

**The relationship between sediment composition and infaunal polychaete communities along the southern coast of Namibia**

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**November 2005**

I declare that **The relationship between sediment composition and infaunal polychaete communities along the southern coast of Namibia** is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.



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**Dylan Thomas Clarke**

**This thesis is dedicated to my family, especially my late father Colin Roy Clarke,  
my mother, Lynette Wilma Clarke, my brothers, Byron Paul Clarke, Alain  
Frank Clarke, my sisters, Roxanne Caitlin Clarke and Lucinda Clarke and my  
fiancée, Sancha Victoria Fahrenfort.**



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**The relationship between sediment composition and infaunal polychaete  
communities along the southern coast of Namibia**

**Dylan Thomas Clarke**

**Keywords:**

Baseline biological information

Southern Namibian coast

Disturbance

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Multivariate

Taxonomic resolutions

Surrogates

Standardized samples



## Abstract

### Abstract

This study examined the relationship between sediment structure and infaunal polychaete communities off the southern coast of Namibia from two separate sets of data, and a total of ninety-two samples. It also examined whether a selected group of organisms (polychaetes) could provide the same level of information regarding community structure, as the entire fauna, at a number of taxonomic resolutions.

A total of 44 samples were collected by De Beers Marine (Pty) Ltd in 1999 off the southern coast of Luderitz from depths between 40 m and 90 m. The sediments varied from soft muds (45  $\mu\text{m}$ ) to gravel (> 710  $\mu\text{m}$ ). Forty-three morpho species of polychaetes were distinguished, of which only 28 known species of polychaetes could be positively identified, which suggests that more information on the diversity of polychaetes in the region is needed. The fauna was dominated by species in the Ampharetidae, Capitellidae, Maldanidae, Spionidae, Lumbrineridae, Flabilligeridae, Nephtyidae, Pectinariidae and Onuphidae. Multi-variate analyses using PRIMER indicated that communities were structured by mud (45  $\mu\text{m}$ ) and very fine sand (45 - 63  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ). Mud and gravel, although selected by the BIOENV procedure as accounting for some of the variation in the polychaete assemblage structure, explained no more of the data (in combination) than did mud on its own. As similar clustering of samples was observed when the data were analysed at both the family and species-level, suggesting that the same level of information was being gained at the two taxonomic levels. The results of the BIOENV analyses were also broadly similar for both taxonomic levels of analyses, in

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terms of both the proportion of the variation in assemblage structure explained by the selected environmental variables and the choice of selected variables. These results suggested the information gathered at the polychaete family-level were equally clear when they are collected at the family-level for the entire infauna.

The use of polychaetes (to the family-level) as surrogates, using sediment structure and depth was independently investigated from a total of 48 samples that were collected by De Beers Marine (Pty) Ltd in 2001, from depths between 20 m and 110 m. The sediment varied from mud ( $< 63 \mu\text{m}$ ) to gravel ( $> 710 \mu\text{m}$ ). Twenty-two families of polychaetes were distinguished, the fauna showing an abundance of Capitellidae, Cirratulidae, Flabilligeridae, Lumbrineridae, Magelonidae, Nephtyidae, Paraonidae, Pilargiidae, Onuphidae, Syllidae and Spionidae. Striking differences were found in the amount of variation accounted for in the biological samples by the environmental data. Interestingly, depth in combination with a particular sediment size fraction featured very strongly in structuring both sets of communities. The biotic patterns in the family-level total infauna were not similar for the polychaetes (at the same taxonomic resolution). These results suggested that one group of organisms (polychaetes at the family-level) may not be useful as a proxy for the entire infauna (at the family-level).

Because of the contrasting results that were obtained in 1999 and 2001, the biological data in 1999 were pooled and the environmental data (sediment size fractions) were adjusted accordingly (i.e. some of the differences in the results may reflect differences in the methods used to collect data). Consequently the results still did not adequately

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explain why there was a low level of similarity between the total infauna and polychaete family-level biotic patterns in 2001. It seemed that pooled data improved the taxonomic resolution (amount of variation obtained), but when the sediment size fraction data were adjusted, it lowered the amount of taxonomic resolution. The results suggest that comprehensive and standardized samples must be collected to fully understand the relationships between biotic patterns and environmental variables. This is potentially important given the costs involved and the potentially long lasting value of the material collected. These sediment and biological samples were collected by industry (for baseline biological monitoring in the mining industry, and not academic purposes). Proper protocols need to be established which allow industry-related monitoring programs to make a real contribution to our understanding of the biodiversity and ecology of the area.



## **General Introduction**

The area of the ocean that lies between the lowest low water mark on the shore to the edge of the continental shelf at a depth of about 200 m is known as the sublittoral zone. The substratum of the sublittoral varies from sand, mud and some areas of hard substrate or gravel depending on the geology and the geological history of the area. The soft sediments are typically dominated by infaunal organisms: animals that live within the sediments.

### **Benthic infauna**

Infauna are commonly divided into categories based on size. Macrofauna are organisms that are greater than 0.5 mm and meiofauna are organisms that belong in the size class of 0.5 to 0.062 mm (Nybakken, 1993). Macrofauna have also been referred to as those organisms that are retained on a 1 mm sieve (Higgins and Thiel, 1992). Microfauna are organisms which fall below the 0.062 mm size class and are generally protozoa and bacteria (Nybakken, 1993).

### **Meiofauna**

Meiofauna live interstitially, that is, they inhabit the microspaces between adjacent sediment particles or live on the individual particles (Nybakken, 1993). Sediment grain size may therefore affect the composition, diversity and abundance of meiofauna as it provides their primary habitat (Higgins and Thiel, 1992). Different assemblages occur in muddy versus sandy versus phytal habitats (Higgins and Thiel,



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1992). Complete reviews on the various aspects of meiofaunal ecology may be found in Swedmark (1964), McIntyre (1969), Gerlach (1971, 1978), Coull (1973), Fenchel (1978), Coull and Bell (1979), Platt and Warwick (1980), Giere and Pfannkuche (1982), Heip *et al.* (1982, 1985), Hicks and Coull (1983), Thiel (1983), Coull and Palmer (1984) and Soyer (1985).

### **Macrofauna**

Four main macrofaunal taxa are present in sublittoral soft-sediment bottoms; polychaetes, crustaceans, echinoderms and molluscs. Polychaetes are the most abundant and are also represented by numerous tube-building, burrowing and errant species (Chambers and Muir, 1997). A few of the dominant crustacean groups in the sublittoral bottoms are the larger ostracods, amphipods, isopods, tanaids, mysids and smaller decapods. Molluscs are represented by various burrowing bivalve species, with some gastropods occurring at the surface of the sediment. Echinoderms include brittle stars, heart urchins, sand dollars, sea stars and some predatory sea stars (Rupert and Barnes, 1994).

### **Factors affecting macrofaunal abundance, composition and diversity**

Numerous factors affect the abundance, composition and diversity of macrofaunal communities including the organic and microbial content of the sediment, wave action or turbulence, temperature and salinity (McConnaughey *et al.*, 2000). The organic content of sublittoral sediments is normally high and this may be due to detritus and productivity by plankton and attached plants such as kelp and seagrasses (Newell *et*

## Introduction

*al.*, 1998). High productivity sustains high populations of macrofaunal organisms. Wave action in the form of ocean swells and storm waves may extend to the bottom sediments and affect the stability of the substrate and the infaunal community found there (Nowell, 1983). Although temperature and salinity may vary more in the sublittoral zone than in the open ocean and deep sea, it does not change sufficiently to be of ecological importance and temperature changes may be used by macrofaunal organisms as cues to begin and end a variety of activities such as reproduction (Nybakken, 1993). However, no single factor has been able to explain patterns observed across many different environments (Snelgrove, 1994).

Disturbance is another factor that influences the abundance, composition and diversity of macrofaunal communities (Newell *et al.*, 1998). An example of disturbance on the seabed and subsequently the macrobenthic community, is fishing and there has been a multitude of systematic research on the resultant effects (Hall, 1999). This research dates back to the 1970s and was undertaken because of the increase in both the use of fishing fleets and the technological advances that accompany modern fishing methods (Blanchard *et al.*, 2004). The fishing gear that is usually necessary to catch demersal and shellfish disturbs the seabed and the benthic organisms living there (Blanchard *et al.*, 2004). The response of benthic communities is usually an increase of small, fast growing species and a reduction in species diversity and evenness (Hall, 1999). The effects of fishing disturbance on benthic communities may not only depend on the concentration and frequency of fishing, but also on the condition of the habitat (Jennings *et al.*, 2002).

Numerous studies have also investigated the real and potential impact of dredging on the ecology of biological communities in coastal and estuarine ecosystems (Jones and Ellis, 1976; Conner and Simon, 1979; Johnston, 1981; Ellis and Heim, 1985; Ellis and Hoover, 1990; Giesen *et al.*, 1990 and Onuf, 1994). These studies have tended to show that dredging causes a decrease in the number of species and a reduction in the population density and biomass of benthic organisms; the rate of recovery is variable for all organisms (Newell *et al.*, 1998).

### **Animal-sediment associations**

The mechanisms determining the distributions of organisms are poorly understood and the significance of animal-sediment associations are often difficult to understand (Snelgrove and Butman, 1994). Some authors have tried to explain the above-mentioned using the influence of bottom boundary-layer flow and related dynamic processes on benthic communities (Nowell and Jumars, 1984; Butman, 1987; Miller and Sternberg, 1988; Palmer, 1988). There is also the view of hydrodynamics and sediment transport processes in general, having an influence on how benthic communities are structured (Nowell, 1983; Grant and Madsen, 1986; Butman, 1987).

Sediment grain size is also an important factor that influences macrofauna (Jansson, 1967; Basford *et al.*, 1990; Küche and Rachor, 1996; Rees *et al.*, 1999). Although the role of sediment in structuring macro-invertebrate communities has often been demonstrated, these studies have focused mainly in estuaries (McNulty *et al.*, 1962; Nichols, 1970; Bloom *et al.*, 1972) or shallow marine bays (Sanders, 1958; Young and Rhoads, 1971; Biernbaum, 1979). Animal-sediment relationships on open

continental shelves have received considerably less attention, but there have been some investigations in Europe (e.g. Glemarec, 1973; Buchanan *et al.*, 1978), Asia (e.g. Rhoads *et al.*, 1985) and North America (e.g. Flint, 1981). The above-mentioned studies have successfully differentiated macrofaunal communities on the basis of sedimentary parameters but, in some shelf environments, the sediment related effects are often masked by considerably greater variation in other, often depth-related, environmental parameters (Weston, 1988; Snelgrove and Butman 1994). Jansson (1967) has also shown that different concentrations of water content, water circulation and oxygen availability caused by grain size distribution, may have a greater importance for the interstitial fauna, than the space-restricting property.

### **Background**

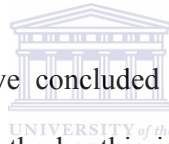


Benthic animals generally have “long” lifespans and their community structures integrate along with environmental conditions in a particular area over periods of up to 20 years (Gray *et al.*, 1990). However, infauna such as polychaetes and peracarid crustaceans may only live for up to twelve or eighteen months, while others go through three or four generations a year (Fauchald, 2001). There are many studies on the seasonal variation in the composition and structure of benthic communities, but long-term studies are scarce (Gray *et al.*, 1990). Many techniques are available to biologists for the analysis of biological community composition and its associated physical environment (Kruskal, 1977; Field *et al.*, 1982; Warwick, 1986; Heip *et al.*, 1988; Magurran, 1991; Warwick and Clarke, 1991; Clarke and Ainsworth, 1993; Clarke and Warwick, 1994). The interpretation of short-term studies may provide more useful information on the abundance and composition of marine communities

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during the recovery process following the termination of dredging, than long-term studies (Kenny and Rees, 1994, 1996; Newell *et al.*, 1998).

A series of such studies have taken place in mining areas in which De Beers Marine (Pty) Ltd operates on behalf of the Namdeb Diamond Corporation. Regular benthic surveys have provided useful information on infaunal community composition changes due to the effects of physical disturbance of the sea floor (Savage, 1996; Van der Merwe, 1996; Field and Parkins, 1998; Pulfrich and Penney, 1999; Winckler, 1999). Responses to that disturbance cannot always be predicted as some species may benefit from hydrodynamic disturbances (Tupper and Boutilier, 1995), whereas accumulated detritus may negatively affect other species (Hall, 1994).



Previous benthic grab studies have concluded that deep-sea mining off southern Namibia had a negative impact on the benthic invertebrate community (Field *et al.*, 1996; Parkins and Field, 1998). The mining impact may lead to the loss and disruption of habitat or through the smothering of the seabed by fine material in the vicinity of mining activities and the slow recovery rates in mined areas may indicate that such impacts are cumulative (Parkins and Field, 1998). Parkins and Field (1998) have also shown that sediment composition strongly influences the benthic invertebrate community structure, but that the effects on benthic communities of natural variability in factors such as dissolved oxygen concentrations are still unclear.

In 1999, De Beers Marine (Pty) Ltd conducted a baseline biological survey of sediment composition and the infaunal benthic communities off the coast of Namibia. It was found that sediment composition strongly influences the benthic invertebrate

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community structure in anthropogenically undisturbed conditions and up to 53% of community composition could be attributed to sediment granulometry (Goosen *et al.* 2000).

Traditionally, environmental monitoring and impact studies require that organisms be identified to the species-level. This is often the pre requisite when the objective of the study is to identify patterns in benthic community structure and relate them to a set of measured environmental variables (Olsgard *et al.*, 1998). Monitoring studies that make use of the abundances of higher-level taxa (e.g. genera, families and phyla) are infrequent (Olsgard *et al.* 1998). The question in studies of the above-mentioned nature would be to ask whether using higher taxonomic levels still provides information on most of the variation in a macrobenthic community structure.



Many workers have investigated whether the same information is gathered at higher taxonomic levels rather than species-level and what level would be sufficient for a particular study (Ellis, 1985; Warwick, 1988; Gray *et al.*, 1990; Vanderklift *et al.*, 1996; Olsgard *et al.*, 1997). Warwick (1988) found that in pollution studies, the sample analysis (univariate or multivariate) of benthic communities was adequate to the level of family and that no additional information was gained at the specific level. He also mentioned that for macrofauna such as polychaetes, there were many difficult families to separate into species, e.g. the Spionidae, Cirratulidae and Capitellidae. This was also true for certain amphipod families, e.g. Ampeliscidae (Warwick, 1988). However, this was based on studies where pollution gradients were present and not on the granulometric properties of the sediments directly and in anthropogenically undisturbed conditions.

Olsgard *et al.* (1998) have claimed that there is often a shortage of taxonomic literature and expertise in marine areas near the tropics. They suggested that persons or organizations might benefit more by observing taxa at the genera or family-level, if no experts were available and depending on what type of investigation it was.

### **Polychaetes**

South Africa is acknowledged as being the third-most biologically rich country in the world, because it contains 8% of the world's vascular plants, 2% of the amphibians and 7% of the reptile, bird and mammal species (Gibbons *et al.*, 1999). South Africa is rich in species numbers and high levels of endemism have been recorded for certain groups (Gibbons *et al.*, 1999). The area also has high marine faunal diversity, but due to the declining number of full-time taxonomists working on marine taxa, there still remains a large proportion of undescribed marine species (Gibbons *et al.*, 1999), especially amongst the invertebrates. One such group of invertebrates is the Polychaeta.

Although comprehensive monographs on the southern African Polychaeta were produced by Augener (1918) and Day (1967), it has been suggested that these documents have become in part outdated. Many of the type specimens are held in the Zoological Museum in Hamburg and at the Natural History Museum in London making access to them difficult from South Africa. New definitions of families, genera and species have been erected since the 1960s (Fauchald, 1977; Rouse and Pleijel, 2001) and therefore there is an urgent need to update this information and describe new species.

## Introduction

Polychaetes are one of the dominant and diverse groups of invertebrates in the marine fauna (Chambers and Muir, 1997). They occur in or on all types of substrata, in waters of all levels of salinity and at all depths in the ocean (Chambers and Muir, 1997). Currently over 15 000 species in 83 families have been described globally (Fauchald, 2001). There are more than 800 species present in southern African, representing a rich and diverse fauna (Day, 1967).

Polychaetes are the main food source for many demersal fish (Chambers and Muir, 1997). Although some polychaete species have a high level of tolerance to pollution (Gray and Pearson, 1982; Dauer, 1984, 1997; Levings *et al.*, 1985; Rygg, 1985 a, 1985 b; Samuelson, 2001), they are valuable indicators of marine environmental health and give useful information about the destructive nature of pollution and mining (Belan, 2003). Polychaetes are farmed for bait, and used by anglers, emphasizing their importance as a fish food (Chambers and Muir, 1997). However, they also have a destructive nature, as they are known to bore into commercially important shellfish and underwater cabling (Chambers and Muir, 1997).

Polychaetes have traditionally been divided into free-living and sedentary forms, the Errantia and Sedentaria respectively (Fauchald, 1977). This separation was based on the development of the anterior end and on life habits (Fauchald, 1977). The Errantia possess large numbers of equal body segments, are considered free living with pronounced parapodia and chaetae and are predacious (possessing jaws). The Sedentaria possess a limited number of body segments, divided into distinct regions namely the thorax and abdomen: they are usually filter feeders and possess short parapodia associated with a burrowing lifestyle. Although this is the most widely used



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system of ordinal classification, it is generally agreed that it is an unnatural one (Fauchald, 1977). Rouse and Pleijel (2001) proposed a new system of classification, which is widely accepted today. The Polychaeta comprises two clades, the Scolecida (no further clades above family) and Palpata with clades Aciculata (Phyllodocida and Eunicida) and Canalipalpata (Sabellida, Spionida, and Terebellida). The Pogonophora are included as the Family Siboglinidae in the clade Sabellida.

### **The aims of this study are:**

- To collect baseline biological information on the polychaete community at the specific level in an anthropogenically undisturbed environment (The Marshall Folk and Elephant Basin areas off the southern coast of Namibia).
- To elucidate the relationship between sediment composition and the polychaete species: are families an adequate proxy for species?
- To collect baseline information on a separate community at the family level (Chapter three).
- To determine the relationship between sediment and the polychaete families: are polychaete families an adequate proxy for the entire fauna at the family level?.



**Sediment structure as an indicator of polychaete assemblages off the southern coast of Namibia**

**Abstract**

The use of polychaetes as indicators of sediment structure is investigated and data are compared with the results of a previous study that included all the infauna. A total of 44 samples were collected by De Beers Marine (Pty) Ltd in 1999; from which 43 morpho species were distinguished. The results suggest that polychaetes may be used as a proxy for the entire infauna (at the family-level). Comparisons revealed similar clustering of samples at different levels of analysis, using the same sediment data. A comparison is also made between sediment structure and polychaete assemblages, as identified at the family and species-level. It is suggested that the information gathered at the species-level was just as clear when they are collected at the family-level. The fauna was dominated by polychaete species in the Ampharetidae, Capitellidae, Maldanidae, Spionidae, Lumbrineridae, Flabelligeridae, Nephtyidae, Pectinariidae and Onuphidae families.

**Introduction**

The marine environment is affected by various anthropogenic disturbances such as pollution, development and the exploitation of living and non-living resources is increasing (Lopez-Jamar *et al.*, 1995). Fishing and other forms of exploitation result in local environmental changes in the coastal zone (Belan, 2003). The benthic communities are often affected by these disturbances and this makes knowledge of

their natural variability vital in order to determine their responses to these disturbances (Warwick, 1993).

Commercial fishing using mobile gear, such as bottom trawls and dredges, is a good example of disturbance. Although a comprehensive bibliography on the effects of fishing gear on the benthos does exist and is provided by Redant (1991), little of this information appears in refereed journals (Hall, 1994). Fishing gear disturbs the sediment and negatively affects the resident community (Hall, 1994). The main concern for the use of fishing gear in the benthos is the increase in size and weight of the gears used in trawling and dredging. More areas are also now accessible to fishermen, because of updated technologies that allow them to fish in deeper water (Hall, 1994).



There have been increased effects on marine biodiversity by fishing in South Africa (Attwood *et al.*, 2000). With respect to the benthic environment it was found that trawls and dredges cause damage by scraping, ploughing and resuspension of sediments (Jennings and Kaiser, 1998). Another effect of fishing on the benthic environment is the trawl catch discards. These discards sink to the bottom where they decompose and reduce oxygen levels in the benthic layer, thus making the habitat less suitable for benthic organisms (Jones, 1992). No impacts of trawling on the west coast of South Africa have been reported thus far.

The marine environment in South Africa is mined in the north-east for titanium, in the south for fossil fuels and in the north-west for diamonds (Attwood *et al.*, 2000). Exploration for phosphate is also currently in progress along the southern and western

## Sediment structure as an indicator of polychaete assemblages

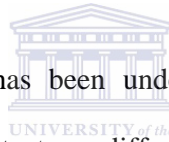
coasts (Attwood *et al.*, 2000). The above-mentioned mining causes disruption of the sediment, which can be widespread in the case of titanium and oil. This in turn leads to partial or complete removal of the resident biological community and may also introduce harmful materials into that environment (Attwood *et al.*, 2000). Oil and gas exploration near Mossel Bay and further on the Agulhas Bank may also cause major loss of benthic diversity, and the threat of an oil spill does exist. Diamond mining along the west coast also leads to a loss of benthic marine biodiversity and through the re-suspension of sediments, may leave toxic concentrations of heavy metals in its tail plume (Lane and Carter, 1999). Concessions have also been granted to local and international companies covering most of the coastal zone and continental shelf. There is little baseline data available for these areas and no “biodiversity maps” currently exist.



There is a growing need, and demand for, Environmental Impact Assessments (EIA's) to be conducted before new mining projects can be initiated, or before existing licenses to disturb are renewed (Attwood *et al.*, 2000). Although there is legislation, which applies to the control of the South African coastal zone, and national policies regarding marine and coastal biodiversity, there are also many short-comings (Attwood *et al.*, 2000). One of the main concerns is staff shortages and limited environmental expertise, but a White Paper is being developed and includes an extensive public participation process (Attwood *et al.*, 2000). All disturbance operations are undertaken on the authority of the Department of Mineral and Energy affairs, in terms of the Minerals Act of 1991 and a proper Environmental Management Programme (EMP) should be in place before any licenses are granted (DME, 1996).

## Sediment structure as an indicator of polychaete assemblages

EIA's and pollution studies of benthic infauna are usually focused on either the entire fauna or on specific groups (Warwick, 1988). Although the ability to identify organisms to species level may be a matter of "pride to benthic ecologists" (Warwick, 1988), taxonomic sufficiency is only required to the level that indicates the community response (Ellis, 1985). However, there is some evidence to suggest that ecologically similar species that belonged to the same genus or family, would respond differently to disturbances or pollution effects (e.g. Bamber and Spencer, 1984; Bamber, 1993). But, it could also be argued that the costs of sampling and species identification increases with the number of groups studied; since macrofaunal groups such as (e.g.) polychaetes often need to be sent to experts for identification. The process is also highly labour intensive and time-consuming (Warwick, 1988).



Research (e.g. Warwick, 1988) has been undertaken to examine the degree of taxonomic resolution required to detect any differences caused by pollution on marine benthic communities. Warwick (1988) used five data sets, three for the macrobenthos and two for meiobenthos, and found that the results would have been equally clear if the fauna was analysed to higher taxonomic groupings (familial level) only, than to the specific level. However, the pollution gradients in those sediments are likely to have been strong and it could be argued that major changes would be expected. Warwick (1988) did not test those theories in areas that were subjected to natural environmental variability and this is one of the aims here.

Polychaetes have been known to be reliable indicators of environmental stress (Belan, 2003; Bergen *et al.*, 2001; Gray and Pearson, 1982; Gray *et al.*, 1990; Pearson *et al.*, 1983; Read *et al.*, 1983; Samuelson, 2001; Van Es *et al.*, 1980) and are used globally

## Sediment structure as an indicator of polychaete assemblages

for the assessment of marine sediment condition (Bergen *et al.*, 2001). Polychaetes are one of the abundant and diverse groups of invertebrates in the marine fauna (Chambers and Muir, 1997). They comprise over one-third of the total number of macrobenthic species (Fauchald and Jumars, 1979). They occur in or on all types of substratum, in waters of all levels of salinity and at all depths in the ocean (Chambers and Muir, 1997). They are widely distributed geographically and occupy a variety of marine and estuarine habitats. Some polychaete species also have a high level of tolerance to pollution (Dauer, 1984, 1997; Levings *et al.*, 1985; Rygg, 1985 a, b; Samuelson, 2001).

Baseline information on the benthic environment is essential for determining the community composition of an area and its relationship with the physical environment (e.g. sediment composition, dissolved oxygen levels, organic Carbon content). Changes in sediment composition for instance may directly reflect on the infaunal species composition and the succession stages after disturbance (Goosen *et al.*, 2000). Parkins and Field (1998) and Goosen *et al.* (2000) found that sediment composition strongly influenced the benthic invertebrate community structure off the southern coast of Luderitz, but that the influence of factors such as dissolved oxygen levels were still unclear.

The aim here is to test two things – Firstly: to determine whether one group of organisms (polychaetes) can be used as a proxy for the entire fauna (at the level of the family) using the data that Goosen *et al.* (2000) collected only in an anthropogenically undisturbed environment. Secondly, to determine whether, in a selected group

(polychaetes), analyses at the family give the same level of information as analyses at the species-level.

### **Materials and methods**

The data set used here (see Appendix two), and the polychaete samples analysed, were collected and provisionally reported upon, by Goosen *et al.* (2000). A complete description of the areas that were sampled is provided in Appendix one.

In order to test whether the biotic patterns that were observed by Goosen *et al.* (2000) from an analysis of the entire community (at the family-level) were similarly displayed by the polychaetes only (at the family-level), their analyses were repeated both with and without polychaetes. I specifically looked for similarities in the structure of the two dendrograms, and in the results of the respective BIOENV procedures. It should be noted that all data used in this analysis were taken from Goosen *et al.* (2000).

In order to test if there is a loss of biological resolution when determining polychaete communities on the basis of species-level or family-level identifications, dendrograms of percent similarity amongst samples were constructed using species-level and family-level information. I specifically looked for similarities in the structure of the two dendrograms, and in the results of the respective BIOENV procedures. It should be noted that I have not used the family-level data from Goosen *et al.* (2000) in this instance, because De Beers Marine (Pty) Ltd were unable to supply me with all the

samples, instead I have used my own family-level data, based on my species-level data.

### **Benthic Sampling and Sample Processing**

The following has been summarized (in part) from the report by Goosen *et al.* (2000). A benthic grab sampling survey was conducted from the De Beers Marine contracted supply tug, *Pentow Salvor*, from 24 – 29 July 1999 in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia (Figure 1). The samples were all taken from hitherto un-mined areas.

An onboard-computerized differential GPS system was used to accurately locate the grab sample site positions. Replicate sediment samples were taken at each sample site using a Van Veen grab. The Van Veen grab sampled 0.2 m<sup>2</sup> area of seabed down to a depth of about 20 cm. A sediment core sample was taken from the grab on retrieval for sediment texture analysis. The samples were then washed through stacked 1 mm and 10 mm sieves and all retained organisms were bottled and fixed in 10% formaldehyde for subsequent analysis ashore.

Data on the physical environment were collected at all the representative grab stations, by using a CTDOT (Conductivity, Temperature, Depth, Dissolved Oxygen and Turbidity) and a Niskin flask. The CTDOT data were collected at metre intervals through the water column, while the Niskin flask was used to collect a sample of near-bottom water. The CTDOT data consisted of dissolved oxygen concentrations (ml/l),



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temperature (°C), salinity (psu) and backscatter (uncalibrated) measurements that were recorded internally and downloaded onto a PC.

All faunal samples were rinsed in fresh water to remove all traces of formaldehyde, prior to being transferred to 1% phenoxyethanol (ethylene-glycol-monophenyl-ether). Polychaete samples were then transferred to 70% ethanol. Samples were hand sorted and the polychaetes that could not be identified (e.g. decapitated specimens) were excluded from the subsequent analysis. All polychaetes that had previously been identified by Goosen *et al.* (2000) to the level of family were identified to the specific level and counted. A dissecting (Stemi D4 Zeiss) and compound microscope (Leitz Laborlux II) were used to identify specimens. When the specimens were damaged or when some of the structures were not easily observable, staining procedures (Wisnes, 1985) were used. Polychaetes were identified using the following literature: Blake, 1996 a, b, c; Blake and Kudenov, 1978; Chambers and Muir, 1997; Day, 1967; Fauchald, 1977; Fauchald and Rouse, 1997; Hutchings and Turvey, 1984; Imajima, 1973; Licher and Westheide, 1997; Mackie, 1984; Mackie, 1996; Maciolek, 1985; Muir, 1982; Pettibone, 1966, 1993; Rouse and Fauchald, 1997; Strelzov, 1979.

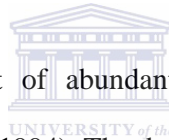
The sediment core samples were used to determine grain size composition. Each sediment sample was removed from the sediment corer, and a brief description of sediment composition was recorded and a sub-sample was taken for further analysis. The sub-sample was carefully washed through a 45 µm sieve to remove all fine clay material. The residue was transferred to a glass beaker and the contents dried at 100 °C. The dried material was weighed to the nearest 0.001 g and sieved through a series of sieves (i.e. 63 µm, 125 µm, 250 µm, 710 µm and a catching pan) for about twenty

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minutes. Each fraction of the sediment was weighed separately and the coarsest material was weighed separately after sieving through a 1000  $\mu\text{m}$  or 2000  $\mu\text{m}$  sieve.

### Statistical Analysis

All data were analysed using PRIMER (Plymouth Routines In Multivariate Ecological Research) v5 software (Clarke and Warwick, 1994). This programme consists of a range of univariate, graphical and multivariate routines for analysing matrices of species by sample abundances that arise in biological monitoring and environmental impact studies. It is also used for studies in community ecology, together with associated physico-chemical data (Clarke and Warwick, 1994).



To reduce the dominating effect of abundant species, all data were root-root transformed (Clarke and Warwick, 1994). The degree of similarity between individual samples was measured using the Bray-Curtis similarity index (Bray and Curtis, 1957). The Bray-Curtis similarity matrix between samples was expressed as a dendrogram. In order to determine which species and families of polychaete were responsible for the structure of the observed clustering, data were analysed using the SIMPER (Similarity Percentage Analysis) procedure in PRIMER (Clarke and Warwick, 1994). The overall percentage contribution each species/family made to the average dissimilarity between two groups (an average of all possible pairs of dissimilarity coefficients, taking one sample from each group) were observed at different level structures and compared. The average abundance percentages were also obtained and compared.

## Sediment structure as an indicator of polychaete assemblages

A number of approaches were used to determine the relationship between sediment granulometry and assemblage structure. In the first instance, the mean values of the various granulometric properties of the samples in the major clusters identified in the previously constructed dendrogram were calculated and then compared using ANOVA (as e.g. Thibault-Botha *et al.*, 2004). Obviously, such comparisons could only be made where the number of samples in any one of the clusters exceeded two. In order to try and determine the relationship between patterns in multivariate community structure and measured environmental parameters, the data were also analysed using the BIOENV procedure in PRIMER (Clarke and Ainsworth, 1993). This is a Spearman rank correlation test which calculates rank correlations between a similarity matrix obtained from biotic data and matrices obtained from various sets of environmental variables, thereby defining suites of variables most closely correlated with the observed biotic structure.



## Results

The data set used here was originally compiled by Goosen *et al.* (2000).

### **Polychaete assemblages versus Total assemblages.**

Figure 2 A shows the dendrogram of percent similarity in the numerical composition of samples, based on the total infauna (identified to family only). Figure 2 B shows the dendrogram of percent similarity in the numerical composition of the samples, based only on the polychaetes (identified to family only).

## Sediment structure as an indicator of polychaete assemblages

Both dendrograms in Figure 2 are characterised by generally low levels of similarity between samples, but those constructed from the total assemblage data (Figure 2 A) show greater similarity than do those from the polychaete assemblage data (Figure 2 B).

There is a general similarity in both the level I and level II structure of the two dendrograms in Figure 2: ECW-1 and ECW-2 is less than 10% similar to the balance of the samples, whilst samples ECN-3, ESS-3, ECN-4, ECN-1 and ECN-2 are less than 20% similar to the other samples. There seems to be little agreement in higher-level structures (Level III - VI) of the two dendrograms. Although common samples were found in the level III to VI structures, there appears to be a good deal of mixing: for example, the two samples that cluster together as part of the level III structure in the total infauna dendrogram (Group C, Figure 2 A), do not cluster similarly in the polychaete family-level dendrogram (Group C, Figure 2 B).

A comparison of the sediment properties for the different levels (using ANOVA) indicated that: significant differences were found in the level I structure for mud (0 - 45  $\mu\text{m}$ ), very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ); for the total infauna (Table 1 A) and the family-level polychaete fauna (Table 1 B). A significant difference was also noted at the level II structure in the proportion of medium sand (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ). The level III and IV structures showed no significant differences for any of the environmental variables in both dendrograms. Significant differences were found in the proportion of mud, and very fine sand, at the level V and VI structure, respectively. Interestingly, the level V structure showed no significant difference for coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ) in the total infauna dendrogram (Table

1 A), whereas it did in the polychaete family-level dendrogram (Table 1 B). The level VI structure in the family-level polychaete dendrogram showed significant differences for both medium and coarse sand, whereas total infauna only showed a significant difference for coarse sand.

The results of the BIOENV analyses were broadly similar for both levels of analyses (Table 2), in terms of both the proportion of the variation in assemblage structure explained by the selected environmental variables and the choice of selected variables. However, the muddy-size fraction of the sediments (0 - 45  $\mu\text{m}$ ) accounted for 45.3% of the structure in the total infauna as identified by family, whereas mud (0 - 45  $\mu\text{m}$ ) and very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ) accounted for 45.7% of the polychaete structure as identified by families. In all cases, the amount of variation explained was greater for communities identified using family-level polychaete data than it was using the total infauna family-level information. Mud (0 - 45  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ), although selected by the BIOENV procedure as accounting for some of the variation in the polychaete assemblage structure, explained no more of the data (in combination) than did mud on its own.

### **Polychaete Families versus Polychaete Species**

Only 26 of the 44 samples used by Goosen *et al.* (2000) analysed above, could be used in this analysis, because extensive damage had been caused to some of the polychaetes present in the original samples and 18 of the samples have been misplaced between the time of the first analysis and this study.

## Sediment structure as an indicator of polychaete assemblages

Figure 3 shows the dendrograms of percent similarity in the numerical composition of samples, based on identification to species (Figure 3 A) and when those data were lumped as families (Figure 3 B).

Although both dendrograms in Figure 3 are characterised by generally low levels of similarity between samples, those constructed from family-level data show greater similarity than do those constructed from species-level data.

There is a general similarity in both the level I and level II structure of the two dendrograms in Figure 3: MC6-3 is less than 5% similar to the balance of the samples, whilst samples ECW-1 and ECW-2 are less than 15% similar to the other samples. There is also a good deal of agreement in the level V structure of the two dendrograms and only ECE-1, ESN-2 (Figure 3 A) and ECN-4 (Figure 3 B) do not cluster similarly in both dendrograms. In other words, there would appear to be little difference in the coarse and fine structure of the two dendrograms. However, there appears to be a good deal of mixing in the level III and level IV pattern: for example, of the four samples that cluster separately as part of the level III structure in the species-level dendrogram (Group D, Figure 3 A), only MC1-1 clusters similarly in the family-level dendrogram (Figure 3 B); the balance of samples cluster together in the level IV structure.

The results of BIOENV analyses were broadly similar for both levels of analyses (Table 2), in terms of both the proportion of the variation in assemblage structure explained by the selected environmental variables and the choice of selected variables. Thus, the muddy-size fraction of the sediments (0 - 45 µm) accounted for

## Sediment structure as an indicator of polychaete assemblages

34.9% of the structure in the polychaete communities as identified by species, and 36.2% of the structure in communities as identified by families. In all cases, the amount of variation explained was greater for communities identified using family-level data than it was using species-level information. Very fine sand (45 - 63  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ), although selected by the BIOENV procedure as accounting for some of the variation in the polychaete assemblage structure, explained no more of the data (in combination) than did mud on its own.

The results of the sediment properties for the different level analysis using ANOVA, indicated that: no significant differences were found for the level III and IV structures for the specific and family-level polychaete dendrograms respectively. Significant differences were found in the level I structure for coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ) in both dendrograms. A significant difference was also noted in the level II structure for mud (0 - 45  $\mu\text{m}$ ), very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ) for the specific (Table 3 A) and family-level (Table 3 B) polychaete fauna respectively. The level V structure showed a significant difference for very fine sand at the species-level (Table 3 A) whereas at the family-level (Table 3 B) there was a significant difference for coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ).

For the purposes of brevity and since there were only significant differences at the level I, II and V structures for the sedimentary properties in both dendrograms, comments on the results of SIMPER are confined to comparisons of those levels. The level I structure revealed that at least five species were responsible for observed differences between cluster A and B (Table 4) in the species-level polychaete dendrogram (Figure 3 A). A comparison of the SIMPER results for both dendrograms

## Sediment structure as an indicator of polychaete assemblages

at the same level structure revealed that four of the dominant species found in cluster B (Table 4) were represented by their respective families (Table 5) in the same cluster. Comparisons of the level II structure revealed similar results, but in this instance all the species (Table 4) which accounted for observed differences between the clusters in Figure 3 A, were also represented by their respective families (Table 5) and they were also found to be dominant in cluster B. Only four of the species (Table 4) that accounted for the observed differences in the level V structure were represented by their respective families (Table 5). Although those species were dominant in cluster B (Table 4), only three of the four families were dominant in the same cluster (Table 6).

### **Comments on the polychaetes of the Marshall Fork and Elephant Basin**



The material examined from the Marshall Fork and Elephant Basin areas yielded 43 morpho-species of polychaete, representing 23 families. Only 28 species could be positively identified to existing species (Table 6). The fauna showed an abundance of species in the Ampharetidae, Capitellidae, Maldanidae, Spionidae, Lumbrineridae, Flabelligeridae, Nephtyidae, Pectinariidae and Onuphidae (Table 4).

### **Discussion**

The species that could not be fully identified in this study (Table 6) may be potentially new. Although numerous species have been described by Day (1967) in a comprehensive monograph that covered most of the southern African species, the present results indicate a need for additional collections around the region.



## Sediment structure as an indicator of polychaete assemblages

Goosen *et al.* (2000) found that sediment samples from each Van Veen grab station had a heterogeneous substrate in sites from both Marshall Fork and Elephant Basin. Parkins and Field (1998) and Pulfrich and Penny (1999) previously conducted studies off the Orange River mouth and found that faunal differences between sampling areas were partly attributed to differences in sediment composition. However, these conclusions were based on a single sediment sample from one grab station. The heterogeneous nature of marine sediments suggests that faunal differences between replicate grab samples could be attributed to differences in sediment composition. Goosen *et al.* (2000) suggested that the natural patchiness of marine benthos could attribute to the above-mentioned, because of gradients in sediment type at comparatively shallow depths and proximity to adjacent reefs.



Muddy sediments are usually dominated by sedentary deposit feeding species and characteristic species include the arenicolid polychaetes (Newell *et al.*, 1998). Coarse-grained sediments may often be highly oxygenated and usually have a low organic Carbon content. These sediments may not be able to support permanent burrows and therefore their fauna would have to be fairly mobile. The errant or scavenger-type polychaetes usually inhabit this type of sediment (Day, 1967). The species (Table 4) and families of polychaete present in this study (Table 5) are usually found in muddy bottoms and are typically tubicolous (Rouse and Pleijel, 2001). Since most of the sediments in the areas sampled contained a larger proportion of mud than fine sand, coarse sand or gravel (see Appendix one), one would expect a greater abundance of sedentary polychaete species to be found in these samples. Table 4 illustrates that it was the sedentary species (*Sabellides (Pterampharete) luderitzi*, *Capitella capitata*, *Prionospio pinnata*, *Pherusa swakopiana*, *Pectinaria (Lagis) neopolitana* and

## Sediment structure as an indicator of polychaete assemblages

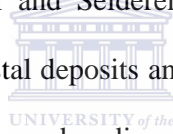
*Euclymene spl.*) that had the largest collective numerical average abundances in each of the clusters at different levels. The greater abundance of the above-mentioned polychaete species in muddier sediments may suggest their preference for mud.

The results of the multi-variate analysis suggest that one group of organisms may be used as a proxy for the entire fauna and the polychaetes (at the level of family) and have generated some interesting findings. When the biological samples clustered relatively well at a particular level structure, it was accompanied by a significant difference in the respective sediment properties. The opposite was observed when there was mixing of samples at another level structure. This may be attributed to a lack of adequate supporting environmental data (other than sedimentary properties). Infauna are also characterized by reasonably rapid turnover rates (Thorson, 1957; Newell *et al.*, 1998), and their responses to changes in the size structure of sediments are such that (at any given time) the composition of the community would reflect the existing granulometry.

The communities (in the case of the polychaete families and species) could be equally well separated if the polychaetes had only been analysed to the family-level as Warwick (1988) suggested. This was evidenced in the fact that generally the same information was gathered at different levels of analysis. More or less the same percentage of the polychaete structure (family or species) was accounted for by mud (0 - 45 $\mu$ m). Interestingly, at the level I and II structure for both sets of data, little or none of the species and families found in cluster B was found in cluster A. This may be attributed to the fact that only species and families with an average abundance of four percent or more were considered. However, the species that were found in this

study were well accounted for by their respective families. Therefore, if macrobenthic organisms were only identified to the level of family, it would be less time-consuming and costly, since experts often have to be consulted when these types of organisms need to be identified to the specific level.

The results also suggested that the structure of the infaunal polychaete community was accounted for, in part, by the structure of the sediments. This agreed with the findings of other workers, both locally (Field *et al.*, 1996; Field and Parkins, 1998; Parkins and Field, 1998; Pulfrich and Penny, 1999) and internationally (Thorson, 1957; Sanders, 1958; Jones *et al.*, 1990; Lopez-Jamar *et al.*, 1995; Mannino and Montagna, 1997). There are however, a number of other studies that contradict the above-mentioned findings. Newell and Seiderer (1997) conducted a study in the English Channel in undredged coastal deposits and analysed the relationship between biological community composition and sediment granulometry. They found little evidence of correlation between the distribution of different sediments types and biological communities in the areas surveyed. Newell *et al.* (1998) suggested that any one or a combination of simple granulometric properties of the sediments did not control biological community composition. These authors further suggested that it was more likely that the community composition was controlled by numerous environmental variables, which reflected the composite associations of chemical and biological factors operating in the sediments over a long period of time. Conversely, Bergen *et al.* (2001) found that depth was the primary factor in organizing southern California benthic communities. Their results were consistent with other studies of marine infaunal distribution (Hyland *et al.*, 1991; Rackocinski *et al.*, 1993; Oug, 1998). Snelgrove and Butman (1994) have also suggested that the hydrodynamic



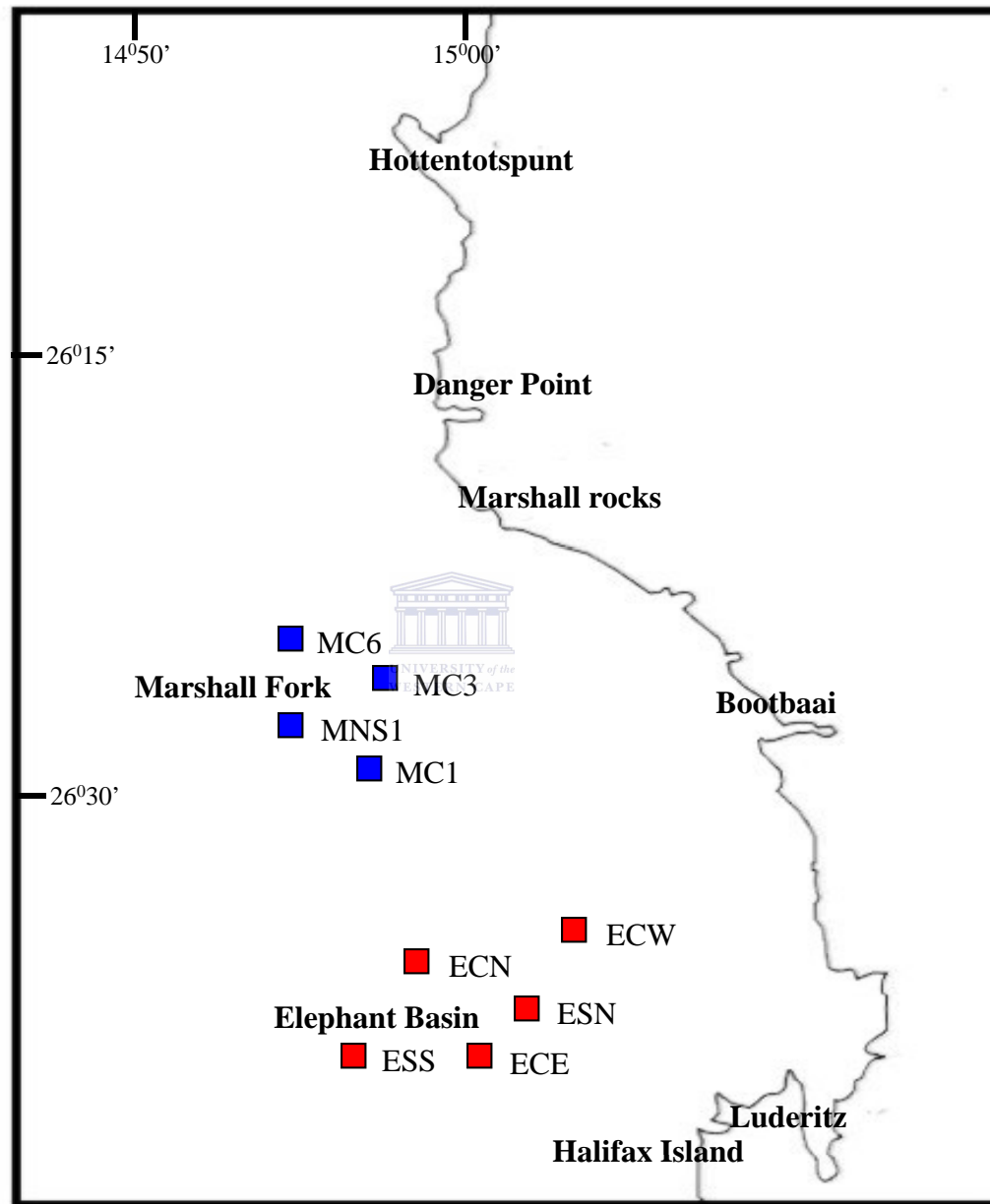
## Sediment structure as an indicator of polychaete assemblages

environment and the amount of organic material present in the sediment are more likely to be the primary factor of benthic infaunal distribution, but the hydrographic environment is difficult to measure when extreme events may be the controlling factor (Posey *et al.*, 1996; Okey, 1997).

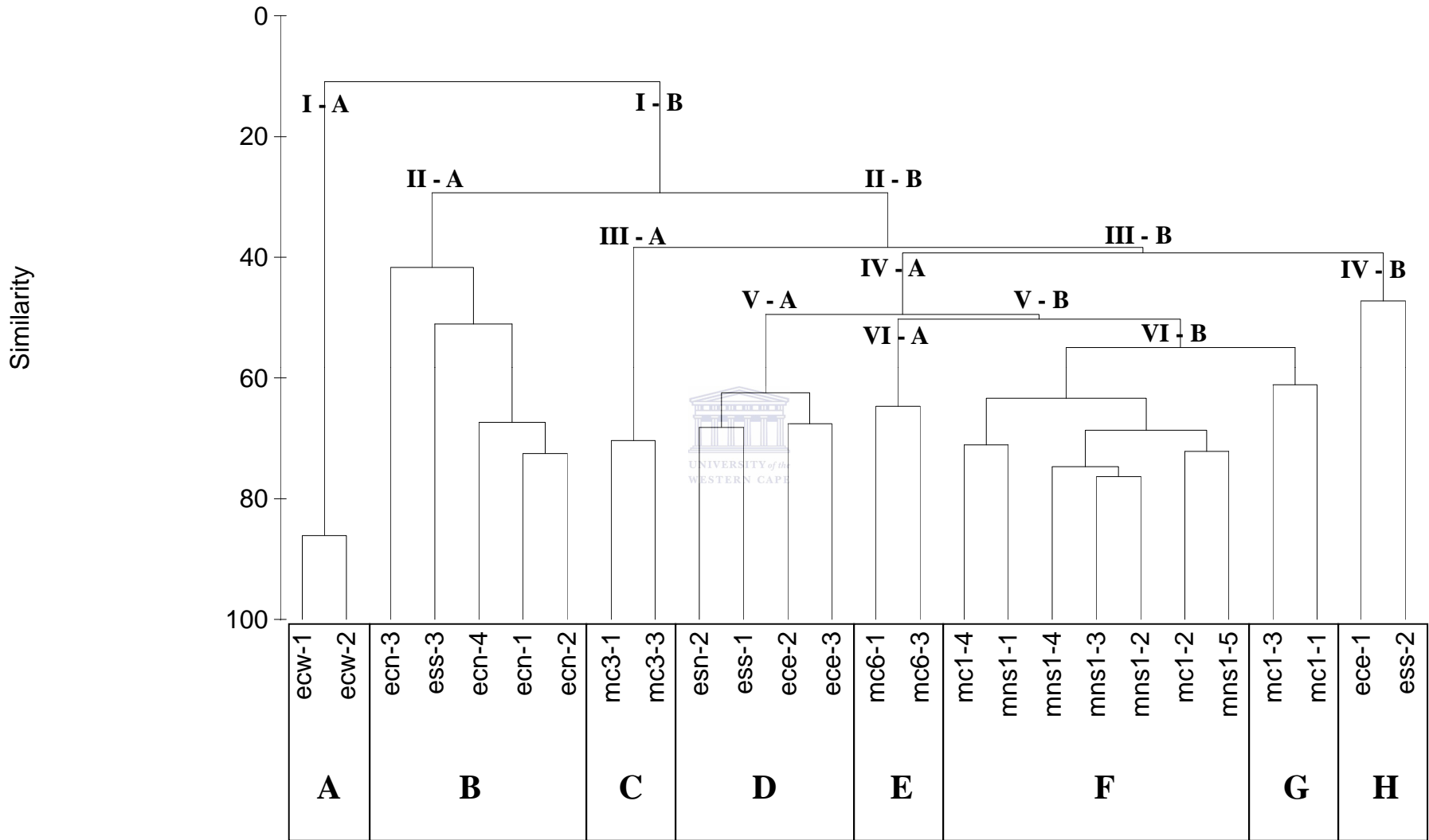
### **Concluding remarks**

There is a strong correlation between sediment granulometric parameters and abundance values of all macrofauna, polychaete families and polychaete species. Additionally, the biotic patterns of the macrofauna, polychaete families and polychaete species were broadly similar. Therefore, the presence of a particular combination of sediment granulometric parameters should be a good indication of the macrofaunal assemblage present within the sediment. Conversely, it should only be necessary to identify polychaetes to family level in order to assess a particular assemblage. Caution is advised, however, as there is no indication of the amount of diversity information that may be lost when only higher-level taxonomic resolutions (e.g. family, order, phyla) are used.

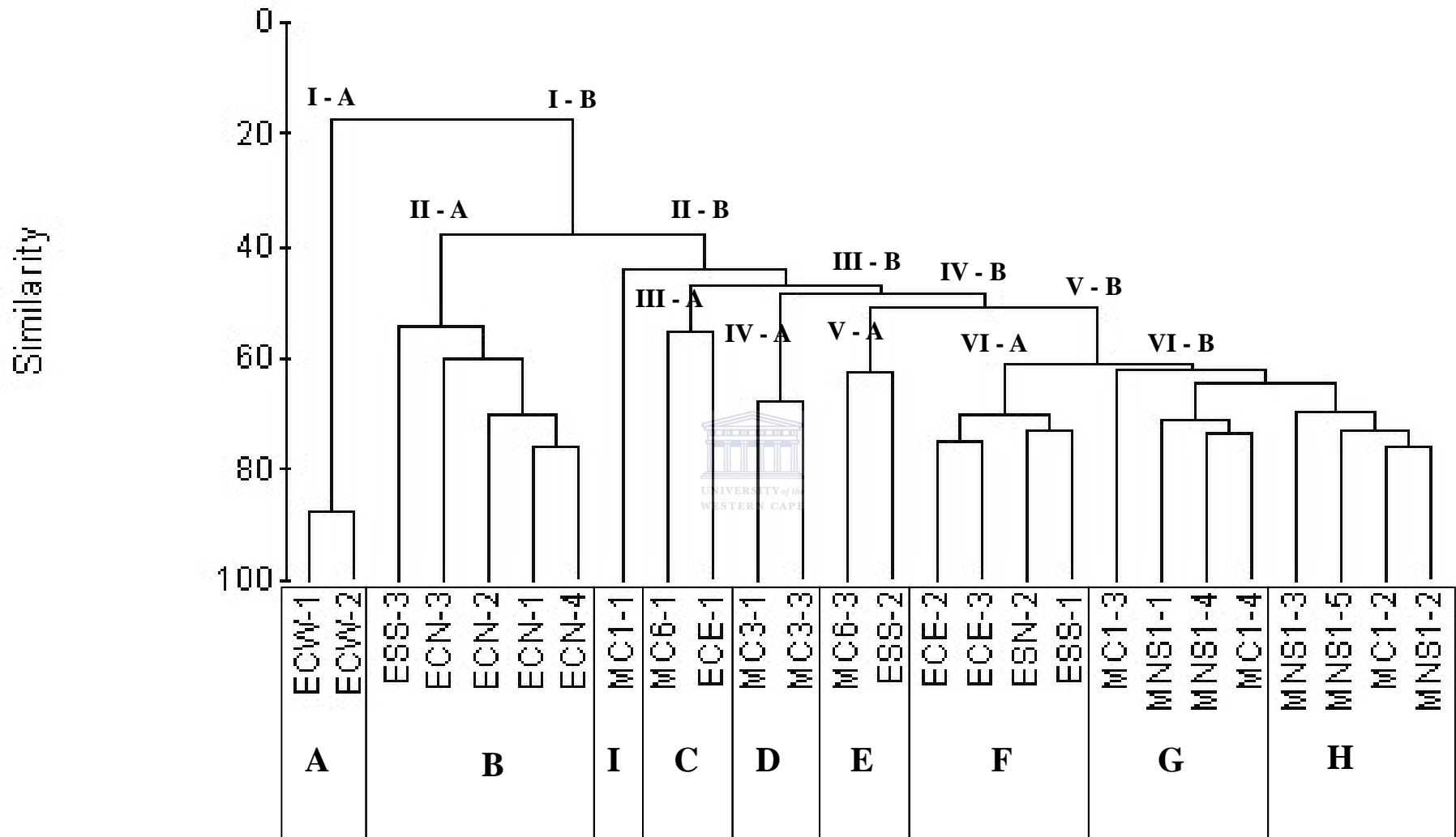




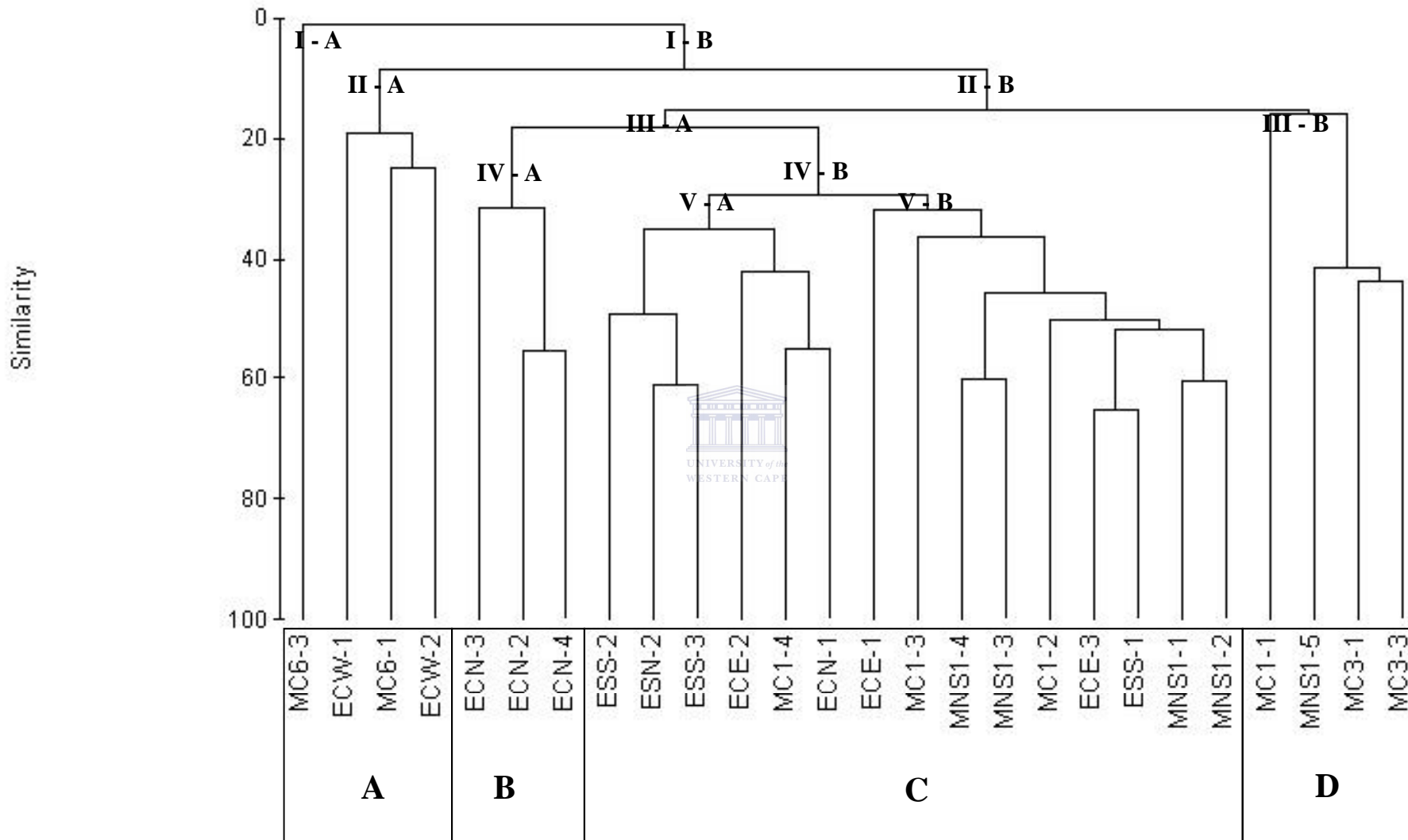
**Figure 1:** Map of sample stations.



**Figure 2 A:** Dendrogram of percent similarity in the numerical composition of the fauna of sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia, based on all the infauna (identified to family only). Data from Goosen *et al.* (2000). (ECW-1, ECE-1, MNS1-1 etc., indicate individual samples within the sample stations, see Figure 1 for localities).

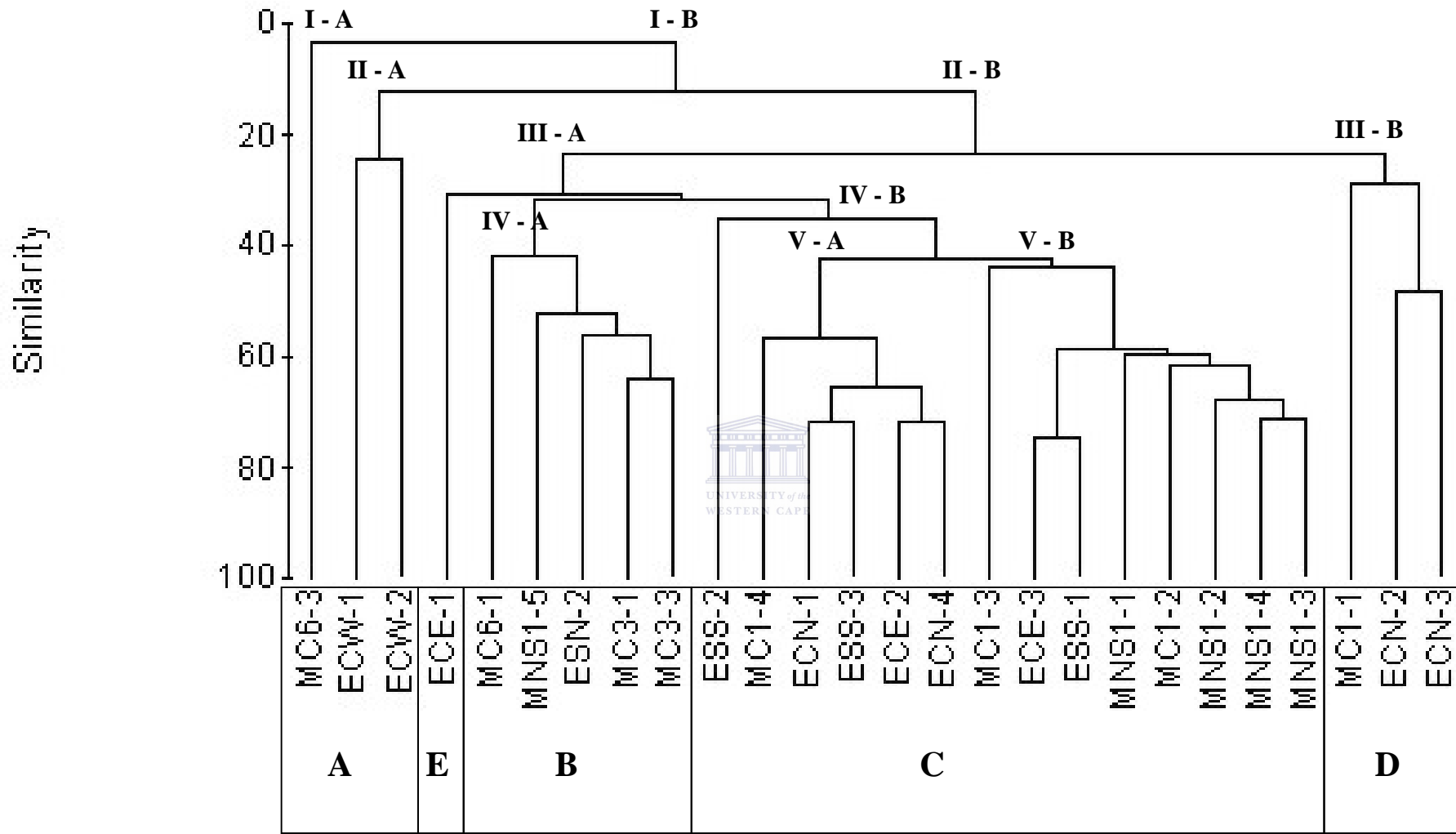


**Figure 2 B:** Dendrogram of percent similarity in the numerical composition of the fauna of sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia, based on all the polychaeta (identified to family only). Data from Goosen *et al.* (2000). (ECW-1, ECE-1, MNS1-1 etc., indicate individual samples within the sample stations, see Figure 1 for localities).



**Figure 3 A:** Dendrogram of percent similarity in the numerical composition of the fauna of sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia, based on all the polychaetes (identified to species). (ECW-1, ECE-1, MNS1-1 etc., indicate individual samples within the sample stations, see Figure 1 for localities).





**Figure 3 B:** Dendrogram of percent similarity in the numerical composition of the fauna of sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia, based on all the polychaetes (identified to family). (ECW-1, ECE-1, MNS1-1 etc., indicate individual samples within the sample stations, see Figure 1 for localities).

## Sediment structure as an indicator of polychaete assemblages

**Table 1 A:** Mean environmental characteristics of each cluster identified in Figure 2 (A).

Data in bold typeface indicate significant differences ( $P < 0.05$ ) between characteristics of clusters (A and B) within any given level of similarity (I - VI). Number of samples within each cluster also shown ( $n$ ). Significance determined by ANOVA.

Level	Cluster	<i>N</i>	Mud 0 - 45 $\mu\text{m}$	Very Fine sand 45 - 63 $\mu\text{m}$	Fine sand 63 - 125 $\mu\text{m}$	Medium sand 125 - 250 $\mu\text{m}$	Course sand 250 - 710 $\mu\text{m}$	Gravel > 710 $\mu\text{m}$
I	A	2	<b>0.09</b>	<b>0.00</b>	0.00	0.00	0.01	<b>0.90</b>
I	B	24	<b>0.48</b>	<b>0.02</b>	0.09	0.17	0.16	<b>0.10</b>
II	A	5	0.50	0.01	0.08	<b>0.06</b>	0.24	0.11
II	B	19	0.47	0.02	0.09	<b>0.19</b>	0.13	0.09
III	A	2	0.41	0.01	0.14	0.18	0.08	0.18
III	B	17	0.48	0.02	0.09	0.20	0.14	0.08
IV	A	15	0.50	0.02	0.09	0.21	0.12	0.06
IV	B	2	0.35	0.01	0.04	0.11	0.28	0.21
V	A	4	<b>0.61</b>	<b>0.01</b>	0.10	0.10	0.17	0.01
V	B	11	<b>0.45</b>	<b>0.02</b>	0.09	0.25	0.10	0.09
VI	A	2	<b>0.32</b>	<b>0.01</b>	0.09	0.15	<b>0.37</b>	0.06
VI	B	9	<b>0.48</b>	<b>0.03</b>	0.09	0.27	<b>0.04</b>	0.09



## Sediment structure as an indicator of polychaete assemblages

**Table 1 B:** Mean environmental characteristics of each cluster identified in Figure 2 (B).

Data in bold typeface indicate significant differences ( $P < 0.05$ ) between characteristics of clusters (A and B) within any given level of similarity (I - VI). Number of samples within each cluster also shown ( $n$ ). Significance determined by ANOVA.

Level	Cluster	N	Mud	Very Fine sand	Fine sand	Medium sand	Course sand	Gravel
			0 - 45 $\mu\text{m}$	45 - 63 $\mu\text{m}$	63 - 125 $\mu\text{m}$	125 - 250 $\mu\text{m}$	250 - 710 $\mu\text{m}$	> 710 $\mu\text{m}$
I	A	2	<b>0.09</b>	<b>0.00</b>	0.00	0.00	0.01	<b>0.90</b>
I	B	24	<b>0.48</b>	<b>0.02</b>	0.09	0.17	0.16	<b>0.10</b>
II	A	5	0.50	0.01	0.08	<b>0.06</b>	0.24	0.11
II	B	19	0.47	0.02	0.09	<b>0.19</b>	0.13	0.09
III	A	2	0.40	0.01	0.11	0.22	0.25	0.01
III	B	16	0.48	0.02	0.08	0.20	0.12	0.11
IV	A	2	0.41	0.01	0.14	0.18	0.08	0.18
IV	B	14	0.49	0.02	0.07	0.20	0.13	0.10
V	A	2	<b>0.28</b>	<b>0.00</b>	0.02	0.04	<b>0.40</b>	0.27
V	B	12	<b>0.52</b>	<b>0.02</b>	0.08	0.23	<b>0.08</b>	0.07
VI	A	4	<b>0.61</b>	<b>0.01</b>	0.10	<b>0.10</b>	<b>0.17</b>	0.01
VI	B	8	<b>0.48</b>	<b>0.03</b>	0.07	<b>0.29</b>	<b>0.04</b>	0.10



## Sediment structure as an indicator of polychaete assemblages

**Table 2:** List of environmental variables identified by the BIOENV procedure as being responsible for differences in the structure of the dendrograms shown in Figures 2 A and B and Figures 3 A and B respectively. Sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia (Data from Goosen *et al.*, 2000).

Variables	Figures			
	2 A (%)	2 B (%)	3 A (%)	3 B (%)
Mud	<b>45.3</b>	45.6	<b>34.9</b>	<b>36.2</b>
Very fine sand			24.7	28.7
Fine sand				
Medium sand				
Coarse sand				
Gravel				
Mud, very fine sand	44.6	<b>45.7</b>	31.0	34.5
Mud, gravel		41.6	26.9	33.1
Mud, very fine sand, gravel	40.2	42.3	28.5	32.9
Mud, coarse sand	43.1	42.5		28.5
Mud, very fine sand, medium sand, gravel			26.1	28.1
Mud, very fine sand, coarse sand, gravel				27.7
Mud, medium sand, gravel			24.9	27.6
Mud, coarse sand, gravel				27.6
Mud, very fine sand, coarse sand	42.7	42.0	23.1	
Mud, medium sand	41.3	41.2	24.4	
Mud, very fine sand, medium sand	40.7	41.1	25.4	
Mud, medium sand, coarse sand	40.6			
Mud, very fine sand, fine sand		40.8		
Mud, fine sand		40.6		
Mud, very fine sand, medium sand, coarse sand	40.4			
Mud, very fine sand, fine sand, coarse sand	40.3			



Bold typeface indicates most influential variable. Variables: mud (0 - 45  $\mu\text{m}$ ); very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ); fine sand (63  $\mu\text{m}$  - 125  $\mu\text{m}$ ); medium sand (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ); coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ); gravel (> 710  $\mu\text{m}$ ). The degree of influence exerted on each of the biological structures for a particular variable are shown as percentages.

## Sediment structure as an indicator of polychaete assemblages

**Table 3 A:** Mean environmental characteristics of each cluster identified in Figure 3 (A).

Data in bold typeface indicate significant differences ( $P < 0.05$ ) between characteristics of clusters (A and B) within any given level of similarity (I - V). Number of samples within each cluster also shown ( $n$ ). Significance determined by ANOVA.

Level	Cluster	<i>N</i>	Mud 0 - 45 $\mu\text{m}$	Very Fine sand 45 - 63 $\mu\text{m}$	Fine sand 63 - 125 $\mu\text{m}$	Medium sand 125 - 250 $\mu\text{m}$	Course sand 250 - 710 $\mu\text{m}$	Gravel > 710 $\mu\text{m}$
I	A	1	0.28	0.00	0.01	0.05	<b>0.55</b>	0.10
I	B	25	0.45	0.01	0.09	0.16	<b>0.13</b>	0.16
II	A	3	<b>0.18</b>	<b>0.00</b>	0.05	0.08	0.07	<b>0.61</b>
II	B	22	<b>0.49</b>	<b>0.02</b>	0.09	0.17	0.14	<b>0.10</b>
III	A	18	0.51	0.02	0.08	0.17	0.15	0.08
III	B	4	0.42	0.02	0.14	0.15	0.08	0.20
IV	A	3	0.56	0.01	0.10	0.08	0.19	0.06
IV	B	15	0.50	0.02	0.07	0.19	0.14	0.08
V	A	6	0.48	<b>0.01</b>	0.08	0.08	0.22	0.13
V	B	9	0.51	<b>0.02</b>	0.07	0.26	0.09	0.04



## Sediment structure as an indicator of polychaete assemblages

**Table 3 B:** Mean environmental characteristics of each cluster identified in Figure 3 (B).

Data in bold typeface indicate significant differences ( $P < 0.05$ ) between characteristics of clusters (A and B) within any given level of similarity (I - V). Number of samples within each cluster also shown ( $n$ ). Significance determined by ANOVA.

Level	Cluster	<i>N</i>	Mud 0 - 45 $\mu\text{m}$	Very Fine sand 45 - 63 $\mu\text{m}$	Fine sand 63 - 125 $\mu\text{m}$	Medium sand 125 - 250 $\mu\text{m}$	Course sand 250 - 710 $\mu\text{m}$	Gravel > 710 $\mu\text{m}$
I	A	1	0.28	0.00	0.01	0.05	<b>0.55</b>	0.10
I	B	25	0.45	0.01	0.09	0.16	<b>0.13</b>	0.16
II	A	2	<b>0.09</b>	<b>0.00</b>	0.00	0.00	0.01	<b>0.90</b>
II	B	23	<b>0.49</b>	<b>0.02</b>	0.09	0.17	0.14	<b>0.09</b>
III	A	20	0.48	0.02	0.09	0.18	0.13	0.10
III	B	3	0.53	0.01	0.14	0.08	0.17	0.07
IV	A	5	0.48	0.01	0.11	0.16	0.09	0.15
IV	B	14	0.48	0.02	0.08	0.19	0.14	0.09
V	A	5	0.48	0.01	0.10	0.10	<b>0.24</b>	<b>0.08</b>
V	B	8	0.52	0.02	0.08	0.27	<b>0.06</b>	<b>0.05</b>



Sediment structure as an indicator of polychaete assemblages

**Table 4:** List of dominant polychaete species identified by SIMPER as responsible for differences in the structure of the clusters (by Level) shown in Figure 3 (A).

Level	Genus	Species	Average Abundance (%)		Contribution (%)
			Cluster A	Cluster B	
I	<i>Sabellides (Pterampharete)</i>	<i>luderitzi</i>	0.00	14.08	17.53
I	<i>Prionospio</i>	<i>pinnata</i>	0.00	14.16	16.26
I	<i>Diopatra</i>	<i>monroi</i>	0.00	7.92	7.38
I	<i>Lumbrineris heteropoda</i>	<i>difficillis</i>	0.00	4.00	5.20
I	<i>Pherusa</i>	<i>swakopiana</i>	0.00	4.28	5.44
II	<i>Sabellides (Pterampharete)</i>	<i>luderitzi</i>	0.00	16.00	16.69
II	<i>Prionospio</i>	<i>pinnata</i>	0.00	16.09	16.11
II	<i>Nephtys</i>	<i>sp1.</i>	1.00	4.18	5.48
II	<i>Lumbrineris heteropoda</i>	<i>difficillis</i>	0.67	4.45	4.84
II	<i>Pherusa</i>	<i>swakopiana</i>	0.00	4.86	5.25
II	<i>Diopatra</i>	<i>monroi</i>	2.33	8.68	6.99
III	<i>Sabellides (Pterampharete)</i>	<i>luderitzi</i>	19.56	0.00	10.42
III	<i>Prionospio</i>	<i>pinnata</i>	17.44	10.00	12.06
III	<i>Pherusa</i>	<i>swakopiana</i>	5.94	0.00	3.33
III	<i>Diopatra</i>	<i>monroi</i>	2.28	37.50	13.55
III	<i>Euclymene</i>	<i>sp1.</i>	0.00	28.50	9.93
III	<i>Pectinaria (Lagis)</i>	<i>neopolitana</i>	0.06	6.50	2.91
IV	<i>Sabellides (Pterampharete)</i>	<i>luderitzi</i>	20.00	19.47	14.55
IV	<i>Prionospio</i>	<i>pinnata</i>	0.00	20.93	14.69
IV	<i>Pherusa</i>	<i>swakopiana</i>	0.33	7.07	5.46
IV	<i>Capitella</i>	<i>capitata</i>	19.00	0.07	10.62
V	<i>Sabellides (Pterampharete)</i>	<i>luderitzi</i>	20.00	19.11	11.79
V	<i>Prionospio</i>	<i>pinnata</i>	0.00	34.89	24.48
V	<i>Lumbrineris heteropoda</i>	<i>difficillis</i>	0.67	5.56	5.42
V	<i>Nephtys</i>	<i>sp1.</i>	3.83	5.00	4.37
V	<i>Pherusa</i>	<i>swakopiana</i>	5.50	8.11	7.35

The mean abundance of each species in each assemblage (cluster A, B) is shown, as are their proportional contribution to dissimilarity (only species with at least a contribution of 4% are reported here).

Sediment structure as an indicator of polychaete assemblages

**Table 5:** List of dominant families identified by SIMPER as responsible for differences in the structure of the clusters (by Level) shown in Figure 3 (B).

Level	Order	Family	Average Abundance (%)		Contribution (%)
			Cluster A	Cluster B	
I	Sabellida	Sabellidae	0.00	14.08	17.53
I	Spionida	Spionidae	0.00	14.20	16.29
I	Phyllodocida	Nephtyidae	0.00	5.88	8.05
I	Flabelligerida	Flabelligeridae	0.00	9.00	8.51
I	Eunicida	Lumbrineridae	0.00	4.16	5.31
I	Eunicida	Onuphidae	0.00	7.92	7.38
I	Capitellida	Capitellidae	0.00	7.88	6.22
II	Sabellida	Sabellidae	0.00	15.30	16.23
II	Spionida	Spionidae	0.00	15.43	15.56
II	Phyllodocida	Nephtyidae	0.00	6.39	7.21
II	Flabelligerida	Flabelligeridae	0.00	9.78	8.10
II	Eunicida	Lumbrineridae	1.00	4.43	4.91
II	Eunicida	Onuphidae	3.00	8.35	7.44
II	Capitellida	Capitellidae	0.00	8.57	5.94
III	Sabellida	Sabellidae	16.85	5.00	13.99
III	Spionida	Spionidae	17.30	3.00	15.38
III	Phyllodocida	Nephtyidae	7.35	0.00	6.55
III	Flabelligerida	Flabelligeridae	11.20	0.33	7.99
III	Eunicida	Lumbrineridae	5.10	0.00	4.49
III	Eunicida	Onuphidae	9.60	0.00	5.39
III	Capitellida	Arenicolidae	0.25	7.33	8.62
III	Phyllodocida	Pilargidae	1.75	4.67	5.65
IV	Sabellida	Sabellidae	6.60	21.71	11.91
IV	Spionida	Spionidae	6.20	21.71	12.67
IV	Flabelligerida	Flabelligeridae	3.60	14.71	7.51
IV	Phyllodocida	Nephtyidae	11.60	5.71	4.99
IV	Eunicida	Onuphidae	34.60	1.36	13.06
IV	Capitellida	Maldanidae	24.80	0.14	9.90
IV	Terebellida	Pectinariidae	5.80	2.93	2.81
IV	Eunicida	Lumbrineridae	9.60	2.71	3.98
V	Sabellida	Sabellidae	25.80	21.50	10.45
V	Spionida	Spionidae	0.00	38.00	23.04
V	Terebellida	Pectinariidae	1.20	4.38	2.43
V	Phyllodocida	Nephtyidae	3.20	7.25	3.83
V	Eunicida	Lumbrineridae	0.80	4.25	3.12
V	Flabelligerida	Flabelligeridae	26.40	9.25	12.41
V	Capitellida	Capitellidae	35.60	0.25	12.88

The mean abundance of each family in each assemblage (cluster A, B) is shown, as are their proportional contribution to dissimilarity (only families with at least a contribution of 4% are reported).



Sediment structure as an indicator of polychaete assemblages

**Table 6:** Species of polychaetes identified from samples in the Marshall Fork and Elephant Basin areas off the southern coast of Luderitz, Namibia.

Family	Genus	Species
Ampharetidae	<i>Amphicteis</i>	<i>Amphicteis gunneri</i> Sars, 1835
	<i>Sabellides (Pterampharete)</i>	<i>Sabellides (Pterampharete) luderitzi</i> Augener, 1918
Capitellidae	<i>Capitella</i>	<i>Capitella capitata</i> Fabricius, 1780
Cirratulidae	<i>Aphelochaeta</i>	<i>Aphelochaeta</i> sp.1
	<i>Cirriformia</i>	<i>Cirriformia</i> sp.1
	<i>Cirriformia</i>	<i>Cirriformia tentaculata</i> Montagu, 1808
Dorvillidae	<i>Dorvillea</i>	<i>Dorvillea rudolphi</i> Delle Chiaje, 1825
	<i>Protodorvillea</i>	<i>Protodorvillea biarticulata</i> Day, 1963
Flabilligeridae	<i>Pherusa</i>	<i>Pherusa saldanha</i> Day, 1961
	<i>Pherusa</i>	<i>Pherusa swakopiana</i> Augener, 1918
	<i>Pherusa</i>	<i>Pherusa tropica</i> Augener, 1918
Glyceridae	<i>Glycera</i>	<i>Glycera tessellata</i> Grube, 1863
Hesionidae	<i>Hesionia</i>	<i>Hesionia</i> sp.1
Lumbrineridae	<i>Lumbrineris</i>	<i>Lumbrineris cavifrons</i> Grube, 1869
	<i>Lumbrineris</i>	<i>Lumbrineris hartmani</i> Day, 1953
	<i>Lumbrineris</i>	<i>Lumbrineris heteropoda difficillis</i> Day, 1963
	<i>Lumbrineris</i>	<i>Lumbrineris</i> sp.1
Magelonidae	<i>Magelona</i>	<i>Magelona capensis</i> Day, 1961
Maldanidae	<i>Euclymene</i>	<i>Euclymene</i> sp.1
	<i>Johnstonia</i>	<i>Johnstonia clymenoides</i> Quatrefages, 1865
	<i>Maldane</i>	<i>Maldane</i> sp.1
	<i>Nicomache</i>	<i>Nicomache</i> sp.1
	<i>Petaloproctus</i>	<i>Petaloproctus</i> sp.1
Nephtyidae	<i>Nephtys</i>	<i>Nephtys hombergi</i> Savigny, 1820
	<i>Nephtys</i>	<i>Nephtys</i> sp.1
Oeonidae	<i>Drilonereis</i>	<i>Drilonereis monroi</i> Day, 1960
Onuphidae	<i>Diopatra</i>	<i>Diopatra monroi</i> Day, 1960
Ophellidae	<i>Ophelia</i>	<i>Ophelia agulhana</i> Day, 1961
Orbinidae	<i>Orbinia</i>	<i>Orbinia agrapequensis</i> Augener, 1918
Owenidae	<i>Owenia</i>	<i>Owenia fusiformis</i> Delle Chiaje, 1844
Paraonidae	<i>Aedicira</i>	<i>Aedicira</i> sp.1
	<i>Aricidea (Allia)</i>	<i>Aricidea (Allia)</i> sp.1



Sediment structure as an indicator of polychaete assemblages

**Table 6 (continued).**

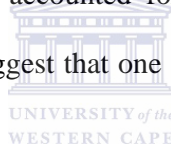
<b>Family</b>	<b>Genus</b>	<b>Species</b>
Pectinariidae	<i>Pectinaria</i>	<i>Pectinaria</i> sp.1
	<i>Pectinaria (Amphictene)</i>	<i>Pectinaria (Amphictene) capensis</i> Pallas, 1776
	<i>Pectinaria (Lagis)</i>	<i>Pectinaria (Lagis) neopolitana</i> Claparede, 1870
	<i>Pectinaria (Amphictene)</i>	<i>Pectinaria (Amphictene)</i> sp.1
Pilargidae	<i>Cabira</i>	<i>Cabira capensis</i> Day, 1963
	<i>Sigambra</i>	<i>Sigambra robusta</i> Ehlers, 1908
Polynoidae	<i>Alentia</i>	<i>Alentia</i> sp.1
	<i>Hololepidella</i>	<i>Hololepidella nigropunctata</i> Horst, 1915
Spionidae	<i>Prionospio</i>	<i>Prionospio pinnata</i> Ehlers, 1901
Syllidae	<i>Syllis (Syllis)</i>	<i>Syllis (Syllis)</i> sp.1
Terrebelidae	<i>Terrebellia</i>	<i>Terrebellia pterochaeta</i> Schmarda, 1861



**Polychaetes as surrogates in a macrobenthic infaunal study, using sediment structure and depth along the southern coast of Namibia.**

**Abstract**

The use of polychaetes as surrogates in a macrobenthic infaunal study, using sediment structure and depth is independently investigated and data are compared with the results of a previous collection that included all the infauna. A total of 48 samples were collected by De Beers Marine (Pty) Ltd in 2001: 22 families of polychaetes were distinguished. Comparisons revealed dissimilar clustering of samples at different levels of analysis, using the same sediment and depth data. Discrepancies were also found in the amount of variation accounted for in the biological samples by the environmental data. The results suggest that one faunal group may not be useful as a proxy for the entire infauna.



**Introduction**

Biodiversity in the marine environment has received much attention recently, because of various disturbances that affect the organisms living there (Lopez-Jamar *et al.*, 1995; Gray, 1997). Macrofaunal bottom communities are important given that most marine species are benthic (Gray, 1997) and the fact that in terms of spatial coverage bottom sediments comprise the largest ecosystems on earth (Snelgrove *et al.*, 1997).

The identification of macrofaunal communities to the species level has been the standard in baseline biological surveys (Olgard and Somerfield, 2000). However,

## Polychaetes as surrogates using sediment structure and depth

there are a number of studies that have examined the use of higher-level taxa as alternatives to species-level identification. For instance, Olsgard *et al.* (1998) used the multivariate analyses of benthic infauna and environmental data from 20 separate investigations in the Skagerrak and the North Sea to examine faunal patterns at different taxonomic levels (namely, species, genus, family, order, class and phylum). The main finding of the study was that there was only a minor reduction in the correlation of information between species and family and they suggested that identification to the level of family may be satisfactory in many routine monitoring surveys. Baseline biological surveys are expensive to conduct (McIntyre, 1983; Warwick, 1993) and the sampling techniques used, are labour intensive and have remained unchanged for a lengthy period of time (e.g. Jones, 1952; Buchanan, 1963; Pearson, 1975; Heip *et al.*, 1992). Taxonomic literature and expertise are also lacking in some marine areas with high biodiversity such as the tropics (Olsgard *et al.*, 1998).



There have been some comparative studies between different regions using different taxonomic levels in terrestrial (Prance, 1994; Williams and Gaston, 1994; Balmford *et al.*, 1996), fresh water (Gaston *et al.*, 1995; Williams *et al.*, 1997) and marine environments (Roy *et al.*, 1996; Myers, 1997), but these studies have all taken place in areas where pollution gradients exist. Experimental studies have also successfully employed higher or different taxonomic levels as a proxy for species-level taxa (Morrisey *et al.*, 1995, 1996). Warwick (1993) pointed out that there were many advantages in analyzing higher taxonomic groups rather than all the species present in an ecological investigation. For example, if it could be shown that analysis of higher taxonomic groupings (e.g. family level) which are easier to identify, are comparable to species analysis and the same type of information could be gathered, then time,

money and labour could be saved (Olsgard and Somerfield, 2000). Some investigations (Warwick, 1988; Ferraro and Cole, 1995; Vanderklift *et al.*, 1996; Olsgard *et al.*, 1997, 1998) have successfully revealed that higher taxonomic groupings may be used as a proxy for species-level investigations, depending on the objectives of that particular study.

Sediment grain size was previously found to be an important factor in structuring benthic invertebrate communities (Basford *et al.*, 1990; Kuche and Rachor, 1996; Rees *et al.*, 1999). However, these types of studies have mainly been directed in estuaries (McNulty *et al.*, 1962; Nichols, 1970; Bloom *et al.*, 1972) and shallow marine bays (Sanders, 1958; Young and Rhoads, 1971; Biernbaum, 1979). Weston (1988) also suggested that studies of the above-mentioned nature were only practical because of the accessibility of those environments and the diversity of sediment types present in close proximity to each other. This may be one of the reasons why animal-sediment relationships on open continental shelves have received considerably less attention, although some investigations in Europe (e.g. Glemarec, 1983; Buchanan *et al.*, 1978), Asia (e.g. Rhoads *et al.*, 1985) and North America (e.g. Flint, 1981) have taken place. There are studies that have successfully differentiated macrobenthic communities on the basis of sedimentary parameters (Snelgrove and Butman, 1994) but, in some shelf environments, the sediment related effects are often masked by considerably greater variation in other, often depth-related, environmental parameters (Weston, 1988).

Polychaetes have been used in this study, because they are one of the abundant and diverse groups of marine infaunal invertebrates (Chambers and Muir, 1997) and they

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are used globally for the assessment of marine sediment condition (e.g. Bergen *et al.*, 2001). They also comprise over one-third of the total number of macrobenthic species (Fauchald and Jumars, 1979); they occur in or on all types of substratum, in waters of all levels of salinity and at all depths in the ocean (Chambers and Muir, 1997). They are widely distributed geographically and occupy a variety of marine and estuarine habitats.

The aim here is to determine whether one group of organisms (polychaetes) can be used as a proxy for the entire fauna (at the level of the family) using the data that De Beers Marine collected along the southern Namibian coast in 2001.

### Materials and methods



The data set used here, and the polychaete samples analysed, were collected by De Beers Marine (Pty) Ltd (see Appendix three).

### Benthic Sampling and Sample Processing

A benthic grab sampling survey was conducted from the De Beers Marine contracted supply tug, the *Ludzcan*, in July 2001 along the southern coast of Namibia from Oranjemund to Lüderitz (Figures 1 A and B). The samples were all taken from hitherto undisturbed areas.

An onboard-computerized differential GPS system was used to accurately locate the grab sample site positions. At least two sediment samples were taken at each sample site using a Van Veen grab. The Van Veen grab sampled 0.2 m<sup>2</sup> area of seabed down

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to a depth of about 20 cm. A sediment core sample was taken from the grab on retrieval for sediment texture analysis. The samples were then washed through stacked 1 mm and 10 mm sieves and all retained organisms were bottled and fixed in 10% formaldehyde for subsequent analysis ashore.

Data on the physical environment were collected at all the grab stations using a CTDOT (Conductivity, Temperature, Depth, Dissolved Oxygen and Turbidity) fitted with a Niskin flask. The CTDOT data were collected at one-metre intervals through the water column, while the Niskin flask was used to collect a sample of near-bottom water. The CTDOT data consisted of dissolved oxygen concentrations (ml/l), temperature (°C), salinity (psu) and backscatter (uncalibrated) measurements that were recorded internally and downloaded onto a PC.



On returning to the laboratory, faunal samples were rinsed in fresh water to remove all traces of formaldehyde, prior to being transferred to 1% phenoxyethanol (ethylene-glycol-monophenyl-ether). Polychaetes were then transferred to 70% ethanol. Samples were hand sorted and the polychaetes that could not be identified (e.g. decapitated specimens) were excluded from the subsequent analysis. A dissecting (Stemi D4 Zeiss) and compound microscope (Leitz Laborlux II) were used to observe the polychaete specimens and Chambers and Muir (1997), Day (1967) and Fauchald, (1977) was used to identify specimens to family-level. When the specimens were damaged or when some of the structures were not easily observable, staining procedures (Wisnes, 1985) were used.

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The sediment core samples were used to determine grain size composition. Each sediment sample was removed from the sediment corer, and a brief description of sediment composition was recorded and a sub-sample was taken for further analysis. The sub-sample was carefully washed through a 45  $\mu\text{m}$  sieve to remove all fine clay material. The residue was transferred to a glass beaker and the contents dried at 100  $^{\circ}\text{C}$ . The dried material was weighed to the nearest 0.001 g and sieved through a series of sieves (i.e. 63  $\mu\text{m}$ , 125  $\mu\text{m}$ , 250  $\mu\text{m}$ , 710  $\mu\text{m}$  and a catching pan) for about twenty minutes. Each fraction of the sediment was weighed separately and the coarsest material was weighed separately after sieving through a 1000  $\mu\text{m}$  or 2000  $\mu\text{m}$  sieve.

### Statistical Analysis

All data were analysed using PRIMER (Plymouth Routines In Multivariate Ecological Research) v5 software (Clarke and Warwick, 1994). This programme consists of a range of univariate, graphical and multivariate routines for analysing matrices of species by sample abundances that arise in biological monitoring and environmental impact studies. It is also used for studies in community ecology, together with associated physico-chemical data (Clarke and Warwick, 1994).

In order to test whether the biotic patterns that were observed by De Beers Marine in 2001 from a collection of the entire community (at the family-level) were similarly displayed by the polychaetes only (at the family-level), the multi-variate analyses were repeated with the total infauna (which included the polychaete family-level data) and the polychaete data only. I specifically looked for similarities in the structure of the two dendrograms, and in the results of their respective BIOENV procedures.



## Polychaetes as surrogates using sediment structure and depth

To reduce the dominating effect of abundant species, all data were root-root transformed (Clarke and Warwick, 1994). The degree of similarity between individual samples was measured using the Bray-Curtis similarity index (Bray and Curtis, 1957). The Bray-Curtis similarity matrix between samples was expressed as a dendrogram. A separate dendrogram for the polychaete families only, was also constructed. In order to determine which families of polychaete were responsible for the structure of the observed clustering, data were analysed using the SIMPER (Similarity Percentage Analysis) procedure in PRIMER (Clarke and Warwick, 1994). The overall percentage contribution each family made to the average dissimilarity between two groups (an average of all possible pairs of dissimilarity coefficients, taking one sample from each group) were observed at different level structures and compared. The average abundances were also obtained and compared.



A number of approaches were used to determine the relationship between sediment granulometry and assemblage structure. In the first case, the mean values of the various granulometric properties of the samples in the major clusters identified in the previously constructed dendrogram were calculated and then compared using the Kolmogorov-Smirnov test (Statistica v5.1, Statsoft, 1995), because the variances were found to be unequal. This test was also performed for total abundance, number of families, species evenness and species diversity. Obviously, such comparisons could only be made where the number of samples in any one of the clusters exceeded two. In order to try and determine the relationship between patterns in multivariate community structure and measured environmental parameters, the data were also analysed using the BIOENV procedure in PRIMER (Clarke and Ainsworth, 1993). This is a Spearman rank correlation test which calculates rank correlations between a

## Polychaetes as surrogates using sediment structure and depth

similarity matrix obtained from biotic data and matrices obtained from various sets of environmental variables, thereby defining suites of variables most closely correlated with the observed biotic structure. In order to determine which of the polychaete families were specifically correlated (positively) with a particular environmental variable only, the above-mentioned process was repeated.

## Results

### **Total assemblages versus Polychaete assemblages.**

Figure 2 shows the dendrogram of percent similarity in the numerical composition of samples, based on the total infauna (identified to family only). Figure 3 shows the dendrogram of percent similarity in the numerical composition of the samples, based only on the polychaetes (identified to family only).

Both dendrograms (Figures 2 and 3) are characterised by generally low levels of similarity between samples, but those constructed from the total assemblage data (Figure 2) show greater similarity than do those from the polychaete assemblage data (Figure 3).

There is a general similarity in the level I (cluster B) structure of the two dendrograms in Figures 2 and 3, but there appears to be a good deal of mixing: for example, the two samples (Hostel North and Hostel South) that cluster together as part of the level I (cluster B) structure in the total infauna dendrogram (Figure 2), do not cluster similarly in the polychaete family-level dendrogram (Figure 3) at the same level and

## Polychaetes as surrogates using sediment structure and depth

cluster. There is a low level of similarity in the level II structure of both dendrograms. The only samples that cluster together in the above-mentioned level structure in both dendrograms (Figures 2 and 3) are Chameis South and Hostel Shallow. There also seems to be very little agreement in the level III structures of both dendrograms. The level IV structure was not considered for comparison here, because the polychaete family-level dendrogram (Figure 3) only produced three comparable level structures whereas the total infauna dendrogram (Figure 2) formed four.

The results of the sediment structure, number of families, total abundance, species evenness and species diversity for the different level analysis using the Kolmogorov-Smirnov test were compared and indicated that: the families of polychaetes in cluster A (level I) were more dominant and there were more polychaetes present in cluster A (Table 2). Results at the level I structure also indicated that mud ( $< 63 \mu\text{m}$ ) medium sand ( $125 \mu\text{m} - < 250 \mu\text{m}$ ) and depth (Table 2) were significant in both clusters A and B (level I). The total infauna structure (Table 1) in cluster A (level I) was more influenced by coarse sand ( $250 \mu\text{m} - < 710 \mu\text{m}$ ) than by fine sand ( $63 \mu\text{m} - < 125 \mu\text{m}$ ), whereas the opposite was noted for cluster B (level I). Gravel ( $> 710 \mu\text{m}$ ) also had a significant influence on the total infaunal structure in both clusters A and B (level I).

Polychaetes in cluster B (Table 2) at the level II structure were more diverse than in cluster A, but the number of families and total abundance showed greater significance in cluster A. Depth, mud ( $< 63 \mu\text{m}$ ) and medium sand ( $125 \mu\text{m} - < 250 \mu\text{m}$ ) also had a significant effect on the polychaete families in both clusters (Table 2). Significant differences in depth, mud ( $< 63 \mu\text{m}$ ), fine sand ( $63 \mu\text{m} - < 125 \mu\text{m}$ ) and medium sand

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(125  $\mu\text{m}$  - < 250  $\mu\text{m}$ ) were also noted for the total infauna (Table 1) at the same level structure (clusters A and B).

Polychaete samples in cluster A at the level III structure were more abundant than in cluster B, but cluster B was significantly deeper than cluster A (Table 2). Significant differences in depth were also noted for the total infauna at the same level structure (Table 1).

Polychaetes at the level III structure (clusters C and D) showed significant differences (Table 2) for fine sand (63  $\mu\text{m}$  - < 125  $\mu\text{m}$ ) and medium sand (125  $\mu\text{m}$  - < 250  $\mu\text{m}$ ). Deeper total infaunal samples in cluster C (level III) were more dominant, than those in cluster D (Table 1). However, total infaunal samples from cluster D contained significantly more taxa and number of families (Table 1), although both showed significant differences in mud (< 63  $\mu\text{m}$ ) and medium sand (125  $\mu\text{m}$  - < 250  $\mu\text{m}$ ).

The results of the BIOENV analyses were not similar for both levels of analyses (Table 3), in terms of both the proportion of the variation in assemblage structure explained by the selected environmental variables and the choice of selected variables. Coarse sand (250  $\mu\text{m}$  - < 710  $\mu\text{m}$ ), medium sand (125  $\mu\text{m}$  - < 250  $\mu\text{m}$ ) and depth accounted for 24.1% of the structure in the polychaete fauna as identified by family (Table 3), whereas gravel (> 710  $\mu\text{m}$ ) and depth accounted for 61.8% of the total infauna structure as identified by families. In all cases, the amount of variation explained was greater for communities identified using family-level total infaunal data than it was using the total polychaete family-level information. Coarse sand (250  $\mu\text{m}$  - < 710  $\mu\text{m}$ ) and depth, although selected by the BIOENV procedure as

## Polychaetes as surrogates using sediment structure and depth

accounting for some of the variation in the polychaete assemblage structure, explained no more of the data (in combination) than did coarse sand and depth on its own. Interestingly, depth in combination with a particular granulometric property featured very strongly in structuring both sets of communities.

For the purposes of brevity and since there were only three comparable level structures; comments on the results of SIMPER are confined to those levels of analysis. The level I structure revealed that at least seven polychaete families were responsible for observed differences between cluster A and B (Table 5) in the family-level polychaete dendrogram (Figure 3). A comparison of the SIMPER results for both dendrograms at the same level structure revealed that four of the dominant polychaete families found in cluster A (Table 5) were also abundant in the total infauna (Table 4) at the same level. Comparisons of the level II structure revealed similar results, but in that case only three of the polychaete families (Table 5) which accounted for observed differences between the clusters in Figure 3, were also represented in the total infauna at that level (Table 4). Only two of the polychaete families (Table 5) that accounted for the observed differences in the level III structure were also represented in the total infauna (Table 4). Interestingly, the SIMPER result showed that those families were also dominant in cluster A (level III) of both dendrograms.

### **Comments on the polychaete families and environmental variables.**

The material examined along the southern coast of Namibia yielded 22 families (Table 6). The fauna showed an abundance of the following families: Capitellidae,

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Cirratulidae, Flabilligeridae, Lumbrineridae, Magelonidae, Nephtyidae, Paraonidae, Pilargiidae, Onuphidae, Syllidae and Spionidae (Table 5). A dendrogram based on similarity of polychaete families in the data set (Figure 4) showed that there were a total of ten “errant” families and twelve “sedentary” polychaete families. The above-mentioned dendrogram (Figure 4) also showed that for the most part sedentary polychaete families grouped together whereas errant ones did not.

Table 7 indicated that Onuphidae and Lumbrineridae were both positively correlated with depth. It also indicated that deeper samples may contain more Onuphids and Lumbrinerids. It was also observed that Glycerids and Magelonids were more likely to be found in shallower samples (Table 7). The polychaete family Ampharetidae was positively correlated with fine sand, medium sand and gravel. Aphroditidae was also associated with medium sand and Cirratulidae with mud (Table 7). The Flabilligeridae and Lumbrineridae were both associated with mud, medium sand and coarse sand. The Glyceridae and Pilargidae were only associated with the sediment size fraction of mud, although the Glyceridae was also correlated with depth. Magelonids and Nephtyids were both correlated with fine sand, whereas Maldanids were associated with gravel. Orbiniidae was associated with fine sand only and Opheliidae was positively correlated with mud, fine sand and coarse sand. Syllids were also associated with mud, fine sand and coarse sand. Many of the polychaete families were associated with a range of sediment size fractions and an example of this was the Onuphidae, which was positively correlated with mud, fine sand, medium sand and gravel.

## Discussion

Polychaetes possess a range of feeding types in the benthic community (Fauchald and Jumars, 1979), although suspension and deposit feeders usually dominate (Hutchings, 1998, Snelgrove *et al.*, 1997). Some polychaetes also burrow into the sediment in search of food and to avoid predation, while others actively swallow mud (Taghon and Greene, 1992). Polychaetes of the genus *Capitella* are usually associated with high numbers in organic rich sediments (that may or may not be polluted), which suggests the type of sediment they are more likely to be found in (Hutchings, 1998). As mentioned in chapter two, muddy sediments are usually dominated by sedentary deposit feeding taxa and polychaete species (Newell *et al.*, 1998). Coarse-grained sediments may often be highly oxygenated and usually have a low organic Carbon content (Newell *et al.*, 1998). Coarse-grained sediments would also not be able to support permanent burrows and therefore their fauna would have to be fairly mobile (Newell *et al.*, 1998). This suggests that the polychaete fauna found there, are more likely to possess well-developed sets of jaws and prostomial appendages (Hutchings, 1998). The families (Table 5) of polychaete present in this study are usually found in muddy bottoms and are typically tubicolous (Rouse and Pleijel, 2001).

Focusing on the dominant families of polychaetes present in this study (Table 5), the Capitellidae are some of the most common and widespread of polychaetes and although most are marine, some are found in estuaries (Rouse and Pleijel, 2001). They are usually found in black anoxic mud and may construct burrows and tubes near the surface of the sediment (Rouse and Pleijel, 2001). Some Capitellids have also been considered as indicators of pollution and environmental disturbance (Reish, 1979).

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Most Cirratulidae live in sediments, under rocks or shells (Rouse and Pleijel, 2001). Cirratulidae may also be the most abundant of macrofaunal taxa in deep-sea sediments (Jumars, 1975) and have been shown to be accumulators of toxins such as arsenic (Milanovich *et al.*, 1976, Gibbs *et al.*, 1983). The conditions for cirratulids that live beneath the sediments are often found to be anoxic (Bestwick *et al.* 1989). The majority of Flabilligeridae (Table 7) and Lumbrineridae are found as burrowers in sand and mud (Rouse and Pleijel, 2001). The Nephtyidae are also burrowers and are distributed worldwide. They are found in muddy to sandy bottoms (Rouse and Pleijel, 2001). Most Magelonidae are found at depths of less than 100 m and they are typically found in intertidal muds and sands (Jones, 1963, 1971, 1978). Paraonids are commonly found in the deep-water regions of the world, but some of them also present themselves in the intertidal (Strelzov, 1979). Many paraonids have been described from depths greater than 600 m (Blake, 1996. b). Paraonidae are found on the surface of sandy and silty sediments (Rouse and Pleijel, 2001). The Pilargidae are mainly found in muddy bottoms (Day, 1967) that range from the intertidal to thousands of metres of depth (Rouse and Pleijel, 2001). Although Onuphids are mostly tubicolous, many are motile and carnivorous. They occur in all kinds of substrata (Rouse and Pleijel, 2001, Table 7). The Syllidae are commonly found on hard substrata with few occurring in soft bottoms (Rouse and Pleijel, 2001), whereas Spionidae are a dominant component of sand and muddy bottoms (Blake, 1996. c).

There was a larger proportion of mud than fine sand, coarse sand or gravel in the areas sampled (Figure 1 B) and thus one may expect a greater abundance of “sedentary” polychaete families to be found in the samples. Table 5 illustrated that it was the “sedentary” polychaete families (Capitellidae, Cirratulidae, Flabilligeridae,



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Magelonidae, Paraonidae and Spionidae) that had the largest collective numerical average abundances in each of the clusters at different levels. The greater abundance of the above-mentioned polychaete families in muddier sediments, may suggest their preference for mud. One would then expect mud to be a major factor in the structure and distribution of the polychaetes found in this study, but Table 3 illustrates that it was in fact coarse sand, medium sand and depth that had the most influence. Sedentary polychaete families such as the Ampharetidae, Opheliidae and Maldanidae were also more closely associated with gravel, coarse sand and fine sand (Table 7) than mud, but they were also part of the polychaete families with the least collective numerical abundances (not present in Table 5) at any given level structure.

I attempted to use sediment structure and depth to assess whether the same information (biotic patterns) could be gathered by looking at one group of infaunal organisms (polychaetes) at the family level compared to the entire fauna at family-level. In this case the results of the multi-variate analysis suggested that one group of organisms (the polychaetes) at the family-level, may not be used as a proxy for the entire fauna. Generally, the comparison of biological samples did not cluster well at any level structure (Figure 2 and 3), although there were accompanying significant results in the sedimentary properties found at a particular level structure (Table 1 and 2). This may be attributed to a lack of adequate supporting environmental data (other than sedimentary properties and depth).

There were also large differences in the amount of variation accounted for by the environmental variables used in both sets of data. Whereas 61.8% of the variation in the total infauna was explained by the environmental variables, less than half this

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percentage was found for the polychaetes using the same set of environmental variables. This indicated that the same information may not be gathered for one group of organisms (polychaetes) at the same taxonomic level. Although all the polychaete families found in the total infaunal analysis were accounted for in the polychaete analysis at the same level structures, it still cannot be considered that the same information was gathered in this case.

The results suggest that the structure of the infaunal polychaete community (at the family-level) was accounted for, only in part, by the structure of the sediments together with depth. This disagreed with the findings of other workers (Thorson, 1957; Sanders, 1958; Jones *et al.*, 1990; Lopez-Jamar *et al.*, 1995; Mannino and Montagna, 1997) who found that sediment structure was the primary factor organizing macrobenthic communities. The above-mentioned findings however, agreed with the conclusions of Newell *et al.* (1998; see chapter two, discussion), but disagreed with the findings of Bergen *et al.* (2001), who noted that depth alone was the primary factor in organizing southern California benthic communities. The results of Bergen *et al.* (2001) were also consistent with other studies of marine infaunal distribution (Hyland *et al.*, 1991; Rackocinski *et al.*, 1993; Oug, 1998).

Many studies have shown that phylum level identification is too crude and has little use in benthic biological baseline studies (Sommerfield and Clarke, 1995; Olgard *et al.* 1997, 1998). However, other studies have shown analyses based on higher taxonomic levels (families for example) may be more useful in macrobenthic communities, since little of the information on the amount of variation, is lost (Warwick, 1988; Ferraro and Cole, 1995; Vanderklift *et al.*, 1996; Olgard *et al.*, 1997, 1998). Olgard and

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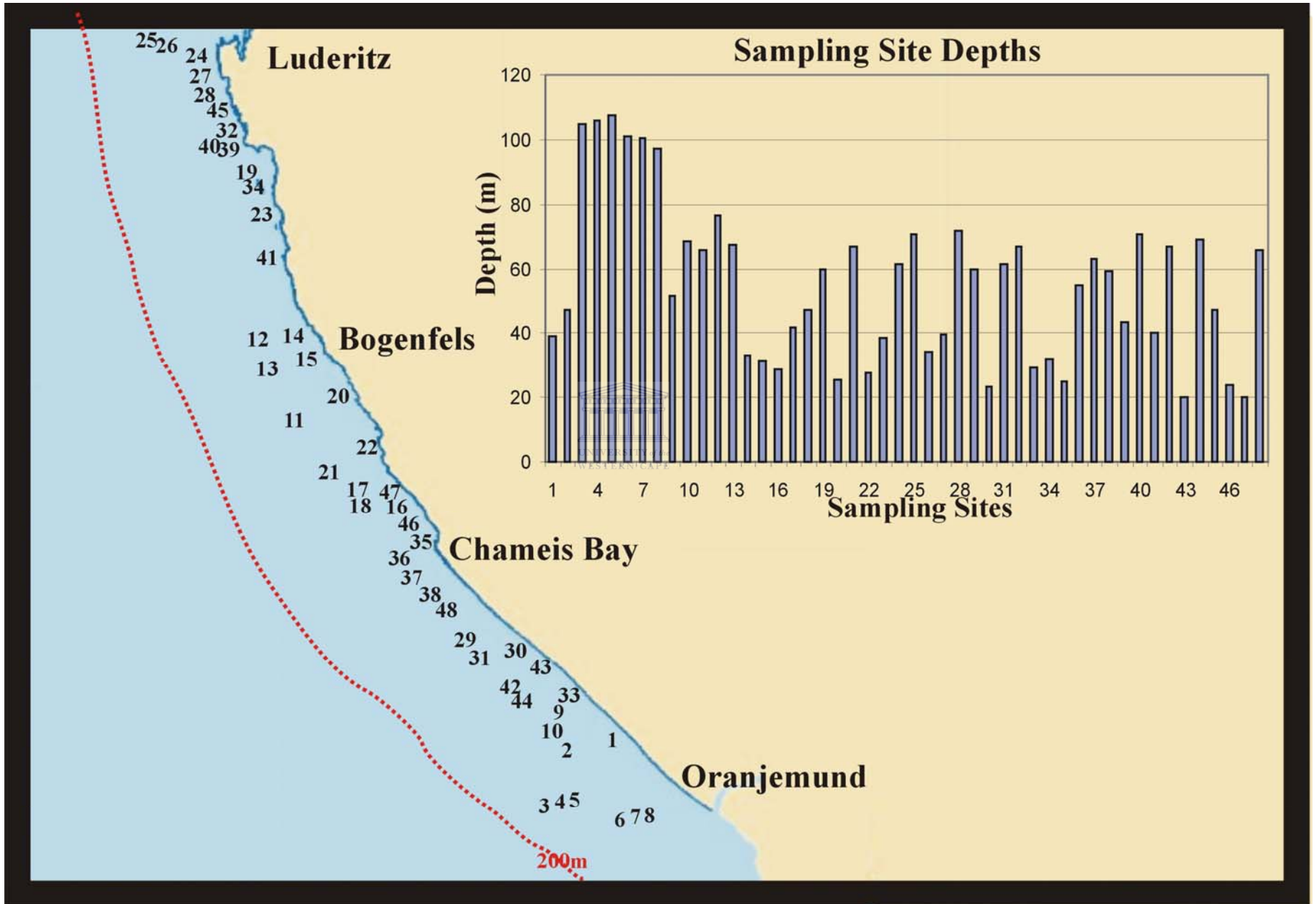
Somerfield (2000) also conducted similar studies on soft sediment macrofauna in the North Sea and they found that little information about inter-sample relationships was lost. This was true when the data was based on family, polychaete species and polychaete family abundances rather than species abundances (Olsgard and Somerfield, 2000). They also suggested that in more anthropogenically undisturbed areas, the correlations between calculated diversity indices and similarity in faunal patterns between species and family were still very high, but less for polychaete species or polychaete family abundances. They also noted that the identification to family-level might be satisfactory in many baseline-monitoring surveys.

Olsgard and Somerfield (2000) noted that polychaetes are often the most labour-intensive of taxonomic groups in studies of macrobenthic communities. The polychaete component of many macrobenthic samples, usually contain many species and high abundances, so the effort involved in their identification is often time-consuming (Olsgard and Somerfield, 2000). Polychaete identification may also be difficult and taxonomic expertise is often required. This would imply that less effort is required to identify all organisms found in a biological survey to the level of family. Based on this, if time and money were driving forces for a particular survey, then using polychaete species as a proxy for the entire fauna may not result in cost savings or time. This would obviously depend on the nature of the project, available expertise, resources and the ultimate aims of a study. Olsgard and Somerfield (2000) suggested that the use of surrogates would probably be more advantageous when species level baseline biological studies had already been completed. The polychaetes in this study were not identified to species. This may have been one of the reasons for the low level of similarity in the results, since the number of species per family was unknown.

### **Concluding remarks**

In the present study, results suggest that polychaetes should be identified to the species-level. There is no indication to the amount of diversity that exists when only family-level information is considered. Polychaete family diversity was not a good proxy for the diversity of the entire macrofaunal assemblage. The biotic patterns in polychaete families and the macrofauna were dissimilar.





65 Figure 1 A: Map of sample stations with corresponding depth profiles. (see station key, pg 67)

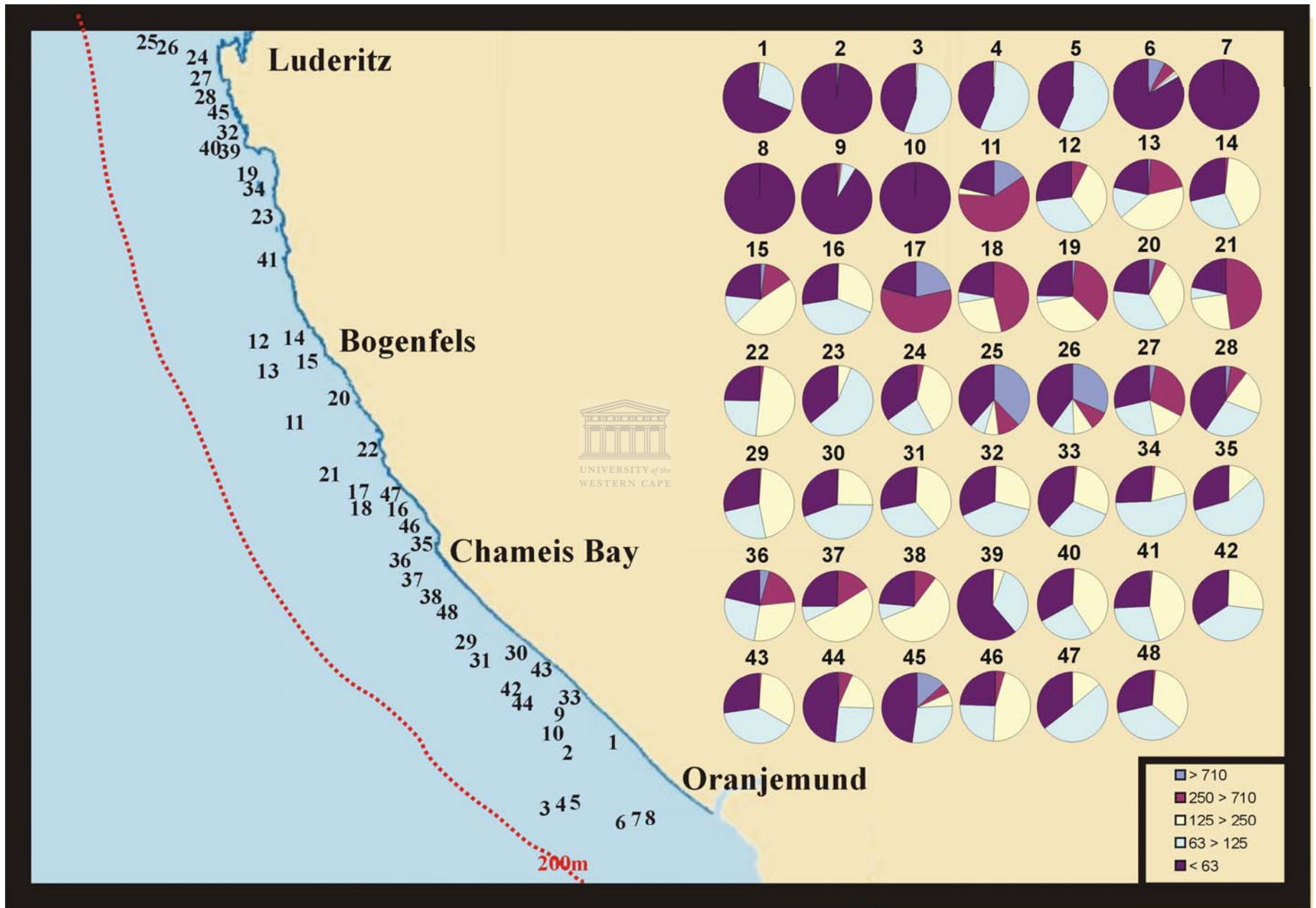


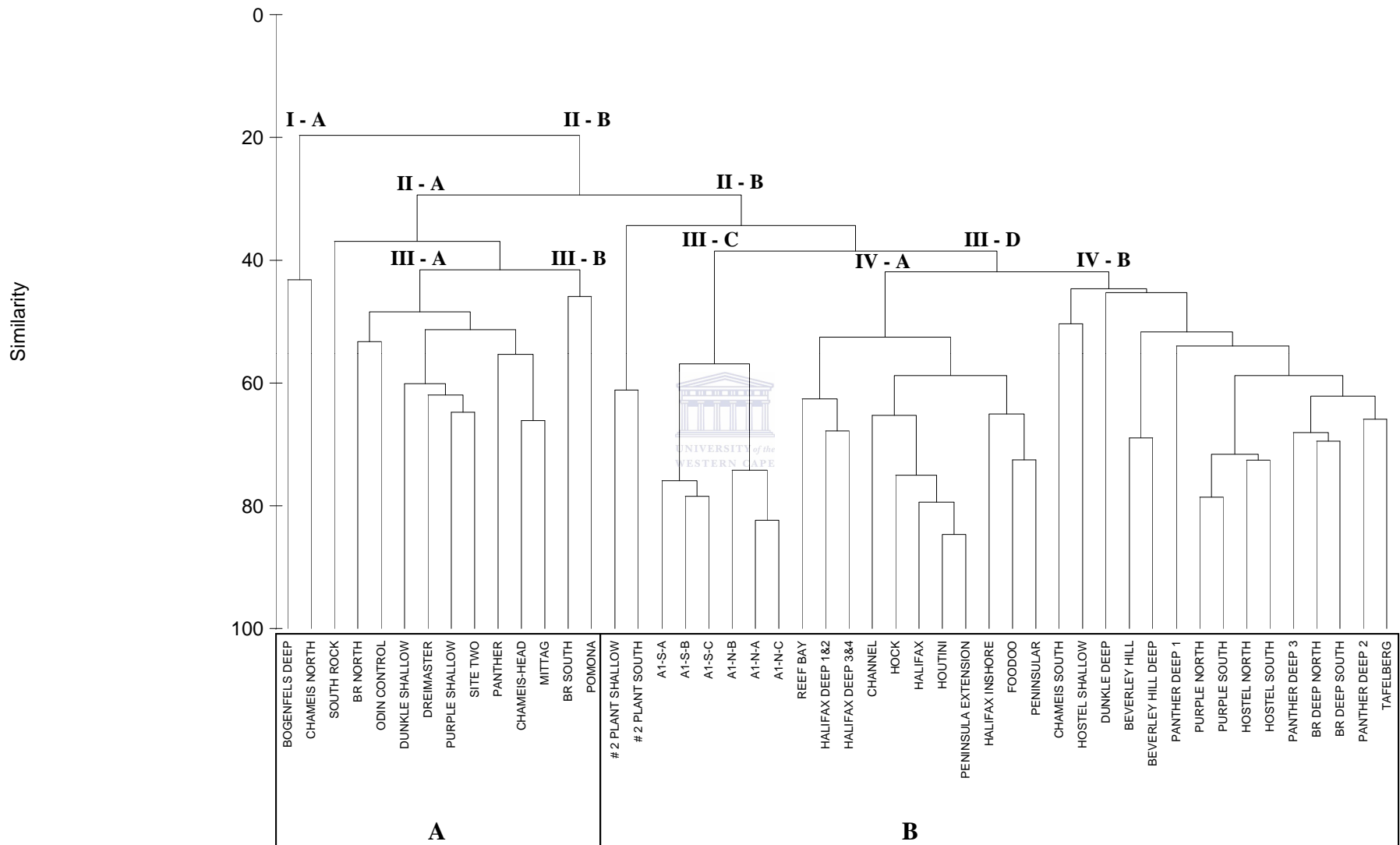
Figure 1 B: Map of sample stations with corresponding sediment granulometry. (see station key, pg 67)

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**Station key:** Site names that correspond to the site numbers shown on Figure 1 A and B in chapter three.

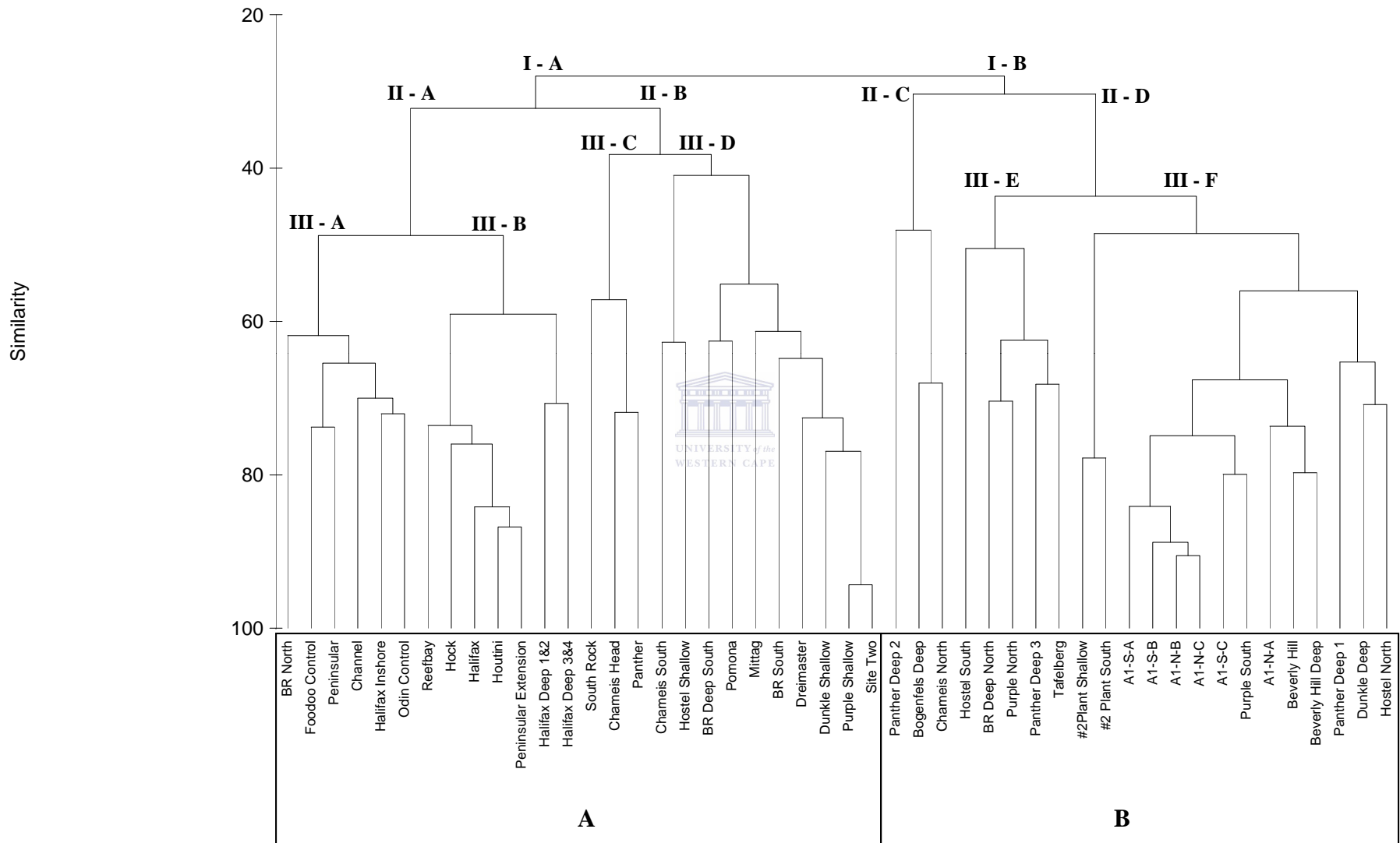
Station number	Site name
1	# 2 Plant Shallow
2	# 2 Plant South
3	A1-N-A
4	A1-N-B
5	A1-N-C
6	A1-S-A
7	A1-S-B
8	A1-S-C
9	Beverly Hill
10	Beverly Hill Deep
11	Bogenfels Deep
12	BR Deep North
13	BR Deep South
14	BR North
15	BR South
16	Chameis Head
17	Chameis North
18	Chameis South
19	Channel
20	Dreimaster
21	Dunkle Deep
22	Dunkle Shallow
23	Foodoo Control
24	Halifax
25	Halifax Deep 1&2
26	Halifax Deep 3&4
27	Halifax Inshore
28	Hock
29	Hostel North
30	Hostel Shallow
31	Hostel South
32	Houtini
33	Mittag
34	Odin
35	Panther
36	Panther Deep 1
37	Panther Deep 2
38	Panther Deep 3
39	Peninsular
40	Peninsular Extension
41	Pomona
42	Purple North
43	Purple Shallow
44	Purple South
45	Reefbay
46	Site Two
47	South Rock
48	Tafelberg



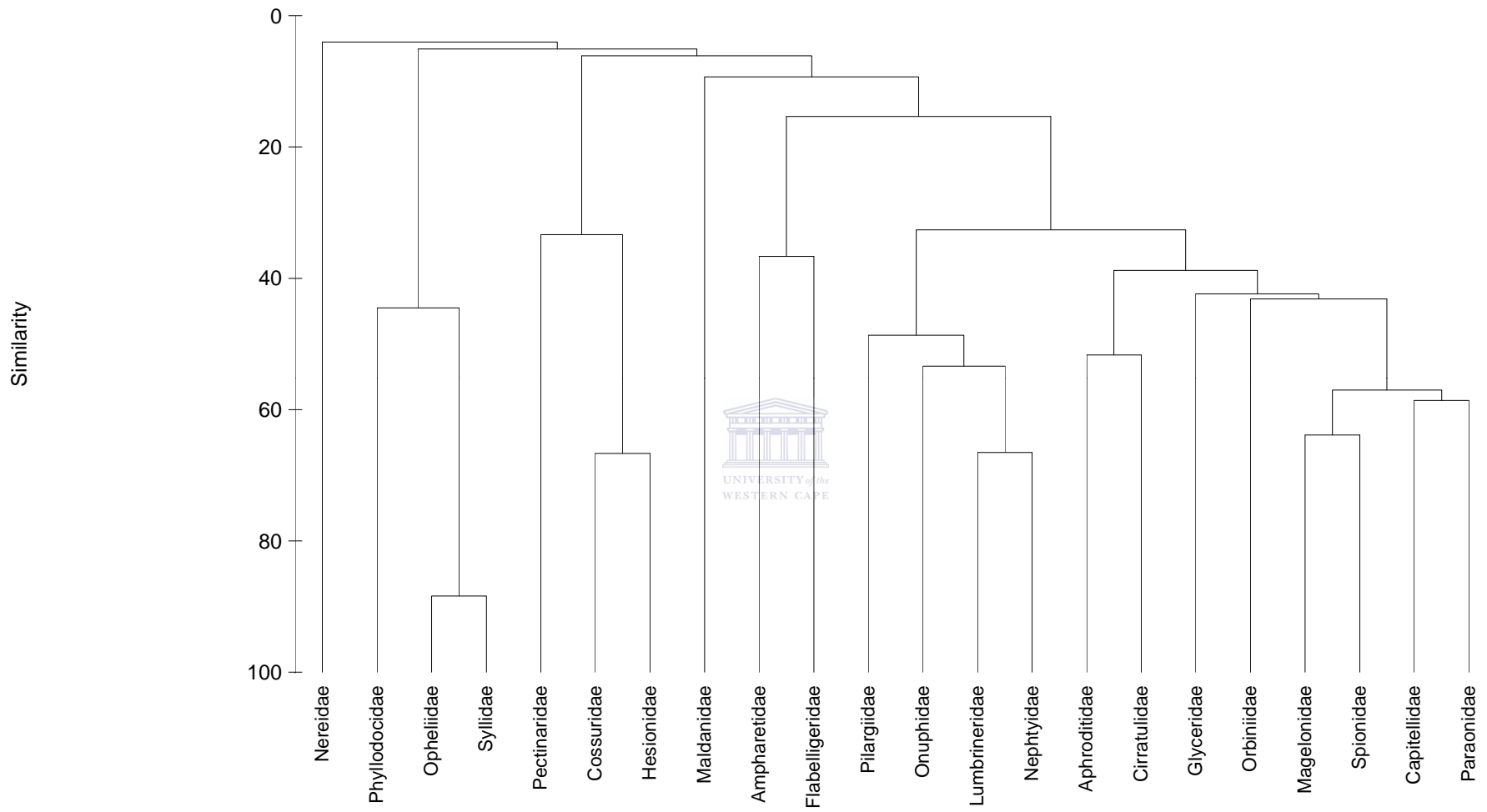


**Figure 2:** Dendrogram of percent similarity in the numerical composition of the fauna of sediment samples collected along the southern coast of Namibia from Oranjemund to Lüderitz, based on all the total infauna (identified to family). Samples collected by De Beers Marine (Pty) Ltd in 2001 (See Figure 1 A and B for localities).





**Figure 3:** Dendrogram of percent similarity in the numerical composition of the fauna of sediment samples collected along the southern coast of Namibia from Oranjemund to Lüderitz, based on all the polychaetes (identified to family). Samples collected by De Beers Marine (Pty) Ltd in 2001 (See Figure 1 A and B for localities).



**Figure 4:** Dendrogram of percent similarity in the composition of polychaetes (identified to family), collected along the southern coast of Namibia from Oranjemund to Lüderitz. Samples collected by De Beers Marine (Pty) Ltd in 2001.

## Polychaetes as surrogates using sediment structure and depth

**Table 1:** Mean environmental characteristics of each cluster identified in Figure 2.

Data in bold typeface indicate significant differences ( $P < 0.05$ ; Kolmogorov-Smirnov test) between characteristics of clusters (e.g. A and B) within any given level of similarity (I - VI). Number of samples within each cluster also shown ( $n$ ). H indicates species diversity, whereas J indicates species evenness.

Level	Cluster	$N$	H	J	No of Families	Total Abundance	Mud	Fine sand < 63 $\mu\text{m}$	63 $\mu\text{m}$ - < 125 $\mu\text{m}$	125 $\mu\text{m}$ - < 250 $\mu\text{m}$	Medium sand 250 $\mu\text{m}$ - < 710 $\mu\text{m}$	Coarse sand > 710 $\mu\text{m}$	Gravel	Depth
I	A	2	-1.69	0.68	12.00	85.00	20.98	<b>0.23</b>	1.61	<b>58.62</b>	<b>18.56</b>			56.58
I	B	46	-1.82	0.67	16.35	423.50	40.97	<b>26.33</b>	23.30	<b>6.89</b>	<b>2.51</b>			55.21
II	A	12	-1.86	0.69	15.33	316.33	<b>27.81</b>	<b>35.54</b>	<b>33.41</b>	2.60	0.64			<b>28.17</b>
II	B	34	-1.80	0.66	16.71	461.32	<b>45.62</b>	<b>23.08</b>	<b>19.73</b>	8.49	3.17			<b>64.76</b>
III	A	9	-1.88	0.68	16.44	398.22	27.66	37.06	32.85	1.90	0.53			<b>27.36</b>
III	B	2	-1.94	0.74	13.50	90.50	24.63	21.24	45.71	6.97	1.46			<b>35.83</b>
III	C	6	-2.00	<b>0.85</b>	<b>10.67</b>	<b>71.83</b>	<b>69.03</b>	28.01	<b>0.58</b>	1.03	1.35			<b>102.65</b>
III	D	26	-1.75	<b>0.61</b>	<b>18.00</b>	<b>529.31</b>	<b>37.28</b>	22.61	<b>25.57</b>	10.74	3.79			<b>57.67</b>
IV	A	11	<b>-2.16</b>	<b>0.69</b>	<b>23.27</b>	<b>877.64</b>	37.92	25.53	19.11	9.29	<b>8.14</b>			54.92
IV	B	15	<b>-1.45</b>	<b>0.56</b>	<b>14.13</b>	<b>273.87</b>	36.81	20.48	30.31	11.81	<b>0.60</b>			59.68

## Polychaetes as surrogates using sediment structure and depth

**Table 2:** Mean environmental characteristics of each cluster identified in Figure 3.

Data in bold typeface indicate significant differences ( $P < 0.05$ ; Kolmogorov-Smirnov test) between characteristics of clusters (e.g. A and B) within any given level of similarity (I - III). Number of samples within each cluster also shown ( $n$ ). H indicates species diversity, whereas J indicates species evenness.

Level	Cluster	$N$	H	J	No of Families	Total Abundance	Mud	Fine sand	Medium sand	Coarse sand	Gravel	Depth
							< 63 $\mu\text{m}$	63 $\mu\text{m}$ - < 125 $\mu\text{m}$	125 $\mu\text{m}$ - < 250 $\mu\text{m}$	250 $\mu\text{m}$ - < 710 $\mu\text{m}$	> 710 $\mu\text{m}$	
I	A	26	-1.24	0.72	<b>6.65</b>	333.00	<b>31.75</b>	29.67	<b>27.08</b>	7.71	3.80	<b>41.33</b>
I	B	22	-1.10	0.80	<b>4.45</b>	47.36	<b>50.05</b>	20.01	<b>16.86</b>	10.63	2.45	<b>71.75</b>
II	A	13	<b>-1.49</b>	0.68	<b>9.31</b>	650.62	<b>36.25</b>	27.88	<b>20.83</b>	8.10	6.93	<b>51.47</b>
II	B	13	<b>-0.99</b>	0.77	<b>4.00</b>	15.38	<b>27.25</b>	31.45	<b>33.34</b>	7.31	0.66	<b>31.19</b>
II	C	3	<b>-1.72</b>	0.85	<b>7.67</b>	33.00	22.31	2.62	18.26	<b>44.34</b>	<b>12.47</b>	58.77
II	D	19	<b>-1.00</b>	0.79	<b>3.95</b>	49.63	54.43	22.76	16.63	<b>5.31</b>	<b>0.86</b>	73.80
III	A	6	-1.27	0.58	9.17	1241.50	34.12	33.35	20.19	11.55	0.80	<b>41.05</b>
III	B	7	-1.68	0.75	9.43	144.14	38.08	23.20	21.37	5.15	12.19	<b>60.40</b>
III	C	3	-1.05	0.77	4.00	24.33	30.86	<b>49.59</b>	<b>19.18</b>	0.34	0.03	24.70
III	D	10	-0.97	0.77	4.00	12.70	26.16	<b>26.01</b>	<b>37.58</b>	9.40	0.85	33.14
III	E	5	<b>-0.67</b>	0.86	<b>2.40</b>	7.60	<b>28.27</b>	29.52	38.09	3.89	0.22	65.91
III	F	14	<b>-1.12</b>	0.77	<b>4.50</b>	64.64	<b>63.77</b>	20.35	8.97	5.82	1.09	76.62

## Polychaetes as surrogates using sediment structure and depth

**Table 3:** List of environmental variables identified by the BIOENV procedure as being responsible for differences in the structure of the dendrograms shown in Figures 2 and 3 respectively. Sediment samples collected along the southern coast of Namibia from Oranjemund to Lüderitz.

Variables	Figure	
	2 (Total Infauna)	3 (Polychaetes)
Mud		
Fine sand		
Medium sand		
Coarse sand		
Gravel		
Depth	55.7	
Gravel, depth	<b>61.8</b>	
Gravel, mud, depth	58.2	
Coarse sand, depth	56.7	23.5
Gravel, coarse sand, depth	55.1	
Gravel, medium sand, depth	53.9	
Coarse sand, mud, depth	53.6	23.1
Gravel, coarse sand, mud, depth	53.5	19.5
Coarse sand, medium sand, depth	53.5	<b>24.1</b>
Gravel, coarse sand, medium sand, depth	53.4	
Coarse sand, medium sand, mud, depth		22.5
Coarse sand, medium sand, fine sand, depth		21.8
Coarse sand, fine sand, mud, depth		21.0
Coarse sand, medium sand, fine sand, mud, depth		20.8
Coarse sand, fine sand, depth		20.8
Gravel, coarse sand, medium sand, mud, depth		19.3



Bold typeface indicates most influential variable. Variables: mud (< 63 µm); fine sand (63 < 125 µm); medium sand (125 < 250 µm); coarse sand (250 µm < 710 µm); gravel (> 710 µm); depth. The degree of influence exerted on each of the biological structures for a particular variable are shown as percentages.

Polychaetes as surrogates using sediment structure and depth

**Table 4:** List of dominant infaunal families identified by SIMPER as responsible for differences in the structure of the clusters (by Level) shown in Figure 2.

Level	Family	Average Abundance				Contribution (%)
		Cluster A	Cluster B	Cluster C	Cluster D	
I (A&B)	Nassariidae	5.00	78.46			17.19
I	Urothoidae	0.00	31.54			6.95
I	Nephtyidae	1.50	20.65			3.12
I	Ampeliscidae	0.00	21.50			5.09
I	Liljeborgiidae	0.00	9.41			2.41
I	Callianassidae	0.00	10.80			2.75
I	Cumacea	0.00	15.07			2.94
I	Lumbrineridae	0.00	5.91			1.67
I	Tellinidae	34.00	8.80			11.16
I	Onuphidae	13.50	9.17			6.00
I	Syllidae	6.00	0.04			2.30
I	Paraonidae	4.50	10.24			2.16
I	Cirratulidae	6.00	1.09			2.39
II (A&B)	Nassariidae	15.92	100.53			17.66
II	Urothoidae	75.25	16.12			10.51
II	Nephtyidae	21.92	20.21			3.20
II	Ampeliscidae	2.75	28.12			5.41
II	Liljeborgiidae	0.17	12.68			2.60
II	Callianassidae	0.00	14.62			3.05
II	Cumacea	23.50	12.09			4.09
II	Lumbrineridae	0.17	7.94			1.83
II	Tellinidae	4.92	10.18			1.97
II	Magelonidae	69.42	131.44			8.19
II	Anthuridae	4.67	0.18			1.05
II	Dexaminidae	6.58	1.38			1.44
III (A&B)	Nassariidae	12.44	39.50			12.34
III	Urothoidae	94.11	19.50			14.25
III	Nephtyidae	27.22	8.50			3.97
III	Cumacea	31.22	0.00			5.43
III	Tellinidae	6.22	1.50			1.69
III	Magelonidae	92.11	2.00			8.80
III	Anthuridae	6.11	0.50			2.24
III	Dexaminidae	8.56	0.00			2.87
III (C&D)	Nassariidae			4.33	123.69	26.84
III	Urothoidae			0.00	21.08	5.81
III	Nephtyidae			8.00	24.19	3.12
III	Ampeliscidae			13.00	25.96	6.96
III	Liljeborgiidae			7.33	14.88	2.38
III	Callianassidae			6.67	17.58	3.61
III	Cumacea			0.50	10.31	2.64
III	Lumbrineridae			8.33	8.27	1.66
III	Tellinidae			0.50	10.38	2.24
III	Upogebiidae			6.83	0.00	2.00

The mean abundance of each family in each assemblage (e.g. cluster A, B) is shown, as are their proportional contribution to dissimilarity (only families with at least a contribution of 4% are reported).

Polychaetes as surrogates using sediment structure and depth

Table 4 (continued)

Level	Family	Average Abundance				Contribution (%)
		Cluster A	Cluster B	Cluster C	Cluster D	
IV (A&B)	Nassariidae	93.27	146.00			14.73
IV	Urothoidae	8.36	30.40			4.35
IV	Nephtyidae	53.27	2.87			3.92
IV	Ampeliscidae	10.45	37.33			5.05
IV	Liljeborgiidae	18.64	12.13			1.61
IV	Callianassidae	35.91	4.13			5.02
IV	Cumacea	12.73	8.53			1.58
IV	Tellinidae	17.00	5.53			1.95
IV	Paraonidae	42.55	0.07			3.10
IV	Pilargiidae	20.27	0.93			3.34
IV	Spionidae	17.73	0.07			2.17
IV	Lumbrineridae	14.64	3.60			1.40
IV	Magelonidae	406.27	0.00			10.71

The mean abundance of each family in each assemblage (e.g. cluster A, B) is shown, as are their proportional contribution to dissimilarity (only families with at least a contribution of 4% are reported).



Polychaetes as surrogates using sediment structure and depth

**Table 5:** List of dominant polychaete families identified by SIMPER as responsible for differences in the structure of the clusters (by Level) shown in Figure 3.

Level	Family	Average Abundance						Contribution (%)
		Cluster A	Cluster B	Cluster C	Cluster D	Cluster E	Cluster F	
I (A&B)	Lumbrineridae	6.27	4.95					9.37
I	Nephtyidae	32.92	4.41					12.21
I	Onuphidae	10.23	8.32					11.69
I	Magelonidae	203.92	0.00					13.82
I	Spionidae	13.65	0.14					4.44
I	Paraonidae	18.08	0.45					4.28
I	Pilargiidae	8.58	0.82					5.38
II (A&B)	Lumbrineridae	12.54	0.00					5.93
II	Nephtyidae	59.85	6.00					11.41
II	Magelonidae	404.31	3.54					21.55
II	Spionidae	26.77	0.54					7.60
II	Paraonidae	36.08	0.08					8.20
II	Pilargiidae	17.15	0.00					10.12
II	Capitellidae	55.62	1.62					9.48
II (C&D)	Lumbrineridae			1.33	5.53			8.09
II	Nephtyidae			1.67	4.84			6.28
II	Onuphidae			9.00	8.21			15.53
II	Cirratulidae			4.00	0.00			5.68
II	Syllidae			4.67	0.00			7.89
III (A&B)	Nephtyidae	104.67	21.43					6.32
III	Onuphidae	0.33	37.43					5.12
III	Magelonidae	873.17	2.43					37.21
III	Spionidae	43.17	12.71					4.24
III	Paraonidae	62.33	13.57					4.87
III	Pilargiidae	3.83	28.57					4.24
III	Capitellidae	118.83	1.43					14.24
III (C&D)	Nephtyidae			5.33	6.20			13.70
III	Magelonidae			11.67	1.10			26.63
III	Orbiniidae			4.33	0.00			16.62
III (E&F)	Lumbrineridae					4.00	6.07	10.97
III	Nephtyidae					2.40	5.71	11.99
III	Onuphidae					0.00	11.14	21.23

The mean abundance of each family in each assemblage (e.g. cluster A, B) is shown, as are their proportional contribution to dissimilarity (only families with at least a contribution of 4% are reported).



Polychaetes as surrogates using sediment structure and depth

**Table 6:** Families of polychaetes identified from the samples collected along the southern coast of Namibia from Oranjemund to Lüderitz.

Order	Family	Authority
Terebellida	Ampharetidae	Malmgren, 1866
Phyllodocida	Aphroditidae	Malmgren, 1867
Capitellida	Capitellidae	Grube, 1862
Spionida	Cirratulidae	Ryckholdt, 1851
Cossurida	Cossuridae	Day, 1963
Flabelligerida	Flabelligeridae	Saint-Joseph, 1894
Phyllodocida	Glyceridae	Fauchald, 1977
Phyllodocida	Hesionidae	Grube, 1850
Eunicida	Lumbrineridae	Schmarda, 1861
Capitellida	Maldanidae	Malmgren, 1867
Spionida	Magelonidae	Cunningham and Ramage, 1888
Phyllodocida	Nephtyidae	Grube, 1850
Phyllodocida	Nereididae	Johnston, 1865
Opheliida	Opheliidae	Malmgren, 1867
Eunicida	Onuphidae	Kinberg, 1865
Orbiniida	Orbiniidae	Hartman, 1942
Orbiniida	Paraonidae	Cerruti, 1909
Phyllodocida	Phyllodocidae	Orsted, 1843
Terebellida	Pectinariidae	de Quatrefages, 1866
Phyllodocida	Pilargiidae	Saint-Joseph, 1899
Spionida	Spionidae	Grube, 1850
Phyllodocida	Syllidae	Grube, 1850

## Polychaetes as surrogates using sediment structure and depth

**Table 7:** Spearman Rank Order Correlations for polychaete families positively correlated with environmental variables.

Significance determined at 95% confidence levels ( $P < 0.05$ ). Rank correlation coefficients are shown for each variable.

Families	Mud < 63 $\mu\text{m}$	Fine sand 63 $\mu\text{m}$ - < 125 $\mu\text{m}$	Medium sand 125 $\mu\text{m}$ - < 250 $\mu\text{m}$	Coarse sand 250 $\mu\text{m}$ - < 710 $\mu\text{m}$	Gravel > 710 $\mu\text{m}$	Depth
Ampharetidae		-0.30158	-0.35632		0.28507	
Aphroditidae			0.28976			
Cirratulidae	-0.36216					
Flabelligeridae	0.32156		-0.34112	-0.33171		
Glyceridae	-0.45857					-0.48319
Lumbrineridae	0.55282		-0.33280	-0.28893		0.63392
Magelonidae		0.32481				-0.47114
Maldanidae					0.38930	
Nephtyidae		0.30245				
Onuphidae	0.46807	-0.45118	-0.70273		0.33313	0.42588
Orbiniidae		0.34223				
Opheliidae	-0.35875	-0.34581		0.38270		
Pilargidae	0.50623					
Syllidae	-0.35986	-0.34744		0.38393		



## General conclusions

### Conclusions

The polychaete species that could not be fully identified in this study may be potentially new. Although numerous species have been described by Day (1967) in a comprehensive monograph that covered most of the southern African species, the results of this study indicate a need for additional collections around the region to better understand the polychaete diversity.

Results in both chapters two and three suggest that the structure of the infaunal polychaete community (at the family and species-level) is accounted for, only in part, by the structure of the sediments: some Ampharetidae, Aphroditidae, Cirratulidae, Flabelligeridae, Glyceridae, Lumbrineridae, Magelonidae, Maldanidae, Nephtyidae, Onuphidae, Orbiniidae, Opheliidae, Pilargidae and Syllidae were positively correlated with, variously, mud (< 63  $\mu\text{m}$ ), fine sand (63  $\mu\text{m}$  - < 125  $\mu\text{m}$ ), medium sand (125  $\mu\text{m}$  - < 250  $\mu\text{m}$ ), coarse sand (250  $\mu\text{m}$  - < 710  $\mu\text{m}$ ) and gravel (> 710  $\mu\text{m}$ ). The results in chapter three also indicate that some polychaete families (Lumbrineridae and Onuphidae) are more likely to be found at deeper depths, whereas others (Glyceridae and Magelonidae) were more often encountered at shallower depths. Despite the similarities, contrasting results were obtained in chapter two and three. Whereas the polychaete family-level information closely resembled the total infauna family-level results in chapter two (i.e. polychaetes were good proxies for the entire fauna, or rather biotic patterns in both were similar) this relationship was less clear in chapter three. Also, sediments in chapter two accounted for a greater percentage of the community structure than in chapter three.

## General conclusions

These differences may have been due to the different types of data in the two chapters. The family-level polychaete data had been combined in chapter three, whereas each sample in chapter two was treated individually.

In order to test whether the biotic patterns that were observed in chapter two and three were the result of pooling the data or not, the raw data that were used in chapter two were pooled and analyses were repeated both with and without polychaetes. Once again, I specifically looked for similarities in the structure of the two dendrograms, and in the results of the respective BIOENV procedures. It should be noted that all data used in this analysis were taken from Goosen *et al.* (2000), because a complete data set (that included all the biological samples) was provided in that instance.



The results indicate that the dendrograms (Figure 1 and 2) were broadly similar as well as the results of their respective BIOENV procedures (Table 1). Interestingly, the medium-size fraction of the sediments (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ) accounted for 54.2% of the structure in the total infauna (Table 1) as identified by family, whereas mud (0 - 45  $\mu\text{m}$ ) accounted for 58.2% of the polychaete community structure (Table 1) as identified by families. In all cases, the amount of variation explained by the sediments was once again greater for communities identified using family-level polychaete data (as in chapter two) than it was using the total infauna family-level information (see chapter two). This suggests that when the data were pooled in chapter two; the same level of information was still being obtained at the family-level in both the total infauna and polychaetes. In other words,

## General conclusions

pooling of the data in chapter three might not be the cause of the inconsistencies in the results observed, between chapters two and three.

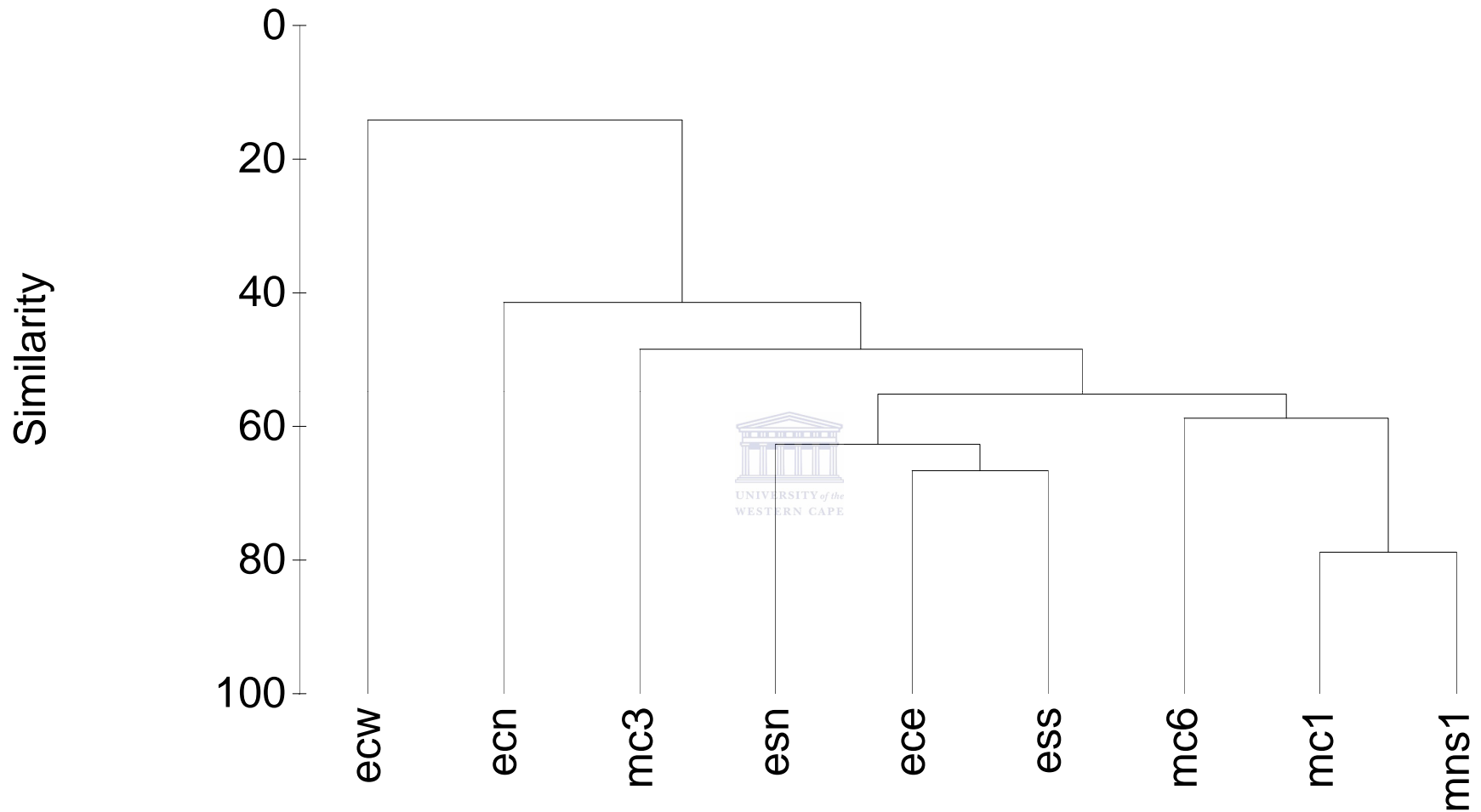
Closer examination of the sediment data used in the two chapters revealed a striking difference. Whereas there were six sediment size fractions accounted for in chapter two (Table 2), only five were used in chapter three (Table 3). In order to test whether this might have accounted for the differences between the BIOENV results (role of the sediments) in chapter three, the data were made comparable in chapter two by repeating the BIO-ENV analyses without mud (0 - 45  $\mu\text{m}$ ) and very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ). The family-level polychaete abundance data from chapter two were treated in an individual and pooled sample manner. I specifically looked for similarities in the results of the respective BIOENV procedures. It should be noted that all data used in this analysis were taken from Goosen *et al.* (2000) for the reason previously mentioned.

Results indicate that the medium sand (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ) size fraction now accounted for most of the variation (Table 2) observed in the individual sample family-level polychaete structure when mud (0 - 45  $\mu\text{m}$ ) and very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ) are excluded in the analysis. When mud (0 - 45  $\mu\text{m}$ ) and very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ) were included in this analysis, mud (0 - 45  $\mu\text{m}$ ) accounted for most of the variation observed and it was much higher than when mud and very fine sand were excluded from the analysis. Gravel (> 710  $\mu\text{m}$ ) and coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ) accounted for most of the variation observed in the pooled sample family-level polychaete structure (Table 3)

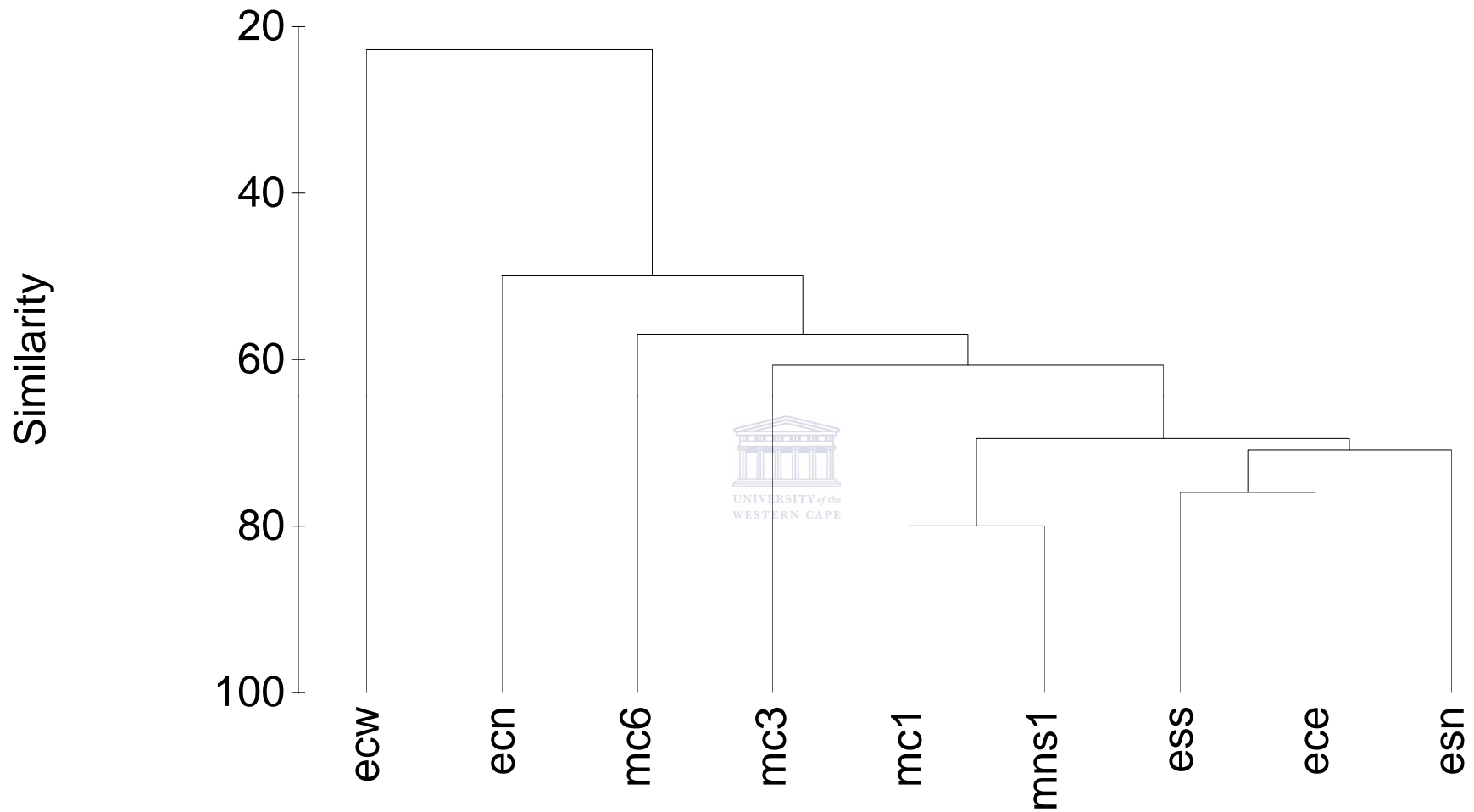
## General conclusions

when mud (0 - 45  $\mu\text{m}$ ) and very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ) were included and excluded from the subsequent analyses.

The above-mentioned results still do not adequately explain why there was a low level of similarity between the total infauna and polychaete family-level biotic patterns in chapter three. It seemed that when the data were pooled, it improved the taxonomic resolution (amount of variation obtained), but when the sediment size fraction data were adjusted, it lowered the amount of taxonomic resolution. The results obtained here suggest that comprehensive and standardized samples must be collected to better establish and understand the relationships between biotic patterns and environmental variables. This is potentially important given the costs involved and the potentially long lasting value of the material. Since these sediment and biological samples were collected by industry (for industry and not academic purposes), proper protocols need to be established so that industry can make a real contribution to our understanding of the biodiversity and ecology of the area. The standardization of identification may be the first step in achieving this. In other words, mutually agreed (updated) checklists of macrofauna between organizations may solve problems regarding currently accepted nomenclature. This may only be realized when the taxonomist and the commercial identifier meet, thereby complimenting each other through collaboration.



**Figure 1:** Dendrogram of percent similarity in the combined numerical composition of the fauna of sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia (chapter 2), based on all the infauna (identified to family only). Data from Goosen *et al.* (2000). (ECW, ECE, MNS1 etc., indicate that the samples were pooled and re-analysed within the sample stations, see Figure 1, chapter 2 for localities).



**Figure 2:** Dendrogram of percent similarity in the combined numerical composition of the fauna of sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia (chapter 2), based on all the polychaetes (identified to family only). Data from Goosen *et al.* (2000). (ECW, ECE, MNS1 etc., indicate that the samples were pooled and re-analysed within the sample stations, see Figure 1, chapter 2 for localities).



## General conclusions

**Table 1:** List of environmental variables identified by the BIOENV procedure as being responsible for differences in the structure of the dendrograms shown in Figures 1 and 2 respectively. Data from Goosen *et al.* (2000). Sediment samples collected in the Marshall Fork and Elephant Basin areas off the southern coast of Namibia (chapter 2).

Variables	Figure	
	1 (Total Infauna)	2 (Polychaetes)
Mud	52.1	<b>58.2</b>
Very fine sand		
Fine sand		
Medium sand	<b>54.2</b>	48.2
Coarse sand		
Gravel		
Mud, very fine sand	51.7	55.5
Mud, coarse sand		54.1
Mud very fine sand, coarse sand		52.4
Mud, very fine sand, medium sand, coarse sand		50.3
Mud, medium sand, coarse sand		50.3
Very fine sand, medium sand	53.6	49.3
Very fine sand, medium sand, coarse sand	47.1	48.7
Mud, medium sand	50.5	48.6
Fine sand, medium sand	49.2	
Mud, very fine sand, medium sand	48.9	
Mud, medium sand, gravel	48.2	
Very fine sand, fine sand, medium sand	48.0	



Bold typeface indicates most influential variable. Variables: mud (0 - 45  $\mu\text{m}$ ); very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ); fine sand (63  $\mu\text{m}$  - 125  $\mu\text{m}$ ); medium sand (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ); coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ); gravel (> 710  $\mu\text{m}$ ). The degree of influence exerted on each of the biological structures for a particular variable are shown as percentages.

## General conclusions

**Table 2:** List of environmental variables identified by the BIOENV procedure as being responsible for differences in the structure of the polychaete families when they were treated individually and when mud and very fine sand were included and excluded in the analysis.

Variables	Polychaete structure	
	Excludes mud and very fine sand	Includes mud and very fine sand
Mud		<b>36.2</b>
Very fine sand		28.7
Fine sand	13.2	
Medium sand	<b>26.5</b>	
Coarse sand		
Gravel	12.8	
Fine sand, medium sand	24.2	
Medium sand, coarse sand	24.1	
Fine sand, medium sand, coarse sand	21.9	
Medium sand, gravel	20.9	
Medium sand, coarse sand, gravel	18.3	
Fine sand, medium sand, gravel	17.4	
Fine sand, medium sand, coarse sand, gravel	16.4	
Mud, very fine sand		34.5
Mud, gravel		33.1
Mud, very fine sand, gravel		32.9
Mud, coarse sand		28.5
Mud, very fine sand, medium sand, gravel		28.1
Mud, very fine sand, coarse sand, gravel		27.7
Mud, medium sand, gravel		27.6
Mud, coarse sand, gravel		27.6



Bold typeface indicates most influential variable. Variables: mud (0 - 45  $\mu\text{m}$ ); very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ); fine sand (63  $\mu\text{m}$  - 125  $\mu\text{m}$ ); medium sand (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ); coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ); gravel (> 710  $\mu\text{m}$ ). The degree of influence exerted on each of the biological structures for a particular variable are shown as percentages.

## General conclusions

**Table 3:** List of environmental variables identified by BIOENV as responsible for differences in the structure of the polychaete families when they were combined and when mud and very fine sand were included and excluded in the analysis.

Variables	Polychaete structure	
	Excludes mud and very fine sand	Includes mud and very fine sand
Mud		29.6
Very fine sand		
Fine sand		
Medium sand		
Coarse sand	21.0	
Gravel	31.1	
Coarse sand, gravel	<b>49.7</b>	<b>53.4</b>
Fine sand, coarse sand, gravel	27.7	35.2
Medium sand, coarse sand, gravel	27.2	29.6
Fine sand, medium sand, coarse sand, gravel	19.5	
Fine sand, gravel	17.0	
Medium sand, gravel	15.2	
Medium sand, coarse sand	7.8	
Fine sand, medium sand, gravel	3.6	
Mud, coarse sand, gravel		44.5
Mud, gravel		40.6
Mud, coarse sand		34.6
Very fine sand, coarse sand, gravel		31.9
Mud, very fine sand, coarse sand, gravel		31.5
Mud, medium sand, coarse sand, gravel		30.2



Bold typeface indicates most influential variable. Variables: mud (0 - 45  $\mu\text{m}$ ); very fine sand (45  $\mu\text{m}$  - 63  $\mu\text{m}$ ); fine sand (63  $\mu\text{m}$  - 125  $\mu\text{m}$ ); medium sand (125  $\mu\text{m}$  - 250  $\mu\text{m}$ ); coarse sand (250  $\mu\text{m}$  - 710  $\mu\text{m}$ ); gravel (> 710  $\mu\text{m}$ ). The degree of influence exerted on each of the biological structures for a particular variable are shown as percentages.

**LITERATURE CITED**

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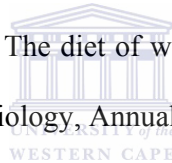
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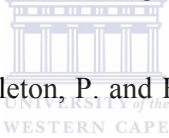
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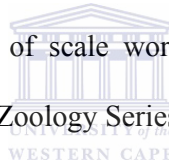
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## Appendix

The Appendix is divided into three parts. Appendix one summarizes the granulometric properties of the sediments found in the biological baseline survey of the Marshall Fork and Elephant Basin areas (chapter two) off the coast of Namibia (Goosen *et al.*, 2000). Figures (1-9) are also provided in order to obtain a representation of the sediment proportions in each sample site.

Appendix two shows the abundance data (biological and physical) that were used in the multivariate analysis for samples found in the Marshall Fork and Elephant Basin areas off the coast of Namibia. Appendix 2 A shows the abundance data that were used in order to test whether the biotic patterns that were observed by Goosen *et al.* (2000) from an analysis of the entire community (at the family-level) were similarly displayed by the polychaetes only (at the family-level). All the data used in this analysis were taken from Goosen *et al.* (2000). Appendix 2 B and C shows the abundance data that were used in order to test if there was a loss of biological resolution when determining polychaete communities on the basis of species-level or family-level identifications. It should be noted that I have not used the family-level data from Goosen *et al.* (2000) in this instance, because De Beers Marine (Pty) Ltd were unable to supply me with all the samples, instead I have used my own family-level data, based on my species-level data. Appendix 2 D shows the sediment size fractions (environmental data as percentages) for samples found in the Marshall Fork and Elephant Basin areas off the coast of Namibia (see chapter 2, Figure 1 for localities).

Appendix three shows the abundance data (biological and physical) that were used in the multivariate analysis for samples found along the southern coast of Namibia from Oranjemund to Lüderitz. Appendix 3 A shows the abundance data that were used in order to test whether the biotic patterns that were observed by De Beers Marine in 2001 from a collection of the entire community (at the family-level) were similarly displayed by the polychaetes only (at the family-level). Appendix 3 B shows the sediment size fractions (environmental data as percentages) for samples found along the southern coast of Namibia from Oranjemund to Lüderitz. (see chapter 3, Figure 1 A and B for localities).



## Description of Study Sites

The granulometric properties of the sediments found in the biological baseline survey of the Marshall Fork and Elephant Basin areas off the coast of Luderitz (Goosen *et al.*, 2000) were summarized by the following:

### Marshall Fork

Marshall Fork consists mainly of Precambrian bedrock, which extended north to south with water depths of 35 m in the north down to below 75 m in the south. The Precambrian surface was generally clear of Quaternary sediments; namely, mud, sand and gravel. The samples in this area were variable in their grain size characteristics.

The samples collected in MC3 were the shallowest with water depths of about 41 m. A variety of grain sizes occurred there, with large proportions of gravel ( $> 710 \mu\text{m}$ ), coarse sand ( $250 \mu\text{m} - 710 \mu\text{m}$ ), fine sand ( $125 \mu\text{m} - 250 \mu\text{m}$ ) and mud ( $0 - 45 \mu\text{m}$ ). This may suggest that wave energy was sufficient to concentrate sand, shell, gravel and mud in that area (Figure 1). Similar results were observed for the MC6 sites (52 m water depth), where there was less mud, gravel and shells, but more sand (Figure 2).

Samples that were collected further down Marshall Fork in the MC1 site (67 m water depth), contained mostly mud except for one sample (MC1-2), which had less coarse sand and gravel (Figure 3). The MNS1 site was characterised by roughly 50% mud ( $0 - 45 \mu\text{m}$  diameter). Generally, these samples had few types of sediment coarser than  $250 \mu\text{m}$ , although there were samples with coarser material (MNS1-5), (Figure 4).

## Elephant Basin

Elephant Basin is situated south of Marshall Fork and northwest of Diaz Point, off Luderitz Bay (Figure 1, chapter 2). This area is a shallow depression, widest in the north and narrowing southwards. Elephant Basin also has a Precambrian basement with latest Quaternary deposits (mainly Holocene). The shallowest samples were collected from water depths of 41 m on the eastern and western sides of the Elephant Basin.

The shoreward sites were characterised by about 50% mud (0 - 45  $\mu\text{m}$ ) with coarse sand, while the offshore margin (ECW1 and 2) was dominated almost exclusively by coarse sand and gravel (> 710  $\mu\text{m}$ ; Figure 5). The ECW site may thus be exposed to swell and wave influence at the seafloor whereas the ECE site (Figure 6) may not, because the samples contained high proportions of mud (0 - 45  $\mu\text{m}$ ). The ECN site (Figure 7) in the north and the ESN site (Figure 8) in the centre of the basin had the muddiest samples ranging from 38% to 82% mud (0 - 45  $\mu\text{m}$  diameter). The ESS site is situated in the south of the Basin centre, where a number of grain sizes occurred, although one sample (ESS-1) was 63% mud (0 - 45  $\mu\text{m}$ ) and the other two samples (ESS-2 and 3) were dominated by coarse sand and gravel (Figure 9).

The distribution of these granulometric properties of the sediments in both Marshall Fork and the Elephant Basin may have reflected the present day wave and swell regime and its ability to sort sediment on the seafloor.

Appendix 1

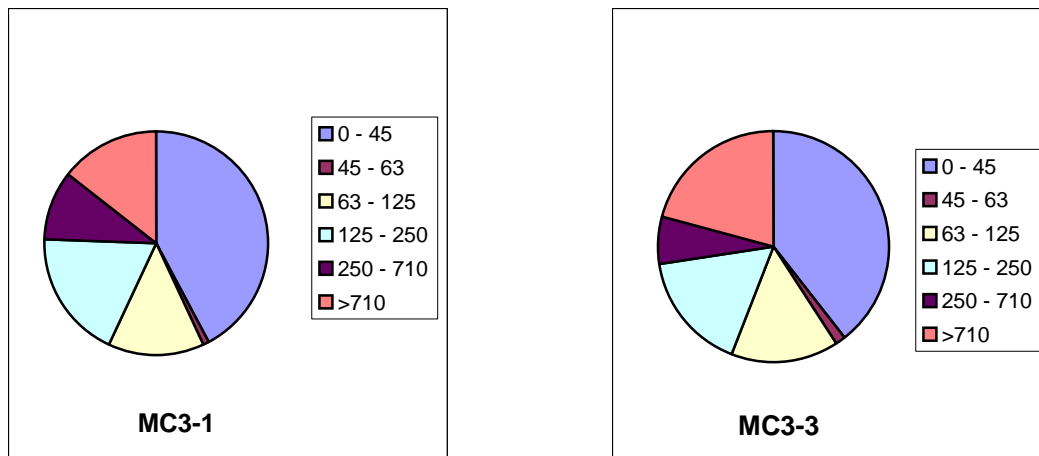


Figure 1: Sediment texture proportions of Marshall Fork grab site, MC3 in  $\mu\text{m}$ .

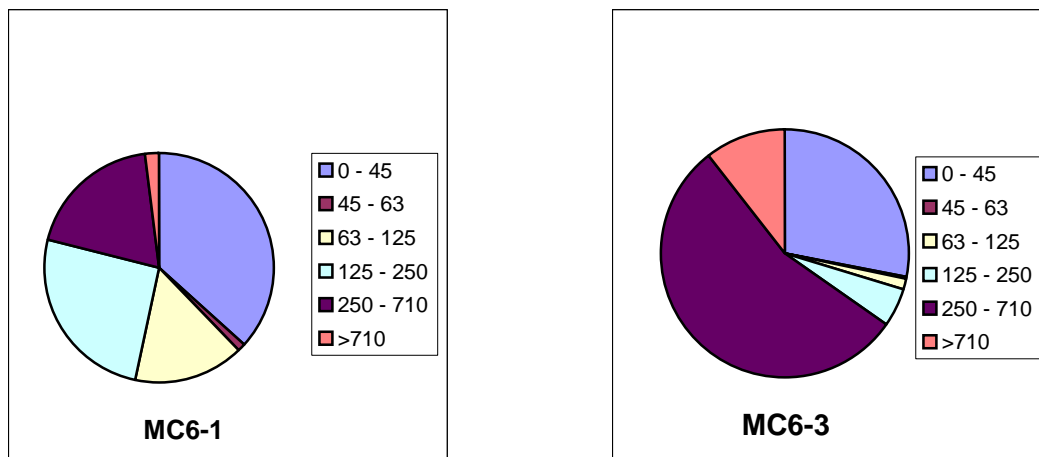


Figure 2: Sediment proportions of Marshall Fork site, MC6 in  $\mu\text{m}$ .



Appendix 1

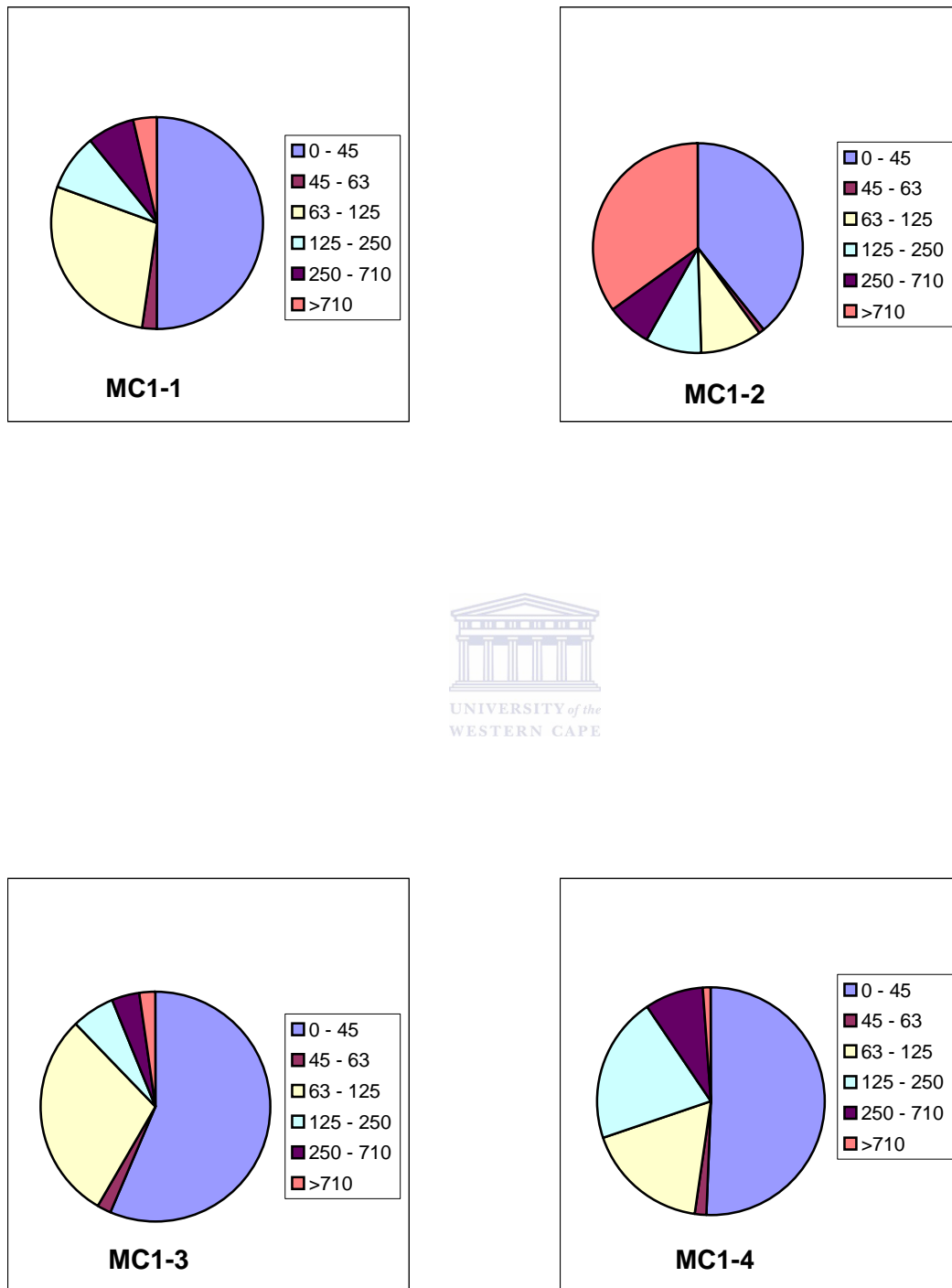


Figure 3: Sediment proportions of Marshall Fork site, MC1 in  $\mu\text{m}$ .

Appendix 1

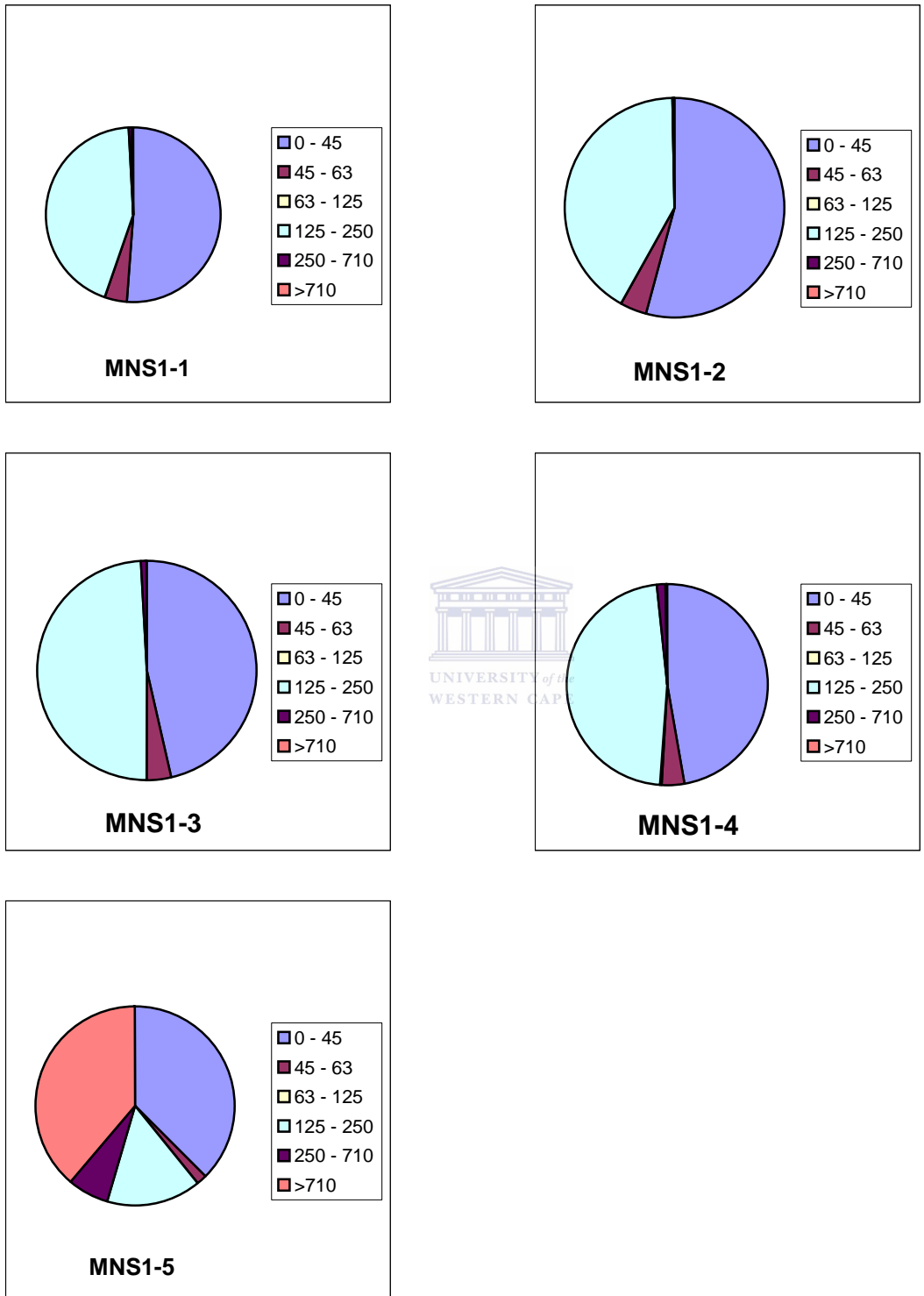


Figure 4: Sediment proportions of Marshall Fork site, MNS1 inum.

Appendix 1

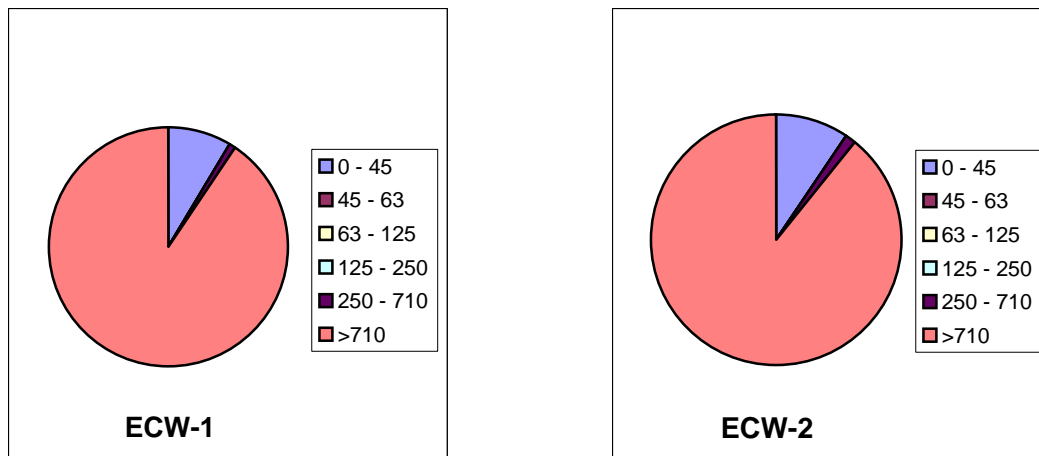


Figure 5: Sediment proportions of Elephant Basin site, ECW in  $\mu\text{m}$ .

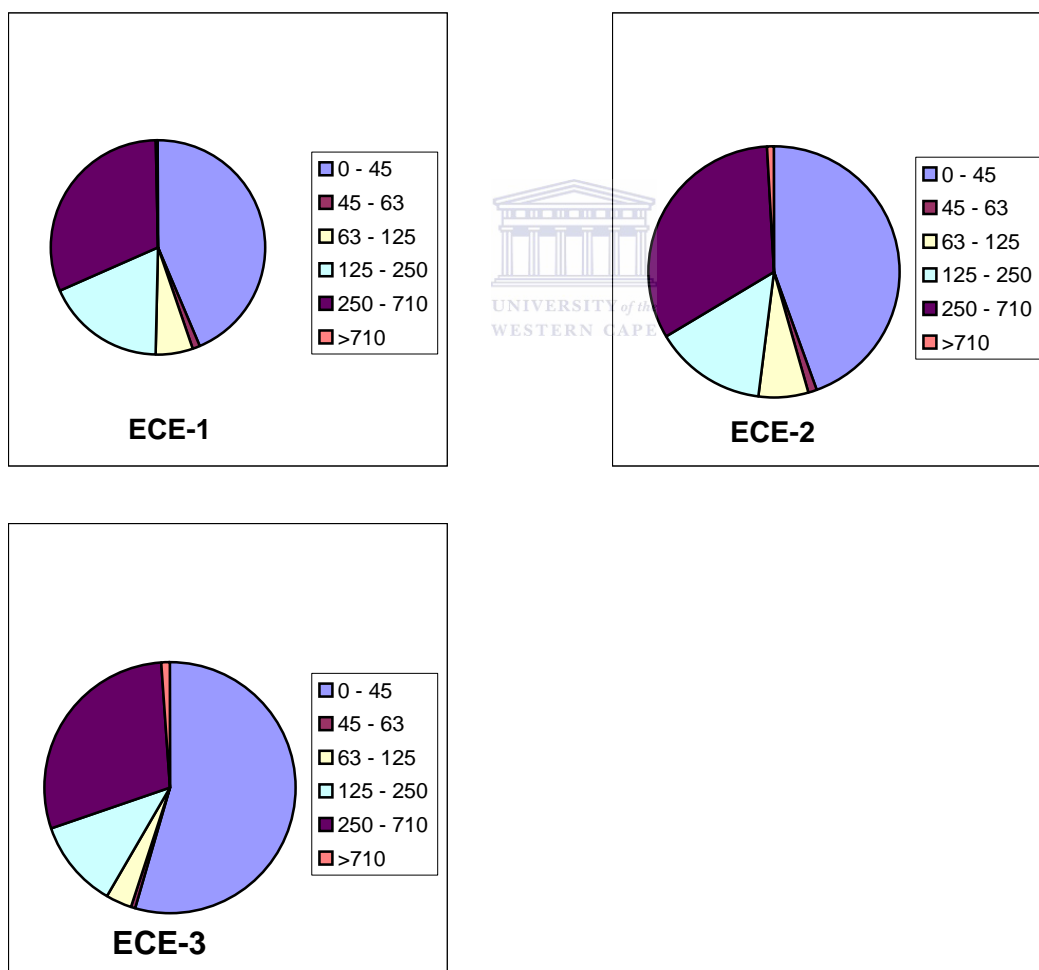


Figure 6: Sediment proportions of Elephant Basin site, ECE in  $\mu\text{m}$ .

Appendix 1

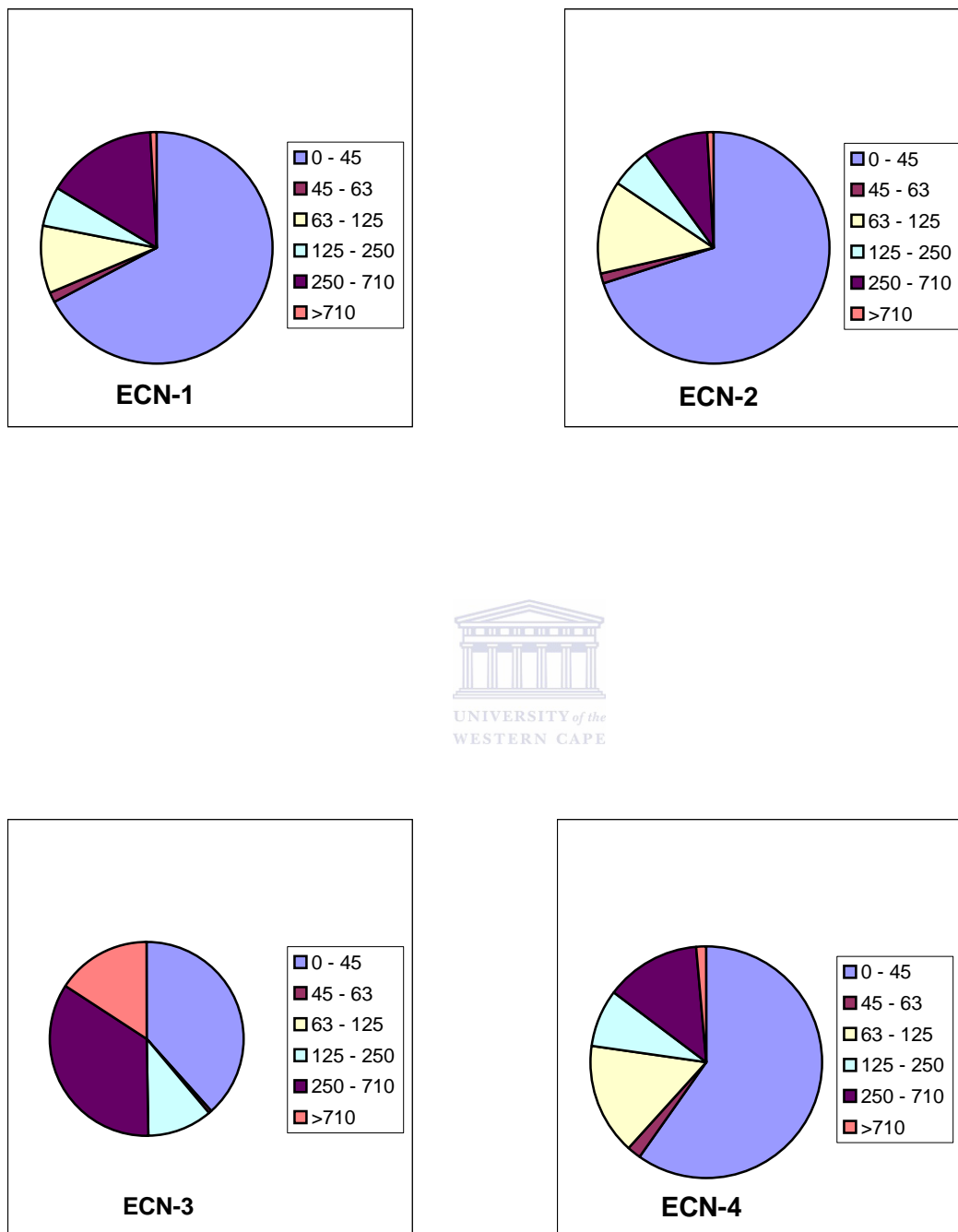


Figure 7: Sediment proportions of Elephant Basin site, ECN in  $\mu\text{m}$ .

Appendix 1

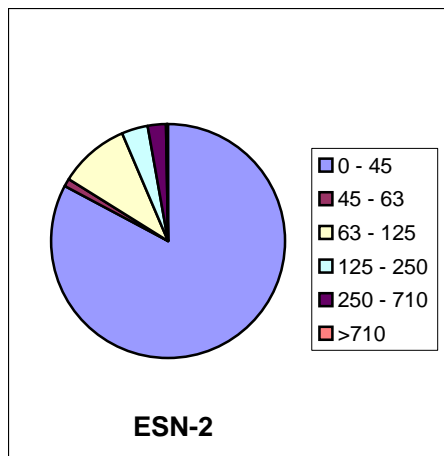


Figure 8: Sediment proportions of Elephant Basin site, ESN in µm.

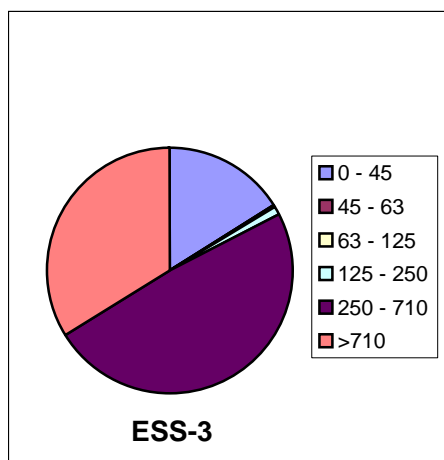
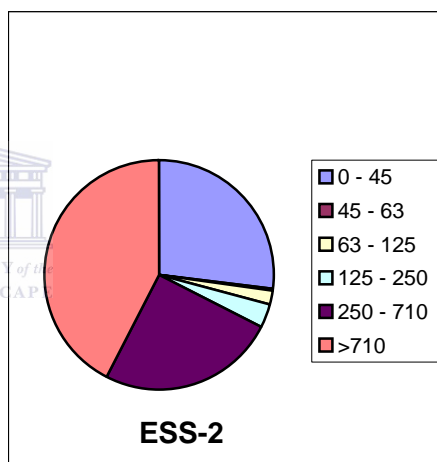
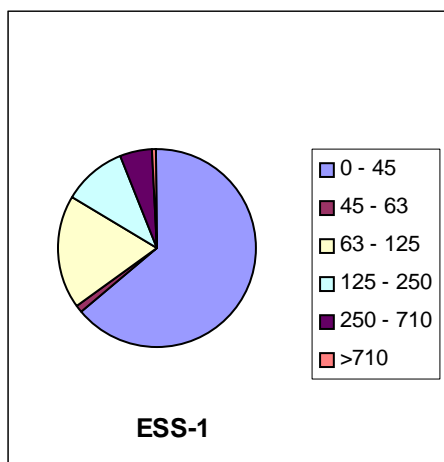


Figure 9: Sediment proportions of Elephant Basin site, ESS in µm.

## Appendix 2 A

### Abundance data: DB (De Beers Marine) family-level total fauna (chapter 2)

#### Elephant Basin

	ece-1	ece-2	ece-3	ecn-1	ecn-2	ecn-3	ecn-4	ecw-1	ecw-2	esn-2	ess-1	ess-2	ess-3
Amphipod A	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampeliscidae	0	2	3	0	0	0	0	0	0	2	4	0	0
Coropiidae	2	3	0	0	0	0	0	0	0	3	2	4	2
Dexaminidae	3	0	0	1	1	0	0	0	0	0	0	0	1
Eusiridae	0	0	7	0	0	0	0	0	0	0	0	0	0
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	1	0
Lijeborgidae	0	6	0	0	0	0	0	0	0	0	0	0	0
Lysianasidae	0	0	0	0	0	0	0	0	0	0	0	1	0
Oedicerotidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Paradallscidae	0	0	0	0	0	0	0	0	0	0	0	0	1
Phoxocephalidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Sebidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Stenothoidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Copepoda	0	1	0	0	0	0	0	0	0	0	0	0	0
Cumacea	23	56	10	9	7	0	6	0	0	2	22	4	16
Corystidae	1	1	0	0	0	0	0	0	0	1	0	0	0
Decapod larvae	1	0	0	0	0	0	0	0	0	0	0	0	0
Callianassidae	2	6	3	0	0	0	0	0	0	0	4	2	0
Arcturidae	0	2	8	0	0	0	0	0	0	0	0	0	0
Anthuridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirolanidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Palinuridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Shrimp A	0	0	3	1	0	0	4	0	1	0	0	0	0
Bivalve A	0	0	0	0	0	0	0	0	0	0	0	0	0
Carditidae	0	0	0	0	0	3	0	0	0	19	0	0	0
Nuculidae	0	0	0	0	0	0	1	0	0	0	0	0	0
Saldanhae	0	0	0	0	0	0	0	0	0	0	0	0	0
Solenidae	9	2	4	0	0	0	0	0	0	0	0	0	0
Tellinidae	0	0	7	0	0	0	0	0	0	7	17	2	3
Veneridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Nassariidae	0	14	55	0	0	0	0	0	0	4	17	0	3
Nemertea A	0	0	5	1	0	0	0	0	0	3	0	2	0
Nemertea B	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea C	0	0	0	0	0	0	0	18	20	0	0	0	0
Nemertea D	0	0	0	0	0	0	0	5	10	0	0	0	0
Nemertea E	0	0	0	0	0	0	0	0	0	4	4	4	0
Nemertea F	0	0	0	0	0	0	0	0	0	0	23	0	0
Ampharetidae	0	39	66	20	13	0	49	0	0	30	27	3	17
Aphroditidae	0	2	6	0	0	0	0	0	0	1	0	0	0
Arencolidae	0	4	8	59	12	13	32	0	0	6	1	0	0
Capitellidae	2	123	270	15	14	3	64	0	0	13	10	3	2
Cirratulidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Cossuridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunicidae	7	1	3	0	1	0	0	53	78	26	6	3	6
Flabelligeridae	2	72	35	12	28	2	70	0	0	20	40	0	8
Glyceridae	2	0	2	0	0	0	0	0	0	0	0	0	0

## Appendix 2 A

Abundance data: DB (De Beers Marine) family-level total fauna (chapter 2, continued)

### Elephant Basin

	ece-1	ece-2	ece-3	ecn-1	ecn-2	ecn-3	ecn-4	ecw-1	ecw-2	esn-2	ess-1	ess-2	ess-3
Hesionidae	0	0	1	0	0	0	0	0	0	2	0	0	0
Maldanidae	6	0	1	0	0	0	0	0	0	2	0	0	0
Magelonidae	0	3	0	0	0	0	0	0	0	0	0	0	0
Nephtyidae	7	8	23	0	0	0	0	0	0	5	13	5	5
Ophelidae	0	0	0	0	1	0	0	0	0	0	0	0	0
Orbiniidae	5	6	13	0	0	0	0	0	0	0	0	1	0
Owenidae	0	0	7	0	0	0	0	0	0	3	6	1	0
Paraonidae	0	2	0	0	0	0	0	0	0	0	3	0	0
Pectinidae	0	3	0	1	0	1	1	1	0	6	0	0	2
Phyllodocidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Pilargidae	1	3	8	0	0	0	1	0	0	1	15	3	0
Sabellidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Scalibregidae	0	1	6	1	0	0	0	11	11	0	0	4	0
Spionidae	1	15	19	0	0	0	1	0	0	5	17	0	0
Syllidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Terrellidae	0	0	0	0	0	0	0	0	0	0	0	0	0



## Appendix 2 A

### Abundance data: DB (De Beers Marine) family-level total fauna (chapter 2)

#### Marshall Fork

	mc1-1	mc1-2	mc1-3	mc1-4	mc3-1	mc3-3	mc6-1	mc6-3	mns1-1	mns1-2	mns1-3	mns1-4	mns1-5
Amphipod A	0	0	0	0	1	0	0	0	0	0	0	0	0
Ampellscidae	1	0	0	0	208	263	4	1	0	0	0	0	0
Coropiidae	0	5	0	0	73	98	0	0	0	0	0	1	0
Dexaminiidae	0	0	0	0	1	5	0	0	0	0	0	0	0
Eusiridae	0	0	0	0	1	0	0	0	0	0	0	0	0
Gammaridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Lijeborgidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Lysianasidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Oedicerotidae	0	1	0	0	0	0	0	0	0	0	0	1	0
Paradallscidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoxocephalidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Sebidae	0	1	0	0	8	15	1	0	0	0	0	1	1
Stenothoidae	0	0	0	0	1	0	0	0	0	0	0	0	0
Copepoda	0	0	0	0	0	0	0	0	0	0	0	0	0
Cumacea	0	1	0	0	1	1	1	1	0	0	0	0	0
Corystidae	0	0	0	1	0	0	0	2	0	0	0	0	0
Decapod larvae	0	0	0	0	0	0	0	0	0	0	0	0	0
Callianassidae	1	13	3	14	1	1	7	8	1	14	16	7	5
Arcturidae	0	0	0	0	7	1	0	0	0	0	0	0	0
Anthuridae	0	0	0	0	1	0	0	0	0	0	0	0	0
Cirolanidae	0	0	0	0	3	1	0	0	0	0	0	0	0
Palinuridae	0	0	0	2	0	0	0	0	1	1	0	0	0
Shrimp A	1	4	3	1	0	0	0	0	0	26	28	3	4
Bivalve A	0	0	0	1	66	0	0	0	2	18	1	1	0
Carditidae	0	1	0	0	0	19	1	0	0	0	0	0	0
Nuculidae	0	1	0	0	4	0	2	0	0	0	0	0	1
Saldanhae	5	1	1	0	0	0	0	2	1	2	0	1	6
Solenidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Tellinidae	0	29	0	45	0	0	19	11	40	88	57	96	231
Veneridae	0	7	8	0	74	39	198	91	1	3	2	2	89
Nassariidae	5	8	10	10	0	0	8	15	64	47	46	24	28
Nemertea A	37	375	6	2	12	14	1	3	2	3	141	242	37
Nemertea B	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea C	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea D	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea E	0	0	0	0	0	0	0	0	0	0	0	0	0
Nemertea F	0	0	0	0	0	0	0	0	0	0	0	0	19
Ampharetidae	1	18	16	15	4	8	1	5	3	30	33	4	20
Aphroditidae	1	3	1	0	1	0	2	0	0	0	2	2	6
Arencolidae	3	0	2	0	0	0	0	0	1	0	0	0	0
Capitellidae	4	15	0	6	5	1	0	0	2	7	8	14	4
Cirratulidae	0	26	0	0	52	2	0	0	0	1	0	0	2
Cossuridae	0	2	0	0	0	0	0	0	0	1	6	0	2
Eunicidae	0	19	1	3	430	44	5	3	1	2	0	2	24
Flabelligeridae	0	4	0	0	1	0	4	0	0	0	1	0	0



## Appendix 2 A

Abundance data: DB (De Beers Marine) family-level total fauna (chapter 2, continued)

### Marshall Fork

	mc1-1	mc1-2	mc1-3	mc1-4	mc3-1	mc3-3	mc6-1	mc6-3	mns1-1	mns1-2	mns1-3	mns1-4	mns1-5
Glyceridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Hesionidae	0	3	1	0	5	11	0	0	0	0	0	0	1
Maldanidae	0	0	1	3	80	29	9	0	0	0	0	0	13
Magelonidae	0	0	0	0	1	0	0	0	0	0	0	0	0
Nephtyidae	0	2	0	3	24	13	3	1	1	17	4	10	4
Ophelidae	0	0	1	0	1	0	0	0	0	0	0	0	0
Orbiniidae	0	2	1	1	6	7	0	2	0	9	0	0	0
Owenidae	0	10	1	0	12	0	0	3	1	4	63	0	4
Paraonidae	0	0	0	0	0	4	0	0	0	0	3	0	0
Pectinoridae	0	7	4	1	5	1	0	0	6	5	16	6	14
Phyllodocidae	0	0	0	0	0	1	0	0	0	0	0	0	0
Pilargidae	9	27	18	6	0	0	0	0	1	27	17	19	6
Sabelliidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Scalibregniidae	0	1	0	0	0	0	2	0	0	0	0	0	0
Spionidae	9	24	47	14	6	1	6	6	21	68	77	80	30
Syllidae	0	0	0	0	3	4	0	0	0	0	0	0	1
Terrellidae	0	0	0	0	0	1	1	0	0	0	0	0	2



## Appendix 2 B

Abundance data: DC (Dylan Clarke) family-level polychaete data (chapter 2).

### Elephant Basin

	ece-1	ece-2	ece-3	ecn-1	ecn-2	ecn-3	ecn-4	ecw-1	ecw-2	esn-2	ess-1	ess-2	ess-3
Ampharetidae	0	0	0	0	0	0	0	0	0	1	0	0	0
Arenicolidae	0	0	1	0	10	9	0	0	0	2	1	0	0
Capitellidae	0	123	0	4	10	1	46	0	0	6	0	0	1
Cirratulidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Dorvilleidae	0	0	0	0	0	0	0	11	0	0	0	0	0
Flabelligeridae	0	46	30	10	0	1	68	0	0	15	40	0	8
Glyceridae	0	0	0	0	0	0	0	0	0	0	0	0	0
Goniadidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	0	0	0	0	0	1	0	0	0
Lumbrineridae	16	1	1	2	0	0	0	2	0	2	6	0	0
Magelonidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Maldanidae	0	0	0	0	0	0	0	0	0	2	0	0	0
Nepthyidae	9	8	23	0	0	0	0	0	0	4	2	6	6
Oeninidae	0	0	0	0	0	0	0	0	0	0	0	0	0
Onuphidae	0	0	0	0	0	0	0	5	1	22	0	1	0
Opheliidae	0	0	0	0	0	0	0	9	0	0	0	0	0
Orbiniidae	2	0	0	0	0	0	0	0	0	0	0	0	0
Owenidae	0	0	0	0	0	0	0	0	0	3	0	1	1
Paraonidae	0	2	0	0	0	0	0	0	0	0	3	0	0
Pectinaridae	0	2	0	1	0	1	0	1	0	3	0	0	2
Pilargidae	0	0	0	0	0	1	0	0	0	1	6	0	0
Polynoidae	0	0	5	0	0	0	0	0	0	0	0	0	0
Sabellidae	0	38	62	15	15	0	45	0	0	33	27	3	17
Spionidae	11	0	19	0	0	0	0	0	0	0	16	0	0
Syllidae	1	0	0	0	0	0	0	0	0	0	0	0	0
Terebellidae	0	0	0	0	0	0	0	0	0	0	0	0	0

## Appendix 2 B

Abundance data: DC (Dylan Clarke) family-level polychaete data (chapter 2).

### Marshall Fork

	mc1-1	mc1-2	mc1-3	mc1-4	mc3-1	mc3-3	mc6-1	mc6-3	mns1-1	mns1-2	mns1-3	mns1-4	mns1-5
Ampharetidae	1	0	0	0	2	5	1	0	0	0	0	0	3
Arenicolidae	3	0	0	0	0	0	0	0	1	0	0	0	0
Capitellidae	0	1	0	4	0	0	0	0	0	1	0	0	0
Cirratulidae	0	24	0	0	0	2	0	0	0	0	0	0	2
Dorvilleidae	0	0	0	0	0	7	0	0	0	0	0	0	0
Flabilligeridae	0	3	0	0	1	0	2	0	0	0	1	0	0
Glyceridae	0	0	2	0	0	0	0	0	0	0	0	0	0
Goniadidae	0	0	0	1	0	0	0	0	0	0	0	0	0
Hesionidae	0	0	0	0	2	11	0	0	0	0	0	0	0
Lumbrineridae	0	9	0	1	39	7	0	0	14	2	0	2	0
Magelonidae	0	0	0	0	1	0	0	0	0	0	0	0	0
Maldanidae	0	0	1	1	87	21	7	0	0	0	0	0	7
Nepthyidae	0	1	0	2	23	23	3	0	1	20	4	7	5
Oeninidae	0	0	0	0	0	0	0	0	0	0	0	0	1
Onuphidae	0	15	3	0	109	26	1	0	0	0	0	0	15
Opheliidae	0	0	1	0	0	0	0	0	0	0	0	0	0
Orbinidae	0	0	0	0	3	1	0	0	0	0	0	0	0
Owenidae	0	0	1	0	11	0	0	0	1	4	0	0	0
Paraonidae	0	1	0	0	0	2	0	2	0	7	2	0	0
Pectinaridae	0	7	3	1	15	1	0	0	6	5	11	3	10
Pilargidae	13	1	0	0	4	1	0	0	0	0	5	14	3
Polynoidae	1	2	0	0	0	0	0	0	0	0	1	0	0
Sabellidae	0	8	13	14	0	0	0	0	3	24	32	3	0
Spionidae	9	22	42	0	0	0	0	0	11	59	73	62	31
Syllidae	0	0	0	0	0	2	0	0	0	0	0	0	1
Terebellidae	0	0	0	0	0	1	0	0	0	0	0	0	2

## Appendix 2 C

Abundance data: DC (Dylan Clarke) species-level polychaete data (chapter 2).

### Elephant Basin

	ece-1	ece-2	ece-3	ecn-1	ecn-2	ecn-3	ecn-4	ecw-1	ecw-2	esn-2	ess-1	ess-2	ess-3
<i>Aedicira sp1.</i>	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Alentia sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ampharetidae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amphicteis gunneri</i>	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Aphelochaeta sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arencolidae</i>	0	0	1	0	10	9	0	0	0	2	1	0	0
<i>Aricidea (Allia) sp1.</i>	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Cabira capensis</i>	0	0	0	0	0	0	0	0	0	0	6	0	0
<i>Capitella capitata</i>	0	0	0	0	10	1	46	0	0	0	0	0	0
<i>Capitellidae</i>	0	123	0	4	0	0	0	0	0	6	0	0	1
<i>Cirriiformia sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cirriiformia tentaculata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Diopatra monroi</i>	0	0	0	0	0	0	0	5	1	22	0	1	0
<i>Dorvillea rudolphi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Drilonereis monroi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Euclymene sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Flabelligeridae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Glycera tessellata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Glyceridae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Goniadidae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hesione sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hesionidae</i>	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Hololepidella nigropunctata</i>	0	0	5	0	0	0	0	0	0	0	0	0	0
<i>Johnstonia clymenoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lumbrineris cavifrons</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lumbrineris hartmani</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lumbrineris heteropoda difficillis</i>	16	1	1	2	0	0	0	2	0	0	6	0	0
<i>Lumbrineris sp 1.</i>	0	0	0	0	0	0	0	0	0	2	0	0	0
<i>Magelona capensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maldane sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Maldanidae</i>	0	0	0	0	0	0	0	0	0	2	0	0	0
<i>Nephtys hombergi</i>	0	1	0	0	0	0	0	0	0	0	2	0	0
<i>Nephtys sp1.</i>	9	7	23	0	0	0	0	0	0	4	0	6	6
<i>Nicomache sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ophelia agulhana</i>	0	0	0	0	0	0	0	9	0	0	0	0	0
<i>Orbinia agrapequensis</i>	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Owenia fusiformis</i>	0	0	0	0	0	0	0	0	0	3	0	1	1
<i>Paraonidae</i>	0	0	0	0	0	0	0	0	0	0	3	0	0
<i>Pectinaria (Amphictene) capensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pectinaria (Lagis) neopolitana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pectinaria sp1.</i>	0	0	0	0	0	0	0	1	0	0	0	0	0
<i>Pectinariidae</i>	0	2	0	0	0	1	0	0	0	3	0	0	2

## Appendix 2 C

Abundance data: DC (Dylan Clarke) species-level polychaete data (chapter 2, continued).

### Elephant Basin

	ece-1	ece-2	ece-3	ecn-1	ecn-2	ecn-3	ecn-4	ecw-1	ecw-2	esn-2	ess-1	ess-2	ess-3
<i>Pectinaris (Amphictene) sp1.</i>	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Petaloproctus sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pherusa saldanha</i>	0	0	0	0	0	0	68	0	0	0	0	0	0
<i>Pherusa swakopiana</i>	0	0	30	10	0	1	0	0	0	15	40	0	8
<i>Pherusa tropica</i>	0	46	0	0	0	0	0	0	0	0	0	0	0
<i>Pilargidae</i>	0	0	0	0	0	1	0	0	0	0	0	0	0
<i>Polynoidae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Prionospio pinnata</i>	11	0	19	0	0	0	0	0	0	0	16	0	0
<i>Protodorvillea biarticulata</i>	0	0	0	0	0	0	0	11	0	0	0	0	0
<i>Sabellides (Pterampharete) luderitzi</i>	0	38	62	15	15	0	45	0	0	33	27	3	17
<i>Sigambra robusta</i>	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Spionidae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Syllidae</i>	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Syllis (Syllis) sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Terrebella pterochaeta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0



## Appendix 2 C

Abundance data: DC (Dylan Clarke) species-level polychaete data (chapter 2).

### Marshall Fork

	mc1-1	mc1-2	mc1-3	mc1-4	mc3-1	mc3-3	mc6-1	mc6-3	mns1-1	mns1-2	mns1-3	mns1-4	mns1-5
<i>Aedicira sp1.</i>	0	0	0	0	0	0	0	2	0	0	2	0	0
<i>Alentia sp1.</i>	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Ampharetidae</i>	1	0	0	0	0	5	1	0	0	0	0	0	3
<i>Amphicteis gunneri</i>	0	0	0	0	2	0	0	0	0	0	0	0	0
<i>Aphelochaeta sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Arencolidae</i>	3	0	0	0	0	0	0	0	1	0	0	0	0
<i>Aricidea (Allia) sp1.</i>	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Cabira capensis</i>	4	1	0	0	1	1	0	0	0	0	5	14	2
<i>Capitella capitata</i>	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Capitellidae</i>	0	0	0	4	0	0	0	0	0	1	0	0	0
<i>Cirriformia sp1.</i>	0	0	0	0	0	2	0	0	0	0	0	0	0
<i>Cirriformia tentaculata</i>	0	24	0	0	0	0	0	0	0	0	0	0	0
<i>Diopatra monroi</i>	0	15	3	0	109	26	1	0	0	0	0	0	15
<i>Dorvillea rudolphi</i>	0	0	0	0	0	7	0	0	0	0	0	0	0
<i>Drilonereis monroi</i>	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Euclymene sp1.</i>	0	0	0	0	87	21	0	0	0	0	0	0	6
<i>Flabilligeridae</i>	0	0	0	0	1	0	0	0	0	0	1	0	0
<i>Glycera tessellata</i>	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Glyceridae</i>	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Goniadidae</i>	0	0	0	1	0	0	0	0	0	0	0	0	0
<i>Hesione sp1.</i>	0	0	0	0	2	7	0	0	0	0	0	0	0
<i>Hesionidae</i>	0	0	0	0	0	4	0	0	0	0	0	0	0
<i>Hololepidella nigropunctata</i>	0	2	0	0	0	0	0	0	0	0	0	0	0
<i>Johnstonia clymenoides</i>	0	0	0	1	0	0	0	0	0	0	0	0	1
<i>Lumbrineris cavifrons</i>	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Lumbrineris hartmani</i>	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Lumbrineris heteropoda difficillis</i>	0	9	0	1	37	7	0	0	14	2	0	2	0
<i>Lumbrineris sp 1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Magelona capensis</i>	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Maldane sp1.</i>	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Maldanidae</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Nephtys hombergi</i>	0	1	0	2	23	0	0	0	1	7	4	7	4
<i>Nephtys sp1.</i>	0	0	0	0	0	23	3	0	0	13	0	0	1
<i>Nicomache sp1.</i>	0	0	0	0	0	0	6	0	0	0	0	0	0
<i>Ophelia agulhana</i>	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Orbinia agrapequensis</i>	0	0	0	0	3	1	0	0	0	0	0	0	0
<i>Owenia fusiformis</i>	0	0	1	0	11	0	0	0	1	4	0	0	0
<i>Paraonidae</i>	0	0	0	0	0	2	0	0	0	7	0	0	0
<i>Pectinaria (Amphictene) capensis</i>	0	0	0	0	0	0	0	0	0	0	0	3	0
<i>Pectinaria (Lagis) neopolitana</i>	0	0	0	1	15	1	0	0	0	0	0	0	10
<i>Pectinaria sp1.</i>	0	0	3	0	0	0	0	0	0	0	11	0	0
<i>Pectinaridae</i>	0	7	0	0	0	0	0	0	6	5	0	0	0
<i>Pectinaris (Amphictene) sp1.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Petaloproctus sp1.</i>	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Pherusa saldanha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0

## Appendix 2 C

Abundance data: DC (Dylan Clarke) species-level polychaete data (chapter 2, continued).

### Marshall Fork

	mc1-1	mc1-2	mc1-3	mc1-4	mc3-1	mc3-3	mc6-1	mc6-3	mns1-1	mns1-2	mns1-3	mns1-4	mns1-5
<i>Pherusa swakopiana</i>	0	3	0	0	0	0	0	0	0	0	0	0	0
<i>Pherusa tropica</i>	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Pilargidae</i>	0	0	0	0	3	0	0	0	0	0	0	0	1
<i>Polynoidae</i>	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Prionospio pinnata</i>	9	22	42	0	0	0	0	0	11	58	73	62	31
<i>Protodorvillea biarticulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sabellides (Pterampharete) luderitzi</i>	0	8	13	14	0	0	0	0	3	24	32	3	0
<i>Sigambra robusta</i>	9	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spionidae</i>	0	0	0	0	0	0	0	0	0	1	0	0	0
<i>Syllidae</i>	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Syllis (Syllis) sp1.</i>	0	0	0	0	0	2	0	0	0	0	0	0	0
<i>Terrebella pterochaeta</i>	0	0	0	0	0	1	0	0	0	0	0	0	2



## Appendix 2 D

### Environmental data (sediment size fractions as percentages): chapter 2

#### Elephant Basin and Marshall Fork

	0 - 45µm	45 - 63µm	63 - 125µm	125 - 250µm	250 - 710µm	>710µm
ece-1	43.52%	1.10%	5.68%	18.15%	31.25%	0.30%
ece-2	44.58%	1.06%	6.37%	14.30%	32.99%	0.70%
ece-3	54.48%	0.52%	3.41%	11.25%	29.09%	1.25%
ecn-1	67.34%	1.24%	9.50%	5.46%	15.71%	0.75%
ecn-2	69.90%	1.39%	13.19%	5.61%	8.95%	0.96%
ecn-3	38.21%	0.64%	0.02%	10.90%	34.37%	15.86%
ecn-4	59.68%	1.88%	15.79%	7.81%	13.40%	1.44%
ecw-1	8.49%	0.00%	0.05%	0.10%	0.79%	90.57%
ecw-2	9.47%	0.00%	0.00%	0.00%	1.39%	89.14%
esn-2	82.86%	0.94%	9.72%	3.82%	2.39%	0.27%
ess-1	63.56%	1.18%	18.76%	10.71%	5.25%	0.54%
ess-2	26.94%	0.41%	1.84%	3.25%	24.94%	42.62%
ess-3	16.06%	0.02%	0.34%	1.07%	48.67%	33.84%
mc1-1	49.94%	2.25%	28.31%	8.68%	7.16%	3.66%
mc1-2	39.05%	0.83%	9.68%	8.37%	7.15%	34.92%
mc1-3	56.30%	1.95%	29.47%	6.19%	3.78%	2.31%
mc1-4	50.54%	1.82%	17.45%	20.74%	8.29%	1.16%
mc3-1	42.11%	0.91%	13.88%	18.55%	10.02%	14.53%
mc3-3	39.44%	1.31%	15.09%	16.65%	6.55%	20.96%
mc6-1	36.64%	1.00%	15.74%	25.37%	19.44%	1.81%
mc6-3	28.10%	0.17%	1.32%	5.11%	54.83%	10.47%
mns1-1	51.02%	4.36%	0.01%	43.82%	0.64%	0.15%
mns1-2	54.24%	3.83%	0.01%	41.58%	0.18%	0.16%
mns1-3	46.44%	3.58%	0.01%	49.06%	0.80%	0.11%
mns1-4	47.38%	3.58%	0.10%	47.33%	1.31%	0.39%
mns1-5	37.59%	1.57%	0.04%	15.22%	6.57%	39.01%



Appendix 3 A

Abundance data: De Beers Marine family-level total fauna (chapter 3).

	Oedicerotidae	Ampeliscidae	Paramphitoidae	Corophiidae	Isaeidae	Dexaminiidae	Gammaridae	Megaluroidea	Metilidae	Urothoidea	Pontoporeiidae	Eusiridae
#2 Plant South	0	23	0	0	2	0	0	0	0	0	0	0
#2Plant Shallow	1	180	0	0	0	1	0	0	0	0	0	103
A1-N-A	0	26	0	0	0	0	0	0	0	0	0	0
A1-N-B	1	17	0	0	0	0	0	0	0	0	0	1
A1-N-C	0	35	0	0	0	0	0	0	0	0	0	0
A1-S-A	0	0	0	0	0	0	0	0	0	0	0	0
A1-S-B	0	0	0	0	0	0	0	0	0	0	0	0
A1-S-C	0	0	0	0	0	0	0	0	0	0	0	0
Beverly Hill	0	2	0	0	0	0	0	0	0	1	0	0
Beverly Hill Deep	0	3	0	0	0	1	0	0	0	0	0	0
Bogenfels Deep	0	0	0	0	0	0	0	0	0	0	0	0
BR Deep North	0	17	0	0	0	0	0	0	0	24	0	0
BR Deep South	0	58	0	0	0	0	0	0	0	36	0	0
BR North	0	4	0	0	0	0	0	0	0	3	0	0
BR South	1	3	0	0	0	0	0	0	0	7	0	0
Chameis Head	2	0	0	0	0	1	0	0	0	12	0	0
Chameis North	0	0	0	0	0	0	0	0	0	0	0	0
Chameis South	0	0	0	0	0	0	0	0	0	15	0	0
Channel	2	95	0	0	0	0	0	0	0	66	0	0
Dreimaster	3	0	0	0	0	4	0	0	0	37	0	0
Dunkle Deep	0	0	0	0	0	0	0	0	0	8	0	0
Dunkle Shallow	1	6	0	0	0	1	1	0	0	15	0	1
Foodoo Control	20	5	0	0	0	1	0	2	0	25	1	1
Halifax	4	2	0	0	0	0	0	0	0	0	1	0
Halifax Deep 1&2	21	3	0	7	10	0	1	0	0	0	0	0
Halifax Deep 3&4	0	1	0	0	7	0	0	0	0	0	0	0
Halifax Inshore	26	6	0	0	3	41	0	1	0	0	0	10
Hock	18	0	0	0	0	0	0	0	0	0	0	0
Hostel North	0	16	0	0	0	0	0	0	0	29	3	0
Hostel Shallow	0	2	0	0	0	0	0	0	0	96	4	1
Hostel South	2	15	0	0	0	0	0	0	0	4	3	0
Houtini	9	1	0	0	0	0	0	0	0	0	0	0
Mittag	1	0	0	0	0	42	0	0	0	30	93	0
Odin Control	5	17	0	0	0	1	0	0	0	132	221	2
Panther	6	0	0	0	0	5	0	0	0	1	0	1
Panther Deep 1	0	23	0	0	9	0	0	0	0	44	2	1
Panther Deep 2	0	135	0	0	0	0	0	0	0	75	0	0
Panther Deep 3	0	27	1	0	3	0	0	0	0	67	0	0
Peninsular	1	1	0	0	1	1	0	1	0	0	0	0
Peninsular Extension	9	0	0	0	0	0	0	0	0	1	0	0
Pomona	0	0	0	0	0	0	0	0	0	32	0	0
Purple North	0	38	0	0	0	0	0	0	0	0	2	0
Purple Shallow	0	3	0	0	0	6	0	5	0	595	0	3
Purple South	0	29	0	0	0	0	0	0	0	0	1	0
Reefbay	8	1	0	0	5	2	0	0	4	0	0	3
Site Two	3	0	0	0	0	17	2	0	0	22	0	11
South Rock	2	0	0	0	0	2	0	0	0	17	0	0
Tafelberg	1	195	0	0	0	0	3	0	0	57	11	0

## Appendix 3 A

### Abundance data: De Beers Marine family-level total fauna (chapter 3), continued.

	Liljeborgii dae	Lysianassi dae	Phoxocep halidae	Platyischn opidae	Hyperiid a	Caprellide a	Callianass idae.	Upogebiid ae	Corystida e	Calocaridi dae	Portunida e	Squillidae
#2 Plant South	0	0	0	0	0	0	0	0	0	0	0	0
#2Plant Shallow	0	1	0	0	0	1	0	0	17	0	0	0
A1-N-A	7	0	0	0	0	0	7	3	0	0	0	3
A1-N-B	9	1	0	0	0	0	7	2	0	0	0	3
A1-N-C	7	0	0	0	3	0	4	1	0	0	0	1
A1-S-A	7	0	0	0	0	0	8	11	0	6	0	0
A1-S-B	1	0	0	0	0	0	6	14	0	0	0	0
A1-S-C	13	0	0	0	0	0	8	10	0	0	0	1
Beverly Hill	2	0	0	0	0	0	0	0	0	0	0	0
Beverly Hill Deep	11	1	0	0	0	0	2	0	0	0	0	0
Bogenfels Deep	0	0	0	0	0	0	0	0	0	0	1	0
BR Deep North	11	1	0	0	0	0	3	0	4	0	0	0
BR Deep South	5	0	0	0	0	0	2	0	0	0	0	0
BR North	0	0	0	1	0	0	0	0	0	0	0	0
BR South	0	1	0	0	0	0	0	0	0	1	0	0
Chameis Head	0	0	0	3	0	0	0	0	1	0	0	0
Chameis North	0	0	0	0	0	0	0	0	0	0	0	0
Chameis South	0	3	0	0	0	0	0	0	1	0	0	0
Channel	9	0	0	0	0	0	26	0	1	0	0	0
Dreimaster	0	11	0	1	0	0	0	0	0	0	0	0
Dunkle Deep	2	0	0	0	1	0	0	0	0	0	0	0
Dunkle Shallow	0	2	0	2	1	0	0	0	0	0	0	0
Foodoo Control	74	0	1	0	8	0	22	0	11	0	0	1
Halifax	34	0	0	0	0	0	56	0	0	0	0	0
Halifax Deep 1&2	13	0	0	0	0	0	34	0	0	0	0	1
Halifax Deep 3&4	7	0	0	0	0	0	16	0	0	0	0	2
Halifax Inshore	7	0	0	0	1	0	4	0	1	0	0	0
Hock	12	0	0	0	0	0	78	0	2	0	0	0
Hostel North	21	0	0	0	0	0	7	0	1	0	0	0
Hostel Shallow	2	0	0	24	0	0	0	0	1	0	0	0
Hostel South	18	0	0	0	0	0	4	0	0	0	0	1
Houtini	15	0	0	0	13	0	53	0	2	0	0	0
Mittag	0	0	0	5	0	0	0	0	2	0	0	0
Odin Control	0	1	2	1	0	0	0	0	7	0	0	0
Panther	0	0	0	1	0	0	0	0	1	0	0	0
Panther Deep 1	10	0	0	0	0	4	4	0	1	0	0	0
Panther Deep 2	18	0	0	0	1	3	4	0	3	0	0	1
Panther Deep 3	3	0	0	0	0	2	7	0	0	0	0	0
Peninsular	3	1	0	0	1	0	28	0	1	0	0	1
Peninsular Extension	22	0	0	0	8	0	50	0	1	0	0	1
Pomona	2	0	0	0	0	0	0	0	0	0	0	0
Purple North	22	0	0	0	0	0	8	0	2	0	0	2
Purple Shallow	0	0	0	17	0	0	0	0	0	0	0	0
Purple South	34	0	0	0	0	0	9	0	7	0	0	0
Reefbay	9	0	0	0	0	0	28	0	4	0	0	1
Site Two	0	0	0	2	0	0	0	0	0	0	0	0
South Rock	0	0	1	0	1	0	0	0	0	0	0	0
Tafelberg	23	0	0	0	0	0	12	0	3	0	0	0

## Appendix 3 A

Abundance data: De Beers Marine family-level total fauna (chapter 3), continued.

	Dromiidae		Anthozoa		Mytilidae		Condylocardiidae		Veneridae		Nuculidae		Lucinidae		Cultellidae		Philobryidae		Brachiopoda		Discinidae		Cancellotryididae	
#2 Plant South	0	1	0	0	0	0	0	0	0	0	0	1	23	0	0	0	0	0	0	0	0	0	0	0
#2Plant Shallow	0	9	0	0	0	0	0	0	0	0	0	0	118	0	0	0	0	0	0	0	0	0	0	0
A1-N-A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1-N-B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1-N-C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1-S-A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1-S-B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A1-S-C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beverly Hill	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Beverly Hill Deep	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Bogenfels Deep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BR Deep North	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
BR Deep South	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
BR North	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
BR South	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Chameis Head	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chameis North	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chameis South	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Channel	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dreimaster	0	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dunkle Deep	2	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
Dunkle Shallow	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foodoo Control	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halifax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halifax Deep 1&2	0	0	0	0	5	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halifax Deep 3&4	0	0	0	0	11	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Halifax Inshore	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hock	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hostel North	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hostel Shallow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hostel South	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Houtini	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mittag	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Odin Control	0	74	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Panther	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Panther Deep 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Panther Deep 2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Panther Deep 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peninsular	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peninsular Extension	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pomona	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Purple North	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Purple Shallow	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Purple South	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Reefbay	0	28	0	8	2	0	6	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Site Two	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tafelberg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

## Appendix 3 A

### Abundance data: De Beers Marine family-level total fauna (chapter 3), continued.

	Nassariida Marginelli Fasciolarii Epitoniida Buccinida											Holidoteid Anthurida	
	Tellinidae	e	dae	dae	e	e	Muricidae	Volutidae	Naticidae	Arcturidae	ae	e	
#2 Plant South	67	102	0	0	0	0	0	0	0	10	0	0	
#2Plant Shallow	6	74	0	0	0	0	0	0	0	0	0	0	
A1-N-A	0	0	0	0	0	1	0	0	0	0	0	0	
A1-N-B	0	0	0	0	0	0	0	0	0	0	0	0	
A1-N-C	0	0	0	0	0	1	0	0	0	0	0	0	
A1-S-A	1	0	0	0	0	0	0	0	0	0	0	0	
A1-S-B	1	10	0	0	0	0	0	0	0	0	0	0	
A1-S-C	1	16	0	0	0	0	0	0	0	0	0	0	
Beverly Hill	5	109	0	0	0	0	0	0	0	0	0	0	
Beverly Hill Deep	3	19	0	0	0	0	0	0	0	0	0	0	
Bogenfels Deep	0	0	1	0	0	0	0	0	0	0	0	2	
BR Deep North	7	169	0	0	0	0	0	0	0	0	0	0	
BR Deep South	6	194	0	0	0	0	0	0	0	0	0	0	
BR North	38	8	0	0	0	0	0	0	0	0	0	6	
BR South	2	1	0	0	0	0	0	0	0	0	0	1	
Chameis Head	0	13	0	0	0	0	0	0	0	0	0	1	
Chameis North	68	10	0	0	0	0	0	0	0	0	0	0	
Chameis South	10	29	0	0	0	0	0	0	0	0	0	0	
Channel	76	84	0	0	0	0	0	0	1	0	0	0	
Dreimaster	7	1	0	0	0	0	0	0	0	0	0	2	
Dunkle Deep	2	280	0	0	0	0	0	0	0	0	1	0	
Dunkle Shallow	0	0	0	0	0	0	0	0	0	0	0	16	
Foodoo Control	1	222	0	0	0	0	0	0	0	0	0	1	
Halifax	2	126	0	0	0	0	0	0	0	0	0	0	
Halifax Deep 1&2	7	10	0	0	0	0	0	0	0	0	0	0	
Halifax Deep 3&4	2	26	1	1	0	0	0	1	0	0	0	0	
Halifax Inshore	44	40	0	0	0	0	1	0	0	1	0	2	
Hock	4	21	0	0	0	0	0	0	0	0	0	0	
Hostel North	2	575	1	0	0	0	0	0	0	0	0	0	
Hostel Shallow	1	5	0	0	1	0	0	0	0	0	0	0	
Hostel South	3	129	0	0	0	0	0	0	0	0	0	0	
Houtini	4	152	0	0	0	0	0	0	0	0	0	0	
Mittag	0	83	0	0	0	0	0	0	0	0	0	13	
Odin Control	2	7	0	0	0	0	0	0	0	0	0	8	
Panther	2	0	0	0	0	0	0	0	0	0	0	2	
Panther Deep 1	2	49	0	0	1	0	0	0	0	0	0	0	
Panther Deep 2	11	86	0	0	0	0	0	0	0	0	0	0	
Panther Deep 3	16	111	0	0	0	0	0	0	0	0	0	0	
Peninsular	26	145	0	0	0	0	0	0	0	0	0	3	
Peninsular Extension	3	188	0	0	0	0	0	0	0	0	0	0	
Pomona	1	78	0	0	0	0	0	0	0	0	0	0	
Purple North	6	277	1	0	0	0	0	0	0	0	0	0	
Purple Shallow	4	0	0	0	0	0	0	0	0	0	0	2	
Purple South	9	68	0	0	0	0	0	1	0	0	0	0	
Reefbay	18	12	1	2	0	0	0	0	0	0	0	0	
Site Two	3	0	0	0	0	0	0	0	0	0	0	5	
South Rock	0	0	0	0	0	0	0	0	0	0	0	0	
Tafelberg	0	90	0	0	0	0	0	0	0	0	0	0	

## Appendix 3 A

Abundance data: De Beers Marine family-level total fauna (chapter 3), continued.

	Cirolanida e	Sphaerom atidae	Ophiuroid ea	Idoteidae	Seapen	Penaeoide a	Cumacea	Nemertea	Apsuedida e	Mysidace a	Pycnogom ida	Sipunculi da
#2 Plant South	0	0	0	0	0	0	135	0	0	0	0	31
#2Plant Shallow	0	0	0	5	0	0	5	0	0	0	0	1
A1-N-A	0	0	0	0	0	4	0	0	0	0	0	0
A1-N-B	0	0	0	0	0	0	0	0	0	0	0	0
A1-N-C	0	0	0	0	0	1	0	0	0	0	0	0
A1-S-A	0	0	0	0	0	0	1	0	0	0	0	0
A1-S-B	0	0	0	0	0	0	0	0	0	0	0	0
A1-S-C	0	0	0	0	0	0	2	0	0	0	0	0
Beverly Hill	0	0	0	0	0	0	14	0	0	0	0	0
Beverly Hill Deep	0	0	0	0	1	0	18	0	0	0	0	0
Bogenfels Deep	0	0	0	0	3	0	0	0	0	0	1	0
BR Deep North	0	0	0	0	0	0	0	0	0	0	0	0
BR Deep South	1	0	0	1	0	0	0	0	0	0	0	0
BR North	0	0	0	0	0	0	1	0	0	0	0	0
BR South	1	0	0	0	0	0	0	0	0	0	0	0
Chameis Head	0	0	0	0	0	0	2	0	0	0	0	0
Chameis North	0	0	0	0	0	1	0	1	0	0	0	0
Chameis South	0	0	0	0	0	0	1	0	0	0	0	0
Channel	0	0	0	0	0	4	22	0	0	0	0	0
Dreimaster	0	0	0	0	0	0	2	0	0	0	0	0
Dunkle Deep	0	0	0	0	1	0	1	0	0	0	0	0
Dunkle Shallow	0	0	0	0	0	0	1	0	0	0	0	0
Foodoo Control	0	0	0	0	0	0	30	0	0	0	0	13
Halifax	0	0	0	0	0	0	19	0	0	0	0	0
Halifax Deep 1&2	0	0	0	0	0	0	11	0	0	0	0	0
Halifax Deep 3&4	0	0	0	0	0	0	0	0	0	0	0	2
Halifax Inshore	0	0	0	0	5	0	14	0	0	0	0	1
Hock	0	0	0	0	0	0	6	0	0	0	0	0
Hostel North	1	0	0	0	0	0	3	0	0	0	0	0
Hostel Shallow	0	0	0	0	0	0	35	0	0	0	0	0
Hostel South	0	0	0	0	0	0	9	0	0	0	0	0
Houtini	0	0	0	0	0	0	4	0	0	0	0	0
Mittag	0	0	0	0	0	0	122	0	0	0	0	0
Odin Control	0	0	0	0	0	0	60	0	0	0	0	0
Panther	0	0	0	2	0	0	5	0	0	0	0	0
Panther Deep 1	1	1	1	0	50	0	1	0	0	0	0	0
Panther Deep 2	0	0	0	0	0	0	0	0	0	0	0	0
Panther Deep 3	0	0	0	1	0	0	0	1	0	0	0	0
Peninsular	0	0	0	0	0	0	18	0	0	0	0	31
Peninsular Extension	0	0	0	0	0	0	9	0	0	0	0	0
Pomona	0	0	0	0	0	0	0	0	0	1	0	0
Purple North	0	0	0	0	0	0	18	0	0	0	0	0
Purple Shallow	0	0	0	0	0	0	83	0	0	0	0	0
Purple South	0	0	0	0	0	0	28	0	0	0	0	0
Reefbay	0	0	0	0	0	0	7	0	0	0	1	0
Site Two	0	0	0	38	0	0	5	0	0	0	0	0
South Rock	0	0	0	0	0	0	1	0	0	0	0	0
Tafelberg	0	0	0	0	0	0	0	0	0	0	0	0

## Appendix 3 A

Abundance data: De Beers Marine family-level total fauna (chapter 3), continued.

	Balanidae	Campanul ariidae	Amphareti dae	Aphrodit dae	Capitellid ae	Cirratulid ae	Cossurida e	Flabellig ridae	Glycerida e	Hesionida e	Lumbriner idae	Maldanida e
#2 Plant South	0	1	279	0	0	0	0	11	0	0	5	0
#2Plant Shallow	0	1	192	0	0	0	0	24	1	0	0	0
A1-N-A	0	0	7	0	0	0	0	0	0	0	11	0
A1-N-B	0	0	0	0	0	0	0	0	0	0	11	0
A1-N-C	0	0	0	0	0	0	0	0	0	0	7	0
A1-S-A	0	0	0	0	0	0	0	0	0	0	7	0
A1-S-B	0	0	0	0	0	0	0	0	0	0	6	0
A1-S-C	0	0	0	0	0	0	0	0	0	0	8	0
Beverly Hill	0	0	3	0	0	0	0	0	0	0	1	0
Beverly Hill Deep	0	0	10	0	0	0	0	1	0	0	10	0
Bogenfels Deep	0	0	1	0	0	10	0	0	0	0	0	0
BR Deep North	0	0	0	0	0	0	0	0	0	0	1	0
BR Deep South	0	0	0	1	0	6	0	0	1	0	0	0
BR North	0	0	0	0	216	0	0	0	2	0	0	0
BR South	0	0	0	0	0	0	0	0	3	0	0	0
Chameis Head	0	0	0	0	1	0	0	0	0	0	0	0
Chameis North	0	0	0	0	0	2	0	0	10	0	0	0
Chameis South	0	0	0	0	0	0	0	0	0	0	0	0
Channel	0	0	0	13	3	12	0	0	2	0	8	0
Dreimaster	0	0	0	0	0	1	0	0	4	0	0	1
Dunkle Deep	0	0	1	0	1	0	0	0	3	0	4	0
Dunkle Shallow	0	0	0	0	1	0	0	0	1	0	0	0
Foodoo Control	0	0	0	6	275	1	0	0	4	0	43	0
Halifax	0	0	0	2	0	0	0	0	0	0	11	0
Halifax Deep 1&2	0	0	1	0	0	0	0	0	0	0	17	53
Halifax Deep 3&4	0	0	0	1	0	0	0	0	0	0	4	1
Halifax Inshore	0	0	0	0	11	0	0	0	11	0	0	0
Hock	0	0	0	10	4	4	0	0	0	1	8	0
Hostel North	0	0	0	0	0	0	0	0	1	0	4	0
Hostel Shallow	0	0	0	0	0	0	0	0	2	0	0	0
Hostel South	0	0	0	0	0	0	0	0	0	0	7	0
Houtini	0	0	0	4	2	0	0	0	0	0	20	0
Mittag	0	0	0	0	0	0	0	0	0	0	0	0
Odin Control	0	0	0	0	26	18	0	4	14	0	2	0
Panther	6	0	0	1	0	6	0	0	0	0	0	0
Panther Deep 1	0	0	27	0	0	0	0	0	1	0	3	0
Panther Deep 2	0	0	1	1	5	0	0	0	0	0	4	0
Panther Deep 3	0	0	0	2	0	0	0	0	0	0	2	0
Peninsular	0	0	0	0	182	0	0	1	3	0	16	0
Peninsular Extension	0	0	0	6	1	1	0	0	0	0	8	0
Pomona	1	0	0	1	18	1	0	0	1	0	0	0
Purple North	0	0	0	0	0	0	0	0	0	0	8	0
Purple Shallow	0	0	0	0	0	0	0	0	1	0	0	0
Purple South	0	0	0	0	0	0	0	0	0	0	8	0
Reefbay	0	0	2	1	3	0	1	0	0	1	26	0
Site Two	0	0	0	0	0	0	0	0	1	0	0	0
South Rock	0	0	0	0	1	0	0	0	0	0	0	0
Tafelberg	0	0	0	0	3	0	0	0	0	0	2	0

## Appendix 3 A

Abundance data: De Beers Marine family-level total fauna (chapter 3), continued.

	Mageloni dae	Nephtyida e	Nereidae	Opheliida e	Onuphida e	Orbiniidae	Paraonida e	Phyllodoc idae	Pectinariid ae	Pilargiida e	Spionidae	Syllidae
#2 Plant South	0	6	0	0	48	0	0	0	0	0	0	0
#2Plant Shallow	0	4	0	0	3	0	0	0	0	0	0	0
A1-N-A	0	11	0	0	10	1	0	0	0	0	0	0
A1-N-B	0	19	0	0	12	0	0	0	0	0	0	0
A1-N-C	0	9	0	0	4	0	0	0	0	0	0	0
A1-S-A	0	6	0	0	10	0	0	0	0	0	2	0
A1-S-B	0	2	0	0	10	0	0	0	0	0	0	0
A1-S-C	0	1	0	0	10	0	0	0	0	4	1	0
Beverly Hill	0	2	0	0	16	0	0	0	0	2	0	0
Beverly Hill Deep	0	8	0	0	25	0	0	0	0	7	0	0
Bogenfels Deep	0	1	0	1	24	0	2	3	0	0	0	7
BR Deep North	0	1	0	0	0	0	0	0	0	0	0	0
BR Deep South	0	5	0	0	0	0	0	0	0	0	1	0
BR North	54	41	0	0	0	2	0	0	0	0	1	0
BR South	1	3	0	0	0	0	1	0	0	0	0	0
Chameis Head	15	9	0	0	0	4	0	0	0	0	0	0
Chameis North	0	2	0	4	3	0	7	0	0	0	0	5
Chameis South	0	1	0	0	0	0	0	0	0	0	0	0
Channel	37	22	0	0	0	23	5	0	0	0	30	0
Dreimaster	1	8	0	0	0	0	0	0	0	0	2	0
Dunkle Deep	0	1	0	0	13	1	0	0	0	0	0	0
Dunkle Shallow	2	12	0	0	2	0	0	0	0	0	1	0
Foodoo Control	4067	281	0	0	0	7	237	0	0	4	31	0
Halifax	8	16	0	0	0	0	24	0	0	22	8	0
Halifax Deep 1&2	0	9	0	0	183	0	2	0	0	35	15	0
Halifax Deep 3&4	1	7	0	0	60	0	0	0	0	34	1	0
Halifax Inshore	262	55	0	0	2	11	20	0	0	0	28	0
Hock	3	43	0	0	2	0	30	0	1	53	34	0
Hostel North	0	1	0	0	1	0	0	0	0	0	0	0
Hostel Shallow	0	1	0	0	0	0	0	0	0	0	0	0
Hostel South	0	0	0	0	0	0	0	0	0	0	0	0
Houtini	2	21	0	0	0	1	16	0	0	13	9	0
Mittag	1	8	0	0	0	0	0	0	0	0	0	0
Odin Control	733	151	1	0	0	7	1	0	0	0	152	0
Panther	20	6	0	0	0	4	0	0	0	0	0	0
Panther Deep 1	0	0	0	0	3	0	0	0	0	0	0	0
Panther Deep 2	0	2	0	1	0	0	1	0	0	0	0	2
Panther Deep 3	0	5	0	0	0	0	0	0	0	0	0	0
Peninsular	86	78	0	0	0	0	111	0	0	19	17	0
Peninsular Extension	2	26	0	0	0	0	10	0	0	5	16	0
Pomona	3	14	0	0	0	0	0	0	0	0	0	0
Purple North	0	1	0	0	0	0	0	0	0	1	0	0
Purple Shallow	1	4	0	0	0	0	0	0	0	0	2	0
Purple South	0	10	0	0	1	0	0	0	0	4	0	0
Reefbay	1	28	0	0	17	1	13	0	0	38	6	0
Site Two	2	6	0	0	0	0	0	0	0	0	1	0
South Rock	0	1	0	0	0	5	0	0	0	0	0	0
Tafelberg	0	5	0	0	0	0	0	0	0	0	0	0

## Appendix 3 B

### Environmental data: Chapter 3.

	< 63 $\mu$ m	63 - < 125 $\mu$ m	125- < 250 $\mu$ m	250 - < 710 $\mu$ m	> 710 $\mu$ m	Depth
# 2 Plant Shallow	68.93	27.90	2.35	0.28	0.53	39.10
# 2 Plant South	98.52	0.72	0.15	0.07	0.55	47.47
A1-N-A	44.38	54.40	0.95	0.10	0.17	104.67
A1-N-B	43.58	55.40	0.85	0.12	0.05	105.67
A1-N-C	43.32	56.07	0.47	0.08	0.07	107.33
A1-S-A	83.42	1.82	1.17	5.87	7.73	100.73
A1-S-B	99.70	0.30	0.00	0.00	0.00	100.20
A1-S-C	99.78	0.08	0.02	0.02	0.10	97.30
Beverly Hill	91.17	6.23	0.65	1.32	0.63	51.70
Beverly Hill Deep	99.48	0.32	0.07	0.03	0.10	68.40
Bogenfels Deep	21.10	0.22	2.83	60.33	15.52	65.70
BR Deep North	26.85	33.23	32.30	7.48	0.13	76.47
BR Deep South	21.62	14.62	42.32	20.25	1.20	67.30
BR North	28.50	28.50	41.28	1.58	0.13	33.20
BR South	23.33	13.95	47.12	13.33	2.27	31.63
Chameis Head	27.63	41.20	30.55	0.59	0.03	28.87
Chameis North	20.87	0.25	0.38	56.90	21.60	47.47
Chameis South	22.43	5.10	25.98	46.27	0.22	41.60
Channel	24.86	2.81	35.13	35.88	1.33	59.88
Dreimaster	23.20	35.08	33.75	4.92	3.05	25.63
Dunkle Deep	21.90	5.43	24.62	47.92	0.13	66.97
Dunkle Shallow	24.77	23.68	49.70	1.70	0.15	27.90
Foodoo Control	36.19	57.71	5.92	0.11	0.07	38.60
Halifax	35.08	22.58	39.06	3.12	0.16	61.10
Halifax Deep 1&2	38.49	6.97	6.35	10.34	37.85	70.47
Halifax Deep 3&4	40.12	10.48	8.85	8.84	31.71	34.47
Halifax Inshore	28.56	24.42	14.47	29.75	2.80	39.52
Hock	40.48	28.71	20.87	7.74	2.21	71.63
Hostel North	28.50	24.55	45.97	0.80	0.18	59.47
Hostel Shallow	30.55	44.27	24.67	0.47	0.05	23.47
Hostel South	28.28	32.80	38.18	0.53	0.20	61.57
Houtini	31.58	39.62	28.21	0.53	0.06	67.05
Mittag	38.12	30.75	29.38	1.35	0.40	29.47
Odin	25.64	53.15	19.23	1.58	0.40	31.79
Panther	29.45	57.03	13.13	0.32	0.07	25.03
Panther Deep 1	21.48	25.88	29.27	18.97	4.40	54.73
Panther Deep 2	24.95	7.40	51.57	15.78	0.30	63.13
Panther Deep 3	23.58	7.45	58.77	10.12	0.08	59.33
Peninsula	60.98	33.51	5.09	0.38	0.04	43.28
Peninsula Extension	33.01	26.03	40.16	0.73	0.08	70.62
Pomona	25.92	28.53	44.30	0.60	0.65	40.03
Purple North	34.12	38.83	26.38	0.37	0.30	66.77
Purple Shallow	27.28	39.38	32.30	0.92	0.12	20.20
Purple South	48.67	25.75	19.05	5.90	0.63	68.90
Reefbay	47.82	28.00	6.13	4.78	13.28	47.45
Site Two	24.40	24.72	46.32	4.17	0.40	24.13
South Rock	35.50	50.53	13.85	0.12	0.00	20.20
Tafelberg	28.53	35.28	34.83	0.97	0.38	65.43