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Title: THE CLASSIFICATION AND STRUCTURE OF MARINE MACROBENTHIC ASSEMBLAGES AT ARTHUR HARBOR, ANVERS ISLAND, ANTARCTICA

Abstract approved: Redacted for privacy

Joel W. Hedgpeth

In January-February 1971 five replicate 0.07 m^2 Van Veen grabs were obtained from each of 12 stations in Arthur Harbor and nine Van Veen grabs were obtained from two stations in nearby Bismark Strait. The 69 grab samples yielded 78,395 individuals which were separated into 282 taxa, including 108 species of annelids (54.5% of the individuals), 117 species of arthropods (30.3%), 35 species of molluscs (11.3%) and 22 species in other phyla (4.0%).

The density of macrofauna (17,522 individuals/m^2) found in Arthur Harbor was high compared to other reported areas. This high density was considered to be the result of high organic input from phytoplankton, phytobenthos and attached macroalgae, the efficient utilization of organic matter by macrobenthos and the slow growth rate of macrobenthic species as an indirect result of cold temperatures.

Diversity values were moderately high with high species richness values and low evenness values. The high species richness values

may be the consequence of seasonal constancy of temperature and salinity in Arthur Harbor, while low evenness values probably result from the physical stress of iceberg grounding coupled with high organic input.

Six macrobenthic assemblages (site groups) and 11 species groups were found in the study area by classification analysis (Bray-Curtis dissimilarity, group-average sorting). Station groups were described by dominant species, density and diversity. Species groups were described by the dominance, fidelity, constancy, and percent abundance of constituent species restricted to site groups.

The existence of discrete assemblages derived from the classification analysis was supported by direct ordination. Assemblages were interpreted to be areas of relative homogeneity which interrupt a general continuum of distribution of species with depth. The depth gradient probably represents several factors including increased constancy of temperature and salinity, lower organic input from attached macroalgae and phytobenthos, and a reduced incidence of iceberg grounding. Diversity, species richness, and evenness values increased with the depth gradient, while density values decreased with depth.

The dominant species obtained in this study are widely distributed throughout the Antarctic, and 46% of the 162 taxa identified to species were also found at Terre Adelie, East Antarctica. Thus assemblages

found in Arthur Harbor are probably circumpolar.

In spite of the stability of temperature and salinity, Arthur Harbor macrobenthic assemblages were moderately stressed by glacial activity. Icebergs, which often ground in Arthur Harbor, destroyed the benthos by crushing and churning the sediment. The disturbed area was first repopulated by motile, opportunistic species. These species fed on macroalgae which collected in the depression left by the iceberg. Scavengers and carnivores appeared later to feed on the grazers and macrofauna destroyed by iceberg grounding. Within a year the depression filled, and typical meiobenthic assemblages were re-established. Several years may be required before macrobenthic assemblages are re-established. Station 8, located near the glacial face had the lowest values of diversity, species richness, evenness, and density of any station in Arthur Harbor. These low values resulted from physical stress of glacial calving. Large pieces of ice calved from the glacial face and crushed the sediment by impact with the bottom. The waves created by impact of the calved ice with the water also disturbed the sediment creating an unstable sediment surface.

The Classification and Structure of Marine Macrobenthic Assemblages at Arthur Harbor, Anvers Island, Antarctica

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THE CLASSIFICATION AND STRUCTURE OF MARINE MACROBENTHIC ASSEMBLAGES AT ARTHUR HARBOR, ANVERS ISLAND, ANTARCTICA

INTRODUCTION

Generalizations about Antarctic shallow-water benthic community structure have been based primarily on the epibenthic flora and fauna attached to hard substrates (Dell, 1972 review). The biota is characterized by high diversity and biomass of slow-growing, sessile, suspension feeding organisms (Dearborn, 1968). The general pattern of zonation and distribution of assemblages of organisms is circumpolar (Hedgpeth, 1971; Knox and Lowry, in press).

The community structure of Antarctic soft-bottom, shallow-water benthos has received little attention until the recent quantitative benthic surveys at Port Foster, Deception Island (Gallardo and Castillo, 1968), Discovery Bay, Greenwich Island (Gallardo and Castillo, 1969; Mills, 1975; and Gallardo, in press), Arthur Harbor, Anvers Island (Kaufman, 1974; Lowry, 1975), and Borge Bay, Signy Island (Hardy, 1972). These studies indicate the soft-bottom is characterized by high diversity and biomass of non-attached, deposit feeding polychaetes, molluscs and crustaceans.

With the exception of Dayton et al. (1974), Arnaud (1974), Lowry (1975), and Gallardo (in press), publications on both hard-bottom and soft-bottom benthic community structure have consisted primarily

of biomass estimates and determination of the dominant megabenthic forms. Most workers have concentrated on taxonomy, biogeography, physiology, reproduction and behavior of specific benthic organisms as opposed to a consideration of the community as a whole. Investigations of macrobenthic communities in the cold, physically stable, highly productive Antarctic environment may yield important contributions to ecological theory (Dayton et al., 1970).

The present study was designed first to determine what macrobenthic assemblages and species groups occur in Arthur Harbor, second to calculate community structure parameters for existing assemblages, third to compare the results to other soft-bottom benthic studies, and fourth to relate the results to current ecological theory. Arthur Harbor was not the physically stable area I presupposed it to be, because of glacial activity. Therefore, the effects of glacial calving, and iceberg grounding on benthic community structure were also investigated.

History of Antarctic Benthic Investigations

James Eights, a member of the Pendleton-Palmer exploring expedition (1829-31), was the first qualified naturalist to work south of the Antarctic Convergence (Hedgpeth, 1971). Eights collected and published descriptions of several characteristic Antarctic invertebrates, including Glyptonotus antarctica (Isopoda), Serolis

trilobitoides (Isopoda), and Decolopoda australis (Pycnogonida).

From 1829 to 1897, expeditions to the Antarctic were primarily concerned with commercial exploitation of whale and seal stocks and geographic exploration. Naturalists often accompanied these expeditions but did not contribute significantly to the knowledge of Antarctic benthos (Dell, 1972). The Challenger Expedition (1772-76) was the only major scientific expedition to collect Antarctic benthic invertebrates during this period. Their collections were restricted to three deep-sea stations south of the Antarctic Convergence in addition to many stations located near subantarctic islands.

From 1897 to 1914, over 30 scientific expeditions representing 10 nations conducted research in the Antarctic. The Belgian Antarctic Expedition (1879-99), working around the South Shetland Islands, the Antarctic Peninsula, and the Bellingshausen Sea was the first expedition to make extensive collections of benthos south of the Antarctic Convergence. Other major expeditions which collected benthic invertebrates during this period included the British "Southern Cross" Expedition (1898-1900), to the Ross Sea; the German Antarctic Expedition (1901-03), to the Davis Sea; the Swedish South Polar Expedition (1901-04), near South Georgia and the Antarctic Peninsula; the British National Antarctic Expedition (1901-04), to the Ross Sea; the Scottish National Antarctic Expedition (1902-04), near the South Orkney Islands and to the Weddell Sea; the first French

Antarctic Expedition (1903-05), near the Antarctic Peninsula; the British "Nimrod" Antarctic Expedition (1907-09), to the Ross Sea; the Second French Antarctic Expedition (1908-10), near the Antarctic Peninsula and to the Bellinghausen Sea; the British "Terra Nova" Antarctic Expedition (1910-13), to the Ross Sea; and the Australasian Antarctic Expedition (1911-14), near the Adelie coast. Scientists and naturalists aboard these expeditions were primarily concerned with the collection and description of Antarctic flora and fauna. Mackintosh wrote in 1963 that over one-half of the existing knowledge of Antarctic flora and fauna resulted from collections of this period (1897-1914). The numerous taxonomic volumes which resulted from these collections support his claim.

From 1925 to 1939 biological work in the Antarctic Ocean was dominated by the research of the Discovery Committee of Great Britain. These investigations were initiated to study commercial whale stocks and included programs to study the biological, physical, chemical and geological conditions of the Antarctic Ocean. The research was conducted over a long term period in contrast to previous short term expeditions. Since the Discovery Committee concentrated on the biology of commercially important whale stocks, most of the research was on whales, physical oceanography and plankton. Very little research on the benthos has been published in the Discovery Reports, now 34 volumes. Other expeditions during the Discovery

era included the Norwegian Antarctic Expedition (1927-28) to Bouvet Island, South Georgia, and the Antarctic Peninsula; and the British, Australian, New Zealand Antarctic Research Expedition (B. A. N. Z. A. R. E., 1929-31) to Eastern Antarctica.

Since World War II, the international importance of scientific cooperation in the Antarctic, together with modern logistical support, have revised the focus of benthic research from the collection, description, and biogeography of benthic invertebrate groups to the biology (behavior, respiration, reproduction, feeding, and physiology) of selected benthic invertebrate species and to studies on the classification, structure, function, and energetics of benthic communities.

The International Geophysical Year (IGY, 1957-58), during which 12 nations operated 43 stations in the Antarctic, was the beginning of international cooperation in Antarctic research (Jones, 1971). The bases established during IGY provided permanent stations for year round biological research. In 1957, the Scientific Committee on Antarctic Research (SCAR) was established to continue the international cooperation started by IGY (Gould, 1971). International cooperation in Antarctic research was further strengthened by the Antarctic Treaty which was signed by 12 nations in December, 1959 and came into force August, 1961 (Jones, 1971).

Improvements in logistic support have enabled the benthic ecologist to conduct year-round research in relative comfort.

Permanent stations are maintained by icebreakers, airplanes, helicopters and snowmobiles (Dater, 1970). Communication satellites, submarines and SCUBA diving have also increased the scope of biological research.

During the last 20 years, much of the benthic research conducted in the Antarctic has been part of large scale multidisciplinary projects such as the Ross Sea Survey by the New Zealand Oceanographic Institute and Stanford University (Bullivant, 1967; Dearborn, 1967), The Soviet Antarctic Expeditions (Andriyashev, 1966), the French expeditions to the Kerguelen Islands and Adelie Coast (Arnaud, 1974), and the United States Eltanin programs (El-Sayed, 1973). The United States (USARP), Great Britain (BAS), Chile (INACH), and Argentina (IAA) have also been active in supporting individual investigations of the benthos.

The first quantitative investigations of benthic communities resulted from the Soviet Antarctic Expeditions 1955-58 (Ushakov, 1963). Emphasis of those investigations was on determining zonation patterns of benthic assemblages based on conspicuous dominant species, and on estimating benthic biomass.

Since these Soviet studies, over 50 papers on zonation or biomass of Antarctic shallow water benthic assemblages have been published. Most of these papers were preliminary in nature and do not contain sufficient detail for comparison of community structure.

Notable exceptions included the work of Dayton et al. (1970) and Dearborn (1965) in the Ross Sea, Arnaud (1974) at Terre Adelie, and Lowry (1975) near the Antarctic Peninsula.

Taxonomic and biogeographic studies are still an integral part of Antarctic benthic research (Knox and Lowry, in press). Many important collections have not been studied and adequate samples are not available from many Antarctic areas to present a complete biogeographic snythesis (Hedgpeth, 1973).

There has been a rapid increase in the study of the biology of Antarctic benthic invertebrates, especially related to cold adaptation as shown by the papers presented at the Third Symposium on Antarctic Biology, Adaptations within Antarctic Ecosystems (1974). Recent papers include studies of reproduction, feeding, growth, behavior, respiration and physiology of dominant species and the relationship between these species and the environment. The most comprehensive work to date is that of Dayton et al. (1974) on biological accommodation of the benthic community at McMurdo Sound. In that paper the biology of dominant and keystone species was combined with ecological studies of species populations interactions to determine the factors which controlled the benthic community structure.

The study of Antarctic benthic ecology will continue to be important, not only because the study of benthos in a relatively

stable, cold and highly productive environment will provide important contributions to ecological theory but as part of the diplomatic posture of Antarctic treaty signatory nations. It is also important to protect this unique, pristine environment from the over exploitation and pollution that characterize much of the rest of the world. The benthic ecosystem in the Antarctic must be understood in its pristine state, if changes in the ecosystem are to be used to evaluate mans impact on the Antarctic Ocean.

The Community Concept in Marine Benthic Ecology

The concept of "community" as used by biologists has a long complicated history. Clifford and Stephenson (1975) found beginnings of the community concept in the writings of Greek philosophers. Aristotle (384-322 BC) divided animals into groups according to habitats, and Theophrastus (380-287 BC) divided plants into associations according to habitats. Both wrote about the relationships between organisms and the relationships between organisms and their environment (Allee et al., 1949). Mills' (1969) definition of community did not differ significantly from the definitions given by Aristotle and Theophrastus:

> .... community means a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and separable by means of ecological survey from other groups. (Mills, 1969)

Most introductory ecology texts order biological systems into levels of increasing size, and complexity, i.e. cells, organs, organisms, populations and communities. Odum (1971) suggested that the concept of community should remain broad enough to include natural assemblages of various sizes from the biota of a log to the biota of an ocean. Odum also suggested that "communities have defined functional unity with characteristic trophic structures, patterns of energy flow and compositional unity." In other words the community has organization, and organisms exist together in an orderly manner not haphazardly strewn over the earth as independent beings. This organization is the community structure.

Extensions of the concept of community organization have led some (Clements, 1905, 1916, and 1920; Tansey, 1920; Allee et al., 1949) to conceive of communities as superorganisms or quasi-organisms having structure, ontogeny, homeostasis, etc.

Gleason (1926), at the other extreme, thought of communities as statistical artifacts of the distribution of individual species, or merely coincidence. This concept of community has been reviewed and expanded by Whittaker (1962, 1967, 1971, and 1975) and McIntosh (1967), and is referred to as the "continuum" approach to the concept of community or the individualistic concept.

The concept of community is not a single concept but a number of interconnected concepts about which ecologists have divergent

points of view. In order to define community several important questions need to be answered. Do communities exist or are they abstractions? If communities exist how do we delineate them? What are the properties of a community that allow the community to be considered a level of biological organization? What factors control community structure? Are communities persistent with time?

A great deal has been written to answer these questions. Terrestrial zoologists and botanists have traditionally been the most active contributors to this body of literature (Whittaker, 1975). Recently biologists have introduced additional mathematical complexities to community concepts (Goodman, 1975). I will attempt to review the contributions of marine benthic ecologists to the concept of community and define community as it pertains to the marine benthic environment.

Karl Mobius (1877) is usually credited with the original formulation of the concept of community in marine benthic ecology (Hedgpeth, 1957; Mills, 1969; and others). Mobius proposed the word bio-coenosis for the community of organisms found on oyster-beds.

> Science possesses ...; no word for a community where the sum of species and individuals, being mutally limited and selected under the average external conditions of life, have, by means of transmission continued in possession of a certain definite territory. I propose the word Biocoenosis for such a community. (Mobius, 1877)

Mobius not only recognized the existence of recurrent groups of species but suggested that the oyster bed biocoenosis was controlled by external factors, including organic input, substrate, salinity, temperature, and man, and population interactions such as predation and competition for space. As long as the external factors did not change from their "ordinary mean" the biocenosis would maintain equilibrium by species reproduction and population interactions, thus gaining permanence. Mobius also suggested that the word "biocoenosis" be used for any such community of organisms. Bashford Dean (1893) disagreed with Mobius (1877) and suggested that an oyster bed was not a "keenly poised life-balance" but a transitory episode in the struggle for survival of individual species.

The recognition of recurrent groups of benthic species in the marine environment actually preceded Mobius' (1877) definition of biocoenosis. Edward Forbes (1859) related different associations of species to changes in environmental conditions with depth. Also Verrill and Smith (1874) distinguished three primary assemblages of species in Vineyard Sound, Massachusetts: (1) animals of bays and sounds, (2) animals of estuaries and other brackish waters, and (3) those of the cold waters of the ocean shores and outer channels. Secondary assemblages within the primary assemblages were recognized where certain groups of animals were restricted to particular localities because of their relationship to substrate.

The quantitative approach to the study of benthic communities began with C. G. Joh. Petersen as early as 1889. Petersen began his studies to determine the amount of food available to bottom fish in the North Sea and had no intention of describing animal communities (Thorson, 1957). After analyzing thousands of grab samples from the North Sea, Petersen recognized that recurrent groups of species occupied similar habitats. Petersen characterized these communities by the dominance and constancy of conspicuous species in his now classic papers (1911, 1913, 1914, 1915, 1918, and 1924).

These early works all demonstrated that pattern exists in the distribution of benthic species. Similar species were often found together under similar environmental conditions. The benthic communities were defined both by the species present and the environmental conditions in which the community was found.

According to Thorson (1957), two different methods of defining the boundaries of benthic communities evolved during this early period. The first, "biocoenosis" (Mobius, 1877), used organisms to determine community boundaries; the second, "biotopic" (Dahl, 1908), used abiotic factors to determine community boundaries. Most benthic ecologists have adopted the biocoenosis approach to defining community boundaries, exceptions being Lindroth (1935), Jones (1950), Peres and Picard (1958), Buchanan (1957), and O'Connor (1972).

Stephenson (1973) defined three schools of divergent views about the nature of communities developed primarily by plant ecologists during this century. The Uppsala School of northern Europe regarded communities as real units, defined by dominant and constant species. The Zurich-Montpellier (Braun-Blanquet) School of southern Europe regarded communities as more or less abstract units, defined by fidelity and constancy of characterizing species. The school of individual dissenters (Whittaker, 1967) regarded communities as abstractions and did not define them.

Two different but interconnected controversies are implicit within these three schools of views on the nature of communities. First, is the community a functional, evolving analog of an organism ("superorganism"), or an abstraction, where species populations are distributed independently over physiological gradients in overlapping binomial distributions (Whittaker, 1975)? Second, is community structure predominantly controlled by biological accommodation or by abiotic physical controls (Sanders, 1968)?

Most early benthic ecologists were influenced by Petersen and the Uppsala School. Communities were thought of as concrete units defined by dominant species. Thorson was the foremost exponent of this approach and the culmination of his ideas was published as the theory of parallel communities (Thorson, 1957). Parallel communities were similar groups of co-adapted species which were found together

under similar environmental conditions throughout the world. Thorson (1971) later restricted the concept of parallel communities to cold-water fauna. At the same time, Clements and Shelford (1939) expanded the idea of concrete communities to that of the "super-organism." According to Mills (1969), Clements and Shelford "forced incomplete data into a theoretical framework of succession, climax and organismic unity, ideas which are not supported by any kind of evidence."

Jones (1950), thought of benthic communities as discrete units primarily controlled by sediment, salinity and temperature as opposed to biological interactions. Communities were classified according to these abiotic factors rather than by the species present.

Other benthic workers, especially in tropical regions were unable to define communities on the basis of dominant species (Stephensen et al., 1970). These communities were very diverse and could not be characterized by a few numerically abundant or large sized species (Thorson, 1971). Hartman (1955) described the distribution of species collected in San Pedro Basin, California as unpredictable and without pattern with respect to physical or biotic limitations.

Several benthic ecologists found communities that graded one into another without discrete boundaries (Stephen, 1933; Lindroth, 1935; MacGinitie, 1935). More recent benthic ecologists found benthic communities that were points along environmental gradients of depth, salininty and sediment type and not discrete units (Cassie and Michael,

1968; Mills, 1969; Jones, 1969; Stephenson et al., 1970; Johnson, 1970; Nicol, 1970; Hughes and Thomas, 1971a; Boesch, 1971, 1973; Lee, 1974). These studies support theories of the continuum concept in which species distributions are independent (Whittaker, 1975).

Intermingled among the various theories about the nature of communities have been concepts related to the control of community structure. Controversy in recent years has evolved around diversity concepts and the applicability of complex ecosystem models to ecological theory. These two areas of investigation are too broad and complex to be discussed here.

Sanders (1968) suggested that the structure of benthic communities in physically fluctuating environments is primarily controlled by physical factors, whereas the structure of benthic communities in physically stable environments is controlled by biological accommodation.

Biological interactions between species populations are well documented in the marine environment (Nicol, 1960; Moore, 1965; Thorson, 1966). Equally well documented are the relationships between species populations and environmental factors (Moore, 1965; Southworth, 1966; Carriker, 1967).

Numerous benthic investigators have correlated the distribution of discrete benthic communities with abiotic factors (Sanders, 1956, 1958, 1960; Lee and Kelley, 1970; Young and Rhoads, 1971; Hughes

and Thomas, 1971; Boesch, 1973). Other investigators have correlated the continuum distribution of benthic communities to abiotic factors (Nicols, 1970; Johnson, 1970; Boesch, 1971; Lee, 1974).

Recent work by Connell (1961), Paine (1966), Dayton (1971, 1975), Dayton et al. (1974), and Woodin (1975) has suggested that biological interactions (e.g. competition, predation, and disturbance) are at least as important as abiotic factors in controlling community structure in both physically stable and stressed environments. They have also shown that dominant (in terms of community influence) species need not have a high rank order of abundance or biomass. It has also been shown (Mills, 1969; Rhoads and Young, 1970; Young and Rhoads, 1971) that benthic species populations can alter the physical environment in which they live, which in turn controls community structure.

Most benthic faunal assemblages have been described from data collected at one point in time, under the assumption that these assemblages were stable with time. Mills (1969) suggested that species constancy and dynamic stability may not be characteristic of some marine communities. Mills cited evidence from the instability of the Ampelisca community in Barnstable Harbor Massachusetts. The existence of seasonal changes in benthic communities is well documented (Thorson, 1957; Boesch, 1971, 1973; Stephensen et al., 1974; Levings, 1976). Long-term fluctuations, although not as well documented, also occur in the benthos.

Eagle (1975) documented dramatic variations in dominant species, feeding types, and species diversity in a coastal benthic community during a five year period. Eagle attributed these variations to severe conditions of water turbulence and the reworking of sediments by deposit feeders. Similar long-term variability in coastal and estuarine benthic communities has been observed by Birkett (1953), Buchanan et al. (1974), Boesch et al. (in press), and Stephensen et al. (in press). By contrast several investigators have found considerable stability in benthic communities over long periods of time (Sanders, 1960, Fager, 1968; Lie and Evans; 1973).

In summary, pattern exists in the distribution of benthic invertebrates, and this pattern is intermediate between the "superorganism" and "continuum" concept of community. The discreteness of benthic communities varies between areas. The species present are the community, and therefore the community should be defined by these species. Both biological interaction and abiotic factors are important in determining the pattern and structure of the community. The importance and relationship between these factors should therefore be studied and related to the pattern and structure of the community. Community pattern and structure are not static and therefore small scale (seasonal and yearly) and geological changes should be investigated.

Many benthic ecologists use Mills' (1969) definition of community. I also find this definition convenient and do not disagree with it, while realizing that the concepts of community are much more complex and controversial than indicated by the definition. Since the community concept is a number of interconnected concepts more emphasis should be placed on determining what factors control community pattern and structure than on how to define community. Definitions should therefore remain flexible enough to include all reasonable community concepts and should not stifle future investigations or controversy.

Description of Study Area

Arthur Harbor (Figure 1) is characterized by numerous enclosed basins, strong tidal currents between inshore islands and "the mainland" (Anvers Island), and quiet water coves (Warnke et al., 1973). Subtidal rocky cliffs grade into soft substrate at an average depth of 15 m. Numerous rock outcroppings are found within the deeper soft substrate. Sediments in Arthur Harbor are poorly to very poorly sorted and consist primarily of silt size particles (Table 1). Organic content of sediments (0.43 to 0.88% by weight) is low (Warnke et al., 1973). Subsurface temperatures (3.0° C to -2.0° C, $\overline{-0.5}$° C) and salinities (32.5°/oo to 33.5 °/oo, $\overline{33.0}$ °/oo) are relatively constant (Krebs, 1974). Meltwater from surrounding glaciers probably

Figure 1. Arthur Harbor, Anvers Island, Antarctic Peninsula, showing location of 12 sampling stations. Station 3 (64°, 49' 50"S, 63° 59' 20"W) and station 4 (64° 45' 32"S, 63° 53' 50"W) located in Bismarck Strait are not shown. Stippled area, glacial face.

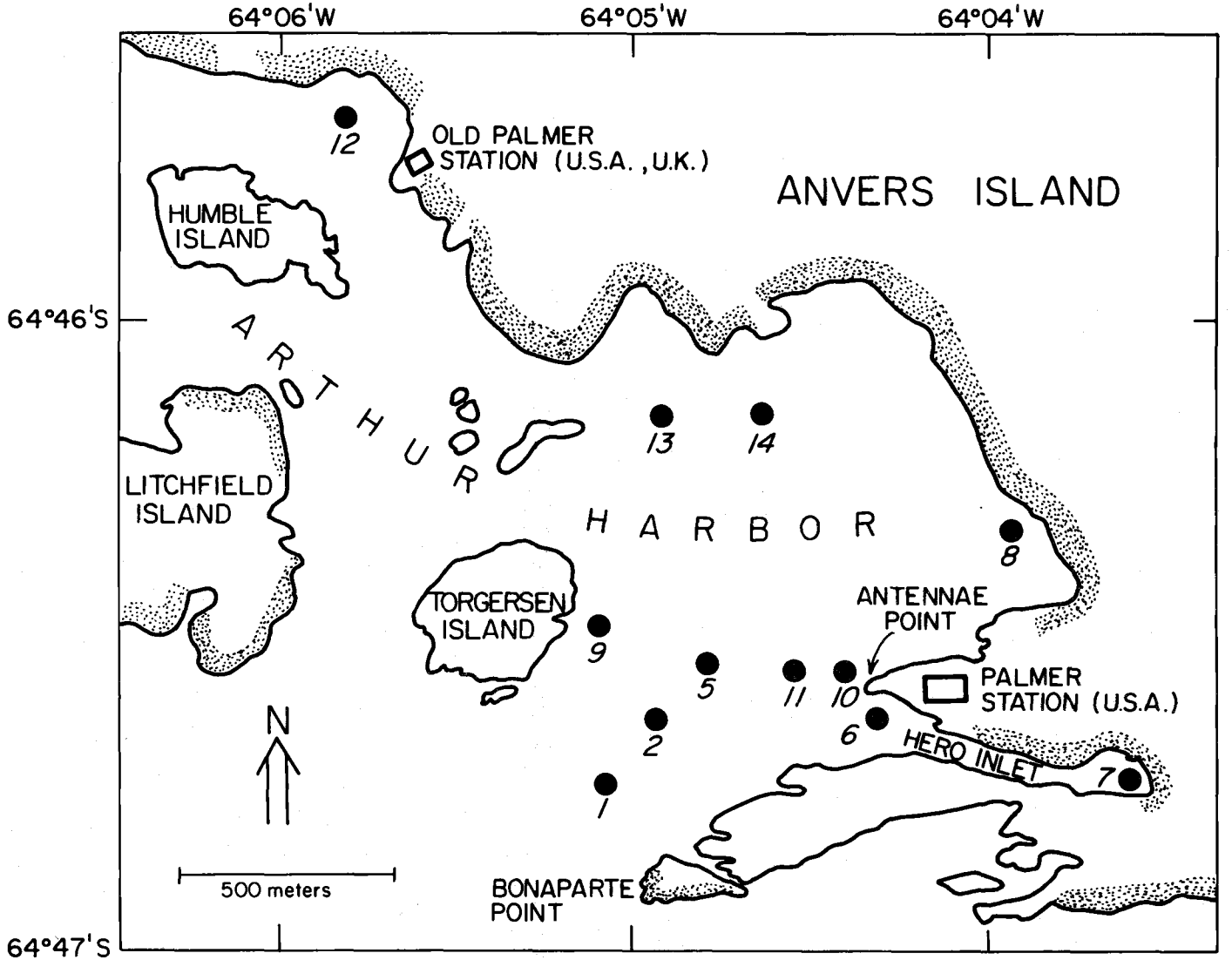

64°06'W
64°05'W
64°04'W
64°46'S
64°47'S
12
OLD PALMER
STATION (U.S.A., U.K.)
ANVERS ISLAND
HUMBLE
ISLAND
ARTHUR
HARBOR
LITCHFIELD
ISLAND
13
14
8
TORGERSEN
ISLAND
9
ANTENNAE
POINT
5
11
10
PALMER
STATION (U.S.A.)
2
6
HERO INLET
7
1
N
500 meters
BONAPARTE
POINT

Table 1. Depth, sediment classification, median particle-diameter (Mdϕ), and standard deviation (σ ϕ) for each station.

Station	Depth (m)	Sediment Classification	(Mdϕ)	σ ϕ
1	65	Silt	5.9	1.90
2	75	Silt	5.3	1.45
3	300-700	Clayey silt	6.0	2.95
4	300-700	Sand-silt-clay	5.6	3.20
5	50	Clayey silt	5.7	1.75
6	18	Sandy silt	5.1	1.90
7	5-7	Sandy silt	5.4	2.65
8	50	Clayey silt	6.0	2.20
9	30	Clayey silt	5.8	2.10
10	15	Sandy silt	5.2	1.85
11	43	Sandy silt	5.0	1.85
12	18	Sandy silt	5.0	2.25
13	23	Silty sand	4.0	1.45
14	30	Sand-silt-clay	6.6	--

influences salinity only in the surface waters.

Short term unconsolidated anchor ice has little effect on the biota (Shabica, 1972). Sea ice formation is highly variable during the austral winter (Krebs, 1974; Lowry, 1975). In 1971, a glacial face 50 to 75 m high outlined most of the mainland around Arthur Harbor (Figure 1). Calving from the glacial face occurred frequently during the austral summer. Large icebergs often ground in Arthur Harbor (Shabica, 1972; Kauffman, 1974).

The unprotected intertidal region is relatively barren and dominated by the limpet Patinigera polaris and a few species of filamentous algae and diatoms (Hedgpeth, 1971). Intertidal areas protected from ice abrasion support a more diverse fauna, dominated by the bivalve Kidderia subquadratum (Stockton, 1973; Shabica, 1974). DeLaca and Lipps (1976) divided the subtidal rocky cliff region into four zones characterized by dominant macroalgae. Protected areas supported a very diverse flora and fauna. Dominant macroalgae included Phyllogigas grandifolius (up to 380 gr. dry wt. /m^2) and Desmarestia menziesii (540 gr. dry wt. /m^2).

Phytoplankton blooms (predominately diatom) are restricted to the austral summer and exhibit marked yearly variability, which is probably related to differences in sea ice formation (Krebs, 1973; 1974). A benthic diatom bloom occurs in the late austral winter which

covers the shallow depths (20-30 m) with a carpet-like mat until the early austral spring (Kaufmann, 1974; Krebs, 1974).

MATERIALS AND METHODS

Sampling Procedures

In January-February 1971 five replicate 0.07 m^2 Van Veen grabs were obtained from each of 12 stations (5 to 75 m deep) in Arthur Harbor, Anvers Island, Antarctic Peninsula. Eight additional Van Veen grabs were obtained from two deeper stations (300 to 700 m) in nearby Bismark Strait (Figure 1, Table 1). Approximately 50 g of the upper 1 cm of sediment was removed from 1 grab sample per station for sediment analysis. The contents of each grab sample were washed through a nested set of two stainless steel screens with 1.0 mm, 0.5 mm apertures. The material retained on each screen was preserved in 5% formalin buffered with Sodium Borate.

Laboratory Procedures

The animals retained on the 1.0 mm screen were sorted from the debris, tentatively identified and counted by myself. Species identifications were confirmed by appropriate taxonomists when possible (see acknowledgments). The animals retained on the 0.5 mm screen were removed from the debris, sorted to major taxonomic group (eg. Polychaeta, Amphipoda), and counted by the Smithsonian Oceanographic Sorting Center, Washington, D. C.

The sediment particle size distribution was determined by standard pipette analysis (Folk, 1961). Cumulative sediment ϕ particle size classes (Table 1) 4.0 through 9.0ϕ were plotted on probability paper and median diameter (Mdϕ) and standard deviation (6ϕ) were calculated from equations given by Inman (1952). Percentages of sand, silt, and clay at each station were plotted on a tertiary diagram, and the sediment was characterized by nomenclature proposed by Shepard (1954)(Figure 2).

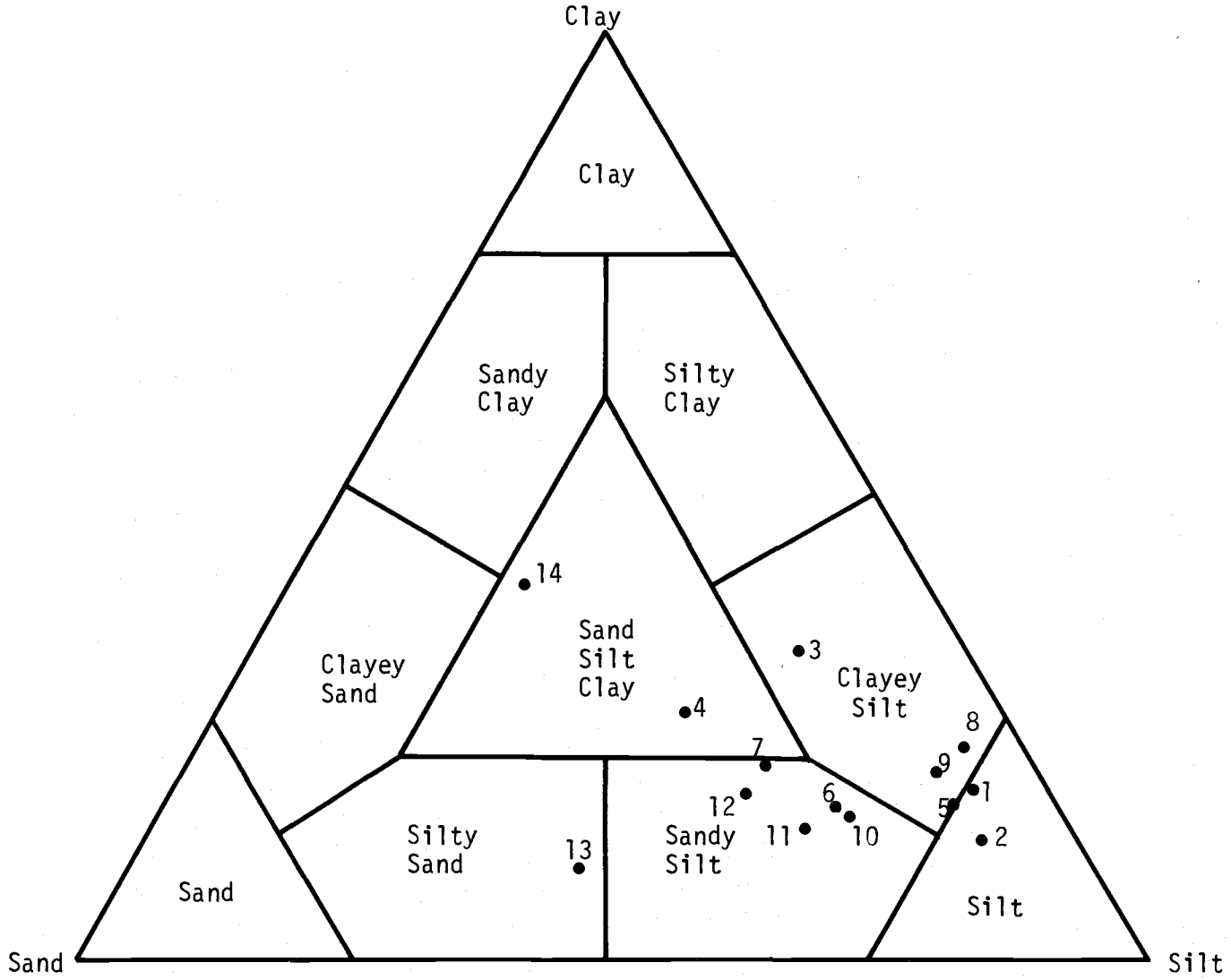
Data Analysis

Two different approaches to analysis of these benthic data were used. The first approach was classification of species and site groupings (Clifford and Stephenson, 1975). Species were classified according to their patterns of distribution among the sites and sites were classified according to their species content. The second approach was community structure analysis. Each site was characterized by its biotic content (density, dominant species and diversity). The data were analyzed by programs developed by myself and Cleo Adams (Oregon State University Computer Center) for the CDC Cyber-73 computer.

Classification

The classification analysis consisted of a multioptional set of

Figure 2. Tertiary diagram of percentage sand, silt, and clay for 14 stations.


Clay
Clay
Sandy Clay
Silty Clay
Clayey Sand
Sand Silt Clay
Clayey Silt
Silty Sand
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14
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programs which was used for data reduction and pattern recognition from a species-site data matrix. The programs were divided into four runs. Run 1 (COORDIN) ordered the original data into a site-species matrix. In the second run (CRUNCH), site-site and species-species resemblance matrices were calculated. Options in CRUNCH included data standardization (none, site, species), data transformation [none, square root, $\log_{10}(x + 1)$, or presence-absence], and choice of resemblance function (Dominance-affinity similarity, Bray-Curtis, Manhattan metric, and Canberra metric dissimilarity). Run III (CLSTR) consisted of seven clustering strategies which were used to group species or sites in the form of a dendrogram. CLSTR was modified from Anderberg (1973) for use on the CDC Cyber. Run IV (SWITCH) reordered the original site-species data matrix into a two-way coincidence table according to the results of the site and species clustering dendrograms. SWITCH was used to indicate the strength of pattern in the data, reallocate misclassified sites and species and adopt levels of classification.

Subjective decisions were required by the investigator at several points in the classification analysis. Since the goal of classification in this paper was data reduction and pattern recognition and not probalistic interpretation of the data structure, subjective decisions seemed appropriate. I agree with Boesch (1973) that the investigator should remain the ultimate arbiter in the classification of ecological data.

Sites were classified using the Bray-Curtis dissimilarity coefficient and the group average sorting strategy. The data were transformed using a square root transformation with no species reduction or standardization. Species were classified using similar techniques except the rare species were eliminated from the data matrix and the species values were standarized (proportions) after a square root transformation. Decisions regarding the reallocation of misclassified sites and species and the adoption of levels of classification will be discussed under the appropriate sections in the results.

The Bray-Curtis dissimilarity coefficient was chosen to classify both species and site groups because of its sensitivity to dominance in the site classification and abundance in the species classification. D_{12} is a measure of dissimilarity between site 1 and 2 where X_{1j} and X_{2j} are the importance values for the jth species at each station and n is the total number of species found at the two stations.

$$D_{12} = \frac{\sum_{1}^{n} |X_{1j} - X_{2j}|}{\sum_{1}^{n} (X_{1j} + X_{2j})}$$

The transponse of the species-site matrix was used for species classification. The Bray-Curtis dissimilarity coefficient is constrained between 0 and 1 where 0 represents no dissimilarity between

species or site and 1 represents complete dissimilarity. The Bray-Curtis dissimilarity coefficient has been used by numerous benthic ecologists either directly, or in its standardized similarity form (Sanders, 1960; Dominance-affinity), or its presence-absence similarity form (Czekanowski 1909, Sorenson, 1948).

A square root transformation for site classification was chosen to increase the importance of rarer species in the analysis without unduly reducing the importance of the dominant species. Site classification was also attempted using no transformation with standardization and $\log(x + 1)$ and presence and absence transformations without standardization, which did not change the results appreciably. Apparently the rarer species had the same distribution patterns as the dominant species. A square root transformation was also used in the species classification to reduce the effects of high values of individual species at certain sites due to patchiness.

Data used for species classification were standardized (species values at each site divided by sum of species values at all sites, i.e. proportions) after transformation because of the interest in similar patterns in the relative distribution of species as opposed to absolute abundances. Without standardization the classification techniques would group species together based on overall abundances (i.e. rare species together and abundant species together) which provides little ecological information. The data used for site classification were not

standandized because the absolute differences in abundance of species between different sites was considered an important criterion for site classification. Several other resemblance functions such as chord distance (Orloci, 1967), percentage similarity (Sanders, 1960) and the Canberra metric (Stephenson et al. 1972) are self-standardizing and were not used since absolute differences were considered to be important.

Both species-species and site-site resemblance matrices were clustered using a group-average sorting strategy. This strategy is an agglomerative, polythetic, hierarchical clustering strategy in which sites or species are successively joined based on the smallest mean dissimilarity value between individual stations or species or groups of stations or groups of species already joined. This strategy was chosen because it is monotonic (no reversals), space conserving and little prone to misclassification (Lance and Williams, 1967).

Classification is a popular method of analysis for multivariate data in many different scientific fields (Anderberg, 1973). Recent reviews by Jardin and Sibson (1971), Sneath and Sokal (1973), Anderberg (1973), Orloci (1975), and Clifford and Stephenson (1975) indicate there is no general agreement on which is the "best" method for use with any particular set of data. The classification techniques used in this thesis have been used successfully by other benthic ecologists in recent years (Field and MacFarlane, 1968; Field, 1969,

1970, 1971; Day et al., 1971; Stephenson, 1972; Stephenson et al., 1975; Richardson et al., 1976; and others).

Community Structure

Structural parameters used to characterize sites included density, dominant species and diversity. Dominant species were determined by a ranking procedure (Fager, 1957), where the most abundant species at a site was given a value 10, the next 9, and so on. The ranks were summed for each site considered and divided by the total number of sites summed. The resultant Biological Index (B. I.) includes both frequency of occurrence and abundance in determining dominant species.

Diversity was calculated from the Shannon and Weaver (1963) information function: $H' = P_i \log_2 P_i$ where P_i is the proportion of individuals in a collection belonging to the ith species (Pielou, 1975). Lloyd and Ghelardi (1964) have shown that diversity values are sensitive to two components, the number of species in a sample (species richness) and the distribution of individuals among species (evenness). Species richness was estimated by: SR = (S-1) Ln N, where S is the number of species and N is the number of individuals in a collection (Margalef, 1958). Evenness was computed as $J' = H'/\log_2 S$, where H' is the Shannon-Weaver diversity and S is the number of species in a collection (Pielou, 1966).

Diversity indices have recently been criticized because of their lack of biological meaning, sample size dependence, and questionable mathematical properties (Hurbert, 1971; Goodman, 1975). It has been shown that by successively pooling replicate samples diversity values reach an asymptotic value which represents the actual diversity of the collection being sampled (Sanders, 1968; Pielou, 1975). Boesch (1971) and Richardson et al. (1976) have shown that five replicates contain an adequate number of individuals to estimate greater than 95 percent of the asymptotic value of H' diversity in a moderately diverse benthic assemblage. Richardson et al. (1976) have also shown the five replicates estimate greater than 90 percent of the (J') evenness values and 78 percent of the (SR) species richness values. The estimates of diversity, evenness and species richness in this study may be closer to their asymptotic values because of the high density of individuals found in Arthur Harbor.

Most of the criticism of diversity indices by biologists relates to the lack of biological process implicit in their calculation, their relationships to ecological theory and the use of cybernetic or thermodynamic analogies related to information based on diversity values. The relationship between diversity and ecological theory, especially diversity-stability concepts, has been criticized by Goodman (1975).

It is probably true that high species diversity does not beget community stability (either persistence or constancy) but the relationships between environmental stability, time, productivity, etc., and diversity still need investigation. As suggested by Hurlbert (1971) and others, a species' importance to community structure may not be related to its abundance, biomass or productivity (see Paine 1966; Dayton et al., 1974). I do not intend to imply cybernetic or thermodynamic overtones in deriving diversity values, but rather that diversity values be considered as attempts to represent the number of species and the distribution of individuals among species in a given area in a quantitative manner. Biological process is not a necessary attribute of diversity indices when used to quantify these relationships.

RESULTS

General

The 69 grab samples yielded 167,853 individuals, 78,395 of which were retained on a 1.0 mm screen. The 78,395 individuals were separated into 282 taxa. Nemerteans, oligochaetes, nematodes, capitellid polychaetes and Oradarea spp. amphipods were not identified at the species level. A species list is presented in Appendix I, including species codes used in this study. A second species list with species codes in numerical order is also included.

The 1.0 mm fraction consisted of the following: 108 species of annelids, 54.4% of the individuals; 117 species of arthropods, 30.3%; 35 species of molluscs, 11.3% and 22 species of other phyla, 4.0%. When all 167,853 individuals were considered the following percentages of major taxa were found: annelids, 62.6%; arthropods, 22.8%; mollusca, 9.8% and other phyla, 4.8%.

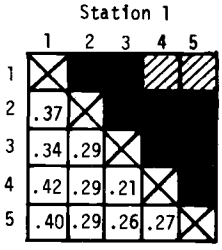
The numerically most abundant species collected from the study were the polychaete, Apistobranchus typicus (11,336 individuals found in 56 grabs); followed by Oligochaetes (7,854/65); the bivalve, Mysella minuscula (6,578/30); the polychaete, Ammotrypane syringopyge (6,072/58); the cumacean, Eudorella gracilior (4,472/59; the amphipod, Cheirimedon femoratus (3,297/11); the polychaete, Tharyx cincinnatus (3,418/56); the polychaete, Rhodine loveni (3,080/48); the tanaid,

Nototanais antarcticus (2, 728/34); the polychaete, Maldanidae sp. #7 (2, 373/53); the amphipod, Gammaropsis n. sp. (2, 338/38); Nematoda (1, 733/65); the polychaete, Paraonis gracilis (1, 552/54); the amphipod, Djerboa furcipes (1, 504/5); the amphipod, Heterophoxus videns (1, 482/49); the bivalve, Yoldia eightsi (1, 443/52); the polychaete, Haploscoloplos kerguelensis (1, 378/62); the amphipod, Methalimedon nordenskjoldi (1, 121/26); the amphipod, Ampelisca bouvieri (856/43); and the polychaete, Oriopsis sp. #64 (763/9).

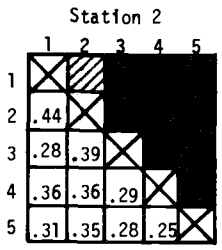
Within Station Variability

Bray-Curtis dissimilarity values were calculated between replicate grabs at each station (Figure 3) to determine within station variability. Values less than 0.40 indicate a high degree of similarity between grabs; 0.40 to 0.50, a moderate degree of similarity; greater than 0.50 a low degree of similarity. These values were consistent with values calculated by Richardson et al. (1976) for replicate grabs obtained from a homogeneous area off the mouth of the Columbia River, U.S.A. Stations 1, 2, 5, 8, 9, and 10 had high to moderate degree of similarity between all replicate grabs. If one replicate is excluded from stations 6, 7, 11, 12, 13, and 14, those stations also had a high to moderate degree of similarity between replicate grabs.

Figure 3. Dissimilarity between replicates at each station shown by Trellis diagrams of Bray-Curtis values between all possible pairs of replicate samples at each station (<40, high similarity, 40-50 moderate similarity, and >50 low similarity). Mean Bray-Curtis dissimilarity values with and without eliminated samples.



$\bar{x}$ = .31



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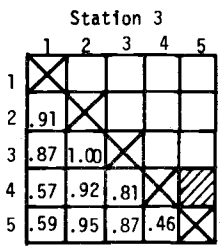
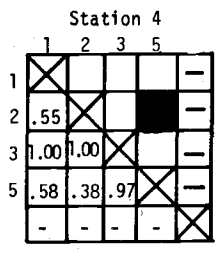
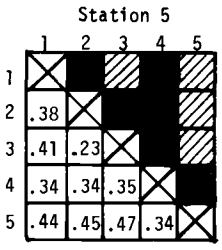


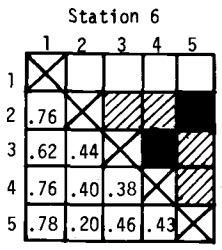
$\bar{x}$ = .54 (.80)



$\bar{x}$ = .50 (.75)



$\bar{x}$ = .38



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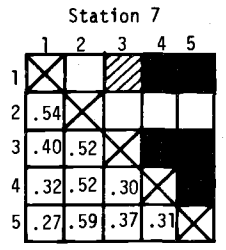
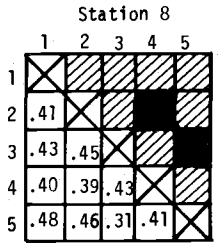
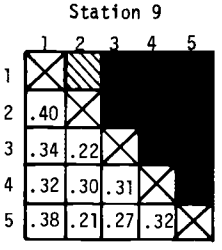


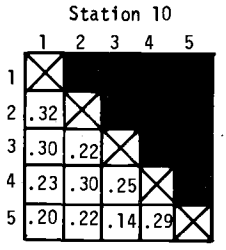
$\bar{x}$ = .33 (.41)



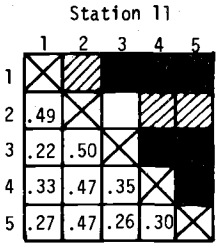
$\bar{x}$ = .42



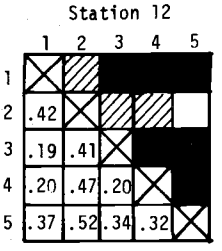
$\bar{x}$ = .31



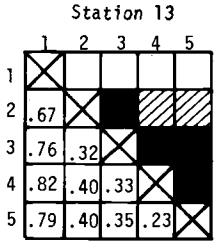
$\bar{x}$ = .28



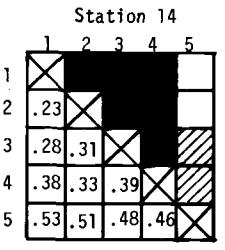
$\bar{x}$ = .28 (.36)



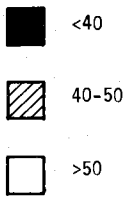
$\bar{x}$ = .27 (.34)



$\bar{x}$ = .34 (.51)



$\bar{x}$ = .32 (.39)



The debris from replicates 6(1) and 13(1) consisted of large volumes of broken macroalgae, and the debris from replicates 7(2) and 11(2) consisted of reduced black sediment with a slight H_2S odor. No difference in substrate or debris was noted between 12(5) and 14(5) and other replicates at those stations.

Stations 3 and 4 had low similarity between all replicates pairs. Replicate 3(2) contained five individuals distributed among five species, replicate 3(3) (10/8), and replicate 4(3)(2/2). The low numbers of individuals and species was probably a result of poor collection by the grab on the deep rocky substrate. The remaining low similarity may be a result of the patchy distribution of species in this heterogeneous environment (soft substrate between rocky outcroppings).

On the basis of the above analysis one replicate from stations 4, 6, 7, 11, 12, 13, and 14 and two replicates from station 3 were eliminated from those stations and a new station x species data matrix was constructed. This new data matrix was used for all station data analysis.

Community Structure

Community structure values, including number of individuals per grab (N), number of species (S), diversity (H'), species richness (SR), and evenness (J'), for each replicate are presented in Table 2.

Table 2. Values of community structure parameters for each replicate sample, including number of individuals (N), diversity (H'), evenness (J'), species richness (SR), and number of species (S).

Station (Replicate)	N	H'	J'	SR	S
1(1)	349	3.45	0.67	5.98	36
1(2)	622	3.92	0.72	6.53	43
1(3)	852	3.39	0.65	5.48	38
1(4)	1171	3.41	0.63	5.94	43
1(5)	1151	3.38	0.62	5.96	43
2(1)	908	4.85	0.78	10.86	75
2(2)	852	3.33	0.58	7.86	54
2(3)	1160	4.41	0.73	9.50	68
2(4)	1076	3.85	0.66	7.88	56
2(5)	805	4.04	0.74	6.58	45
3(1)	89	5.10	0.93	9.80	45
*3(2)	5	2.32	1.00	2.49	5
*3(3)	10	2.92	0.97	3.04	8
3(4)	153	4.36	0.81	7.95	41
3(5)	206	4.18	0.79	7.32	40
4(1)	58	3.93	0.87	5.42	23
4(2)	165	4.67	0.85	8.81	46
*4(3)	2	1.00	1.00	1.44	2
4(5)	168	4.50	0.83	8.20	43
5(1)	383	2.76	0.59	4.04	25
5(2)	557	2.43	0.56	3.01	20
5(3)	601	2.80	0.59	4.06	27
5(4)	386	3.50	0.70	5.21	32
5(5)	598	3.58	0.65	6.88	45

Table 2. Continued.

Station (Replicate)	N	H'	J'	SR	S
*6(1)	1052	3.00	0.49	4.89	35
6(2)	1293	2.53	0.49	4.75	35
6(3)	357	3.84	0.75	5.61	34
6(4)	409	3.49	0.69	5.49	34
6(5)	1319	3.07	0.60	4.59	34
7(1)	1230	3.44	0.66	5.06	37
*7(2)	282	3.27	0.67	5.14	30
7(3)	754	3.22	0.64	4.68	32
7(4)	1622	3.54	0.68	5.01	38
7(5)	1912	3.33	0.63	4.90	38
8(1)	399	2.81	0.58	4.68	29
8(2)	136	2.29	0.55	3.46	18
8(3)	308	1.13	0.28	2.79	17
8(4)	254	1.90	0.42	4.15	24
8(5)	319	0.75	0.19	2.43	15
9(1)	817	3.13	0.59	5.82	40
9(2)	1839	3.85	0.66	7.58	58
9(3)	1598	3.52	0.60	7.59	57
9(4)	1108	3.58	0.65	6.56	47
9(5)	1841	3.54	0.62	6.78	52
10(1)	2238	2.72	0.51	5.06	40
10(2)	2483	3.49	0.62	6.14	49
10(3)	2036	3.31	0.59	6.17	48
10(4)	2956	2.45	0.50	5.38	44
10(5)	2287	3.23	0.59	5.68	45

Table 2. Continued.

Station (Replicate)	N	H'	J'	SR	S
11(1)	1223	3.84	0.69	6.75	49
*11(2)	749	2.05	0.43	4.08	28
11(3)	1324	3.79	0.68	6.40	47
11(4)	444	3.83	0.73	6.07	38
11(5)	901	3.56	0.66	6.17	43
12(1)	1447	4.02	0.70	7.15	53
*12(2)	3119	2.67	0.46	7.09	58
12(3)	1792	4.08	0.69	8.14	62
12(4)	1712	4.12	0.73	6.72	51
12(5)	1301	3.44	0.62	6.28	46
*13(1)	5265	1.90	0.32	7.49	65
13(2)	1435	4.49	0.71	11.01	81
13(3)	1219	3.56	0.62	7.46	54
13(4)	1670	3.37	0.62	5.80	44
13(5)	1496	3.52	0.63	6.43	48
14(1)	1715	2.90	0.49	7.52	57
14(2)	1727	3.29	0.57	7.11	54
14(3)	2239	2.57	0.46	5.96	47
14(4)	2660	3.46	0.62	6.09	49
*14(5)	1781	3.44	0.62	6.15	47

*Sample excluded from station analysis

The replicates eliminated from the station analysis are marked with an asterisk.

Replicates 3(2), 3(3), and 4(3) had much lower values of all community structure parameters than other replicates at those stations. The low diversity values from replicates 12(2) and 13(1) were a result of low evenness and rather than reduced species richness. Replicate 11(2) had lower diversity because of reduced species richness and evennes. Community structure parameters calculated from replicates 6(1), 7(2) and 14(5) were similar to those calculated from replicates at the same station, but these replicates differed in the rank order of species abundance and/or species composition as indicated by Bray-Curtis dissimilarity values.

The values of community structure parameters for summed stations are presented in Table 3. Mean values of diversity (H') and evenness (J') calculated from each of the replicates included are generally within 10% of values calculated from summed stations (Table 4), indicating that diversity and evenness values rapidly approach the asymptotic values for the stations, eliminating sample size dependence. Mean values of species richness (SR) and species (S) calculated from replicates are lower than values calculated from summed stations (ratio, $0.\overline{70}$ for SR, $0.\overline{58}$ for S). The values for S probably do not approach the asymptote with five replicates and therefore are poor estimates of the number of species per station.

Table 3. Values of community structure parameters for each station (replicates combined), including mean number of individuals per m^2 (N/m^2), diversity (H'), evenness (J'), species richness (SR), and number of species (S).

Station	N/m^2	H'	J'	SR	S
1	11,842	3.69	0.60	8.52	72
2	13,717	4.43	0.65	13.45	115
3	2,137	4.89	0.78	12.78	79
4	1,866	4.85	0.80	10.89	66
5	7,214	3.39	0.57	8.04	64
6	12,064	3.30	0.58	6.15	51
7	19,707	3.67	0.64	6.15	54
8	4,046	2.02	0.37	5.65	42
9	20,580	3.78	0.59	9.34	84
10	34,286	3.15	0.50	8.09	77
11	13,900	3.86	0.62	8.85	74
12	22,329	4.15	0.65	9.27	82
13	20,786	3.99	0.60	11.77	103
14	29,796	3.35	0.53	8.97	82

Table 4. Ratio of mean values of community structure parameters for replicate samples at each station to values for each station (replicates combined), including diversity (H'), evenness (J'), species richness (SR), number of species (S).

Station	H'	J'	SR	S
1	0.95	1.10	0.70	0.56
2	0.93	1.08	0.63	0.60
3	0.91	1.08	0.65	0.53
4	0.90	1.06	0.69	0.57
5	0.89	1.09	0.58	0.47
6	0.98	1.09	0.83	0.67
7	0.92	1.02	0.80	0.64
8	0.88	1.08	0.62	0.49
9	0.93	1.05	0.74	0.60
10	0.97	1.12	0.70	0.59
11	0.97	1.11	0.72	0.60
12	0.94	1.06	0.76	0.65
13	0.94	1.07	0.65	0.55
14	0.91	1.00	0.74	0.63
Mean	.93	1.07	.70	.58

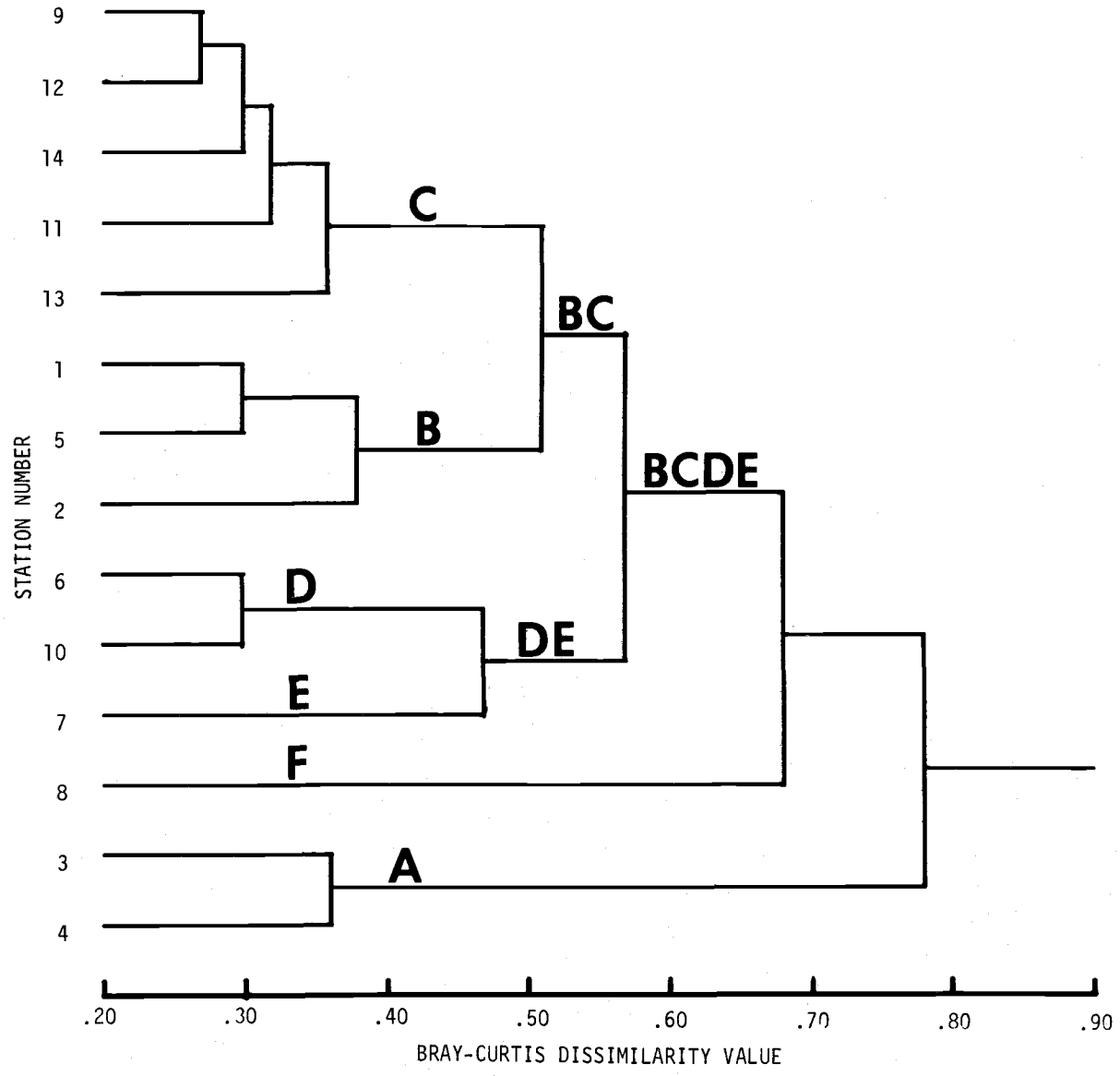
Values of SR for summed stations may be less than the asymptotic values for stations but are acceptable estimates. To test this hypothesis, values of S and SR were calculated for summed stations in assemblage C (see next section) which had similar values for community structure parameters (stations 9, 11, 12, 14). The species richness value for the summed stations was 11.52 which was 80% of the mean species richness values for those stations, and the number of species for summed stations was 118 which was 68% of the mean number of species per station.

Almost identical results for comparison of summed and mean values of community structure parameters were found by Richardson et al. (1976) for benthic samples collected in a homogeneous area off the mouth of the Columbia River, U.S.A.

Benthic Assemblages

The 14 stations occupied in this study were clustered into six site groups (Figure 4). Stations were fused to form site groups at less than 0.40 Bray-Curtis units, which indicated a high degree of similarity between stations. Assemblages B and C fused at 0.51 units and D and E at 0.47 units. The same site groups were formed by classification of the 69 individual samples (Figure 5). Replicate samples which had been eliminated from the station analysis fused with site groups at high Bray-Curtis values which supports

Figure 4. Dendrogram of site groups based on group-average sorting of Bray-Curtis dissimilarity values between all possible pairs of stations (station-species matrix).


9
12
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10
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3
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STATION NUMBER
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B
BCDE
D
DE
E
F
A
.20
.30
.40
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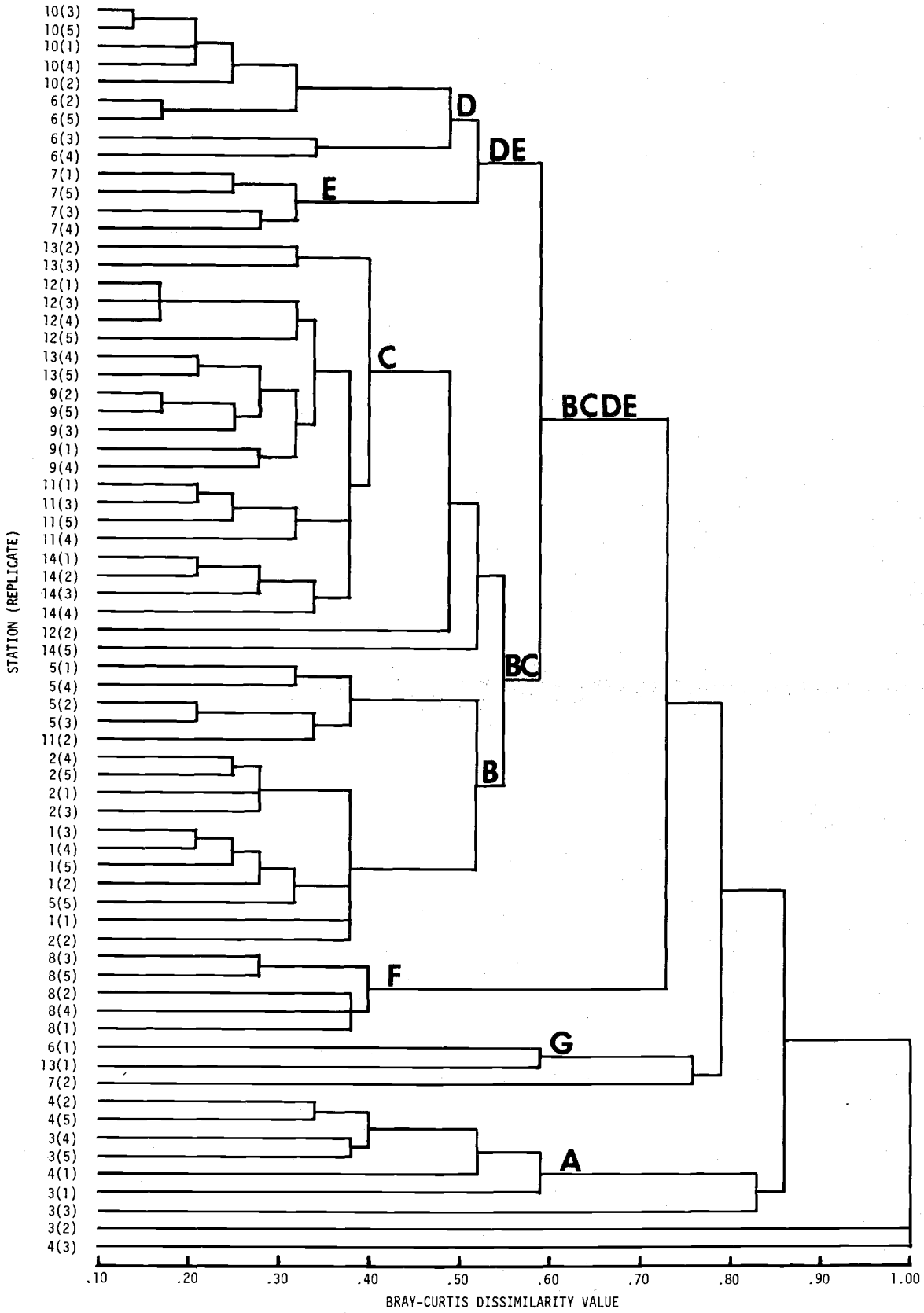
.60
.70
.80
.90
BRAY-CURTIS DISSIMILARITY VALUE

Figure 5. Dendrogram of site groups based on group-average sorting of Bray-Curtis dissimilarity values between all possible pairs of samples (sample-species matrix).


10(3)
10(5)
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3(4)
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3(1)
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3(2)
4(3)
D
DE
E
C
BCDE
BC
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G
A
STATION (REPLICATE)
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.30
.40
.50
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1.00
BRAY-CURTIS DISSIMILARITY VALUE

elimination of those samples. Replicate samples 6(1) and 13(1), which contained broken macroalgae, fused at 0.59 Bray-Curtis units and were designated site group G.

Fusion levels for station site groups were lower than for sample site groups (Table 5). By combining replicate grabs at one site to form a station, the effect of patchiness was reduced and the similarity between stations in the same assemblage was increased. The difference in fusion levels for combined assemblages may also be a result of including replicates eliminated from the station classification in the sample classification.

Richardson et al. (1976) calculated Bray-Curtis dissimilarity values between 0.27 and 0.32 from four (5 grab/station) replicate stations at the same location off the mouth of the Columbia River. Assemblages were fused at between 0.40 and 0.60 Bray-Curtis units in the same study. If 0.60 was used as a fusion criterion, three assemblages (BCDE, A, and F) would have been formed from the Arthur Harbor data, and if 0.51 was used four assemblages (BC, DE, F, and A) would have been formed. The 0.40 criterion was used for fusion of assemblages in this study because of the small areal coverage of the samples.

In the following paragraphs each site group is described, in terms of dominant species, density and diversity. Values for station density and diversity were presented in Table 3, and environmental

Table 5. Comparison of fusion levels (Bray-Curtis dissimilarity values) for assemblages as determined by station-species and sample-species classification.

Assemblage	Fusion Level		
	Stations	Samples	Sample/Station
A	0.36	0.59	1.64
B	0.38	0.52	1.36
C	0.36	0.42	1.16
D	0.30	0.49	1.63
E	--	0.32	--
F	--	0.42	--
G	--	0.59	--
BC	0.51	0.55	1.07
DE	0.47	0.52	1.11
BCDE	0.57	0.62	1.09
BCDEF	0.68	0.73	1.07
ABCDEF	0.78	0.86	1.10

data were presented in Table 1.

Assemblage A (stations 3 and 4)

Assemblage A was located 300-700 m deep in the Bismark Strait. The animals were collected from small patches of poorly sorted clayey silt and sand-clay silt sediment found in a primarily rocky substrate. Dominant species included the oligochaete Torodrilus lowryi; nematodes; the polychaetes Myrioglobula antarctica, Prionospio sp. #85, Sternaspis scutata, and Aedicira belgicae; the ophiuroid Amphioplus acutus; and the bivalve Thyasira falklandica (Table 6). The mean density, 1,605 individuals/m^2 was lower than other assemblages whereas, the values of diversity, species richness and evenness were higher (Table 3).

Assemblage B (stations 1, 2, 5)

Assemblage B was located in the channel between Torgerson Island and Palmer Station (50 to 75 m deep). The sediment was poorly sorted and mostly silt. Dominant species included the oligochaete Torodrilus lowryi, the polychaete Tharyx cincinnatus and the cumacean Eudorella gracilior (Table 7). Other common species included the polychaetes Haploscoloplos kerguelensis, Apistobranchus typicus, Maldanidae sp. #7, Paraonis gracilis and Ammotrypane syringopyge, and the cumacean Vaunthompsonia meridionalis. The

Table 6. Dominant species in Assemblage A as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

Species Code	Species	BI	f(6 samples)	$\bar{N}/m^2$
218	Torodrilus lowryi	8.92	6	271
219	Nematoda	8.00	6	298
140	Myrioglobula antarctica	7.08	6	162
196	Prionospio sp. #85	6.08	6	138
146	Sternaspis scutata	5.66	6	107
147	Aedicira belgicae	4.08	6	76
93	Amphioplus acutus	3.00	6	57
66	Thyasira falklandica	2.91	6	62

Table 7. Dominant species in Assemblage B as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

Species Code	Species	BI	f(15 samples)	$\bar{N}/m^2$
218	Torodrilus lowryi	8.46	15	2170
131	Tharyx cincinnatus	8.40	15	1959
102	Eudorella gracilior	7.50	15	1404
132	Haploscoloplos kerguelensis	5.30	15	580
133	Apistobranchus typicus	4.40	15	779
118	Maldanidae sp. #7	3.60	15	379
104	Vaunthompsoni meridionalis	3.53	13	468
134	Paraonis gracilis	2.60	15	332
130	Ammotrypane syringopyge	2.23	13	320

mean density for assemblage B was 10,925 individuals/m^2. Species richness and evenness values followed a similar trend with depth.

Assemblage C (stations 9, 11, 12, 13, 14)

Assemblage C was located in the central basin of Arthur Harbor at depths of 18 to 43 m. Sediment types were variable with an increased amount of sand size particles at several of the stations. The dominant species were the polychaetes Apistobranchus typicus, and Ammotrypane syringopyge and the oligochaete Torodrilus lowryi (Table 8). Also common were the polychaetes Maldanidae sp. #7, Rhodine loveni, Paraonis gracilis and Haploscoloplos kerguelensis; nematodes; the cumacean Eudorella gracilior; the tanaid Nototanais antarcticus; and the amphipods Heterophoxus videns, Ampelisca bouvieri and Methalimedon nordenskjolki. The mean density of individuals was 21,434 individuals/m^2. The mean values of H' diversity (3.8), species richness (9.64) and evenness (0.59) were relatively constant throughout this assemblage.

Assemblage D (stations 6, 10)

Assemblage D was located in shallow water (15 to 18 m) near Antenna Point. The sediment was a poorly sorted sandy silt. Dominant species were the polychaete Ammotrypane syringopyge and the bivalve Mysella minuscula (Table 9). The bivalve Yoldia eightsi; the

Table 8. Dominant species in Assemblage C as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

Species Code	Species	BI	f(21 samples	$\bar{N}/m^2$
133	Apistobranchus typicus	9.62	21	6607
218	Torodrilus lowryi	8.21	21	3120
130	Ammotrypane syringopyge	5.76	21	1435
118	Maldanidae sp. #7	3.95	21	866
116	Rhodine loveni	3.83	21	932
219	Nematoda	3.02	21	760
102	Eudorella gracilior	2.90	21	759
108	Nototanais antarcticus	2.74	15	855
134	Paraonis gracilis	2.69	21	661
233	Heterophoxus videns	2.14	21	529
234	Ampelisca bouvieri	2.07	17	381
254	Methalimedon nordenskjoldi	2.04	18	565
132	Haploscoloplos kerguelensis	1.57	21	378

Table 9. Dominant species in Assemblage D as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

Species Code	Species	BI	f(9 samples)	$\bar{N}/m^2$
130	Ammotrypane syringopyge	9.11	9	4549
63	Mysella minuscula	8.89	9	9802
57	Yoldia eightsi	5.83	9	1327
102	Eudorella gracilior	5.78	9	1751
116	Rhodine loveni	4.44	9	1163
118	Maldanidae sp. #7	3.56	8	870
133	Apistobranchus typicus	2.88	9	427
188	Ophryotrocha claparedii	2.44	9	368
77	Philomedes orbicularis	2.27	5	594
233	Heterophoxus videns	2.00	9	408
243	Monoculodes scabriculous	1.78	9	332

cumacean Eudorella gracilior; the polychaetes Rhodine loveni, Maldanidae sp. #7, Apistobranchius typicus and Ophryotrocha claparedii; and the amphipods Heterophoxus videns and Monoculodes scabriculous were also common. The ostracod Philomedes orbicularis was a common species found at station 10 but not station 6. The mean density was 24, 409 individuals/m^2 with higher density at station 10 (34, 286) than station 6 (12, 064). Diversity, species richness and evenness values were only moderately high.

Assemblage E (station 7)

Assemblage E was located at the head of Hero Inlet in 5-7 m of water. The sandy silt sediments were poorly sorted. Dominant species included the tanaid Nototanais antarcticus; the cumacean Eudorella gracilior; the only large concentration of the burrowing anemone Edwardsia sp.; the polychates Rhodine loveni, and Ammotrypane syringopyge; the amphipods, Heterophoxus videns, and Methalimedon nordenskjoldi; and the bivalves Yoldia eightsi and Mysella minuscula (Table 10). The mean density was 19, 707 individuals/m^2. Diversity was high in spite of the low species richness value because of an even distribution of individuals among species.

Assemblage F (station 8)

Assemblage F was located in 50 m depth very near the glacial

Table 10. Dominant species in Assemblage E as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

Species Code	Species	BI	f(4 samples)	$\bar{N}/m^2$
108	Nototanais antarcticus	8.25	4	4289
102	Eudorella gracilior	7.75	4	2229
76	Edwardsia sp.	7.50	4	2150
116	Rhodine loveni	7.00	4	2686
130	Ammotrypane syringopyge	6.00	4	2046
233	Heterphoxus videns	5.50	4	1329
57	Yoldia eightsi	4.00	4	1021
254	Methalimedon nordenskjoldi	3.25	4	757
63	Mysella minuscula	2.25	4	671

face and was exposed to glacial calving. Tharyx cincinnatus, a polychaete, was the overwhelmingly dominant species, accounting for 72% of the total number of individuals in this assemblage (Table 11). The cumacean Eudorella gracilior; the bivalve Mysella minuscula; the amphipods Ampelisca bouvieri and Heterophoxus videns; the polychaete Apistobranchus typicus; and the tanaid Nototanais antarcticus were common but occurred in low numbers compared to Tharyx cincinnatus. The mean density, 4,045 individuals/m^2, was the lowest density of any assemblage in Arthur Harbor. The diversity, species richness and evenness values were much lower than in other assemblages.

Assemblage G [replicates 6(1), 13(1)]

Assemblage G included two grab samples characterized by a large volume of broken macroalgae. Dominant species included the amphipods, Djerboa furcipes, Schraderia gracilis, Oradarea spp., and Cheirimedon fermoratus; nematodes; and the polychaete Ophryotrocha claparedii (Table 12). Sample 6(1) had 15,028 individuals/m^2 and 13(1) had 75,214 individuals/m^2. Diversity values were 1.9 for grab 13(1) and 3.0 for 6(1). Differences between the two grabs included high numbers of individuals of Cheirimedon fermoratus found in grab 13(1) and not 6(1) and the absence of Ophryotrocha claparedii from grab 13(1).

Table 11. Dominant species in Assemblage F as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

Species Code	Species	BI	f(samples)	$\bar{N}/m^2$
131	Tharyx cincinnatus	10.00	5	2931
102	Eudorella gracilior	8.30	5	208
63	Mysella minuscula	5.40	4	54
234	Ampelisca bouvieri	4.70	5	103
233	Heterophoxus videns	4.00	3	131
133	Apistobranchus typicus	3.90	3	68
108	Nototanais antarcticus	3.70	4	54

Table 12. Dominant species in Assemblage G as determined by Fager's (1957) ranking procedure (Biological Index = BI), including frequency of occurrence (f), and mean number of individuals/m^2 ($\bar{N}/m^2$).

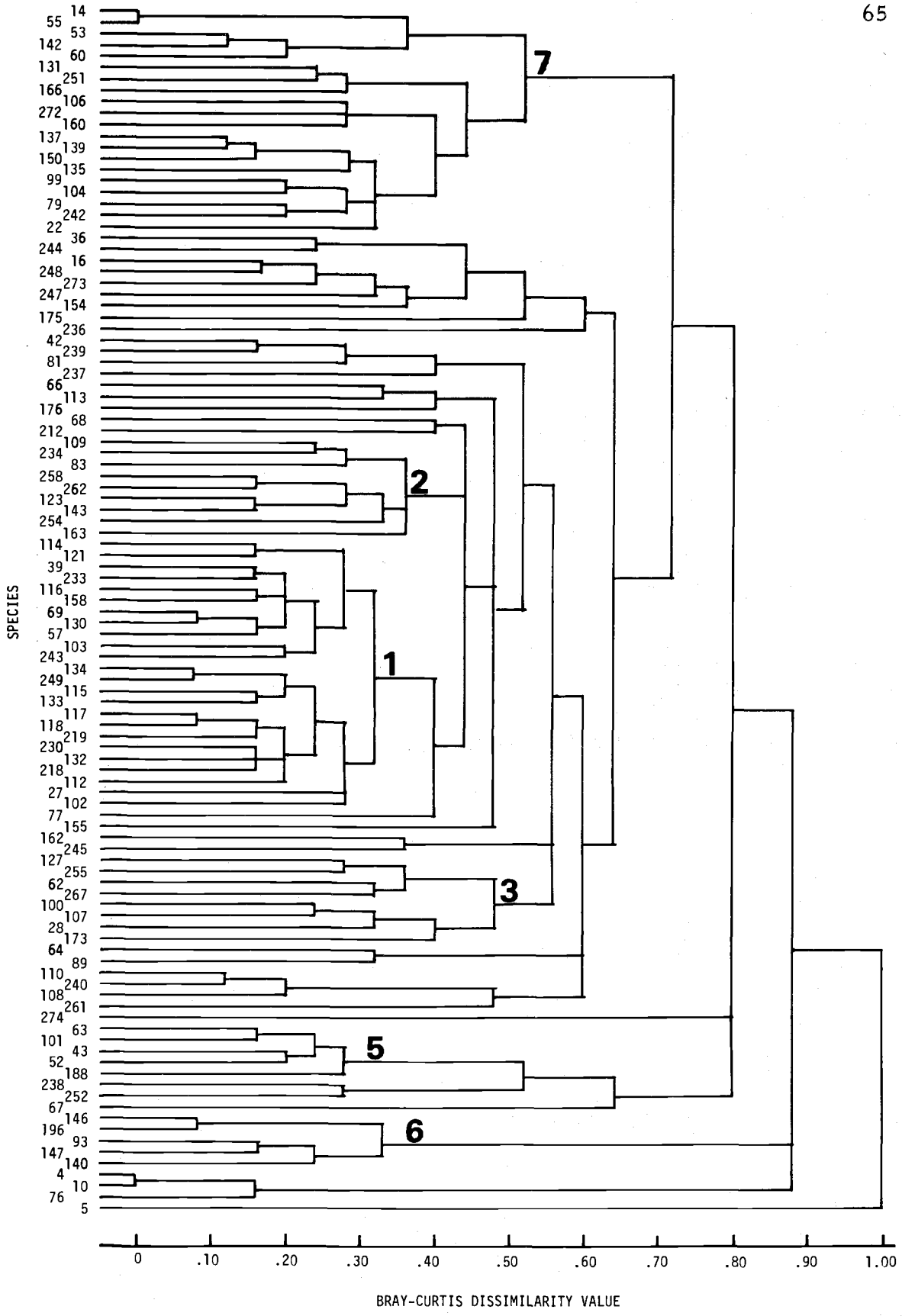
Species Code	Species	BI	f(2 samples)	$\bar{N}/m^2$
238	Djerboa furcipes	9.00	2	10,700
248	Schraderia gracilis	7.00	2	1650
247	Oradarea spp.	6.50	2	1471
219	Nematoda	5.50	2	678
237	Cheirimedon femoratus	5.00	2	23,400
188	Ophryotrocha claparedii	5.00	1	2521

Species Classification

Classification of 282 species with the present techniques was beyond the computational capacity of the CDC CYBER, therefore some form of species reduction was necessary. It has been noted by several authors that rare species carry little classificatory information (Boesch, 1973; Stephensen et al., 1975). In general species that occurred in less than 5 grabs or species represented by less than 20 individuals were excluded. Seven species which were represented by less than 20 individuals but occurred at more than 4 stations were not excluded. Three additional rare species were inadvertently left in the analysis. The 107 species chosen for species classification comprised 99% of the total number of individuals in the study.

Species were classified on the basis of their abundance in separate grabs (sample x species matrix) and their abundance at each station (station x species matrix). Dendrograms from the two analyses (Figures 6, 7) were compared to site groups with two-way coincidence tables [the original site-species data matrices, with the sites and species rearranged in the same order as the site and species dendrograms (Stephensen et al., 1970)] to determine species groups. Because of the difference between the two dendrograms a certain amount of reallocation was necessary especially in the station X

Figure 6. Dendrogram of species groups based on group-average sorting of Bray-Curtis dissimilarity values between all possible pairs of species (station-species matrix).


SPECIES
14
55 53
142 60
131 251
166 106
272 160
137 139
150 135
99 104
79 242
22 36
244 16
248 273
247 154
175 236
42 239
81 237
66 113
176 68
212 109
234 83
258 262
123 143
254 163
114 121
39 233
116 158
69 130
57 103
243 134
249 115
133 117
118 219
230 132
218 112
27 102
77 155
162 245
127 255
62 267
100 107
28 173
64 89
110 240
108 261
274 63
101 43
52 188
238 252
67 146
196 93
147 140
4 10
76 5
7
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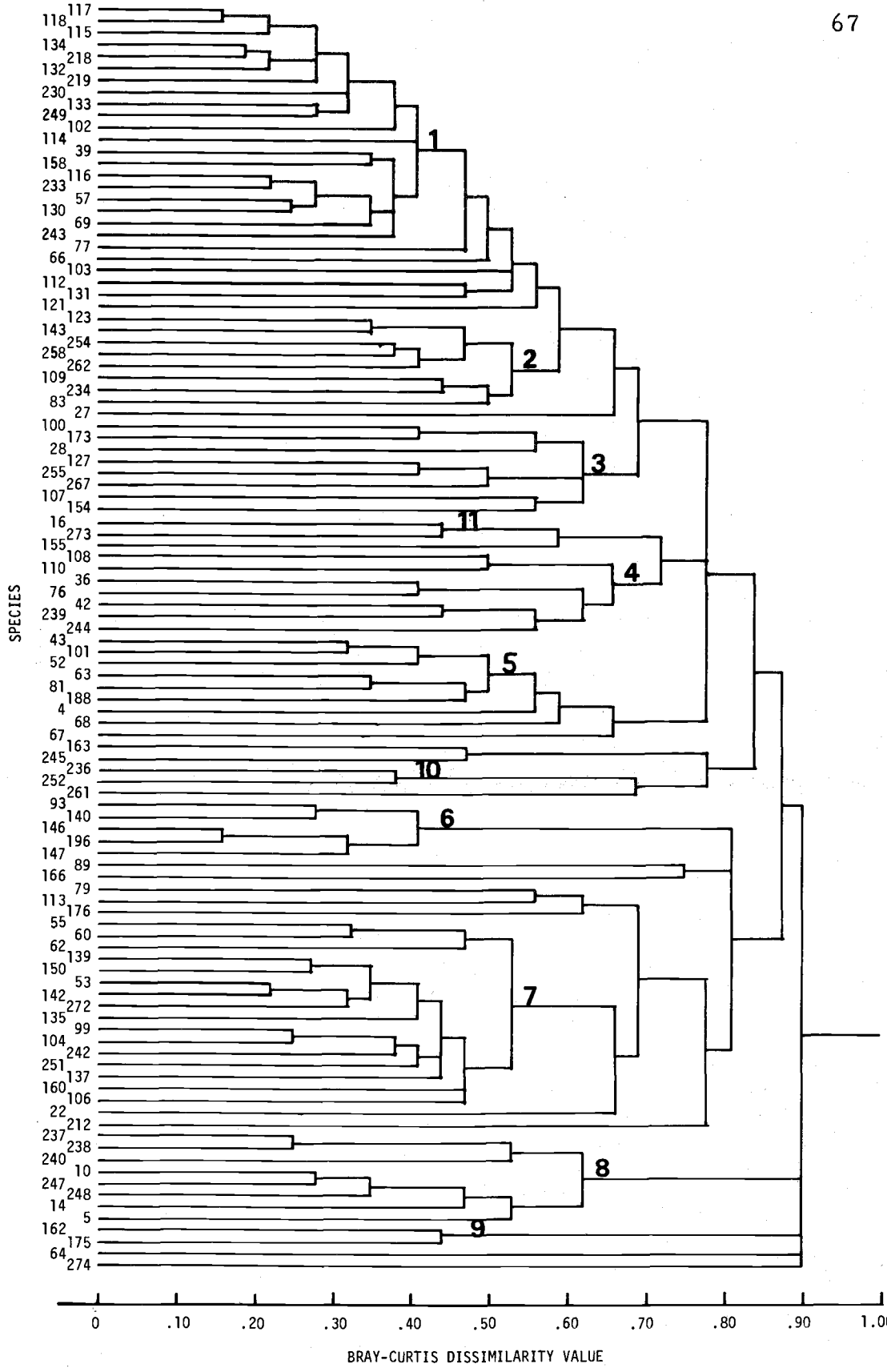
1.00
BRAY-CURTIS DISSIMILARITY VALUE

Figure 7. Dendrogram of species groups based on group-average sorting of Bray-Curtis dissimilarity values between all possible pair of species (sample-species matrix).


SPECIES
117
118 115
134 218
132 219
230 133
249 102
114 39
158 116
233 57
130 69
243 77
66 103
112 131
121 123
143 254
258 262
109 234
83 27
100 173
28 127
255 267
107 154
16 273
155 108
110 36
76 42
239 244
43 101
52 63
81 188
4 68
67 163
245 236
252 261
93 140
146 196
147 89
166 79
113 176
55 60
62 139
150 53
142 272
135 99
104 242
251 137
160 106
22 212
237 238
240 10
247 248
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BRAY-CURTIS DISSIMILARITY VALUE

species dendrogram. Four species groups (8, 9, 10, 11) were present only in the sample x species dendrogram because the species which comprised them were abundant only in the grab samples eliminated from the stations (see section on within station variability). Species groups 1, 2, 3, 5, 6, 7 were found in both dendrograms and were accepted with little modification. Species group 4 was only present in the sample x species dendrogram.

Seventeen species, which were not included in any species group had wide distributions, and were therefore included as additional species to species group 1. The seven remaining species were not included in any species group.

In the following paragraphs each species group is described. The areal distribution is given along with the dominance, constancy, fidelity, and percent abundance of each species within the areal distribution pattern, where appropriate.

Species Group 1

Species group 1 consisted of 20 species which were widely distributed over the entire study area (Table 13). Included in this group were 11 of the 16 species which had rank dominance values greater than 1.0 for the 66 grab samples (3 poorly collected replicates at station 3 and 4 excluded). All species occurred in more than half of the grabs (77% mean) and at least 10 of the 14 stations (89%

Table 13. Species group 1 (wide-ranging species), including number of individuals/m^2 (N/m^2), Biological Index (BI) and percent occurrence in samples, stations and assemblages for each species.

Species Code	Species	N/m^2	BI	Percent Occurrence		
				Sample (67)	Stations (14)	Assemblages (7)
117	Axiothella antarctica	530	0.38	73	93	71
118	Maldanidae sp. #7	2373	2.71	80	86	86
115	Lumbriclymenella robusta	476	0.06	71	86	71
134	Paraonis gracilis	1552	1.52	82	93	86
218	Torodrilus lowyri	7854	5.98	97	100	100
132	Haploscoloplos kerguelensis	1378	2.09	94	100	100
219	Nematoda	1733	2.19	97	100	100
230	Nemertea	471	0.40	88	100	100
133	Apistobranchus typicus	11336	5.03	85	86	86
249	Pseudharpinia n. sp. #17a	614	0.50	65	71	57
102	Eudorella gracilior	4472	4.62	89	93	100
114	Capitella spp.	476	0.50	77	93	100
39	Priapulus tuberculatospinosus	158	0.10	62	86	86
158	Brania rhopalophora	142	0.09	55	79	86
116	Rhodine loveni	3080	2.54	73	86	86
233	Heterophoxus videus	1482	1.59	74	86	86
57	Yoldia eightsi	1443	1.16	79	93	86
130	Ammotrypane syringopyge	6072	4.26	88	93	100
69	Laternula elliptica	132	0	52	71	57
243	Monoculodes scabriculous	381	0.32	55	79	71

mean). All species occurred in assemblages B, C, D. Eight species were not found in the deepest assemblage (A) and seven species were not found in the 2 grabs with macroalgae combined to form assemblage G. Four species did not occur in assemblage F, the station affected by glacial activity, and only two species were not found at the shallowest assemblage E.

Four species were included in species group 1 in the station x species dendrogram but not the sample x species dendrogram. The four species, Brada villosa, Vaunthompsoni inermis, Aglaophamus ornatus and Echinozone spinosa, occurred at more than 9 of the 14 stations but less than half of the grabs (Table 14). Thirteen additional species, which were not placed in species groups, had wide distribution patterns (Table 14). These species did not fuse with species group 1 because of their low frequency and abundance.

Species Group 2

Species group 2 consisted of eight species primarily located in the central basin of Arthur Harbor (Assemblage C; 18-43 m). Methalimedon nordenskjoldi and Ampelisca bouvieri were the only dominant species in species group 2 (Table 15). The percentage abundance restricted to assemblage C ranged from 81-99% (mean 92%). All species had high constancy values (83%) except Goldfingia mawsoni which occurred in low abundance. Gammaropsis n. sp. which

Table 14. Additional wide ranging species not in species group 1, including number of individuals/m^2 (N/m^2), Biological Index (BI) and percent occurrence in samples, stations, and assemblages for each species.

Species Code	Species	N/m^2	BI	Percent Occurrence		
				Samples (67)	Stations (14)	Assemblages (7)
121	Brada villosa	104	0	48	93	86
103	Vaunthompsonia inermis	138	0.05	44	79	86
112	Aglasphamus ornatus	73	0.08	50	79	57
27	Echinozone spinosa	33	0	29	64	57
77	Philomedes orbicularis	601	0.31	53	72	57
66	Thyasira falklandica	160	0.21	59	93	71
155	Lumbrineris sp. #44	50	0	33	71	86
113	Amphictes gunneri antarctica	36	0	24	71	71
68	Thracia meridionalis	27	0	26	50	57
166	Tharyx epitoca	22	0	15	57	86
176	Kefersteinia cirrata	20	0.04	21	57	43
28	Echinozone magnifica	18	0	15	36	29
212	Exogone heterosetosa	18	0	12	43	43
79	Empoulsenia pentathrix	17	0	20	50	43
163	Eulalia subulifera	10	0	14	50	57
89	Nebaliella extrema	10	0	14	43	43
64	Genaxinus debilis	8	0	8	36	43

Table 15. Species group 2, including abundance, constancy, fidelity and Biological Index (BI) for each species in Assemblage C.

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
123	Barrukia cristata	97	74	94	0
143	Spiophanes sp. #32	98	96	88	0.5
254	Methalimedon nordenskjoldi	81	87	77	2.0
258	Paroediceroides sp. #26	92	91	68	0
262	Gammaropsis n. sp.	99	96	58	0.9
109	Leptognathia gracilis	94	70	73	0.2
234	Ampelisca bouvieri	89	83	44	2.2
83	Goldfingia mawsoni	89	52	67	0

occurred in low numbers in assemblages B, D, E and Ampelisca bouvieri which occurred in moderate numbers in assemblages B, C, E, F were the only species in this group with low fidelity values.

Species Group 3

Species group 3 consisted of eight species which were abundant at station 9. These species were also found in high numbers at stations 2, 12 and 13. None of the species were dominant at these stations (Table 16). The percentage abundance restricted to stations 2, 9, 12 and 13 ranged from 72 to 100% (91% mean). Constancy and fidelity values were only moderately high for most species indicating the frequency of occurrence in samples at these stations was not high and that these species occurred in low numbers in other samples. The only common factor between stations 2, 9, 12, 13 was high species richness (mean 11.0) and diversity (mean 4.09) value, which may be a result of the presence of these species at those stations.

Species Group 4

Species group 4 consisted of seven species which had their maximum abundance at station 7 (5-7 meters). Three of the species, Nototanais antarcticus, Edwardsia sp. and Prostebbingia gracilis, were dominant species at that station (Table 17). The constancy was 100% for all species except Nototanis dimorphus but the fidelity was

Table 16. Species group 3, including abundance, constancy, fidelity, and Biological Index (BI) for each species at stations 2, 9, 12, and 13.

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
100	Diastylis anderssoni	72	52	58	0
173	Octobranchus antarcticus	90	26	62	0
107	Leptognathia gallardoi	94	84	64	0.26
127	Maldane sarsi	94	68	62	0.37
255	Urothoe n. sp.	98	68	93	0
62	Cyamiocardium denticulatum	100	47	100	0.10
267	Harpiniopsis n. sp.	92	89	71	0
154	Paraonis sp. #43	91	47	81	0

Table 17. Species group 4, including abundance, constancy, fidelity and Biological Index (BI) for each species in Assemblage E.

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
108	Nototanais antarcticus	46	100	15	8.40
110	Nototanais dimorphus	32	60	30	0
36	Isopoda P sp. lunata	72	100	71	0
76	Edwardsia sp.	98	100	42	6.00
42	Laevilitorina umbilicata	36	100	26	0
239	Pontogeneia sp. #7	42	100	25	0
244	Prostebbingia gracilis	32	100	25	3.20

low. Only Edwardsia sp. and Isopoda N. genus P were restricted to station 7. The other species were found at other stations, especially the shallower stations 6, 10, 12, 13 and 14. This species group was determined from the species x grab dendrogram and was not found in the species x station dendrogram.

Species Group 5

Species group 5 consisted of six species primarily found in shallow water (Assemblages D and E; 5-18 m depth). Mysella minusula was a dominant species in assemblages D and E and Ophryotrocha claparedii was moderately dominant (Table 18). All species except Ophryotrocha claparedii had greater than 82 percent of their abundance restricted to assemblages D and E. If sample 6(1) is included, 93 percent of Ophryotrocha claparedii occurred within assemblages D and E. The mean percentage abundance restricted to assemblages D and E plus sample 6(1) was 92% (range 82-97%). These six species can be divided into two groups. Subonoba turqueti, Campylaspis maculata and Nucula n. sp. occurred in low numbers and had low constancy values and high fidelity values. Mysella minsula, Sclerochoncla gallardoi and Ophryotrocha claparedii occured in high numbers and had high constancy values but low fidelity values (i.e. they occurred in other assemblages).

Table 18. Species group 5, including abundance, constancy, fidelity and Biological Index (BI) for each species at stations 6, 7, and 10.

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
43	Subonoba turqueti	82	84	79	0.5
101	Campylaspis maculata	93	62	89	0
52	Nucula n. sp.	95	53	78	0
63	Mysella minuscula	97	100	43	6.8
81	Sclerochoncha gallardoi	90	100	43	0.7
188	Ophryotrocha claparedii	37 (93)*	85	41	1.7

* Including sample 6(1)

Species Group 6

Species group 6 consisted of 4 species of polychaetes and one ophiuroid that were primarily restricted to the deep-water assemblage A. All five species were dominant members of that assemblage as indicated by Biological Index values (Table 19). Sternaspsis scutata and Prionospio sp. #85 were restricted to assemblage A and occurred in every grab. Amphioplus acutus, Myrioglobula antarctica and Aedicira belgicae were also found in assemblage B (50-75 m) but in no other assemblage.

Species Group 7

Species group 7 consisted of 16 species (Table 20) found primarily at stations 1 and 2 and in replicate 5(5) which grouped with these two stations in the sample x species classification. Except for the cumacean Vaunthompsoni meridionalis, no species was dominant at those stations. All species except Ampelisca anversi, Pseudharpinia n. sp. #19 and Leaena sp. #49 had greater than 75% abundance restricted to these stations. Except for Yoldiella valettei and Pseudokellija cardiformis, which had 100% fidelity, all species had high constancy values. The low fidelity values indicated most species were not restricted to stations 1 and 2. Ammotrypane breviata was also abundant in assemblage A, the deepest assemblage.

Table 19. Species group 6, including abundance, constancy, fidelity and Biological Index (BI) for each species in Assemblage A.

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
93	Amphioplus acutus	80	83	63	3.0
140	Myrioglobula antarctica	30	100	60	7.1
146	Sternaspsis scutata	100	100	100	5.7
196	Prionospio sp. #85	100	100	100	6.1
147	Aedicira belgicae	76	100	60	4.1

Table 20. Species group 7, including abundance, constancy, fidelity and Biological Index (BI) for each species at stations 1, 2 and sample 5(1).

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
55	Yoldiella valettei	100	46	100	0
60	Pseudokellija cardiformis	100	64	100	0
22	Desmosoma #1	72	55	60	0
139	Lysilla loveni macintoshi	87	100	85	0
150	Ammotrypane breviata	87	100	69	0.3
53	Nuculana inaequisculpta	95	82	90	0
142	Aedicira sp. #31	99	100	85	1.40
272	Paroediceroides sinulata	89	82	69	0
135	Exogone minuscula	81	91	48	0.5
99	Leucon sagitta	89	100	39	1.7
104	Vaunthompsonia meridionalis	86	100	33	4.8
242	Ampelisca anversi	65	91	56	0
251	Pseudharpinia n. sp. #19b	56	91	59	0
137	Ampharete kerguelensis	77	73	73	0
160	Leaena sp. #49	63	91	33	1.0
106	Leptograthia elongata	75	82	56	1.3

Vaunthompsoni meridionalis, Pseudharpinia n. sp. #19 and Leaena sp. #49 were abundant in assemblage C in moderate depths. Ampelisca anversi, Leptognathia elongata and Desmosona sp. #1 were abundant at the deeper stations in assemblage C (30-50 m) and Exogone minuscula and Leucon sagitta occurred in moderate numbers in both assemblages A and C.

Species Group 8

Species group 8 included eight species which were primarily found in samples 13(1) and 6(1) (Table 21). The grab samples contained large amounts of broken and decaying algae. The percentage abundance of these species restricted to assemblage G ranged from 36 to 99% (77%). If sample 13(2), which also contained large amounts of broken macroalgae, was included, the percent abundance would be increased to 93% with a range of 77-99%. All species except Munna antarctica were present in both grabs resulting in high constancy values. Fidelity values were low because these species were found in low numbers in other samples. Cheirimedon fermortus, Djerboa furcipes, Oradarea spp. and Schraderia gracilis were all dominant species in assemblage G as indicated by the high Biological Index values. Although these eight species were included in the station x species analysis, no pattern was evident because samples 13(1), and 6(1) were excluded from that analysis.

Table 21. Species group 8, including abundance, constancy, fidelity and Biological Index (BI) for each species in replicate samples 6(1) and 13(1).

Species Code	Species	Abundance (%)	Constancy (%)	Fidelity (%)	BI
237	Cheirimedon femoratus	99(99)*	100	18	5.0
238	Djerboa furcipes	99(99)*	100	40	9.0
240	Pontogeneiella sp. #8	77(77)*	100	29	1.5
10	Janiridae B sp. # 1 and 2	77(92)*	100	40	1.0
247	Oradarea spp.	64(91)*	100	15	6.5
248	Schraderia gracilis	87(95)*	100	18	7.0
14	Munna antarctica	36(98)*	50	17	0.8

* Including sample 13(2)

Species Group 9

Two polychaetes, Scoloplos (Leodames) marginatus and Oriopsis sp. #64, were primarily restricted to sample 14(5). Oriopsis sp. #64 was the most dominant species in sample 14(5) and 97 percent of its abundance was restricted to 14(5). Scoloplos (Leodames) marginatus was not abundant and 80% of its abundance was restricted to 14(5). Both species occurred at other stations in low numbers with no discernible pattern.

Species Group 10

Species group 10 consisted of two amphipods Kuphocheira setimanus and Orchomone litoralis which were primarily restricted to sample 12(2). Both species were abundant in replicate 12(2) but occurred in low numbers at other stations. The Biological Index value for Kuphocheira setimanus in sample 12(2) was 6.0 and with 91% abundance restricted to that station (Orchomone litoralis, B. I. 4.0; abundance 89%).

Species Group 11

Species group 11 consisted of two crustaceans which were abundant in samples 13(2) and 13(3). The isopod Munna cf. maculata had 81% of its abundance restricted to samples 13(2) and 13(3), and

the amphipod Parhalimedon sp. had 48%. Neither species was dominant in samples 13(2), 13(3) and both occurred in low numbers at stations 7 and 14.

Species Not in Species Groups

A total of seven of the 107 species were not included in a species group. Serolis cf. polita, Glyptonotus sp., Haplocheira n. sp. Hippomedon kergueleni and Paraphoxus uninatus all had patchy distributions with no discernible patterns. Kidderia subquadrata, an intertidal species, was restricted to station 10, with 31 individuals found in four of the five replicates.

Tharyx cincinnatus would have been included in species group 1, except 89% of its abundance was found at stations 1, 2, 5 and 8. All four stations have a similar substrate and are at moderate depths (50-75 m).

Comparison of Species and Site Classifications

A two-way coincidence table derived from the sample x species classification is summarized in Figure 8. Cell constancy was calculated as percentage occupancy for each site-group, species group cell. Assemblage A was characterized by very high constancy of species group 6, assemblage B by high constancy of species groups 1 and 7, and assemblage C by very high constancy of species groups

Figure 8. Species group-constancy at site groups (i.e., "cell density") based on sample-species classification. Very high (VH) $\geq$ 75% cell occupancy, high (H) 50 to 75%, moderate (M) 25 to 50%, low (L) 10 to 25%, and very low (VL) $\leq$ 10%.

SITE GROUPS

SPECIES GROUPS

	A	B	C	D	E	F	G
1	M 31	H 74	VH 95	VH 93	H 70	H 51	H 55
2	VL 6	L 21	VH 83	M 28	M 34	L 15	L 25
3	L 13	M 29	H 53	VL 6	— 0	— 0	— 0
4	VL 2	VL 4	M 29	M 33	VH 93	M 31	M 43
5	VL 3	VL 10	L 19	VH 94	H 54	L 23	L 25
6	VH 97	M 29	— 0	— 0	— 0	— 0	— 0
7	L 18	H 70	L 21	VL 1	— 0	VL 4	VL 3
8	— 0	VL 2	L 15	VL 10	L 20	— 0	VH 88
9	L 17	— 0	L 19	VL 6	— 0	— 0	L 25
10	— 0	VL 3	L 14	L 17	— 0	— 0	— 0
11	VL 8	— 0	M 33	— 0	H 63	— 0	H 50

1 and 2, and high constancy of species group 3. Assemblage D was characterized by very high constancy of species groups 1 and 5, assemblage E by high constancy of species groups 1 and 5, and assemblage F by high constancy of species group 1 and low constancy of other species groups. Assemblage G was characterized by very high constancy of species group 8 and high constancy of species group 1. Species groups 9 and 10 were restricted to single replicates and had low constancy values with all assemblages. Although species group 11 had high constancy in assemblages E and G, the abundance of these two species was low.

Similar results were obtained from a two-way coincidence table calculated from the station x species classification analysis (Figure 9). Site group G and species groups 8, 9, 10, and 11 were not included in Table 23 because they were predominant only in samples eliminated from the station x species analysis. All values in the station x species two-way coincidence table are higher than the sample x species table.

A second two-way coincidence table was calculated to correspond to the distribution of abundance of species groups in site groups (Figure 10). The percentage abundance of each species group per site group was calculated for the station-site classification. To reduce the effects of the patchy distribution of species and the dominant influence of more abundant species the square root

Figure 9. Species group-constancy at site group (i.e., "cell density") based on station-species classification. Very high (VH) $\geq$ 75% cell occupancy, high (H) 50 to 75%, moderate (M) 25 to 50%, low (L) 10 to 25%, and very low (VL) $\leq$ 10%.

SITE GROUPS

SPECIES GROUPS	A	B	C	D	E	F
1	M 45	VH 93	VH 100	VH 97	VH 90	VH 75
2	L 19	H 58	VH 97	H 50	H 50	M 38
3	L 22	H 56	VH 76	L 11	— 0	— 0
4	L 14	L 14	H 60	H 71	VH 100	H 71
5	VL 8	L 23	M 43	VH 100	VH 83	H 50
6	VH 100	M 33	— 0	— 0	— 0	— 0
7	M 38	VH 90	M 41	VL 6	— 0	L 19

Figure 10. Percentage abundance of species groups at site groups based on station-species classification. Calculations made on square root transformed, and standardized species values. The number of stations per assemblage were standardized. Very high (VH $\geq$ 75%, high (H) 50 to 75%, moderate (M) 25 to 50%, low (L) 10-25%, and very low (VL) $\leq$ 10%.

SITE GROUPS

SPECIES GROUPS

	A	B	C	D	E	F
1	VL 4	L 14	M 27	M 27	L 22	VL 5
2	VL 4	VL 9	H 56	VL 9	L 14	VL 7
3	VL 6	M 32	H 60	VL 2	— 0	— 0
4	VL 1	VL 1	L 13	VL 9	H 68	VL 8
5	VL 1	VL 1	VL 5	H 67	L 21	VL 4
6	VH 86	L 14	— 0	— 0	— 0	— 0
7	L 12	H 73	L 12	— 0	— 0	VL 3

transformed, species standardized data were used. The percentages were standarized to equal number of sites per cell. Species group 1 was distributed throughout all assemblages but was most abundant in assemblage C and D. Species group 2 was most abundant in assemblage C; species group 3 in assemblage C; species group 4 in assemblage E; and species group 5 in assemblage D. Species group 6 was primarily restricted to assemblage A and species group 7 to assemblage B. Assemblage F was characterized by very low abundances of all species groups. All other assemblages were characterized by high abundance of at least one species group.

DISCUSSION

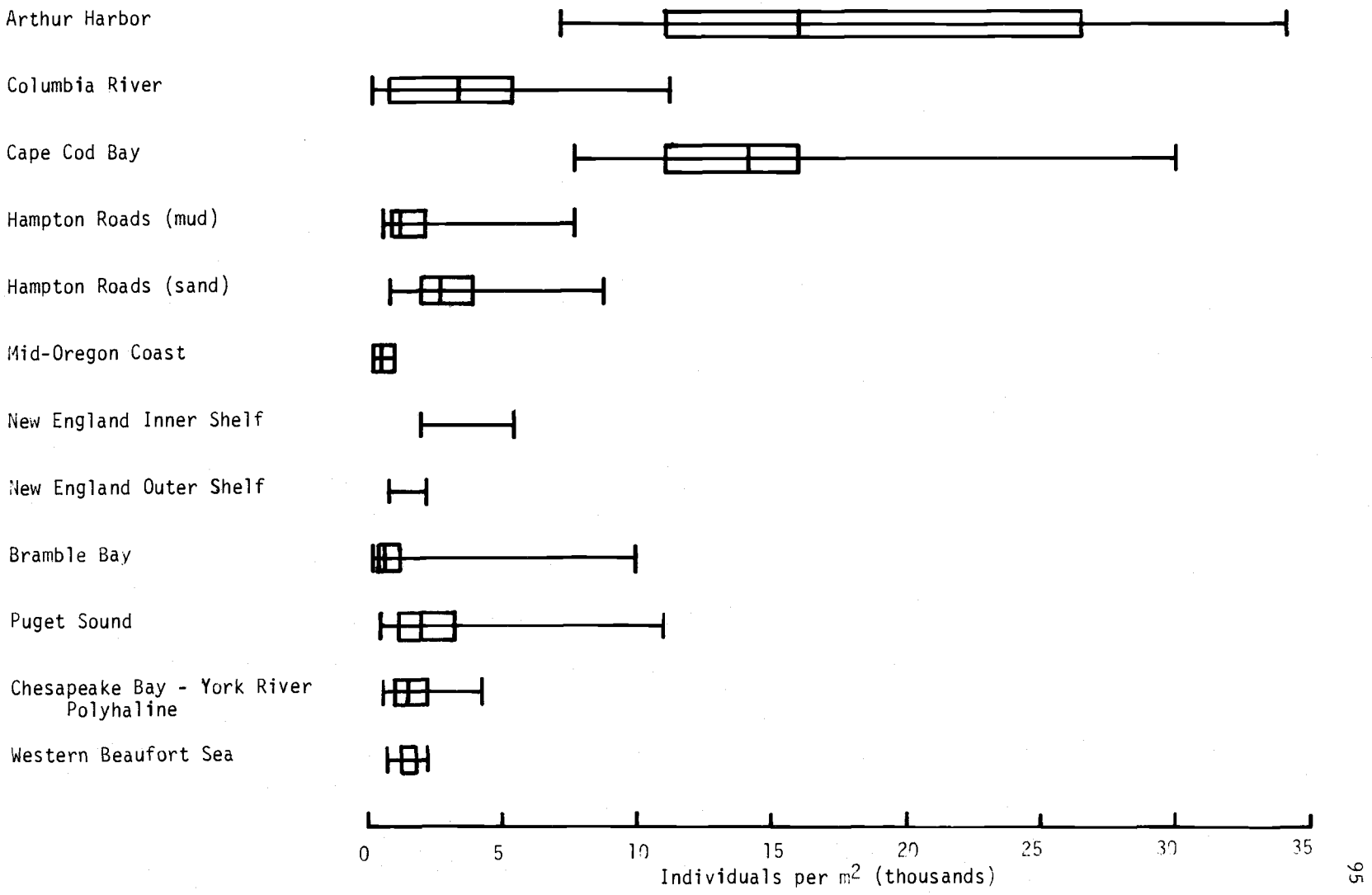
Density

The density values ranged from 1,844 individuals/m^2 at station 4 to 34,286 individuals/m^2 at station 10. There was a decrease in density with depth (Spearman rank correlation; $r_s = 0.747$, $p>0.01$). The mean density in Arthur Harbor was 17,522 individuals/m^2 which was more than twice the values reported by Lowry (1975) for two stations in Arthur Harbor and five times higher than values reported by Gallardo and Castillo (1969) for similar depths in Discovery Bay, Greenwich Island, Antarctica. The values from this study are also higher than those reported by Mills (1975) from three stations in the South Shetland Islands.

Density values calculated from this study were compared to those obtained from studies using similar methods outside the Antarctic (Figure 11). All studies used either Smith-McIntyre or Van Veen grab which obtain comparable samples (Longhurst, 1964). The screen size was 1.0 mm in all studies and replicate samples were obtained in all studies except Young and Rhoads (1971).

The median value of density from Arthur Harbor was higher than any of these reported studies and the median quartile overlapped only with density values reported from Cape Cod Bay (Young and Rhoads, 1971).

Figure 11. Comparison of macrofauna abundance values calculated from the present study, Arthur Harbor; the western Beaufort Sea (Carey, et al., 1975); seaward of the mouth of the Columbia River (Richardson et al., 1976); Hampton Roads, Virginia mud and sand (Boesch, 1973); the mid-Oregon continental shelf (Bertrand and Carey, unpublished manuscript); Cape Cod Bay (Young and Rhodes, 1971); the New England inner and outer continental shelf (Wigley and MacIntyre, 1964); Bramble Bay, Australia (Stephenson et al. in press); Puget Sound (Lee, 1968); and Chesapeake Bay polyhaline (Boesch, 1971). All values include range, median and median quartile.


Arthur Harbor
Columbia River
Cape Cod Bay
Hampton Roads (mud)
Hampton Roads (sand)
Mid-Oregon Coast
New England Inner Shelf
New England Outer Shelf
Bramble Bay
Puget Sound
Chesapeake Bay - York River Polyhaline
Western Beaufort Sea
0
5
10
15
20
25
30
35
Individuals per m2 (thousands)

Three factors may contribute to the high density of macrobenthos in Arthur Harbor. The input of organic matter is high because of intense summer phytoplankton productivity, high productivity of phytobenthos, and continuous supply of macroalgae which is attached to rocky subtidal cliffs. The low values of total organic matter in sediments suggests a rapid and efficient utilization of organic matter by the benthos (Mills and Hessler, 1974; Mills, 1975). Antarctic species are reported to have slow growth rates (Bregazzi, 1972; Dayton et al., 1974) as an indirect result of cold temperatures (Dunbar, 1968). With slow growth rates the Antarctic macrobenthos could theoretically support larger populations than temperate macrobenthos given the same amount of organic input.

Biogeography

Biogeographical synthesis should be based on the analysis of the distribution pattern of whole communities of organisms (Knox and Lowry, in press). Except for the analysis of zonation patterns of the littoral zone (Knox, 1960; Arnaud, 1974), this has not been attempted for the Antarctic. I am faced with several problems in attempting any biogeographical comparisons between the benthic assemblages found in Arthur Harbor and those found in other parts of the Antarctic. First, any identifications not confirmed by expert taxonomists may be incorrect. Second is the lack of completed

comprehensive surveys of soft-bottom benthic assemblages in other areas of the Antarctic. Although the Antarctic may be one of the worlds best known areas taxonomically, most of the samples studied have either been wide-spread, not quantitative, from rocky substrates or from large trawl nets which sample megabenthic forms. Several workers (see introduction) have begun comparable soft-bottom benthic surveys in the Antarctic, but none have been completed except in Arthur Harbor. Third, since several benthic assemblages were found in Arthur Harbor, biogeographical comparisons should be based on comprehensive surveys which delineate the assemblages which occur within the area studied. Therefore, only two biogeographical comparisons were attempted in this paper.

Of the 282 taxa identified in this study from Arthur Harbor, 162 have either been confirmed by expert taxonomists or been given species names by the author. Seventy-five or 46% of these species were also found in extensive sampling of Terre Adelie, East Antarctica (Arnaud, 1974). A comparison of major taxonomic groups is presented in Table 22.

There were 15 species in Arthur Harbor which had Biological Index values greater than 1.0. Maldanidae species #7 and nematodes were not identified to species which leaves 13 dominant species for biogeographical comparison. Using the same criteria as Knox and Lowry (in press), three of these species were cosmopolitan, six

Table 22. Number of species found in Arthur Harbor (this study), identified to species and the number of those species also found at Terra Adelie (Arnaud, 1974).

Taxonomic Group	Arthur Harbor	Terra Adelie	Percent species in common
Priapulida	1	1	100
Polychaeta	57	25	44
Amphineura	1	1	100
Gastropoda	8	5	63
Pelecypoda	17	6	35
Scaphopoda	2	1	50
Pycnogonida	4	4	100
Ostrocoda	5	0	0
Nebaliacea	2	1	50
Mysidacea	1	1	100
Cumacea	7	2	29
Tanaidacea	5	3	60
Isopoda	15	8	53
Amphipoda	28	13	46
Sipunculida	1	1	100
Echinoidea	1	1	100
Ophiuroidea	5	2	40
Ascidiacea	1	0	0

species were circumpolar (Antarctic and subantarctic), two species were circumantarctic, one species was restricted to the Antarctic Peninsula and South Georgia and Torodrilus lowryi has not been found outside Arthur Harbor. Most of the dominant species found in Arthur Harbor are widely distributed throughout the Antarctic and the assemblages found in Arthur Harbor are probably circumpolar.

Diversity

Diversity values increased with depth (Spearman rank correlation; $r_s = 0.63$, $p>0.05$) in the study area, primarily in response to an increase in species richness with depth ($r_s = 0.60$, $p>0.05$) (Table 23). No relationship between diversity and sediment particle size distribution was found. Both species richness ($r_s = 0.84$) and evenness ($r_s = 0.90$) were highly correlated with diversity and accounted for 94% of its variability.

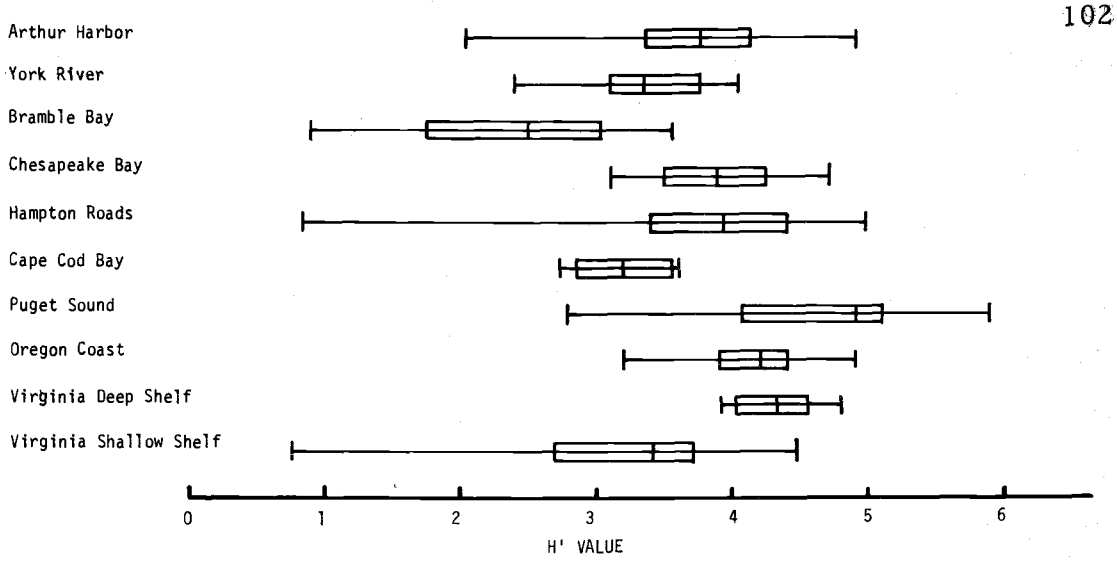
Diversity values calculated from this study were about the same as values from inner continental shelf areas, higher than some estuarine areas and lower than the Virginia deep continental shelf and Puget Sound (Figure 12). Species richness values calculated from this study were higher than all areas except Puget Sound, while evenness values were lower than most areas.

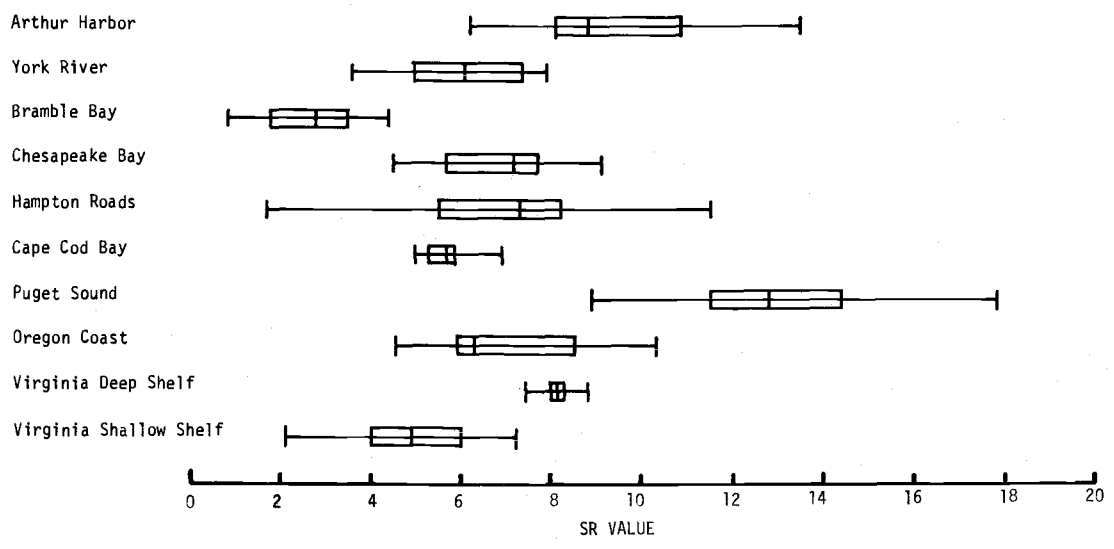
High species richness values may be the consequence of seasonal constancy of temperature and salinity in Arthur Harbor,

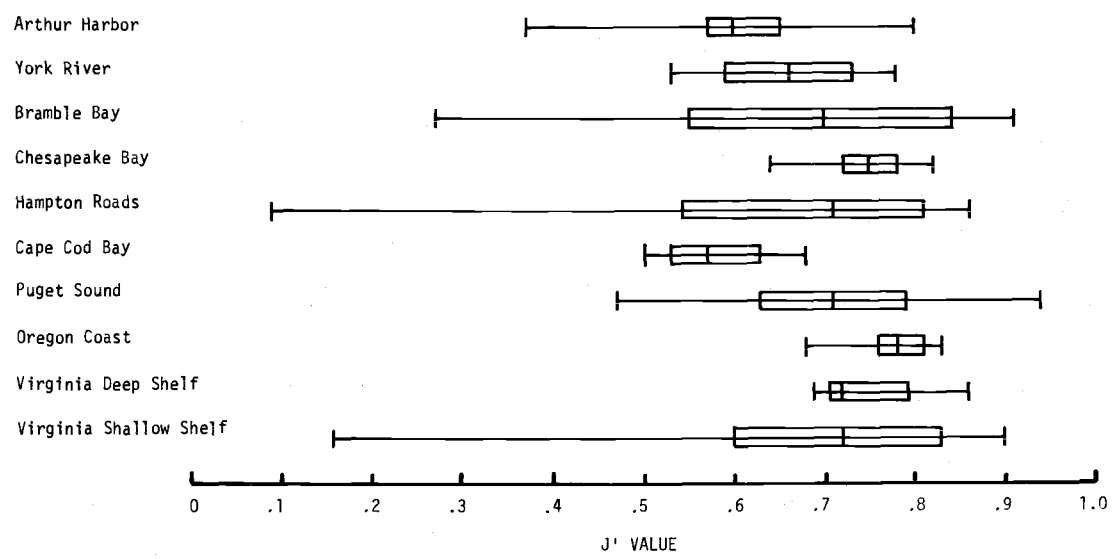
Table 23. Spearman rank correlation coefficients (r_s) for all possible pair combinations of station values of diversity (H'), evenness (J'), species richness (SR), number of individuals/m^2 (N/m^2), and depth (m). Station 8 was excluded from the analysis.

Rank Comparison		r_s	p(two tailed test)
H'	- SR	0.84	> 0.01
H'	- J'	0.90	> 0.01
J'	- SR	0.55	> 0.10
H'	- N/m^2	0.38	--
J'	- N/m^2	0.51	> 0.10
SR	- N/m^2	0.04	--
H'	- Depth (m)	0.63	> 0.05
J'	- Depth (m)	0.48	> 0.10
SR	- Depth (m)	0.60	> 0.05
Depth(m)	- N/m^2	0.74	> 0.01
H'	- SR and J'	0.97	> 0.01

Figure 12. Comparison of diversity (H'), species richness (SR), and evenness (J') values calculated from the present study, Arthur Harbor; the York River, Virginia (Orth, 1973); Bramble Bay, Australia (Stephenson et al. in press); Chesapeake Bay, polyhaline (Boesch, 1973); Cape Cod Bay (Young and Rhodes, 1971); Puget Sound (Lee, 1968); seaward of the mouth of the Columbia River, Oregon Coast (Richardson et al., 1976); and the Virginia deep and shallow continental shelf (Boesch, 1972; personal communication). All values include range, median, and median quartile.


Arthur Harbor
York River
Bramble Bay
Chesapeake Bay
Hampton Roads
Cape Cod Bay
Puget Sound
Oregon Coast
Virginia Deep Shelf
Virginia Shallow Shelf
0
1
2
3
4
5
6
H' VALUE


Arthur Harbor
York River
Bramble Bay
Chesapeake Bay
Hampton Roads
Cape Cod Bay
Puget Sound
Oregon Coast
Virginia Deep Shelf
Virginia Shallow Shelf
0
2
4
6
8
10
12
14
16
18
20
SR VALUE


Arthur Harbor
York River
Bramble Bay
Chesapeake Bay
Hampton Roads
Cape Cod Bay
Puget Sound
Oregon Coast
Virginia Deep Shelf
Virginia Shallow Shelf
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
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J' VALUE

while low evenness values probably result from the physical stress of iceberg grounding coupled with high organic input. The result was moderately high diversity values. The two deepest stations, which were probably little affected by iceberg grounding, had high evenness ($\overline{0.79}$) and species richness ($\overline{11.84}$) values. The diversity ($\overline{4.66}$) values were as high as values calculated from Puget Sound and higher than the Virginia outer continental shelf. Assemblage F, which was affected by glacial calving had the lowest evenness value (0.37) in the study site but the species richness value (5.65) was only moderately low. Assemblage G, which was affected by iceberg grounding, also had much reduced evenness values with a slight reduction of species richness values.

Community Concept

The use of classification as opposed to ordination techniques in this thesis suggests that I agree with concepts which favor communities as discrete statistical units with definite boundaries as opposed to a continuum of overlapping binomal distributions of individual species. As suggested by Greig-Smith (1964), McIntosh (1967), and Orloci (1975) the use of classification or ordination does not a priori commit the investigator to such community concepts. Ordination techniques have been used to classify benthos by several workers (Lee and Kelley, 1970; Hughes and Thomas, 1971a, 1971b;

Lee, 1974), and classification techniques have been used to ordinate benthic stations along an environmental gradient (Boesch, 1971).

Terborgh (1971) used direct ordination techniques to explain the distribution of birds along an environmental gradient. Measures of the species abundance were plotted along the environmental gradient as well as a measure of "faunal congruity" or assemblage resemblance between all possible pairs of stations along the gradient. Since no gradient in sediment type was found in this study a gradient of depth was chosen for direct ordination. The depth gradient probably represents several factors including reduced fluctuations in temperature and salinity, lower organic input from macroalgae and phytobenthos and reduced stress from iceberg grounding and glacial calving.

Since distribution plots of 282 species along the depth gradient would be too complex to present in a single figure, percentage abundance (square-root transformed values) for species groups was plotted. Bray-Curtis dissimilarity values were used as a measure of "faunal congruity." Mean values of Bray-Curtis dissimilarity values between replicates at each station were used as intrastation dissimilarity values. Station 8 was not included in the analysis because of the effects of glacial calving.

The faunal congruity values presented in a single figure are difficult to interpret because of the numerous overlapping curves,

but do show areas of relative homogeneity between stations. In order to facilitate interpretation, the faunal congruity values were plotted separately for each assemblage (Figure 13). The similarity between faunal congruity curves for stations within the same assemblage was evident in these figures as well as the discontinuity between assemblages. Percentage abundance values for species groups (Figure 14) also show similar results with areas of relative homogeneity within assemblages and discontinuities between assemblages.

The existence of discrete assemblages derived from the classification analysis was supported by the direct ordination. These results suggest that the distribution of species in Arthur Harbor is intermediate between the concept of a continuum distribution of species and that of organization into discrete communities. Assemblages are interpreted to be areas of relative homogeneity which interrupt a general continuum of distribution of species with depth.

Effects of Iceberg Grounding

Iceberg grounding is a common occurrence in shallow water near the Antarctic Peninsula (Richardson, 1972; Shabica, 1972; Kauffman, 1974). A large iceberg was grounded in Hero Inlet near station 6 from mid October to mid January 1971. After the iceberg left, Van Veen grab samples were taken in the vicinity of the iceberg

Figure 13. Faunal congruity values based on Bray-Curtis dissimilarity values between each station and all other stations. Station 8 excluded. Intrastation congruity values are mean Bray-Curtis dissimilarity values between all replicate samples at that station. A) includes stations 9, 11, 12, 13, and 14, B) includes stations 1, 2, 5, and 7, C) includes stations 3, 4, 6, and 10.

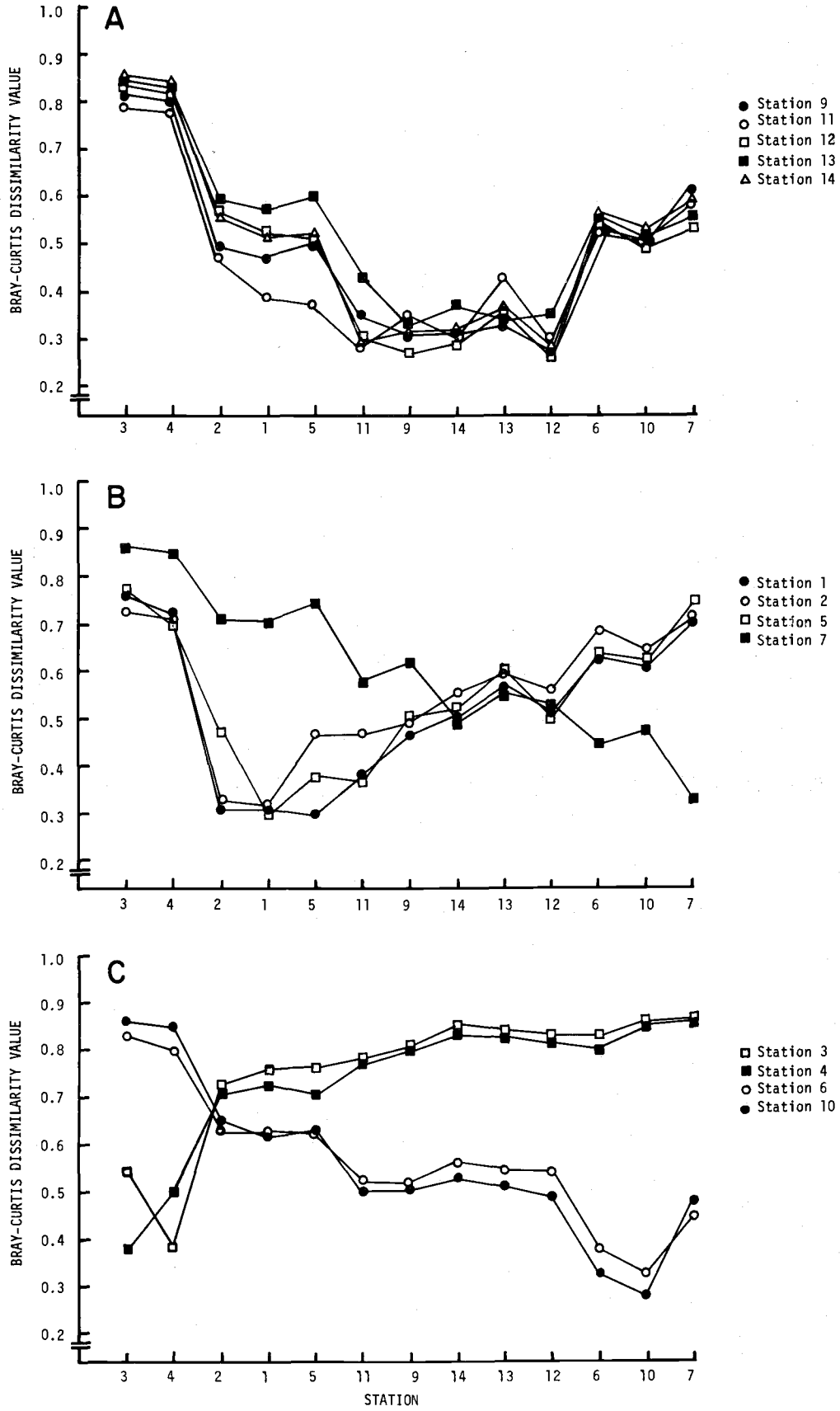
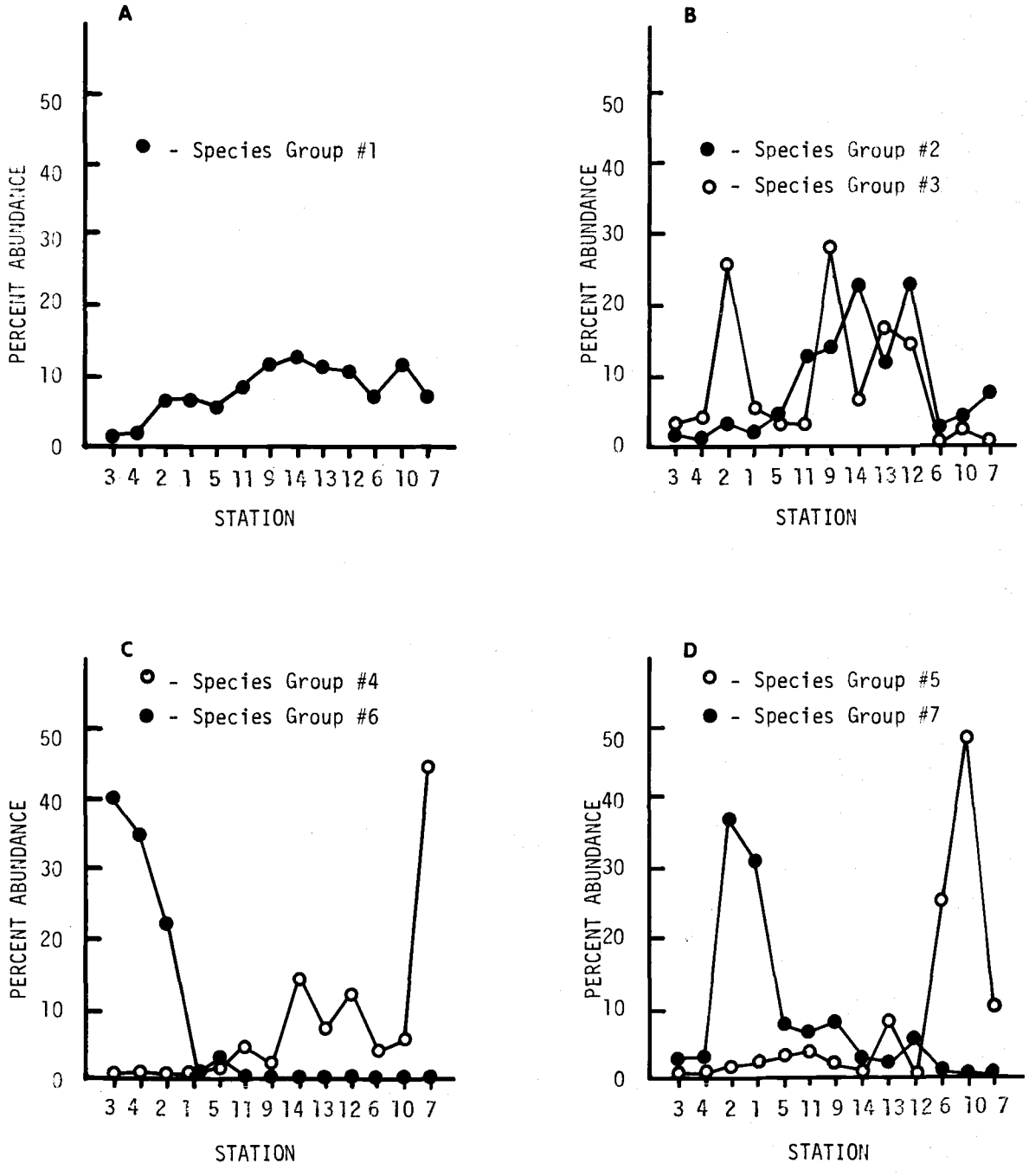

A
B
C
BRAY-CURTIS DISSIMILARITY VALUE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
3 4 2 1 5 11 9 14 13 12 6 10 7
STATION
Station 9
Station 11
Station 12
Station 13
Station 14
Station 1
Station 2
Station 5
Station 7
Station 3
Station 4
Station 6
Station 10

Figure 14. Distribution of percent abundance for each species group at each station (values used in calculation of percent abundance were square root transformed). A) species group 1, B) species groups 2 and 3, C) species groups 4 and 6, D) species groups 5 and 7.


A
B
C
D
PERCENT ABUNDANCE
STATION
3 4 2 1 5 11 9 14 13 12 6 10 7
0
10
20
30
40
50
● - Species Group #1
● - Species Group #2
○ - Species Group #3
○ - Species Group #4
● - Species Group #6
○ - Species Group #5
● - Species Group #7

grounding and the area was inspected visually with the aid of SCUBA. A similar iceberg grounding in Hero Inlet was observed by Kauffman (1974) in March 1973. From these two studies a sequence of events from the grounding of an iceberg to the recovery of the benthic assemblage was postulated.

An iceberg grounds in shallow water and destroys the fauna and flora by crushing and churning the sediment. The iceberg leaves a depression in the substrate. Flocculent sediments, 1-2 cm deep, cover the disturbed area within about one week. Macroalgae, which has broken off the surrounding rocky cliffs by ice action, collects in the depression. Motile, opportunistic species such as the amphipods Cheirimedon femoratus, Djerboa furcipes, Schraderia gracilis, Oradarea spp., and the polychaete Ophryotrocha claparedii migrate into the area to graze on the broken and decaying algae. Larger scavengers and carnivores such as the isopod Glyptonotus antarcticus, and the nemertean Lineus corrugatus also migrate into the area to feed on the grazers and macrofauna destroyed by the iceberg grounding. The depression fills within a year and superficially resembles the surrounding area. Rapidly reproducing meiobenthic flora and fauna (diatoms, foraminifera, copepods, and small polychaetes) re-establish typical meiobenthic assemblages during this period. The length of time required to re-establish the typical macrofaunal assemblage by immigration and reproduction is not known but

probably requires several years for most species.

Replicate sample 11(2) differed from other samples obtained at station 11 and may represent a later stage in the recovery sequence. Two large bivalves, Yoldia eightsi and Laternula elliptica which were characteristic of station 11 were not found in sample 11(2). The debris in sample 11(2) contained higher amounts of broken macroalgae than other replicates at station 11, and lacked the rocks and gravel found in other replicates. The sediment also had a slight H_2S odor. Diversity, species richness, and evenness were much lower in sample 11(2) than other samples at station 11. The number of species present and the number of individuals/m^2 were also reduced. The numbers of individuals of the cumaceans Vaunthompsonia meridioralis and Eudorella gracilior, the tanaid Nototanais antarcticus, and the amphipods Heterphoxus videns and Ampelisca bouvieri were also lower than in other samples at station 11, perhaps because of the stress of a reducing environment.

Effects of Glacial Calving

Station 8 (assemblage F), located near the glacial face, was overwhelmingly dominated by the polychaete Tharyx cincinnatus, and had the lowest values of diversity, species richness, evenness, and density of any station in Arthur Harbor. These low values were a result of the physical stress of glacial calving. Large pieces of

ice calve from the glacier face and crush the sediment by impact with the bottom. Waves created by the impact of the calved ice with the water also mix the sediment. The unstable sediment surface prevents the establishment of less motile species, which may be crushed or buried, and filter-feeding species whose feeding mechanisms would become clogged.

Station 7 (assemblage E), also located near a glacial face, had much higher values of diversity, species richness, evenness and density than station 8. Glacial calving had little effect on station 7 because of the small size of the glacier face in the area and the presence of numerous rock outcroppings which protected the substrate from the effects of wave action caused by calving.

SUMMARY

1. The macrobenthos (>1.00 mm) of Arthur Harbor, Anvers Island, Antarctic Peninsula was surveyed in January-February 1971, first to determine what macrobenthic assemblages and species groups occur in Arthur Harbor, second to calculate community structure parameters for existing assemblages, third to compare the results to other soft bottom benthic studies, and fourth to relate the results to current ecological theory.

2. The 69 grab samples obtained from 14 stations yielded 78,395 individuals which were separated into 282 taxa, including 108 species of annelids (54.5% of the individuals), 117 species of arthropods (30.3%), 35 species of molluscs (11.3%) and 22 species in other phyla (4.0%).

3. The density of macrofauna (17,522 individuals/m^2) found in Arthur Harbor was high compared to other reported areas. This high density was considered to be the result of high organic input from phytoplankton, phytobenthos and attached macroalgae, the efficient utilization of organic matter by macrobenthos and the slow growth rates of macrobenthic species as an indirect result of cold temperatures.

4. Diversity values were moderately high with high species richness values and low evenness values. The high species richness

values may be the consequence of seasonal constancy of temperature and salinity in Arthur Harbor, while low evenness values probably result from the physical stress of iceberg grounding coupled with high organic input.

5. Six macrobenthic assemblages (site groups) and 11 species groups were found in the study area by classification analysis. Station groups were described by dominant species, density, and diversity. Species groups were described by the dominance, fidelity, constancy, and percent abundance of constituent species restricted to site groups.

6. The dominant species from this study are widely distributed throughout the Antarctic, and 46% of the 162 taxa identified to species were also found at Terre Adelie, East Antarctica. The assemblages found in Arthur Harbor are therefore probably circumpolar.

7. The existence of discrete assemblages derived from the classification analysis was supported by direct ordination. Assemblages were interpreted to be areas of relative homogeneity which interrupt a general continuum of distribution of species with depth.

8. In spite of the stability of temperature and salinity, Arthur Harbor macrobenthic assemblages were moderately stressed by glacial activity. Icebergs, which often ground in Arthur

Harbor, destroyed the benthos by crushing and churning the sediment. The disturbed area was first repopulated by motile, opportunistic species. These species fed on macroalgae which collected in the depression left by the iceberg. Scavengers and carnivores appeared later to feed on the grazers and macrofauna destroyed by iceberg grounding. Within a year the depression filled, and typical meiobenthic assemblages were re-established. Several years may be required before macrobenthic assemblages are re-established. Station 8, located near the glacial face had the lowest values of diversity, species richness, evenness, and density of any station in Arthur Harbor. These low values resulted from physical stress of glacial calving. Large pieces of ice calved from the glacial face and crushed the sediment by impact with the bottom. The waves created by impact of the calved ice with the water also disturbed the sediment creating an unstable sediment surface.

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APPENDIX

APPENDIX 1A

Species collected in Arthur Harbor, Anvers Island, Antarctic Peninsula, January-February 1971

	Species Code
Anthozoa	
Edwardsia sp.	76
Nemertea	
22 species	230
Priapulida	
Priapulus tuberculatospinosus Baird	39
Nematoda	
Nematodes	219
Polychaeta	
Polynoidae	
Antinoella antarctica (Bergstrom)	125
Barrukia cristata (Willey)	123
Harmothoe magellanica (McIntosh)	124
Harmothoe sp. #96	207
sp. #97	208
Phyllodocidae	
Eteone sculpta Ehlers	170
Eulalia subulifera Ehlers	163
sp #30	141
sp. #33	144
sp. #98	209
sp. #105	216
Hesionidae	
Kefersteinia cirrata (Keferstein)	176
Syllidae	
Brania rhopalophora (Ehlers)	158
Exogone heterosetosa McIntosh	212
Exogone minuscula Hartman	135
Exogone sp. #102	213
Exogone sp. #103	214
Pionosyllis comosa Gravier	210
Syllis sp. #83	194
Trypanosyllis gigantea (McIntosh)	192
sp. #104	215
Nereidae	
Neanthes kerguelensis (McIntosh)	122
sp. #56	167
Nephtyidae	
Aglaophamus foliosus Hartman	129
Aglaophamus ornatus Hartman	112

Family uncertain

Falkandiella annulata Hartman	191
sp. #93	204
sp. #100	211

Oligochaeta

Torodrilus lowryi Cook	218

Possibly additional species not separated from *T. lowryi*

Hirudinea

Antarctobdella sp.	74

Amphineura

Callochiton gaussi Thiele	51
Chiton #1	50

Solenogastres

Dorymenia paucidentata Salv.-Plawen	73

Caudofoveata

Falcidens n. sp.	72
Chaetoderma n. sp.	282

Gastropoda

Chlanidota signeyana Powell	46
Eatoniella kerguelensis (Smith)	44
Laevilitorina umbilicata (Martens)	42
Margarella antipoda (Lamy)	40
Neobuccinum eatoni (Smith)	45
Pellilitorina pellita (Martens)	41
Philine alata Thiele	47
Subonoba turqueti (Lamy)	43

Pelecypoda

Cuspidaria kerguelensis Smith	70
Cyamiocardium denticulatum (Smith)	62
Cyamiomactra laminifera (Lamy)	61
Genaxinus debilis (Thiele)	64
Kidderia subquadrata (Pelseneer)	67
Laternula elliptica (King and Broderip)	69
Limopsis sp. #6	59
Mysella minuscula var. *charcoti* (Pfeffer)	63
Nucula n. sp.	52
Nuculana (s.l.) *inaequisculpta* (Lamy)	53
Philobrya sublaevis (Pelseneer)	58
Propeleda longicaudata (Thiele)	56
Pseudokellija cardiformis Smith	60
Thracia meridionalis Smith	68
Thyasira bongraini (Lamy)	65
Thyasira falklandica (Smith)	66
Yoldia eightsi (Couthouy in Jay)	57

Pelecypoda (cont.)		
	Yoldiella ecaudata (Pelseneer)	54
	Yoldiella valettei (Lamy)	55
	sp. #9	71
Scaphopoda		
	Cadulus dalli antarcticus Odhner	49
	Fissidentalium majorinum Mabille and Rochebrune	48
Pycnogonida		
	Achelia communis (Bouvier)	223
	Achelia spicata (Hodgson)	224
	Ascorhynchus sp.	225
	Austrodecus glaciale (Hodgson)	222
	Nymphon sp.	221
	Pentanymphon antarcticum Hodgson	220
Ostracoda		
	Empoulsenis pentathrix (Kornicker)	79
	Homasterope maccaini Kornicker	80
	Philomedes orbicularis Brady	77
	Sclerochoncha gallardoi Kornicker	81
	Skorgsbergiella scotti Kornicker	82
	Halocypridae sp.	78
Harpacticoida		
	Peltidiidae sp.	37
Nebaliacea		
	Nebalia longicornis Thomson	90
	Nebaliella extrema Thiele	89
Mysidacea		
	Mysidetes posthon Holt and Tattersall	75
Cumacea		
	Campylaspis maculata Zimmer	101
	Diastylis anderssoni Zimmer	100
	Diastylopsis annulata Zimmer	97
	Eudorella gracilior Zimmer	102
	Leucon sagitta Zimmer	99
	Leucon n. sp.	105
	Makrokylindrus n. sp.	98
	Vaunthompsonia inermis Zimmer	103
	Vaunthompsonia meridionalis Sars	104
Tanaidacea		
	Nototanais antarcticus (Hodgson)	108
	Nototanais dimorphus (Beddard)	110
	Leptognathia elongata Shiino	106
	Leptognathia gallardoi Shiino	107

Tanaidacea (cont.)

Leptognathia gracilis (Kroyer)	109
Paranarthura sp.	111

Isopoda

Limnoriidae	
sp. #1	1
Sphaeromidae	
sp. #1	2
Plakarthriidae	
Plakarthrium punctatissimum Pfeffer	3
Serolidae	
Serolis cf. *polita* Richardson	4
Idotheidae	
Glyptonotus sp.	5
sp. #1	38
Arcturidae	
sp. #1	6
sp. #2	7
Gnathiidae	
sp. #1	8
Janiridae	
Genus A sp. #1	9
Genus B sp. #1	10
Genus B sp. #2	
Genus C sp. #1	11
Microparasellidae	
sp. #1	12
Antiasidae	
Antias charcoti Richardson	13
Munnidae	
Munna antarctica (Pfeffer)	14
Munna neglecta Monod	15
Munna cf. *maculata* Beddard	16
Munna cf. *affinis* Nordenstam	17
Munna sp. (near *pallida*) Beddard	18
Munna sp. j	19
Munna sp. k	20
Munna sp. m	21
Desmosomatidae	
Desmosoma #1	22
Desmosoma #2	23
Momedossa #1	24
Evgerdella #1	25
Ilyarachnidae	
Ilyaracha #9 (cf. *acarina*)	26
Echinozone spinosa (Hodgson)	27
Echinozone magnifica Vanderhoffen	28
Echinozone cf. *aries* (Vanderhoffen)	29
Echinozone n. sp. 2	30
Echinozone spicata (Hodgson)	31

Isopoda (cont.)

Pleurogoniidae

Paramunna rostrata (Hodgson)	32
Paramunna n. sp.	33
Austrimunna antarctica (Richardson)	34
Genus Incertae sedis n. sp.	35
New Genus P sp. *lunata*	36

Amphipoda

Ampeliscidae

Ampelisca bouvieri Chevreux	234
Ampelisca richardsoni Karaman	276
Ampelisca anversi Karaman	242

Calliopiidae

Metaleptamphopus sp. #21	253
Oradarea sp. #15	247

Ephliantidae

Wandelia crassipes Chevreux	275

Eusiridae

Atyloella sp. #37	269
Djerboa furcipes Chevreux	238
Paramoera sp. #48	280
Pontogeneia sp. #7	239
Pontogeneiella sp. #8	240
Prostebbingia gracilis Chevreux	244
Schraderia gracilis Pfeffer	248

Haustoriidae

Urothoe n. sp.	255
New Genus n. sp. #9	241

Isaeidae

Gammaropsis n. sp.	262
Haplocheira n. sp.	274
Kuphocheira setimanus Barnard	236

Ischyroceridae

Ischyrocerus camptonyx Thurston	266
Jassa falcata (Montagu)	257

Leucothoidae

Leucothoe spinicarpa (Abildgaard)	264

Liljeborgiidae

Liljeborgia sp. #38	270

Lysianassidae

Cheirimedon femoratus (Pfeffer)	237
Hippomedon kergueleni (Miers)	245
Lepidepecreum cingulatum (Barnard)	265
Orchomene litoralis (Schellenberg)	252
Orchomene sp. #49	281
Shackletonia robusta Barnard	246
Waldackia obesa (Chevreux)	263

Oedicerotidae

Bathymedon sp. #46	278
Methalimedon nordenskjoldi Schellenberg	254

APPENDIX 1B

Species collected in Arthur Harbor, Anvers Island, Antarctic Peninsula, January-February 1971

Species Code Number	
1	Limnoriidae sp. #1
2	Sphaeromidae sp. #1
3	Plakarthrium punctatissimum Pfeffer
4	Serolis cf. polita Richardson
5	Glyptonotus sp.
6	Arcturidae sp. #1
7	Arcturidae sp. #2
8	Gnathiidae sp. #1
9	Janiridae Genus A sp. #1
10	Janiridae Genus B sp. #1, 2
11	Janiridae Genus C sp. #1
12	Microparasellidae sp. #1
13	Antias charcoti Richardson
14	Munna antarctica (Pfeffer)
15	Munna neglecta Monod
16	Munna cf. maculata Beddard
17	Munna cf. affinis Nordenstam
18	Munna sp. (near pallida) Beddard
19	Munna sp. j
20	Munna sp. k
21	Munna sp. m
22	Desmosoma #1
23	Desmosoma #2
24	Momedossa #1
25	Evgerdella #1
26	Ilyaracha #9 (cf. acarina)
27	Echinozone spinosa (Hodgson)
28	Echinozone magnifica Vanderhoffen
29	Echinozone cf. aries (Vanderhoffen)
30	Echinozone n. sp. 2
31	Echinozone spicata (Hodgson)
32	Paramunna rostrata (Hodgson)
33	Paramunna n. sp.
34	Austrimunna antarctica (Richardson)
35	Isopoda Incertae sedis n. sp.
36	Isopoda New Genus P sp. lunata
37	Peltidiidae sp.
38	Idotheidae sp. #1
39	Priapulus tuberculatospinosus Baird
40	Margarella antipoda (Lamy)
41	Pellilitorina pellita (Martens)
42	Laevilitorina umbilicata (Martens)

43 Subonoba turqueti (Lamy)
44 Eatoniella kerguelensis (Smith)
45 Neobuccinum eatoni (Smith)
46 Chlanidota signeyana (Powell)
47 Philine alata Thiele
48 Fissidentalium majorinum Mabille and Rochebrune
49 Cadulus dalli antarcticus Odhner
50 Amphineura Chiton #1
51 Callochiton gaussi Thiele
52 Nucula n. sp.
53 Nuculana (s.l.) inaequisculpta (Lamy)
54 Yoldiella ecaudata (Pelseneer)
55 Yoldiella valettei (Lamy)
56 Propeleda longicaudata (Thiele)
57 Yoldia eightsi (Couthouy in Jay)
58 Philobrya sublaevis (Pelseneer)
59 Limopsis sp. #6
60 Pseudokellija cardiformis Smith
61 Cyamiomactra laminifera (Lamy)
62 Cyamiocardium denticulatum (Smith)
63 Mysella minuscula var. charcoti (Pfeffer)
64 Genaxinus debilis (Thiele)
65 Thyasira bongraini (Lamy)
66 Thyasira falklandica (Smith)
67 Kidderia subquadrata (Pelseneer)
68 Thracia meridionalis Smith
69 Laternula elliptica (King and Broderip)
70 Cuspidaria kerguelensis Smith
71 Pelecypoda sp. #9
72 Falcidens n. sp.
73 Dorymenia paucidentata Salv.-Plawen
74 Antarctobella sp.
75 Mysidetes posthon Holt and Tattersall
76 Edwardsia sp.
77 Philomedes orbicularis Brady
78 Halocyprídae sp.
79 Empoulsenis pentathrix (Kornicker)
80 Homasterope maccaini Kornicker
81 Sclerochoncha gallardoi Kornicker
82 Skorgsbergiella scotti Kornicker
83 Goldfingia mawsoni (Benham)
84 Prashadus sp.
85 Thalassema sp.
86 Echiurida sp. #86
87 Cucumariidae juv.
88 Holothurioidea sp. #88
89 Nebaliella extrema Mortensen
90 Nebalia longicornis Thomson
91 Amphioplus peregrinator Koehler
92 Ophionotus victoriae Bell
93 Amphioplus acutus Mortensen

94 Ophiura vouchi (Koehler)
95 Amphiura joubini (Koehler)
96 Ophiuroidea sp. #96
97 Diastylopsis annulata Zimmer
98 Makrokylindrus n. sp.
99 Leucon sagitta Zimmer
100 Diastylis anderssoni Zimmer
101 Campylaspis maculata Zimmer
102 Eudorella gracilior Zimmer
103 Vaunthompsonia inermis Zimmer
104 Vaunthompsonia meridionalis Sars
105 Leucon n. sp.
106 Leptognathia elongata Shiino
107 Leptognathia gallardoi Shiino
108 Nototanais antarcticus (Hodgson)
109 Leptognathia gracilis (Kroyer)
110 Nototanais dimorphus (Beddard)
111 Paranarthura sp.
112 Aglaophamus ornatus Hartman
113 Amphieteis gunneri antarctica Hessle
114 Capitella spp.
115 Lumbriclymenella robusta Arwidsson
116 Rhodine loveni Malmgren
117 Axiothella antarctica Monro
118 Maldanidae sp. #7
119 Terebella ehlersi Gravier
120 Amphitrite kerguelensis McIntosh
121 Brada villosa (Rathke)
122 Neanthes kerguelensis (McIntosh)
123 Barrukia cristata (Willey)
124 Harmothoe magellanica (McIntosh)
125 Antinoella antarctica (Bergstrom)
126 Thelepus cincinnatus (Fabricius)
127 Maldane sarsi Malmgren
128 Praxilella kerguelensis (McIntosh)
129 Aglaophamus foliosus Hartman
130 Ammotrypane syringopyge Ehlers
131 Tharyx cincinnatus (Ehlers)
132 Haploscoloplos kerguelensis (McIntosh)
133 Apistobranchus typicus (Webster and Benedict)
134 Paraonis gracilis (Tauber)
135 Exogone minuscula Hartman
136 Sabellidae sp. #25
137 Ampharete kerguelensis McIntosh
138 Euchone pallida Ehlers
139 Lysilla loveni macintoshi Gravier
140 Myrioglobula antarctica Hartman
141 Phyllodocidae sp. #30
142 Aedicira sp. #31
143 Spiophanes sp. #32
144 Phyllodocidae sp. #33
145 Lumbrineris antarctica Monro

146 Sternaspis scutata (Renier)
147 Aedicira belgicae (Fauvel)
148 Euchone sp. #37
149 Ampharetidae sp. #38
150 Ammotrypane breviata Ehlers
151 Ampharetidae sp. #40
152 Phyllochaetopterus monroi Hartman
153 Terebellidae sp. #42
154 Paraonis sp. #43
155 Lumbrineris sp. #44
156 Terebellides stroemii kerguelensis McIntosh
157 Glycera capitata Oersted
158 Brania rhopalophora (Ehlers)
159 Flabelligera sp. #48
160 Leaena sp. #49
161 Phylo sp. #50
162 Scoloplos marginatus (Ehlers)
163 Eulalia subulifera Ehlers
164 Artacama crassa Hartman
165 Trichobranchus glacialis antarcticus Hessle
166 Tharyx epitoca Monro
167 Nereidae sp. #56
168 Potamethus sp. #57
169 Leaena sp. #58
170 Eteone sculpta Ehlers
171 Polycirrus sp. #60
172 Hauchiella tritullata (McIntosh)
173 Octobranchus antarcticus Monro
174 Anobothrella antarctica (Monro)
175 Oriopsis sp. #64
176 Kefersteinia cirrata (Keferstein)
177 Maldanidae sp. #66
178 Leaena sp. #67
179 Pherusa sp. #68
180 Potamilla antarctica (Kingberg)
181 Pygospio dubia Monro
182 Sphaerodorum fusum Hartman
183 Laonice cirrata (Sars)
184 Sabellidae sp. #73
185 Serpulinae #74
186 Ampharetidae sp. #186
187 Travisia kerguelensis McIntosh
188 Ophryotrocha claparedii Studer
189 Mesospio moorei Gravier
190 Cirratulus cirratus (Muller)
191 Falkandiella annulata Hartman
192 Trypanosyllis gigantea (McIntosh)
193 Spirorbinae #82
194 Syllis sp. #83
195 Scalibregma inflatum Rathke
196 Prionospio sp. #85
197 Ammotrypane sp. #86

198 Spiophanes sp. #87
199 Travisia sp. #88
200 Flabelligeridae sp. #89
201 Sabellidae sp. #90
202 Sabellidae sp. #91
203 Maldanidae sp. #92
204 Polychaeta sp. #93
205 Sphaerodorum parvum Ehlers
206 Ampharetidae sp. #95
207 Harmothoe sp. #96
208 Polynoidae sp. #97
209 Phyllodocidae sp. #98
210 Pionosyllis comosa Gravier
211 Polychaeta sp. #100
212 Exogone heterosetosa McIntosh
213 Exogone sp. #102
214 Exogone sp. #103
215 Syllidae sp. #104
216 Phyllodocidae sp. #105
217 Brada sp. #106
218 Torodrilus lowyri Cook
219 Nematodes
220 Pentanymphon antarcticum Hodgson
221 Nymphon sp.
222 Austrodecus glaciale (Hodgson)
223 Achelia communis (Bouvieri)
224 Achelia spicata (Hodgson)
225 Ascorhynchus sp.
226 Caenognesia sp.
227 Ascida meridionalis Herdman
228 Cnemidocarpa sp.
229 Ascidiacea sp. #4
230 Nemertea
231 Sterechinus neumayeri (Meissner)
232 Echinoidea sp. #232
233 Heterphoxus videns Barnard
234 Ampelisca bouvieri Chevreux
235 Monoculodes antarcticus Barnard
236 Kuphocheira setimanus Barnard
237 Cheirimedon femoratus (Pfeffer)
238 Djerboa furcipes Chevreux
239 Pontogeneia sp. #7
240 Pontogeneiella sp. #8
241 Haustoriidae New Genus n. sp. #9
242 Ampelisca anversi Karaman
243 Monoculodes scabriculous Barnard
244 Prostebbingia gracilis Chevreux
245 Hippomedon kergueleni (Miers)
246 Shakletonia robusta Barnard
247 Oradarea spp. #15
248 Schraderia gracilis Pfeffer

249	Pseudharpinia n. sp. #17a
250	Oediceroides sp. #18
251	Pseudharpinia n. sp. #19b
252	Orchomene litoralis (Schellenberg)
253	Metaleptamphopus sp. #21
254	Methalimedon nordenskjoldi Schellenberg
255	Urothoe n. sp.
256	Paraperioculedes brevimas Barnard
257	Jassa falcata (Montagu)
258	Paroediceroides sp. #26
259	Thaumatelson herdmani Walker
260	Oediceroides macrodactylus Schellenberg
261	Paraphoxus uninatus Chevreux
262	Gammaropsis n. sp.
263	Waldackia obesa (Chevreux)
264	Leucothoe spinicarpa (Abildgaard)
265	Lepidepecreum cingulatum (Barnard)
266	Ischyrocerus camptonyx Thurston
267	Harpiniopsis n. sp. #35
268	Prothaumatelson nasutum (Chevreux)
269	Atyloella sp. #37
270	Liljeborgia sp. #38
271	Podocerus sp. #39
272	Paroediceroides sinulata Schellenberg
273	Parhalimedon sp. #41
274	Haplocheira n. sp.
275	Wandelia crassipes Chevreux
276	Ampelisca richardsoni Karaman
277	Amphipoda sp. #45
278	Bathymedon sp. #46
279	Oedicerotidae sp. #47
280	Paramoera sp. #48
281	Orchomene sp. #49
282	Chaetoderma n. sp.