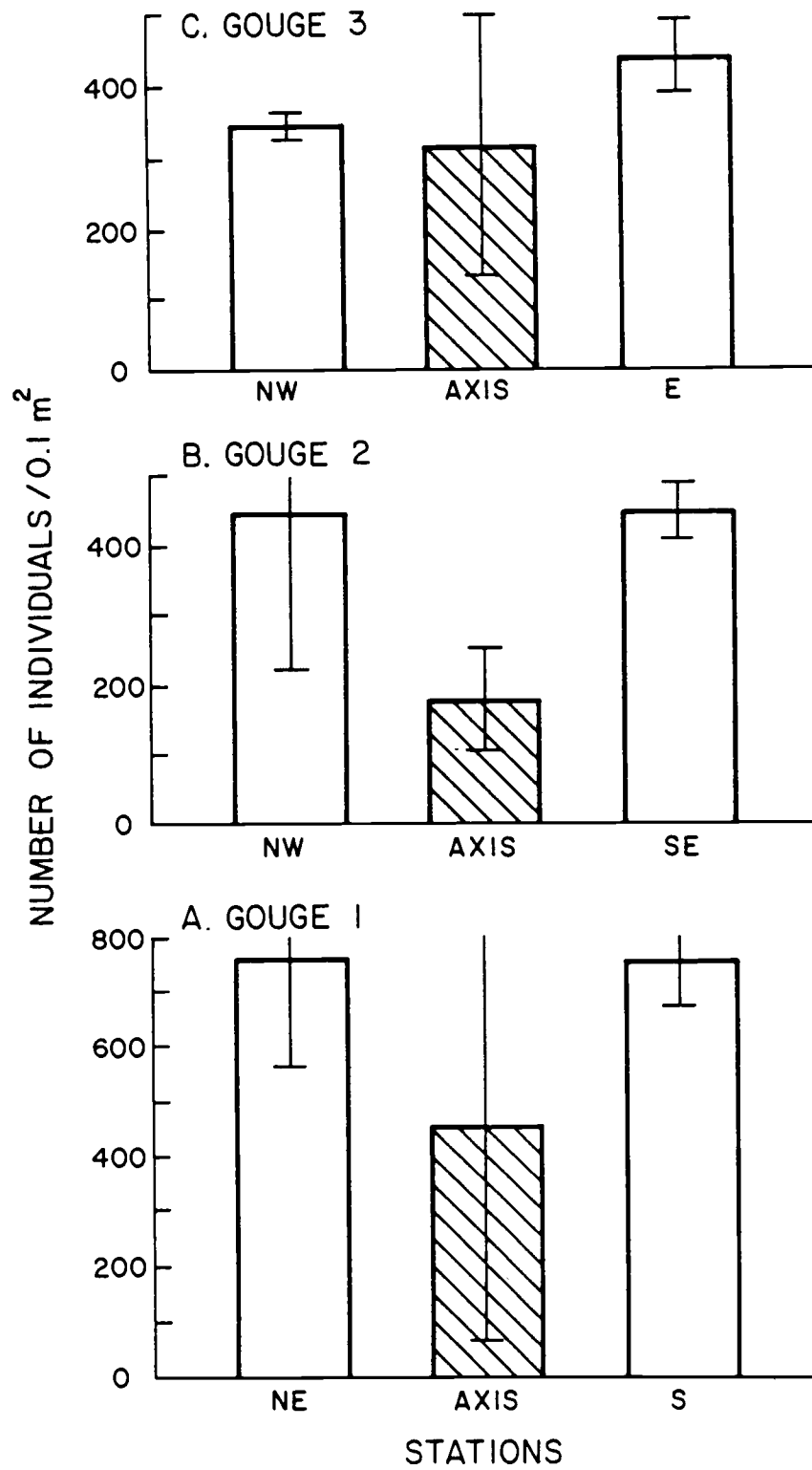


Figure 6. Total mean number of Polychaeta and Pelecypoda at each station (± 1 standard deviation) from all three gouge areas (A = Gouge 1, B = Gouge 2, C = Gouge 3). The abundances of the polychaetes and pelecypods from Gouges 1 and 2 are significantly lower at the axis station. The differences at Gouge 3 are not significant (station designations are directions relative to gouge axes). Note the different scales for the polychaetes and pelecypods.

Figure 6.

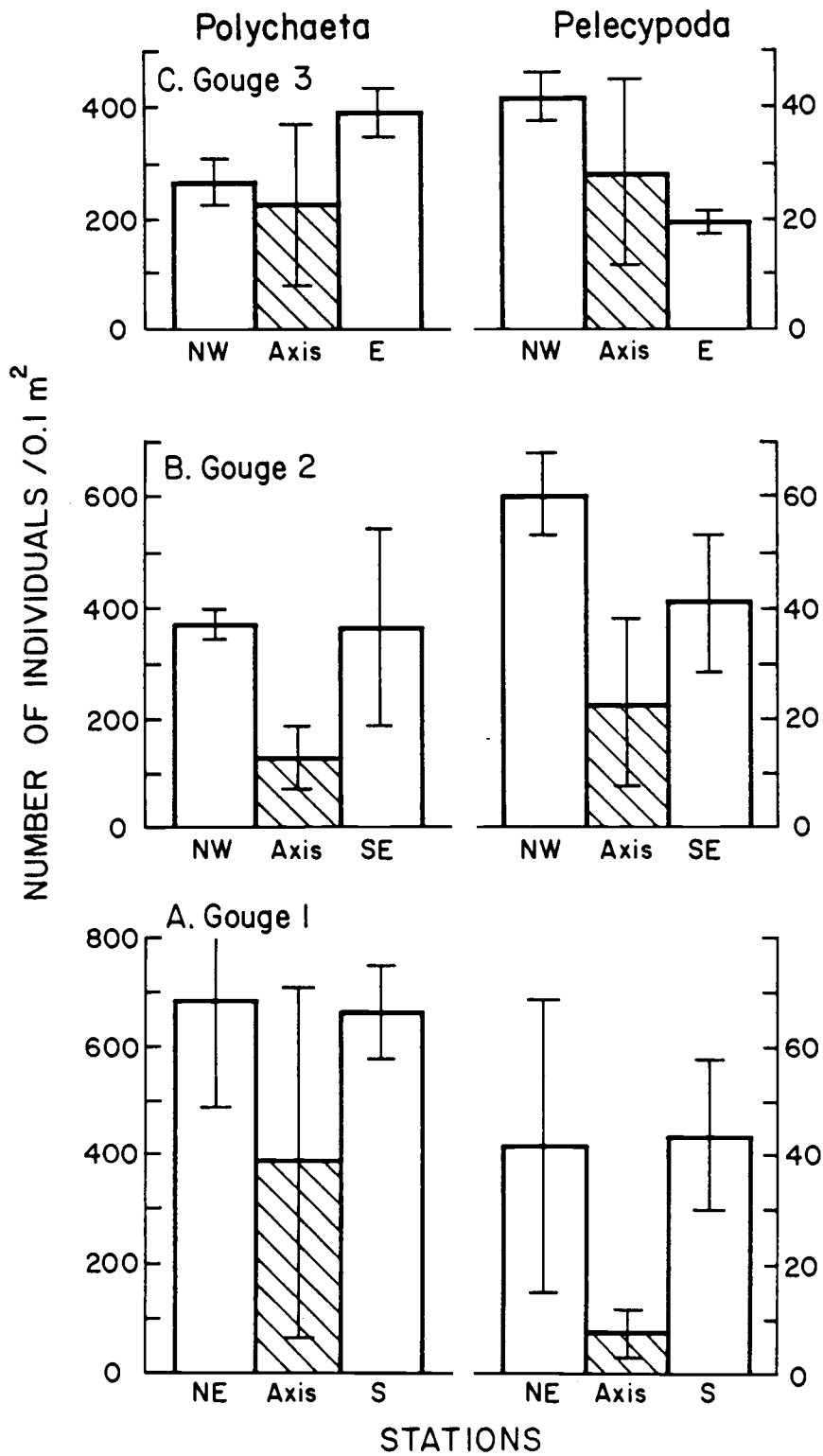


Table 5. Mean (± 1 standard deviation) total abundance of all individuals at each station divided into size fractions.

Gouge 1	NE	Axis	S
0.5 mm - 1.0 mm	438.2 \pm 157.5	356.8 \pm 277.8	486.6 \pm 63.4
≥ 1.0 mm	326.0 \pm 85.1	98.6 \pm 114.9	276.4 \pm 33.2
Total	764.2 \pm 203.7	455.4 \pm 38.89	763.0 \pm 87.8
Gouge 2	NW	Axis	SE
0.5 mm - 1.0 mm	285.8 \pm 20.8	103.4 \pm 52.4	277.2 \pm 190.8
≥ 1.0 mm	171.0 \pm 19.7	73.4 \pm 27.7	173.2 \pm 54.7
Total	456.8 \pm 36.5	176.8 \pm 73.2	450.4 \pm 230.3
Gouge 3	NW	Axis	E
0.5 mm - 1.0 mm	224.8 \pm 23.2	170.2 \pm 102.5	299.0 \pm 45.6
≥ 1.0 mm	134.4 \pm 39.6	153.2 \pm 117.0	147.8 \pm 24.7
Total	359.2 \pm 25.0	323.4 \pm 187.0	446.8 \pm 49.6

difference between stations (Figure 6C and Table 5).

Abundances of the dominant species (hereafter defined as the species making up $\geq 1.0\%$ total abundance/station) at each gouge area were compared between the outside stations and the gouge axis station. Minuspio cirrifera, a polychaete, was dominant at every station at all 3 gouge areas (Table 6). It was less abundant inside all three gouge axes, but the difference was significant only at Gouges 1 and 2 (Table 7). The numerical density of dominant species varied between the three gouge areas but in general there was decreased abundance inside each gouge axis. At Gouge 1, 6 of the 13 dominant species had significantly lower abundances inside the axis, 3 had significantly higher abundances and 4 were not different (Table 7 and Figure 7). Six of the fourteen dominant species at Gouge 2 showed significantly fewer individuals in the axis than at least one of the outside control stations (Table 7). Only Boeckosimus affinis was significantly more abundant inside the axis, and the remaining seven dominant species showed no significant differences (Table 7 and Figure 8). At Gouge 3, only 4 of the 17 dominant species showed a significantly lower abundance in the gouge axis compared to at least one outside station (Table 7). Two dominant species displayed significant increases in the gouge axis as compared to at least one outside station (Table 7 and Figure 9). Eleven species showed no difference (Table 7).

The fluctuations of diversity (H') and evenness (J') indices between stations were calculated for all taxa at each station for each gouge area (Figure 10). Both diversity (H') and evenness (J') indices were higher at the axis station than the outside stations at all three gouge areas (Figure 10). The outside stations were very similar to

Table 6. Numerically dominant species ($\geq 1.0\%$ per station), rank and percent composition of dominant species (per station) at Gouges 1, 2 and 3 (n = total number of individuals per 5 grab samples). Station locations relative to the gouge axis identified as NW, NE, E, SE, S.

	RANK			% COMPOSITION		
	NE	S	AXIS	NE	S	AXIS
Gouge 1						
<u>Minuspio cirrifera</u>	1	1	1	69.9	70.9	66.5
<u>Sphaerodoropsis minuta</u>	2	2	3	7.1	6.0	2.3
<u>Chone nr. murmanica</u>	3	4		5.4	2.6	0.3
<u>Portlandia arctica</u>	4	3	7	4.6	5.1	1.2
<u>Eteone longa</u>	5	5.5		1.3	1.3	0.04
<u>Scolecopides arcticus</u>	6	5.5		1.2	1.3	--
<u>Hesionidae sp. A</u>			2	0.1	0.3	4.8
<u>Monoculodes crassirostris</u>			4.5	0.9	0.8	1.5
<u>Micronephtyes minuta</u>			4.5	0.1	0.03	1.5
<u>Antinoella sarsi</u>			6	0.2	0.07	1.3
<u>Hesionidae sp. B</u>			8	0.2	0.2	1.1
<u>Chaetozone gracilis ?</u>			9.5	0.8	0.3	1.0
<u>Boeckosimus affinis</u>			9.5	0.05		1.0
Total no. taxa/station	70	63	63			
Total no. individuals				3820	3815	2276
	NW	SE	AXIS	NW	SE	AXIS
Gouge 2						
<u>Minuspio cirrifera</u>	1	1	1	51.6	63.6	38.5
<u>Chone nr. murmanica</u>	2	5	3.5	13.2	2.3	5.7
<u>Axinopsida orbiculata</u>	3	2.5	3.5	5.7	3.6	5.7
<u>Portlandia arctica</u>	4	2.5	6	5.6	3.6	4.1
<u>Ampharete vega</u>	5	10	10.5	2.6	1.0	1.4
<u>Sphaerodoropsis minuta</u>	6	4	5	2.3	3.4	4.4
<u>Scolecopides arcticus</u>	7	8	2	2.0	1.3	8.5
<u>Chaetozone gracilis ?</u>	8	6	7	1.6	1.6	1.7
<u>Eteone longa</u>	9		13	1.2	0.5	1.1
<u>Capitella capitata</u>		7	8.5	0.6	1.5	1.5
<u>Monoculodes crassirostris</u>		9		0.6	1.2	0.8
<u>Monoculopsis longicornis</u>			10.5	0.7	0.3	1.4
<u>Boeckosimus affinis</u>			8.5	0.1	0.04	1.5
<u>Diastylus sulcata</u>			12	0.5	0.9	1.2
Total no. taxa/station	52	47	43			
Total no. individuals				2284	2251	884

Table 6 (cont.)

Gouge 3	<u>NW E AXIS</u>			<u>NW E AXIS</u>		
	<u>Minuspio cirrifera</u>	1	1	1	56.2	60.4
<u>Portlandia arctica</u>	2	4	2	9.6	3.9	7.6
<u>Sphaerodoropsis minuta</u>	3	2	3	6.7	9.6	2.8
<u>Priscillina armata</u>	4			2.1	0.1	--
<u>Hesionidae sp. A</u>	5		8	1.7	0.3	1.8
<u>Monoculodes crassirostris</u>	6.5		5	1.4	0.3	2.1
<u>Antinoella sarsi</u>	6.5		7	1.4	0.1	1.9
<u>Axinopsida orbiculata</u>	8.5			1.3	0.2	0.5
<u>Diastylus sulcata</u>	8.5			1.3	0.4	0.9
<u>Scolecopides arcticus</u>	10	5		1.2	2.2	--
<u>Chaetozone gracilis ?</u>	11		4	1.0	0.7	2.2
<u>Chone nr. murmanica</u>		3		0.6	7.3	0.4
<u>Cossura soyeri</u>			6	0.05	0.9	2.0
<u>Monoculopsis Tongicornis</u>			9	0.4	0.2	1.7
<u>Brada villosa</u>			10	0.05	0.1	1.6
<u>Trochochaeta carica</u>			11	0.05	--	1.1
<u>Capitella capitata</u>			12	0.5	0.4	1.0
Total no. taxa/station	56	65	49			
Total no. individuals				1795	2237	1617

Table 7. F values, significance values and station similarities for the dominant species ($\geq 1.0\%$ total abundance/station) at the three gouge areas. Stations are arranged in order of increasing mean abundance (from left to right); underlining signifies no difference between the mean abundances at the stations (A = axis, NW = northwest, NE = northeast, E = east, S = south, SE = southeast stations).

	F	P	Station similarities		
Gouge 1					
<u>Minuspio cirrifera</u>	4.64	.05	A	<u>NE</u>	<u>S</u>
<u>Sphaerodoropsis minuta</u>	8.73	.005	A	<u>S</u>	<u>NE</u>
<u>Chone nr. murmanica</u>	48.40	.001	A	<u>S</u>	<u>NE</u>
<u>Portlandia arctica</u>	14.92	.001	A	<u>NE</u>	<u>S</u>
<u>Eteone longa</u>	36.97	.001	A	<u>NE</u>	<u>S</u>
<u>Scolecopides arcticus</u>	22.83	.001	A	<u>NE</u>	<u>S</u>
<u>Hesionidae sp. A</u>	21.26	.001	NE	<u>S</u>	<u>A</u>
<u>Antinoella sarsi</u>	5.66	.025	<u>S</u>	<u>NE</u>	<u>A</u>
<u>Hesionidae sp. B</u>	5.10	.025	<u>NE</u>	<u>S</u>	<u>A</u>
<u>Micronephthys minuta</u>	2.45	.25	<u>S</u>	<u>NE</u>	<u>A</u>
<u>Boeckosimus affinis</u>	1.55	.26	<u>S</u>	<u>NE</u>	<u>A</u>
<u>Monoculodes crassirostris</u>	0.882	.50	<u>A</u>	<u>NE</u>	<u>S</u>
<u>Chaetozone gracilis ?</u>	0.95	.50	<u>S</u>	<u>A</u>	<u>NE</u>
Gouge 2					
<u>Minuspio cirrifera</u>	15.00	.001	A	<u>NW</u>	<u>SE</u>
<u>Portlandia arctica</u>	7.48	.01	A	<u>SE</u>	<u>NW</u>
<u>Chone nr. murmanica</u>	6.71	.025	A	<u>SE</u>	<u>NW</u>
<u>Ampharete vega</u>	8.47	.01	A	<u>SE</u>	<u>NW</u>
<u>Eteone longa</u>	4.82	.05	A	<u>SE</u>	<u>NW</u>
<u>Boeckosimus affinis</u>	10.67	.005	<u>SE</u>	<u>NW</u>	<u>A</u>
<u>Scolecopides arcticus</u>	1.93	.25	<u>SE</u>	<u>NW</u>	<u>A</u>
<u>Sphaerodoropsis minuta</u>	0.86	.50	<u>A</u>	<u>NW</u>	<u>SE</u>
<u>Capitella capitata</u>	1.44	.50	<u>A</u>	<u>NW</u>	<u>SE</u>
<u>Monoculodes crassirostris</u>	0.545	.75	<u>A</u>	<u>NW</u>	<u>SE</u>
<u>Monoculopsis longicornis</u>	1.09	.50	<u>SE</u>	<u>A</u>	<u>NW</u>
<u>Diastylus sulcata</u>	0.563	.75	<u>NW</u>	<u>A</u>	<u>SE</u>
<u>Axinopsida orbiculata</u>	4.72	.05	<u>A</u>	<u>SE</u>	<u>NW</u>

Table 7 (cont.)

	F	P	Station similarities		
Gouge 3					
<u>Sphaerodoropsis minuta</u>	8.84	.005	A	NW	E
<u>Chone nr. murmanica</u>	30.49	.001	A	NW	E
<u>Scolecopides arcticus</u>	50.05	.001	A	NW	E
<u>Minuspio cirrifera</u>	2.41	.25	A	NW	E
<u>Portlandia arctica</u>	1.72	.25	A	E	NW
<u>Priscillina armata</u>	1.92	.25	A	E	NW
<u>Axinopsida orbiculata</u>	6.28	.025	E	A	NW
<u>Diastylus sulcata</u>	2.70	.25	E	A	NW
<u>Hesionidae sp. A</u>	2.26	.25	E	A	NW
<u>Monoculodes crassirostris</u>	0.64	.75	E	NW	A
<u>Antinoella sarsi</u>	8.70	.005	E	NW	A
<u>Chaetozone gracilis ?</u>	0.20	--	E	NW	A
<u>Cossura soyeri</u>	2.76	.25	NW	E	A
<u>Brada villosa</u>	2.56	.25	NW	E	A
<u>Trochochaeta carica</u>	1.63	.25	E	NW	A
<u>Capitella capitata</u>	0.59	.75	NW	E	A
<u>Monoculopsis longicornis</u>	13.27	.001	E	NW	A

Figure 7. The total number of individuals of the dominant species from Gouge 1 which showed significantly higher or lower abundances from at least one outside station (see Table 6 for complete species names; station designations are directions relative to the gouge axis).

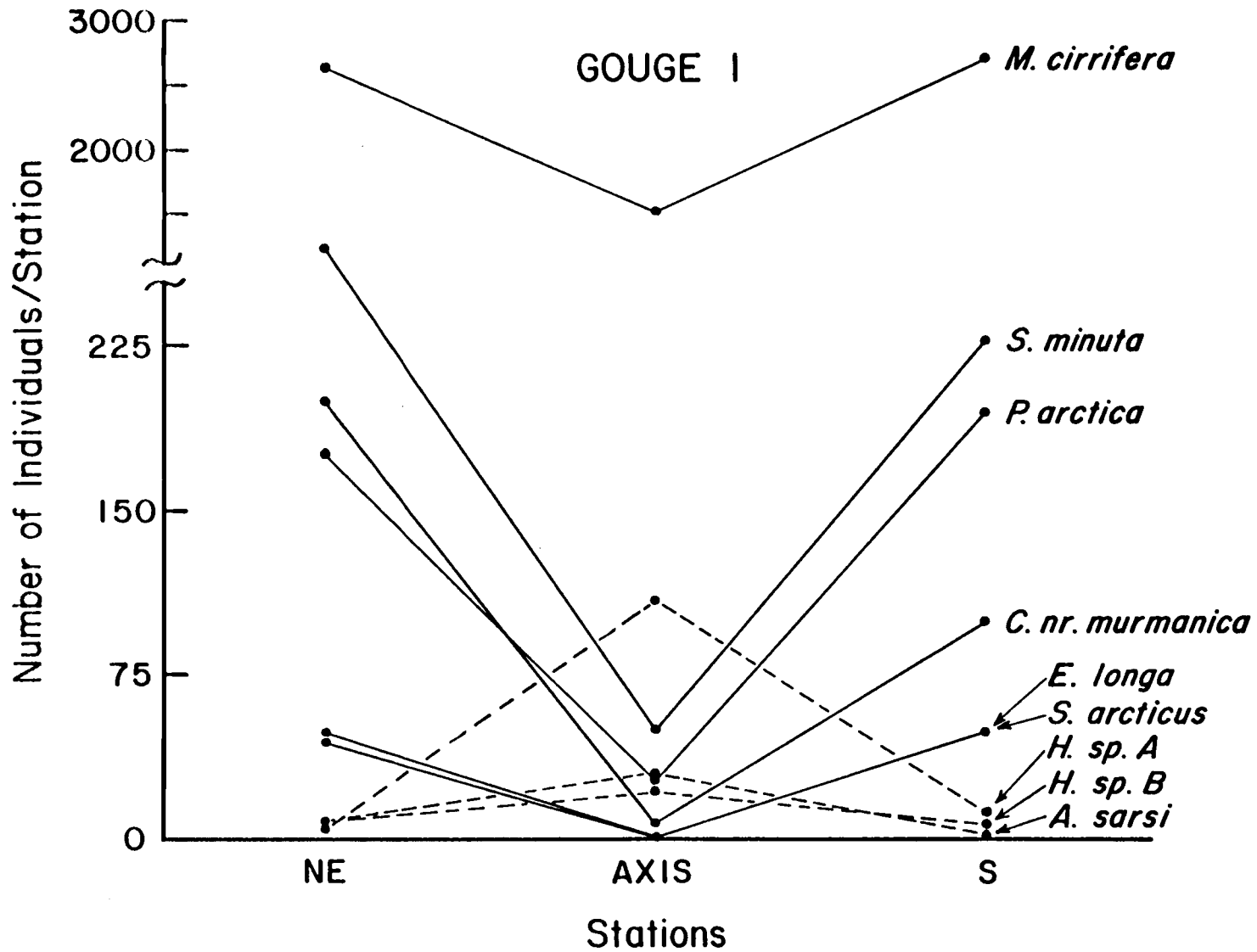


Figure 7.

Figure 8. The total number of individuals of the dominant species from Gouge 2 which showed significantly higher or lower abundances from at least one outside station (see Table 6 for complete species names; station designations are directions relative to the gouge axis).

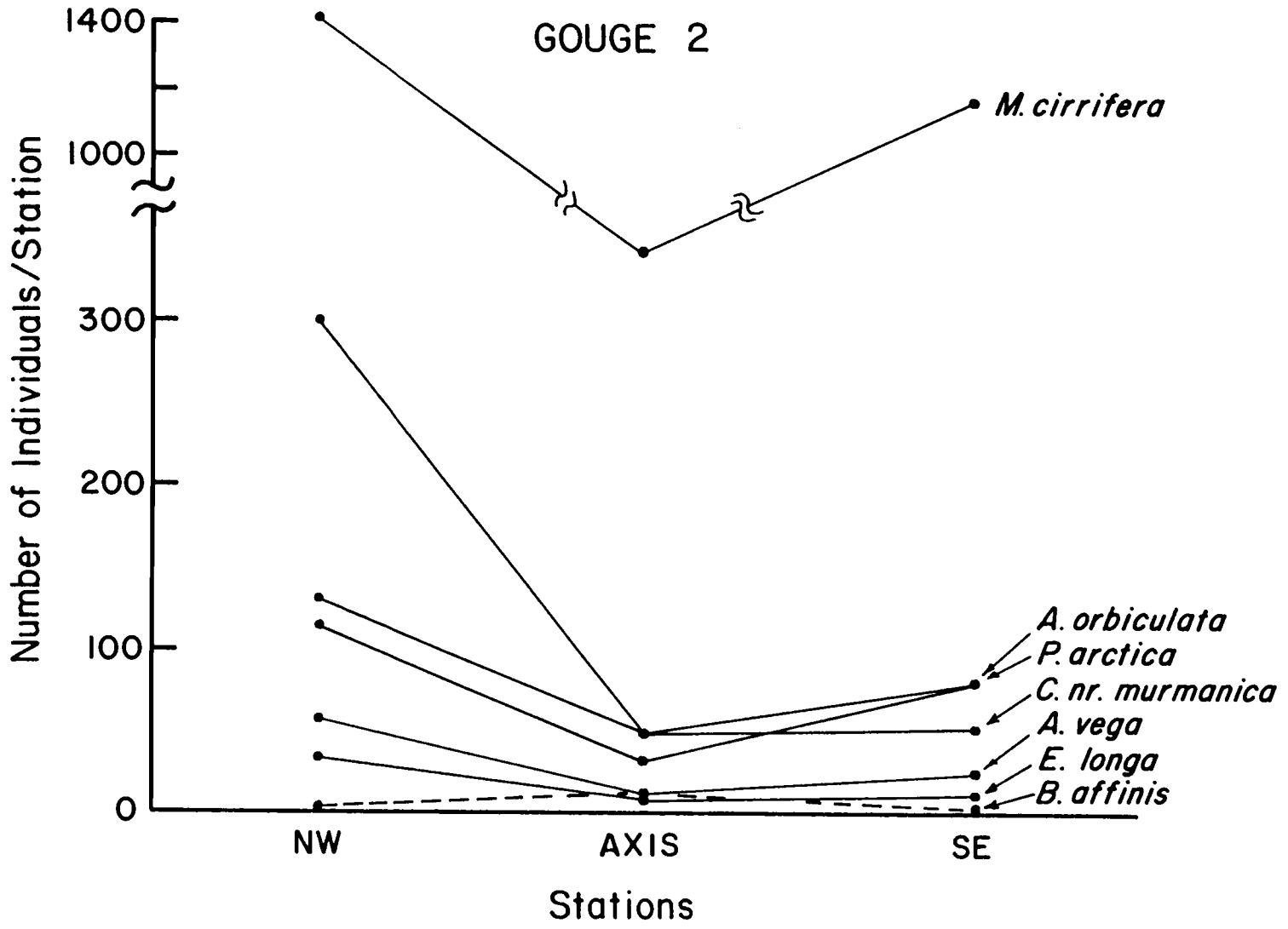


Figure 8.

Figure 9. The total number of individuals of the dominant species from Gouge 3 which showed significantly higher or lower abundances from at least one outside station (see Table 6 for complete species names; station designations are directions relative to the gouge axis).

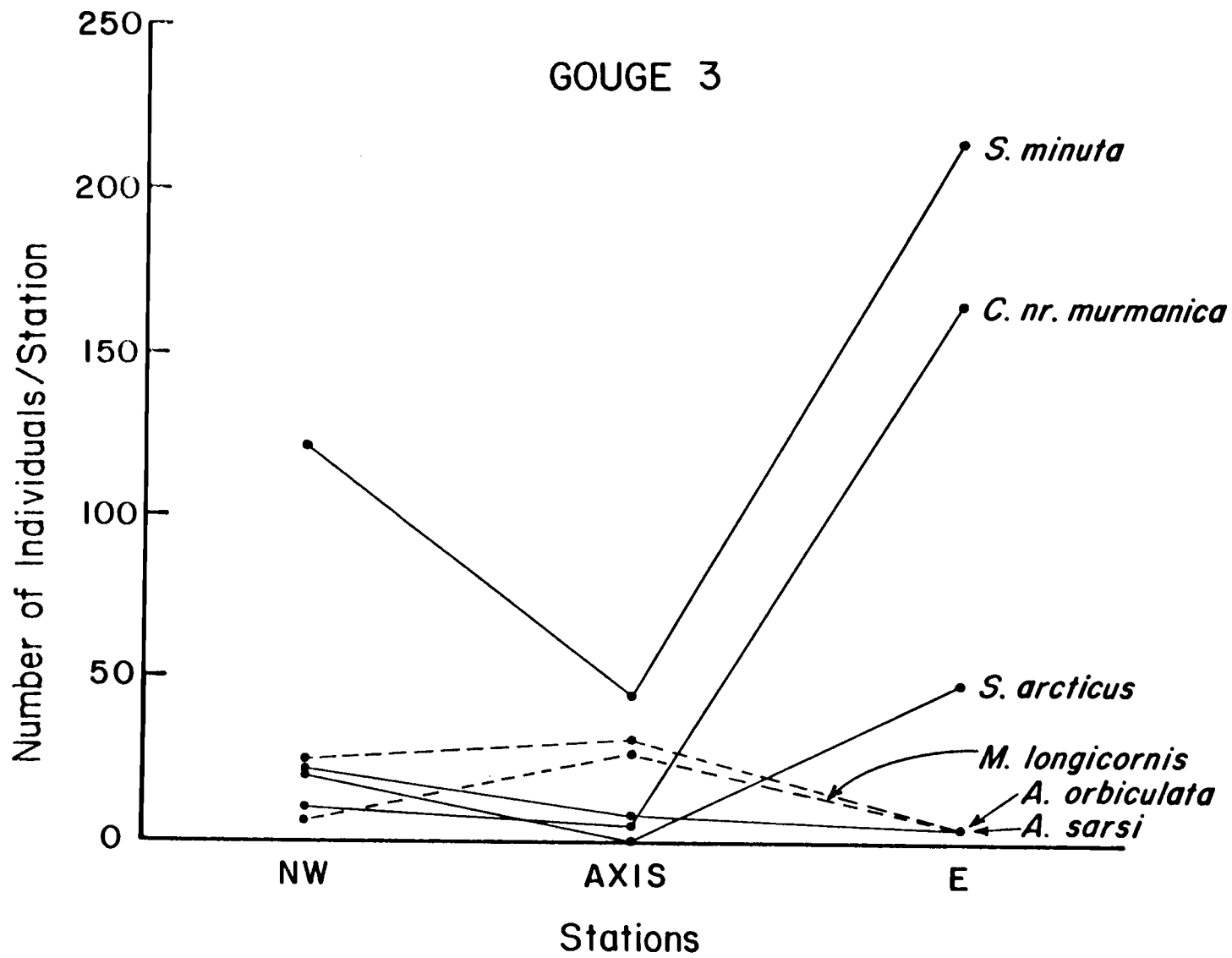
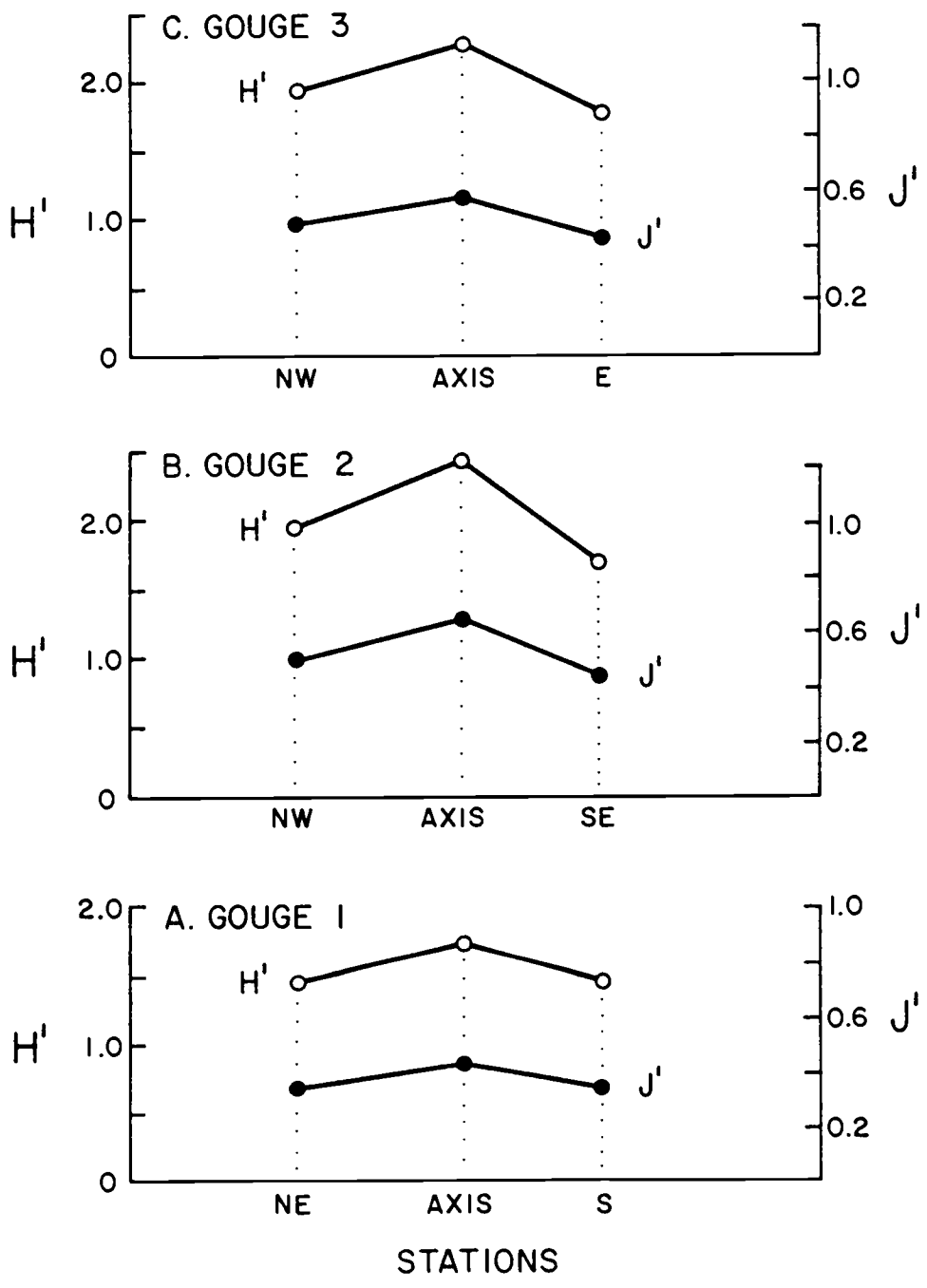


Figure 9.

Figure 10. Diversity (H') and evenness (J') values at each station for all three gouge areas. Both indices are consistently higher at the axis station in the three gouge areas (station designations are directions relative to the gouge axis). Note the change in scale for the two indices.

Figure 10.



each other at all 3 gouge areas. Total numbers of taxa per station (Table 6) were compared and no significant differences (Gouge 1: $\chi^2_2 = 0.50$, Gouge 2: $\chi^2_2 = 0.893$, Gouge 3: $\chi^2_2 = 2.27$; $P > 0.05$) in total number of taxa between stations at any gouge site were found. However, there does seem to be a slight trend towards fewer taxa at the axis stations (Table 6). Since the number of taxa was not different at the axis station, it appears that increased evenness accounted largely for the increase in diversity at all gouge axes. The increase in evenness at the axis stations is shown in Table 6 where a larger number of species represent $\geq 1.0\%$ total abundance/station.

There were ice gouge-related differences in the rank order of the dominant taxa between the inside and outside stations at Gouge 1 (Table 6). The rank order of relative abundance of the dominant species from the two outside stations were highly correlated ($r_s = 0.945$, $P < .001$) indicating very similar rank order. The ranks of the dominant species between the NE outside station and the axis station were not significantly correlated ($r_s = 0.076$). At the Gouge 1 area, there were seven new species which accounted for $\geq 1.0\%$ of the total abundance at the axis station (Table 6). These species represented substitutions and additions to the dominant taxa list as compared to the outside stations at Gouge 1. Only three dominant species from the axis station were also dominant at the outside stations. For example, *Hesionidae* sp A was not among the dominant taxa at the outside stations but ranked second inside the axis. *Monoculodes crassirostris*, *Micronephthyes minuta*, *Antinoella sarsi*,

Hesionidae sp B, Chaetozone gracilis? and Boeckosimus affinis were also higher in relative abundance at the axis station, However, when all the species found at a particular station are considered, the axis species represent rearrangements rather than substitutions (Appendix 2).

The rank order of the dominant taxa was very similar between the two outside stations ($r_s = 0.848$, $P < .001$) and between the axis station and the SE outside station at Gouge area 2. Spearman's Rank Correlation Coefficient showed significant correlation between the axis and the SE stations ($r_s = 0.737$, $P < .005$) indicating that the ranks of the dominant taxa were similar. Table 6 shows that only 3 new species, Monoculopsis longicornis, Boeckosimus affinis and Diastylus sulcata, from the gouge axis were added to the dominant taxa list and these were additions to the bottom of the list, not substitutions.

The rank order of the dominant species at the outside stations were correlated with each other ($r_s = 0.466$, $P < .05$). Spearman's Rank Correlation test was performed between the axis station and the station east of the gouge. This correlation was not significant ($r_s = 0.384$) indicating that the ranks of the dominant species differ at the two stations. In this comparison, between the axis and the East side stations, 9 new species were added to the dominant species list at the axis station and only 3 species were common to both stations (Table 6). It is interesting to note that 4 of the 7 species which were added to the dominant taxa list in the axis of Gouge 1 (C. gracilis, M. crassirostris, A. sarsi and Hesionidae sp A) were also added in

the axis of Gouge 3 when compared to the station east of the gouge. There was only one added species common to gouge axes 1 and 2 (B. affinis) and only 2 added species common to gouge axes 2 and 3 (Table 6). This result correlates well with the conclusion that Gouges 1 and 3 are relatively older than Gouge 2 and may indicate a distinct fauna inside the older gouge axes.

By treating each gouge as a discrete event and by analyzing each gouge individually, I found that there were clear patterns common to all three gouge areas. In general inside the gouge axes, there was: 1) reduced total abundance of most taxa; a few species had higher abundances, 2) increased diversity, 3) increased evenness and 4) Minuspio cirrifera was the dominant species at all locations and its abundance was also decreased inside gouge axes. These patterns indicate that regardless of the relative age of a gouge, there were common characteristics for all gouges.

Relationships Among Stations From All Three Gouge Areas

Cluster analysis was performed to determine if the disturbed sites (ie. the gouge axes) possessed a fauna different from the relatively undisturbed sites (ie. the outside stations). When cluster analysis was performed on the nine different stations (5 pooled replicate grab samples) based on species abundances from all three gouge areas, interpretable results were obtained with 3 clusters. Cluster 1 consisted of the three stations, both outside locations and the axis station, from Gouge area 2. The second cluster was composed of the axis stations from Gouge areas 1 and 3, and the last cluster consisted of the outside stations from Gouge areas 1 and 3. These cluster groups are composed of the same stations as the resulting

groups from the sediment parameter cluster analysis, suggesting a probable correlation between species distributions and sediment parameters. These cluster groups were used as the input groups for the discriminant analysis. The DFA plot showed these groups to be very distinct (Figure 11). These results indicate that in two of the three gouges studied, the community structure at the axis station was different from the outside control stations. The two axes that clustered together were from the relatively older gouges. The younger gouge axis was more similar to its surrounding stations than it was to the other axes. However, by running the cluster program until it forced the clusters apart (i.e. 7 clusters), the axis station from Gouge 2 formed a separate cluster while the Gouge 2 outside stations remained together (Appendix 5).

Based on these cluster groups, I compared the composition of the dominant species ($\geq 1.0\%$ total abundance / station) from each gouge axis (Table 8). I found large differences in the composition of the dominant species between the axes of Gouges 1 and 2, where only 5 out of 18 species were common to both axes (Table 8). Large differences in the composition of the dominant species also existed between Gouge axes 2 and 3. In this case, out of 19 species, only 6 were common to both axes (Table 8). The rank order of the dominant species between Gouge axes 1 and 3 appeared to be more similar with 7 of 15 species in common (Table 8). The patterns of the dominant species in the gouge axes agree well with the patterns observed in the cluster analysis.

Comparisons of the dominant species at the outside stations between gouge areas showed that, in general, the composition of the

Figure 11. Clusters of station locations based on species characteristics generated by a discriminant function analysis. Composition of the groups (1-3) are explained in the text. The stars represent the mean of the group.

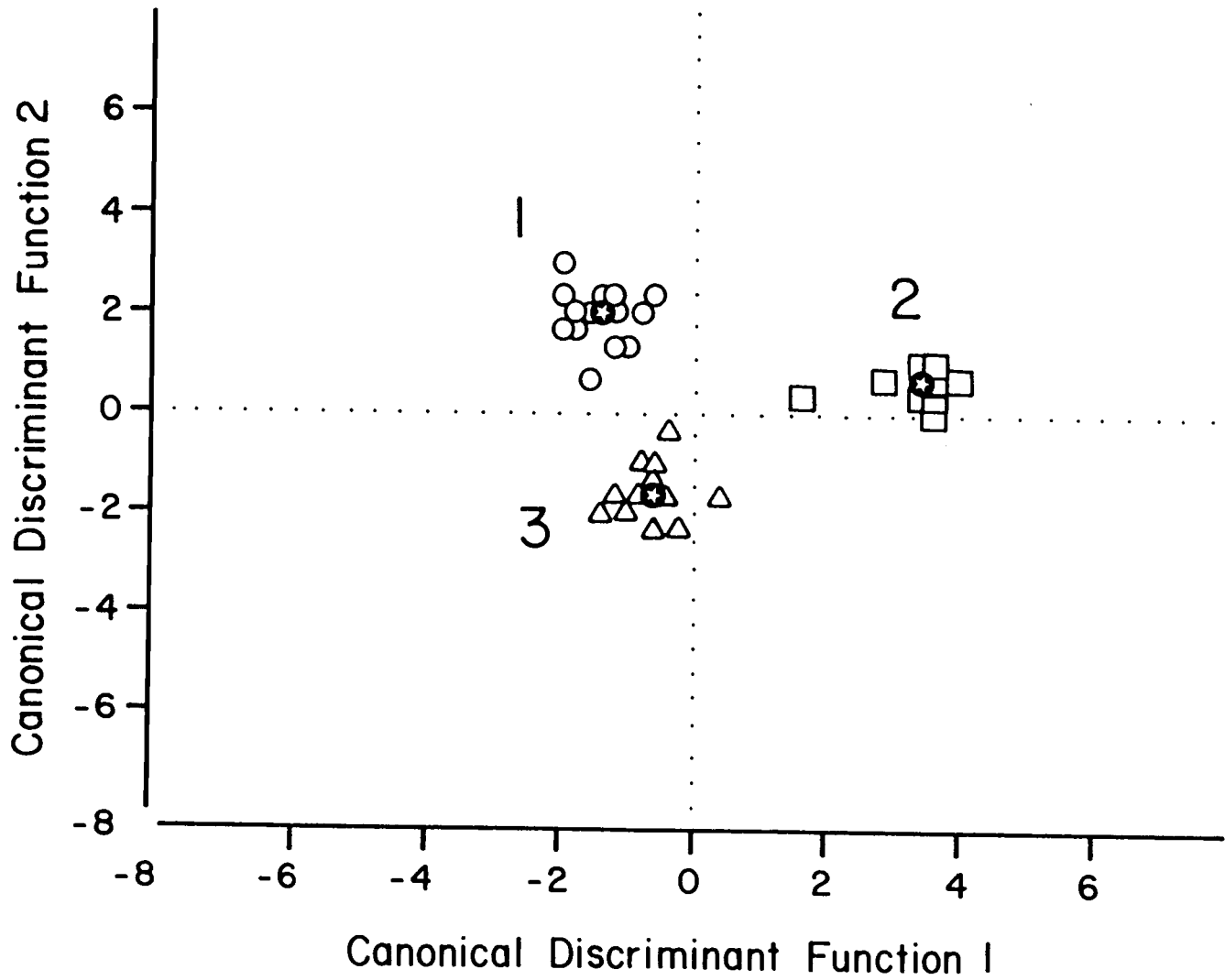


Figure 11.

Table 8. Total number of individuals and percent composition per station of the dominant species ($\geq 1.0\%$ total abundance per station) from Gouge axes 1, 2, and 3 (G1 = Gouge 1, G2 = Gouge 2, G3 = Gouge 3).

	G1		G2		G3	
	#	%	#	%	#	%
<u>Minuspio cirrifera</u>	1514	66.5	340	38.5	765	47.3
<u>Hesionidae sp. A</u>	110	4.8	1	0.1	29	1.8
<u>Sphaerodoropsis minuta</u>	52	2.3	39	4.4	45	2.8
<u>Monoculodes crassirostris</u>	35	1.5	7	0.8	34	2.1
<u>Micronephthys minuta</u>	34	1.5	--	--	11	0.7
<u>Antinoella sarsi</u>	30	1.3	5	0.6	31	1.9
<u>Portlandia arctica</u>	27	1.2	36	4.1	123	7.6
<u>Hesionidae sp. B</u>	25	1.1	--	--	6	0.4
<u>Chaetozone gracilis?</u>	22	1.0	15	1.7	36	2.2
<u>Boeckosimus affinis</u>	22	1.0	13	1.5	--	--
<u>Scolecopides arcticus</u>	0	--	75	8.5	--	--
<u>Chone nr. murmanica</u>	7	0.3	50	5.7	7	0.4
<u>Axinopsida orbiculata</u>	2	0.1	50	5.7	8	0.5
<u>Capitella capitata</u>	20	0.9	13	1.5	16	1.0
<u>Ampharete vega</u>	--	--	12	1.4	--	--
<u>Monoculopsis longicornis</u>	17	0.8	12	1.4	28	1.7
<u>Diastylus sulcata</u>	13	0.6	11	1.2	15	0.9
<u>Eteone longa</u>	1	0.04	10	1.1	1	0.1
<u>Cossura soyeri</u>	1	0.04	--	--	32	2.0
<u>Brada villosa</u>	8	0.4	--	--	25	1.6
<u>Trochochaeta carica</u>	17	0.8	--	--	17	1.1

dominant species was similar among all outside gouge areas (Table 9). Only one station from each gouge area (the same station as was used in the individual gouge analysis) was used in these comparisons. At these stations, 5 out of 11 dominant species were common to all three outside stations. The species composition of the outside stations from Gouges 1 and 3 were very similar with 5 out of 6 dominant species in common (Table 9). The species composition at the Gouge 2 outside station consisted of more dominant species than the other outside stations (Table 9). This difference may help explain the observed patterns from the cluster analysis.

Table 9. Total number of individuals and percent composition per station of the dominant species ($\geq 1.0\%$ total abundance per station) from the relatively ungouged control areas outside the three ice gouged areas (G1NE = northeast station of Gouge 1, G2SE = southeast station of Gouge 2, and G3E = east station of Gouge 3).

	G1NE		G2SE		G3E	
	#	%	#	%	#	%
<u>Minuspio cirrifera</u>	2669	69.9	1431	63.6	1351	60.4
<u>Sphaerodoropsis minuta</u>	270	7.1	77	3.4	215	9.6
<u>Chone nr. murmanica</u>	206	5.4	52	2.3	164	7.3
<u>Portlandia arctica</u>	175	4.6	80	3.6	88	3.9
<u>Eteone longa</u>	48	1.3	11	0.5	13	0.6
<u>Scolecotepides arcticus</u>	45	1.2	30	1.3	49	2.2
<u>Axinopsida orbiculata</u>	10	0.3	80	3.6	4	0.2
<u>Chaetozone gracilis?</u>	31	0.8	37	1.6	16	0.7
<u>Capitella capitata</u>	4	0.1	34	1.5	9	0.4
<u>Monoculodes crassirostris</u>	33	0.9	28	1.2	7	0.3
<u>Ampharete vega</u>	4	0.1	23	1.0	--	--

DISCUSSION

Ice Gouging as a Physical Disturbance

The role of disturbance in structuring natural communities in different habitats has received much attention (see reviews by Sousa, 1984; Thistle, 1981). This study follows the definition of disturbance presented by Sousa (1984): "a disturbance is a discrete, punctuated killing, displacement, or damaging of one or more individuals (or colonies) that directly or indirectly creates an opportunity for new individuals (or colonies) to become established." In this respect, gouging of the sediments by the plowing effects of ice keels qualifies as a physical disturbance. As an ice keel moves through the sediments all infaunal organisms in its path are either killed, damaged or at least displaced, creating open space for establishment of new individuals.

To determine how important a disturbance agent is, several characteristics of the disruptive force need to be described. Sousa (1984) lists 5 major characteristics of disturbance: 1) size of disturbed area, 2) intensity / severity of disturbance, 3) frequency - number / unit time, 4) predictability - return rate of disturbance, and 5) turnover rate - time to disturb the entire area.

Most of these characteristics have been quantified for the ice gouging of sediments along the Alaskan continental shelf. The size of an individual gouging event may vary from 0.5 m to 67 m wide and from 0.2 m to 4 m deep (Barnes et al, 1984). In this study, the three ice gouges were on the order of 3-5 m wide and 0.5-1.0 m deep

(slightly above average dimensions for individual events, Weeks et al, 1983). The intensity / severity of gouging varies with depth and location of barrier islands. Gouging is most intense in the stamukhi zone (15 - 25 m) where the major ice-pressure ridges form and impinge on the bottom sediments. Gouging is least intense on the lee side of barrier islands where few ice ridges form (Reimnitz et al, 1978). The three study gouges were located in slightly shallower water than the intense stamukhi zone. However, Weeks et al, (1983) note that a second ridge system often forms near the 10 m isobath in Harrison Bay indicating that these gouges were in a fairly intensely disturbed area. There are no barrier islands near the three gouge areas in Harrison Bay. Ice gouging is a fairly frequent form of disturbance occurring on average of 5.2 gouges/km/year and ranging from 2.4 to 7.9 gouges/km/year (Weeks et al, 1984). The return rate or predictability has been calculated from the average gouging rate of 5.2 gouges/km/year and gives a return rate of 0.2 years/km (Weeks et al, 1984). Barnes and Reimnitz (1974) estimated that the bottom sediments could be reworked to a depth of 20 cm every 50 years from the movements of ice keels.

The persistence of the disturbance feature is another important characteristic to be considered. On the Alaskan continental shelf the persistence of an ice gouge feature depends on the sedimentation rate and the hydrodynamic regime near the ice gouges. With low and uniform sedimentation, gouges may persist for thousands of years (Weeks et al, 1983). However, considering that the gouges are depressions in the sediment and probably act as sediment traps, the persistence of gouge features is much shorter (Barnes and

Reimnitz, 1979). Reimnitz and Kempema (1983) found that strudel-scour craters along the inner shelf of the Beaufort Sea were completely filled in with sediments in 2-3 years. These strudel-scour craters are formed by different processes but are similar to ice gouges in acting as sediment traps. They are found in shallow water (2-4 m) where the bedload transport of sediment is probably higher than in water depths associated with the three ice gouges in this study. Therefore the infill rates, due to bedload transport, of ice gouges in water depths of 8-13 m are probably lower than the inshore rates. In a temperate study off SE England, the rate of infilling of dredge borrow pits was found to be on the order of 2-4 years depending on the exposure regime (McGrorty and Reading, 1984). When the added effects of storms and currents are considered, the persistence of gouge relief features can be even shorter (Weeks et al, 1983). Barnes and Reimnitz (1979) observed the obliteration of many gouges in water to 13 m deep and the infilling of others in deeper waters due to the effects of large storm waves and associated currents. The three sampled ice gouges may have been influenced by this event.

In general, the three ice gouges sampled are of approximately average size and are located in a fairly intense disturbance area. The exact ages of the gouges are unknown but, as discussed earlier, the relative ages and the persistence of each ice gouge feature may be estimated. With these characteristics of ice gouge disturbance quantified, the relationship of the disturbance to the benthic community can be investigated.

Once a disturbance has created or opened up a resource (in this study, space is opened), how that resource is colonized has been

the subject of many field (see reviews of Connell and Slatyer, 1977; Thistle, 1981; Sousa, 1984) and theoretical (Usher, 1979; Abugov, 1982; Miller, 1982) studies. Several theories of recolonization or species succession have been proposed for soft-substrate marine benthic invertebrates (Johnson, 1973; Grassle and Sanders, 1973) but a rigorous theory of soft bottom succession has not yet been developed (Thistle, 1981).

Most of these theories predict that there will be an initial pulse of opportunistic species into the newly exposed space. These first arrivals display life history and recruitment characteristics which allow them to colonize new areas quickly (e.g. rapid dispersal of larvae, high fecundity, high growth rate, short life cycles). However, they are poor competitors and over time they will be outcompeted. Consequently they will be replaced by other species which are better resource competitors only to be themselves displaced by succeeding colonists as recolonization proceeds (Grassle and Sanders, 1973). A consequence of this theory is that at intermediate stages of succession there will be higher diversity, since some individuals from each stage will be overlapping. The role of resource competition as the controlling factor of recolonization sequences in soft substrates is under debate and other factors may be more important (Thistle, 1981). Other factors which may be important in determining the sequence of succession include: 1) life histories of species present or nearby prior to the disturbance, 2) routes of recolonization (via larval dispersal or adult migration and advection), 3) characteristics of the disturbed patch (ie. size and shape, intensity/severity, location and degree of isolation from

potential colonists, heterogeneity of the internal environment and the time when it was created) (Sousa, 1984).

These theories generally overlook the potential changes in the habitat caused by the disturbance. In fact, none of these theories considers the changes in the habitat by purely abiotic processes (i.e. changes in sediment characteristics over time). Results of VanBlaricom's (1982) study on the recolonization of ray pits indicates that abiotic changes in the disturbed habitat may be very important.

One of the major effects of disturbance is the reduction of the abundance of animals inside the disturbed area. This has been demonstrated in a number of studies including: Gray whale feeding pits (Oliver et al, 1984; Nerini and Oliver, 1983), Walrus feeding pits (Oliver et al, 1983) bottom dredging (Swartz et al, 1980), oil spills (Elmgren et al, 1983) and ray pits (VanBlaricom, 1982). In this study the total abundance of benthic animals was decreased inside the disturbed ice gouge axes of 2 of the 3 gouges. At the major taxa level, all three gouge axes demonstrated reduced total abundances. Polychaetes and bivalves were significantly less abundant at Gouge axes 1 and 2. Similar differences at the major taxa level were found inside walrus feeding furrows (Oliver et al, 1983). Walrus and gray whale feeding furrows are very similar to the disturbance created by ice gouging of the sediments. Both of these activities leave gouges in the bottom sediments and are created by the plowing activities of the animals (Oliver et al, 1983; 1984). These disturbances differ from ice gouging because the predators are selectively preying upon certain species, whereas ice gouging is a nonselective process. However, it is apparent from the reduced numbers of individuals inside

the feeding pits that these predators still act as disturbance agents.

At the species level, the most abundant species at all stations, Minuspio cirrifera, was reduced inside all gouge axes but significantly so only at Gouges 1 and 2. In general, most species showed lower abundances inside gouge axes (Figures 7, 8, and 9). However, inside each gouge axis there were a few species which demonstrated increased abundances. These species may be opportunists or they may be attracted to some enriched resource which collected inside the gouge axes similar to the ray pits of VanBlaricom (1982).

Diversity and evenness indices were consistently increased inside gouge axes at all 3 gouge areas (Figure 10). Interpreted in light of the recolonization theories discussed above, these values indicate that the sampling found these communities in intermediate stages of recolonization. This agrees with the other data presented. Total abundances of only some of the species were reduced inside the gouge axes and a few were increased. The reduction of M. cirrifera inside each gouge axis is reflected in the evenness indices. Since M. cirrifera is the overwhelming dominant at all stations outside the gouges, its reduction may allow other species to increase in relative abundance thus leading to higher evenness values.

The route of recolonization may be an important aspect in successional studies in the Arctic. Species exhibiting life history patterns which involve dispersal of pelagic larvae are generally thought to be the colonizing species in temperate regions (Rhoads et al, 1978; Guillou and Hily, 1983; Grassle and Grassle, 1974; Sousa, 1984). However, in many communities recolonization of disturbed areas is through migration of the adults or young juveniles (Dauer, 1984;

Levin, 1984; VanBlaricom, 1982 but see Santos and Simon, 1980a). In the Arctic, there is less incidence of species with pelagic larvae while most species exhibit some type of nonpelagic or direct development (Thorson, 1936, 1950; Picken, 1980; Clarke, 1979; Mileikovsky, 1971, Chia, 1970). In temperate regions, recolonization via migration has been hypothesized (Miller, 1982; Sousa, 1984) and demonstrated for small-scale disturbances (VanBlaricom, 1982). In the Arctic with the low incidence of pelagic larvae, even the relatively large scale disturbances (e.g. ice gouging) may be recolonized by migration or advection of adults and juveniles rather than by pelagic recruits.

In this study, the life histories of the common Arctic species have not been studied. Therefore, it is difficult to classify the dispersal abilities of these species since many polychaete species are able to vary their mode of reproduction in response to various environmental conditions (Mileikovsky, 1971). However, by classifying the polychaetes into the feeding / motility guilds of Fauchald and Jumars (1979), I found that 84% of the polychaete families found in this study were motile or discretely motile (Appendix 6). This rough classification in no way identifies migration as the dominant route of recolonization but it does lend support to the hypothesis. Life history studies on the dominant species are needed to confirm or disprove this hypothesis.

These data indicate that ice gouging of the sediments are an important physical disturbance of the inner continental shelf of the Beaufort Sea. Consistent differences were found between the stations outside each gouge and inside the disturbed area at each gouge

location. These differences were not dependent on the depth, the associated sediment parameters or the age of a disturbance event. Decreased abundances of the total fauna, the major taxa for Gouges 2 and 3 and certain dominant species inside the gouge locations, as well as the increases in diversity and evenness of the fauna inside disturbed areas, demonstrate that ice gouging is an important structuring force in this environment.

General Patterns of the Benthos along the Alaskan Coast

The results of comparisons among gouged and ungouged stations from the three ice gouge areas indicate that, at least for discrete gouging events in the Harrison Bay area, the ice gouging process is important. The generality of these processes may be explored through comparisons with other more general survey studies along the Arctic shelf. The studies of Carey (1978) and Wacasey (1974) along the Beaufort Sea coast, as well as the studies of Stoker (1981) and Haflinger (1981) in the Bering/Chukchi Seas and Ellis (1960) in the eastern Canadian Arctic provide comparable data.

The mean number of benthic individuals from each gouge area in the present study varied (Table 3 and Table 10) but are similar to the estimates of mean abundances of previous studies along the Arctic coast (all comparisons are adjusted for the sieve size used and the depth sampled). Wacasey (1974) sampled near the mouth of the Mackenzie River and found a mean density of 4661.5 ± 1084 ind/sq m. The data in Table 3 show the similarity between the two studies. However, he found fewer species at his stations ($\bar{x} = 24$) than I did (66 - 96). Wacasey (1974) attributed the low number of species to the

Table 10. Means, standard deviations and ranges of the total number of individuals, by major taxa, greater than 1.0 mm per 1.0 sq. meter from the three gouge areas (3 stations combined - 15 grab samples per area), from the two stations outside the gouge axis, and from the gouge axis.

	Gouge Area	Outside Stations	Axis Station
<u>GOUGE 1</u>			
Polychaeta	1932.0 \pm 1194	2531.0 \pm 751.8	734.0 \pm 1014
Pelecypoda	293.3 \pm 225	409.0 \pm 182.8	62.0 \pm 44.4
Amphipoda	58.0 \pm 77.3	34.0 \pm 46.0	106.0 \pm 108.8
Totals	2336.7 \pm 1279	3012.0 \pm 662.5	986.0 \pm 1149
<u>GOUGE 2</u>			
Polychaeta	979.3 \pm 478.2	1233.0 \pm 361.9	472.0 \pm 153
Pelecypoda	356.7 \pm 179.1	443.0 \pm 130.6	184.0 \pm 134.2
Amphipoda	20.7 \pm 13.4	16.0 \pm 11.7	30.0 \pm 12.2
Totals	1392.0 \pm 592	1721.0 \pm 378.8	734.0 \pm 277
<u>GOUGE 3</u>			
Polychaeta	1038.7 \pm 596.3	1037.0 \pm 319.7	1042.0 \pm 1007
Pelecypoda	286.0 \pm 132.5	293.0 \pm 116.4	272.0 \pm 174.8
Amphipoda	12.7 \pm 11.6	18.0 \pm 10.3	2.0 \pm 4.5
Totals	1451.3 \pm 678	1411.0 \pm 318.9	1532.0 \pm 1170

influence of the freshwater from the Mackenzie River. My study site is located near the Colville River, one of the major rivers on the Alaskan coast, but apparently is not comparably influenced by the freshwater river input. Investigations in the eastern Canadian Arctic reported mean numerical densities ranging from 209 ind/sq m to 1815 ind/sq m (Ellis, 1960). These estimates agree quite closely with results obtained in this study (Table 10). Estimates of the mean numerical abundances in the Bering/Chukchi Seas (Stoker, 1981) appear to be higher (4605 ind/sq m) than those in this study (Table 10). A potential explanation of this difference is the relatively higher primary production in the Bering/Chukchi Seas than in the Beaufort Sea (Clasby, Alexander and Horner, 1976).

The most comparable study is that of Carey (1978). Carey's study compared the abundances and species composition of benthic invertebrates from five different shallow transects (5-25 m) along the Alaskan coast from Point Barrow to Barter Island (Figure 1, inset). He found an average density of 3703.6 ± 2350.7 ind/sq m, which is slightly higher than in my study but my data are within the variability of his samples. He attributed the high degree of variability to the intensity of ice gouging of the sediments along the coast (Barnes and Reimnitz, 1974). The data from this study add support to his contention. When the axis stations are removed from the analysis and just the outside stations considered, the within station variability is lower at all three gouge areas (Table 10). Comparisons at the major taxa level among the 10 m stations from Carey's (1978) data (which are comparable to depths in this study) and the three gouge areas reveals that the mean abundances of the major taxa from this

study are lower than two of three of Carey's (1978) stations. The polychaete numbers in particular appear to be much lower (Tables 10 and 11). When just the axis stations and Carey's (1978) 15 m stations are compared, the abundances at two of the three stations (Point Barrow and Pingok Island, Table 11) appear to be fairly similar to the three axis stations (Table 10). The 15 m stations are associated with the intensely gouged stamukhi zone (Reimnitz et al, 1978). Comparisons at the species level were made using the five most dominant polychaete species from each transect station (Carey, 1978) and each gouge area, as well as from the gouge axis stations (Table 12). The similarity between the transect stations and the gouge areas varied with the location of the transect. For example, the Pingok Island transect station was the most similar in dominant polychaete species composition to the three gouge areas and to the three gouge axes (Table 12). This is the closest transect to my study area so this similarity is not unexpected. The two transects which were the most distant were also the least similar (Table 12). The 15 and 20 m stations from all transects, which are considered to be part of the stamukhi zone, had at least as many and usually more dominant polychaete species in common with the gouge axis stations as with the overall gouge areas (Table 12). Support for the generality of the importance of ice gouging along the entire Alaskan coast is found in these comparisons. The lower mean abundances, the reduced variability when the axis stations are removed, and the increased similarity between the gouge axes and the deeper transect stations all support this contention.

Table 11. Means and standard deviations of the total number of individuals, by major taxa, from Carey's (1978) five cross-shelf transect stations (5 grabs per station). Two different depth stations are shown (BRB = Point Barrow, PIB = Pingok Island, BAB = Barter Island, PPB = Pitt Point, NIB = Narwal Island transects). * = no major taxa data available.

Transect (10 m)		Transect (15 m)	
<u>BRB 10</u>			
Polychaeta	3238 \pm 2790.1	454 \pm	844.7
Pelecypoda	410 \pm 282.4	54 \pm	34.4
Amphipoda	164 \pm 70.9	200 \pm	118.5
Totals	4444 \pm 2947.4	782 \pm	899.0
<u>PIB 10</u>		<u>PIB 15</u>	
Polychaeta	6120 \pm 1705.3	804 \pm	196.9
Pelecypoda	840 \pm 301.2	440 \pm	149.0
Amphipoda	52 \pm 89.0	112 \pm	49.7
Totals	7384 \pm 1796.3	1904 \pm	456.9
<u>BAB 10</u>		<u>BAB 15</u>	
Polychaeta	1102 \pm 641.7	1958 \pm	758.0
Pelecypoda	196 \pm 144.3	788 \pm	332.6
Amphipoda	34 \pm 18.2	428 \pm	400.8
Totals	1540 \pm 640.0	4442 \pm	1512.4
<u>PPB 10*</u>			
Totals	1950 \pm ?	1300 \pm	?
<u>NIB 10*</u>			
Totals	3200 \pm ?	1600 \pm	?

Table 12. Summary of the dominant polychaete species (5 most abundant species) comparisons between Carey's (1978) transect stations, the three gouge areas and the gouge axes (BRB = Point Barrow, PPB = Pitt Point, PIB = Pingok Island, NIB = Narwal Island, BAB = Barter Island transects; G1 = Gouge 1, G2 = Gouge 2, G3 = Gouge 3, A = gouge axis). The numbers in the table represent the number of species in common.

Transect (m)	Gouge Area	Gouge Axes
BRB 10	1 species - G1, G2, G3	0 species
BRB 15	1 species - G3	2 species - G1A 1 species - G3A
BRB 20	1 species - G3	2 species - G1A 1 species - G3A
PPB 10	3 species - G1, G3 2 species - G2	1 species - G1A 3 species - G2A 2 species - G3A
PPB 15	1 species - G1, G2, G3	2 species - G1A 1 species - G2A, G3A
PPB 20	1 species - G1, G2, G3	1 species - G1A, G2A, G3A
PIB 10	3 species - G1, G2, G3	3 species - G1A, G2A 2 species - G3A
PIB 15	1 species - G1, G2, G3	2 species - G2A 1 species - G1A, G3A
NIB 10	2 species - G2 1 species - G1, G3	1 species - G1A, G2A, G3A
NIB 15	2 species - G2 1 species - G1, G3	2 species - G1A, G2A 1 species - G3A
BAB 10	2 species - G2 1 species - G1, G3	2 species - G2A 1 species - G1A, G3A
BAB 15	1 species - G1, G2, G3	2 species - G1A, G2A 1 species - G3A
BAB 20	0 species	1 species - G1A, G2A

Relationships Among Gouges - Potential Causes for Observed Patterns

Relationships between individual ice gouging events were investigated to determine if similar benthic invertebrate assemblages existed among the disturbed gouge axes and among the outside stations at each gouge area. Species cluster analysis was performed to examine the existence of any consistent patterns. I found that three clusters of station locations, defined by similarities of species densities and composition between locations, provided meaningful information. The cluster analysis identified the gouge axes from two of the gouges, 1 and 3 (group 2) as being more similar to each other than to any other stations (Figure 11). The four outside stations from these gouges were also most similar to each other (group 3). These two groups reinforce the hypothesis that distinct benthic assemblages form in disturbed gouge axes. The third cluster (group 1) was composed of all stations from Gouge area 2. At this gouge the axis was more similar to the surrounding outside stations than to the other gouge axes. This same pattern, among the three gouge axes was observed by comparison of the rank order of relative abundance of the dominant species (Table 8).

Interpretation of clustering techniques relies on use of external information, for example environmental variables, which determine the ecologic significance of cluster groups. In this study environmental variables which were measured include the sediment parameters, depth of each station, bottom salinity and temperature, and the relative age and location of the gouging disturbance.

Correlation of the species cluster groups with the sediment parameter cluster groups from the two gouge areas, where sediment data

is available, reveals a one to one correspondence of each cluster group (Figures 4 and 11). All sediment samples from Gouge 2 clustered together indicating a fairly uniform substrate between the disturbed axis and outside stations. The species appear to respond to this consistent substrate and exhibited no real compositional differences inside or outside the gouge axis (Table 6). This was demonstrated by the significant correlations found between the ranks of the relative abundances of the dominant species at Gouge 2. The other two sediment clusters separated the axis from the outside stations at Gouge 1, based mainly on the higher silt/clay content inside the axis (Table 2). Gouge 1 and Gouge 3 species clusters follow these patterns which is interesting since there was no sediment data for Gouge 3. The combination of Gouges 1 and 3 species clusters which conform to the sediment groups generated only by Gouge 1 sediment data, suggests a strong correlation of species associations with sediment parameters. Diver observations of Gouge 3 suggested that this axis was filled in with silty sediments much like that of Gouge 1. Thus, it is not surprising that the species patterns from Gouge 3 correspond to those of Gouge 1 if, as seems to be the case, sediment parameters are a major factor in determining the observed patterns of benthic assemblages. Many other studies have shown the importance of sediment type in determining benthic community distributions (Fresi et al, 1983; Whitlatch, 1981; Pearson, 1970; Cassie and Michael, 1968; Gray, 1974).

The role of the ages of the gouges must be considered when discussing causes for observed patterns. The cluster groups agree quite well with what might be expected when relative ages and

recolonization stages are considered. Ice gouging creates a disturbance in the benthic communities. If the route of recolonization is dominated by local adult migration or advection, I hypothesize that the benthic assemblage of the youngest gouge should be more similar to its surrounding outside stations than to the other gouge axes. This appears to be true. If, however, immigration of components of the local fauna was the primary mode of faunal recolonization of gouged sediments, then the species composition of older gouges, which have had more time to accumulate a greater fraction of the local species pool, should have been more similar to their surrounding outside stations than the youngest gouge. This was not the case for the two older gouges in this study. Neither Gouge axis 1 or 3 was significantly correlated with its outside stations. This indicates that other factors, such as the sediment characteristics, may be more important than local adult migration or advection in determining benthic assemblages in this environment. Older gouges in later stages of recolonization should show similar patterns to each other. This appears to be the case in my data. Examination of the species composition of Gouge axes 1 and 3 revealed that four species (C. gracilis?, M. crassirostris, A. sarsi and Hesionidae sp A) were shared which were not among the dominant species at, at least one station outside the gouge axes (Table 6). Only 1 added species was common to Gouge axes 1 and 2, while 2 added species were common between Gouge axes 2 and 3 (Table 6). Thus, the age of a gouge may strongly influence benthic community structure. Unfortunately, my data did not allow an adequate test of this factor.

The depth of water in which the gouges are located is another

factor which may add to the explanation of the observed cluster patterns (both the species and sediment clusters). The youngest gouge (Gouge 2) was in the shallowest water (8.5 m). The other two gouges are in deeper but similar water depths (12 and 13 m). Again, this matches the observed patterns of both the species and sediment clusters. Depth influences many of the physical processes thus far discussed, hence it is not surprising that both species and sediment patterns correlate. Depth gradients have been shown to be important in other regions (McLachlan et al, 1984; Persson, 1983).

Hydrodynamic processes vary with water depth, bottom topography, and wave and current intensity (Nowell and Jumars, 1984). Flow effects may also influence bottom topography (Barnes and Reimnitz, 1979; Reimnitz and Kempema, 1983), sedimentary parameters (Nowell and Jumars, 1984) and benthic animals (Eckman, 1983; 1979; Hannan, 1984; Jumars and Nowell, 1984). Differing wave intensities affect the magnitudes of hydrodynamic processes on or near the bottom both temporally and spatially. Studies have shown that unusually large waves caused by storms can disturb the associated benthic communities by scouring and reworking the bottom sediments (Oliver et al, 1980; Yeo and Risk, 1979). Decreasing wave intensities associated with depth gradients have also been shown to influence benthic animal distribution (Hogue, 1982).

In my study area, large waves usually do not occur due to the dampening effect of the ice. However, in open water years when ice is absent large waves associated with long fetches and large storms can develop (Norton and Weller, 1984; Barnes and Reimnitz, 1979). In the summer of 1977 a large storm event similar to those just described,

occurred. Barnes and Reimnitz (1979), monitoring ice gouges in the study area, attributed the major reworking and infilling of gouges to the storm event and associated wind generated shelf currents. This event correlates well with the relative ages of the studied ice gouges. Both Gouges 1 and 3 were described by divers to be filled with silts, while Gouge 2 was not (Table 2). Thus, Gouge 2 was likely to have been formed after the gouge infilling event of 1977 while the other two gouges were probably formed before it. This suggests ages of a maximum of 2 years for Gouge 2 and > 3 years for the other two. Therefore, the rates of benthic community recovery from ice gouging are presumed to be slow, taking longer than 3 years. The sediment redistribution and gouge infilling event demonstrates how important hydrodynamic processes can be in controlling the distributions of benthic communities.

Observed patterns at this study site may be explained by the interaction of many environmental variables. The initial disturbances were created by the physical gouging of the bottom sediments. The hydrodynamic effects associated with varying bottom topography, depth, and wave and current intensities influences the rate at which gouges are infilled with sediment. The sediment parameters associated with the stations outside and in the gouge axes are largely controlled by the flow effects. The effects of biotic interactions, though not specifically addressed in this study, appear to be relatively unimportant due to the predominance of physical factors. It appears that the benthic species are responding to the sediment parameters within ice gouge axes which are controlled by all the other factors.

In general, ice gouging of the sediments by keels of ice

pressure-ridges on the inner continental shelf of the Beaufort Sea is an important structuring force in benthic communities. Ice gouging exerts direct effects on benthic communities by the reduction of individuals in the path of ice keels, and indirectly by affecting the local sediment characteristics which in turn influences the recolonization process.

CONCLUSIONS

1) The structure of the benthic communities studied in this arctic environment were comparable to other communities along the Alaskan coast in terms of numerical abundances.

2) Ice gouging was demonstrated to be an important physical disturbance of the sediments and associated benthic assemblages at three discrete gouged sites along the inner continental shelf of the Beaufort Sea. Consistently reduced abundances of the total fauna, the major taxa and certain dominant species, as well as increase diversity and evenness of the fauna inside the disturbed gouge axes, indicates that ice gouging is an important structuring force in this environment. These differences were not dependant on differences in gouge depth, age or associated sediment parameters.

3) Comparisons of the three discrete gouging events with other studies along the inner continental shelf lend support to the generality of the importance of ice gouging along the entire Alaskan coast.

4) Three discrete ice gouging events were treated as replicates to determine if the disturbed axes represented characteristic gouge assemblages. Results of the species cluster analysis revealed that 2 of the 3 gouge axes clustered together

suggesting distinct assemblages. However, the species clusters were better explained by correlation with sediment parameters. Other factors such as water depth and relative gouge ages also correlate quite well with the clusters. Therefore, one factor alone was unable to account for the observed patterns. Interactions of the many physical factors in this environment are proposed to explain the observed distributions. Ice gouging of the sediments initiates a disturbance by creating a depression in the sediment and disrupting the benthic community. Hydrodynamic processes associated with varying bottom topography, depth, wave and current intensities, controls the rate of gouge infill by sediments. The characteristics of sediments are influenced by the flow effects. Benthic communities in this environment respond to these sediment parameters. In this way, ice gouging exerts both direct and indirect effects on benthic community structure.

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APPENDICES

Appendix 1. Latitude and longitude of the three gouge locations
(approximate).

Gouge 1

70° 37.1591' latitude
150° 27.3328' longitude

13,190 miles northwest of Thetis Island

Gouge 2

70° 34.5639' latitude
150° 15.1414' longitude

4340 miles northwest of Thetis Island

Gouge 3

70° 36.5569' latitude
150° 24.6528' longitude

11,390 miles northwest of Thetis Island

Appendix 2. List of taxa, major taxa designation and percent composition at each station from the three gouge areas (G1=Gouge 1, G2=Gouge 2, G3=Gouge 3; station designations are A=axis, NW=northwest, NE=northeast, E=east, SE=southeast, S=south). P=polychaete, B=pelecypod, A=amphipod, C=cumacea, I=isopods.

<u>G1NE</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	69.9
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	7.1
<u>Chone nr. murmanica</u> Lukasch, 1910	P	5.4
<u>Portlandia arctica</u> (Gray, 1824)	B	4.6
Sipunculida		1.3
<u>Eteone longa</u> (Frabicius, 1780)	P	1.3
<u>Scolecopides arcticus</u> Chamberlin, 1920 (<u>viridis</u>)	P	1.2
Tanaidacea		0.9
<u>Monoculodes crassirostris</u>	A	0.9
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	0.8
Priapulida		0.7
Cirratulidae ant frag	P	0.5
Mollusc juveniles	B	0.4
<u>Haploops tubicola</u> Liljeborg, 1855	A	0.4
<u>Diastylus sulcata</u> Calman, 1912	C	0.3
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	0.3
<u>Marenzelleria wireni</u> Augener, 1913	P	0.3
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	0.2
<u>Hesionidae</u> sp. B	P	0.2
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	0.2
<u>Anaitides groenlandica</u> (Orsted, 1843)	P	0.2
<u>Ampharete acutifrons</u> (Grube, 1860)	P	0.2
<u>Schistomeringos ceacus</u> (Webster and Benedict, 1884)	P	0.2
<u>Chaetozone setosa</u> (Malmgren, 1867)	P	0.2
<u>Micronephthys minuta</u> (Theel, 1879)	P	0.1
<u>Hesionidae</u> sp. A	P	0.1
<u>Capitella capitata</u> (Frabicius, 1780)	P	0.1
<u>Sphaerodoropsis</u> sp. D	P	0.1
Oligochaeta		0.1
<u>Macoma moesta</u> (Deshayes, 1854)	B	0.1
<u>Sternaspis scutata</u> (Ranzani, 1817)	P	0.1
<u>Ophryotrocha</u> spp.	P	0.1
<u>Astarte montagui</u> (Dillwyn, 1817)	B	0.1
<u>A.aricidea minuta</u>	P	0.1
<u>Parheteromastus</u> sp. A	P	0.1
<u>Diastylus rathkei</u> (Kroyer, 1841)	C	0.1
<u>Ampharete vega</u> (Wiren, 1883)	P	0.1

Appendix 2 (cont.)

<u>G1NE</u>	<u>Taxa</u>	<u>%</u>
<u>Leitoscolopos acutus</u> (Verrill, 1873)	P	0.07
<u>Corophoroidea</u>	A	0.07
<u>Boeckosimus affinis</u> Hansen, 1886	A	0.05
<u>Spio theeli</u> (Soderstrom, 1920)	P	0.05
<u>Nephtys ciliata</u> (Muller, 1789)	P	0.05
<u>Mysidacea</u>		0.05
<u>Phloe minuta</u> (Fabricius, 1780)	P	0.05
<u>Gastropoda</u>		0.05
<u>Cossura soyeri</u> Laubier, 1964	P	0.05
<u>Levensenia gracilis</u> (Tauber, 1879)	P	0.05
<u>Mystides borealis</u> Theel, 1879	P	0.05
<u>Nemertea</u>		0.05
<u>Tryphosa schneideri</u> (Stephensen, 1921)	A	0.03
<u>Leucon</u> spp.	C	0.03
<u>Nephtys longosetosa</u> Oersted, 1843	P	0.03
<u>Onisimus</u> spp.	A	0.03
<u>A.allia quadrilobata</u> (Webster and Benedict, 1887)	P	0.03
<u>Apistobranthus tullbergi</u> (Theel, 1879)	P	0.03
<u>Paramphitrite tetrabranchiata</u> Holthe, 1976	P	0.03
<u>Terebellides stroemi</u> Sars, 1835	P	0.03
<u>Ampelisca macrocephala</u> Liljeborg, 1852	A	0.03
<u>Corophium</u> spp.	A	0.03
<u>Ampharetidae</u> n. gen.	P	0.03
<u>Bathymedon</u> spp.	A	0.03
<u>Acanthostephia behringiensis</u> (Lockington, 1877)	A	0.03
<u>Polydora socialis</u> (Schmarda, 1861)	P	0.03
<u>A.allia nolani</u> (Webster and Benedict, 1887)	P	0.03
<u>Scolopos armiger</u> (Muller, 1776)	P	0.03
<u>Terebellidae</u> sp. A	P	0.03
<u>Ophelina cylindricaudatus</u> (Hansen, 1878)	P	0.03
<u>Mollusca</u>		0.03
<u>Chordata - Lipparididae</u>		0.03

Appendix 2 cont.

<u>GIA</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	66.5
<u>Hesionidae</u> sp. A	P	4.8
Priapulida		3.4
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	2.3
Sipundulida		2.3
<u>Micronephthys minuta</u> (Theel, 1879)	P	1.5
<u>Monoculodes crassirostris</u>	A	1.5
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	1.3
Cirratulidae ant frag	P	1.3
<u>Portlandia arctica</u> (Gray, 1824)	B	1.2
<u>Hesionidae</u> sp. B	P	1.1
<u>Boeckosimus affinis</u> Hansen, 1886	A	1.0
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	1.0
Gastropoda		1.0
<u>Capitella capitata</u> (Fabricius, 1780)	P	0.9
<u>Tryphosa schneideri</u> (Stephensen, 1921)	A	0.8
<u>Trochochaeta carica</u> (Birula, 1897)	P	0.8
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	0.8
<u>Diastylus sulcata</u> Calman, 1912	C	0.6
<u>Pholoe minuta</u> (Fabricius, 1780)	P	0.5
<u>Brada villosa</u> (Rathke, 1843)	P	0.4
Tanaidacea		0.4
<u>Onisimus glacialis</u> (Sars, 1900)	A	0.4
<u>Onisimus</u> spp.	A	0.4
<u>Ophryotrocha</u> spp.	P	0.4
<u>Chone</u> nr. <u>murmanica</u> Lukasch, 1910	P	0.3
<u>Nephtys longosetosa</u> Oersted, 1843	P	0.3
Oligochaeta		0.3
<u>Pontoporeia femorata</u> Kroyer, 1842	A	0.2
<u>Leucon</u> spp.	C	0.2
Lysianassidae	A	0.2
Mollusc juveniles	B	0.2
<u>Leitoscoloplos acutus</u> (Verrill, 1873)	P	0.1
<u>Spio theeli</u> (Soderstrom, 1920)	P	0.1
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	0.1
<u>Saduria sabini</u>	I	0.1
Mysidacea		0.1
<u>Anaitides groenlandica</u> (Oersted, 1843)	P	0.1
<u>Sternaspis scutata</u> (Ranzani, 1817)	P	0.1
Arthropoda-mites		0.1
Nemertea		0.1
<u>Melita formosa</u> Murdoch, 1866	A	0.04
<u>Sphaerodoropsis</u> sp. D	P	0.04
<u>Saduria entomon</u>	I	0.04
<u>Macoma moesta</u> (Deshayes, 1859)	B	0.04
<u>Saduria siberica</u>	I	0.04

Appendix 2 (cont.)

<u>GIA</u>	<u>Taxa</u>	<u>%</u>
Oedicerotidae	A	0.04
<u>Apherusa</u> spp.	A	0.04
<u>Ampharete acutifrons</u> (Grube, 1860)	P	0.04
<u>Cossura soyeri</u> Laubier, 1964	P	0.04
<u>Heteromastus filiformis</u> (Claparede, 1864)	P	0.04
Polynoidae	P	0.04
<u>A.allia quadrilobata</u> (Webster and Benedict, 1887)	P	0.04
<u>Levensenia gracilis</u> (Tauber, 1879)	P	0.04
<u>Eteone longa</u> (Fabricius, 1780)	P	0.04
<u>Sphaerosyllis eriaceus</u> (Claparede, 1863)	P	0.04
<u>Schistomeringos ceacus</u> (Webster and Benedict, 1884)	P	0.04
<u>Astarte montagui</u> (Dillwyn, 1817)	B	0.04
<u>Brachydiastylus resima</u> (Kroyer, 1846)	C	0.04
<u>Pontoporeia affinis</u> (Lindstrom, 1855)	A	0.04
Corophoroidea	A	0.04
Unidentified		0.2

Appendix 2 cont.

<u>GIS</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	70.9
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	6.0
<u>Portlandia arctica</u> (Gray, 1824)	P	5.1
<u>Chone nr. murmanica</u> Lukasch, 1910	P	2.6
Tanaidacea		2.2
Priapulida		1.4
<u>Eteone longa</u> (Fabricius, 1780)	P	1.3
<u>Scolecopides arcticus</u> Chamberlin, 1920 (viridis)	P	1.3
Sipunculida		0.8
<u>Monoculodes crassirostris</u>	A	0.8
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	0.6
<u>Ampharete acutifrons</u> (Grube, 1860)	P	0.5
<u>Marenzelleria wireni</u> Augener, 1913	P	0.5
<u>Trochochaeta carica</u> (Birula, 1897)	P	0.4
<u>Diastylus sulcata</u> Calman, 1912	C	0.4
<u>Corophium</u> spp.	A	0.4
<u>Hesionidae</u> sp. A	P	0.3
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	0.3
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	0.3
<u>Capitella capitata</u> (Fabricius, 1780)	P	0.2
<u>Hesionidae</u> sp. B	P	0.2
<u>Macoma moesta</u> (Deshayes, 1854)	B	0.2
<u>Leitoscoloplos acutus</u> (Verrill, 1873)	P	0.2
<u>Ampharete vega</u> (Wiren, 1883)	P	0.2
<u>Terebellidae</u> sp. A	P	0.2
<u>Leucon</u> spp.	C	0.1
<u>Nephyts longosetosa</u> Oersted, 1843	P	0.1
Oligochaeta		0.1
Gastropoda		0.1
<u>Schistomeringos ceacus</u> (Webster and Benedict, 1884)	P	0.1
<u>Paramphitrite tetrabranchiata</u> Holthe, 1976	P	0.1
<u>Praxillella praetermissa</u> (Malmgren, 1865)	P	0.1
<u>Priscillina armata</u> (Boeck, 1861)	A	0.1
<u>Amphicteis sundevalli</u> Malmgren, 1866	P	0.1
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	0.07
<u>Sphaerodoropsis</u> sp. D	P	0.07
<u>Ophryotrocha</u> spp.	P	0.07
<u>Mystides borealis</u> Theel, 1879	P	0.07
<u>Melaenis loveni</u> Malmgren, 1865	P	0.07
<u>Spio theeli</u> (Soderstrom, 1920)	P	0.05
Mollusc juveniles	B	0.05
<u>Anaitides groenlandica</u> (Oersted, 1843)	P	0.05
<u>Sternaspis scutata</u> (Ranzani, 1817)	P	0.05
<u>Astarte montagui</u> (Dillwyn, 1817)	B	0.05
<u>Terebellides stroemi</u> Sars, 1835	P	0.05

Appendix 2 (cont.)

<u>G1S</u>	<u>Taxa</u>	<u>%</u>
<u>Diastylus rathkei</u> (Kroyer, 1841)	C	0.05
<u>A.allia nolani</u> (Webster and Benedict, 1887)	P	0.05
<u>Scolopolos armiger</u> (Muller, 1776)	P	0.05
<u>Scalibregma inflatum</u> Rathke, 1843	P	0.05
<u>Liosyma fluctosa</u> (Gould, 1841)	B	0.05
Nemertea		0.05
<u>Tryphosa schneideri</u> (Stephensen, 1921)	A	0.03
<u>Micronephthys minuta</u> (Theel, 1879)	P	0.03
<u>Pontoporeia femorata</u> Kroyer, 1842	A	0.03
<u>Pholoe minuta</u> (Fabricius, 1780)	P	0.03
<u>Brachydiastylus resima</u> (Kroyer, 1846)	C	0.03
<u>Ampelisca macrocephala</u> Liljeborg, 1852	A	0.03
<u>Acanthostephia behringiensis</u> (Lockington, 1877)	A	0.03
<u>Caulleriella</u> sp. B	P	0.03
<u>Photis</u> spp.	A	0.03
Unidentified		0.3

Appendix 2 cont.

<u>G2NW</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	51.6
<u>Chone nr. murmanica</u> Lukasch, 1910	P	13.2
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	5.7
<u>Portlandia arctica</u> (Gray, 1824)	B	5.6
Cirratulidae ant frag	P	4.9
<u>Ampharete vega</u> (Wiren, 1883)	P	2.6
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	2.3
<u>Scolecopides arcticus</u> Chamberlin, 1920 (<u>viridis</u>)	P	2.0
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	1.6
Mollusc juveniles	B	1.5
<u>Eteone longa</u> (Fabricius, 1780)	P	1.2
Priapulida		1.1
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	0.7
<u>Monoculodes crassirostris</u>	A	0.6
<u>Capitella capitata</u> (Fabricius, 1780)	P	0.6
Sipunculida		0.5
<u>Diastylus sulcata</u> Calman, 1912	C	0.5
<u>Liosyma fluctosa</u> (Gould, 1841)	B	0.4
Oligochaeta		0.4
Gastropoda		0.4
Tanaidacea		0.4
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	0.3
<u>Clymenura polaris</u> (Theel, 1879)	P	0.2
<u>Sphaerodoropsis</u> sp. D	P	0.2
<u>Acanthostephia behringiensis</u> (Lockington, 1877)	A	0.2
<u>Boeckosimus affinis</u> Hansen, 1886	A	0.1
<u>Ophryotrocha</u> spp.	P	0.1
<u>Saduria entomon</u>	I	0.1
<u>Saduria sabini</u>	I	0.1
Hesionidae sp. A	P	0.1
<u>A.aricidea minuta</u> Southward, 1956	P	0.1
<u>Atylus carinatus</u> (Fabricius, 1793)	A	0.1
<u>Terebellides stroemi</u> Sars, 1835	P	0.1
<u>Leitoscoloplos acutus</u> (Verrill, 1873)	P	0.1
Oedicerotidae		0.04
<u>Lyonsia arenosa</u> (Moller, 1842)	B	0.04
<u>Heteromastus filiformis</u> (Claparede, 1864)	P	0.04
<u>Apherusa</u> spp.	A	0.04
<u>Macoma moesta</u> (Deshayes, 1854)	B	0.04
<u>Parheteromastus</u> sp. A	P	0.04
<u>Pontoporeia femorata</u> Kroyer, 1842	A	0.04
<u>Brada villosa</u> (Rathke, 1843)	P	0.04
Hesionidae sp. B	P	0.04
<u>Mysis relicta</u>	M	0.04
<u>Marenzellaria wireni</u> Augener, 1913	P	0.04

Appendix 2 (cont.)

<u>G2NW</u>	<u>Taxa</u>	<u>%</u>
<u>Saduria siberica</u>	I	0.04
<u>Priscillina armata</u> (Boeck, 1861)	A	0.04
<u>Terebellidae</u> sp. A	P	0.04
<u>Aceroides latipes</u> (Sars, 1892)	A	0.04
Nemertea		0.04

Appendix 2 cont.

<u>G2A</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	38.5
<u>Scolecopides arcticus</u> Chamberlin, 1920 (<u>viridis</u>)	P	8.5
Sipunculida		7.2
Cirratulidae ant frag		7.0
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	5.7
<u>Chone nr murmanica</u> Lukasch, 1910	P	5.7
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	4.4
<u>Portlandia arctica</u> (Gray, 1824)	B	4.1
Mollusc juveniles	B	1.7
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	1.7
Priapulida		1.7
<u>Boeckosimus affinis</u> Hansen, 1886	A	1.5
<u>Capitella capitata</u> (Fabricius, 1780)	P	1.5
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	1.4
<u>Ampharete vega</u> (Wiren, 1883)	P	1.4
<u>Diastylus sulcata</u> Calman, 1912	C	1.2
<u>Eteone longa</u> (Fabricius, 1780)	P	1.1
<u>Monoculodes crassirostris</u>	A	0.8
<u>Liosyma fluctosa</u> (Gould, 1841)	B	0.8
Oligochaeta		0.7
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	0.6
<u>Clymenura polaris</u> (Theel, 1879)	P	0.5
<u>Sphaerodoropsis</u> sp. D	P	0.1
<u>Onisimus</u> spp.	A	0.1
Oedicerotidae	A	0.1
<u>Caulleriella</u> sp. B	P	0.1
<u>Ampharete acutifrons</u> (Grube, 1860)	P	0.1
<u>Ophryotrocha</u> spp.	P	0.1
<u>Scolopelos armiger</u> (Muller, 1776)	P	0.1
<u>Lyonsia arenosa</u> (Moller, 1842)	B	0.1
<u>Saduria entomon</u>	C	0.1
<u>Mysis oculata</u>	M	0.1
<u>Anaitides groenlandica</u> (Oersted, 1843)	P	0.1
<u>Heteromastus filiformis</u> (Claparede, 1864)	P	0.1
<u>Astarte montagui</u> (Dillwyn, 1817)	B	0.1
<u>Apherusa</u> spp.	A	0.1
<u>Macoma moesta</u> (Deshayes, 1859)	B	0.1
<u>Mysis</u> spp.	M	0.1
<u>Hesionidae</u> sp. A	P	0.1
<u>Tryphosa schneideri</u> (Stephensen, 1921)	A	0.1
<u>Saduria sabini</u>	C	0.1
Unidentified		0.2

Appendix 2 cont.

<u>G2SE</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	63.6
Priapulida		6.3
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	3.6
Cirratulidae ant frag	P	3.6
<u>Portlandia arctica</u> (Gray, 1824)	B	3.6
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	3.4
<u>Chone nr. murmanica</u> Lukasch, 1910	P	2.3
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	1.6
<u>Capitella capitata</u> (Fabricius, 1780)	P	1.5
<u>Scolecopides arcticus</u> Chamberlin, 1920 (viridis)	P	1.3
Mollusc juveniles	B	1.3
<u>Monoculodes crassirostris</u>	A	1.2
<u>Ampharete vega</u> (Wiren, 1883)	P	1.0
<u>Diastylus sulcata</u> Calman, 1912	C	0.9
Sipunculida		0.6
<u>Eteone longa</u> (Fabricius, 1780)	P	0.5
<u>Liosyma fluctosa</u> (Gould, 1841)	B	0.4
<u>Monoculopsis longicornis</u> (Boeck, 1923)	A	0.3
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	0.3
Oligochaeta		0.3
<u>Saduria entomon</u>	I	0.3
<u>Brada villosa</u> (Rathke, 1843)	P	0.3
<u>Pholoe minuta</u> (Fabricius, 1780)	P	0.3
<u>Sphaerodoropsis</u> sp. D	P	0.2
<u>Acanthostephia behringiensis</u> (Lockington, 1877)	P	0.2
Miscellaneous crustacean		0.2
<u>Ophryotrocha</u> spp.	P	0.1
<u>Astarte montagui</u> (Dillwyn, 1817)	B	0.1
<u>Hesionidae</u> sp. A	P	0.1
<u>Boeckosimus affinis</u> Hansen, 1886	A	0.04
<u>Onisimus</u> spp.	A	0.04
<u>Ampharete acutifrons</u> (Grube, 1860)	P	0.04
<u>Lyonsia arenosa</u> (Moller, 1842)	B	0.04
<u>Mysis oculata</u>	M	0.04
<u>Macoma moesta</u> (Deshayes, 1859)	B	0.04
<u>Saduria sabini</u>	I	0.04
Tanaidacea		0.04
<u>Leitoscoloplos acutus</u> (Verrill, 1873)	P	0.04
<u>Saduria siberica</u>	I	0.04
<u>Terebellidae</u> sp. A	P	0.04
<u>Pontoporeia femorata</u> Kroyer, 1842	A	0.04
<u>Sternaspis scutata</u> (Ranzani, 1817)	P	0.04
Mysidacea	M	0.04
<u>Acanthostephia incarinata</u>	A	0.04
<u>Corophium</u> spp.	A	0.04
Unidentified		0.04

Appendix 2 cont.

<u>G3NW</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	56.2
<u>Portlandia arctica</u> (Gray, 1824)	B	9.6
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	6.7
Priapulida		4.6
Sipunculida		2.0
Oligochaeta		1.9
Hesionidae sp. A	P	1.7
<u>Monoculodes crassirostris</u>	A	1.4
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	1.4
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	1.3
<u>Diastylus sulcata</u> Calman, 1912	C	1.3
<u>Scolecopides arcticus</u> Chamberlin, 1920 (<u>viridis</u>)	P	1.2
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	1.0
Cirratulidae ant frag	P	0.8
<u>Chone nr. murmanica</u> Lukasch, 1910	P	0.6
<u>Capitella capitata</u> (Fabricius, 1780)	P	0.5
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	0.4
Mollusc juveniles	B	0.4
<u>Eteone longa</u> (Fabricius, 1780)	P	0.4
Hesionidae sp. B	P	0.4
Tanaidacea		0.4
<u>Ophryotrocha</u> spp.	P	0.3
Gastropoda		0.2
<u>Pholoe minuta</u> (Fabricius, 1780)	P	0.2
<u>Tryphosa schneideri</u> (Stephensen, 1921)	A	0.2
<u>Nephtys longosetosa</u> Oersted, 1843	P	0.2
<u>Diastylus rathkei</u> (Kroyer, 1841)	C	0.2
<u>Boeckosimus plautus</u> (Kroyer, 1845)	A	0.2
<u>Macoma moesta</u> (Deshayes, 1854)	B	0.1
<u>Chaetozone setosa</u> (Malmgren, 1867)	P	0.1
<u>Onisimus</u> spp.	A	0.1
<u>Spio theeli</u> (Soderstrom, 1920)	P	0.1
<u>Terebellides stroemi</u> Sars, 1835	P	0.1
<u>Haploops tubicola</u> Liljeborg, 1855	A	0.1
<u>Ampharete acutifrons</u> (Grube, 1860)	P	0.1
<u>Ampharete vega</u> (Wiren, 1883)	P	0.05
<u>Saduria sabini</u>	I	0.05
<u>Pontoporeia femorata</u> Kroyer, 1842	A	0.05
<u>Brada villosa</u> (Rathke, 1843)	P	0.05
<u>Scalibregma inflatum</u> Rathke, 1843	P	0.05
<u>Micronephthys minuta</u> (Theel, 1879)	P	0.05
<u>Cossura soyeri</u> Laubier, 1964	P	0.05
<u>Heteromastus filiformis</u> (Claparede, 1864)	P	0.05
<u>A.Allia quadrilobata</u> (Webster and Benedict, 1884)	P	0.05
<u>Trochochaeta carica</u> (Birula, 1897)	P	0.05

Appendix 2 (cont.)

<u>G3NW</u>	<u>Taxa</u>	<u>%</u>
Oedicerotidae	A	0.05
Nemertea		0.05
<u>Leitoscolopolos acutus</u> (Verrill, 1873)	P	0.05
Haustoriidae	A	0.05
<u>Anaitides groenlandica</u> (Oersted, 1843)	P	0.05
<u>Levensenia gracilis</u> (Tauber, 1879)	P	0.05
Hesionidae n. gen.?	P	0.05
<u>Mystides borealis</u> Theel, 1879	P	0.05
<u>Saduria entomon</u>	I	0.05
Unidentified		0.1

Appendix 2 cont.

<u>G3A</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	47.3
<u>Portlandia arctica</u> (Gray, 1824)	B	7.6
<u>Oligochaeta</u>		6.9
<u>Priapulida</u>		5.1
<u>Cirratulidae ant frag</u>	P	3.8
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	2.8
<u>Gastropoda</u>		2.7
<u>Sipunculida</u>		2.4
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	2.2
<u>Monoculodes crassirostris</u>	A	2.1
<u>Cossura soyeri</u> Laubier, 1964	P	2.0
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	1.9
<u>Hesionidae sp. A</u>	P	1.8
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	1.7
<u>Brada villosa</u> (Rathke, 1843)	P	1.6
<u>Trochochaeta carica</u> (Birula, 1897)	P	1.1
<u>Capitella capitata</u> (Fabricius, 1780)	P	1.0
<u>Diastylus sulcata</u> Calman, 1912	C	0.9
<u>Micronephthys minuta</u> (Theel, 1879)	P	0.7
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	0.5
<u>Sternaspis scutata</u> (Ranzani, 1817)	P	0.5
<u>Saduria sabini</u>	I	0.4
<u>Chone nr. murmanica</u> Lukasch, 1910	P	0.4
<u>Hesionidae sp. B</u>	P	0.4
<u>Nephtys ciliata</u> (Muller, 1789)	P	0.2
<u>Pholoe minuta</u> (Fabricius, 1780)	P	0.2
<u>Tryphosa schneideri</u> (Stephensen, 1921)	A	0.2
<u>Pontoporeia femorata</u> Kroyer, 1842	A	0.1
<u>Lyonsia arenosa</u> (Moller, 1842)	B	0.1
<u>Mollusc juveniles</u>	B	0.1
<u>Scalibregma inflatum</u> Rathke, 1843	P	0.1
<u>Eteone longa</u> (Fabricius, 1780)	P	0.1
<u>Astarte montagui</u> (Dillwyn, 1817)	B	0.1
<u>Pandora glacialis</u> Leach, 1819	B	0.1
<u>Arthropoda-mites</u>		0.1
<u>Macoma moesta</u> (Deshayes, 1854)	B	0.1
<u>Ophryotrocha</u> spp.	P	0.1
<u>Heteromastus filiformis</u> (Claparede, 1864)	P	0.1
<u>Chaetozone setosa</u> (Malmgren, 1867)	P	0.1
<u>A.Aricidea minuta</u> Southward, 1956	P	0.1
<u>Tanaidacea</u>		0.1
<u>Mysidacea</u>		0.1
<u>Onisimus</u> spp.	A	0.1
<u>A.Allia nolani</u> (Webster and Benedict, 1887)	P	0.1
<u>A.Allia quadrilobata</u> (Webster and Benedict, 1887)	P	0.1
<u>Nephtys longosetosa</u> Oersted, 1843	P	0.1

Appendix 2 (cont.)

<u>G3A</u>	<u>Taxa</u>	<u>%</u>
<u>Mysis oculata</u>	M	0.1
<u>Protomeia spp.</u>	A	0.1
Unidentified amphipod	A	0.1

Appendix 2 cont.

<u>G3E</u>	<u>Taxa</u>	<u>%</u>
<u>Minuspio cirrifera</u> (Wiren, 1883)	P	60.4
<u>Sphaerodoropsis minuta</u> (Webster and Benedict, 1887)	P	9.6
<u>Chone nr. murmanica</u> Lukasch, 1910	P	7.3
<u>Portlandia arctica</u> (Gray, 1824)	B	3.9
<u>Scolecopides arcticus</u> Chamberlin, 1920 (<u>viridis</u>)	P	2.2
Sipunculida		2.1
Oligochaeta		1.9
Priapulida		1.4
Tanaidacea		1.0
Cirratulidae ant frag	P	0.9
<u>Cossura soyeri</u> Laubier, 1964	P	0.9
<u>Chaetozone gracilis?</u> (Moore, 1923)	P	0.7
<u>Eteone longa</u> (Fabricius, 1780)	P	0.6
Hesionidae sp. B	P	0.5
<u>Diastylus sulcata</u> Calman, 1912	C	0.4
<u>Capitella capitata</u> (Fabricius, 1780)	P	0.4
<u>Sternaspis scutata</u> (Ranzani, 1817)	P	0.4
<u>Monoculodes crassirostris</u>	A	0.3
Hesionidae sp. A	P	0.3
<u>Sphaerodoropsis</u> sp. D	P	0.3
<u>Monoculopsis longicornis</u> (Boeck, 1871)	A	0.2
<u>Axinopsida orbiculata</u> (Sars, 1878)	B	0.2
<u>Chaetozone setosa</u> (Malmgren, 1867)	P	0.2
<u>Marenzellaria wireni</u> Augener, 1913	P	0.2
<u>Spio theeli</u> (Soderstrom, 1920)	P	0.2
Nemertea		0.2
<u>Leitoscoloplos acutus</u> (Verrill, 1873)	P	0.2
<u>Antinoella sarsi</u> (Malmgren, 1865)	P	0.1
Mollusc juveniles		0.1
<u>Brada villosa</u> (Rathke, 1843)	P	0.1
<u>Micronephthys minuta</u> (Theel, 1879)	P	0.1
<u>Nephtys ciliata</u> (Muller, 1789)	P	0.1
Arthropoda-mites		0.1
<u>Heteromastus filiformis</u> (Claparede, 1864)	P	0.1
<u>Pholoe minuta</u> (Fabricius, 1780)	P	0.1
<u>A.Aricidea minuta</u> Southward, 1956	P	0.1
<u>A.Allia nolani</u> (Webster and Benedict, 1887)	P	0.1
<u>A.Allia quadrilobata</u> (Webster and Benedict, 1887)	P	0.1
<u>Diastylus rathkei</u> (Kroyer, 1841)	C	0.1
<u>Priscillina armata</u> (Boeck, 1861)	A	0.1
<u>Boeckosimus plautus</u> (Kroyer, 1845)	A	0.1
Haustoriidae	A	0.1
<u>Ophelina cylindricaudatus</u> (Hansen, 1878)	P	0.1
<u>Anaitides groenlandica</u> (Oersted, 1843)	P	0.1
<u>Ampelisca macrocephala</u> Liljeborg, 1852	A	0.1

Appendix 2 (cont.)

<u>G3E</u>	<u>Taxa</u>	<u>%</u>
<u>Melaenis loveni</u> Malmgren, 1865	P	0.1
<u>Caulleriella</u> sp. B	P	0.1
<u>Pandora glacialis</u> Leach, 1819	B	0.04
<u>Macoma moesta</u> (Deshayes, 1854)	P	0.04
<u>Ophryotrocha</u> spp.	P	0.04
Mysidacea		0.04
<u>Onisimus</u> spp.	A	0.04
<u>Nephtys longosetosa</u> Oersted, 1843	P	0.04
<u>Orchomene minuta</u> (Kroyer, 1846)	A	0.04
Oedicerotidae		0.04
<u>Amphicteis sundevalli</u> Malmgren, 1866	P	0.04
<u>Leucon</u> spp.	C	0.04
<u>Praxillella praetermissa</u> (Malmgren, 1865)	P	0.04
<u>Terebellides stroemi</u> Sars, 1835	P	0.04
<u>Boeckosimus affinis</u> Hansen, 1886	A	0.04
<u>Paramphitrite tetrabranchiata</u> Holthe, 1976	P	0.04
<u>Levensenia gracilis</u> (Tauber, 1879)	P	0.04
<u>Schistomeringos ceacus</u> (Webster and Benedict, 1884)	P	0.04
Nematoda		0.04
Unidentified		0.04

Appendix 3. Species list and data codes for species used as input for the cluster analysis (CLUSB).

<u>Minuspio cirrifera</u>	PSP2
<u>Boeckosimus affinis</u>	ALY1
<u>Tryphosa schneideri</u>	ALY6
<u>Sphaerodoropsis minuta</u>	PSH1
<u>Micronephthys minuta</u>	PNE1
<u>Portlandia arctica</u>	MBV7
<u>Antinoella sarsi</u>	PP01
Hesionidae sp. A	PHE1
Unidentified	MSC7
Sipunculida	MSI1
<u>Capitella capitata</u>	PCA1
<u>Cirratulidae</u>	PCI4
<u>Trochochaeta carica</u>	PT01
<u>Chaetozone gracilis?</u>	PCI1
Hesionidae sp. B	PHE2
<u>Monoculopsis longicornis</u>	AOE7
<u>Priapulida</u>	MPR1
<u>Diastylus sulcata</u>	CUM1
<u>Spio theeli</u>	PSP5
<u>Chone nr. murmanica</u>	PSA1
<u>Sphaerodoropsis sp. D</u>	PSH2
<u>Brada villosa</u>	PFL1
<u>Tanaidacea</u>	TAN1
<u>Monoculodes crassirostris</u>	AOE5
<u>Pholoe minuta</u>	PPH1
<u>Nephtys longosetosa</u>	PNE3
<u>Oligochaeta</u>	MOL1
<u>Macoma moesta</u>	MBV5
Mollusc juveniles	MBV8
<u>Onisimus spp.</u>	ALY4
<u>Anaitides groenlandica</u>	PPY1
<u>Sternaspis scutata</u>	PST1
<u>Gastropoda</u>	MGA1
<u>Ophryotrocha sp.</u>	PD01
<u>Axinopsida orbiculata</u>	MBV2
<u>Leitoscoloplos acutus</u>	POR1
<u>Ampharete acutifrons</u>	PAM1
<u>Cossura soyeri</u>	PC01
<u>Eteone longa</u>	PPY2
<u>Haploops tubicola</u>	AAM2
<u>Scolecopides viridis</u>	PSP4
<u>Chaetozone setosa</u>	PCI3
<u>Marenzelleria wireni</u>	PSP1
<u>Diastylus rathkei</u>	CUM2
<u>Corophium spp.</u>	AC03
<u>Ampharete vega</u>	PAM2
<u>Priscillina armata</u>	AHA4
<u>Lyosyma fluctosa</u>	MBV4

Appendix 4. Species used as input for the discriminant function analysis. The 15 most dominant species from each gouge area and all species $\geq 1.0\%$ of the total abundance at each station.

Minuspio cirrifera
Sphaerodoropsis minuta
Portlandia arctica
Chone nr. murmanica
Eteone longa
Monoculoides crassirostris
Scolecopides viridis
Chaetozone gracilis?
Monoculopsis longicornis
Diastylus sulcata
Micronephtys minuta
Antinoella sarsi
Hesionidae sp. B
Capitella capitata
Axinopsida orbiculata
Ampharete vega
Lyosyma fluctosa
Cossura soyeri
Pontoporeia armata
Boeckosimus affinis
Brada villosa
Trochochaeta carica

Appendix 5. Clusters of station locations output from the species cluster analysis (Axis = disturbed station, NW, NE, E, SE, S = direction of stations outside of disturbed area). * = number of clusters used in the analysis.

Number of clusters	Stations	New clusters defined by
2	Gouge 1 NE Gouge 1 S Gouge 2 SE Gouge 2 Axis Gouge 2 NW Gouge 3 E Gouge 3 NW Gouge 1 Axis Gouge 3 Axis	Gouge 1 Axis $\bar{x} = 90.772$
* 3	Gouge 2 SE Gouge 2 Axis Gouge 2 NW Gouge 1 Axis Gouge 3 Axis Gouge 1 NE Gouge 1 S Gouge 3 E Gouge 3 NW	Gouge 1 S $\bar{x} = 69.318$
4	Gouge 2 SE Gouge 2 Axis Gouge 2 NW Gouge 1 Axis Gouge 1 NE Gouge 1 S Gouge 3 E Gouge 3 Axis Gouge 3 NW	Gouge 3 Axis $\bar{x} = 54.070$

Appendix 5 (cont.)

Number of clusters	Stations	New clusters defined by
5	Gouge 2 SE Gouge 2 Axis Gouge 2 NW Gouge 1 Axis Gouge 1 NE Gouge 3 E Gouge 3 NW Gouge 3 Axis Gouge 1 S	Gouge 1 S $\bar{x} = 50.589$
6	Gouge 2 SE Gouge 2 Axis Gouge 2 NW Gouge 1 Axis Gouge 1 NE Gouge 3 E Gouge 3 Axis Gouge 1 S Gouge 3 NW	Gouge 3 NW $\bar{x} = 42.341$
7	Gouge 2 SE Gouge 2 NW Gouge 1 Axis Gouge 1 NE Gouge 3 E Gouge 3 Axis Gouge 1 S Gouge 3 NW Gouge 2 Axis	Gouge 2 Axis $\bar{x} = 30.204$

Appendix 6. Feeding / motility guilds of the polychaete families (after Fauchald and Jumars, 1979) and the bivalve species (Carey, Scott and Montangua, 1984) found from the gouge areas.

Ampharetidae	SST
Apistobranchidae	SDT
Capitellidae	SMX, BMX
Cirratulidae	SMT, (SDT)
Cossuridae	BMX
Dorvilleidae	HMJ, CMJ, SMJ
Flabelligeridae	?FDT, SMT, SDT
Hesionidae	HMJ, CMJ, ?SMJ, BMJ
Maladanidae	BSX
Nephtyidae	CMJ, BMJ
Ophellidae	BMX
Orbinidae	BMX
Paraonidae	HMX, SMX
Phyllodocidae	CMX, BMX (Eteoninae), others - CMS
Polynoidae	CMJ, CDJ
Sabellidae (Fabricinnae)	FST, SDT
Scalibregmidae	BMX
Sigalionidae	CMJ
Sphaerodoridae	BMX
Spionidae	FDT, SDT
Sternaspidae	BMX
?Syllidae	HMJ, CMJ
Terebellidae	SST
Trichobranchidae	SST
Trochochaetidae	SDT

Feeding mode of bivalves (after Carey, Scott, Montague, 1984)
(S = suspension feeder, D = deposit feeder)

<u>Axinopsida orbiculata</u>	S
<u>Portlandia arctica</u>	D
<u>Macoma moesta</u>	D
<u>Lyonsia arenosa</u>	S
<u>Lyosyma fluctosa</u>	S
<u>Pandora glacialis</u>	S
<u>Astarte montagui</u>	S

Appendix 7. Total number of individuals of each major taxa collected in each grab sample at all stations (SMG # = Smith-McIntyre grab sample number).

GOUGE 1	S					Axis					NE				
	SMG #:	1808	1809	1810	1811	1813	1802	1803	1804	1805	1806	1796	1797	1798	1799
Polychaeta	535	731	626	647	765	325	170	223	240	957	620	416	634	940	796
Pelecypoda	60	48	27	51	32	5	4	6	4	15	72	27	66	32	10
Amphipoda	10	17	18	17	16	38	6	17	18	44	20	4	21	16	6
Cumacea	2	4	3	3	13	1	--	5	1	11	2	2	2	4	7
Tanaidacea	20	14	13	17	20	--	2	1	--	7	17	1	9	8	1
Isopoda	--	--	--	--	--	--	2	1	--	2	--	--	--	--	--
Sipunculida	5	10	7	3	4	3	16	23	4	6	11	2	13	10	12
Priapulida	16	11	3	13	11	2	2	2	6	66	10	1	9	4	3
Others*	10	4	3	4	2	5	1	2	--	34	2	--	5	2	4
Totals	658	839	700	755	863	379	203	280	273	1142	754	453	759	1016	839

Appendix 7 (cont.)

GOUGE 2	SE					Axis					NW				
	SMG #:	1762	1763	1764	1765	1766	1768	1769	1770	1771	1772	1773	1774	1775	1776
Polychaeta	652	279	287	406	183	40	156	172	90	175	355	364	344	377	415
Pelecypoda	40	29	28	59	46	3	44	30	15	19	57	49	64	68	66
Amphipoda	21	8	7	7	--	9	7	6	7	7	12	1	6	8	15
Cumacea	11	5	1	2	2	3	2	3	1	2	1	3	5	--	3
Tanaidacea	--	1	--	--	--	--	--	--	--	--	5	1	--	1	3
Isopoda	--	2	4	--	2	--	1	--	--	1	3	1	1	--	--
Sipunculida	5	5	1	--	3	11	13	11	15	14	--	4	--	3	5
Priapulida	93	33	5	9	1	--	4	4	3	4	1	10	1	4	8
Others*	10	1	1	--	3	--	2	2	6	2	12	3	1	3	1
Totals	832	363	334	483	240	66	229	228	137	224	446	436	422	464	516

Appendix 7 (cont.)

GOUGE 3	E					Axis					NW				
SMG #:	1779	1780	1781	1782	1783	1785	1786	1787	1788	1789	1790	1791	1792	1793	1794
Polychaeta	349	364	459	408	368	264	296	397	118	33	217	225	310	288	268
Pelecypoda	20	18	19	19	21	21	40	46	2	29	36	45	47	39	40
Amphipoda	4	9	5	5	2	39	6	16	7	2	41	27	4	5	7
Cumacea	3	6	2	2	1	3	2	2	1	7	7	7	2	7	5
Tanaidacea	6	3	7	3	3	--	--	2	--	--	3	--	1	2	2
Isopoda	--	--	--	--	--	2	2	2	--	--	--	1	1	--	--
Sipunculida	15	6	11	5	10	5	--	1	25	7	9	6	11	3	7
Priapulida	3	8	12	5	3	9	27	40	3	4	27	14	11	13	17
Others*	5	11	14	9	14	23	56	49	1	28	7	10	14	2	8
Totals	405	422	529	456	422	366	429	555	157	110	347	335	401	359	354

* Others include: Oligochaetes, Mysidacea, Gastropoda, unidentified crustaceans, Nemertea Lipparididae, and unidentified others.