Nearshore subtidal soft-bottom macrozoobenthic community structure in the western sector of Algoa Bay, South Africa

By

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Submitted in fulfilment of the requirements for the degree of *Magister Scientiae* at the Nelson Mandela Metropolitan University

2011

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Acknowledgements

This is probably the most important section of my study for without the assistance of the following people this work would have been close to impossible. Firstly, I would like to thank my supervisor Prof. Tris H. Wooldridge for his guidance and advice during the course of the study. In the same breath, I owe my sincere gratitude to Mr. Shaun H. P. Deyzel for his mentorship and many discussions we shared on the subject. You have been more than a mentor. It must have been particularly difficult and annoying reading through my initial ramblings. *Dankie* Shaun!

I would also like to thank SAEON Staff, especially Dr. Angus W. Paterson, Dr. Kim Bernard, Dr. Nicola James (now at SAIAB) and Dr. Albrecht 'Ali' Götz for their academic support. A big 'thank you' is also extended to Russell Chalmers for producing maps of my study area and to Dr. Wayne Goschen (SAEON Egagasini (Offshore) Node) for the discussion and proof-reading of my section on bottom currents in Algoa Bay. Transnet National Ports Authority is also thanked for their generous financial support for this study

I would like to thank all my friends and colleagues in academia, especially Dr. Brent K. Newman (Council for Scientific and Industrial Research, Durban) for analysing my sediment samples for heavy metals and Fiona MacKay (Oceanographic Research Institute) for sharing her passion and expertise in the identification of some of the macrofaunal groups, principally polychaetes. I also thank Fiona MacKay for doing quality control on some of the identified specimens. On the same note I would like to

thank Mrs. Glynn Armstrong (Rhodes University Geography Department) for sharing her expertise in sediment analysis (particle size and organic content), as well as the Rhodes University Department of Ichthyology and Fisheries Science for allowing me to use their muffle furnace when the 'golden oldie' gave up on me. I also thank Mr. Leon Vivier (University of Zululand) for believing in me before I could realise my potential and for sharing his passion for research with me during my formative years. Other friends in academia that I am indebted to are Mr. Lukhanyiso 'McVee' Vumazonke, Mr. Bongumusa 'Msholozi' Zuma and Mr. Luzuko Dali for their companionship. You guys were always there when this project was taking its toll on me. Endless debates on various issues ranging from academia to politics will not be forgotten. A special thanks to my partner in crime, Luzuko, who never refused when I dragged him to the lab during the witching hours.

Most importantly I would like to thank all my field assistants including Luzuko 'Lusko' Dali, Shaun 'Herculator' Deyzel, Kim Bernard, Anthony 'Ant' Bernard, Ryan 'Farmie' Palmer, my skipper Sean 'Mashonisa' Bailey (all SAEON Staff), Ryan Wasserman, Bevan O'Reiley, Peter Watt-Pringle, Wesley de Klerk (all NMMU), Bernard McKenzie (SAIAB) and all who also participated in the back-breaking field work. Without you guys this work would have been impossible. Gratitude is also extended to SAEON Parataxonomists: Kholekile 'Stix' Mpako, Lulama 'Dlalani' Poni and Toyoyo 'Mvangeli' Koliti for sorting out some of my macrozoobenthic fauna from sediment samples. I know this is the most time consuming task in benthic ecology yet you guys were always up to the challenge. I will never forget all the fun we had while sorting out those little 'beasts'.

I would also like to thank my long time friends Thokozani ‘Thokoz’ Sithole, Khumbulani ‘Doda’ Makhaye, Siyabonga ‘Njomane’ Mhlongo and Mthokozisi ‘Mthoko’ Biyela for their moral support and motivation even if they have no idea what benthos is. That is what friends are for! My appreciation also extends to my parents, Mr. Thulasizwe J. Masikane and Mrs. Jabulile M. Masikane, as well as my brothers Muziwenhlanhla, Philani and Siphamandla, for their moral and financial support as well as their confidence and belief in me. It really meant a world of difference to me and made this adventure a worthy course.

Ultimately thanks to the Almighty!

Dedication

This work is dedicated to my grandmother, Mrs. Nomasonto Linah Margaret Masikane, who passed away during the course of this study and to whom I never got the chance to say my final goodbyes. Rest in peace Tiba.

Declaration

I, Ntuthuko Fortune Masikane, hereby declare that this dissertation is my own work and that it has not previously been submitted for assessment to another University or for another qualification.

Signature: _____

Date: _____

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Abstract

The objectives of this study were to characterise macrozoobenthic community structure of the western sector of Algoa Bay, to identify the drivers of community structure and to develop a long-term monitoring framework.

Data were collected from six study sites stratified along-shore. Each site comprised three stations; most sites were located in areas directly influenced by anthropogenic activities such as inflow from storm water drains and areas where dredged spoil was dumped. Other sites included areas in close proximity to estuary mouths. Physico-chemical parameters of the water column were measured with a YSI instrument, sediment for faunal and physico-chemical analyses was sampled with a Van Veen grab, and collected macrofauna were sedated and preserved pending analysis. In the laboratory, macrofauna were identified to finest taxonomic resolution possible under dissecting and compound microscopes, and enumerated. Sediment samples for physico-chemical analyses were kept frozen pending analysis.

Up to 187 species belonging to 137 genera and 105 families were identified. Univariate community parameters such as abundance and number of species varied significantly along-shore, generally increasing towards less wave-exposed sites. Multivariate analyses revealed that community assemblages were heterogeneously distributed along-shore, corresponding to areas where anthropogenic influences such as effluent discharge and commercial harbour activities prevailed. During the 2008 survey, species assemblages separated into six groups corresponding to the six sites but

during the 2009 survey, species assemblages separated into four groups probably due to changes in environmental parameters such as the hydrodynamic regime. In both surveys the assemblage opposite a drainage canal (Papenkuils outfall) was distinct as it was dissimilar to all other assemblages. This site was also heterogeneous over relatively small spatial scales.

Important physico-chemical variables influencing community structures during the 2008 survey included bottom measurements of temperature, salinity, dissolved oxygen, coarse sand and mud. During the 2009 survey, only bottom temperature and mud content were identified as important physico-chemical variables structuring community assemblages. The principal variable was probably the hydrodynamic regime, driving community structure at a larger scale in Algoa Bay. On a localised scale, communities were probably structured by other factors such as effluent discharges, influence of estuary mouths and activities associated with the harbour.

With a lack of information on keystone species (regarded as good monitoring species) in Algoa Bay, it was proposed that groups that cumulatively comprise 50–75 % of total abundance within communities be monitored annually. Included are amphipods, polychaetes, cumaceans, ostracods, tanaids and bivalves. It was also proposed that areas opposite estuary mouths, effluent outfalls and the dredged spoil dumpsite be monitored. This routine monitoring programme should be accompanied by periodic hypothesis driven research to assess the importance of stochastic events (e.g., upwelling) on macrozoobenthic community dynamics.

***Keywords*:** macrozoobenthos, soft-bottom, community assemblages, spatial distribution patterns, environmental drivers, long-term monitoring framework.

Preface

In response to global climate change that will *inter alia* manifest in environmental change, the South African government has responded by establishing an environmental observation facility responsible for the collection of long-term environmental data. This facility is referred to as the South African Environmental Observation Network (SAEON) and is composed of several nodes responsible for the study of different ecosystems ranging from terrestrial systems to coastal waters. SAEON Elwandle Node, situated in Grahamstown and hosted by the South African Institute for Aquatic Biodiversity (SAIAB), is a coastal node mandated with initiating and maintaining long-term monitoring programmes for coastal waters like estuarine and nearshore ecosystems. Algoa Bay was initially earmarked as SAEON's core site for long-term monitoring. Work reported in this thesis is an initial step in establishing a long-term monitoring framework for the macrozoobenthic community in Algoa Bay and is a product of the newly established Algoa Bay Long-term Monitoring and Research Programme coordinated by SAEON Elwandle Node.

"It is a sad fact that we know more about the backside of the moon than we do about the bottom of the deep sea! Yet do we know enough about coastal biodiversity?"

Gray 2001

Professor John Stuart Gray (1941–2007).

Chapter 1

General Introduction

1.1. Introduction

The most important step in understanding community structure and functioning is through descriptive ecology (Gray 1974), which entails an understanding of the abundance and distribution patterns of animals and their interaction with the surrounding environment (Underwood *et al.* 2000; Begon *et al.* 2006). Distribution patterns of macrozoobenthic fauna have been studied for decades, and environmental parameters that influence these patterns are complex (Snelgrove & Butman 1994). Sediment parameters, particularly grain size, have been recognised as principal drivers of macrozoobenthic distribution (Gray 1974; Snelgrove & Butman 1994; Sakamaki & Nishimura 2009). These conclusions are, however, mainly drawn from correlative analyses (Snelgrove & Butman 1994). Sediment itself is correlated to other parameters like the hydrodynamic regime, which is supposedly more important to benthic faunal distribution than sediment (Snelgrove & Butman 1994).

Spatial scale is also a critical aspect in benthic ecology as it influences conclusions made on species richness and distribution. At broader scales (regional or biogeographical), physical factors like water movement and depth become important as these determine large scale distribution patterns, while biotic interactions are crucial at smaller or local scales (Morrisey *et al.* 1992; Gray 2001; Bergström *et al.* 2002; Arvanitidis *et al.* 2009; Renaud *et al.* 2009; Somerfield *et al.* 2009).

The importance of spatial scale is clearly demonstrated with large data sets collected over broader spatial scales, for example the MacroBen database of Europe (Vanden Berghe *et al*. 2009). This sort of database is lacking for the South African coast. There is also a concern of low research output on benthic research in the southern hemisphere, thus limiting advances in the discipline (Gray 2001).

Relatively few studies have investigated the soft-bottom benthic fauna of the coastal nearshore in southern Africa (e.g., Field 1970; 1971; Christie 1976; Christie & Moldans 1977; McClurg 1988; Fleischack & de Freitas 1989; Awad *et al.* 2002). As a consequence, information is patchy and mostly limited to composition, basic ecology and impacts of pollution on marine benthic communities (Leslie *et al.* 2000). The major reason for the paucity of information is the difficulty in sampling these high energy systems (McLachlan *et al.* 1984). The situation is further aggravated by the lack of benthic biologists and ecologists (Leslie *et al.* 2000).

Coastal studies undertaken in southern Africa have shown that nearshore community structures are influenced by, *inter alia*: ocean hydrodynamics, geomorphology, biological dynamics and anthropogenic activities (Morgans 1962; Field 1970; 1971; Christie 1976; Moldan 1978; Wooldridge 1981; 1983; McLachlan *et al.* 1984; Webb *et al.* 1987; Webb & Wooldridge 1990; Kruger *et al.* 2005). Oceanic dynamics include altered current flow patterns, depth of the water column and/or turbulence. Geomorphology mainly includes sediment dynamics such as particle size and sediment movement as well as sources of sediment. Biological dynamics include migratory patterns, food availability, predation, competition and larval dynamics. Anthropogenic

activities mainly include harbour activities such as harbour construction, dredging activities, disposal of dredged spoil and effluent disposal.

Of these investigations, only a small number report on Algoa Bay (e.g., Wooldridge 1983; McLachlan *et al.* 1984; Malan & McLachlan 1985; Cockcroft & Tomalin 1987; Webb & Wooldridge 1990). This sector of the coastline is reported to have the highest benthic species richness and endemism along the entire South African coastline (Awad *et al.* 2002). Available studies are intensive but taxon focused (e.g., Wooldridge 1983; Cockcroft & Tomalin 1987; Webb & Wooldridge 1990). Others are specialised and restricted to small portions of the bay like the area around the Port of Ngqura construction site (e.g., CES 2001; CSIR 2002a). Taxon focused studies concentrated on typical hyperbenthic organisms such as *Mesopodopsis wooldridgei* (*slabberi*) and deep burrowing infauna like *Callianassa kraussi* and *C. gilchristi* (Wooldridge 1983; Cockcroft & Tomalin 1987; Webb & Wooldridge 1990).

Algoa Bay is currently a focal area for industrial development, directed by the construction of the Port of Ngqura. In other areas (e.g., Saldanha Bay), port construction has had considerable impact on benthic communities (see Kruger *et al.* 2005). The recently proposed Greater Addo Elephant National Park in the eastern sector of Algoa Bay includes the marine nearshore and will provide much-needed protection to part of the Algoa Bay complex (CSIR 2002b). Anthropogenic impacts associated with infrastructure development will probably escalate and will require effective management of the Algoa Bay ecosystem. This will only be possible if the information base includes an understanding of the biota, trophic structures and interactions.

Benthic organisms have proven to be useful indicators of environmental disturbance or change (Raffaelli & Mason 1981; Bilyard 1987; Gray *et al.*1990; Newell *et al.* 1990; Agard *et al.* 1993; Rainbow 1995). This is due to their ecological importance (Grosse *et al.* 1986; Simpson *et al.* 2005) and sessile nature that allow for the identification of site-specific consequences of anthropogenically induced disturbances (Simpson *et al.* 2005). It is imperative to understand the impacts of contaminants over long periods on a scale of months to years. By comparison, plankton only reflects contamination of point sources over a short time period (Pohle & Thomas *not dated*). In other countries benthic fauna are central to environmental monitoring tools as they are integral in ecological indices developed to assess sediment ecological status. Examples of ecological indices include, *inter alia,* AMBI (Borja & Perez 2000), BENTIX (Simboura & Zenetos 2002), BRI (Smith *et al.* 2001), BOPA (Dauvin & Ruellet 2007) and Sediment Quality Triad (Long & Chapman 1985).

The present study is designed to contribute towards filling the information gap and thus informing effective management of the Algoa Bay complex. Baseline data generated in this study is also used to propose a long-term monitoring framework for macrozoobenthic fauna.

1.2. Objectives of the study

The overall objectives of this study were to:

1. Characterise the macrozoobenthic community in the western sector of Algoa Bay by determining the community composition and identifying community sub-structures.

2. Identify environmental variables driving the zoobenthic community dynamics.
3. Establish a long-term monitoring framework for Algoa Bay.

The key questions to be addressed in the present study were:

1. Is the macrozoobenthic community spatially homogenous along the 10 m depth contour?
2. What are the environmental parameters that best describe the zoobenthic community dynamics?
3. Do communities close to known anthropogenically-influenced areas reflect comparatively different dynamics in terms of structure, diversity and abundance?

1.3. Dissertation structure

This dissertation consists of six chapters.

Chapter 1: General Introduction

In this section the study is contextualised. Objectives and aims of the study are outlined and key questions to be addressed, from which hypotheses can be drawn, are also stated.

Chapter 2: Description of the Study Area

The geographical location of the study area relative to the marine bioregions of South Africa and study sites are described in this section. Characteristics and important features in the bay are also described.

Chapter 3: Materials and Methods

Field and laboratory protocols plus statistical analysis procedures undertaken for this study are described in detail. Quality Assurance and Quality Control procedures (QA/QC) implemented to ensure the quality of data are also described. Quality Assurance procedure is a formalised system of evaluating technical adequacy of sample collection and laboratory analysis activities (US EPA 1995; 2001). This procedure is implemented throughout the study. Quality Control procedure is the implementation of measures for determining bias and precision (US EPA 1995; 2001). It includes activities such as replicating samples, setting benchmark standards, calibration of equipment, and sample custody and recordkeeping.

Chapter 4: Results

This section describes the findings of the study. The relationship between physico-chemical and biological data is explored and described.

Chapter 5: General Discussion

Results are discussed in this section and the key questions of the study are addressed.

Chapter 6: Macrozoobenthic Monitoring Framework

This chapter outlines and discusses a provisional monitoring framework for subtidal soft-bottom macrozoobenthic community in Algoa Bay.

Additional sections include references and the appendix section.

Chapter 2

Description of the Study Area

2.1. Marine bioregions of South Africa

In a recent review, the National Spatial Biodiversity Assessment programme proposed nine marine bioregions for the South African marine environment (Driver *et al.* 2005). Five of the nine bioregions are located inshore and extend from the shoreline to the continental shelf. These inshore bioregions (see Appendix 1) include:

- The Namaqua bioregion (extending from Sylvia Hill in Namibia to Cape Columbine),
- The South-western Cape Bioregion (extending from Cape Columbine to Cape Point),
- The Agulhas bioregion (extending from Cape Point to Mbashe River),
- The Natal bioregion (extending from Mbashe River to Cape Vidal), and
- The Delagoa bioregion (extending from Cape Vidal to Inhaca).

The present study area in Algoa Bay is therefore located within the warm temperate inshore Agulhas bioregion (Sink *et al.* 2004).

2.2. Geographical location and features of Algoa Bay

Algoa Bay (Figure 2.1) is the eastern most and best formed logarithmic-spiral bay along the Cape south coast of South Africa (Bremner 1983).

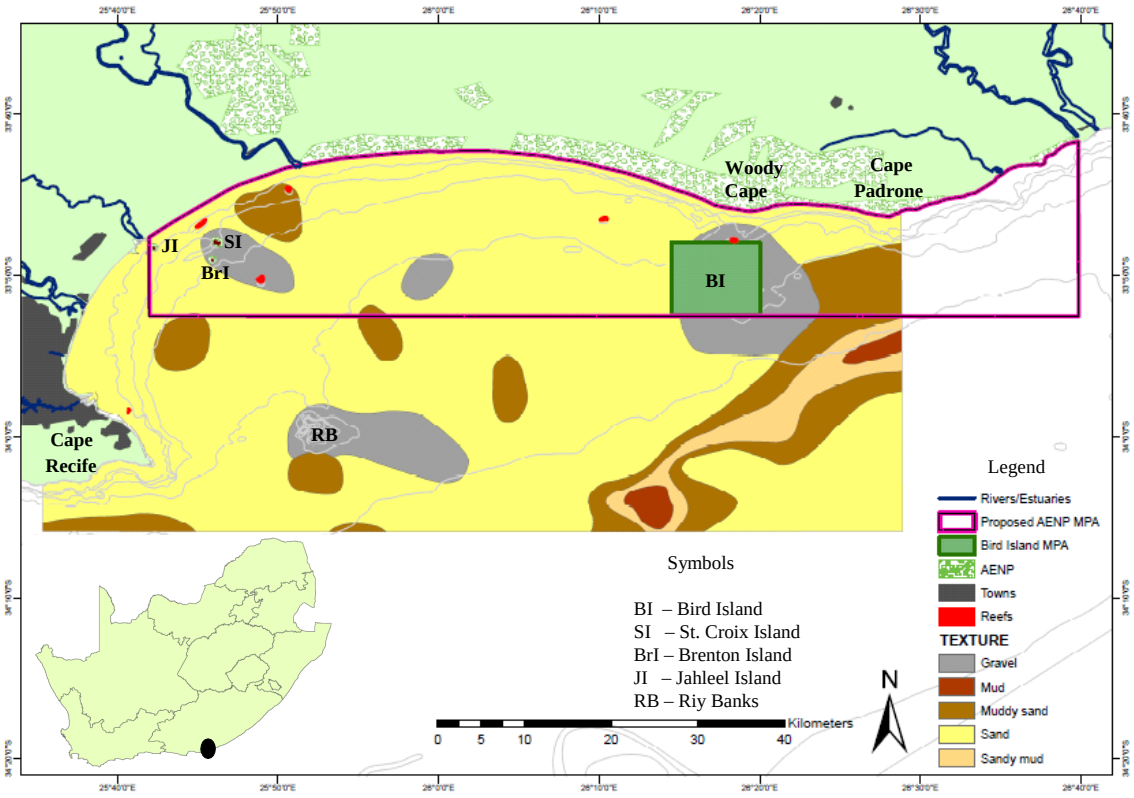

Figure 2.1. The log spiral Algoa Bay and its general features explained in the legend. The inserted map indicates the geographical position of the bay on the South African coastline. AENP = Addo Elephant National Park and MPA = Marine Protected Area.

The Bay extends from Cape Padrone (shelf width: ~ 43 km) in the east to Cape Recife (shelf width: ~73 km wide) in the west (Flemming 1980; Talbot & Bate 1987). The bay is predominantly shaped by wave refractions around the rocky headlands of Cape Recife and consequent longshore sediment movement (Phipps 1997). According to Phipps (1997), the bay developed during the Cenozoic period and contains more

sediment than similar bays on the Cape south coast. It is situated in a high energy zone of the Southeast African Continental Margin and is dominated by south-westerly swells (Flemming 1980; 1981; Bremner 1983; Talbot & Bate 1987; Schumann *et al.* 1995). Currently, the bay is in a dynamic equilibrium state since a constant supply of sediment passes through the system (Phipps 1997).

The nearshore region behind the surf line around Algoa Bay is made up of sand and patches of hard-bottom substrata (Figure 2.1). The more extensive shallow-water reef patches include Phillips Reef at a depth range of ~ 6–15 m off Kings Beach (McLachlan *et al.* 1984; Cockcroft & Tomalin 1987; Talbot & Bate 1987; Roberts 1990). The other important hard-bottom structure or rocky outcrop is the Riy Banks which is situated towards the east of Cape Recife and at shallower depths of ~ 12 m (CSIR 2002b). Some low relief reefs, the 'Black Bushes' run for some distance between the Sundays River mouth and Bird Island. Some extensive reefs are also associated with Bird Island (CSIR 2002b).

Four islands are associated with Algoa Bay. Jahleel, St. Croix and Brenton Islands are located in the innermost part of the bay between the Port of Ngqura and Sundays River mouth. Jahleel and St. Croix Islands are within the 20 m depth contour, while Brenton Island is located along the 30 m depth contour. Bird Island, in the eastern sector of the bay, is situated south of Woody Cape (CSIR 2002b).

Important man-made structures along the shoreline of Algoa Bay include ports, effluent outfalls, and city drainage canals, while natural features include estuaries. The container port of Port Elizabeth is the current operational port and is in the western

sector just north of Cape Recife. The newly constructed Port of Ngqura is an extension of the non-functional Ngqura Estuary previously modified as salt works.

There are five major land drainage systems along the shoreline of the bay. The small Baakens River (Figure 2.2) flows into the dock area of the port of Port Elizabeth (Emmerson *et al.* 1983), while the Papenkuils River is canalised in the lower reaches (Figure. 2.2) and flows directly into the bay (Watling & Emmerson 1981; Emmerson *et al.* 1983; Roberts 1990). Swartkops and Sundays River estuaries are much larger land drainage systems that drain into the bay via permanently open mouths. The Coega (Ngqura) Estuary is non functional and has previously been converted into salt works (Whitfield 2000). At its mouth the new Port of Ngqura is under construction.

2.3. Sampling Sites

Sampling sites (Figure 2.2) were located in the western sector of the bay and represent different habitats. A description of each site is provided below. Each site is comprised of three sampling stations, located 100 m apart along the 10 m depth contour. Accompanying GPS co-ordinates are for central stations. Based on a 20 point scoring system for sandy beaches by McLachlan (1980b), Algoa Bay is exposed to wave activity with exposure rating increasing from 12.5 at Kings Beach to 15.5 along the Sundays River beach.

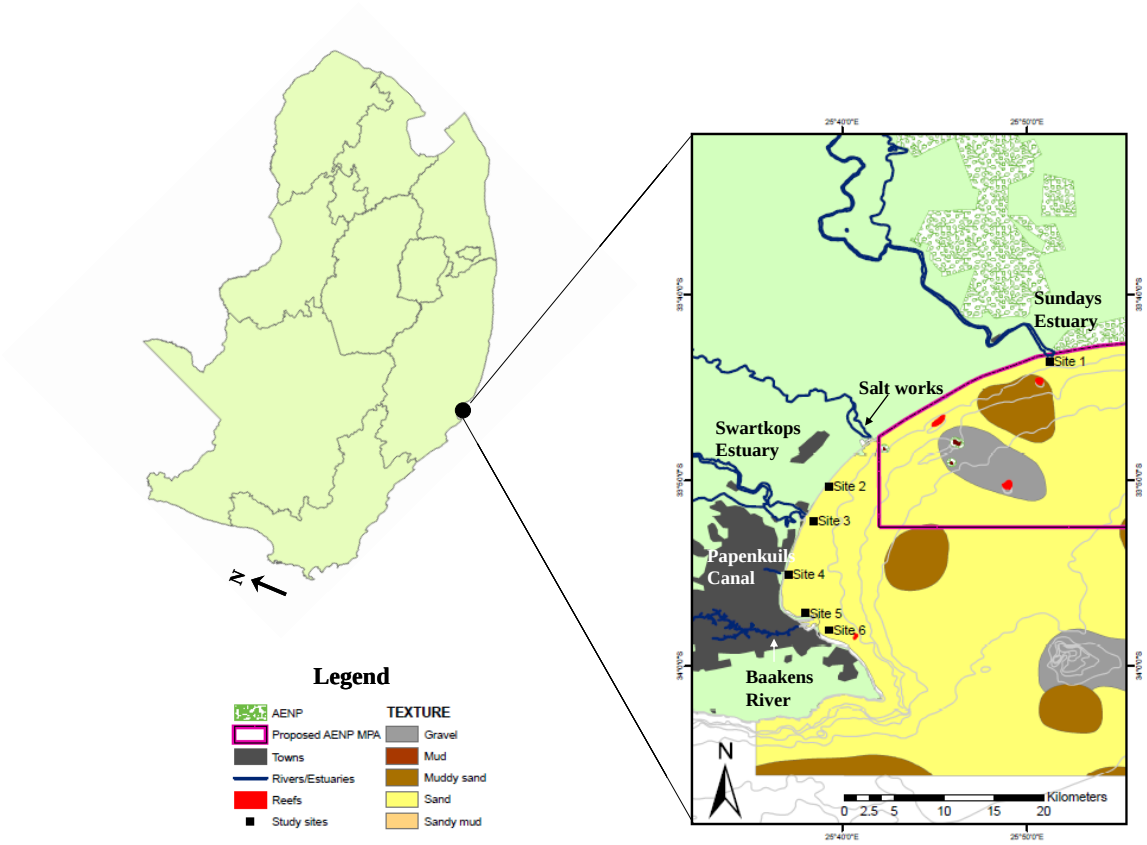

Figure 2.2. Map of the western sector of Algoa bay showing six study sites along the 10 m depth contour. Information about the characteristics of the sites is listed in the key provided.

- **Site 1, Exposed estuary mouth (33º 43' 35" S; 25º 55' 13" E),** is located off the Sundays River Estuary and is the most exposed in terms of wave energy (Malan & McLachlan 1985).
- **Site 2, Exposed sandy area (33º 50' 19" S; 25º 39' 19" E),** is a soft-bottom sandy area equidistant between the Port of Ngqura and the Swartkops Estuary.
- **Site 3, Sheltered estuary mouth (33º 52' 12" S; 25º 38' 30" E),** is across the Swartkops Estuary mouth. The estuary receives some treated domestic effluent from Dispatch and Uitenhage towns plus untreated storm water from the Motherwell Township (Emmerson *et al.* 1983; Roberts 1990). Swartkops Estuary is a few kilometres away from the Fishwater Flats sewage works treatment plant.

- **Site 4, Effluent impacted area (33º 55' 5" S; 25º 37' 7" E**), is the single most highly disturbed site off Papenkuils Canal. Industrial and domestic waste is dumped below the low water mark at this site (Roberts 1990).
- **Site 5, Dredge spoil dumpsite (33º 57' 9" S; 25º 38' 2" E),** is near the port of Port Elizabeth inlet and a fish mariculture facility. It is within the designated area for the dumping of dredged spoil.
- **Site 6, Sheltered sandy area (33º 58' 4" S; 25º 39' 19" E),** is located off Kings Beach (a safe and favourite recreational beach of Port Elizabeth) and is presumed to be relatively undisturbed (physico-chemically). This site is least exposed to wave activity (Malan & McLachlan 1985) and is located near Phillips Reef (Roberts 1990).

Sediment texture in all sampling sites is predominantly sandy (Bremner 1991) although Site 4, which is across the Papenkuils outfall also receives much fine material. This site is less sandy compared with the rest of the sites.

Chapter 3

Materials and Methods

Three major field excursions were undertaken between 2007 and 2009. An initial pilot study in November 2007 was undertaken to facilitate protocol or design, but this information is not reported in the present dissertation. The first major field trip was undertaken in February 2008 and a second in January 2009. Sampling commenced from chemically uncontaminated sites (i.e., Sites 1, 2 and 6). This approach was followed to prevent cross-contamination and to minimise variability. Failure to adhere to this QA/QC measure may lead to degradation of data quality as contaminants from one site may be introduced to samples of another site.

3.1. Field sampling

The physico-chemical variables (temperature (°C), salinity (psu), pH, dissolved oxygen (mg l^{-1}) and turbidity (NTU)) were measured with an YSI 650 MDS multi-parameter probe at 1 meter intervals from the water surface to the bottom of the water column. This procedure ensured that measurements such as turbidity were not influenced by disturbed sediment. Bottom values using the YSI instrument were measured at least one meter above the sediment.

Sediment samples for biological analysis were collected with a modified Van Veen grab (211 cm^2 bite area and sampling depth of up to 10 cm) operated manually from

the sides of an 8 meter semi-rigid inflatable boat. Seventy five replicates were collected from three stations comprising a site. The study area is comprised of six sites.

A Van Veen grab is a recommended sampler when a larger volume of surface soft sediment sampled to a depth of ≤15 cm and at water depths greater than four meters is required (US EPA 2001). The grab was released slowly at a constant speed avoiding free fall. The controlled descending speed also minimises the creation of bow waves that potentially disperse surface sediments (Simpson *et al.* 2005). The grab was then lifted at a constant speed and its contents gently and thoroughly washed through a 500 µm mesh bag to remove excess fine sediment. Although biomass information gained by using finer sieves is not substantially improved when compared to the information gained using a coarser mesh bag (e.g., 1000 µm; Thompson *et al.* 2003; Lampadariou *et al.* 2005), information on abundance and number of species is greatly improved (Reish 1959; James *et al.* 1995; Schlacher & Wooldridge 1996) because the increased retention efficiency of finer mesh screens also increases the potential of catching smaller sized species.

Organisms and the coarser sediment were then stored in clean 250 ml plastic bottles. A solution of 7 % $MgCl_2$, buffered in seawater, was added to the sample bottles in order to sedate the fauna, thus aiding polychaete identification in the laboratory (Costa-Paiva *et al.* 2007). After the sedation period lapsed (maximum time: ~ 3 hrs), a small amount (approximately 5 - 10 ml) of 45 % formaldehyde was added to the sample as a fixative. Samples were then stored in a dark cool container until transferred to the laboratory for further analysis. Sieve bags were thoroughly washed before moving to

the next station in order to prevent biological cross contamination. A total of 900 biological samples were collected for this study (450 samples for 2008 and 450 samples for 2009, each set collected at 18 stations).

A single sediment sample for metal analysis was also collected with the Van Veen grab from each sampling station and stored in 250 ml clean plastic bottles. Whole samples were stored in a tightly closing cooler box together with sealed ice packs until transported to the laboratory where they were kept frozen pending analysis. Triplicate samples were additionally collected from each station for granulometry and organic content analysis. These samples were collected and treated similarly to the sediment samples stored for metal analysis. To ensure that the integrity of the sediment collected from the field was not compromised, grabs were thoroughly rinsed before moving to the next station and/or site. Storage time did not exceed two weeks for sediment samples collected for particle size and total organic content analyses. For metal analysis, sample storage time did not exceed six months (US EPA 1995; 2001).

3.2. Laboratory analyses

Sediment samples were decanted into a 500 µm hand-held mesh screen to isolate preservatives and/or fixatives for appropriate disposal. The retained material was repeatedly rinsed with freshwater to remove excess formaldehyde. Fauna was then manually sorted from the sediment under Leica dissecting microscopes by a team of trained technicians. Sorted fauna was temporarily stored in plastic flip-top pill vials (approximately 20 ml) in 70 % ethanol pending identification and enumeration. The sorting efficiency of technicians was then calculated, as a quality control measure, from a minimum of 10 % of the sorted samples (Russell 2001). Failure to remove all

species from the sediment can lead to under-representation of species and their abundances (Ranasinghe *et al.* 2003). Sorting efficiency was calculated using the following equation (Russell 2001):

$$\text{SE (\%)} = \frac{\#\text{ of individuals picked from sample}}{\#\text{ of individuals originally picked} + \#\text{ of individuals found during re-pick}} \times 100$$

The predetermined sorting efficiency standard was set at 95 %. Where sorting efficiency was 90–95 % the relevant sorter was advised on how to improve effectiveness and which groups to focus on. A sorting efficiency of below 90 % required that the whole batch of a particular sorter be re-worked. The quality control report was then prepared and filed with SAEON Elwandle Node in Grahamstown, South Africa.

Macrofauna were identified (by the author) to the finest taxonomic resolution possible under dissecting (Leica EZ4D mounted with a digital camera; 35x maximum magnification) and compound (Leica CME, 100x maximum magnification) microscopes. Targeted taxonomic sufficiency was the species level. Where species could not be identified to the finest resolution, specimens were identified to higher taxonomic levels (genus, family, order, and class) following guidelines of Wu (1982) to reduce errors in the calculation of diversity indices. Several studies have also indicated that information lost when identifying to higher taxonomic levels, such as family, is not substantial (Warwick 1988a; Ferraro & Cole 1990; James *et al.* 1995; Dauvin *et al.* 2003; Thompson *et al.* 2003; Lampadariou *et al.* 2005). Major taxonomic groups were identified using the following literature: Polychaeta (Day, 1967a; 1967b), Amphipoda (Griffiths 1976), Isopoda (Kensley 1978), Tanaidacea

(Day 1974), shrimps and prawns (Kensley 1972), decapods (i.e., anomuran and brachyuran crabs; Barnard 1972), bivalves and gastropods (Steyn & Lussi 1998). All samples were preserved in 70 % ethanol and stored at SAEON Elwandle Node after identification.

After identification and enumeration was completed, several identified species were also sent to independent taxonomists for a second opinion, especially where doubts occurred. Mis-identification of species can underestimate or overestimate species richness (Ranasinghe *et al.* 2003). Finally, the species names of identified organisms were cross-referenced with the World Register of Marine Species Database (www.marinespecies.org) to confirm whether the used nomenclature is still applicable or whether it had been reviewed. This was an important procedure as most of the literature used for identification had not been recently updated.

Frozen sediment samples for metal analysis were sent to an independent laboratory for analysis where concentrations of selected heavy metals were measured using Inductively Coupled Plasma Optic Emission Spectroscopy (ICP-OES). Resultant metal concentrations were fitted into a geochemical baseline model generated through a geochemical normalisation procedure. Geochemical normalisation procedure allows for a better separation of anthropogenic concentrations from baseline concentrations. The geochemical normalisation procedure mathematically normalises metal concentrations to a conservative co-occurring element known as a normaliser or reference element. Commonly used normalisers are iron and aluminium. For this study aluminium was selected as the normaliser. See Newman & Watling (2007) for an account of geochemical normalisation.

Algoa Bay sediment contains a higher percentage (up to 60 %) of terrigenous material (i.e., quartz and clay minerals) and particle size can thus be analysed by almost any technique (Bremner 1991). Sediment particle size was determined by a classical dry sieving method, which separates sediment grains according to their intermediate axial length (d_I) (Wentworth 1926; Percival & Lindsay 1997; Blair & McPherson 1999). Frozen sediment samples were dried at 56 °C in a Labcon mini oven. Dry sediment was then gently disaggregated in a mortar with a pestle where necessary, as it tended to form aggregates, and homogenised using a stainless steel tablespoon. Occasionally, sediment was stirred with a stainless steel tablespoon during the drying process. This minimised the aggregation of sediment. Total dry mass of the sediment was measured with an electrical micro scale (accurate to two decimal places). Sediment was then run through a sieve stack of decreasing mesh sizes and mechanically shaken for a standard duration of 10 minutes using a mechanical shaker. Sieves with stainless steel square meshes were used for particle size analysis, with 1000 µm mesh sieve at the top and a collecting pan at the bottom. In-between sieves were 500 µm, 250 µm, 125 µm and 63 µm mesh sizes. Mass of sediment retained by each sieve was weighted and represented as a proportion of the total sediment and/or as *phi* units (φ). The sediment particle size analysis by sieve stacking separates sediment fractions into the widely accepted Udden–Wentworth size classification (Table 3.1).

To compare particle size distribution within and between sites, total sediment mass was standardised at 300 g, since total mass of replicates varied (see Appendix 3). Whole sediment samples were used for particle size analyses, although 100 g is a recommended minimum volume (US EPA 1995). Consult US EPA (1995; 2001) for

recommended minimal standards of sediment collection methods, sample size, preservation techniques and storage duration.

Table 3.1. A re-presentation of the Udden–Wentworth sedimentary grain-scale (source: Blair & McPherson 1999)

Particle length (d_I)		**Grade**	**Class**	**Fraction**	
mm	φ			Unlithified	Lithified
1	0	very coarse	Sand	Sand	Sandstone
0.500	1	coarse			
0.250	2	medium			
0.125	3	fine			
0.063	4	very fine			
0.031	5	coarse	Silt	Mud	Mudstone or Shale
0.015	6	medium			
0.008	7	fine			
0.004	8	very fine			
0.002	9		Clay		
0.001	10				
0.0005	11				
0.0002	12				
0.0001	13				

Before particle size analysis was undertaken, a subsample of ≥60 g of homogenised sediment was removed for further analysis of total organic content. The subsamples were divided into two almost equal portions to be combusted in separate crucibles. Partitioning the subsample was necessary because of the small size of the crucibles and secondarily, it assisted in determining the homogeneity of the sample. To determine total organic content (TOC), subsamples were pre-weighed, combusted at 520 °C for 18 to 24 hrs in a muffle furnace and then reweighed. Percentage weight loss between the two masses was regarded as the total organic content.

3.3. Data analysis

3.3.1. General characterisation

Physico-chemical variables were described according to depth profile and space with difference and variability described for both scales. The section plots drawn with the software package Ocean Data View version 3.4.0 were used to aid visual definition of the spatial patterns (vertical and horizontal) of physico-chemical variables (Appendix 2B).

For sediment analysis, dominance of different sediment grades was calculated for the whole study area. Dominance was calculated from pooled data (n = 54). Furthermore the contribution and dominance of sediment grades to the sediment structure was described per site. Mud fraction, an important determinant of macrofauna occupancy and abundance (Sakamaki & Nishimura 2009), was also separately represented because this fraction's contribution to the overall sediment structure was masked. Quantity of total organic content was described per site.

Taxonomic composition of the macrozoobenthic community was assessed for the whole study area (Appendix 7A and Appendix 7B) and per site, with five most abundant taxonomic groups identified. Each taxonomic group per site (n = 3 stations) represents the sum of average abundances (n = 75) of species making up each group.

3.3.2. Multivariate analysis

All multivariate analyses were performed with PRIMER (Plymouth Routines In Multivariate Ecological Research) version 6 software (Clarke & Gorley 2006). The

analytical procedure followed the basic strategy of Field *et al.* (1982), amended by Clarke (1993) and Clarke & Ainsworth (1993). Abundance by station data matrix was constructed with stations representing mean species abundance calculated for 25 benthic grabs or replicates. Abundance data were square root transformed and similarity of stations based on species composition was calculated using Bray–Curtis similarity which does not take joint absences into consideration (Field *et al.* 1982). Transformation decreases the weight (or score) of overly abundant species and increases the score of rare or less abundant species in the calculation of similarity (Field *et al.* 1982). Absence of some species from other stations is a common feature of macrozoobenthic data and any method that considers joint absences in the similarity calculation is generally not preferred in marine ecology.

A group average linking technique (Field *et al.* 1982) which joins stations at an average similarity level was used to classify stations in a dendrogram. Dendrograms indicate how stations are related to each other (Field *et al.* 1982). Groups of stations in a dendrogram that could be significantly differentiated from each other were analysed using the Similarity Profile (SIMPROF) test (Clarke & Gorley 2006). Additionally, similar stations in species composition were assessed using the non-metric multidimensional scaling (MDS) ordination technique. This technique places stations with similar species compositions closer to each other while stations with different species compositions are placed at a distance. This ordination technique is based on the degree of similarity between stations, and the ordination is restricted by pre-determined dimensions of the plot. Multiple dimensions usually reflect better ordination but are usually difficult to interpret and therefore two dimensional (2-D) plots are used in this study. The stress value in ordinations of multiple dimensions

compressed into a defined number of dimensions (e.g., from 3-D to 2-D) gives an indication of how accurate the high dimensional ordination is represented. For this study, stress levels above 0.15 were not acceptable. Generally, a stress level above 0.2 is considered to be high (Clarke & Warwick 1994).

The degree of similarity between different groups is judged qualitatively by the distance between the groups of stations (MDS plots) and statistically by the Analysis of Similarity (ANOSIM). One way ANOSIM was performed to assess the degree of similarity between groups determined *a priori* (i.e., Sites in the present study). In ANOSIM pairwise comparison tests, *R* statistic is accompanied by probability (*P*) values that are largely influenced by sample size. For this reason, *R* statistic, which measures absolute differences between two groups, is the most useful statistic to use (Clarke & Gorley 2006). In the present study *R* statistic of >0.5 represented groups with significantly different species composition.

Similarity percentages routine (SIMPER) of PRIMER was used to define the degree of similarity between stations comprising a group and dissimilarities between different groups and/or sites, as defined in MDS ordination plots and ANOSIM (Clarke 1993, Clarke & Gorley 2006). From this routine, species typifying the group (i.e., indicator species) and species that discriminate two groups (i.e., discriminator species) were identified. An indicator species must be highly abundant across stations thus contributing more to similarity; but what distinguishes a 'reliable' indicator species is its consistency in abundance amongst stations thus having a high Sim/SD ratio (Clarke 1993). A discriminator species must have the highest contribution to overall dissimilarity between groups, but a 'reliable' discriminator species must consistently

contribute to the dissimilarity (e.g., high Diss/SD ratio (Clarke 1993, Clarke & Gorley 2006)). When identifying indicator or discriminator species, emphasis is on the species contribution to similarity or dissimilarity, respectively (Clarke 1993, Clarke & Gorley 2006). Reliable indicators and discriminators may be important in this study. Reliable indicator taxa for this study had to meet two requirements:

1. Increased abundance and contribution to similarity.
2. Consistency to similarity should be $\geq \frac{\max . \, Sim / SD \; ratio}{2}$

where max = maximum, Sim = similarity and SD = standard deviation.

Similarly, a reliable discriminator species also had to meet two requirements:

1. Large contribution to dissimilarity.
2. Consistency to dissimilarity should be $\geq \frac{\max . \, Diss / SD \; ratio}{2}$

where max = maximum, Diss = dissimilarity and SD = standard deviation.

Reliable discriminator species are usually highly abundant in one group but rare or largely (but not totally) absent in the other (Clarke 1993).

Environmental data were not transformed but normalised, as parameters were measured in different scales before they were subjected to similarity calculation, classification (Euclidean distance) and ordination. Similarity of groups in ordination plots were assessed using the principal component analysis (PCA) technique (Clarke & Gorley 2006).

The BEST procedure (BVSTEP and/or BIOENV methods) of PRIMER was employed to identify the suite of environmental variables that best described the community assemblage patterns. Integrated means (for the whole water column) of environmental variables and bottom measurements were both used in the BEST procedure. Additionally, sediment parameters (sediment grades, sediment fractions and heavy metal concentrations) were also included. Before the BEST procedure was performed the correlation of environmental variables was tested. Where strong correlations ($\geq$0.95 or $\geq$-0.95) were found, one variable was eliminated. If environmental variables included in the analysis were $\geq$17, for example in the 2008 data set, a BVSTEP method was used. If <17, for example in the 2009 data set, BIOENV method was used (see Clarke & Gorley 2006). Note that sediment metal concentrations were not measured for 2009, thus further decreasing environmental variables to be included in the BEST procedure. The hypothesis that macrozoobenthic assemblage responds to physico-chemical variables measured at the bottom rather than integrated measurements was also tested. To test this hypothesis, integrated and bottom physico-chemical measurements of the water column were included in the BEST procedure, but metal concentrations were excluded in the analysis since minute enrichments were not expected to greatly influence the assemblage pattern (B.K. Newman *pers. comm.*).

3.3.3. Univariate analysis

A one way Analysis of Variance (ANOVA) was used to test the null hypothesis of no difference in physico-chemical variables, community descriptors (i.e., number of individuals and number of species) and diversity indices (Shannon–Wiener diversity,

Margalef's species richness and Pielou's evenness) between study sites. Abundance (*N*), number of species (*S*), Shannon–Wiener diversity (*H'*), Margalef's species richness (*d*) and Pielou's evenness (*J'*) were generated using PRIMER. ANOVA tests were performed using the SigmaStat statistical package. Data were first tested for normality (Kolmogorov–Smirnov goodness of fit test) and equal variance (Levene's equal variance test) before the actual analysis was performed. Where either of these tests failed, data were appropriately transformed (square root, fourth root or log transformation). Failure to meet these assumptions even after transformation required ANOVA (Kruskal Wallis) to be run on ranked data (Sokal & Rohlf 1987). Where significant differences were measured between sites, appropriate *post hoc* pairwise comparison tests were performed.

Physico-chemical data (integrated) and sand fraction data did not meet ANOVA assumptions. Very coarse sand for 2008 required square root transformation and log transformation for 2009. Mud fraction, for both surveys, required square root transformation, and total organic content for 2008 required square root transformation.

Chapter 4

Results

4.1. Physico-chemical characteristics

All physico-chemical variables showed significant spatial changes or gradation patterns during both sampling excursions (Table 4.1a, b). In 2008, surface and bottom temperatures differed but with no apparent thermocline (2–3 °C difference; Figure 4.1A). However, there were notable differences between surface and bottom temperatures at Sites 3, 5 and 6. Differences between surface and the bottom water temperatures increased towards Kings Beach (Site 6). Surface temperature (mean ± 1 SD) ranged between 18.48 ± 0.78 °C at Site 5 and 22.42 ± 0.05 °C at Site 6, while the bottom temperatures were lower when compared to surface temperatures and ranged between 15.34 ± 0.74 °C at Site 5 and 20.83 ± 0.26 °C at Site 4 (see Appendix 2A). Water column temperature varied significantly along-shore between Sundays Estuary mouth (Site 1) and Kings Beach (Table 4.1a). Temperatures between Papenkuils outfall (Site 4) and the dredged spoil dumpsite (Site 5) showed significant differences (Dunnet's pairwise test: $Q = 9.774$, $P < 0.05$). Bottom temperature also decreased significantly from Sundays Estuary mouth towards Kings Beach (Table 4.1b).

Table 4.1a. Kruskal–Wallis analysis of variance (ANOVA) on ranks for selected physico-chemical variables of the water column (integrated). n = number of samples pooled and SE = standard error. Letters represent pairwise comparisons. Similar letters represent homogeneity.

Parameter	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6			H	P
	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE		
2008																				
Temperature (°C)	32	19.61^{a}	0.07	31	20.24^{a}	0.12	33	19.16^{a}	0.34	27	21.69^{b}	0.12	33	17.14^{c}	0.17	30	19.52^{a}	0.31	103.004	< 0.001
Salinity (psu)	32	34.81^{ac}	0.00	31	34.85^{a}	0.01	33	34.82^{a}	0.03	27	35.03^{b}	0.01	33	34.76^{c}	0.01	30	34.84^{ac}	0.02	86.699	< 0.001
pH	32	8.66^{abg}	0.00	31	8.68^{a}	0.00	33	8.60^{bef}	0.01	27	8.55^{cf}	0.01	33	8.40^{d}	0.00	30	8.62^{eg}	0.01	146.115	< 0.001
Turbidity (NTU)	32	3.68^{ad}	0.20	31	5.53^{ab}	0.60	33	7.72^{b}	1.02	27	4.60^{ab}	0.28	33	4.76^{bc}	0.21	30	3.06^{d}	0.03	73.853	< 0.001
Dissolved oxygen (mg l^{-1})	32	8.13^{af}	0.02	31	7.96^{abe}	0.06	33	6.48^{be}	0.34	27	6.84^{bce}	0.21	33	5.20^{d}	0.05	30	7.73^{ef}	0.28	77.414	< 0.001
2009																				
Temperature (°C)	31	21.00^{a}	0.01	29	20.64^{ab}	0.03	30	20.64^{b}	0.04	30	19.51^{c}	0.12	29	19.61^{c}	0.08	36	19.76^{c}	0.05	149.117	< 0.001
Salinity (psu)	31	33.20^{ac}	0.05	29	33.41^{abd}	0.02	30	33.52^{bde}	0.02	30	32.91^{c}	0.08	29	33.51^{de}	0.02	36	33.65^{e}	0.04	96.994	< 0.001
pH	31	8.84^{ade}	0.01	29	8.89^{bg}	0.00	30	8.90^{b}	0.00	30	8.59^{c}	0.03	29	8.87^{deg}	0.00	36	8.88^{be}	0.01	102.233	< 0.001
Turbidity (NTU)	31	3.91^{ab}	0.15	29	4.69^{ac}	0.35	30	3.37^{bd}	0.12	30	4.20^{bc}	0.28	29	2.92^{de}	0.07	36	2.75^{e}	0.07	101.818	< 0.001
Dissolved oxygen (mg l^{-1})	31	8.59^{a}	0.02	29	8.33^{a}	0.05	30	8.56^{a}	0.09	30	6.53^{b}	0.24	29	8.18^{ac}	0.15	36	8.37^{a}	0.11	63.508	< 0.001

Table 4.1b. Variability of selected physico-chemical variables near the bottom in the western sector of Algoa Bay. Symbols represent appropriate *post hoc* pairwise comparisons and similar symbols represent homogeneity. SE = standard error.

Parameter	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6			F/H	P
	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE		
2008																				
Temperature (°C)	3	19.16^{a}	0.00	3	19.53^{a}	0.10	3	16.01^{bd}	0.07	3	20.83^{c}	0.15	3	15.34^{d}	0.43	3	17.74^{e}	0.06	123.219	< 0.001
Salinity (psu)	3	34.81^{a}	0.02	3	34.81^{a}	0.01	3	34.63^{bd}	0.02	3	35.05^{c}	0.01	3	34.69^{de}	0.02	3	34.72^{e}	0.01	101.289	< 0.001
pH	3	8.66^{a}	0.01	3	8.71^{a}	0.00	3	8.67^{a}	0.02	3	8.50^{bc}	0.01	3	8.41^{c}	0.02	3	8.56^{bd}	0.03	35.625	< 0.001
Turbidity (NTU)	3	5.83^{ab}	1.34	3	9.40^{ab}	2.35	3	13.53^{a}	2.19	3	6.97^{ab}	1.11	3	6.37^{ab}	1.68	3	3.37^{b}	0.07	4.545	0.015
Dissolved oxygen (mg l^{-1})	3	8.50^{a}	0.07	3	7.86^{a}	0.03	3	6.35^{ab}	0.59	3	5.28^{b}	0.60	3	5.06^{bc}	0.14	3	5.03^{bd}	0.34	13.565	< 0.001
2009																				
Temperature (°C)	3	20.90^{a}	0.01	3	20.54^{b}	0.03	3	20.47^{bc}	0.01	3	18.48^{d}	0.05	3	18.94^{e}	0.03	3	19.19^{f}	0.03	1181.36	< 0.001
Salinity (psu)	3	33.03	0.36	3	33.52	0.10	3	33.61	0.11	3	32.74	0.49	3	33.51	0.10	3	33.79	0.21	2.109	0.134
pH	3	8.81^{ab}	0.06	3	8.90^{ab}	0.01	3	8.91^{a}	0.01	3	8.52^{b}	0.14	3	8.87^{ab}	0.01	3	8.86^{ab}	0.03	13.719^{H}	0.017
Turbidity (NTU)	3	4.47	0.85	3	7.30	1.69	3	3.70	0.55	3	6.43	1.68	3	3.63	0.27	3	2.93	0.03	2.663	0.076
Dissolved oxygen (mg l^{-1})	3	8.57^{a}	0.09	3	8.09^{ac}	0.10	3	8.35^{ac}	0.22	3	5.62^{b}	0.39	3	7.38^{cd}	0.18	3	7.66^{ad}	0.14	25.803	< 0.001

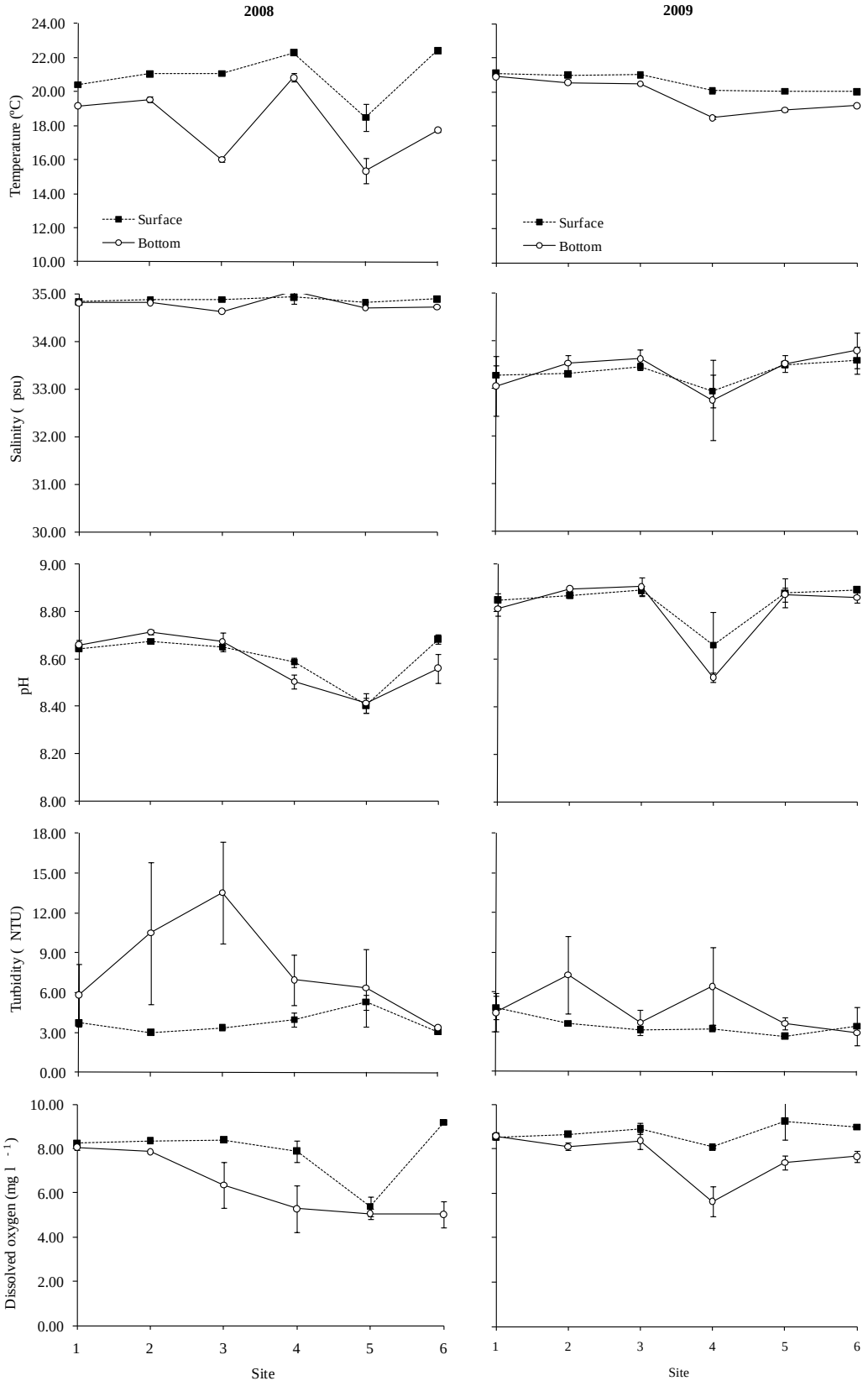

Figure 4.1. Surface and bottom measurements of water temperature (A, B), salinity (C, D), pH (E, F), turbidity (G, H) and dissolved oxygen (I, J) during 2008 and 2009 sampling trips. Data represent mean values (n = 3) ± 1 SD.

Surface and bottom temperature measured in 2009 consistently decreased towards Kings Beach with bottom temperature values lower when compared to surface temperature values (Figure 4.1B). Differences between surface and bottom temperatures were negligible (generally isothermal) off Sundays Estuary mouth (surface–bottom difference = 0.2 ºC) but increased progressively towards Kings Beach with highest differences recorded off Papenkuils (Site 4) (Figure 4.1B). Surface temperature ranged between 20.02 ± 0.03 °C at Site 6 and 21.10 ± 0.04 °C off Sundays Estuary mouth (Site 1), while bottom temperatures ranged between 18.48 ± 0.08 °C off Papenkuils (Site 4) and 20.90 ± 0.03 °C off Sundays Estuary mouth (Appendix 2A). Bottom temperature values decreased significantly between Sundays Estuary mouth and Kings Beach (Table 4.1b) with water column temperature between Papenkuils outfall and Kings Beach generally lower when compared to temperatures recorded in the eastern sector (Sites 1–3; Table 4.1a).

Even though salinity values in the water column were relatively similar in 2008 (Figure 4.1C), minor differences recorded along-shore were significant (H = 86.699, P <0.001; Table 4.1a). Salinity recorded near the Papenkuils outfall was significantly higher compared to other sites (Table 4.1a, b). Surface salinity ranged between 34.81 ± 0.06 at the dumpsite (Site 5) and 34.92 ± 0.14 off Papenkuils (Site 4), while bottom salinity values ranged between 34.63 ± 0.04 off Swartkops Estuary mouth (Site 3) and 35.05 ± 0.02 off Papenkuils. In 2009, salinity of the water column varied along-shore with salinity values at the Papenkuils site significantly reduced (Figure 4.1D; Table 4.1a). However, bottom salinity values along-shore were isohaline (Table 4.1b). Salinity near the surface ranged between 32.93 ± 0.34 off Papenkuils and 33.58 ± 0.28 towards

Kings Beach, while bottom salinity values ranged between 32.74 ± 0.84 off Papenkuils and 33.79 ± 0.37 at Kings Beach.

In 2008, pH of the water column was significantly lower at the dumpsite (Site 5) compared to other sites but generally varied along-shore (Figure 4.1E; Table 4.1a). Near the bottom, pH at the dumpsite and off Papenkuils were similarly low (Table 4.1b). In 2009, pH varied along-shore, with bottom pH at Papenkuils only significantly different to pH adjacent to Swartkops Estuary mouth (Table 4.1b). In 2008, pH near the surface ranged between 8.40 ± 0.04 at the dumpsite and 8.68 ± 0.02 at Kings Beach (Appendix 2A). Near the bottom of the water column, pH ranged between 8.41 ± 0.04 at the dumpsite and 8.71 ± 0.01 at Site 2. Surface pH in 2009 ranged between 8.66 ± 0.13 off Papenkuils and 8.89 ± 0.02 off Swartkops Estuary mouth (Site 3) and Kings Beach (8.89 ± 0.03). Bottom pH ranged between 8.52 ± 0.24 off Papenkuils and 8.91 ± 0.02 off Swartkops Estuary mouth.

Turbidity near the bottom was generally higher than at the surface during both sampling excursions (Figure 4.1G, H). Bottom turbidity was highest off Swartkops Estuary mouth in 2008 but decreased towards Kings Beach where differences between surface and bottom turbidity were relatively low (Figure 4.1G, H; Table 4.1a). Turbidity varied along-shore in 2008 while it was homogeneous in 2009 (Table 4.1b), although it generally decreased towards Kings Beach (Figure 4.1J). Turbidity in 2008 near the surface of the water column ranged between 3.00 ± 0.10 NTU at Site 2 and 5.30 ± 0.56 at the dumpsite (Site 5), while turbidity at the bottom ranged between 3.07 ± 0.06 at Kings Beach and 13.53 ± 3.80 off Swartkops Estuary mouth. In 2009, turbidity near the surface ranged between 2.67 ± 0.06 at Site 5 and 4.83 ± 0.86 off

Sundays Estuary mouth, while turbidity at the bottom ranged between 2.93 ± 0.06 at Kings Beach (Site 6) and 7.30 ± 2.93 at Site 2.

Oxygen content of the water column was generally high during both sampling excursions only decreasing significantly off Papenkuils (Site 4) and at the dumpsite (Table 4.1a). Surface water was generally more oxygenated than bottom waters (Figure 4.1I, J). Dissolved oxygen at the bottom was generally low compared to the surface and consistently decreased towards Kings Beach during both sampling excursions, with the oxygen content significantly lower off Papenkuils (Table 4.1a, b). Maximum difference between surface and bottom oxygen content was recorded adjacent to Kings Beach (difference = 4.14 mg l^{-1}) in 2008. Although bottom waters were generally less oxygenated during both sampling excursions, the water column off Sundays Estuary was generally well mixed (differences of surface and bottom concentrations = 0.19 and -0.05 mg l^{-1}, respectively for both sampling excursions). Bottom water in 2009 was slightly more oxygenated than surface water. Differences in oxygen content in 2009 between surface and bottom water increased towards Kings Beach (Figure 4.1 J). Dissolved oxygen near the surface in 2008 ranged between 5.38 ± 0.44 mg $l^{-1}$from the dumpsite and 9.18 ± 0.07 mg l^{-1} towards Kings Beach, while dissolved oxygen at the bottom ranged between 5.03 ± 0.59 mg l^{-1} from Kings Beach and 8.05 ± 0.12 mg l^{-1} off Sundays Estuary mouth (Appendix 2A). In 2009, dissolved oxygen near the surface ranged between 8.08 ± 0.05 mg l^{-1} off Papenkuils and 9.24 ± mg l^{-1} at the dumpsite, while dissolved oxygen at the bottom ranged between 5.62 ± 0.67 mg l^{-1} off Papenkuils and 8.57 ± 0.15 mg l^{-1} off Sundays Estuary mouth.

Multivariate analysis of physico-chemical variables

The physico-chemical environment of the water column in 2008 varied along the shore, separating sites into four major groups (Figure 4.2A, B). Sites 3, 4 and 5 formed individual groups while the remaining sites (Sites 1, 2 and 6) formed one group. Near the bottom, the physico-chemical environment off Kings Beach (Site 6) differed from that of Sites 1 and 2 and was closely similar to that of Site 5 (Figure 4.2C, D). Physico-chemical environment of Site 4 was unique and the least similar to the rest of the sites (Figure 4.2C).

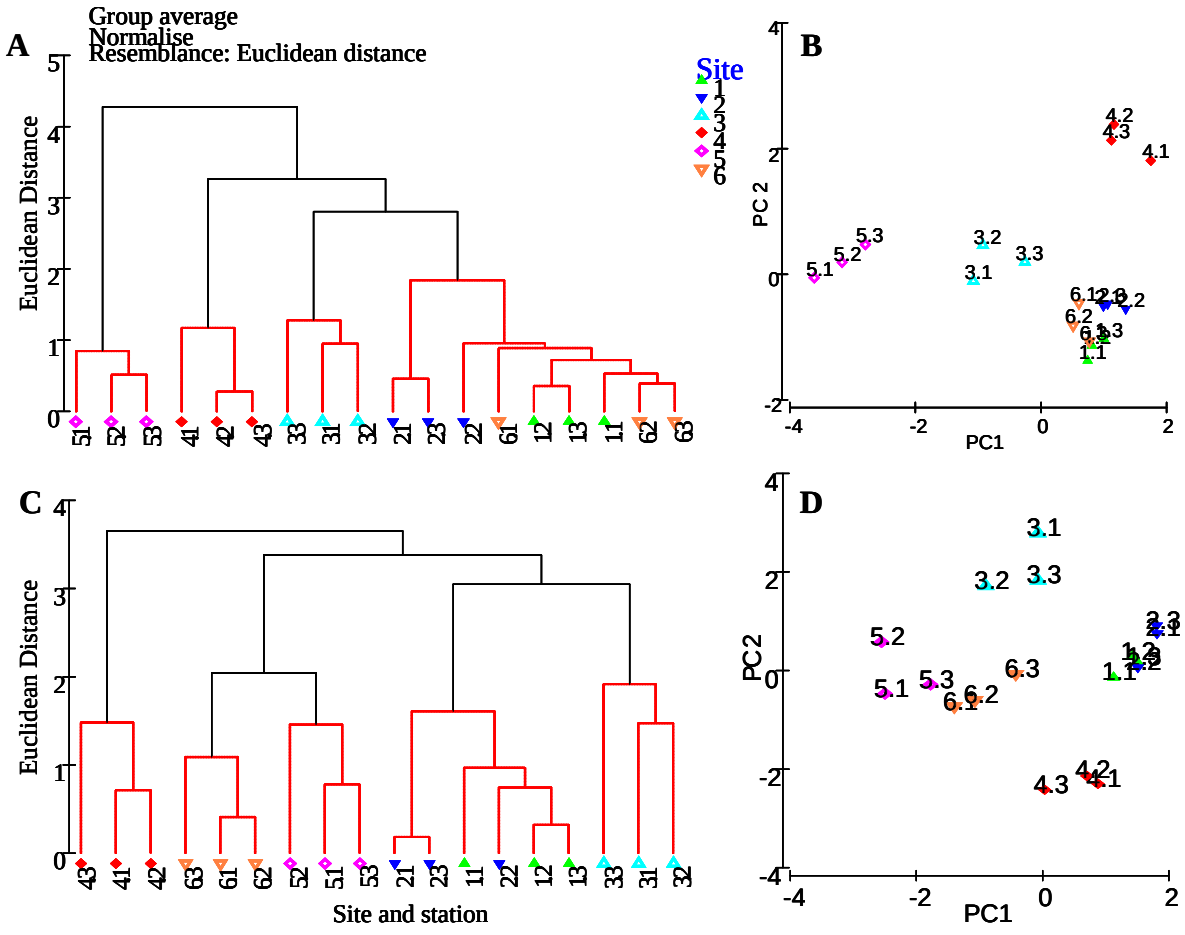

Figure 4.2. Cluster dendrograms with SIMPROF results and PCA ordination plots showing similarities of sites based on the analysis of integrated water column measurements (A, B) and bottom measurements (C, D) in 2008. A site comprises three stations. Therefore 5.1, for example, should be interpreted as Station 1 of Site 5.

The physico-chemical features of the water column at Site 4 (adjacent to Papenkuils outfall) were consistently different to other sites during the second survey. Physico-chemical features of Site 5 and Site 6 were similar during the 2009 sampling excursion (Figure 4.3A, B). Physico-chemical features of the other sites were variable without a clear pattern but features of Sites 1–3 were generally similar. Based on physico-chemical features of the water column, sites generally separated into four broad groups (Figure 4.3A, B). Near the bottom, physico-chemical environment was homogeneous across all sites except for Site 4 (Figure 4.3C, D). The outlier Station 4.1 is situated right at the 'spit' of the effluent.

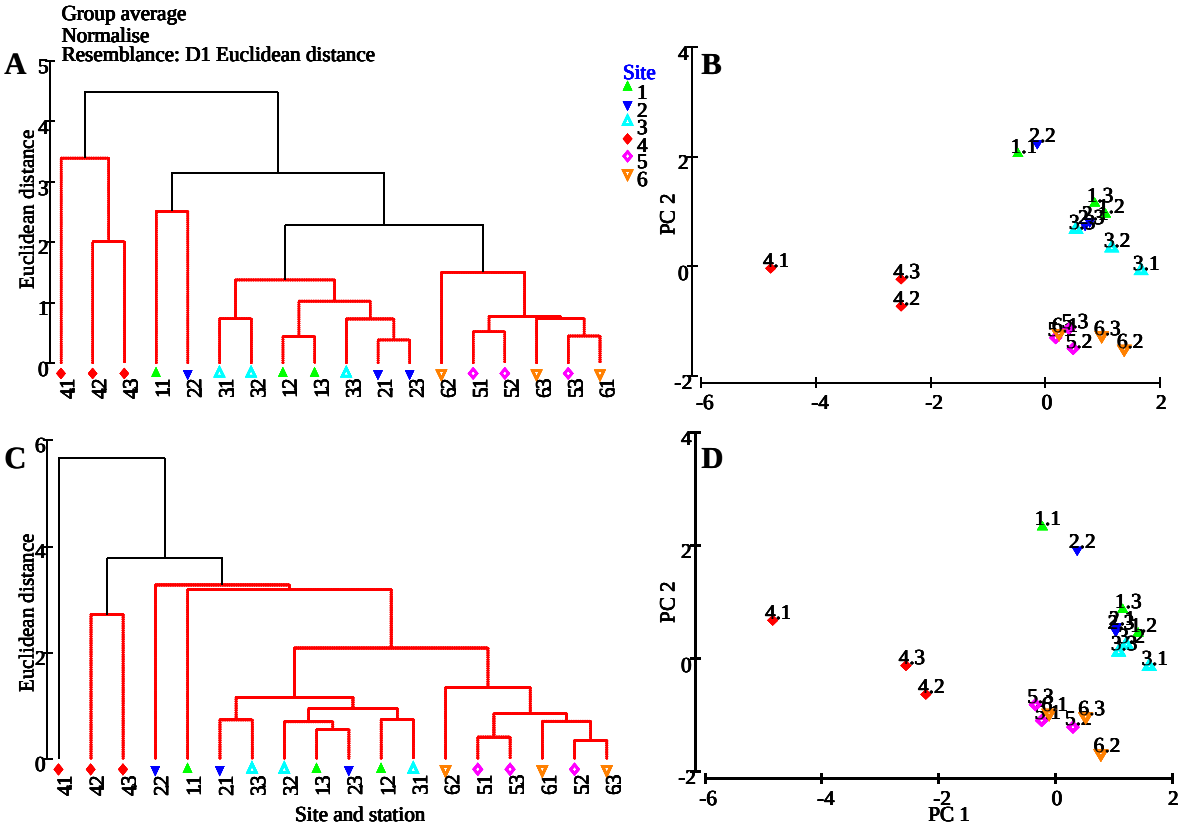

Figure 4.3. Cluster dendrograms with SIMPROF results and PCA ordination plots showing similar sites based on physico-chemical parameters in 2009. A and B represent the whole water column while C and D represent the bottom environment.

4.2. Sediment analysis

4.2.1. Granulometry

Dominant sediment grades were, in their order of dominance: medium sand > fine sand > very fine sand > coarse sand > mud fraction ≥ very coarse sand (Figure 4.4). Medium sized sediment (250–500 µm) dominated sediment composition at 53.40 % and 58.61 % by weight in 2008 and 2009 respectively (Figure 4.4). Fine sediment (125–250 µm) contributed 29.99 % and 26.60 % by weight in 2008 and 2009 respectively. Very fine sediment (63–125 µm) contributed 10.24 % and 6.67 % weight in 2008 and 2009 respectively. Coarse sediment (500–1000 µm) contributed 2.77 % and 2.99 % by weight in 2008 and 2009 respectively. Very coarse sediment (1000–2000 µm) and mud fraction (<63 µm) contributed least (<3 %) to sediment composition. The mud fraction contributed 2.17 % and 1.46 % by weight in 2008 and 2009 respectively. Very coarse sediment contributed 1.44 % weight in 2008 and 3.68 % weight in 2009.

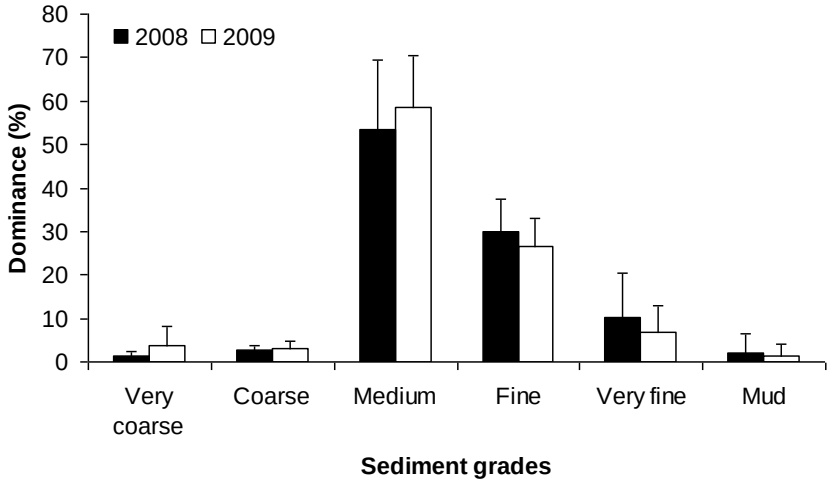

Figure 4.4. Relative contribution (mean + 1 SD; n = 54) of sediment particle size measured from six sites in the western sector of Algoa Bay at a 10 m depth contour. Mud fraction is composed of silt and clay grades.

Contribution and distribution patterns of sediment grades varied between sites (Figure 4.5). Medium sand contribution at Site 4 was reduced by the introduction of finer sediments from the effluent outfall (Figure 4.5A, B). Sites 2 and 5 had the highest percent contribution of the medium sized sediment in 2008 whilst the remaining sites had similar, but lower contributions to the sediment structure except for Site 4, which had the least contribution. The quantity of medium sand at Site 4 was significantly lower when compared to Site 2 and Site 5 (ANOVA, $P = 0.003$ and $P = 0.009$ respectively) in 2008 (Table 4.2a) but was not significantly different to other sites. Sites 2 and 3 in 2009 contributed similarly large quantities of medium sand compared with Site 4 (Figure 4.5; Table 4.2b). Contribution of very coarse and coarse sediment in 2009 was relatively high due to increased quantities of mollusc shell fragments (*pers. obs.*) but was homogeneously distributed between sites. The quantity of very fine sediment at Site 4 was significantly greater compared to other sites during both years (Figure 4.5, Table 4.2a, b). All sites, excluding Site 4, possessed similar quantities of very fine sand (Table 4.2a, b).

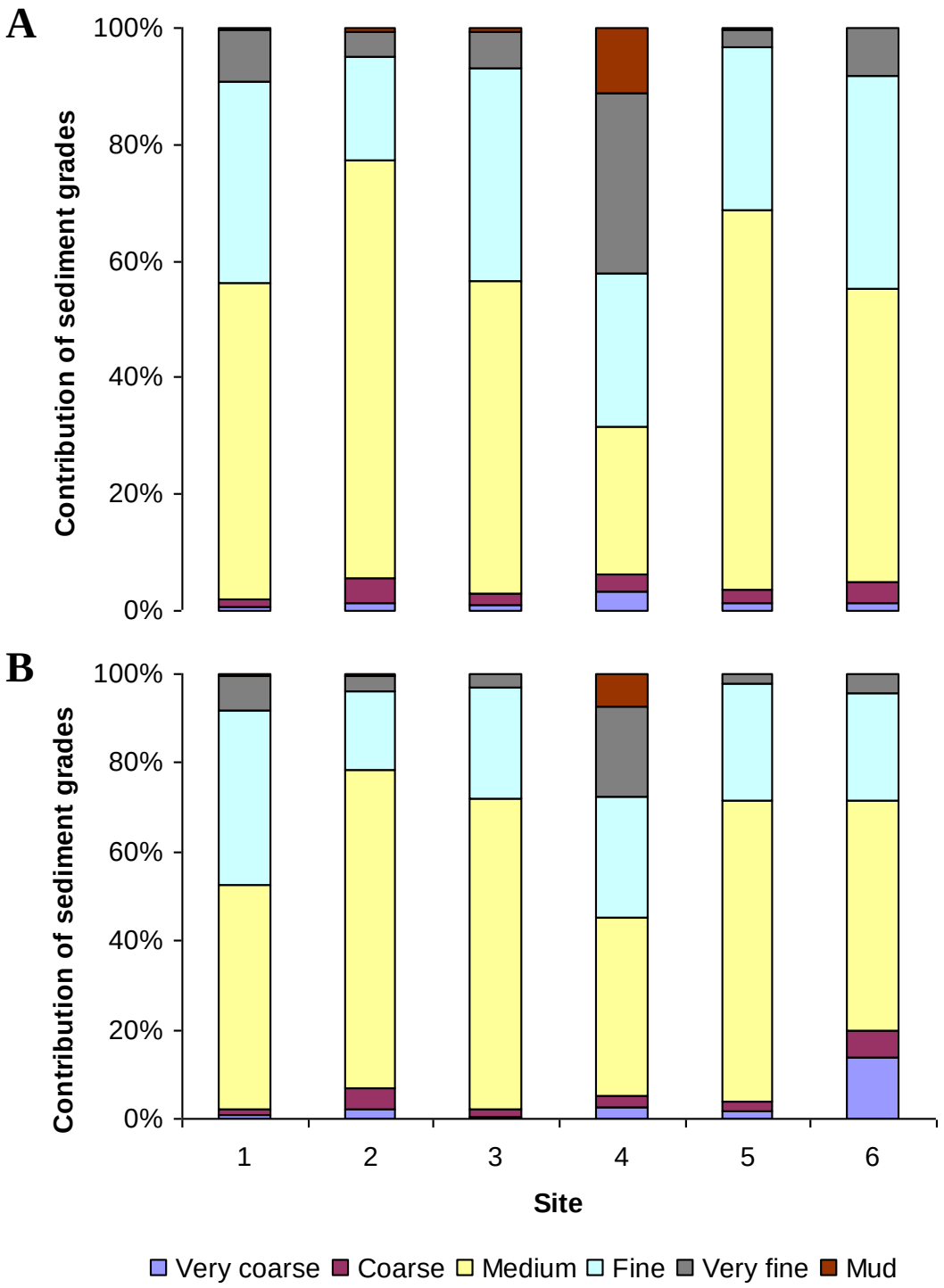

Figure 4.5. Spatial variability in particle size composition of sediment from Sundays Estuary mouth (Site 1) to Kings Beach (Site 6) in the western sector of Algoa Bay, measured in the summer of 2008 (A) and summer of 2009 (B).

Table 4.2a. ANOVA on sediment texture (particle size) for 2008 with pairwise comparison tests (represented by letters). Similar letters indicate homogeneity between sites. * = sediment grades pooled into fractions and X represents the mean.

Sediment parameter	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6			F/H	P value
	n	X	SE	n	X	SE	n	X	SE	n	X	SE	n	X	SE	n	X	SE		
Very coarse	3	0.66	0.10	3	1.20	0.15	3	0.85	0.11	3	3.26	0.50	3	1.20	0.07	3	1.45	0.21	1.535	0.251
Coarse	3	1.35	0.17	3	4.24	1.14	3	2.02	0.47	3	3.13	1.06	3	2.47	0.12	3	3.39	0.85	1.885	0.171
Medium	3	54.15^{ac}	8.04	3	71.97^{a}	2.54	3	53.58^{ac}	9.86	3	25.33^{bc}	7.84	3	65.1^{a}	1.57	3	50.27^{ac}	4.01	6.182	0.005
Fine	3	34.53	5.79	3	17.70	2.16	3	36.61	6.75	3	26.33	4.28	3	28.09	1.03	3	36.65	3.47	2.884	0.062
Very fine	3	9.03^{a}	2.11	3	4.29^{a}	1.47	3	6.30^{a}	2.21	3	30.76^{b}	6.70	3	2.97^{a}	0.30	3	8.08^{a}	1.51	10.855	< 0.001
Mud*	3	0.27^{a}	0.05	3	0.59^{a}	0.29	3	0.63^{a}	0.29	3	11.18^{b}	2.32	3	0.17^{a}	0.04	3	0.16^{a}	0.25	40.533	< 0.001
Sand*	3	99.73	0.05	3	99.41	0.29	3	99.37	0.29	3	88.82	2.32	3	99.83	0.04	3	99.84	0.03	12.967^{H}	0.024

Table 4.2b. Analysis of variance on sediment texture for 2009 with pairwise comparison tests (represented by letters). Similar letters indicate homogeneity between sites. * = sediment grades pooled into fractions and X represents the mean.

Sediment parameter	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6			F/H	P value
	n	X	SE	n	X	SE	n	X	SE	n	X	SE	n	X	SE	n	X	SE		
Very coarse	3	1.05	0.40	3	2.35	0.48	3	0.59	0.14	3	2.66	0.36	3	1.54	0.05	3	13.88	12.02	2.622	0.080
Coarse	3	1.28^{a}	0.27	3	4.48^{a}	1.43	3	1.45^{a}	0.09	3	2.32^{a}	0.13	3	2.33^{a}	0.15	3	6.08^{a}	2.23	14.076^{H}	0.015
Medium	3	50.29^{ac}	8.87	3	71.78^{bc}	0.94	3	70.06^{bc}	6.77	3	40.44^{a}	5.37	3	67.56^{ac}	3.06	3	51.53^{ac}	7.87	4.436	0.016
Fine	3	39.38	6.89	3	17.71	1.39	3	25.00	5.35	3	26.81	1.33	3	26.28	2.82	3	24.40	7.41	2.105	0.135
Very fine	3	7.51^{a}	2.21	3	3.41^{a}	0.83	3	2.73^{a}	1.37	3	20.35^{b}	3.40	3	2.10^{a}	0.49	3	3.92^{a}	1.77	13.015	< 0.001
Mud*	3	0.48^{a}	0.23	3	0.27^{a}	0.07	3	0.19^{a}	0.14	3	7.41^{b}	1.19	3	0.20^{a}	0.01	3	0.19^{a}	0.04	45.140	< 0.001
Sand*	3	99.52	0.23	3	99.73	0.07	3	99.81	0.14	3	92.59	1.19	3	99.80	0.02	3	99.81	0.04	8.863^{H}	0.115

The quantity of the mud fraction (silt + clay) was significantly greater at Site 4 but homogeneously distributed in the rest of the study area (Figure 4.6). This variability pattern is similar to that of very fine sand (Table 4.2a, b).

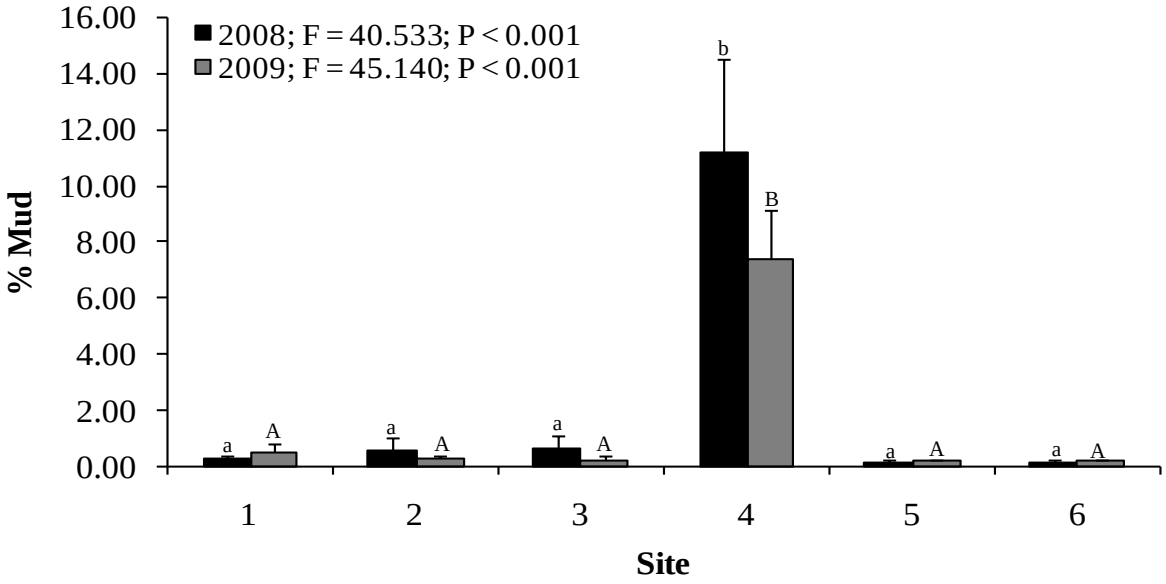

Figure 4.6. Spatial distribution of mud (<63 µm) in the western sector of Algoa Bay. Presented in the graph are mean percentage weights (n = 3) + 1 SD. Similar letters represent homogeneity after Tukey pairwise comparison tests.

4.2.2. Total organic content

Total organic content (TOC) in 2008 ranged between 0.98 % at Site 5 and 2.43 % at Site 4 (Figure 4.7; Appendix 4). In 2009 total organic content of the sediment was slightly lower, ranging between 0.90 % from Site 2 and Site 3 to 1.78 % at Site 4 (Appendix 4). TOC off Papenkuils (Site 4) was consistently high (Figure 4.7), closely resembling the distribution of the mud fraction (see Figure 4.6 above). Lower quantity of TOC at Papenkuils outfall in 2009 was similar to the quantities of organic matter off Kings Beach (Figure 4.7). Although TOC at Site 4 (Papenkuils outfall) in 2008 was

significantly higher compared with the rest of the sites it was also highly variable indicating within-site distribution variability (Figure 4.7).

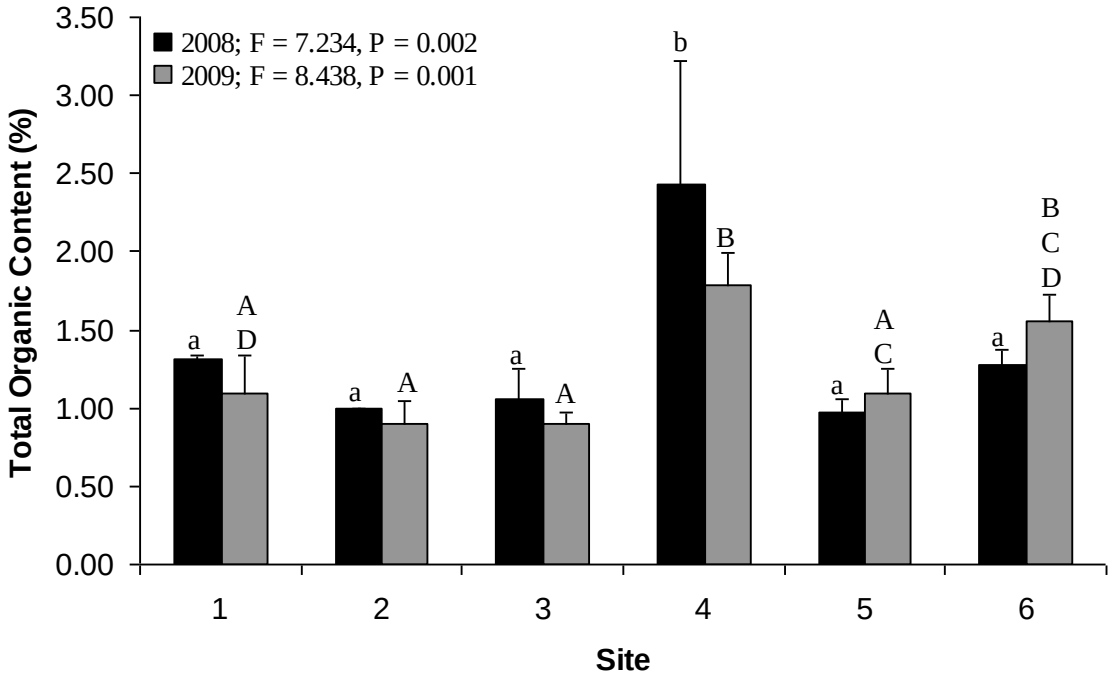

Figure 4.7. Quantity (mean + 1 SD, n = 3) and distribution of total organic content in the western sector of Algoa Bay during the two sampling excursions. Symbols represent pairwise comparison tests, with similar symbols indicating homogeneity.

4.2.3. Sediment heavy metals: 2008

Heavy metal concentrations were within baseline ranges except for slight copper enrichment of 12.32 µg g^{-1} and 7.23 µg g^{-1} at Stations 4.2 and 4.3, respectively (Figure 4.8, Appendix 5). These stations are located at the Papenkuils site that receives a combination of domestic and industrial effluent. Cadmium enrichment at Station 3.2

(0.64 µg g^{-1}) and Station 4.1 (2.34 µg g^{-1}) was also measured (Appendix 5). Baseline concentration for cadmium is 0.322 µg g^{-1} (Newman & Watling 2007).

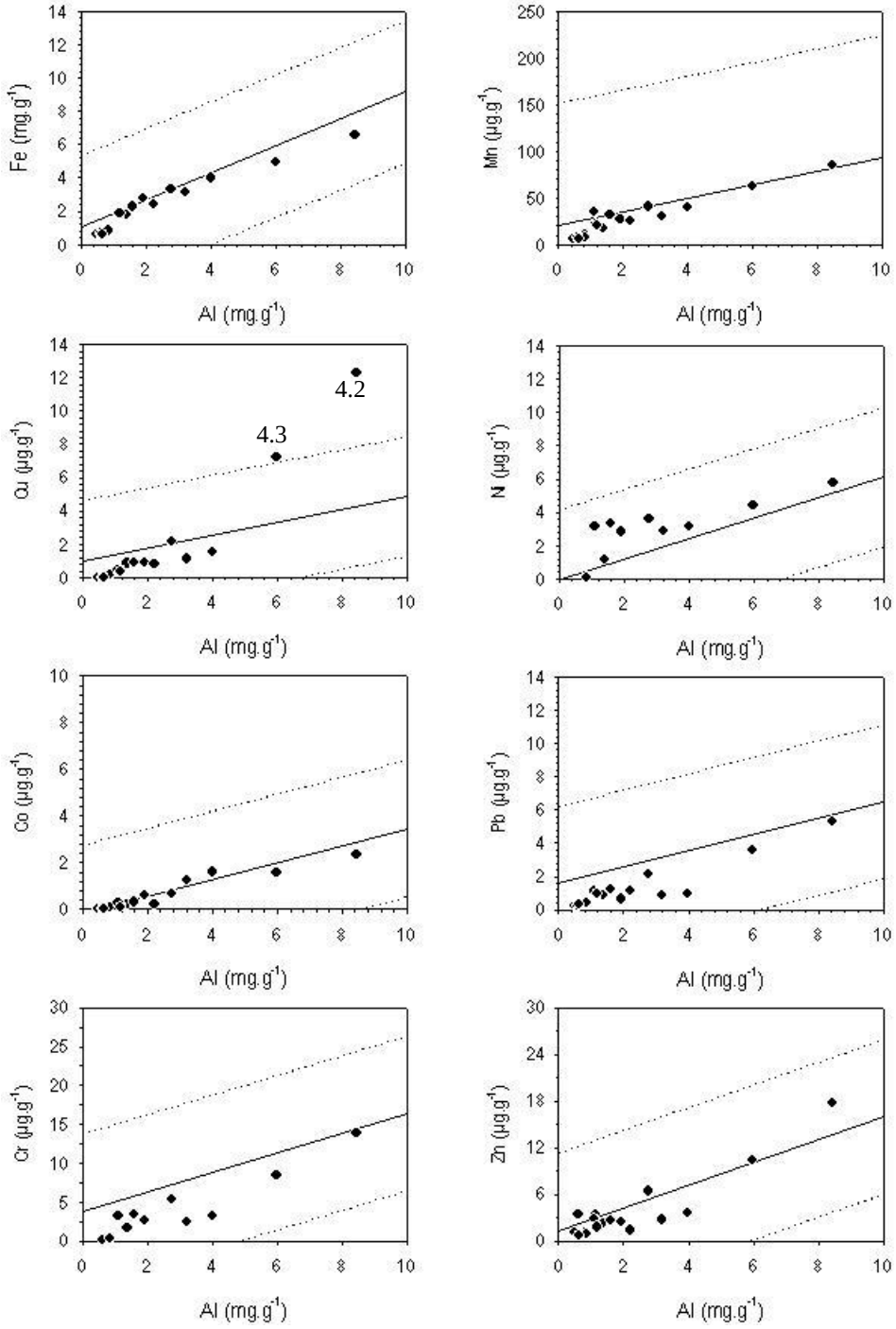

Figure 4.8. Metal-normaliser relationships resulting from the geochemical normalisation procedure. Raw data is overlain on the Eastern Cape baseline model developed by Newman & Watling (2007). Solid lines represent the regression line and dotted lines represent 99 % confidence limits. Concentrations above the confidence limits indicate metal enrichment.

4.2.4. Multivariate analysis of sediment parameters

Analysis of sediment grades sampled in 2008 grouped stations into five categories, in addition to four outliers (Figure 4.9 A, B), while the analysis of sediment fractions (i.e., % sand and % mud) resulted in two categories and one outlier (Figure 4.9 C, D). Papenkuils outfall (Site 4), including its outlier Station 4.1, formed one group and had relatively high mud content (see Figure 4.6). The remaining sites grouped together to form a second category characterised by a higher sand content. The outlier station possibly received larger quantities of finer material that was carried by the effluent as it is located at the 'spit'.

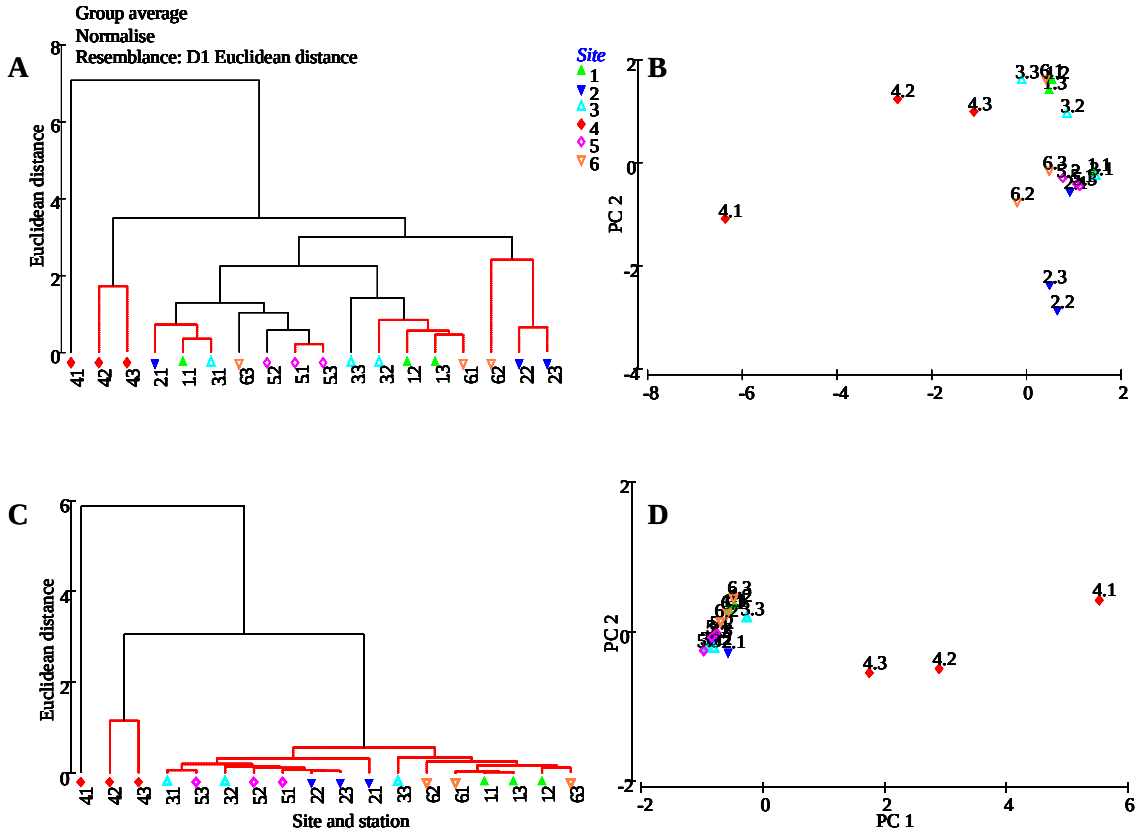

Figure 4.9. Cluster dendrograms with SIMPROF results and PCA ordination plots showing similarities of stations based on sediment texture in 2008. A and B represent results of analysis performed on sediment grades while C and D represent results of analysis performed on sediment fractions (i.e., sand and mud).

Multivariate analysis of sediment grades sampled in 2009 also separated sites into five categories, in addition to outliers (Figure 4.10A, B). Analyses on sediment fractions, however, separated stations into two categories (Figure 4.10C, D). Site 4 consistently separated into an independent but homogeneous group. All other sites separated into a single homogeneous group (Figure 4.10 C, D) and had reduced mud content. Hereafter, Site 4 is referred to as the muddy site and all other sites as sandy sites.

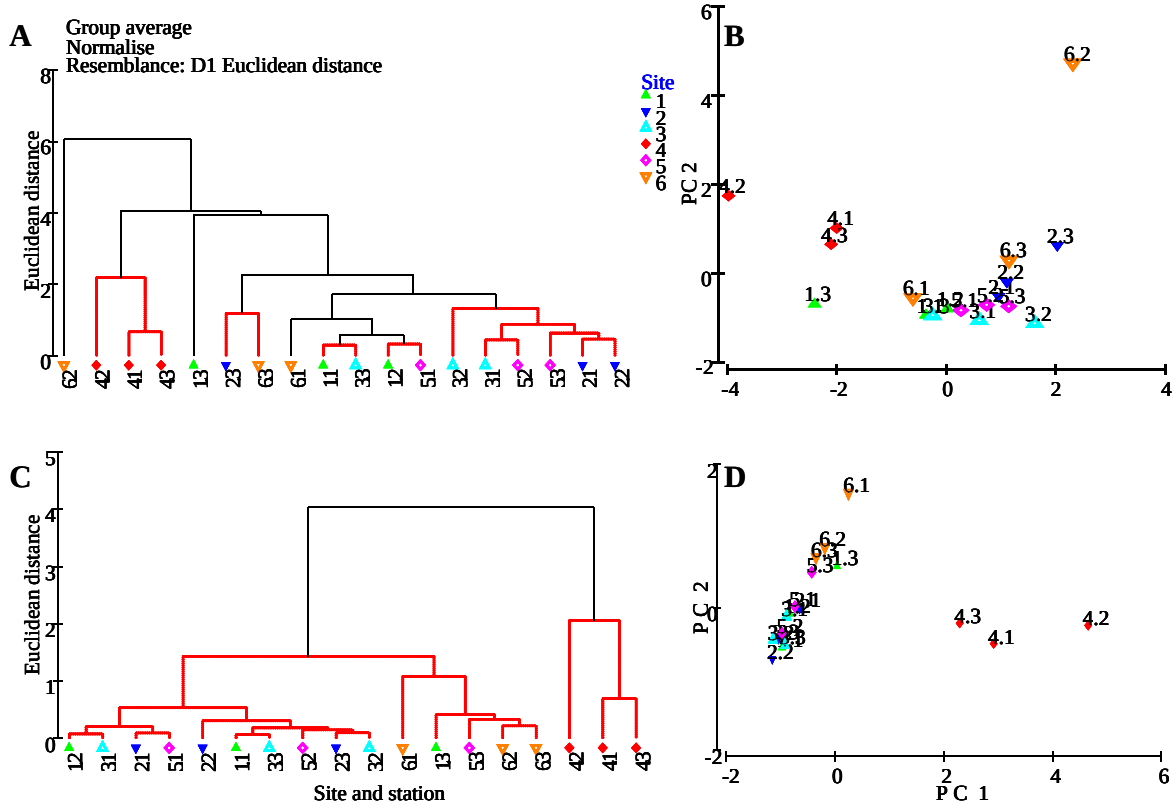

Figure 4.10. Cluster dendrograms with SIMPROF results and PCA ordination plots showing similarities of sites (and stations) based on the analyses of sediment grades (A, B) and sediment fractions (C, D).

4.3. Macrozoobenthic community analysis

4.3.1. Taxonomic composition: 2008

With a calculated sorting efficiency of 94.80 %, a total of 77 437 individuals were removed from the sediment samples. Represented were 174 species, 128 genera, 94 families, 34 orders and 18 classes. The two most important taxonomic groups in terms of abundance were the Amphipoda and Polychaeta (Appendix 7A). Although these two groups cumulatively contributed 50 % to the total faunal abundance, contribution varied spatially (Figure 4.11).

The five most important groups in terms of abundance at each site are given below (also see Table 4.3):

- Site 1: Amphipoda > Polychaeta > Cumacea > Isopoda > Bivalvia.
- Site 2: Amphipoda > Polychaeta > Decapoda > Bivalvia > Cumacea.
- Site 3: Amphipoda > Polychaeta > Cumacea > Isopoda >Echinodermata.
- Site 4: Polychaeta > Bivalvia > Amphipoda > Other > Decapoda.
- Site 5: Amphipoda > Polychaeta > Cumacea > Tanaidacea > Ostracoda.
- Site 6: Amphipoda > Polychaeta > Cumacea > Ostracoda > Mysidacea.

Amphipoda numerically dominated most groups in the study area followed by polychaetes. However, Site 4 was distinctive, with polychaetes dominating composition (Figure 4.11); at this site, bivalves also exceeded amphipods in abundance (Table 4.3).

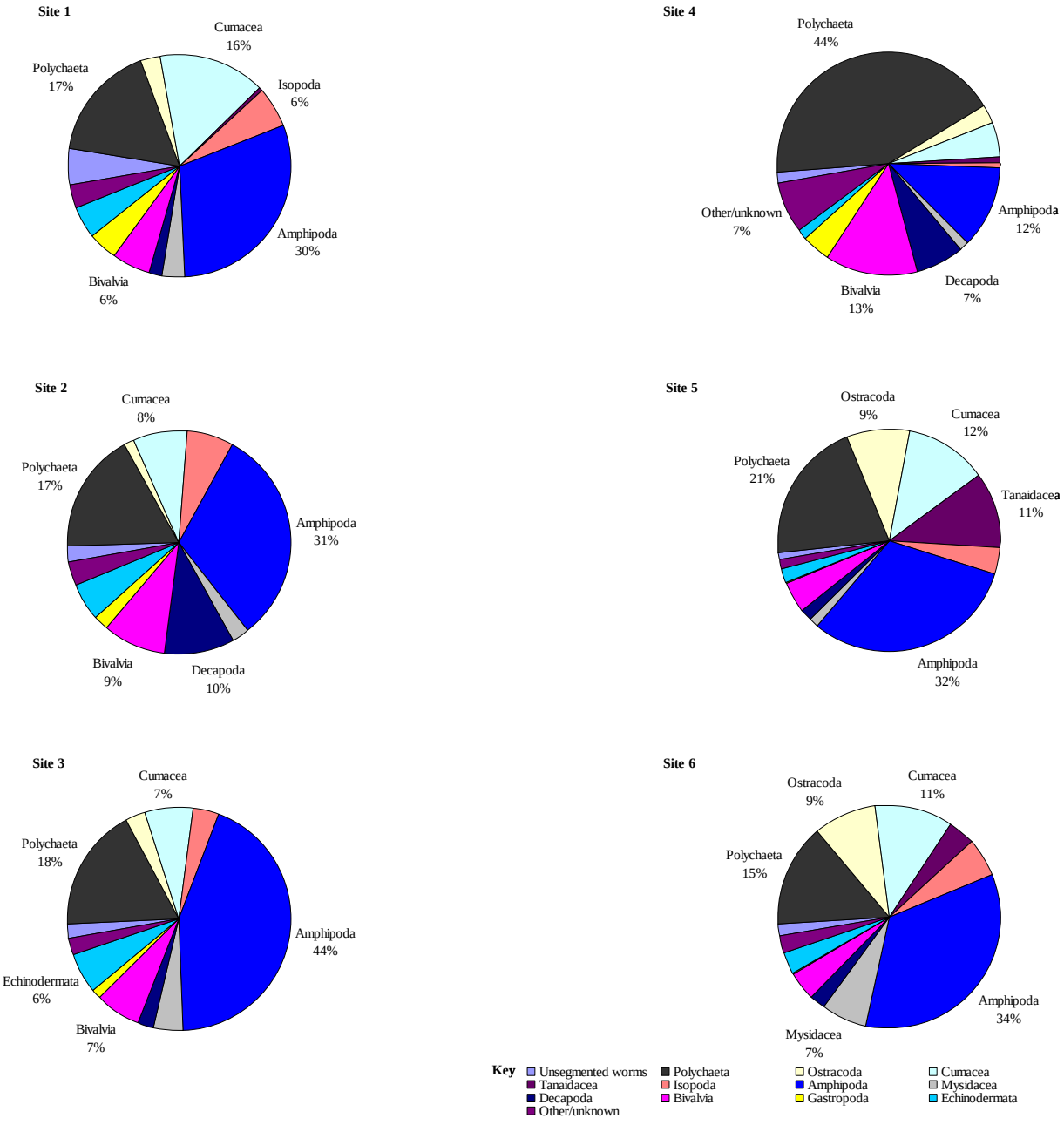

Figure 4.11. Site specific taxonomic composition showing the five most numerically important taxonomic groups for the 2008 community assemblages. The other/unknown category shown is a combination of smaller groups (less abundant or rare) that included: Cnidaria, Oligochaeta, Pycnogonida, Phyllocarida, Caridea, Shrimps, Cephalochordata and unknown organisms. Decapoda were represented by brachyuran and anomuran crabs only.

Table 4.3. Top five numerically abundant groups in the western sector of the bay ranked according to their average abundance (individuals per square meter). Abundance data represent the mean of pooled abundance (n = 75) plus 1 SD (standard deviation). Overall contribution of the top five to site abundance is expressed in percentages.

2008

Rank	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6		
	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD
1	Amphipoda	1029.06	37.48	Amphipoda	956.09	43.35	Amphipoda	1734.68	51.36	Polychaeta	936.68	30.07	Amphipoda	2878.45	69.33	Amphipoda	1723.48	36.77
2	Polychaeta	580.69	18.03	Polychaeta	531.19	25.98	Polychaeta	716.44	21.18	Bivalvia	292.58	24.51	Polychaeta	1894.56	56.39	Polychaeta	748.34	27.31
3	Cumacea	541.16	51.85	Decapoda	305.42	86.98	Cumacea	296.42	29.14	Amphipoda	258.02	9.28	Cumacea	1115.39	199.95	Cumacea	562.72	40.63
4	Isopoda	200.80	23.75	Bivalvia	287.32	36.29	Isopoda	139.54	18.82	Other	163.11	27.82	Tanaidacea	1030.03	282.93	Ostracoda	464.14	64.91
5	Bivalvia	197.99	21.13	Cumacea	247.82	29.64	Echinoderm	239.03	39.43	Decapoda	152.70	18.43	Ostracoda	836.31	113.32	Mysidacea	334.91	29.86
Total contribution (%)		75			75			82			83			85			76	

2009

Rank	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6		
	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD	Taxa	Abundance	SD
1	Polychaeta	982.91	48.46	Amphipoda	938.15	33.42	Amphipoda	1124.93	32.41	Polychaeta	760.42	23.86	Amphipoda	3001.84	61.85	Amphipoda	3154.45	44.45
2	Amphipoda	875.55	30.85	Polychaeta	474.97	23.18	Polychaeta	600.55	25.26	Amphipoda	363.33	11.36	Polychaeta	1462.40	39.50	Polychaeta	1497.57	59.27
3	Other	289.35	20.07	Decapoda	338.66	94.34	Cumacea	208.40	31.62	Bivalvia	213.03	18.81	Tanaidacea	1282.04	361.58	Ostracoda	813.08	54.97
4	Isopoda	272.51	23.39	Cumacea	174.54	31.68	Decapoda	165.87	15.98	Isopoda	189.57	25.20	Ostracoda	1027.84	87.58	Tanaidacea	553.58	147.89
5	Cumacea	243.79	50.60	Gastropoda	173.77	22.49	Bivalvia	126.38	13.94	Decapoda	171.14	21.98	Cumacea	374.75	50.28	Cumacea	453.48	62.21
Total contribution (%)		72			83			79			71			84			83	

4.3.2. Taxonomic composition: 2009

Sorting efficiency in 2009 decreased by 3.85 % to 90.95 %. However, more individuals (80 390) were sampled and were represented by 187 species, 137 genera, 105 families, 38 orders and 17 classes.

Species composition was generally dominated by amphipods and polychaetes between sites, both groups cumulatively contributing 47 to 61 % to total abundance (Figure 4.12). The top five most abundant groups are shown below (also see Table 4.3):

- Site 1: Polychaeta > Amphipoda > Other > Isopoda > Cumacea.
- Site 2: Amphipoda > Polychaeta > Decapoda > Cumacea > Gastropoda.
- Site 3: Amphipoda > Polychaeta > Cumacea > Decapoda > Bivalvia.
- Site 4: Polychaeta > Amphipoda > Bivalvia > Isopoda >Decapoda.
- Site 5: Amphipoda > Polychaeta > Tanaidacea > Ostracoda > Cumacea.
- Site 6: Amphipoda > Polychaeta > Ostracoda > Tanaidacea > Cumacea.

The combination of these five groups cumulatively contributed over 71 % (range: 71–84 %) to total abundance (Table 4.3). The five most abundant groups recorded near the Papenkuils outfall (Site 4) contributed least to overall total abundance. Although amphipods generally dominated at most sites, polychaetes were numerically more important at Site 4 (adjacent to the Papenkuils outfall) and Site 1 (adjacent to the Sundays Estuary mouth). The specific contribution of polychaetes at these two sites was 32 % and 26 %, respectively (Figure 4.12).

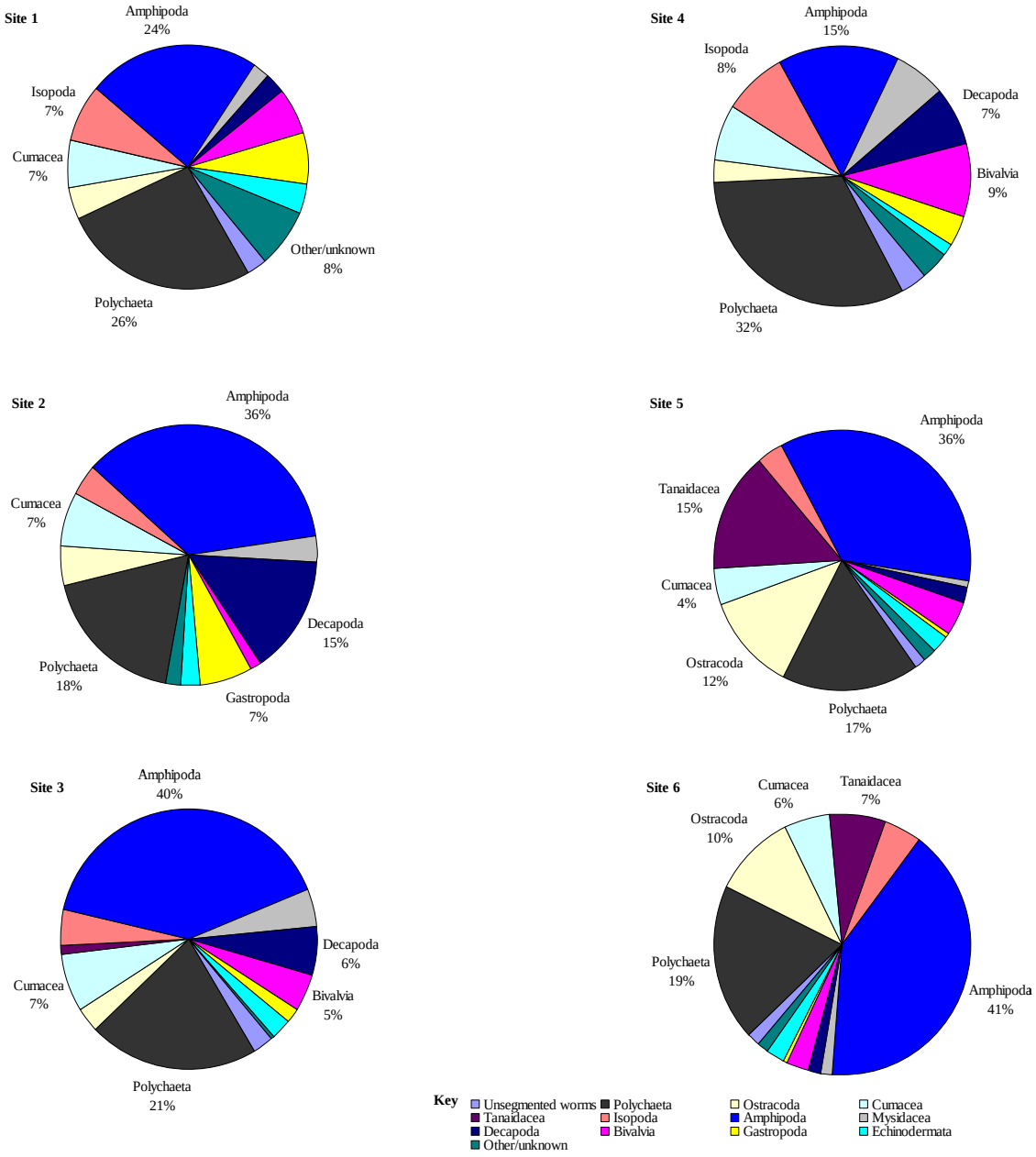

Figure 4.12 Site specific taxonomic composition and five most abundant groups for the 2009 community assemblages. Other/unknown is a combination of smaller groups (least abundant or rare) that included: Cnidaria, Oligochaeta, Pycnogonida, Caridea, Shrimps, Cephalochordata and unknown fauna. Decapoda were represented by brachyuran and anomuran crabs only.

4.3.3. Community descriptors and diversity indices: 2008

Abundance (individuals/m^2) varied significantly (F = 52.618, P <0.001) along-shore, generally increasing towards Kings Beach (Site 6; Figure 4.13A). The area between Sundays Estuary mouth and Swartkops Estuary mouth (Site 1 to Site 3) had similar abundances compared to the area between the Papenkuils outfall and Kings Beach (Site 4 to Site 6) where the number of individuals varied significantly (Figure 4.13A). Highest abundance (mean ± 1SD: 9 014.33 ± 753.34) was recorded at Site 5 (a dredged spoil dumpsite) and the lowest abundance (2 094.33 ± 580.91) was recorded at Site 4 (across Papenkuils).

Number of species (per square meter) also varied significantly (F = 15.661, P <0.001) along-shore (Figure 4.13B). A large number of species was sampled at the dumpsite (81.67 ± 1.76) while fewer species were recorded off Papenkuils outfall (33.33 ± 4.81). Number of species recorded off Papenkuils was significantly fewer than species recorded off Swartkops Estuary mouth, dredged spoil dumpsite and off Kings Beach (Site 6). Variability pattern of the number of species followed that of abundance.

Diversity varied significantly (F = 6.449, P = 0.004) from site to site but with no clear pattern (Figure 4.13C). Margalef's species richness also varied significantly along-shore (F = 12.537, P <0.001), with species richness similar between Sundays Estuary to Swartkops Estuary mouth, while species richness from Papenkuils outfall to Kings Beach varied significantly (Figure 4.13D). Pielou's evenness (which measures the number of individuals per species) showed a significant variability (F = 8.505, P = 0.001) along-shore with evenness at the dumpsite significantly low compared to the rest of the sites but was similar to that of Site 2 (Figure 4.13E).

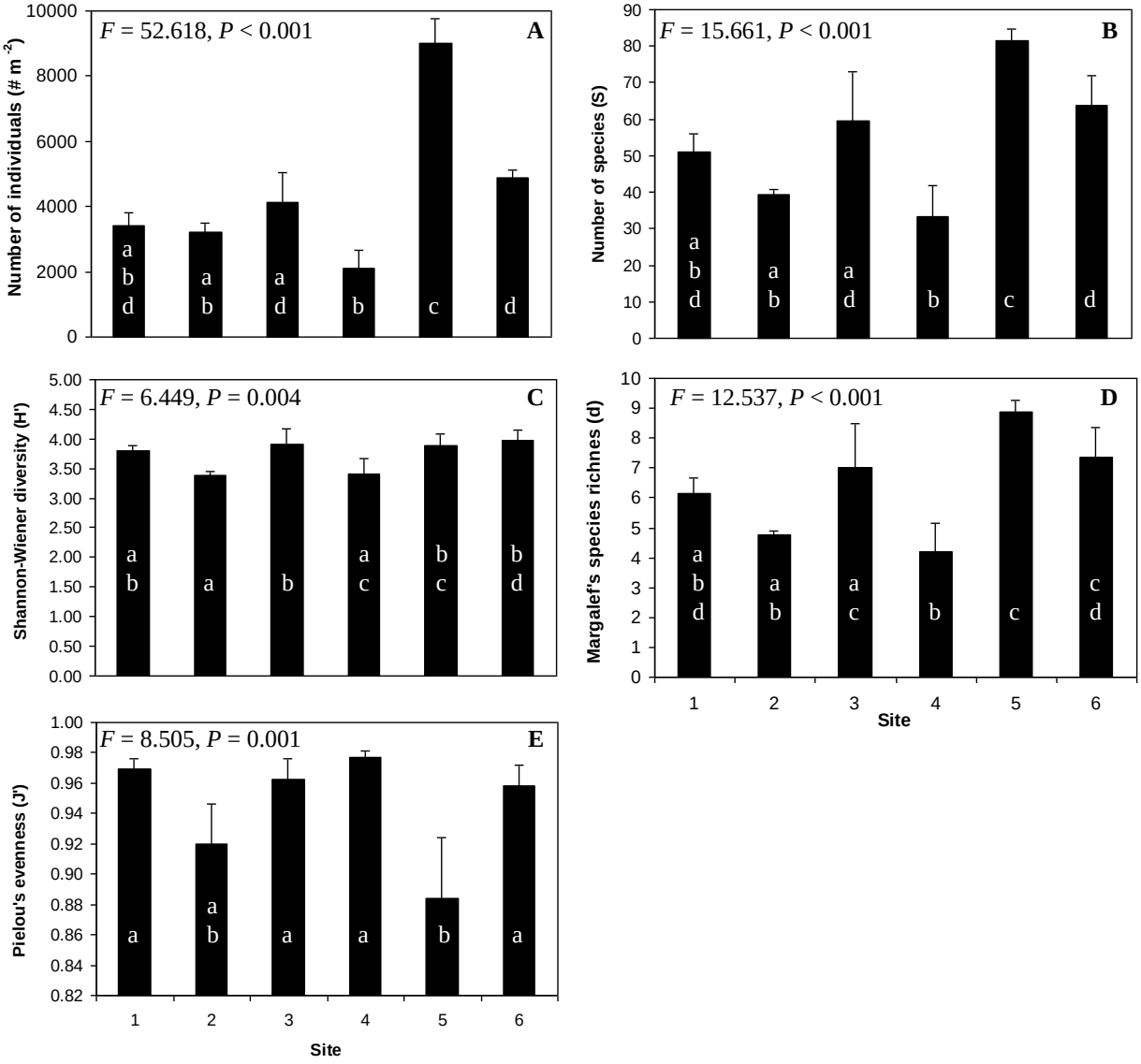

Figure 4.13. Community indices calculated for the 2008 community assemblages. Data represent mean (n = 3) + 1 SD. Letters represent *post hoc* Tukey pairwise comparisons, and similar letters indicate homogeneity or no significant differences.

4.3.4. Community descriptors and diversity indices: 2009

Abundance, number of species and Margalef's species richness were similar between Site 5 (dumpsite) and Site 6 (off Kings Beach) and significantly higher than all other sites (Figure 4.14A, B, D). Diversity between Site 2 and Site 4 (Papenkuils outfall) were similar and significantly lower than diversity levels recorded at Site 5 and Site 6 (Figure 4.14C). Pielou's evenness did not show any significant spatial variability along the shore (Figure 4.14E).

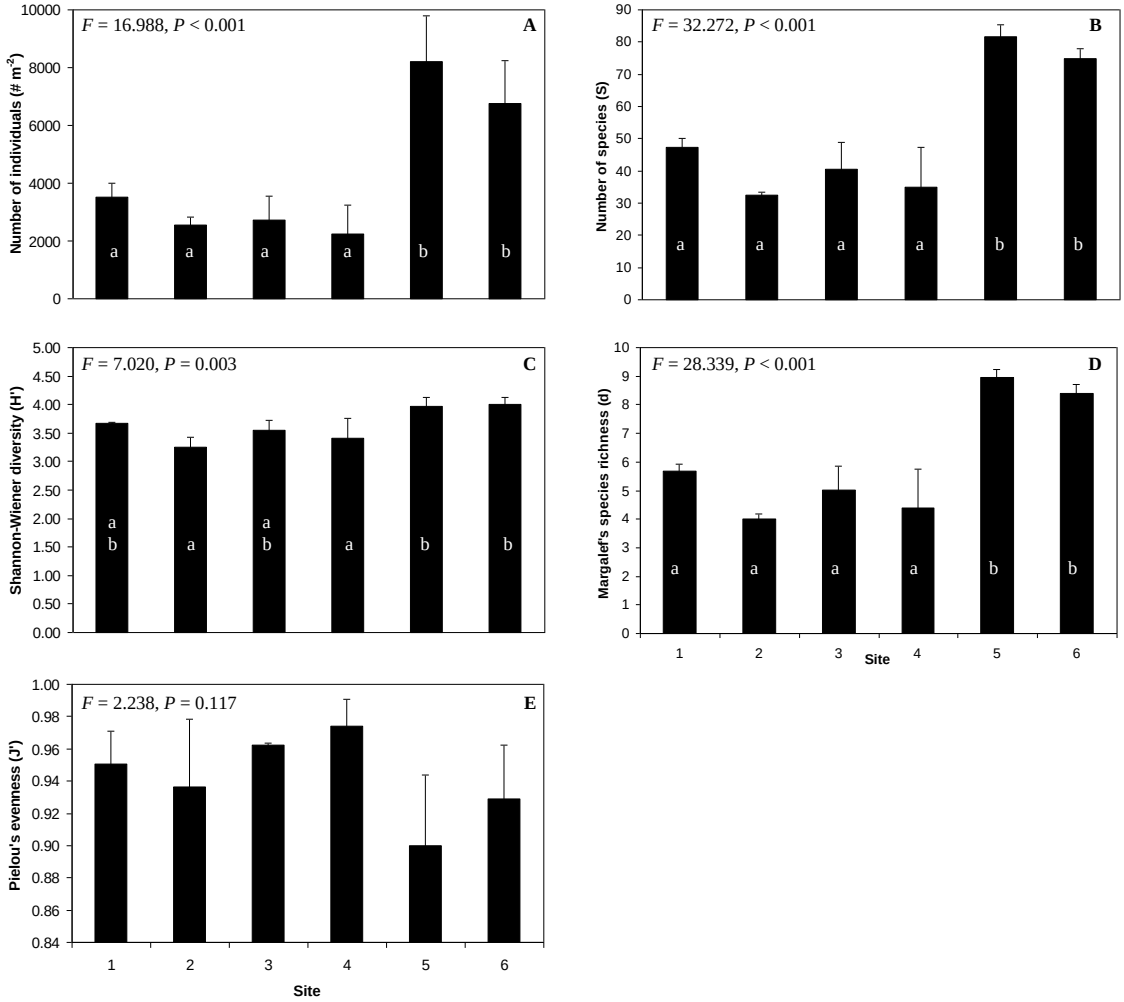

Figure 4.14 Community indices for 2009 community assemblages. Data represent mean (n = 3) + 1 SD. Similar symbols indicate homogeneity or no significant differences between compared sites after *post hoc* Tukey pairwise comparison tests.

4.3.5. Community assemblage pattern in 2008: Cluster and ordination

Community assemblages separated into six groups based on a classification analysis (SIMPROF; Figure 4.15). These groups were separated by site and supported different species assemblages that were significantly different from each other (ANOSIM: global $R = 0.86$, $P < 0.001$; Figure 4.16). Group A = Site 1, Group B = Site 2, Group C = Site 3, Group D = Site 4, Group E = Site 5 and Group F = Site 6. Only one outlier, Station 3.1, was identified in the classification (cluster) dendrogram, and was located at a 'spit' across the Swartkops Estuary mouth. The separation of this station in the two dimensional (2-D) ordination plot (MDS) indicated a slight difference in species composition relative to the two stations at the site (Figure 4.16).

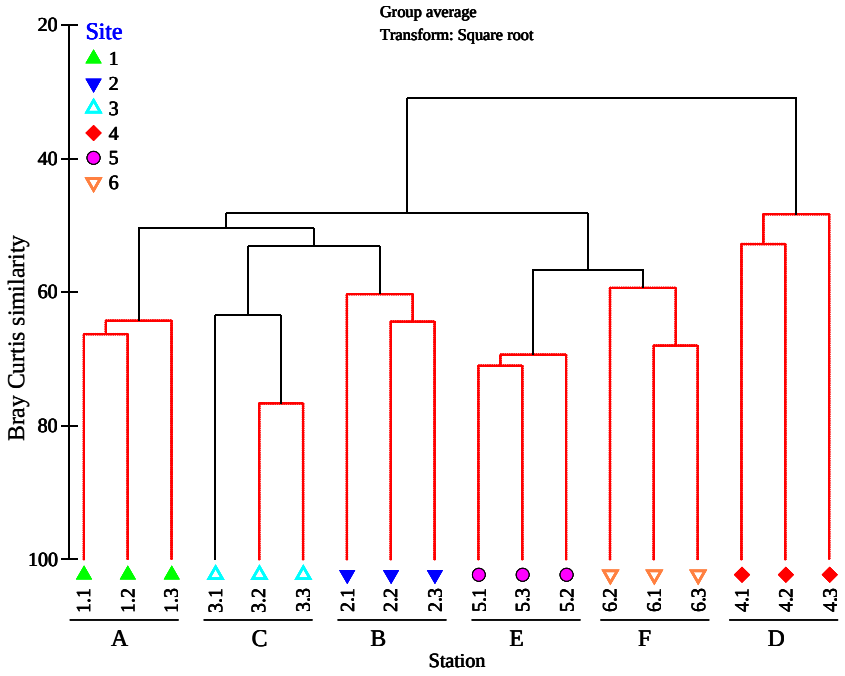

Figure 4.15. A classification (cluster) dendrogram showing six groups identified by a SIMPROF test (red lines). Red lines indicate stations that could not be significantly differentiated (p = <0.05).

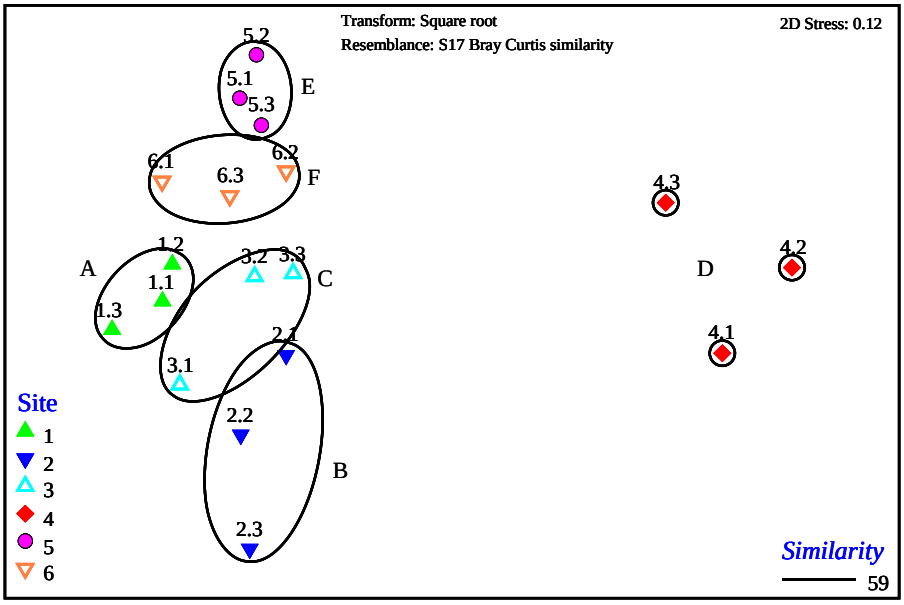

Figure 4.16. Ordination (MDS) of groups (indicated by letters) identified through one way ANOSIM (groups defined *a priori*) in two dimensions. Distance between groups indicates a degree of similarity or dissimilarity in species composition.

4.3.6. Community assemblage pattern in 2009

Cluster analysis separated the benthic community of 2009 into five groups, with two outliers: Stations 3.3 and 6.1 (Figure 4.18). Although assemblages of Site 5 (dredged spoil dumpsite) and Site 6 (Kings Beach site) were different in their internal multivariate structure (Figure 4.18), the species compositions were not significantly different from each other (ANOSIM: R = 0.44, also see Figure 4.19). For easier reference in the present study, Site 5 and Site 6 were assigned similar symbols (e.g., C1 and C2). Site 2 and Site 3 were similar in both internal structures (SIMPROF) and species composition (R statistic = 0.33). ANOSIM result was then used to identify assemblage groups. Group A was represented by Site 1, Group B was represented by Site 2 and Site 3, Group C was represented by Site 5 and Site 6, and Group D was represented by Site 4 (Figure 4.19).

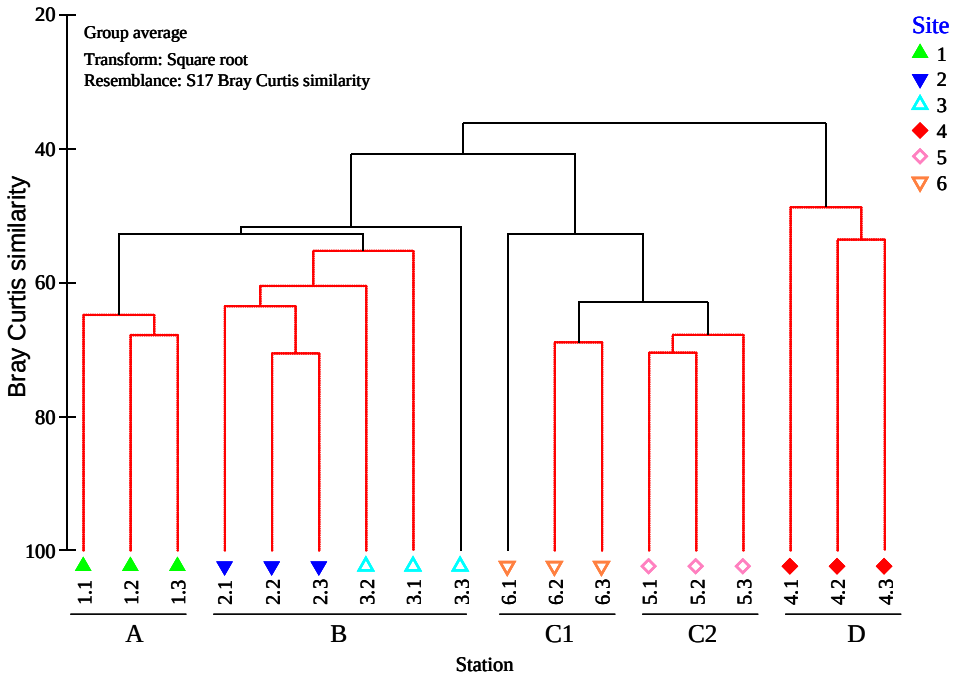

Figure 4.18. Cluster dendrogram showing five groups or assemblages that can be significantly differentiated from each other (SIMPROF test shown in red). Assemblages showing significant different internal structure (e.g., Site 5 and Site 6) but sharing similar species composition (ANOSIM: global R<0.5) are indicated with similar symbols (e.g., C1 and C2).

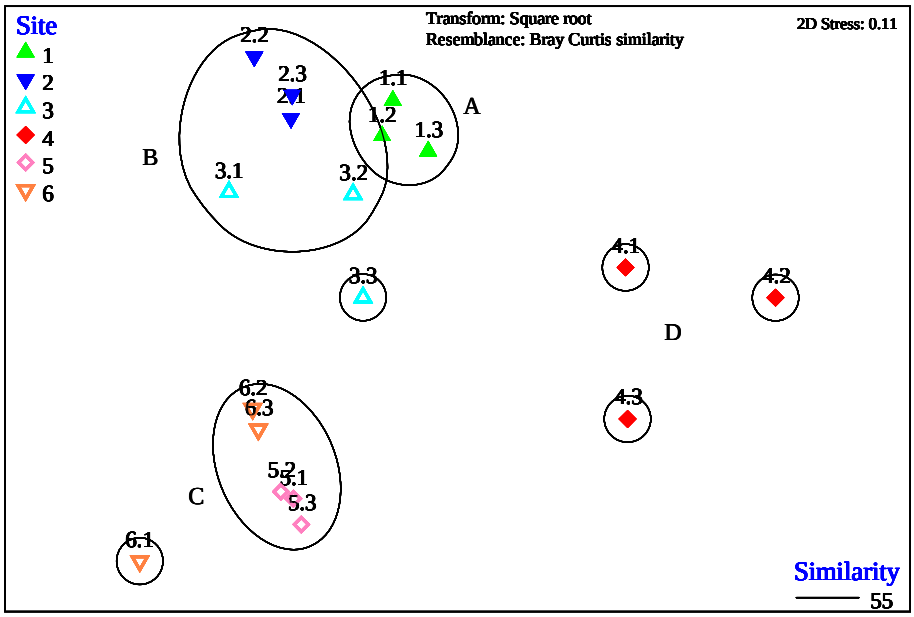

Figure 4.19. Ordination of community assemblage (MDS) in two dimensions for summer of 2009. Group C is composed of Group C1 and Group C2.

4.3.7. Indicator species and discriminator species for 2008 assemblage

Stations comprising Site 1 (n = 3) were 69.41 % similar in terms of species composition (Table 4.4) with 14 taxa contributing 51.37 % to overall average similarity (69.41 %). The five most important indicator taxa (taxa that contributed the most to similarity) were *Bathyporeia sp* (amphipod), *Urothoe pinnata* (amphipod), *U. tumorosa* (amphipod), nannastacid and gynodiastylid cumaceans respectively. Taxa that were consistently abundant among stations at Site 1 (i.e., high Sim/SD ratio) were the amphipods *U. pinnata*, *Laetmatophilus sp* and ceratocumatid cumaceans. *U. pinnata* was the most reliable indicator species at Site 1 (see Chapter 3 for details on identification of indicator species).

Table 4.4. Taxa that contributed ~50 % to the site similarity based on SIMPER analysis. Taxa are arranged in their order of contribution to similarity (Av.Sim). The top five taxa are indicators of the site.

Site 1
Average similarity: 64.91 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Bathyporeia sp.	15.43	3.34	7.24	5.15	5.15
Urothoe pinnata	11.21	2.79	48.81	4.29	9.44
Urothoe tumorosa	11.21	2.72	17.09	4.19	13.64
Nannastacidae	11.33	2.71	14.83	4.18	17.82
Gynodiastylidae	10.39	2.53	10.64	3.9	21.72
Bodotriidae	10.93	2.39	4.68	3.69	25.4
Laetmatophilus sp.	9.32	2.33	31.68	3.58	28.99
Gnathia africana	9.78	2.19	8.59	3.37	32.36
Ceratocumatidae	8.75	2.18	20.75	3.36	35.72
Micronephtys sphaerocirrata	8.76	2.14	19	3.29	39.01
Bivalve juvenile	8.95	2.13	11.6	3.29	42.3
Megaluropus namaquaeensis	8.79	2.04	3.93	3.14	45.44
Magelona papillicornis	7.98	1.98	9.63	3.04	48.49
Nemertea	8.92	1.87	10	2.89	51.37

Stations at Site 2 (n = 3) were 62.11 % similar with only 10 taxa contributing 50.96 % to overall average similarity (Table 4.5). The amphipod *Laetmatophilus sp* contributed most to the observed similarity followed by the isopod *Gnathia africana*, Donacid/Tellinid bivalves, *Mandibulophoxus stimpsoni* (amphipod) and nannastacid cumaceans, respectively. *Laetmatophilus sp* (amphipod) and *G. africana* were also the most abundant at the site with their abundances consistent across the three stations. *G. africana* and *Laetmatophilus sp* were therefore reliable indicator species (Table 4.5). Other important taxa were bivalve juveniles and amphipods of the genus *Heterophoxus*. These latter taxa are referred to as common.

Table 4.5. Taxa that contributed ~50 % to the site similarity. Taxa are arranged in descending order of their contribution to similarity.

Site 2
Average similarity: 62.11 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Laetmatophilus sp.	18.33	5.46	19.72	8.8	8.8
Gnathia africana	13.07	3.86	27.73	6.22	15.02
Donacidae/Tellinidae	11.78	3.35	4.64	5.39	20.41
Mandibulophoxus stimpsoni	11.29	3.22	6.92	5.18	25.59
Nannastacidae	9.31	2.85	11.22	4.59	30.17
Spionidae	12.26	2.82	12.14	4.54	34.71
Bivalve juvenile	8.7	2.66	28.13	4.29	39
Heterophoxus spp	8.45	2.59	25.72	4.17	43.17
Nemertea	8.35	2.42	6.19	3.9	47.07
Micronephtys sphaerocirrata	8.07	2.42	6.19	3.9	50.96

Stations at Site 3 (n = 3) were 67.81 % similar with 17 taxa contributing 51.52 % to overall average similarity (Table 4.6). Top five indicator taxa were *U. pinnata, U. tumorosa, M. stimpsoni*, bivalve juveniles and ophiuroid echinoderms respectively (Table 4.6). Not only did these taxa have the highest similarity, but they were also the

most abundant. However, abundance was not consistent across all stations except for bivalve juveniles (Table 4.6). Bivalve juveniles were thus reliable indicators of the site. Common taxa were nemertean worms and *Micronephtys sphaerocirrata* (polychaete).

Table 4.6. Taxa that contributed ~50 % to the group similarity. Indicator taxa were those with highest contribution to similarity while reliable taxa had, in addition, consistent abundance across stations.

Site 3
Average similarity: 67.81 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum. (%)
Urothoe pinnata	19.57	3.9	10.26	5.75	5.75
Urothoe tumorosa	11.74	2.55	8.32	3.77	9.52
Mandibulophoxus stimpsoni	11.66	2.2	2.66	3.25	12.77
Bivalve juvenile	10.67	2.18	33.9	3.22	15.99
Ophiuroidea	10.85	2.15	13.13	3.17	19.16
Micronephtys sphaerocirrata	10.21	2.06	21.32	3.04	22.2
Echinocardium cordatum	9.33	2.01	13.42	2.97	25.16
Heterophoxus spp	9.55	1.99	8.65	2.94	28.1
Perioculodes longimanus	8.73	1.88	7.43	2.77	30.87
Mesopodopsis wooldridgei	8.8	1.84	7.18	2.71	33.58
Donacidae/Tellinidae	8.68	1.82	8.65	2.69	36.27
Gnathia africana	8.71	1.82	7.09	2.68	38.96
Nannastacidae	8.27	1.81	11.81	2.67	41.63
Diastylidae	8.04	1.77	7.89	2.6	44.23
Phoxocephalidae	8.13	1.68	4.33	2.48	46.72
Nemertea	8.57	1.63	36.53	2.4	49.12
Ostracoda sp 3	7.75	1.63	6.24	2.4	51.52

Stations at Site 4 (n = 3) had the lowest similarity (50.28 %) with only eight taxa contributing 53.3 % to overall average similarity (Table 4.7). Indicator taxa that contributed most to similarity were *M. sphaerocirrata*, glycerid polychaetes, donacid/tellinid bivalves, *Glycinde capensis* (polychaete) and other nephtyid

polychaetes (Table 4.7). Nephtyid polychaetes, orbiniid polychaetes and *G. capensis* were the most consistently abundant across stations. Based on this, nephtyid polychaetes were considered reliable indicators of the Site 4 assemblage.

Table 4.7. Taxa that contributed ~50 % to the similarity of the assemblage opposite the effluent outfall (Station 4). Taxa are arranged in a descending order of contribution to similarity.

Site 4
Average similarity: 50.28 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Micronephtys sphaerocirrata	10.91	4	5.54	7.95	7.95
Glyceridae	9.17	3.53	8.29	7.01	14.96
Donacidae/Tellinidae	9.87	3.51	5.54	6.99	21.95
Glycinde capensis	9.89	3.46	12.42	6.89	28.84
Nephtyidae	9.36	3.41	24.03	6.79	35.63
cf Queubus jamesanus	10.34	3.19	2.98	6.35	41.98
Orbiniidae	8.67	3.02	13.8	6	47.98
Magelona papillicornis	7.38	2.79	7.75	5.54	53.53

The three stations at Site 5 were 69.96 % similar in species composition. More taxa (21 taxa) contributed 51.13 % to the overall average group similarity (Table 4.8). Indicator taxa were gynodiastylid cumaceans, *U. tumorosa*, *M. sphaerocirrata*, *Maera sp 1* (amphipod), and diastylid cumaceans respectively. Of the five indicators, cumaceans of the family Diastylidae were the most consistently abundant at all stations and are therefore considered as the most reliable indicators (Table 4.8). Common taxa of the dumpsite were *G. africana*, opportunistic polychaetes of the family Cirratulidae and ophiuroids (Table 4.8).

Table 4.8. Taxa that contributed ~50 % to the similarity of the group at Site 5. Taxa are arranged in descending order of their contribution to similarity.

Site 5
Average similarity: 69.96 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Gynodiastylidae	24.13	2.71	2.92	3.87	3.87
Urothoe tumorosa	19.67	2.31	5.42	3.31	7.18
Micronephtys sphaerocirrata	17.82	2.22	6.68	3.17	10.35
Maera sp1	16.85	2.14	7.28	3.06	13.41
Diastylidae	15.67	2.08	38.76	2.97	16.38
Ostracoda sp 4	19.2	2.06	2.22	2.95	19.33
Urothoe pinnata	15.32	1.93	10.3	2.76	22.1
Apseudes minutus	25.62	1.83	2.42	2.62	24.71
Ostracoda sp 2	14.93	1.82	5.78	2.59	27.31
Cirratulidae sp 2	14.62	1.73	4.01	2.48	29.79
Mandibulophoxus stimpsoni	13.77	1.58	5.22	2.25	32.04
Cirratulidae	12.62	1.56	46.22	2.23	34.27
Gnathia africana	11.06	1.44	58.72	2.06	36.33
Bivalve juvenile	13.29	1.43	16.74	2.04	38.37
Ostracoda sp 3	11.78	1.38	6.07	1.98	40.35
Urothoe platypoda	12.58	1.36	37.52	1.94	42.29
Gammaridae	12.91	1.31	25.48	1.87	44.16
Isopod larvae	11.51	1.3	4.51	1.85	46.02
Donacidae/Tellinidae	11.22	1.27	22.7	1.81	47.83
Ophiuroidea	9.34	1.18	46.21	1.69	49.52
Spionidae	9.13	1.13	4.74	1.61	51.13

Stations at Site 6 (n = 3) were 63.20 % similar with 18 taxa contributing 52.10 % to overall similarity (Table 4.9). Indicator taxa were: Ostracod sp 2, *M. stimpsoni, M. sphaerocirrata*, diastylid cumaceans and *U. platypoda* respectively. The most consistently abundant (and common) taxa were *Apseudes minutus* (tanaid), *Amakusanthura africana* (isopod), gynodiastylid cumaceans, Ostracod sp 3 and *U. platypoda* (Amphipoda).

Table 4.9. Taxa that contributed ~50 % to the site similarity. Taxa are arranged in descending order of their contribution to similarity.

Site 6
Average similarity: 63.20 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Ostracoda sp 2	15.21	2.59	8.64	4.1	4.1
Mandibulophoxus stimpsoni	13.94	2.49	5.2	3.93	8.03
Micronephtys sphaerocirrata	12.72	2.32	9.8	3.66	11.7
Diastylidae	11.49	1.99	16.02	3.15	14.84
Urothoe platypoda	10.04	1.96	21.72	3.09	17.94
Urothoe tumorosa	10.8	1.89	6.79	2.98	20.92
Bathyporeia sp.	11.17	1.79	8.87	2.84	23.76
Gnathia africana	9.66	1.77	11.84	2.8	26.56
Ostracoda sp 3	10.3	1.76	21.68	2.79	29.35
Bivalve juvenile	9.96	1.71	18	2.71	32.06
Bodotriidae	10.01	1.65	12.17	2.61	34.66
Apseudes minutus	9.49	1.63	58.53	2.57	37.24
Hippomedon longimanus	8.3	1.6	18.03	2.53	39.77
Ceratocumatidae	8.3	1.59	10.8	2.51	42.28
Amakusanthura africana	8.46	1.57	37.3	2.49	44.77
Gynodiastylidae	8.11	1.57	29.32	2.48	47.24
Nannastacidae	8.79	1.55	5.99	2.46	49.7
Spionidae	7.89	1.51	18.72	2.4	52.1

Dissimilarity between groups (or sites) ranged between 43 % to 70 % with assemblages at the dumpsite (Site 5) and Kings Beach (Site 6) being least dissimilar (Table 4.10). Highest dissimilarity was measured between Site 2 and Site 4 assemblages. High dissimilarities were generally recorded when species composition of sites were compared to that of the assemblage opposite Papenkuils outfall (Site 4). Reliable discriminators could not be identified when sites were compared with Site 5 (Table 4.10). Reliable discriminators are usually highly abundant in one site while less abundant in the compared site (see Appendix 6A).

Table 4.10. Top 5 discriminator taxa, with an indication of their ability to consistently contribute to the level of dissimilarity (i.e., Dissimilarity/Standard Deviation (Diss/SD) ratio) for the 2008 community assemblage. Dissimilarity (%), maximum Diss/SD ratio and most reliable discriminator taxa are indicated in bold.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Site 1						
Site 2	**51.18 %** **max Diss/SD: 17.98** *Bathyporeia sp.* (2.63) Diogenidae (0.91) *Laetmatophilus sp.* (3.45) *Urothoe tumorosa* (2.05) *Mandibulophoxus stimpsoni* (1.81)					
Site 3	**47.99 %** **max Diss/SD: 11.11** *Bathyporeia sp.* (2.74) ***Heterophoxus spp*** (7.88) *Mandibulophoxus stimpsoni* (1.64) *Urothoe pinnata* (2.98) *Heterophoxus cephalodens* (4.49)	**46.72 %** **max Diss/SD: 8.64** *Laetmatophilus sp.* (2.75) ***Urothoe pinnata*** (4.42) Diogenidae (1.12) *Urothoe tumorosa* (2.11) *Heterophoxus cephalodens* (3.60)				
Site 4	**68.86 %** **max Diss/SD: 10.32** ***Bathyporeia sp.*** (5.50) ***Urothoe pinnata*** (10.32) ***Glycinde capensis*** (6.80) ***Gnathia africana*** (5.83) Nannastacidae (1.90)	**69.81 %** **max Diss/SD: 16.80** *Laetmatophilus sp.* (3.19) *Gnathia africana* (5.38) *Mandibulophoxus stimpsoni* (5.81) *cf Queubus jamesanus* (3.16) Diogenidae (0.93)	**68.52 %** **max Diss/SD: 8.17** ***Urothoe pinnata*** (5.90) *Mandibulophoxus stimpsoni* (2.75) *cf Queubus jamesanus* (2.87) ***Heterophoxus spp* (6.18)** *Urothoe tumorosa* (1.99)			
Site 5	**53.32 %** **max Diss/SD: 31.63** *Apseudes minutus* (1.38) *Ostracoda sp 4* (3.07) *Maera sp 1* (8.04) Gynodiastylidae (2.13) *Mandibulophoxus stimpsoni* (2.62)	**57.84 %** **max Diss/SD: 43.30** *Apseudes minutus* (1.56) Gynodiastylidae (2.90) *Ostracoda sp 4* (3.07) *Urothoe tumorosa* (3.02) *Cirratulidae sp 2* (4.97)	**46.31 %** **max Diss/SD: 11.60** *Apeudes minutus* (1.54) *Ostracoda sp 4* (2.97) Gynodiastylidae (2.37) *Maera sp 1* (3.24) *Urothoe platypoda* (2.90)	**69.10 %** **max Diss/SD: 16.31** *Apseudes minutus* (1.55) Gynodiastylidae (2.59) *Ostracoda sp 4* (3.02) *Urothoe tumorosa* (2.88) *Maera sp 1* (7.39)		
Site 6	**47.73 %** **max Diss/SD: 19.24** *Mandibulophoxus stimpsoni* (2.26) Mysid larvae (1.42) *Ostracoda sp 2* (2.09) ***Urothoe platypoda*** (19.24) *Hippomedon longimanus* (6.38)	**53.28 %** **max Diss/SD: 21.38** *Laetmatophilus sp.* (2.85) Mysid larvae (1.32) *Ostracoda sp 2* (2.17) ***Urothoe platypoda*** (21.38) *Apseudes minutus* (5.35)	**48.63 %** **max Diss/SD: 10.60** Mysid larvae (1.29) *Urothoe pinnata* (2.28) ***Urothoe platypoda*** (8.88) ***Heterophoxus spp*** (8.37) *Apseudes minutus* (4.64)	**68.34 %** **max Diss/SD: 11.43** *Mandibulophoxus stimpsoni* (5.54) *Ostracoda sp 2* (2.49) Diastylidae (4.02) *Bathyporeia sp.* (2.96) Mysid larvae (1.42)	**43.08 %** **max Diss/SD: 30.24** *Apseudes minutus* (1.02) Gynodiastylidae (2.47) *Maera sp 1* (3.58) *Ostracoda sp 4* (1.92) Isopod larvae (4.23)

4.3.8. Indicator species and discriminator species for the 2009 assemblage

Stations of Site 1, comprising Group A (n = 3), were 65.79 % similar with 15 taxa contributing 51.61 % to overall average similarity (Table 4.11). Indicator taxa were *U. pinnata*, spionid polychaetes, nannastacid cumaceans, *M. sphaerocirrata* and bodotriid cumaceans, respectively. Cirratulid polychaetes, nannastacid cumaceans and *U. pinnata* were the most consistently abundant amongst stations. Nannastacid cumaceans were more reliable indicator taxa of the five, although their consistency was low. Cirratulid polychaetes were consistently abundant across stations but had lower contribution to similarity.

Table 4.11. Taxa that contributed ~50 % to the site similarity plus their major attributes to the site. Taxa are arranged in descending order of their contribution to similarity.

Group A: Site 1
Average similarity: 65.79 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Urothoe pinnata	13.25	3.32	36	5.04	5.04
Spionidae	16.11	3.24	6.83	4.92	9.96
Nannastacidae	11.54	2.72	45.75	4.14	14.1
Micronephtys sphaerocirrata	10.3	2.55	14.93	3.87	17.97
Bodotriidae	9.66	2.39	14.87	3.63	21.6
Bathyporeia sp.	10.78	2.33	6.05	3.54	25.14
Perioculodes longimanus	10.18	2.26	5.41	3.43	28.57
Laetmatophilus sp.	9.48	2.05	3.61	3.12	31.69
Magelona papillicornis	8.65	2.04	16.52	3.11	34.8
Cirratulidae	12.76	2.03	81.25	3.09	37.89
Ostracoda sp 3	7.53	1.9	15.06	2.89	40.78
Ampelisca brachyceras	7.71	1.81	11.43	2.75	43.52
Monoculodopsis longimana	7.27	1.79	12.88	2.73	46.25
Nemertea	7.24	1.76	17.87	2.68	48.93
Capitellidae	7.15	1.76	17.87	2.68	51.61

Group B was comprised of six stations (Site 2 and Site 3) that were 57.33 % similar. Eleven taxa contributed 52.84 % to overall average similarity (Table 4.12). The five indicator taxa were: *U. pinnata, M. stimpsoni, G. africana, H. cf opus* and nannastacid cumaceans. *G. africana, H. cf opus* and nannastacid cumaceans were more reliable indicator taxa with their relatively consistent abundances across all six stations (Table 4.19).

Table 4.12. Taxa that contributed ~50 % to the similarity of Sites 2 and 3 assemblages. Taxa are arranged in descending order of their contribution to similarity.

Group B: Site 2 + Site 3
Average similarity: 57.33 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Urothoe pinnata	12.91	3.46	4.91	6.04	6.04
Mandibulophoxus stimpsoni	11.63	3.34	3.76	5.82	11.86
Gnathia africana	9.58	3.06	5.18	5.33	17.19
Heterophoxus cf opus	8.78	2.69	7.76	4.69	21.88
Nannastacidae	8.59	2.66	8.76	4.64	26.52
Cirratulidae	10.13	2.65	4.05	4.63	31.15
Spionidae	9.49	2.63	4.93	4.59	35.74
Micronephtys sphaerocirrata	8.45	2.58	7.38	4.49	40.23
Laetmatophilus sp.	8.85	2.52	4.07	4.4	44.63
Bodotriidae	7.52	2.37	9.46	4.13	48.76
Monoculodopsis longimana	7.18	2.34	8.35	4.08	52.84

Stations representing Group C (Site 5 and Site 6, n = 6) were 61.03 % similar with 26 taxa contributing 51.35 % to overall average similarity (Table 4.13). Indicator taxa were: *A. minutus*, *M. stimpsoni*, *U. tumorosa*, diastylid cumaceans and *Ostracod sp 11*, respectively. Though not highly consistent in abundance, *U. tumorosa* was a relatively reliable indicator species.

Table 4.13. Taxa that contributed ~50 % to the similarity in Group C (Sites 5 and 6). Taxa are arranged in descending order of their contribution to similarity.

Group C: Site 5 + Site 6
Average similarity: 61.03 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum.(%)
Apseudes minutus	25.57	2.3	1.96	3.77	3.77
Mandibulophoxus stimpsoni	12.73	1.48	4.3	2.43	6.2
Urothoe tumorosa	11.69	1.44	7.56	2.35	8.56
Diastylidae	12.12	1.42	5.94	2.32	10.88
Ostracoda sp 11	13.69	1.4	2.92	2.29	13.17
Urothoe pinnata	12.68	1.33	3.49	2.18	15.35
Micronephtys sphaerocirrata	11.16	1.27	5.05	2.08	17.44
Ostracoda sp 2	11.37	1.24	2.6	2.03	19.47
Nannastacidae	10.38	1.23	5.15	2.02	21.49
Heterophoxus cf opus	9.89	1.22	7.57	2	23.49
Bivalve juvenile	9.74	1.2	10.9	1.96	25.45
Cirratulidae	10.34	1.18	7.58	1.94	27.39
Urothoe platypoda	10.67	1.16	3.83	1.9	29.29
Spionidae	12.94	1.12	9.72	1.84	31.14
Ostracoda sp 3	9.42	1.11	6.71	1.83	32.96
Ostracoda sp 4	12.01	1.11	3.78	1.82	34.78
Ampelisca brevicornis	9.64	1.06	5.92	1.73	36.51
Hippomedon longimanus	8.65	1.06	7.14	1.73	38.24
Capitellidae	9.29	1.05	4.02	1.72	39.97
Gnathia africana	8.34	1.04	8.08	1.7	41.67
Monoculodopsis longimana	8.25	1.02	11.2	1.67	43.33
Donacidae/Tellinidae	8.68	1.01	8.21	1.66	44.99
Eusiridae	9.62	0.98	6.62	1.61	46.6
Magelona papillicornis	7.76	0.97	11.16	1.59	48.19
Nemertea	7.6	0.97	13.9	1.58	49.77
Glyceridae	7.96	0.96	12.38	1.58	51.35

Stations representing Group D (n = 3) were 50.32 % similar with only nine taxa contributing 51.28 % to overall average similarity (Table 4.14). Indicator taxa were: *M. sphaerocirrata*, *Mesopodopsis wooldridgei*, *Magelona papillicornis*, glycerid polychaetes and Cirratulidae sp 2, respectively. The reliable indicator species was an

opportunistic polychaete, Cirratulidae sp 2, which was the most consistently abundant (Table 4.14).

Table 4.14. Taxa that contributed ~50 % to the site similarity in Group D (Site 4). Taxa are arranged in descending order of their contribution to similarity.

Group D: Site 4
Average Similarity: 50.32 %

Species	Av.Abund	Av.Sim	Sim/SD	% Contrib	Cum. (%)
Micronephtys sphaerocirrata	9.17	3.27	6.45	6.5	6.5
Mesopodopsis wooldrigei	9.64	3.26	4.87	6.48	12.98
Magelona papillicornis	8.56	3.13	5.83	6.21	19.19
Glyceridae	8.56	3.07	5.4	6.1	25.29
Cirratulidae sp 2	9.08	2.71	13.46	5.38	30.67
Spionidae	8.23	2.67	10.68	5.31	35.97
Cirratulidae	7.15	2.6	5.18	5.17	41.14
Nermetea	6.88	2.55	5.83	5.07	46.21
Capitellidae	7.3	2.55	5.83	5.07	51.28

Dissimilarity between groups ranged between 47.60 % (Group A vs. Group B) and 66.47 % (Group C vs. Group D; Table 4.15 and Appendix 6B). Dissimilarities were highest when species composition of groups was compared to that of Group D (Table 4.15). Reliable discriminators between Group A and Group B were gastropods of the family Nassariidae and the copepod *Sapphirina sp 2* (Table 4.15). Cirratulidae sp 2, belonging to a generally opportunistic Cirratulidae family (Dauvin & Ruellet (2007)), and the amphipod *Perioculodes loningamanus* were reliable discriminator species between Group A and Group C. *U. tumorosa* (amphipod) reliably discriminated Group A from Group D, while the amphipod *H. cf. opus* discriminated Group B from Group C (Table 4.15).

Table 4.15. Top 5 discriminator taxa with highest contribution to group dissimilarities (SIMPER results) for 2009. Dissimilarity (%) between groups, maximum Diss/SD ratio and reliable discriminator taxa are indicated in bold.

	Group A	Group B	Group C	Group D
Group A				
Group B	**47.60 %** **max Diss/SD: 10.49** *Arcturina scutula* (3.35) ***Sapphirina sp 2*** (6.24) **Nassariidae** (10.49) *cf Queubus jamesanus* (1.47) Eulimidae (1.19)			
Group C	**61.11 %** **max Diss/SD: 6.87** *Urothoe pinnata* (2.21) ***Bathyporeia sp.*** (3.90) ***Perioculodes longimanus*** (4.15) ***Laetmatophilus sp.*** (3.58) ***Cirratulidae sp 2*** (6.67)	**62.53 %** **max Diss/SD: 5.74** *Urothoe pinnata* (1.86) *Mandibulophoxus stimpsoni* (1.85) ***Laetmatophilus sp.*** (2.96) ***Heterophoxus cf opus*** (4.61) *Cirratulidae sp 2* (2.77)		
Group D	**60.21 %** **max Diss/SD: 11.54** *Apseudes minutus* (2.01) *Ostracoda sp 11* (2.42) *Ostracoda sp 4* (1.90) ***Urothoe tumorosa*** (5.97) Corophiidae (1.52)	**58.69 %** **max Diss/SD: 10.13** *Apseudes minutus* (1.82) *Ostracoda sp 11* (2.01) *Ostracoda sp 2* (2.64) *Ostracoda sp 4* (1.60) *Urothoe platypoda* (3.19)	**66.47 %** **max Diss/SD: 8.53** *Apseudes minutus* (1.99) *Ostracoda sp 11* (2.35) *Ostracoda sp 2* (2.53) *Urothoe platypoda* (3.05) *Mandibulophoxus stimpsoni* (2.14)	

4.3.9. Relating community assemblages to environmental variables: 2008

Although a total of 32 environmental measurements were related to the community assemblage, only a combination of eight were highly correlated with the assemblage pattern (Spearman Rank correlation (ρ) = 0.87; Table 4.16). These variables were bottom measurements of temperature, salinity, pH, dissolved oxygen (DO), coarse sediment, mud fraction and metals (e.g., copper (Cu)). Of the eight variables, salinity best described the community assemblage pattern (Table 4.17) at the 72.2% level, but in general other individual variables were weakly correlated with community assemblages (Table 4.17).

Table 4.16. Stepwise correlation results from the BVSTEP method indicating the combination of environmental variables that best explained community assemblage patterns observed in 2008.

# of Variables	Correlation	Environmental Variables
1	0.722	Salinity
2	0.758	Salinity, Cu
3	0.769	Salinity, pH, Cu
4	0.808	Salinity, pH, Mud, Cu
5	0.833	Salinity, pH, Mud, Cu, Fe
6	0.852	Salinity, pH, DO, Mud, Cu, Fe
7	0.865	Salinity, pH, Do, Coarse sand, Mud, Cu, Fe
8	0.868	Temperature, Salinity, pH, DO, Coarse sand, Mud, Cu, Fe

Table 4.17. Spearman rank correlation between individual environmental variables (bottom only) and community assemblage pattern of 2008.

Correlation	Environmental Variables
0.722	Salinity
0.587	Total Organic Content
0.569	Mud fraction
0.456	Medium sand
0.444	Temperature
0.325	pH
0.29	Dissolved Oxygen
0.268	Very coarse sand
0.108	Coarse sand
0.003	Fine sand
-0.027	Turbidity

When water column variables (integrated measurements) and metal concentrations were excluded from the analysis (as explained in Chapter 3), a suite of six environmental variables (6 of 11) best described the community assemblage pattern (BIOENV method, ρ = 0.82; Table 4.18). These were: salinity, pH, dissolved oxygen (DO), coarse sand, total organic content (TOC) and mud fraction (Table 4.17). Medium sand played a negligible role as it did not change the correlation when included in the analysis (Table 4.18).

Table 4.18. Combination of environmental variables (bottom measurement and sediment parameters only) that best explained the community assemblage pattern for 2008 based on Spearman rank correlation calculated from BIOENV method of PRIMER.

# of Variables	Correlation	Environmental Variables
6	0.824	Salinity, pH, DO, Coarse sand, TOC, Mud
7	0.824	Salinity, pH, DO, Coarse sand, Medium sand, TOC, Mud

4.3.10. Relating community assemblages to environmental variables: 2009

Correlation of individual environmental variables with the community assemblages was also weak in 2009 (ρ range: -0.117–0.657) with temperature being the single most important environmental parameter (Table 4.19). When combined with the mud fraction, a stronger correlation between abiotic and biotic data was apparent (ρ = 0.78; Table 4.20).

Table 4.19. Spearman rank correlation of individual environmental variables to community assemblage for 2009 calculated with BIOENV method.

Correlation	Environmental Variables
0.657	Temperature
0.606	Dissolved oxygen
0.448	Very fine sand
0.441	Total Organic Content
0.424	pH
0.409	Mud fraction
0.388	Dissolved oxygen (integrated)
0.321	Turbidity (integrated)
0.208	Turbidity
0.184	Medium sand
0.094	Salinity
-0.055	Very coarse sand
-0.056	Fine sand
-0.117	Coarse sand

Table 4.20. Combinations of environmental variables and their Spearman rank correlations (ρ) to community assemblage pattern for 2009. 'i' refers to integrated measurement of the water column.

Correlation	Environmental Variables
0.778	Temperature, Mud fraction
0.774	Temperature, Mud fraction, TOC
0.769	DO (i), Temperature, Mud fraction, TOC
0.768	Turbidity (i), Temperature,DO, Very fine sand,Mud fraction,TOC
0.766	Temperature, DO, Very fine sand, Mud fraction
0.766	DO (i), Temperature, Very fine sand, Mud fraction
0.765	Temperature, Very fine sand, Mud fraction
0.765	Temperature, DO, Mud fraction, TOC
0.764	Turbidity (i), DO (i), Temperature, DO, Very fine sand, Mud fraction, TOC
0.764	Temperature, DO, Very fine sand, Mud fraction, TOC
0.763	DO (i), Temperature, Very fine sand
0.761	Temperature, Very fine sand
0.760	Turbidity (i), DO (i), Temperature, Very fine sand, Mud fraction, TOC
0.760	DO (i), Temperature, DO, Mud fraction, TOC

Chapter 5

General Discussion

5.1. Spatial distribution patterns

Heterogeneity (or patchiness) and scale, both in space and time, are now recognised as critical and integral factors in benthic assemblages (Legendre *et al*. 1997, Ellis & Schneider 2008). These parameters are key drivers that structure spatial and temporal trends in benthic assemblages and, if not considered, may lead to misinterpretation of data (Thrush 1991). It is also critical to understand that patterns measured in smaller spatial scales may not necessarily persist in larger scales (Ellis & Schneider 2008).

The concept of small or large spatial scale is poorly defined in the literature, and is applied relatively among authors. In an attempt to standardise the scale at which diversity is measured, Gray (2000) measured Point Diversity in a single sampling unit (e.g., one grab sample). Alpha Diversity was measured from replicate samples within a specific habitat, while Beta or Turnover Diversity was measured at a larger scale along an environmental gradient. In the present study, local scale refers to the three stations that contributed to each site (i.e., located across 200 m), while the distance between any two sites contributed to large scale comparisons (i.e., kilometres between sites).

5.1.1. Small scale spatial distribution

Community assemblages when considered at small spatial scales in Algoa Bay varied according to different sediment types (i.e., sandy vs. muddy sediments). No significant variability in species composition was apparent when considering assemblages located 100 m apart in sandy substrata. These findings are consistent with other studies that also confirmed homogeneity of sandy bottom assemblages across small spatial scales. For example, Kendall & Widdicombe (1999) demonstrated that the composition of the community in fine sandy substrata collected in samples ≤500 m apart in Cawsand Bay (Plymouth Sound) were mostly homogeneous.

The sediment sampled around the Papenkuils effluent outfall (Site 4) was relatively fine in composition. In contrast to elsewhere in the bay, benthic assemblages at the Papenkuils site varied considerably between stations, reflecting small spatial scale heterogeneity. Kendall & Widdicombe (1999) also recorded small scale spatial heterogeneity (sites were 50 m apart) for the assemblage of species at disturbed muddy sites in Jennycliff Bay, Plymouth Sound. Heterogeneity in their study was however, a result of bioturbation caused by two thalassinids, *viz*: *Upogebia deltura* and *Callianassa subterranean* (Kendall & Widdicombe 1999). Sediment structure at the Papenkuils outfall site reflected spatial homogeneity and was therefore not considered as a possible driver responsible for spatial heterogeneity of the benthic community. Instead, effluent dynamics and organic enrichment were probably the likely factors influencing community structure around the Papenkuils outfall.

Small scale distribution patterns between the two surveys also differed in the present study. Small scale heterogeneity between assemblages at the muddier Papenkuils site

persisted in both surveys, suggesting a consistent influence by the driving factors such as effluent outfall. In contrast to the Papenkuils site, small scale homogeneity recorded among sandy sediment assemblages was inconsistent between the two surveys. For example, Site 2 assemblages were homogeneous with Site 3 assemblages during the second survey and when compared to the first survey, despite the potential influence of the Swartkops Estuary adjacent to Site 3. Similarly, the community assemblages recorded at Site 5 and Site 6 were also closely similar during the second survey. This study therefore suggests that the structure of benthic communities in Algoa Bay can become relatively homogeneous over spatial scales measured in tens of metres and even kilometres on occasions (<5 km), especially if sediments are relatively homogeneous.

Mechanisms influencing observed distribution patterns in Algoa Bay over small spatial scales are not fully understood. Particularly, it is not understood how homogeneity of assemblages over small spatial scales (meters) persists over larger scales (<5 kilometres), as observed between Sites 2 & 3 and Sites 5 & 6. It was therefore suggested that benthic community is generally homogeneous over a relatively larger spatial scale as a result of sediment structure, while smaller assemblages may be the result of modified environmental conditions at localised areas. Algoa Bay is predominantly sandy over a larger area (Bremner 1991). Some researchers (e.g., Snelgrove and Butman 1994) have also suggested that factors acting over large areas, such as the hydrodynamic regime and water circulation, are more important in structuring benthic communities as these factors influence other significant factors, such as sediment structure and organic matter content.

5.1.2. Large scale distribution patterns

Gradients (e.g., depth, wave energy and/or turbulence) are principal parameters influencing large scale distribution patterns (see McLachlan *et al.* 1984; Fleischack & de Freitas 1989; Hourston *et al.* 2005; Wildsmith *et al.* 2005). Previous studies in Algoa Bay (e.g., McLachlan *et al.* 1984) have shown that macrofaunal assemblages sampled perpendicular to shore change along the nearshore depth gradient; while distribution along-shore in Algoa Bay is relatively unknown. Several studies in Australia have shown that benthic assemblages along the shore change in relation to the wave energy gradient (e.g., Hourston *et al.* 2005; Wildsmith *et al.* 2005). Consequently, distribution patterns measured on a relatively large scale (kilometres) in the present study were predicted to vary in relation to environmental gradients. Since the macrozoobenthos in the present study was investigated along the 10 m depth contour, wave exposure was possibly one parameter that linked to changing community structure around the bay. Wave climate was not measured directly during this study; however, previous research on sandy beaches clearly showed increasing wave energy towards the eastern extremity of the bay (McLachlan 1980b).

McLachlan (1980a) and McLachlan *et al.* (1981) regarded sandy beaches and their associated surf zones as single functional units. Generally, nearshore Algoa Bay was described as moderately exposed to wave energy (McLachlan 1980b; Malan & McLachlan 1985). Kings Beach and Sundays Beach scored 12.5 and 15.5, respectively on a 20 point exposure rating system (McLachlan 1980b; Malan & McLachlan 1985), indicating increasing wave energy towards the eastern extremity of the bay. Sheltered beaches have a score of <10 and very exposed beaches have a score of >15 (see McLachlan 1980b for details). McLachlan *et al.* (1984) also studied macrozoobenthic

distribution along two transects (Kings Beach and Sundays River Beach) which were perpendicular to shore and concluded that the across-shore distribution pattern was influenced by wave energy. Although the depth gradient was more important in their study, assemblages at the 'transitional zone' (located between 5–12 m depth) between the two transects were heterogeneous. Fleischack & de Freitas (1989) in their depth gradient study in the Durban Bight also observed that macrofaunal species richness, abundance and biomass increased towards the sheltered sites along the shore as wave energy decreased.

Distribution of macrozoobenthos in Algoa Bay varied along the 10 m depth gradient in the present study. On a larger scale where wave energy gradients exist, sheltered and exposed sites usually possess distinct assemblages (e.g., Hourston *et al.* 2005; Wildsmith *et al.* 2005). In the present study, the Papenkuils assemblage reflected a distinct assemblage. Generally, this species assemblage was highly dissimilar to other assemblages at a larger scale and consistently showed heterogeneity over small spatial scales (during both surveys and in the pilot study). However, rather than wave climate being the primary factor responsible for this dissimilarity, the Papenkuils community assemblage was probably influenced by the effluent dynamics.

Organic and metal enrichment at the Papenkuils site occurs as domestic and industrial effluent (Roberts 1990) and is known to be intolerable to crustaceans such as amphipods. Other groups such as polychaetes generally flourish (Dauvin & Ruellet 2007). The Papenkuils assemblage was typified by carnivorous nephtyid polychaetes, especially *M. sphaerocirrata* and glycerid polychaetes (Fauchald & Jumars 1979). Other polychaetes characteristic of areas influenced by organic enrichment includes

Capitellidae, Cirratulidae and Spionidae families, which were also common at the Papenkuils site. Capitellidae; Cirratulidae and some genera of Spionidae are known opportunistic taxa (Pearson & Rosenberg 1978; Dauvin & Ruellet 2007). These opportunists were not highly abundant, although patterns are likely to change with increasing volume of effluent.

A further distinct assemblage in Algoa Bay was the assemblage associated with the Sundays Estuary mouth area (Site 1). However, key factors influencing this community cannot be explicitly ascertained since sediment was homogeneous when compared to other sites. However, factors such as the plume of lower salinity water exported from the estuary probably played a role in structuring this distinct community.

5.2. Assemblage drivers

Although combinations of several physicochemical variables were shown to structure the assemblages in Algoa Bay, other potential factors not measured during this study cannot be dismissed. Distribution of community assemblages around Algoa Bay are probably influenced by factors such as estuaries, storm water canal outfalls and dredging activities. Several studies (e.g., Dauer *et al.* 2000; Van Dolah *et al.* 2008; Hepp & Santos 2009) have documented the impacts of external factors such as catchment activities and urbanisation on receiving waters. The impact of these external influences was generally greatest if the source was within 10 km of the sampling stations (Dauer *et al.* 2000; Van Dolah *et al.* 2008). Dauer *et al.* (2000) for example, demonstrated that, while catchment activities altered benthic communities in Chesapeake Bay, it was 'near-field' factors that had greater influence on benthic

community compared to 'far-field' activities. In the present study 'far-field' influences are probably represented by plumes (estuarine and storm water canals), while harbour activities such as dumping of dredged spoil represent 'near-field' influences.

5.2.1. Estuaries

Estuarine plumes in the nearshore are areas of high biological activity, being characterised by high nutrient concentrations and sources of organic carbon that support planktonic and benthic assemblages (Fetzer & Deubel 2006; Gaston *et al.* 2006). For example, nutrients like phosphorus can be limiting to phytoplankton production (Emmerson 1985; Winter & Baird 1991), while silicate is a major component of diatoms (Jennings 2005).

The Sundays Estuary has higher concentrations of nutrients (except phosphate) and chlorophyll *a* compared to the Swartkops Estuary (Scharler *et al.* 1997). Sundays Estuary does not act as a sink for nutrients such as nitrogen, phosphorus and silicates and these are potentially flushed in to the nearshore due to strong tidal currents of up to 0.98 m s^{-1} in the lower estuary (Emmerson 1989). Swartkops Estuary by comparison, acts as a sink for nutrients and retains approximately 88 % phosphorus and 73 % of nitrate with the balance exported to sea (Emmerson 1985; Winter & Baird 1991). Low concentrations of nutrients are generally exported during spring tide while higher concentrations are exported during neap tides (Emmerson 1985). Nutrient export is influenced by sedimentology, floral status with regard to senescence of macrophytes, freshwater input and hydrology of the estuary (Winter & Baird 1991). Nutrients derived from Swartkops and Sundays estuaries support a large biomass of the surf diatom *Anaulus birostratus* in Algoa Bay (Emmerson 1989). Consequently, the

smaller Swartkops Estuary probably has less influence on benthic assemblages due to its more limited export of nutrients compared to Sundays Estuary.

Although estuaries contribute to the carbon pool of coastal waters, previous work has suggested that Sundays and Swartkops estuaries do not contribute much to the organic carbon of Algoa Bay since the major source of organic carbon is detritus (Talbot & Bate 1988; Heymans & McLachlan 1996). Live sources of organic material are dominated by the surf diatom *Anaulus birostratus*, contributing <20 % of the organic source. *Anaulus birostratus* is largely restricted to the surf zone where estuarine derived nutrients are retained. Gaston *et al.* (2006) also found that organic carbon associated with the plume from the Mooloolah Estuary in Australia did not contribute substantially to the nearshore carbon pool and concluded that organic carbon in the marine sediment was largely autochthonous.

The daily carbon pool in Algoa Bay is estimated to be 1317 mg C m^{-2} (Heymans & McLachlan 1996). Most of this (523 mg C m^{-2} day^{-1}) is absorbed by the microbial loop while the interstitial and macrofauna consume 263 and 68 mg C m^{-2} day^{-1}, respectively. The surplus (332 mg C m^{-2} day^{-1}) is exported further offshore where detritus or organic content increases (Talbot & Bate 1988). This distribution of organic material also correlates with increasing abundance and species richness of the macrofauna in Algoa Bay (McLachlan *et al.*1984). In their study, organic content especially near the Sundays Estuary showed a trend of increasing organic content with increasing distance from shore. In contrast, the depth gradient opposite the more sheltered Kings Beach showed a trend of constant organic content with increasing distance, probably due to calmer conditions.

Biotic (faunal) exchange between estuaries and coastal waters may also be important in structuring the nearshore benthic community of Algoa Bay. Biotic exchange is often numerically dominated by decapod larvae, since most decapods present in estuaries as adults have obligatory marine life history stages during their respective life histories (e.g., Emmerson 1983; Pereyra Lago 1993; Wooldridge & Loubser 1996). Adult forms can also be exported from estuaries to coastal waters under certain hydrodynamic conditions. For instance, Swartkops Estuary has a mean annual runoff of approximately 84 x 10^6 m^3 yr^{-1} that includes occasional floods (Hanekom *et al.* 1988; Emmerson 1989). Subtidal benthic communities in this estuary are dominated by *Callianassa kraussi* in the lower reaches and by *Upogebia africana* and bivalves in the middle reaches (McLachlan & Grindley 1974; Hanekom *et al.* 1988; Hanekom 1989; Scharler *et al.* 1997). Bivalves include two important species: *Solen capensis* and *S. cylindraceus* (Hanekom *et al.* 1988). McLachlan & Grindley (1974) determined that increased flows in Swartkops Estuary after floods decimated the population of *S. cylindraceus*, presumably because of flushing to the marine nearshore. Deep burrowing species like *C. kraussi* and small sized *U. africana* were also adversely affected by floods (Hanekom 1989). In the present study, bivalve juveniles were relatively important in the bay, especially near the mouth of Swartkops Estuary.

S. cylindraceus in the Algoa Bay nearshore is also present in considerable numbers off Papenkuils, suggesting that this bivalve is probably flushed out to sea and transported south westward by bottom currents, which flow predominantly in that direction due to the Agulhas current entrainment (Schuman *et al.* 2005). Goschen (unpublished data, see Appendix 9) also showed that bottom currents in Algoa Bay flow in a predominantly southwest direction during summer. Thus, present data support

Snelgrove & Butman's (1994) proposition that the hydrodynamic regime is a principal factor of benthic faunal distribution in coastal waters.

5.2.2. Canals and storm water drains

Papenkuils Canal introduces relatively fine material into the bay that locally modifies sediment structure. Furthermore, Papenkuils also introduces large quantities of organic matter. Generally, organic content most likely decreases with increasing distance from the source (Knox & Fenwick 1981). The influence of organic enrichment is also generally more marked at sheltered sites compared to exposed sites (Knox & Fenwick 1981). In both these situations, water movement plays a critical role in the deposition of organics, with little movement and turbulence allowing organics to settle and thereafter lead to the development of hypoxic conditions (Knox & Fenwick 1981). Hypoxic conditions (<3 mg l^{-1}) were not recorded at the 10 m depth contour during this study, even off the effluent outfall area (Papenkuils Canal). Sediment quality off Papenkuils is probably degraded by increased levels of hydrogen sulphide associated with blackened sediment (*pers. obs.*), thus leading to relatively low densities in the benthic community.

Although effluents in Algoa Bay can have a positive effect on the benthic fauna (see Emmerson *et al.* 1983), organic enrichment above certain thresholds 'superimposes' its own gradient in marine environments, with fauna changing gradually along that gradient (Pearson & Rosenberg 1978; Knox & Fenwick 1981). There are generally fewer species in areas highly enriched with organic material or in areas closer to source. This leads to increases in faunal density as enrichment decreases and as oxygen concentration increases (Pearson & Rosenberg 1978). Oxygen reduction is

regarded as the most important consequence of organic enrichment (Pearson & Rosenberg 1978).

Response by the benthic fauna to organic enrichment is successional and can be spatially distinguished along an enrichment gradient, *viz*: an opportunistic zone, ecotone point and transitional zone (Pearson & Rosenberg 1978). The opportunistic zone is typified by high abundances of opportunistic fauna (e.g., capitellid polychaetes) occupying enriched areas, while at the ecotone point the opportunists are mixed with fewer and less abundant 'normal fauna.' The transitional zone is dominated by less tolerant and slow growing fauna. Papenkuils study site is probably located in the transitional zone since fewer and less abundant opportunists such as cirratulids and capitellids are mixed with 'normal' fauna (Dauvin & Ruellet 2007).

5.2.3. Harbours

Harbour construction, infrastructure development and maintenance activities such as dredging also influence benthic communities (Kruger *et al.* 2005; Dauvin *et al.* 2006). Harbours, as physical structures, influence the physical environment by changing water circulation and sediment movement patterns, concurrently introducing organics and metals into the environment (Kruger *et al.* 2005). The impact of the harbour structure on benthic fauna can range from a shift in community distribution to complete alteration responding to the altered environmental parameters such as water circulation and accumulation of contaminants (Kruger *et al.* 2005).

In a closed embayment environment, like Saldanha Bay, the construction of the harbour 'radically' altered the benthic fauna as the sediment structure was changed by

the modified hydrodynamic regime (Kruger *et al.* 2005). There was a general decline in the number of species due to harbour construction whereas the change in species composition was a result of species replacement (Kruger *et al.* 2005). In an open environment where the system flushes adequately, the distribution of the benthic community merely shifts rather than undergoing 'radical' alteration (Anderson *et al.* 1981). Algoa Bay, with its wide mouth, is an open system with a dynamic oceanography and it is expected that the distribution of benthic community around the harbour merely shifts under certain environmental conditions instead of undergoing complete alteration.

Prevailing oceanic and/or hydrodynamic regimes determine the sediment characteristics in an area and are considered principal factors of large (broad) scale community patterns (Thrush 1991; Morrisey *et al.* 1992; Hall 1994; Snelgrove & Butman 1994). At local scales, water movement, habitat disturbances and/or stochastic events and biotic interactions are important in influencing faunal distribution patterns (Thrush 1991; Morrisey *et al.*1992; Bergström *et al.* 2002). Community assemblages on either side of Port Elizabeth Port in Algoa Bay (Site 5 and Site 6) indicated both heterogeneity and homogeneity between the two surveys. It is suggested that local activities, such as the dumping of dredged spoil coupled with modified water circulation patterns by the harbour, largely influenced the distribution of the assemblages (Site 5 and Site 6). During calmer and more stable oceanic conditions, species compositions differed between the two sites as local environments were probably more important, whereas more variable oceanic conditions would override local factors, resulting in a homogeneous assemblage as observed in the 2009 survey. If the hydrodynamic regime is the principal factor of benthic faunal distribution on a

large scale (Hall 1994; Snelgrove & Butman 1994), then activities such as disposal of dredged material are more likely to be factors of local importance.

Dredging and disposal of dredged material is a common management practice in harbours and is necessary for the maintenance of navigation channels (Miller *et al.* 2002). This practice influences sediment dynamics by altering sedimentation and deposition, which *inter alia* influence faunal dynamics. The quantity of dredged sediment and the frequency of dredging are determined by erosion and land degradation of the host catchment as well as sediment circulation in the sea (Bateman 1996). Dredging frequency in the Port of Port Elizabeth should primarily be driven by sediment circulation as the catchment of the harbour is highly urbanised with Baakens River introducing small volumes of freshwater and sediment inside the harbour. The frequency of dredging should therefore be low, and this may explain the high abundance of macrozoobenthos at the dumpsite. Of particular relevance in this study is the dumping of dredged spoil at Site 5, which is located in the periphery of the dumpsite. This community reflected high abundance as well as high numbers of species typified by cumaceans.

In benthic ecology it is generally assumed that dumping of dredged material kills the fauna by burial or smothering (Miller *et al.* 2002). There are three successional stages associated with sediment perturbations. These include (1) sediment defaunation, (2) recruitment and exponential abundance of opportunistic species and (3) the gradual replacement of opportunists by slow growing or equilibrium species (Blanchard & Feder 2003). This process is known as "community re-adjustment" in favour of "community recovery" since the community does not return to its original state (Blanchard & Feder 2003, p 1590). Community re-adjustment is reliant on several

factors of perturbation including type and frequency of perturbation, life histories of the colonising species, larval dynamics and environmental dynamics (Blanchard & Feder 2003). In frequently disturbed sediments, community re-adjustment can never be complete. Re-adjustment is complete when community assemblage of disturbed sediments is similar to the pre-disturbance period and/or is in equilibrium with adjacent assemblages. Duration of readjustment in a disturbed area is highly variable and can even take up to 10 yrs (Newell *et al.* 1998; Blanchard & Feder 2003). Species composition of the readjusted community is influenced by the timing and severity of the disturbance in conjunction with the reproductive biology and motility of the adjacent fauna.

In dredging studies the burial effects of disposed sediment is largely ignored. Maurer *et al.* (1981a, 1981b, 1982) have shown that venerid and nuculid bivalves, haustoriid amphipods, orbiniid and nereid polychaetes have the ability to migrate vertically when buried. This migration is influenced by the depth of burial, the particle size of disposed sediment, duration of vertical migration as well as temperature. For example, if the sediment particle size is different to that of the receiving environment the impact on vertical migration is negative in almost all studied groups. These studies then indicate that besides succession, vertical migration may also contribute to community re-adjustment. Besides prevalent sediment disturbance at Site 5, species richness and abundance is high. This can probably be explained by the intermediate disturbance hypothesis, which basically states that biodiversity increases at intermediate disturbances (Collins & Glenn 1997; Roxburgh *et al.* 2004). This then suggests that the impact of dumping dredged spoil is not severe in the periphery of the dump site in Algoa Bay.

Where smothering is likely to occur, the impact of dredge spoil on macrozoobenthic communities can be mitigated by adjusting dump volumes. Since benthic fauna is capable of vertical migration (Maurer *et al.* 1981a, 1981b, 1982; Miller *et al.* 2002), it is suggested that instead of dumping large quantities of sediment at a time, this should be reduced to smaller volumes. For example, instead of dumping sediment of up to 1 m in depth, this could be reduced to 10 x 10 cm of sediment dumped at different time periods (Miller *et al.* 2002). Unfortunately this increased frequency of dredging is expectedly very expensive in terms of boat time and fuel consumption, and may increase harbour traffic. Alternatively, large volumes of dredged sediment can be evenly spread within the dumpsite area rather than dumping at one station thus reducing 10 dredging excursions but minimising the impact of dumping.

5.3. Biotic – Abiotic relationships

Environmental variables that best described the distribution pattern of community assemblages in Algoa Bay were inconsistent between the two surveys. Important environmental variables during the 2008 survey included temperature, salinity, dissolved oxygen, coarse sand, total organic content and mud. During the 2009 survey only temperature and mud emerged as important variables. Contrary to expectations, sediment was not found to be the most important individual factor influencing benthic assemblages in the present study (see Chapter 4, pp 69–72). This is probably due to the fact that sediment is generally homogeneous (i.e., sandy) over large areas, with particular exception of the Papenkuils area. It is therefore probable that other variables not monitored in this study also act as drivers of distribution pattern. It is suggested

that variables measured in this study influence and maintain small scale or local distribution patterns of the assemblages.

Physico-chemical parameters like salinity and temperature (the two most significant variables in this study) are relatively stable in the marine environment compared to estuaries. In the nearshore marine environment, these parameters are expected to change markedly in response to freshwater inputs, effluent inflow, estuarine dynamics and climatologic conditions. The Sundays and Swartkops estuaries appear to influence salinity and temperature in the bay on a localised scale, but these changes do not persist for long periods (Schumann *et al.* 2005). Even though fluctuations in salinity and temperature are of relatively short duration, they are known to influence *inter alia* the physiology of the benthic fauna (e.g., Du Preez 1983; de Villiers & Allanson 1988). For example, the filtration rate of the bivalve *S. cylindraceus* is known to be affected by short term changes in temperature and salinity (de Villiers & Allanson 1988).

5.4. Hydrodynamic regime during the study

Although climatological parameters such as precipitation were not measured, data collected from this study suggests that ocean dynamics combined with turbulence imposed considerable differences on the hydrodynamic regime between the two surveys. During the 2008 survey, the oceanic and hydrodynamic conditions were probably more stable (i.e., due to low precipitation), allowing the development of minor stratification of salinity and temperature across the water profile (see Appendix 2B). It rained, however, before the sampling period of the 2009 survey. This affected the salinity profiles for both surveys, especially across Papenkuils. Salinity has been

used by Roberts (1990) as a proxy for tracing effluent in Algoa Bay. Elevated salinity values adjacent to Papenkuils in 2008 (present study) suggested that the effluent was less dilute compared to the 2009 survey (see Appendix 2A, B) when rainfall occurred prior to sampling.

The distribution of organic content, number of species and abundance strengthens the view that Algoa Bay is semi exposed to wave activity, with wave energy increasing eastward (McLachlan 1980b; Malan & McLachlan 1985). It is suggested that subtidal macrozoobenthos of Algoa Bay is generally controlled or structured by physical factors, at a larger scale (Sanders 1968). Large scale distribution patterns are believed to be influenced by physical environmental factors such as water depth, water circulation, tidal currents and grain size (Gray 1974; Thrush 1991; Morrisey *et al.* 1992; Bergström *et al.* 2002; Dauvin *et al.* 2004), while at smaller spatial scales distribution patterns are influenced by either biotic (e.g., predation, competition) or abiotic factors (e.g., sediment dynamics), and sometimes a combination of both (Thrush 1991). For example, hydrodynamic regimes on the Belgian Continental Shelf have been shown to influence the *Abra alba* community at a broader (larger) scale, while other factors such as food availability influenced the community at local scales (Van Hoey *et al.* 2005).

McLachlan *et al.* (1984) also identified wave energy as an important factor influencing the distribution of the subtidal macrozoobenthic community in Algoa Bay. Although they sampled macrofauna at transects perpendicular to the shoreline, multivariate analysis revealed that assemblages at the Kings Beach and Sundays River transects were similar in species composition at the inner turbulent zone (<5 m depth) but different at the transitional zone (5–12 m depth) and outer turbulent zone (>12 m

depth). The suggested importance of physical factors at a larger scale is, in the present study, further strengthened by the fact that the 10 m depth contour is between the transitional and the outer turbulent zone where turbulence is highly variable (McLachlan *et al.* 1984; Malan & McLachlan 1985).

5.5. Conclusion

This study has shown that species compositions at locations up to 100 m apart tend to be relatively homogeneous in sandy sediments, whereas species compositions on similar scale but in muddier sediments are heterogeneous. Similar results have been recorded by other researchers (e.g., Kendal & Widdicombe (1999). Small scale distribution patterns in Algoa Bay are also important as they modify larger scale distribution patterns (100 m to <5 km scale). For example, Site 2 & Site 3 and Site 5 & 6 assemblages were homogeneous during the second survey (2009) but were heterogeneous in the first survey (2008). These sites were all less than 4 km apart. It is suggested that small scale distribution patterns are driven by local conditions that modify the physico-chemical environment at localised areas such as across effluents.

On a larger scale, community assemblages of the semi sheltered Algoa Bay were heterogeneously distributed and physically controlled. Distinct assemblages (i.e., Papenkuils assemblages) were however, influenced and maintained by local environmental conditions such as the effluent from the outfall. In the absence of a distinct community assemblage at the most sheltered site off Kings Beach (e.g., Wildsmith *et al.* 2005), the Papenkuils assemblage emerged as the most distinct due to the influence of effluent dynamics and organic enrichment. Community assemblages off Sundays Estuary were also distinct although drivers were not identified in this

study. The distribution patterns of assemblages adjacent to Sundays Estuary mouth and the Papenkuils outfall were consistent at small and large spatial scales suggesting a consistency in the influence of driving factors.

Effluent dynamics, organic enrichment, mud content and variable salinity were probably the most important local factors maintaining the community assemblage adjacent to the Papenkuils outfall area. Papenkuils assemblage was numerically dominated and taxonomically characterised by polychaetes. The low abundances of opportunist polychaetes such as cirratulids, capitellids and spionids, especially during calmer conditions, suggest that this habitat may be transitional along a successional pathway where opportunists are mixed with other less abundant 'normal' fauna (Pearson & Rosenberg 1978; Knox & Fenwick 1981; Blanchard & Feder 2003). This suggests that poor sediment quality at this site is not yet at critical stages (i.e., grossly organically enriched) where the community would be less diverse and dominated by opportunistic fauna tolerant to organic enrichment.

Faunal re-adjustment in disturbed habitats such as Site 4 (Papenkuils) and Site 5 (dredged spoil dumpsite) is generally in a successional state (Pearson & Rosenberg 1978; Knox & Fenwick 1981), with opportunistic fauna being the first colonisers under disturbed conditions. With increasing stability and improving health of the habitat these opportunists are gradually displaced by 'equilibrium, slow growing species' (Knox & Fenwick 1981; Miller *et al.* 2002; Blanchard & Feder 2003). Colonisation of disturbed habitat may also occur through vertical migration of buried fauna in the case of Site 5 where macrofauna may be temporarily buried under dredged spoil (Maurer *et al.* 1981a, 1981b, 1982).

Chapter 6

Macrozoobenthic Monitoring Framework

6.1. Introduction

A routine macrozoobenthic monitoring framework emanating from the baseline data generated from this study is presented. This proposed framework should be refined and amended as additional data becomes available.

Major challenges associated with long-term monitoring programmes can be grouped under three important questions. These, according to Gray (1981), include:

1. How long is long-term?
2. How often should the system be monitored?
3. Which species should be monitored?

6.2. Duration and frequency of a proposed monitoring framework

Long-term monitoring should span over decades in order to integrate the influences of long-term climatic changes that are *inter alia* manifested in benthic fauna (Gray 1981). For instance, the population of the amphipod *Pontoporeia affinis* in the Baltic Sea undergoes long-term cycles of 6 to 7 years, probably responding to climatic cycles (Gray 1981; Gray & Christie 1983). Unfortunately such a long duration in monitoring

programmes has financial implications, as long-term monitoring programmes are also influenced by available funding (Kingston & Riddle 1989; Warwick1993).

With regard to the frequency of sampling in monitoring programmes, Gray (1981) suggested annual surveys, during winter when populations are low and when there are minimal larvae present. In agreement with Gray (1981), it is suggested that the macrozoobenthic community in Algoa Bay be monitored annually. Annual monitoring would create a better understanding of natural variability and cycles of abundance. Since this study was initiated in the summer, it is suggested that annual monitoring also be carried out during summer, thus incorporating baseline data generated by the present study. Additional studies in winter should also be carried out in order to identify any differences between winter and summer community dynamics.

6.3. Identification of target monitoring species

Gray (1981) eliminated rare species and opportunistic species as target species for long-term monitoring. He argued that rare species are sampled infrequently (probably due to patchy distribution) while lack of understanding on their biology further complicates the problem. Opportunistic species on the other hand can change rapidly in response to slight environmental changes (Grassle & Grassle 1974; Gray & Christie 1983). Gray (1981) then recommended the monitoring of species that control community dynamics (i.e., keystone species). Such an approach is probably more appropriate for environments like rocky shores where there are usually fewer keystone species (Paine 1969; Gray 1981; Gray 1982).

According to Gray (1981), the identification of keystone species in soft sediments requires manipulation experiments, but he later suggested that echinoderms are generally good indicators of non-polluted sediments (Gray *et al.* 1988; Warwick 1988b). Since structuring forces in soft sediment are different to rocky shores, identification of keystone species may require monitoring of more than one species, probably ranging from 9–12 (Gray 1981). To solve challenges associated with identification of keystone species, Gray & Pearson (1982) recommended an assessment of the Log-normal distribution of individuals among species. Carignan & Villard (2002) proposed a simpler procedure, which entails determining the frequency of occurrence of species among areas with contrasting degrees of disturbance. Libralato *et al.* (2006) on the other hand recommended a food web modelling approach in the identification of keystone species. This procedure models the interaction of groups (including potential keystone species) of similar sizes and feeding habits with the aim of identifying one group's effect on the abundance of other groups. There are probably numerous other methods or procedures available for the identification of keystone species. Identification of keystone species is a much debated and critical issue in ecological studies (see Bolger 2001).

Since further research is required in identifying keystone species in Algoa Bay, it is suggested that the most numerically abundant groups representing 50 to 75 % of the total abundance should be monitored. These groups include amphipods, polychaetes, cumaceans, ostracods, tanaids and bivalves. Amphipods and polychaetes contribute 50 % to the total abundance of macrofauna in the western sector of Algoa Bay (Appendix 7A, B). These proposed monitoring taxa can be replaced by target species or keystone species as information accumulates.

Although abundance and diversity parameters are important in ecological studies and may be used as a focus area in long-term monitoring, it is recommended that multivariate parameters should also be included in the monitoring protocol. As indicated in Chapter 4, descriptive statistics such as abundance and species richness measures (see Figure 4.14) may be misleading when used exclusively. For example, data for the 2009 survey showed homogeneity between Site 1 to Site 4, which was different to the homogeneous Site 5 and Site 6. This potentially misleading finding was clarified in the multivariate analysis, which showed that species composition across the study area significantly differentiated into four groups. Warwick & Clarke (1991) have also shown that multivariate techniques are more sensitive than univariate and graphical (or distributional) techniques in monitoring programmes.

Figure 6.1 highlights the differences between the three levels at which the macrozoobenthic community in Algoa Bay can be monitored. Here, all faunal groups were included (Fig. 6.1A, B), followed by the six groups proposed for monitoring (Fig. 6.1C, D) and lastly all other taxa excluded but the most abundant groups (i.e., amphipods and polychaetes) (Fig. 6.1E, F).

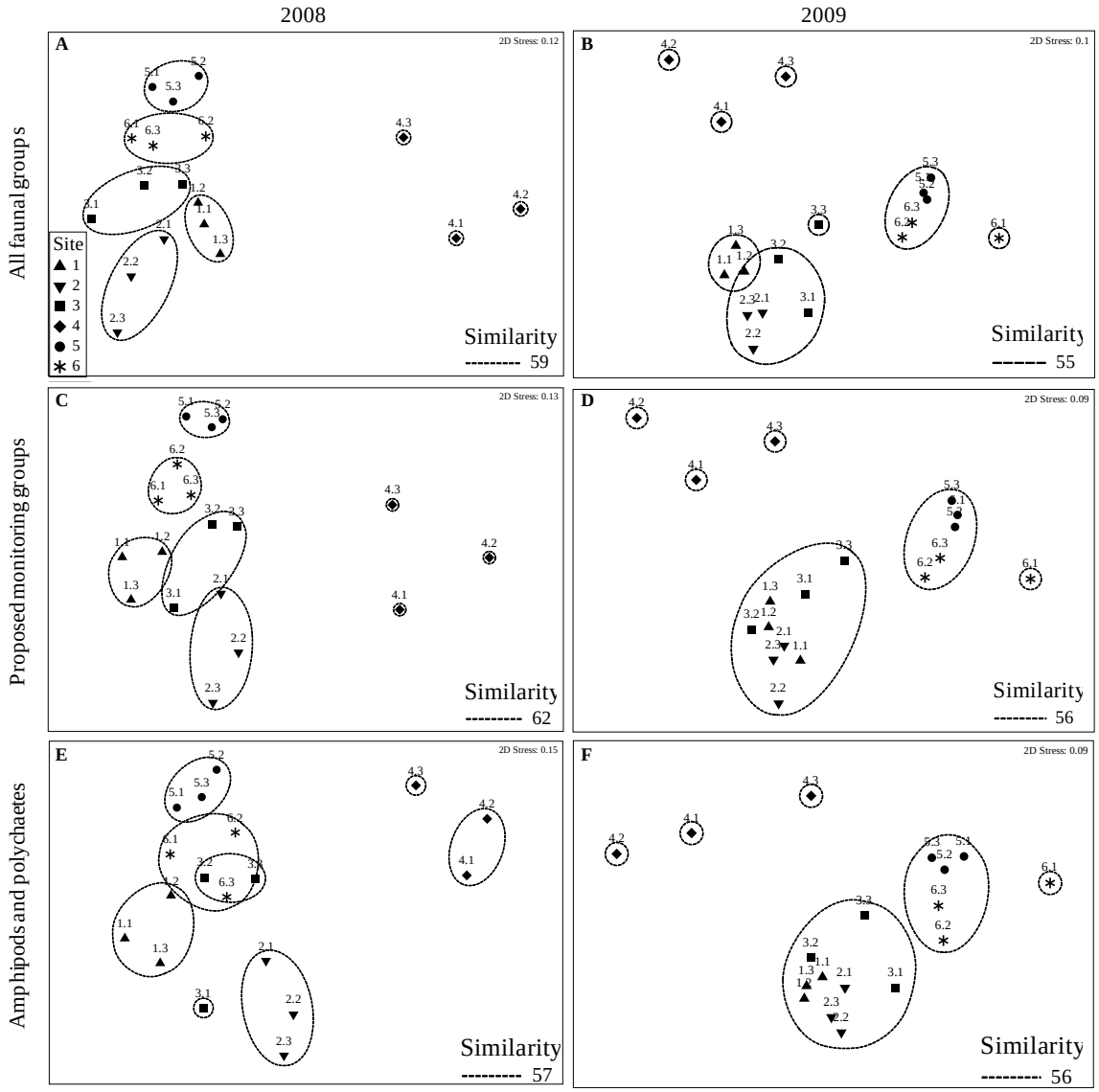

Figure 6.1. MDS ordination plots showing differences in ordination when different groups, selected subjectively based on their overall contribution to total abundance, are used in the analyses. A and B represent MDS plots for all groups, C and D represent MDS plots for the proposed six groups, while E and F represent MDS plots for only two groups. Abundance data used in the analyses were square root transformed.

There is no severe loss of information when six groups instead of the whole species list are used in the multivariate analyses (Figure 6.1C, D). The only minor differences are in the configuration of the ordination plots. For example, Site 1 assemblage is grouped together with Site 2 and Site 3 in the 2009 survey. Although Site 1 species composition can be significantly differentiated from that of Site 2 and 3, the

community assemblages are similar at the same similarity level (see cluster dendrogram, Figure 4.18 in Chapter 4). Similar differences in the configuration of the ordination plots are noted when amphipods and polychaetes are used as monitoring taxa (Figure 6.1E, F). For example, the 2008 survey revealed the outlier Station 3.1, which is not shown in the other two levels of analyses (Figure 6.1A-D). Other than these minor configuration differences, there are no major differences in the re-presentation of distribution patterns (i.e., stress levels). Although the stress level is slightly increased when only amphipods and polychaetes are analysed in the 2008 survey, it still falls within the desired limit of 0.15 (Clarke & Warwick 1994).

6.4. Recommendations

To improve and maintain temporal comparability for this routine monitoring programme, it is suggested that field and laboratory methodology employed in this study be adopted as protocol for sampling and analysing subtidal benthos along the 10 metre depth contour of Algoa Bay. Unfortunately, appropriate replicates for this study were not identified, but this can be estimated from species area curves (Scheiner 2003; Shen *et al.* 2003). Theory dictates that the curve should advance in an upward slope as more species are 'discovered' with every sample replicate added. The angle of the slope should steadily decrease as less species are added, ultimately approaching an asymptote when no more species are discovered. The amount of replicates needed to reach the asymptote serves as an indication of the amount of replicates to be collected in order to capture an acceptable estimate of the number of species present relative to that area scale. Gray (2002) argued that the species area curves for coastal and deep sea macrofauna will probably never reach an asymptote. The reason is that sampling equipment such as grabs only samples a small portion of the large area, and each

sample potentially captures a new species (Gray 2002). It is for this reason that replicates should be maintained at 25 as a precautionary measure till new research indicates otherwise.

It is recommended, however, that the number of stations per site be reduced from three to one. This way both boat and laboratory time associated with the collection and sorting of such large numbers of samples will be reduced significantly. With the exception of the Papenkuils community, this study has shown that species compositions of sandy bottoms that are 100 meters apart cannot significantly be differentiated. To further reduce laboratory time, it is suggested that taxonomic sufficiency be reduced to genus or family level since information lost at these levels is not substantial (Warwick 1988a; Ferraro & Cole 1990; James *et al.* 1995; Dauvin *et al.* 2003; Thompson *et al.* 2003; Lampadariou *et al.* 2005). Where the family possesses more than three species, it is recommended that taxonomic sufficiency be increased to genus level. Where genera possess more than three species the taxonomic sufficiency should be increased to species level. This procedure will reduce the influence of taxonomic uncertainty in the calculations of diversity indices (Wu 1982).

If taxonomic groups are identified to family level, then essential dyes like Phloxine B and Rose Bengal may be used in order to increase sorting efficiency thus further reducing laboratory time (Mason & Yevich 1967). During the 2008 survey, Rose Bengal was used in order to aid sorting, but this dye interfered with some of the important morphological features necessary for identification to species level (*pers. obs.*). In the second survey (2009) this dye was not used, which contributed to a drop in sorting efficiency.

In addition to monitoring target taxa, areas of influence, like estuarine mouths (Site 1 and Site 3), effluent outfalls (Site 4) and dredged spoil dumpsite (Site 5), should be monitored in the western sector of Algoa Bay and similar log spiral bays. It is also suggested that additional sites be established for long-term monitoring. These should be located in the eastern sector so that the entire bay is covered. The eastern sector of the bay is less influenced by anthropogenic activity but is more exposed to wind and higher wave energy compared to the western sector.

The proposed routine monitoring programme is very coarse in scale and can be implemented annually with relative ease. It is envisaged that trained technicians (or non specialist personnel) can play an important role in this programme, since high level expert knowledge is not needed. It is also suggested that this routine monitoring programme be accompanied by detailed studies to be conducted at least every three years. Detailed studies should address community dynamics. Routine monitoring should also be accompanied by occasional hypothesis driven studies to understand influences of stochastic events like upwelling, flooding of estuaries and high wave energy.

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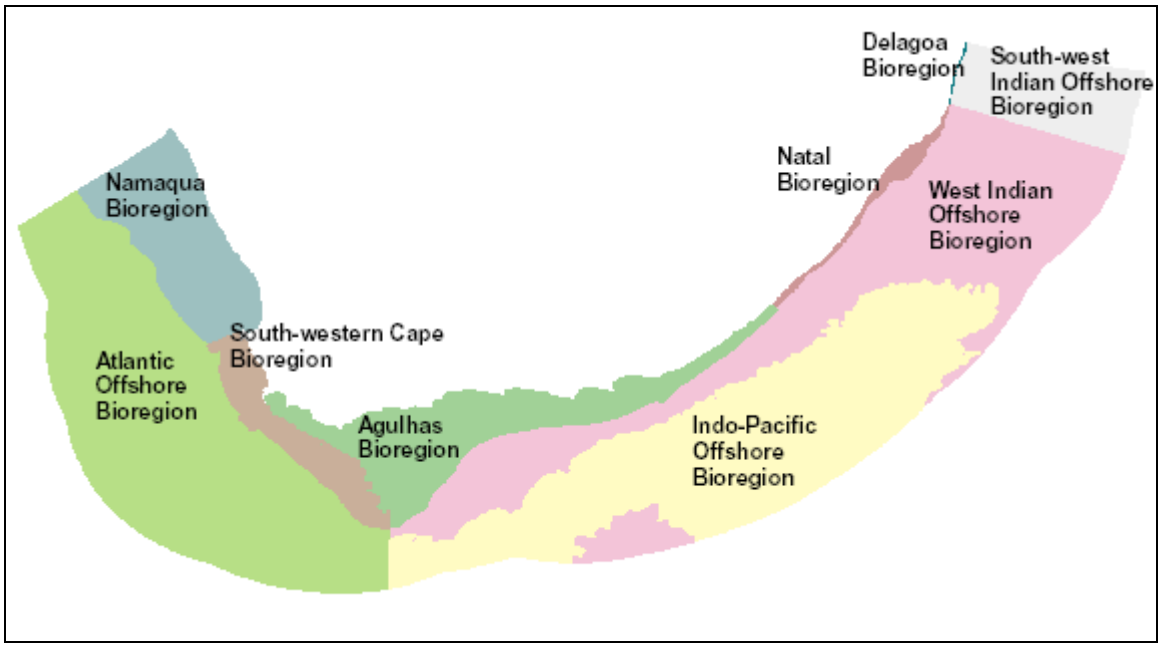
Appendix

Section

Appendix 1. Marine Bioregions of South Africa within the exclusive economic zone (from Sink *et al.* 2004).



Appendix 2A. Variability profile of environmental parameters of the water column in the western sector of Algoa Bay during 2008 and 2009 sampling sessions. Reported hereunder are average conditions (n = 3) plus 1 SD of surface and bottom waters.

Site	Year	Temperature (°C)		Salinity (psu)		pH		Turbidity (NTU)		Dissolved Oxygen (mg/l)	
		Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
1	2008	20.41 ± 0.05	19.16 ± 0.00	34.83 ± 0.03	34.81 ± 0.03	8.64 ± 0.01	8.66 ± 0.02	3.73 ± 0.25	5.83 ± 2.35	8.23 ± 0.05	8.05 ± 0.12
	2009	21.10 ± 0.04	20.90 ± 0.03	33.26 ± 0.21	33.03 ± 0.63	8.85 ± 0.05	8.81 ± 0.10	4.83 ± 0.86	4.47 ± 1.46	8.52 ± 0.04	8.57 ± 0.15
2	2008	21.04 ± 0.03	19.53 ± 0.17	34.87 ± 0.01	34.81 ± 0.01	8.67 ± 0.01	8.71 ± 0.01	3.00 ± 0.10	10.50 ± 5.34	8.35 ± 0.02	7.86 ± 0.05
	2009	20.99 ± 0.08	20.54 ± 0.05	33.30 ± 0.05	33.52 ± 0.17	8.87 ± 0.01	8.90 ± 0.01	3.63 ± 0.06	7.30 ± 2.93	8.65 ± 0.07	8.09 ± 0.17
3	2008	21.06 ± 0.05	16.01 ± 0.12	34.87 ± 0.02	34.63 ± 0.04	8.65 ± 0.01	8.67 ± 0.04	3.37 ± 0.06	13.53 ± 3.80	8.39 ± 0.09	6.35 ± 1.02
	2009	21.01 ± 0.04	20.47 ± 0.02	33.44 ± 0.08	33.61 ± 0.19	8.89 ± 0.02	8.91 ± 0.02	3.17 ± 0.21	3.70 ± 0.95	8.91 ± 0.24	8.35 ± 0.37
4	2008	22.29 ± 0.02	20.83 ± 0.26	34.92 ± 0.14	35.05 ± 0.02	8.59 ± 0.02	8.50 ± 0.03	3.97 ± 0.50	6.97 ± 1.91	7.88 ± 0.49	5.28 ± 1.05
	2009	20.06 ± 0.06	18.48 ± 0.08	32.93 ± 0.34	32.74 ± 0.84	8.66 ± 0.13	8.52 ± 0.24	3.23 ± 0.06	6.43 ± 2.92	8.08 ± 0.05	5.62 ± 0.67
5	2008	18.48 ± 0.78	15.34 ± 0.74	34.81 ± 0.06	34.69 ± 0.03	8.40 ± 0.04	8.41 ± 0.04	5.30 ± 0.56	6.37 ± 2.90	5.38 ± 0.44	5.06 ± 0.23
	2009	20.03 ± 0.06	18.94 ± 0.06	33.49 ± 0.06	33.51 ± 0.17	8.88 ± 0.02	8.87 ± 0.01	2.67 ± 0.06	3.63 ± 0.46	9.24 ± 0.84	7.38 ± 0.31
6	2008	22.42 ± 0.05	17.74 ± 0.11	34.89 ± 0.01	34.72 ± 0.02	8.68 ± 0.02	8.56 ± 0.06	3.07 ± 0.06	3.37 ± 0.12	9.18 ± 0.07	5.03 ± 0.59
	2009	20.02 ± 0.03	19.19 ± 0.05	33.58 ± 0.28	33.79 ± 0.37	8.89 ± 0.03	8.86 ± 0.05	3.43 ± 1.44	2.93 ± 0.06	8.97 ± 0.06	7.66 ± 0.25

Appendix 2B. Section plots of Ocean Data View depicting the variability of physico-chemical variables in the western sector of Algoa Bay.

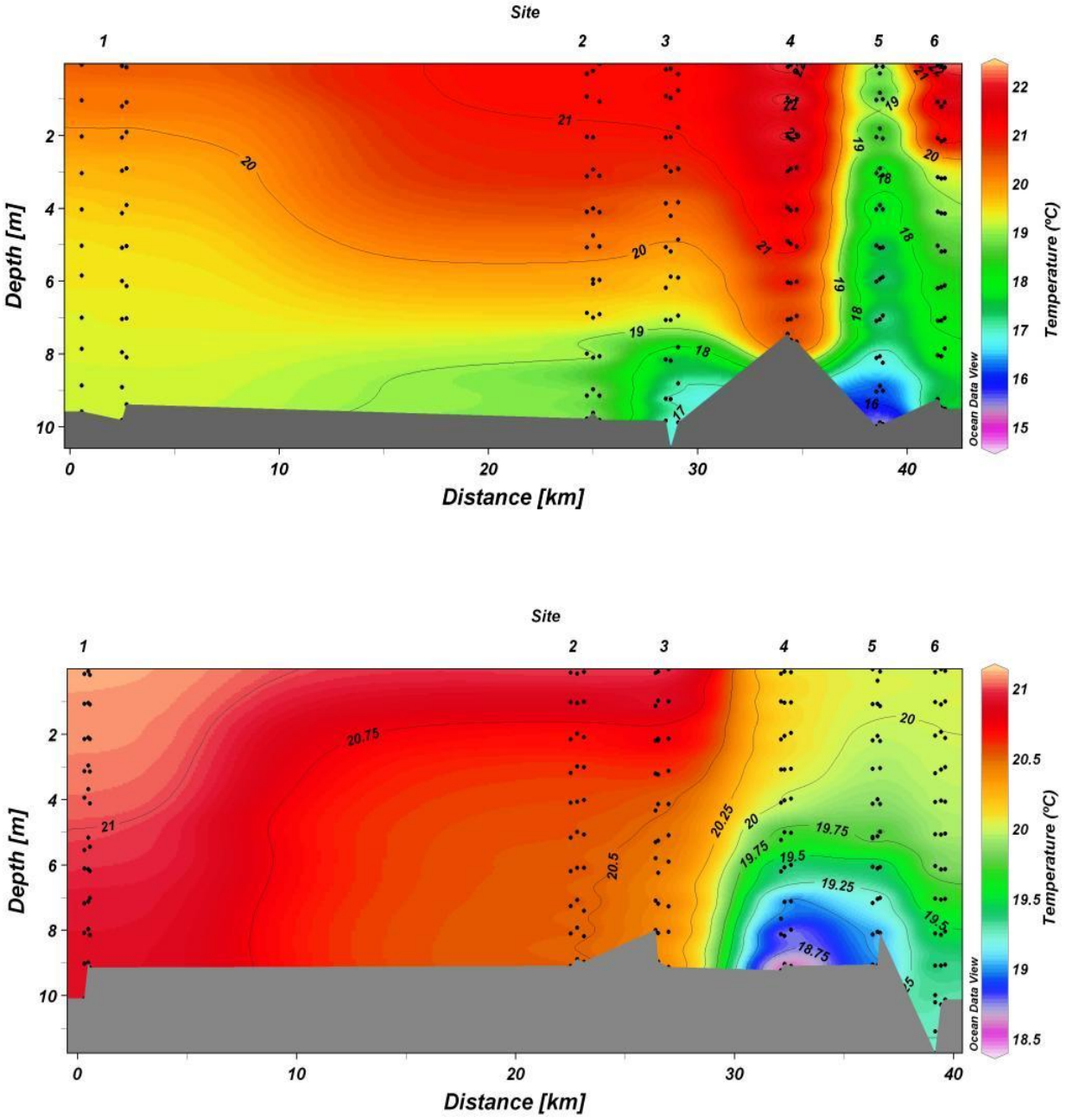


Figure A2B.1 Spatial (vertical and horizontal) profiles of temperature (°C) in the western sector of Algoa during 2008 (top) and 2009 (bottom) benthic surveys.

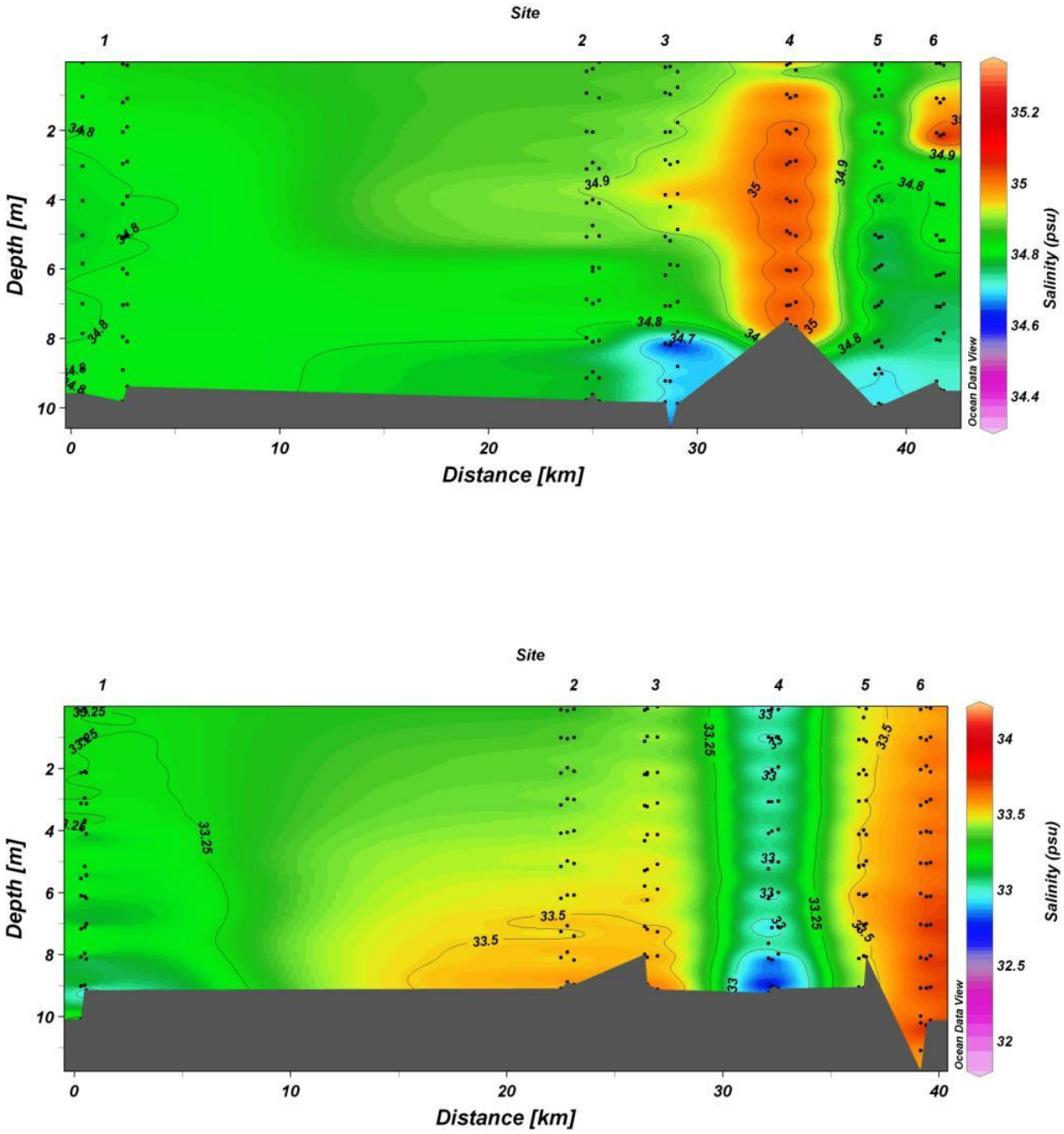


Figure A2B.2. Spatial (vertical and horizontal) profile of salinity (psu) in the western sector of Algoa Bay during 2008 (top) and 2009 (bottom) benthic surveys.

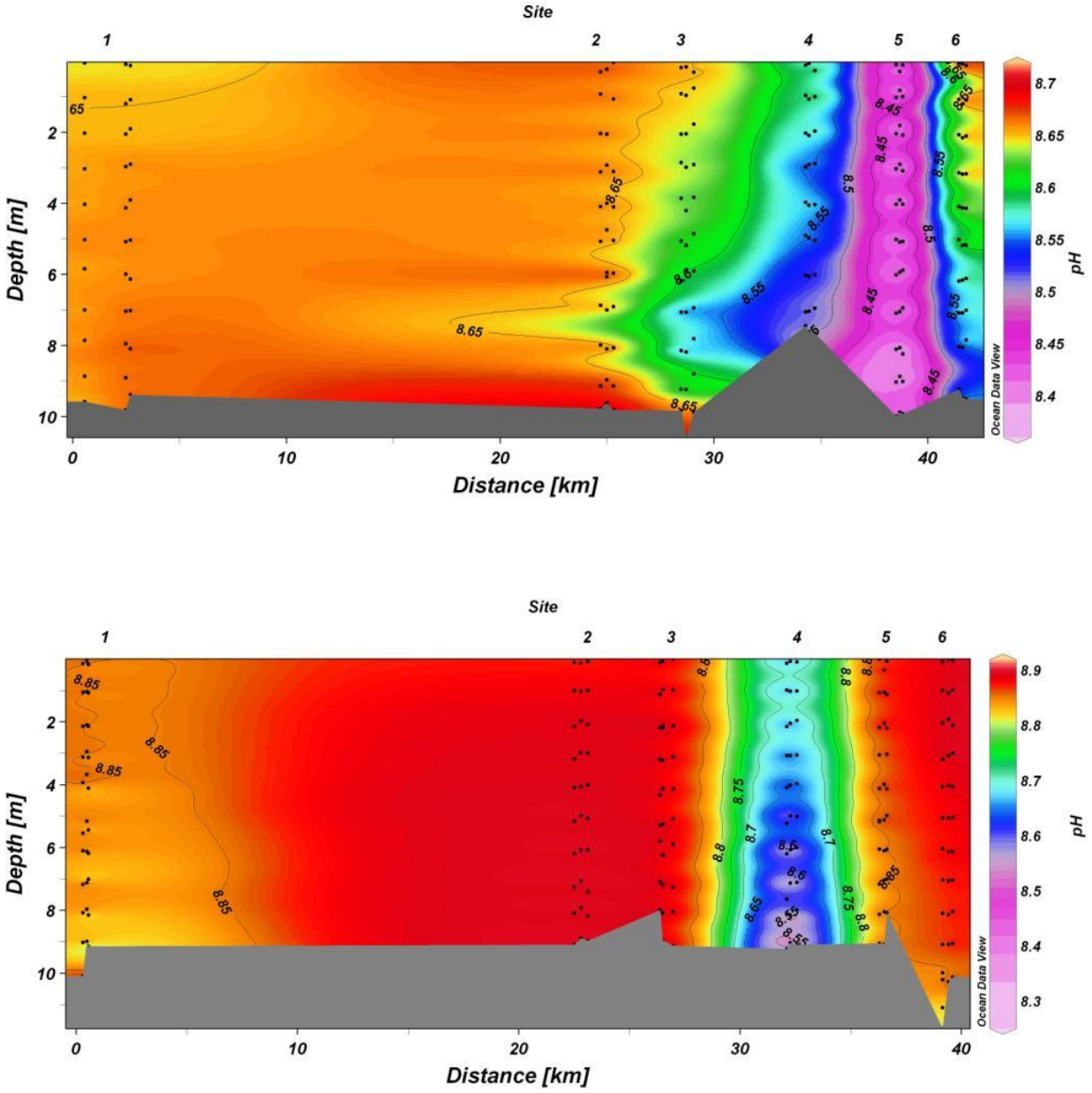


Figure A2B.3. Vertical and horizontal profile of pH in the western sector of Algoa Bay during 2008 (top) and 2009 (bottom) benthic surveys.

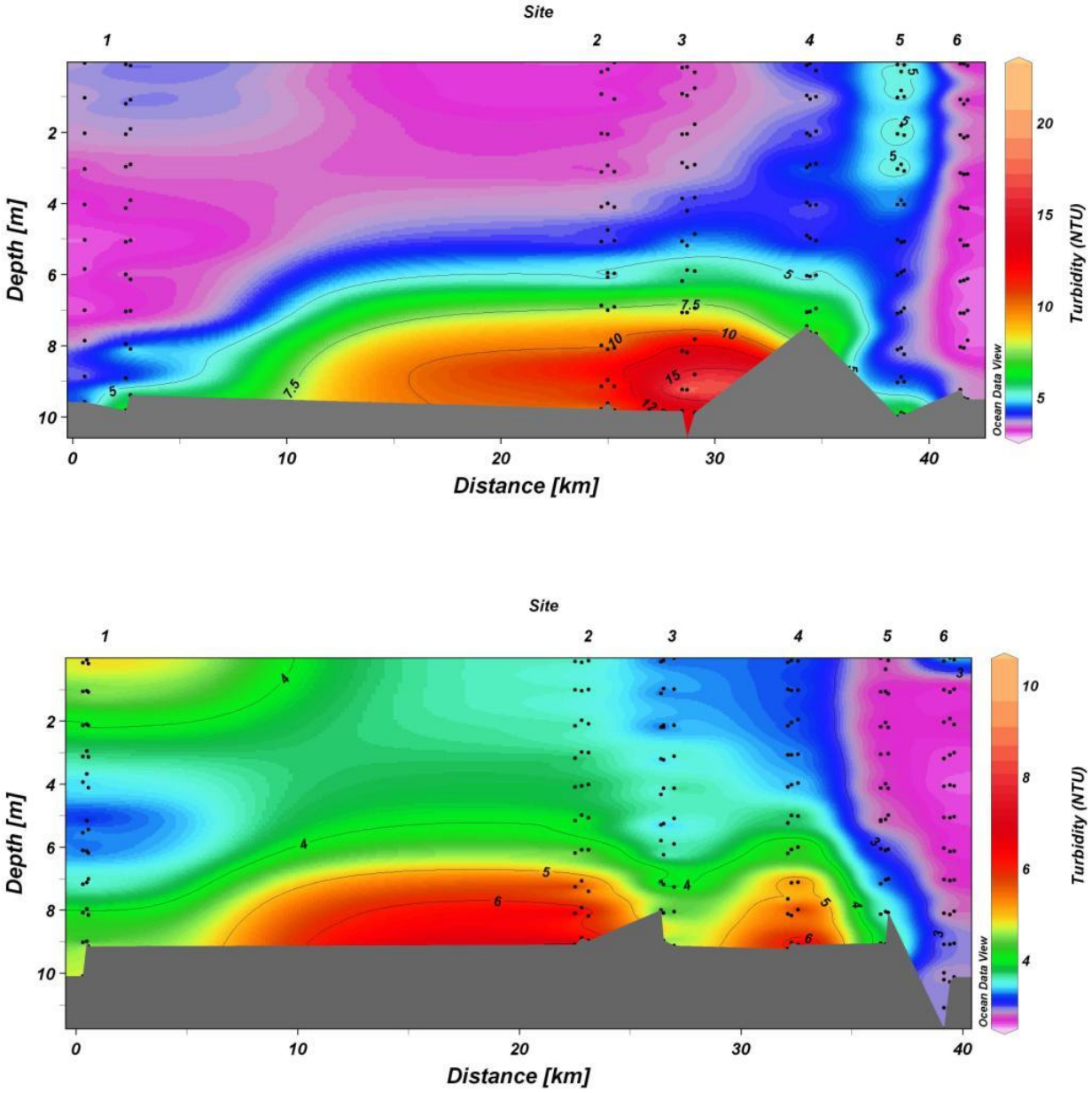


Figure A2B.4. Vertical and horizontal profile of turbidity (NTU) in the western sector of Algoa Bay during 2008 (top) and 2009 (bottom) benthic surveys.

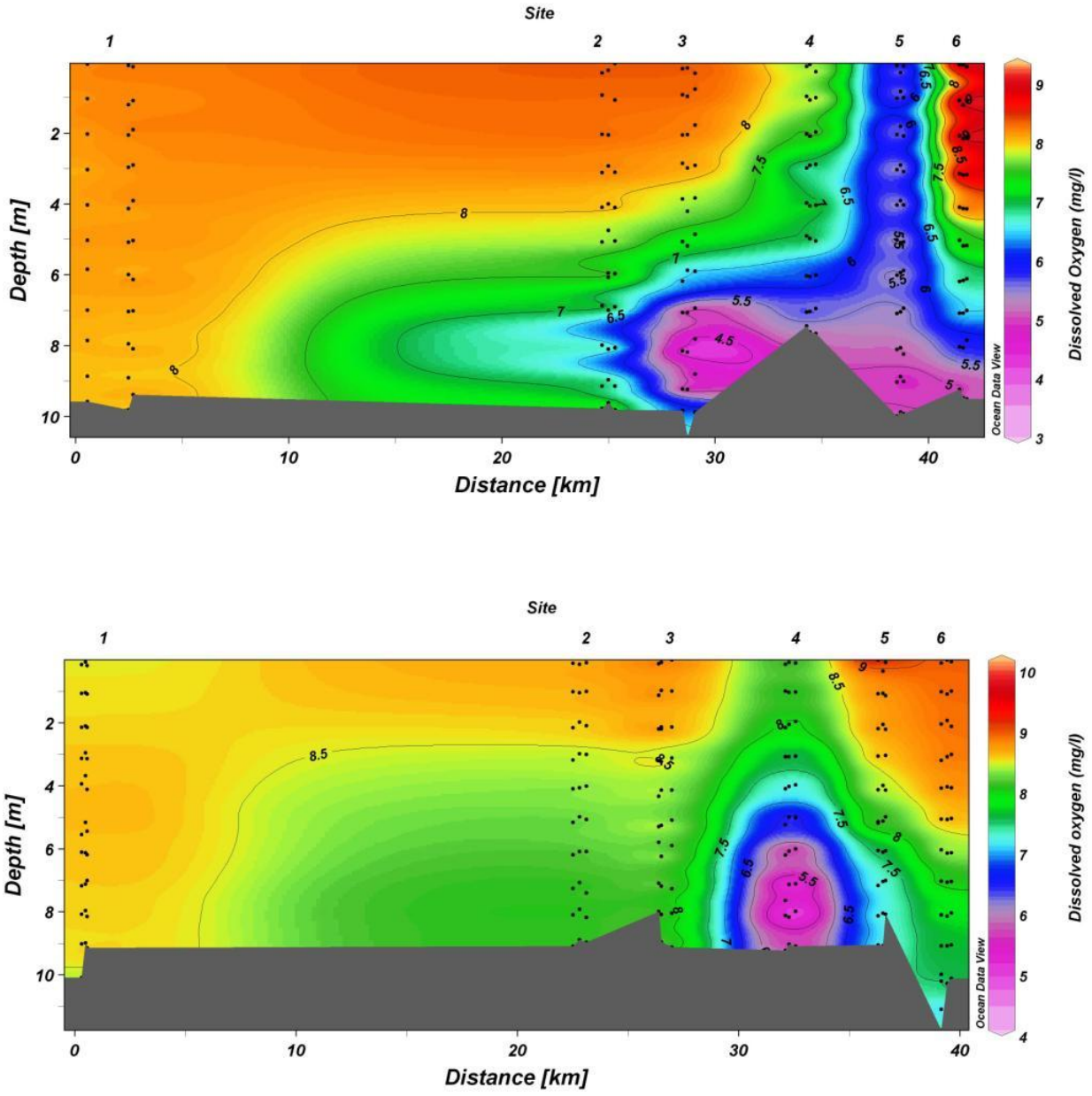


Figure A2B.5. Vertical and horizontal profile of dissolved oxygen (mg l^{-1}) in the western sector of Algoa Bay during 2008 (top) and 2009 (bottom) benthic surveys.

Appendix 3A. Sediment data (2008 survey) for particle size analysis. Sample label (e.g., 1.1.R1) represents: *Site. Station. Replicate*, respectively. *phi* (φ) units are represented in bold. Total mass was measured in grams.

Sample	Total Mass	1 mm	0.5 mm	0.25 mm	0.125 mm	0.063 mm	<0.063 mm
		0	**1**	**2**	**3**	**4**	**>5**
1-1-R1	492.30	2.17	5.49	391.22	76.16	15.72	1.32
1-1-R2	379.66	2.10	4.40	246.75	105.53	20.51	0.62
1-1-R3	499.50	1.68	5.41	330.79	128.17	32.00	1.27
1-2-R1	459.50	1.30	3.91	219.51	177.58	55.46	1.64
1-2-R2	451.06	1.08	3.60	242.36	158.46	44.64	1.32
1-2-R3	262.60	3.07	5.54	95.09	119.91	37.63	1.19
1-3-R1	281.72	4.42	6.57	99.98	133.95	35.96	0.77
1-3-R2	443.46	1.30	4.19	235.15	161.01	40.92	0.94
1-3-R3	485.59	5.32	8.39	245.00	187.26	38.69	0.76
2-1-R1	519.51	2.90	10.73	402.40	81.35	19.22	2.43
2-1-R2	490.32	3.33	9.49	305.59	120.02	43.90	7.51
2-1-R3	539.09	3.49	16.53	443.85	60.69	12.56	1.22
2-2-R1	476.34	9.87	28.33	351.48	72.23	11.86	1.94
2-2-R2	548.31	4.68	34.48	441.56	57.96	8.38	0.31
2-2-R3	503.80	4.12	23.80	372.56	82.94	17.67	1.68
2-3-R1	395.46	7.70	19.36	281.52	72.09	13.11	1.28
2-3-R2	518.55	3.97	22.40	413.39	66.38	10.76	0.81
2-3-R3	503.10	6.09	27.51	373.33	79.81	14.21	1.76
3-1-R1	448.28	5.57	10.71	295.79	123.05	11.28	1.60
3-1-R2	462.06	1.41	4.57	327.97	115.90	11.82	0.53
3-1-R3	485.63	1.17	3.68	365.33	101.67	12.97	0.71
3-2-R1	468.57	4.52	8.28	220.52	201.92	31.14	2.19
3-2-R2	477.66	1.61	6.27	259.06	177.72	30.37	2.32
3-2-R3	426.02	3.49	9.34	250.99	137.23	22.13	2.48
3-3-R1	352.77	4.30	7.94	96.80	192.44	44.37	7.22
3-3-R2	471.03	4.45	11.92	190.96	211.85	47.01	4.50
3-3-R3	453.20	7.15	18.23	188.96	199.17	36.99	2.46
4-1-R1	208.76	14..37	12.68	34.51	42.02	83.42	20.95
4-1-R2	289.03	1.02	5.73	28.37	48.69	143.45	61.63
4-1-R3	194.80	26.92	14.77	21.63	31.63	69.70	29.42
4-2-R1	319.16	5.40	6.15	70.15	92.45	102.80	41.82
4-2-R2	418.23	2.30	6.51	132.17	125.81	103.69	47.55
4-2-R3	316.07	8.77	10.98	57.11	97.85	119.60	21.35
4-3-R1	346.11	3.46	6.04	133.49	113.49	60.28	28.72
4-3-R2	324.88	4.61	8.12	115.14	102.01	68.37	26.09
4-3-R3	456.85	3.53	5.89	203.40	133.30	80.87	29.30
5-1-R1	469.49	3.98	8.88	313.31	126.44	15.71	0.88
5-1-R2	367.07	4.98	12.19	239.54	99.38	10.05	0.45
5-1-R3	449.37	3.27	9.74	293.58	126.66	15.37	0.59
5-2-R1	451.50	8.29	13.41	275.61	139.18	14.06	0.78
5-2-R2	441.06	8.51	15.29	280.50	123.90	11.16	1.35
5-2-R3	428.69	3.39	6.84	263.70	134.48	18.86	1.13
5-3-R1	448.57	8.55	11.11	288.26	129.21	10.53	0.69
5-3-R2	457.47	3.18	9.08	329.33	105.47	9.80	0.47
5-3-R3	462.46	3.32	10.86	304.51	130.95	12.40	0.51
6-1-R1	469.04	2.28	8.35	241.37	173.18	43.27	0.79
6-1-R2	379.59	1.96	6.62	123.23	196.79	50.38	0.83
6-1-R3	419.30	4.58	9.35	182.86	176.05	45.35	1.02
6-2-R1	443.71	13.44	30.55	259.55	114.74	24.25	0.54
6-2-R2	416.41	11.12	17.01	199.07	163.28	25.42	0.45
6-2-R3	405.19	6.42	14.68	206.43	145.44	31.22	0.75
6-3-R1	427.00	5.69	13.41	220.74	153.07	33.26	0.80
6-3-R2	388.01	6.22	19.09	237.20	104.33	20.54	0.37
6-3-R3	471.75	3.33	9.90	258.45	167.14	33.06	0.53

Appendix 3B. Sediment data (2009 survey) used for granulometry analysis.

Sample	Total Mass	1 mm	0.5 mm	0.25 mm	0.125 mm	0.063 mm	<0.063 mm
		0	**1**	**2**	**3**	**4**	**>5**
1-1-R1	382.95	1.96	3.50	259.91	98.30	18.24	0.69
1-1-R2	452.79	2.11	5.24	235.77	165.53	41.25	2.29
1-1-R3	400.21	1.96	4.05	228.28	135.27	28.74	1.99
1-2-R1	426.20	1.40	4.02	295.01	113.19	12.19	0.42
1-2-R2	406.48	2.70	3.55	255.31	128.22	15.93	0.70
1-2-R3	181.10	8.06	6.55	82.88	73.73	9.18	0.26
1-3-R1	324.65	2.86	3.01	101.95	180.25	34.09	2.56
1-3-R2	198.69	1.22	1.68	45.03	112.35	35.10	3.51
1-3-R3	160.83	1.72	1.95	70.08	76.21	10.43	0.34
2-1-R1	408.19	4.04	10.45	309.55	67.33	14.77	1.69
2-1-R2	438.81	7.27	11.74	307.94	87.26	22.60	1.56
2-1-R3	419.25	7.01	13.75	313.38	66.52	14.66	3.35
2-2-R1	466.13	4.04	9.73	313.80	110.70	25.25	2.47
2-2-R2	470.02	3.84	11.03	349.84	89.44	14.48	0.94
2-2-R3	300.79	22.46	18.31	204.69	46.23	8.38	0.20
2-3-R1	355.40	20.88	57.10	242.57	30.32	2.45	0.28
2-3-R2	504.51	6.34	20.33	389.41	73.93	12.44	1.41
2-3-R3	422.17	2.35	7.06	311.08	91.09	9.88	0.44
3-1-R1	450.30	2.34	6.14	322.08	111.11	8.25	0.31
3-1-R2	285.97	3.33	5.24	179.25	89.57	8.04	0.20
3-1-R3	459.22	3.55	5.92	326.62	113.51	8.95	0.56
3-2-R1	496.75	1.73	7.24	409.19	75.33	3.04	0.05
3-2-R2	497.36	1.32	6.51	414.46	71.61	3.35	0.08
3-2-R3	429.54	1.86	8.43	350.98	65.19	2.96	0.03
3-3-R1	408.85	2.61	5.99	261.74	118.58	18.11	1.81
3-3-R2	334.22	0.94	3.97	185.11	120.23	22.25	1.59
3-3-R3	238.03	2.04	2.84	138.35	82.00	11.56	1.09
4-1-R1	403.74	6.06	7.63	179.80	105.33	70.51	34.08
4-1-R2	376.52	2.94	5.73	235.86	75.90	45.29	10.25
4-1-R3	351.52	26.77	14.80	112.58	92.42	70.31	34.18
4-2-R1	273.39	7.97	5.89	81.50	80.24	72.83	24.72
4-2-R2	358.70	13.80	12.01	104.58	103.22	85.86	39.34
4-2-R3	330.56	3.74	4.81	99.84	90.85	101.72	29.55
4-3-R1	455.37	6.33	9.44	280.27	117.13	33.76	8.15
4-3-R2	410.41	11.62	9.91	169.58	100.60	85.12	33.14
4-3-R3	422.53	8.29	7.63	137.15	138.55	101.45	29.25
5-1-R1	402.09	4.54	7.22	265.37	114.63	9.74	0.60
5-1-R2	415.06	6.57	10.08	246.92	138.83	11.55	0.81
5-1-R3	422.62	6.96	7.86	257.59	136.82	12.21	1.07
5-2-R1	407.77	4.07	7.08	300.18	87.95	7.88	0.65
5-2-R2	452.55	3.42	7.07	313.35	116.90	10.95	0.83
5-2-R3	268.95	7.65	10.91	162.31	79.21	8.13	0.61
5-3-R1	475.75	5.58	11.00	362.78	92.12	3.71	0.33
5-3-R2	458.09	4.54	10.04	346.37	91.80	4.49	0.61
5-3-R3	440.64	11.99	13.16	292.72	114.05	7.18	2.03
6-1-R1	395.17	3.75	6.66	206.37	154.86	22.91	0.64
6-1-R2	445.12	4.90	9.96	207.90	180.84	39.97	1.32
6-1-R3	208.40	3.15	7.01	112.86	71.73	13.28	0.26
6-2-R1	318.49	9.62	12.79	221.81	71.00	2.94	0.21
6-2-R2	101.33	39.72	15.06	33.85	11.80	0.61	0.10
6-2-R3	165.57	118.13	18.93	18.66	6.58	2.03	1.00
6-3-R1	205.76	7.86	17.66	133.95	40.50	5.22	0.08
6-3-R2	415.65	7.67	14.86	274.35	99.74	18.33	0.59
6-3-R3	399.06	7.62	19.53	258.69	94.31	17.76	0.77

Appendix 4. Data for total organic content analysis in the western sector of Algoa Bay during both surveys.

Sample	Year 2008			Year 2009		
	Mass 1 (g DW)	**Mass 2 (g DW)**	**TOC (%)**	**M ass 1 (g DW)**	**Mass 2 (g DW)**	**TOC (%)**
1-1-R1	96.93	95.78	1.19	96.34	95.64	0.73
1-1-R2	99.07	97.63	1.45	97.17	96.25	0.95
1-1-R3	102.36	101.10	1.23	111.21	110.26	0.85
1-2-R1	95.07	93.98	1.15	97.21	96.47	0.76
1-2-R2	95.14	93.91	1.29	92.60	91.69	0.98
1-2-R3	95.68	94.13	1.62	81.52	80.43	1.34
1-3-R1	97.10	96.16	0.97	94.30	93.16	1.21
1-3-R2	96.72	95.31	1.46	92.60	91.01	1.72
1-3-R3	95.50	94.14	1.42	92.78	91.54	1.34
2-1-R1	97.79	96.90	0.91	114.13	113.16	0.85
2-1-R2	96.59	95.36	1.27	99.06	97.54	1.53
2-1-R3	98.17	97.37	0.81	115.58	114.57	0.87
2-2-R1	96.52	95.71	0.84	115.61	114.72	0.77
2-2-R2	100.12	99.12	1.00	116.77	115.97	0.69
2-2-R3	93.48	92.46	1.09	118.28	117.33	0.80
2-3-R1	96.98	95.85	1.17	95.25	94.32	0.98
2-3-R2	97.21	96.34	0.89	117.85	116.99	0.73
2-3-R3	100.99	100.05	0.93	93.55	92.71	0.90
3-1-R1	96.93	96.09	0.87	58.64	58.19	0.77
3-1-R2	96.66	95.76	0.93	91.93	90.52	1.53
3-1-R3	100.23	99.33	0.90	112.76	111.97	0.70
3-2-R1	93.96	92.96	1.06	92.08	90.91	1.27
3-2-R2	99.32	98.48	0.85	118.14	117.48	0.56
3-2-R3	93.03	92.18	0.91	115.18	114.37	0.70
3-3-R1	94.47	92.76	1.81	114.21	113.29	0.81
3-3-R2	106.40	105.13	1.19	92.21	91.63	0.63
3-3-R3	98.93	97.93	1.01	96.06	94.95	1.16
4-1-R1	86.02	82.96	3.56	97.64	95.87	1.81
4-1-R2	79.32	76.71	3.29	100.46	99.28	1.17
4-1-R3	60.00	57.79	3.68	88.66	86.92	1.96
4-2-R1	98.51	96.70	1.84	91.60	89.32	2.49
4-2-R2	105.07	103.25	1.73	91.79	90.02	1.93
4-2-R3	96.00	93.35	2.76	94.39	92.65	1.84
4-3-R1	103.36	101.62	1.68	100.84	99.65	1.18
4-3-R2	100.53	98.77	1.75	90.44	89.24	1.33
4-3-R3	103.31	101.66	1.60	93.40	91.21	2.34
5-1-R1	93.98	93.11	0.93	90.68	89.67	1.11
5-1-R2	94.48	93.58	0.95	90.45	89.67	0.86
5-1-R3	95.78	94.69	1.14	90.60	89.46	1.26
5-2-R1	95.51	94.71	0.84	112.31	111.71	0.53
5-2-R2	90.61	89.55	1.17	112.33	111.68	0.58
5-2-R3	90.41	89.35	1.17	92.01	90.53	1.61
5-3-R1	93.40	92.40	1.07	96.52	95.33	1.23
5-3-R2	98.50	97.83	0.68	94.26	93.20	1.12
5-3-R3	96.53	95.71	0.85	94.98	93.52	1.54
6-1-R1	95.87	94.48	1.45	91.18	90.29	0.98
6-1-R2	87.60	86.58	1.16	84.14	82.35	2.13
6-1-R3	96.59	95.44	1.19	78.27	76.47	2.30
6-2-R1	92.05	91.11	1.02	97.42	95.88	1.58
6-2-R2	91.17	90.08	1.20	94.82	93.60	1.29
6-2-R3	95.33	94.10	1.29	91.27	89.88	1.52
6-3-R1	100.34	99.02	1.32	99.06	97.64	1.43
6-3-R2	91.82	90.50	1.44	98.34	97.19	1.17
6-3-R3	88.71	87.41	1.47	94.14	92.68	1.55

Appendix 5. Concentrations of heavy metals measured in stations of the western sector of Algoa Bay during 2008 benthic survey. Reference metals (i.e., Aluminium (Al) and Iron (Fe)) were measured in milligrams per gram dry weight and the rest of the metals were measured in micrograms per gram dry weight.

Sample Labels	Al 308.215	As 193.696	Be 313.042	Cd 226.502	Co 228.615	Cr 205.560	Cu 324.754	Fe 259.940	Mn 257.610	Ni 231.604	Pb 220.353	V 292.401	Zn 213.857
1.1	1.92	6.69	0.15	<0.01	0.60	2.61	0.88	2.75	27.59	2.84	0.65	7.80	2.47
1.2	3.98	6.86	0.26	0.31	1.60	3.20	1.57	3.99	40.25	3.13	0.93	14.31	3.58
1.3	3.20	6.08	0.18	<0.01	1.22	2.52	1.13	3.17	30.58	2.88	0.84	8.37	2.74
2.1	0.83	5.50	0.00	<0.01	0.13	0.50	0.28	0.94	10.45	0.08	0.43	2.61	1.03
2.2	0.47	5.25	<0.01	<0.01	0.01	<0.01	0.02	0.59	6.07	<0.01	0.24	1.63	1.14
2.3	0.60	5.17	<0.01	<0.01	0.02	0.05	0.01	0.66	7.18	<0.01	0.25	1.90	3.36
3.1	0.85	5.55	<0.01	<0.01	0.11	0.23	0.21	0.84	7.64	<0.01	0.44	2.05	0.88
3.2	0.64	4.92	<0.01	0.64	0.03	<0.01	0.01	0.63	5.79	<0.01	0.33	1.73	0.67
3.3	1.38	6.44	0.07	<0.01	0.23	1.66	0.87	1.76	17.28	1.15	0.89	4.20	2.20
4.1	2.77	7.39	0.20	2.34	0.67	5.30	2.19	3.35	40.82	3.59	2.16	7.54	6.41
4.2	8.44	8.03	0.54	0.11	2.37	13.84	12.32	6.56	84.99	5.76	5.27	17.42	17.74
4.3	5.98	7.42	0.37	0.06	1.57	8.53	7.23	4.99	62.35	4.46	3.56	12.95	10.44
5.1	1.15	5.23	0.07	<0.01	0.20	3.24	0.49	1.91	21.65	3.12	1.02	5.06	3.45
5.2	1.10	4.96	0.07	<0.01	0.26	3.20	0.49	1.87	34.62	3.15	1.10	5.06	2.86
5.3	1.60	6.31	0.10	<0.01	0.31	3.47	0.87	2.28	31.73	3.37	1.20	6.48	2.66
6.1	2.21	<0.01	0.07	<0.01	0.21	<0.01	0.80	2.43	26.66	<0.01	1.22	5.98	1.14
6.2	2.22	<0.01	0.07	<0.01	0.21	<0.01	0.84	2.40	25.30	<0.01	1.14	6.27	1.37
6.3	1.19	<0.01	0.03	<0.01	0.10	<0.01	0.36	1.85	20.32	<0.01	0.99	4.84	1.78

Appendix 6A. Results or the analysis of dissimilarity between sites (SIMPER) during the 2008 benthic survey.

Site 1 vs Site 2
Average dissimilarity: 51.18 %

Taxa	Site 1 Av. Abund	Site 2 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Bathyporeia sp	15.43	2.57	1.85	2.63	3.62	3.62
Diogenidae	4.59	14.12	1.36	0.91	2.66	6.28
Laetmatophilus sp	9.32	18.33	1.31	3.45	2.56	8.84
Urothoe tumorosa	11.21	2.65	1.25	2.05	2.44	11.28
Mandibulophoxus stimpsoni	2.81	11.29	1.24	1.81	2.42	13.70
Phoxocephalidae	0.00	8.56	1.23	3.75	2.40	16.10
Heterophoxus spp	0.00	8.45	1.22	8.77	2.39	18.49
Gynodiastylidae	10.39	2.29	1.19	2.16	2.32	20.86
Sthenelais cf boa	7.24	0.00	1.05	8.06	2.05	22.86
Cirratulidae sp 2	6.88	0.00	0.99	17.98	1.94	24.80
Gastropoda larvae	6.88	0.00	0.99	17.98	1.98	26.74
Sipunculida-like	0.00	6.27	0.92	1.20	1.81	28.55
Donax burnupi	0.00	5.89	0.87	1.31	1.70	30.25
Orbiniidae	0.00	5.54	0.80	1.26	1.56	31.81
Nudibranch	5.54	0.00	0.80	1.30	1.56	33.37
Spionidae	6.88	12.26	0.78	1.01	1.53	34.90
Corophiidae	5.54	0.00	0.78	1.26	1.52	36.42
Sigalionidae	5.11	0.00	0.74	1.33	1.44	37.86
Arcturina scutula	5.11	0.00	0.72	1.30	1.40	39.26
Ophelia anomala	0.00	4.81	0.69	1.32	1.34	40.61
Sipunculida spp	4.59	0.00	0.68	1.33	1.33	41.93
Ampelisca palmata	4.59	0.00	0.68	1.33	1.33	43.26
Ostracoda sp 3	6.88	2.29	0.68	1.33	1.32	44.58
Platyhelminthes	4.59	0.00	0.67	1.33	1.30	45.88
Sthenelais spp	4.59	0.00	0.67	1.33	1.30	47.19
Pectinaria capensis	0.00	4.59	0.66	1.33	1.29	48.47
Amakusanthura africana	6.88	2.29	0.66	1.33	1.28	49.75
Oedicerotidae	0.00	4.59	0.66	1.33	1.28	51.03

Appendix 6A. Continued.

Site 1 vs Site 3
Average dissimilarity: 47.99 %

Taxa	Site 1 Av. Abund	Site 3 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Bathyporeia sp	15.43	4.59	1.27	2.74	2.65	2.65
Heterophoxus spp	0.00	9.55	1.15	7.88	2.40	5.05
Mandibulophoxus stimpsoni	2.81	11.66	1.12	1.64	2.34	7.38
Urothoe pinnata	11.21	19.57	1.00	2.98	2.07	9.46
Phoxocephalidae	0.00	8.13	0.99	4.49	2.07	11.53
Heterophoxus cephalodens	0.00	7.55	0.93	3.77	1.93	13.46
Pectinaria capensis	0.00	7.26	0.88	11.11	1.82	15.29
Ampelisca brachyceras	0.00	7.24	0.87	8.41	1.82	17.11
Haminoeidae	0.00	7.10	0.86	9.31	1.79	18.89
Laetmatophilus sp	9.32	2.48	0.86	1.70	1.78	20.68
Amakusanthura africana	6.88	0.00	0.83	7.72	1.74	22.41
Phaxas decipiens	0.00	6.88	0.83	7.72	1.74	24.15
Gastropoda lavae	6.88	0.00	0.83	7.72	1.74	25.89
Nudibranch	5.54	0.00	0.67	1.28	1.39	27.28
Urothoe sp 2	0.00	5.96	0.66	1.31	1.38	28.66
Urothoe sp 1	0.00	5.90	0.66	1.30	1.37	30.03
Spiroplax spiralis	0.00	5.11	0.66	1.25	1.37	31.40
Urothoe sp	3.63	5.78	0.65	1.20	1.36	32.76
Sigalionidae	5.11	0.00	0.62	1.30	1.29	34.05
Urothoidae	2.29	7.40	0.62	1.43	1.28	35.33
Capitellidae	0.00	5.46	0.61	1.29	1.26	36.59
Arcturina scutula	5.11	0.00	0.60	1.28	1.26	37.85
Urothoe grimaldi	0.00	4.59	0.58	1.31	1.22	39.07
Corophiidae	5.54	2.29	0.58	1.13	1.20	40.27
Sipunculida spp	4.59	0.00	0.57	1.30	1.18	41.45
Ampelisca palmata	4.59	0.00	0.57	1.30	1.18	42.63
Urothoe sp 4	0.00	5.11	0.57	1.32	1.18	43.82
Platyhelminthes	4.59	0.00	0.56	1.30	1.16	44.98
Cirratulidae sp 1	2.29	5.54	0.55	1.17	1.15	46.13
Ceratocumatidae	8.75	4.59	0.55	1.06	1.14	47.27
Nephtys capensis	4.59	0.00	0.54	1.31	1.13	48.40
Eurydice longicornis	2.29	6.88	0.54	1.31	1.13	49.53
Sipunculida-like	0.00	4.59	0.51	1.33	1.06	50.59

Appendix 6A. Continued.

Site 1 vs Site 4
Average dissimilarity: 68.86 %

Taxa	Site 1 Av. Abund	Site 4 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Bathyporeia sp	15.43	0.00	2.40	5.50	3.49	3.49
Urothoe pinnata	11.21	0.00	1.76	10.32	2.56	6.05
Glycinde capensis	0.00	9.89	1.55	6.80	2.25	8.30
Gnathia africana	9.78	0.00	1.53	5.83	2.22	10.52
Nannastacidae	11.33	2.65	1.41	1.90	2.04	12.56
Nemertea	8.92	0.00	1.39	4.19	2.02	14.58
Megaluropus namaquaeensis	8.79	0.00	1.39	4.51	2.02	16.60
Bodotriidae	10.93	2.29	1.39	1.91	2.01	18.61
Urothoe tumorosa	11.21	2.65	1.38	1.96	2.00	20.61
Orbiniidae	0.00	8.67	1.35	9.86	1.96	22.57
cf Queubus jamesanus	2.29	10.34	1.28	1.71	1.85	24.42
Echinocardium cordatum	7.91	0.00	1.25	4.82	1.82	26.24
Gynodiastylidae	10.39	2.81	1.23	1.65	1.79	28.04
Perioculodes longimanus	7.59	0.00	1.19	5.97	1.73	29.77
Capitellidae	0.00	7.61	1.19	9.26	1.72	31.49
Sthenelais cf boa	7.24	0.00	1.14	6.44	1.66	33.15
Laetmatophilus sp	9.32	2.29	1.11	1.94	1.62	34.77
Glyceridae	2.29	9.17	1.11	1.84	1.61	36.38
Cirratulidae sp 2	6.88	0.00	1.08	9.55	1.57	37.95
Gastrosaccus psammodytes	6.88	0.00	1.08	9.55	1.57	39.52
Gastropoda larvae	6.88	0.00	1.08	9.55	1.57	41.10
Nephtyidae	2.29	9.36	1.08	2.09	1.57	42.66
Hemipodus sp	0.00	5.54	0.90	1.31	1.30	43.96
Nudibranch	5.54	0.00	87.00	1.29	1.26	45.22
Monoculodopsis longimana	7.62	2.29	0.85	1.46	1.24	46.46
Corophiidae	5.54	0.00	0.85	1.25	1.23	47.69
Urothoe sp	3.63	4.29	0.83	0.89	1.20	48.89
Mesopodopsis wooldridgei	7.24	2.29	2.81	1.38	1.18	50.07

Appendix 6A. Continued.

Site 1 vs Site 5
Average dissimilarity: 53.32 %

Taxa	Site 1 Av. Abund	Site 5 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	2.29	25.62	2.09	1.38	3.92	3.92
Ostracoda sp 4	0.00	19.20	1.73	3.07	3.25	7.18
Maera sp1	0.00	16.85	1.52	8.04	2.85	10.02
Gynodiastylidae	10.39	24.13	1.24	2.13	2.33	12.35
Gammaridae	0.00	12.91	1.16	2.62	2.13	14.53
Urothoe platypoda	0.00	12.58	1.14	2.93	2.13	16.66
Isopod juvenile	0.00	11.51	1.04	4.26	1.94	18.60
Diastylidae	4.59	15.67	1.01	2.85	1.89	20.49
Mandibulophoxus stimpsoni	2.81	13.77	0.99	2.07	1.86	22.35
Ostracoda sp 2	4.59	14.93	0.94	2.34	1.76	24.11
Micronephtys sphaerocirrata	8.76	17.82	0.82	3.67	1.53	25.64
Glycinde capensis	0.00	9.08	0.82	5.40	1.53	27.17
Capitellidae	0.00	8.90	0.80	5.05	1.50	28.67
Urothoe tumorosa	11.21	19.67	0.76	2.16	1.43	30.10
Colomastix keiskama	0.00	8.44	0.76	6.92	1.42	31.53
Cirratulidae	4.59	12.62	0.73	1.97	1.37	32.90
Ampelisca brevicornis	0.00	7.94	0.72	27.62	1.34	34.24
Aora gibbula	0.00	7.83	0.70	5.73	1.32	35.56
Cirratulidae sp 2	6.88	14.62	0.70	2.64	1.31	36.87
Bathyporeia sp	15.43	7.83	0.68	2.26	1.27	38.14
Pectinaria capensis	0.00	6.97	0.63	31.63	1.18	39.31
Eteone sp 1	0.00	6.88	0.62	31.54	1.16	40.48
Ostracoda sp 6	0.00	6.88	0.62	31.54	1.16	41.64
Phaxas decipiens	0.00	6.88	0.62	31.54	1.16	42.80
Gastropoda larvae	6.88	0.00	0.62	31.54	1.16	43.97
Corophiidae	5.54	8.91	0.60	1.27	1.13	45.10
Megaluropus namaquaeensis	8.79	2.29	0.59	1.71	1.11	46.20
Dendronereides sp	0.00	6.27	0.57	1.21	1.06	47.26
Glyceridae	2.29	8.36	0.66	1.59	1.04	48.30
Sigambra parva	0.00	6.06	0.55	1.32	1.03	49.33
Urothoe sp	3.63	6.88	0.54	3.80	1.01	50.34

Appendix 6A. Continued.

Site 1 vs Site 6
Average dissimilarity: 47.73 %

Taxa	Site 1 Av. Abund	Site 6 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Mandibulophoxus stimpsoni	2.81	13.94	1.27	2.26	2.66	2.66
Mysid larvae	2.29	12.02	1.27	1.42	2.66	5.31
Ostracod sp 2	4.59	15.21	1.22	2.09	2.56	7.87
Urothoe platypoda	0.00	10.04	1.13	19.24	2.37	10.24
Phoxocephalidae	0.00	8.34	0.94	6.38	1.97	12.22
Hippomedon longimanus	0.00	8.30	0.94	13.47	1.96	14.18
Orbiniidae	0.00	8.02	0.91	4.72	1.91	16.08
Apseudes minutus	2.29	9.49	0.81	1.84	1.70	17.78
Diastylidae	4.59	11.49	0.80	1.57	1.67	19.45
Ampelisca brevicornis	0.00	6.88	0.78	17.47	1.63	21.08
Gastropod larvae	6.88	0.00	0.78	17.47	1.63	22.71
Ostracod sp 6	0.00	6.88	0.76	1.14	1.59	24.30
Stegocephaloides sp	2.29	8.83	0.75	1.64	1.56	25.86
Anthuridae	0.00	6.27	0.72	1.17	1.51	27.37
Urothoe sp	3.63	7.24	0.69	2.90	1.44	28.81
Mesopodopsis wooldridgei	7.24	3.25	0.64	2.24	1.34	30.16
Cirratulidae sp 2	6.88	3.25	0.63	2.67	1.31	31.47
Nudibranch	5.54	0.00	0.62	1.30	1.30	32.77
Urothoe sp 4	0.00	5.13	0.57	0.67	1.20	33.97
Sthenelais cf boa	7.24	2.29	0.56	1.40	1.18	35.15
Lysianassidae	0.00	5.11	0.56	1.30	1.18	36.33
Bathyporeia sp	15.43	11.17	0.56	1.62	1.16	37.49
Pectinaria capensis	0.00	4.86	0.55	1.33	1.15	38.64
Laetmatophilus sp	9.32	4.59	0.55	1.29	1.14	39.79
Ostracoda sp 4	0.00	4.94	0.54	1.33	1.14	40.92
Spiroplax spiralis	0.00	4.59	0.53	1.33	1.11	42.03
Sipunculida spp	4.59	0.00	0.53	1.33	1.11	43.14
Ampelisca palmata	4.59	0.00	0.53	1.33	1.11	44.24
Capitellidae	0.00	4.69	0.52	1.33	1.09	45.33
Ampelisca sp	0.00	4.59	0.52	1.33	1.09	46.42
Cephalochordata sp 1	0.00	4.59	0.52	1.33	1.09	47.51
Echinoidea	4.59	0.00	0.52	1.33	1.09	48.60
Nephtys capensis	4.59	0.00	0.51	1.33	1.06	49.66
Pseudocumatidae	0.00	4.59	0.50	1.33	1.06	50.72

Appendix 6A. Continued.

Site 2 vs Site 3
Average dissimilarity: 46.72 %

Taxa	Site 2 Av. Abund	Site 3 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Laetmatophilus sp	18.33	2.48	2.17	2.75	4.64	4.64
Urothoe pinnata	7.35	19.57	1.62	4.42	3.46	8.11
Diogenidae	14.12	2.29	1.59	1.12	3.40	11.51
Urothoe tumorosa	2.65	11.74	1.23	2.11	2.63	14.14
Heterophoxus cephalodens	0.00	7.55	1.03	3.60	2.20	16.34
Urothoidae	0.00	7.40	0.99	7.62	2.11	18.45
Ampelisca brachyceras	0.00	7.24	0.97	7.97	2.07	20.53
Hamnimoeidae	0.00	7.10	0.95	8.64	2.03	22.56
Donax burnupi	5.89	0.00	0.81	1.28	1.72	24.28
Gynodiastylidae	2.29	7.83	0.75	1.48	1.60	25.88
Ostracoda sp 3	2.29	7.75	0.74	1.49	1.59	27.47
Spiroplax spiralis	0.00	5.11	0.73	1.25	1.57	29.03
Urothoe sp 2	0.00	5.96	0.73	1.31	1.56	30.59
Urothoe sp1	0.00	5.90	0.72	1.30	1.54	32.14
Urothoe sp	0.00	5.78	0.71	1.31	1.51	33.65
Cirratulidae sp 1	0.00	5.54	0.67	1.29	1.44	35.09
Cirratulidae sp 2	0.00	5.48	0.67	1.33	1.43	36.52
Orbiniidae	5.54	2.57	0.66	1.12	1.42	37.94
Sipunculida-like	6.27	4.59	0.66	1.04	1.41	39.35
Nephtyidae	0.00	4.59	0.65	1.30	1.39	40.74
Urothoe grimaldi	0.00	4.59	0.65	1.30	1.39	42.13
Spionidae	12.26	7.59	0.64	0.87	1.38	43.51
Ophelia anomala	4.81	0.00	0.64	1.29	1.37	44.88
Phaxas decipiens	2.29	6.88	0.63	1.30	1.34	46.22
Urothoe sp 4	0.00	5.11	0.62	1.32	1.33	47.57
Eurydice longicornis	2.29	6.88	0.61	1.30	1.31	48.86
Capitellidae	2.29	5.46	0.60	1.17	1.28	50.13

Appendix 6A. Continued.

Site 2 vs Site 4
Average dissimilarity: 69.81 %

Taxa	Site 2 Av. Abund	Site 4 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Laetmatophilus sp	18.33	2.29	2.91	3.19	4.17	4.17
Gnathia africana	13.07	0.00	2.35	5.38	3.37	7.54
Mandibulophoxus stimpsoni	11.29	0.00	2.02	5.81	2.90	10.44
cf Queubus jamesanus	0.00	10.34	1.87	3.16	2.68	13.11
Diogenidae	14.12	5.26	1.71	0.93	2.45	15.57
Nephtyidae	0.00	9.36	1.67	16.80	2.39	17.96
Echinocardium cordatum	8.73	0.00	1.56	5.16	2.24	20.20
Phoxocephalidae	8.56	0.00	1.53	3.64	2.19	22.38
Heterophoxus spp	8.45	0.00	1.52	6.66	2.18	24.56
Nemertea	8.35	0.00	1.51	4.89	2.16	26.17
Glycinde capensis	2.29	9.89	1.37	1.97	1.97	28.69
Urothoe pinnata	7.35	0.00	1.32	8.46	1.89	30.58
Megaluropus namaquaeensis	7.24	0.00	1.30	7.16	1.87	32.44
Glyceridae	2.29	9.17	1.26	1.84	1.81	34.25
Nannastacidae	9.31	2.65	1.24	1.58	1.78	36.03
Diastylidae	6.88	0.00	1.24	9.10	1.77	37.81
Donax burnupi	5.89	0.00	1.09	1.29	1.56	39.36
Hemipodus sp	0.00	5.54	1.03	1.31	1.47	40.84
Monoculodopsis longimana	7.71	2.29	0.99	1.50	1.42	42.25
Sipunculida-like	6.27	2.29	0.98	1.20	1.41	43.66
Spionidae	12.26	6.88	0.98	1.00	1.40	45.07
Capitellidae	2.29	7.61	0.93	1.49	1.33	46.40
Bodotriidae	7.07	2.29	0.88	1.35	1.25	47.65
Cnidaria	0.00	4.59	0.86	1.32	1.24	48.89
Sipunculida spp	0.00	4.59	0.86	1.32	1.24	50.13

Appendix 6A. Continued.

Site 2 vs Site 5
Average dissimilarity: 57.84 %

Taxa	Site 2 Av. Abund	Site 5 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	0.00	25.62	2..47	1.56	4.28	4.28
Gynodiastylidae	2.29	24.13	2.13	2.90	3.68	7.96
Ostracoda sp 4	0.00	19.20	1.87	3.07	3.23	11.19
Urothoe tumorosa	2.65	19.67	1.60	3.02	2.86	14.05
Cirratulidae sp 2	0.00	14.62	1.42	4.97	2.45	16.51
Maera sp 1	2.29	16.85	1.41	3.70	2.44	18.94
Urothoe platypoda	0.00	12.58	1.22	2.98	2.12	21.06
Isopod larvae	0.00	11.51	1.11	4.27	1.93	22.99
Laetmatophilus sp	18.33	7.33	1.07	4.40	1.85	24.84
Gammaridae	2.29	12.91	1.03	1.77	1.78	26.61
Ostracoda sp 2	4.59	14.93	1.00	2.44	1.73	28.35
Cirratulidae	2.29	12.62	1.00	2.70	1.72	30.07
Micronephtys sphaerocirrata	8.07	17.82	0.95	3.86	1.64	31.71
Ostracoda sp 3	2.29	11.78	0.93	2.23	1.60	33.31
Diogenidae	14.12	4.59	0.91	0.90	1.57	34.88
Diastylidae	6.88	15.67	0.85	9.81	1.47	36.35
Colomastix keiskama	0.00	8.44	0.82	7.03	1.41	37.77
Corophiidae	0.00	8.19	0.80	1.16	1.39	39.16
Urothoe pinnata	7.35	15.32	0.77	4.25	1.34	40.49
Ampelisca brevicornis	0.00	7.94	0.77	35.67	1.33	41.82
Sthenelais cf boa	0.00	7.83	0.76	5.11	1.32	43.14
Aora gibbula	0.00	7.83	0.76	5.81	1.31	44.45
Cirratulidae sp 1	0.00	7.30	0.71	12.74	1.22	45.68
Stegephaloides sp	0.00	7.24	0.70	15.08	1.21	46.89
Cnidaria	0.00	6.88	0.67	43.30	1.15	48.05
Ostracoda sp 6	0.00	6.88	0.67	43.30	1.15	49.20
Urothoe sp	0.00	6.88	0.67	43.30	1.15	50.35

Appendix 6A. Continued.

Site 2 vs Site 6
Average dissimilarity: 53.28 %

Taxa	Site 2 Av. Abund	Site 6 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Laetmatophilus sp	18.33	4.59	1.72	2.85	3.24	3.24
Mysid larvae	0.00	12.02	1.49	1.32	2.79	6.02
Ostracod sp 2	4.59	15.21	1.33	2.17	2.50	8.52
Urothoe platypoda	0.00	10.01	1.24	21.38	2.33	10.85
Apseudes minutus	0.00	9.49	1.17	5.35	2.20	13.05
Diogenidae	14.12	4.59	1.15	0.91	2.16	15.22
Stegocephaloides sp	0.00	8.83	1.10	4.08	2.07	17.29
Bathyporeia sp	2.57	11.17	1.09	1.65	2.05	19.33
Heterophoxus spp	8.45	0.00	1.05	8.92	1.97	21.30
Hippomedon longimanus	0.00	8.30	1.03	13.98	1.93	23.23
Urothoe tumorosa	2.65	10.80	1.02	1.86	1.91	25.14
Ostracod sp 3	2.29	10.30	1.00	2.01	1.87	27.01
Urothoe sp	0.00	7.24	0.90	8.07	1.69	28.70
Platyhelminthes	0.00	6.88	0.85	18.56	1.60	30.30
Ampelisca brevicornis	0.00	6.88	0.85	18.56	1.60	31.90
Ostracod sp 6	0.00	6.88	0.83	1.14	1.56	33.47
Anthuridae	0.00	6.27	0.79	1.17	1.49	34.95
Sipunculida-like	6.27	0.00	0.79	1.20	1.48	36.44
Amakusanthura africana	2.29	8.46	0.75	1.77	1.42	37.85
Gynodiastylidae	2.29	8.11	0.73	1.66	1.37	39.22
Corophiidae	0.00	5.54	0.70	1.30	1.31	40.53
Arcturina scutula	0.00	5.54	0.68	1.31	1.28	41.82
Sigalionidae	0.00	5.32	0.66	1.32	1.24	43.06
Donax burnupi	5.89	2.29	0.65	1.22	1.21	44.27
Urothoe sp 4	0.00	5.13	0.63	0.67	1.18	45.46
Lysianassidae	0.00	5.11	0.61	1.30	1.15	46.61
Ostracod sp 4	0.00	4.94	0.59	1.33	1.11	47.72
Ophelia anomala	4.81	0.00	0.59	1.32	1.11	48.83
Mesopodopsis wooldridgei	4.59	3.25	0.69	1.37	1.11	49.94
Sthenelais spp	0.00	4.59	0.58	1.33	1.09	51.03

Appendix 6A. Continued.

Site 3 vs Site 4
Average dissimilarity: 68.52 %

Taxa	Site 3 Av. Abund	Site 4 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Urothoe pinnata	19.57	0.00	2.82	5.90	4.11	4.11
Mandibulophoxus stimpsoni	11.66	0.00	1.73	2.75	2.53	6.64
cf Queubus jamesanus	0.00	10.34	1.51	2.87	2.20	8.84
Heterophoxus spp	9.55	0.00	1.38	6.18	2.01	10.85
Urothoe tumorosa	11.74	2.65	1.35	1.99	1.97	12.82
Echinocardium cordatum	9.33	0.00	1.35	7.55	1.97	14.79
Perioculodes longimanus	8.73	0.00	1.27	4.64	1.86	16.65
Gnathia africana	8.71	0.00	1.26	5.55	1.84	18.49
Nemertea	8.57	0.00	1.22	8.17	1.78	20.27
Phoxocephalidae	8.13	0.00	1.19	3.85	1.74	22.01
Ophiuroidea	10.85	2.29	1.19	2.50	1.73	23.75
Diastylidae	8.04	0.00	1.17	5.69	1.71	25.45
Heterophoxus cephalodens	7.55	0.00	1.12	3.29	1.63	27.08
Glycince capensis	2.51	9.89	1.11	1.67	1.62	28.70
Urothoidae	7.40	0.00	1.07	6.18	1.56	30.26
Pectinaria capensis	7.26	0.00	1.05	7.27	1.53	31.79
Ampelisca brachyceras	7.24	0.00	1.05	6.30	1.53	33.32
Glyceridae	2.29	9.17	1.04	1.72	1.52	34.84
Gastrosaccus psammodytes	7.15	0.00	1.03	6.72	1.51	36.35
Eurydice longicornis	6.88	0.00	1.00	5.76	1.46	37.81
Megaluropus namaquaeensis	6.88	0.00	1.00	5.76	1.46	39.27
Mesopodopsis wooldridgei	8.80	2.29	0.98	1.61	1.44	40.71
Orbiniidae	2.57	8.67	0.94	1.59	1.38	42.08
Urothoe sp	5.78	4.29	0.86	1.29	1.26	43.34
Gynodiastylidae	7.83	2.81	0.85	1.63	1.24	44.58
Nannastacidae	8.27	2.65	0.84	1.36	1.23	45.81
Hemipodus sp	0.00	5.54	0.83	1.27	1.21	47.02
Urothoe sp 2	5.96	0.00	0.78	1.30	1.14	48.16
Urothoe sp 1	5.90	0.00	0.77	1.29	1.13	49.29
Monoculodopsis longimana	7.20	2.29	0.72	1.35	1.06	50.34

Appendix 6A. Continued.

Site 3 vs Site 5
Average dissimilarity: 46.31 %

Taxa	Site 3 Av. Abund	Site 5 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	0.00	25.62	2.19	1.54	4.72	4.72
Ostracoda sp 4	0.00	19.20	1.65	2.97	3.56	8.28
Gynodiastylidae	7.83	24.13	1.40	2.37	3.03	11.31
Maera sp 1	2.29	16.85	1.26	3.24	2.71	14.02
Urothoe platypoda	0.00	12.58	1.08	2.90	2.33	16.36
Isopod juvenile	0.00	11.51	0.98	4.01	2.13	18.48
Gammaridae	2.29	12.91	0.92	1.70	1.99	20.48
Cirratulidae sp 2	5.48	14.62	0.81	1.60	1.75	22.22
Colomastix keiskama	0.00	8.44	0.72	6.03	1.56	23.78
Ostracoda sp 2	6.88	14.93	0.69	3.25	1.48	25.27
Urothoe tumorosa	11.74	19.67	0.68	2.03	1.47	26.73
Micronephtys sphaerocirrata	10.21	17.82	0.66	2.44	1.43	28.16
Cirratulidae	5.24	12.62	0.66	1.51	1.42	29.58
Diastylidae	8.04	15.67	0.65	6.97	1.41	30.99
Corophiidae	2.29	8.19	0.64	1.17	1.39	32.38
Stegocephaloides sp	0.00	7.24	0.62	9.34	1.34	33.72
Eteone sp 1	0.00	6.88	0.59	11.60	1.27	34.99
Ostracoda sp 6	0.00	6.88	0.59	11.60	1.27	36.26
Glycince capensis	2.51	9.08	0.59	1.66	1.27	37.53
Heterophoxus spp	9.55	3.25	0.57	1.53	1.23	38.76
Dendronereides sp	0.00	6.27	0.54	1.20	1.16	39.92
Glyceridae	2.29	8.36	0.53	1.55	1.15	41.07
Sigambra parva	0.00	6.06	0.52	1.31	1.13	42.20
Heterophoxus cephalodens	7.55	3.25	0.50	1.84	1.07	43.27
Ampelisca brevicornis	2.29	7.94	0.50	1.59	1.07	44.35
Elasmopus affinis	0.00	5.62	0.49	0.66	1.05	45.40
Aora gibbula	2.29	7.83	0.49	1.46	1.05	46.46
Decapod larvae & megalopae	2.29	7.40	0.45	1.42	0.98	47.43
Laetmatophilus sp	2.48	7.33	0.45	1.46	0.97	47.40
Sigalionidae	0.00	5.11	0.44	1.30	0.95	49.35
Urothoe sp 2	5.96	2.29	0.43	1.26	0.93	50.29

Appendix 6A. Continued.

Site 3 vs Site 6
Average dissimilarity: 48.63 %

Taxa	Site 3 Av. Abund	Site 6 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Mysid larvae	0.00	12.02	1.27	1.29	2.62	2.62
Urothoe pinnata	19.57	9.18	1.10	2.28	2.26	4.88
Urothoe platypoda	0.00	10.04	1.06	8.88	2.19	7.07
Heterophoxus spp	9.55	0.00	1.01	8.37	2.08	9.14
Apseudes minutus	0.00	9.49	1.00	4.64	2.07	11.21
Stegocephaloides sp	0.00	8.83	0.94	3.81	1.94	13.15
Amakusanthura africana	0.00	8.46	0.90	8.15	1.84	14.99
Ostracoda sp 2	6.88	15.21	0.89	2.46	1.84	16.83
Hippomedon longimanus	0.00	8.30	0.88	8.04	1.81	18.64
Heterophoxus cephalodens	7.55	0.00	0.81	4.01	1.67	20.31
Urothoidae	7.40	0.00	0.78	8.37	1.61	21.92
Ampelisca brachyceras	7.24	0.00	0.77	9.22	1.58	23.49
Haminoeidae	7.10	0.00	0.75	10.60	1.55	25.04
Platyhelminthes	0.00	6.88	0.73	8.70	1.50	26.54
Eurydice longicornis	6.88	0.00	0.73	8.70	1.50	28.04
Ostracoda sp 6	0.00	6.88	0.72	1.13	1.47	29.51
Urothoe sp 4	5.11	5.13	0.71	1.31	1.46	30.97
Bathyporeia sp	4.59	11.17	0.69	1.46	1.42	32.39
Anthuridae	0.00	6.27	0.68	1.16	1.39	33.78
Mesopodopsis wooldridgei	8.80	3.25	0.66	1.45	1.36	35.14
Orbiniidae	2.57	8.02	0.63	1.46	1.30	36.44
Arcturina scutula	0.00	5.54	0.59	1.28	1.20	37.64
Urothoe sp 1	5.90	0.00	0.58	1.30	1.20	38.84
Sigalionidae	0.00	5.32	0.57	1.30	1.17	40.01
Cirratulidae sp 1	5.54	0.00	0.54	1.29	1.12	41.13
Urothoe sp 2	5.96	2.29	0.53	1.26	1.09	42.22
Lysianassidae	0.00	5.11	0.53	1.29	1.09	43.31
Cirratulidae sp 2	5.48	3.25	0.52	1.17	1.08	44.38
Corophiidae	2.29	5.54	0.51	1.14	1.06	45.44
Ostracoda sp 4	0.00	4.94	0.51	1.31	1.05	46.49
Ampelisca brevicornis	2.29	6.88	0.51	1.31	1.05	47.54
Ampelisca sp	0.00	4.59	0.49	1.31	1.01	48.54
Pseudocumatidae	0.00	4.59	0.47	1.31	0.98	49.52
Urothoe cf serrulidactylus	0.00	4.59	0.47	1.31	0.98	50.50

Appendix 6A. Continued.

Site 4 vs Site 5
Average dissimilarity: 69.10 %

Taxa	Site 4 Av. Abund	Site 5 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	0.00	25.62	2.61	1.55	3.78	3.78
Gynodiastylidae	2.81	24.13	2.21	2.59	3.19	6.97
Ostracoda sp 4	0.00	19.20	1.97	3.02	2.86	9.83
Urothoe tumorosa	2.65	19.67	1.76	2.88	2.54	12.37
Maera sp 1	0.00	16.85	1.73	7.39	2.50	14.87
Diastylidae	0.00	15.67	1.61	11.84	2.32	17.20
Urothoe pinnata	0.00	15.32	1.57	8.14	2.27	19.47
Cirratulidae sp 2	0.00	14.62	1.50	4.79	2.17	21.64
Mandibulophoxus stimpsoni	0.00	13.77	1.41	4.48	2.04	23.68
Gammaridae	0.00	12.91	1.32	2.60	1.91	25.59
Ostracoda sp 2	2.29	14.93	1.30	2.91	1.88	27.47
Urothoe platypoda	0.00	12.58	1.29	2.93	1.87	29.34
Isopod larvae	0.00	11.51	1.18	4.16	1.70	31.04
Gnathia africana	0.00	11.06	1.13	9.84	1.64	32.68
cf Queubus jamesanus	10.34	0.00	1.06	3.25	1.54	34.22
Colomastix keiskama	0.00	8.44	0.86	6.57	1.25	35.47
Corophiidae	0.00	8.19	0.85	1.16	1.23	36.70
Nemertea	0.00	8.04	0.82	8.69	1.19	37.89
Ampelisca brevicornis	0.00	7.94	0.81	16.31	1.18	39.06
Sthenelais cf boa	0.00	7.83	0.80	4.90	1.16	40.23
Aora gibbula	0.00	7.83	0.80	5.55	1.16	41.39
Bathyporeia sp	0.00	7.83	0.80	5.55	1.16	42.55
Ostracoda sp 3	4.59	11.78	0.76	1.60	1.09	43.64
Perioculodes longimanus	0.00	7.33	0.75	8.35	1.09	44.73
Cirratulidae sp 1	0.00	7.30	0.75	10.49	1.08	45.81
Echinocardium cordatum	0.00	7.24	0.74	9.59	1.07	46.89
Cirratulidae	5.35	12.62	0.74	1.65	1.07	47.96
Stegocephaloides sp	0.00	7.24	0.74	11.68	1.07	49.03
Nephytidae	9.36	2.29	0.72	2.03	1.04	50.07

Appendix 6A. Continued.

Site 4 vs Site 6
Average dissimilarity: 68.34 %

Taxa	Site 4 Av. Abund	Site 6 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Mandibulophoxus stimpsoni	0.00	13.94	1.86	5.54	2.72	2.72
Ostracoda sp 2	2.29	15.21	1.74	2.49	2.55	5.27
Diastylidae	0.00	11.49	1.54	4.02	2.25	7.52
Bathyporeia sp	0.00	11.17	1.51	2.96	2.20	9.72
Mysid larvae	2.29	12.02	1.49	1.42	2.19	11.91
cf Queubus jamesanus	10.34	0.00	1.38	3.18	2.02	13.93
Urothoe platypoda	0.00	10.04	1.34	11.43	1.95	15.88
Gnathia africana	0.00	9.66	1.29	5.50	1.89	17.78
Apseudes minutus	0.00	9.49	1.26	5.00	1.84	19.62
Urothoe pinnata	0.00	9.18	1.21	2.94	1.76	21.38
Stegocephaloides sp	0.00	8.83	1.19	3.84	1.73	23.12
Phoxocephalidae	0.00	8.34	1.11	5.70	1.63	24.75
Urothoe tumorosa	2.65	10.80	1.11	1.80	1.62	26.37
Echinocardium cordatum	0.00	8.26	1.11	4.26	1.62	27.98
Hippomedon longimanus	0.00	8.30	1.11	9.66	1.62	29.60
Bodotriidae	2.29	10.01	1.05	1.70	1.53	31.13
Glycince capensis	9.89	2.29	1.01	2.00	1.48	32.61
Nephytidae	9.36	2.29	0.95	1.93	1.39	34.00
Glyceridae	9.17	2.29	0.92	1.90	1.35	35.35
Platyhelminthes	0.00	6.88	0.92	10.83	1.34	36.69
Ampelisca brevicornis	0.00	6.88	0.92	10.83	1.34	38.03
Gastrosaccus psammodytes	0.00	6.88	0.92	10.83	1.34	39.37
Urothoe sp	4.29	7.24	0.90	4.64	1.32	40.69
Ostracoda sp 6	0.00	6.88	0.89	1.13	1.31	42.00
Nannastacidae	2.65	8.79	0.86	1.65	1.27	43.26
Anthuridae	0.00	6.27	0.85	1.16	1.25	44.51
Amakusanthura africana	2.29	8.46	0.84	1.70	1.23	45.74
Ostracoda sp 3	4.59	10.30	0.78	1.33	1.15	46.89
Gynodiastylidae	2.81	8.11	0.76	1.42	1.12	48.00
Hemipodus sp	5.54	0.00	0.76	1.30	1.11	49.11
Corophiidae	0.00	5.54	0.75	1.29	1.10	50.21

Appendix 6A. Continued.

Site 5 vs Site 6
Average dissimilarity: 43.08 %

Taxa	Site 5 Av. Abund	Site 6 Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	25.62	9.49	1.34	1.02	3.12	3.12
Gynodiastylidae	24.13	8.11	1.31	2.47	3.05	6.16
Maera sp 1	16.85	2.29	1.19	3.58	2.76	8.93
Ostracoda sp 4	19.20	4.94	1.18	1.92	2.73	11.65
Isopod larvae	11.51	0.00	0.94	4.23	2.18	13.83
Cirratulidae sp 2	14.62	3.25	0.93	1.99	2.16	15.99
Mysid larvae	2.29	12.02	0.92	1.45	2.13	18.12
Gammaridae	12.91	2.29	0.86	1.79	1.99	20.11
Urothoe tumorosa	19.67	10.80	0.72	2.12	1.68	21.79
Colomastix keiskama	8.44	0.00	0.69	6.87	1.60	23.39
Cirratulidae	12.62	4.59	0.66	1.96	1.54	24.93
Aora gibbula	7.83	0.00	0.64	5.69	1.48	26.41
Cirratulidae sp 1	7.30	0.00	0.60	11.94	1.38	27.79
Platyhelminthes	0.00	6.88	0.56	30.24	1.30	29.10
Eteone sp 1	6.88	0.00	0.56	30.24	1.30	30.40
Glycinde capensis	9.08	2.29	0.55	1.75	1.28	31.69
Corophiidae	8.19	5.54	0.54	1.32	1.26	32.94
Urothoidae	6.49	0.00	0.53	1.33	1.23	34.17
Anthuridae	0.00	6.27	0.52	1.18	1.20	35.38
Urothoe pinnata	15.32	9.18	0.52	1.71	1.20	36.58
Dendronereides sp	6.27	0.00	0.51	1.21	1.19	37.77
Sigambra parva	6.06	0.00	0.50	1.32	1.15	38.92
Glyceridae	8.36	2.29	0.50	1.60	1.15	40.07
Amakusanthura africana	2.69	8.46	0.48	1.46	1.11	41.18
Elasmopus affinis	5.62	0.00	0.46	0.67	1.08	42.26
Sthenelais cf boa	7.83	2.29	0.45	1.48	1.05	43.31
Arcturina scutula	0.00	5.54	0.45	1.30	1.05	44.36
Urothoe sp 4	0.00	5.13	0.42	0.67	0.97	45.33
Micronephtys sphaerocirrata	17.32	12.72	0.41	1.85	0.96	46.29
Mesopodopsis wooldridgei	4.59	3.25	0.39	1.38	0.90	47.19
Ostracoda sp 6	6.88	6.88	0.38	1.33	0.88	48.08
Sthenelais sp 1	6.88	2.29	0.38	1.33	0.87	48.95
Other/unknown	4.59	0.00	0.37	1.33	0.87	49.82
Diopatra neopolitana	4.59	0.00	0.37	1.33	0.86	50.68

Appendix 6B. Analysis of dissimilarity between groups for species assemblages of the 2009 benthic survey.

Group A (Site 1) vs Group B (Site 2 & Site 3)
Average dissimilarity: 47.60 %

Taxa	Group A Av. Abund	Group B Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Arcturina scutula	8.73	0.00	1.26	3.35	2.65	2.65
Sapphirina sp 2	7.30	0.00	1.07	6.24	2.24	4.89
Nassaridae	7.15	0.00	1.04	10.49	2.18	7.07
Spionidae	16.11	9.49	0.99	1.47	2.07	9.14
cf Queubus jamesanus	6.69	0.00	0.94	1.19	1.97	11.11
Eulimidae	7.83	3.44	0.92	2.05	1.94	13.05
Diogenidae	7.24	10.39	0.87	0.87	1.83	14.89
Decapod larvae	0.00	5.91	0.86	2.10	1.80	16.69
Oedicerotidae	6.62	3.13	0.86	1.25	1.80	18.49
Cirratulidae	12.76	10.13	0.85	1.11	1.79	20.28
Nephtyidae	5.54	0.00	0.82	1.33	1.72	22.00
Echinoidea	5.54	0.00	0.81	1.34	1.69	23.70
Bivalve juveniles	7.55	2.29	0.79	1.46	1.67	25.37
Nemertea	7.24	2.49	0.75	1.48	1.57	26.94
Bathyporeia sp	10.78	7.02	0.75	1.27	1.57	28.50
Lucinidae	4.59	1.99	0.74	1.47	1.55	30.05
Diastylidae	2.29	6.50	0.73	1.30	1.53	31.58
Nephtys capensis	4.86	0.00	0.72	1.36	1.52	33.10
cf Queubus sp	4.86	0.00	0.72	1.36	1.52	34.61
Amakusanthura africana	6.88	2.43	0.70	1.47	1.47	36.09
Mandibulophoxus stimpsoni	6.88	11.63	0.70	1.77	1.47	37.55
Philyra punctata	5.54	2.29	0.68	1.19	1.43	38.99
cf Holothuroidea	4.59	0.00	0.68	1.36	1.42	40.40
Mytilidae	4.59	0.00	0.63	0.68	1.33	41.73
Echinocardium cordatum	5.96	4.59	0.63	1.33	1.33	43.06
Heterophoxus cf opus	4.59	8.78	0.63	1.12	1.33	44.39
Perioculodes longimanus	10.18	6.07	0.63	1.24	1.32	45.71
Gnathia africana	5.54	9.58	0.60	1.07	1.26	46.97
Ophiuroidea	2.29	4.89	0.60	1.13	1.25	48.22
Bullia laevissima	4.59	1.15	0.59	1.21	1.25	49.47
Sipunculida spp	4.59	1.15	0.59	1.21	1.25	50.72

Appendix 6B. Continued.

Group A (Site 1) vs Group C (Site 5 & Site 6)
Average dissimilarity: 60.21 %

Taxa	Group A Av. Abund	Group C Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	0.00	25.57	2.24	2.01	3.72	3.72
Ostracoda sp 11	0.00	13.69	1.22	2.42	2.03	5.75
Ostracoda sp 4	0.00	12.01	1.06	1.90	1.76	7.51
Urothoe tumorosa	0.00	11.69	1.04	5.97	1.72	9.23
Corophiidae	0.00	11.20	0.95	1.52	1.57	10.80
Urothoe platypoda	0.00	10.67	0.95	3.18	1.57	12.37
Maera sp 1	0.00	10.41	0.89	1.22	1.48	13.85
Diastylidae	2.29	12.12	0.87	2.38	1.44	15.29
Ampelisca brevicornis	0.00	9.64	0.85	3.58	1.41	16.70
Eusiridae	0.00	9.62	0.83	2.82	1.39	18.08
Ostracoda sp 2	2.29	11.37	0.81	1.75	1.34	19.42
Spionidae	16.11	12.94	0.76	1.56	1.26	20.68
Gammaridae	2.29	9.47	0.75	1.45	1.24	21.92
Stegocephalidae	0.00	8.22	0.72	4.43	1.19	23.12
Eulimidae	7.83	0.00	0.70	4.46	1.16	24.27
Phoxocephalidae	0.00	7.33	0.65	6.67	1.08	25.35
Sapphirina sp 2	7.30	0.00	0.65	7.27	1.07	26.43
Nassariidae	7.15	0.00	0.63	11.54	1.05	27.48
Stegocephaloides sp	0.00	6.60	0.60	1.21	0.99	28.47
cf Queubus jamesanus	6.69	0.00	0.58	1.19	0.96	29.43
Hippomendon longimanus	2.29	8.65	0.57	1.73	0.94	30.38
Colomastix keiskama	0.00	6.30	0.56	2.08	0.93	31.30
Diogenidae	7.24	3.66	0.55	2.24	0.92	32.22
Urothoidae	2.29	7.48	0.53	1.49	0.88	33.10
Urothoe sp 1	0.00	6.05	0.53	2.11	0.88	33.98
Pectinaria capensis	0.00	5.81	0.52	1.33	0.87	34.85
Mandibulophoxus stimpsoni	6.88	12.73	0.52	2.08	0.87	35.72
Solen cylindraceus	0.00	5.74	0.52	2.15	0.86	36.58
Ophiuroidea sp 3	0.00	5.74	0.52	2.15	0.86	37.44
Ischyroceridae	0.00	6.25	0.51	0.68	0.84	38.28
Ostracoda sp 5	2.29	8.00	0.50	1.58	0.83	39.11
Syllidae	0.00	5.90	0.50	1.20	0.83	39.95
Pholoe minuta	0.00	5.80	0.50	1.31	0.83	40.77
Ophiuroidea	2.29	7.20	0.50	1.47	0.82	41.60
Nephtyidae	5.54	0.00	0.49	1.33	0.82	42.42
Cirratulidae	12.76	10.34	0.49	1.10	0.81	43.23
Bathyporeia sp	10.78	6.10	0.48	1.30	0.80	44.03
Heterophoxus cf opus	4.59	9.89	0.48	1.40	0.80	44.83
Orbiniidae	2.29	7.73	0.47	1.51	0.79	45.61
Atylus swammerdami	0.00	5.35	0.47	1.32	0.79	46.40
Urothoe grimaldi	0.00	5.27	0.47	1.34	0.79	47.19
Cirratulidae sp 2	0.00	5.06	0.47	1.36	0.77	47.96
Gynodiastylidae	0.00	5.24	0.47	1.34	0.77	48.73
Arcturina scutula	8.73	3.55	0.46	1.24	0.77	49.50
Synidotea variegata	3.97	3.92	0.46	1.11	0.76	50.26

Appendix 6B. Continued.

Group A (Site 1) vs Group D (Site 4)
Average dissimilarity: 61.11 %

Taxa	Group A Av. Abund	Group D Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Urothoe pinnata	13.25	2.65	1.67	2.21	2.73	2.73
Bathyporeia sp	10.78	0.00	1.65	3.90	2.70	5.43
Perioculodes longimanus	10.18	0.00	1.56	4.15	2.55	7.99
Laetmatophilus sp	9.48	0.00	1.46	3.58	2.39	10.37
Cirratulidae sp 2	0.00	9.08	1.35	6.67	2.21	12.59
Arcturina scutula	8.73	0.00	1.33	3.02	2.17	14.76
Eulimidae	7.83	0.00	1.21	3.44	1.98	16.74
Spionidae	16.11	8.23	1.20	1.60	1.97	18.71
Ampelisca brachyceras	7.71	0.00	1.19	4.26	1.94	20.66
Sapphirina sp 2	7.30	0.00	1.12	4.76	1.84	22.49
Sthenelais cf boa	7.30	0.00	1.11	6.43	1.82	24.32
Nassaridae	7.15	0.00	1.09	6.34	1.79	26.11
Solen cylindraceus	0.00	7.10	1.08	6.87	1.78	27.88
Amakusanthura africana	6.88	0.00	1.05	6.39	1.72	29.61
Echinocardium cordatum	5.96	0.00	0.92	1.30	1.50	31.11
cf Queubus jamesanus	6.69	2.65	0.91	1.13	1.50	32.61
Nannastacidae	11.54	6.79	0.89	0.98	1.45	34.06
Oedicerotidae	6.62	2.29	0.88	1.19	1.44	35.50
Nephtyidae	5.54	0.00	0.86	1.27	1.41	36.92
Echinoidea	5.54	0.00	0.85	1.28	1.39	38.31
Cirratulidae	12.76	7.15	0.83	0.78	1.36	39.67
Ostracoda sp 3	7.53	2.29	0.82	1.43	1.35	41.02
Synidotea hirtipes	0.00	6.07	0.81	0.67	1.33	42.35
Megaluropus namaquaeensis	7.40	2.29	0.80	1.39	1.31	43.66
Synidotea variegata	3.97	3.97	0.77	0.84	1.26	44.92
Nepthys capensis	4.86	0.00	0.76	1.30	1.25	46.16
Spiroplax spiralis	0.00	5.46	0.76	1.32	1.24	47.40
Gnathia africana	5.54	2.29	0.76	1.09	1.24	48.64
Glycera cf longipinis	0.00	4.59	0.75	1.30	1.22	49.87
Mandibulophoxus stimpsoni	6.88	2.29	0.75	1.30	1.22	51.09

Appendix 6B. Continued.

Group B (Site 2 & Site 3) vs Group C (Site 5 & Site 6)
Average dissimilarity: 58.69 %

Taxa	Group B Av. Abund	Group C Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	1.62	25.57	2.30	1.82	3.91	3.91
Ostracoda sp 11	1.15	13.69	1.23	2.01	2.10	6.01
Ostracoda sp 2	0.00	11.37	1.11	2.64	1.89	7.90
Ostracoda sp 4	1.15	12.01	1.03	1.60	1.76	9.66
Urothoe platypoda	0.00	10.67	1.03	3.19	1.75	11.41
Maera sp 1	0.00	10.41	0.96	1.24	1.64	13.06
Corophiidae	1.15	11.20	0.95	1.45	1.62	14.68
Diogenidae	10.39	3.66	0.91	1.15	1.55	16.23
Eusiridae	0.00	9.62	0.91	2.89	1.54	17.77
Gammaridae	1.41	9.47	0.83	1.34	1.42	19.19
Hippomedon longimanus	0.00	8.65	0.83	5.27	1.42	20.61
Stegocephalidae	0.00	8.22	0.78	4.48	1.33	21.94
Ostracoda sp 5	0.00	8.00	0.76	6.46	1.30	23.24
Urothoe tumorosa	4.21	11.69	0.75	1.66	1.28	24.52
Bivalve juveniles	2.29	9.74	0.72	2.04	1.23	25.76
Ampelisca brevicornis	2.29	9.64	0.71	1.70	1.21	26.96
Platyhelminthes	0.00	7.13	0.68	10.13	1.17	28.13
Stegocephaloides sp	0.00	6.60	0.65	1.22	1.11	29.24
Urothoidae	2.29	7.48	0.57	1.54	0.97	30.21
Capitellidae	3.65	9.29	0.57	1.38	0.97	31.18
Solen cylindraceus	0.00	5.74	0.56	2.17	0.96	32.14
Ophiuroidea sp 3	0.00	5.74	0.56	2.17	0.96	33.10
Glyceridae	2.29	7.96	0.55	1.60	0.93	34.03
Ischyroceridae	0.00	6.25	0.54	0.69	0.93	34.96
Diastylidae	6.50	12.12	0.54	1.44	0.92	35.88
Pholoe minuta	0.00	5.80	0.54	1.32	0.92	36.80
Colomastix keiskama	1.15	6.30	0.53	1.63	0.91	37.71
Bathyporeia sp	7.02	6.10	0.53	1.26	0.90	38.61
Spionidae	9.49	12.94	0.52	0.74	0.89	39.49
Nemertea	2.49	7.60	0.52	1.55	0.88	40.37
Atylus swammerdami	0.00	5.35	0.51	1.34	0.88	41.25
Syllidae	1.15	5.90	0.51	1.16	0.87	42.12
Ostracoda sp 8	2.77	7.28	0.50	1.83	0.86	42.98
Cirratulidae sp 2	1.62	5.06	0.49	1.38	0.84	43.82
Ostracoda sp 6	0.00	5.16	0.49	1.38	0.84	44.66
Donacidae/Tellinidae	3.44	8.68	0.49	1.34	0.84	45.50
Urothoe sp 1	3.00	6.05	0.49	1.57	0.83	46.33
Urothoe grimaldi	1.32	5.27	0.48	1.27	0.83	47.98
Oedicerotidae	3.13	5.20	0.48	1.33	0.82	48.81
Gynodiastylidae	1.15	5.24	0.47	1.26	0.80	49.61
Amakusanthura africana	2.43	6.25	0.47	1.32	0.80	50.41

Appendix 6B. Continued.

Group B (Site 2 & Site 3) vs Group D (Site 4)
Average dissimilarity: 62.53 %

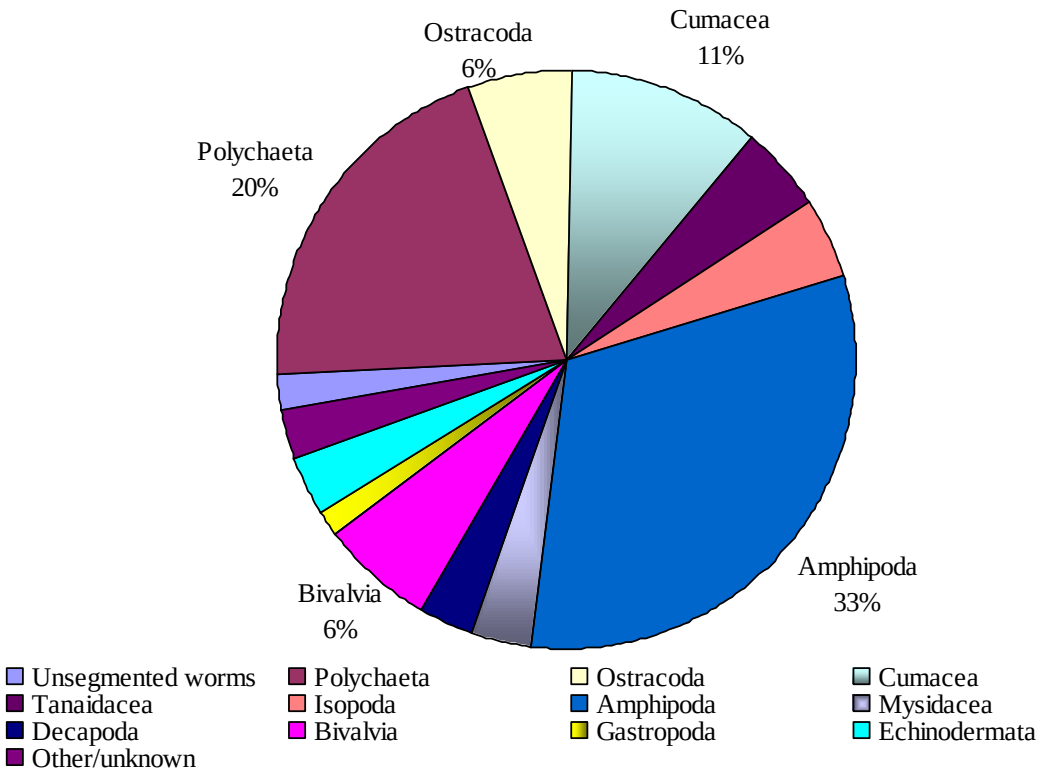
Taxa	Group B Av. Abund	Group D Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Urothoe pinnata	12.91	2.65	1.86	1.86	2.97	2.97
Mandibulophoxus stimpsoni	11.63	2.29	1.74	1.85	2.78	5.74
Laetmatophilus sp	8.85	0.00	1.59	2.96	2.55	8.29
Heterophoxus cf opus	8.78	0.00	1.56	4.61	2.50	10.79
Cirratulidae sp 2	1.62	9.08	1.36	2.77	2.18	12.96
Gnathia africana	9.58	2.29	1.34	1.80	2.14	15.11
Bathyporeia sp	7.02	0.00	1.30	1.25	2.08	17.19
Solen cylindraceus	0.00	7.10	1.26	5.74	2.02	19.21
Bullia sp	0.00	6.88	1.23	5.37	1.96	21.17
Glyceridae	2.29	8.56	1.15	1.69	1.84	23.01
Diogenidae	10.39	7.83	1.11	0.91	1.77	24.78
Perioculodes longimanus	6.07	0.00	1.06	2.03	1.69	26.47
Ampelisca brachyceras	5.85	0.00	1.03	1.97	1.65	28.12
Synidotea hirtipes	0.00	6.07	0.93	0.68	1.48	29.60
Ostracoda sp 3	7.28	2.29	0.91	1.38	1.46	31.06
Urothoe sp 1	3.00	4.59	0.91	0.95	1.45	32.52
Glycera cf longipinis	0.00	4.59	0.88	1.32	1.40	33.92
Nemertea	2.49	6.88	0.87	1.45	1.39	35.31
Bivalve juveniles	2.29	6.88	0.85	1.32	1.36	36.68
Hydrozoa	0.00	4.59	0.85	1.30	1.36	38.03
Megaluropus namaquaeensis	6.88	2.29	0.85	1.30	1.36	39.39
Nannastacidae	8.59	6.79	0.85	1.09	1.35	40.75
Echinocardium cordatum	4.59	0.00	0.84	1.32	1.35	42.37
Sthenelais cf boa	4.59	0.00	0.80	1.31	1.27	43.37
Maera sp 1	0.00	4.94	0.78	1.36	1.25	44.62
Orbiniidae	4.85	2.29	0.75	1.07	1.21	45.83
Spiroplax spiralis	3.70	5.46	0.75	1.11	1.20	47.03
Corophiidae	1.15	3.97	0.73	0.82	1.17	48.20
Ophiuroidea	4.89	2.29	0.73	1.10	1.17	49.37
Capitellidae	3.65	7.30	0.72	1.08	1.15	50.52

Appendix 6B. Continued.

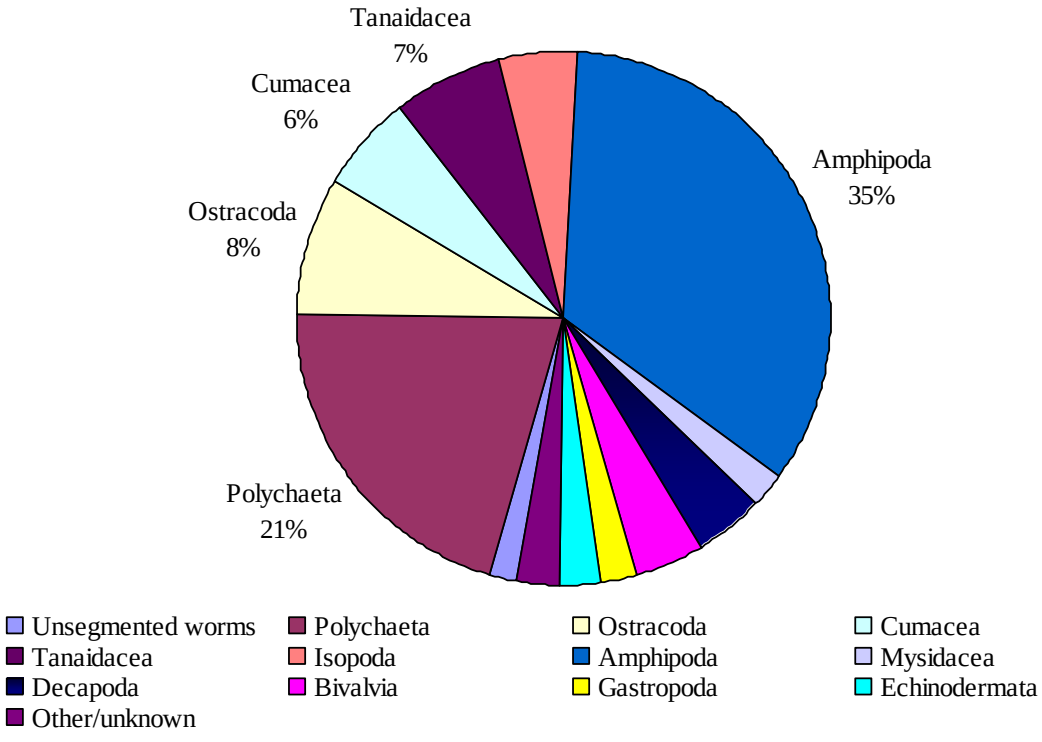
Group C (Site 5 & Site 6) vs Group D (Site 4)
Average dissimilarity: 66.47 %

Taxa	Group C Av. Abund	Group D Av. Abund	Av. Diss	Diss/SD	% Contrib	Cum. %
Apseudes minutus	0.00	25.57	2.51	1.99	3.78	3.78
Ostracoda sp 11	0.00	13.69	1.37	2.35	2.06	5.84
Ostracoda sp 2	0.00	11.37	1.15	2.53	1.72	7.56
Urothoe platypoda	0.00	10.67	1.06	3.05	1.60	9.16
Mandibulophoxus stimpsoni	2.29	12.73	1.06	2.14	1.59	10.75
Urothoe pinnata	2.65	12.68	1.02	1.71	1.53	12.29
Heterophoxus cf opus	0.00	9.89	0.98	5.32	1.48	13.76
Urothoe tumorosa	2.29	11.69	0.95	2.24	1.43	15.20
Ampelisca brevicornis	0.00	9.64	0.95	3.46	1.43	16.62
Eusiridae	0.00	9.62	0.93	2.80	1.40	18.03
Corophiidae	3.97	11.20	0.93	2.80	1.40	19.43
Ostracoda sp 4	2.29	12.01	0.93	1.36	1.40	20.83
Gammaridae	0.00	9.47	0.90	1.29	1.35	22.18
Maera sp 1	4.94	10.41	0.86	1.39	1.30	23.48
Hippomedon longimanus	0.00	8.65	0.86	4.81	1.29	24.77
Stegocephalidae	0.00	8.22	0.81	4.22	1.21	25.98
Phoxocephalidae	0.00	7.33	0.73	5.62	1.10	27.08
Ostracoda sp 8	0.00	7.28	0.72	8.25	1.08	28.16
Ostracoda sp 3	2.29	9.42	0.71	1.83	1.07	29.23
Ampelisca brachyceras	0.00	6.93	0.71	1.92	1.06	30.30
Sigalionidae	0.00	6.90	0.70	2.00	1.05	31.35
Perioculodes longimanus	0.00	6.99	0.69	7.92	1.04	32.39
Bullia sp	6.88	0.00	0.68	8.53	1.03	33.42
Stegocephaloides sp	0.00	6.60	0.67	1.20	1.01	34.43
Diogenidae	7.83	3.66	0.66	2.17	0.99	35.42
Urothoe sp 1	4.59	6.05	0.65	2.20	0.97	36.69
Synidotea hirtipes	6.07	2.29	0.64	0.93	0.96	37.35
Amakusanthura africana	0.00	6.25	0.63	1.98	0.95	38.30
Colomastix keiskama	0.00	6.30	0.62	2.03	0.94	39.24
Laetmatophilus sp	0.00	6.24	0.62	1.29	0.93	40.17
Gnathia africana	2.29	8.34	0.61	1.66	0.92	41.09
Bathyporeia sp	0.00	6.10	0.61	1.28	0.92	42.00
Urothoidae	2.29	7.48	0.61	1.45	0.91	42.91
Echinocardium cordatum	0.00	5.83	0.59	1.29	0.89	43.81
Pectinaria capensis	0.00	5.81	0.59	1.32	0.88	44.69
Sthenelais cf boa	0.00	5.74	0.58	2.11	0.88	45.56
Ostracoda sp 5	2.29	8.00	0.57	1.55	0.85	46.42
Ischyroceridae	0.00	6.25	0.56	0.68	0.84	47.26
Syllidae	0.00	5.90	0.56	1.20	0.84	48.10
Ophiuroidea	2.29	7.20	0.56	1.45	0.84	48.94
Orbiniidae	2.29	7.73	0.55	1.46	0.83	49.77
Urothoe grimaldi	0.00	5.27	0.53	1.33	0.80	50.57

Appendix 7A. Overall taxonomic composition during the 2008 benthic survey.



Appendix 7B. Overall taxonomic composition: 2009 benthic survey.



Appendix 8A. Mean (n = 75) abundance (individuals m^{-2}) for 2008 benthic survey.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Cnidaria						
Cnidaria	15.80	0.00	15.80	31.59	47.39	31.59
Hydrozoa	15.80	31.60	15.80	0.00	31.59	15.80
Unsegmented worms						
Nematoda	31.60	0.00	0.00	0.00	15.80	0.00
Nemertea	84.25	71.09	75.88	0.00	65.30	42.13
Platyhelminthes	31.59	0.00	0.00	0.00	0.00	47.39
Sipunculida spp	31.59	0.00	0.00	31.59	15.80	0.00
Sipunculida-like	0.00	61.39	31.59	15.80	15.80	0.00
Oligochaeta	0.00	0.00	0.00	15.80	0.00	15.80
Polychaeta						
Ampharetidae	0.00	0.00	0.00	0.00	15.80	0.00
Armandia longicaudata	15.80	34.47	0.00	0.00	0.00	15.80
Capitellidae	0.00	15.80	45.81	58.88	82.12	31.59
Cirratulidae	31.59	15.80	41.17	43.88	162.19	31.59
Cirratulidae sp 1	15.80	0.00	47.39	0.00	53.71	0.00
Cirratulidae sp 2	47.39	0.00	45.14	0.00	221.50	31.60
cf Cossuridae	0.00	0.00	0.00	15.80	0.00	0.00
Dendronereides sp	0.00	0.00	0.00	0.00	63.19	0.00
Diopatra neopolitana	0.00	0.00	0.00	0.00	31.59	0.00
Epidiopatra cf gilchristi	0.00	0.00	0.00	0.00	15.80	0.00
Eteone sp 1	0.00	15.80	0.00	0.00	47.39	0.00
Eupanthalis cf kinbergi	0.00	0.00	0.00	15.80	0.00	0.00
Glyceridae	15.80	15.80	15.80	84.26	72.01	15.80
Glycinde capensis	0.00	15.80	18.96	100.05	85.13	15.80
Hemipodus sp	0.00	0.00	0.00	47.39	0.00	0.00
Hesionidae	15.80	0.00	15.80	31.59	31.59	0.00
Magelona cincta	0.00	0.00	0.00	31.59	31.59	0.00
Magelona papillicornis	63.87	31.59	44.76	54.63	54.50	54.41
Maldanidae	0.00	0.00	0.00	15.80	0.00	15.80
Micronephtys sphaerocirrata	77.14	65.82	105.88	120.31	322.62	163.90
Micronereides cf capensis	0.00	0.00	0.00	0.00	15.80	0.00
Neoleanira tetragona	0.00	0.00	0.00	0.00	0.00	15.80
Nephtyidae	15.80	0.00	31.59	88.47	15.80	15.80
Nephtys capensis	31.59	0.00	0.00	0.00	15.80	0.00
Nephtys cf paradoxa	15.80	0.00	0.00	0.00	0.00	0.00
Nereididae	0.00	0.00	0.00	0.00	31.59	0.00
Onuphidae	0.00	0.00	0.00	0.00	31.59	0.00
Opheliidae	0.00	0.00	15.80	0.00	0.00	0.00
Ophelia anomala	0.00	34.75	0.00	0.00	0.00	0.00
Orbiniidae	0.00	47.39	19.75	76.73	39.49	65.82
Orbinia sp	15.80	0.00	15.80	0.00	0.00	0.00

Appendix 8A. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Pectinaria capensis	0.00	31.59	52.81	0.00	48.61	35.54
Pherusa sp 1	0.00	0.00	0.00	0.00	15.80	0.00
Phyllodocidae	0.00	0.00	0.00	15.80	0.00	0.00
Sigalionidae	39.49	0.00	0.00	15.80	39.49	42.43
Sigalion cf squamosus	0.00	0.00	31.59	0.00	0.00	0.00
Sigalion sp	0.00	0.00	0.00	0.00	15.80	0.00
Sigambra parva	0.00	0.00	0.00	0.00	55.26	0.00
Spionidae	47.39	174.99	57.83	47.39	85.25	62.40
Sthenelais cf boa	52.66	0.00	31.59	0.00	63.19	15.80
Sthenelais cf limicola	15.80	0.00	0.00	0.00	0.00	0.00
Sthenelais sp 1	15.80	15.80	31.59	0.00	47.39	15.80
Sthenelais spp	31.59	0.00	31.59	0.00	31.59	31.59
Polychaete larvae	0.00	15.80	0.00	0.00	0.00	0.00
Unidentified	15.80	0.00	15.80	72.52	51.34	71.09
Pycnogonida						
cf Queubus jamesanus	15.80	0.00	0.00	115.72	0.00	0.00
Ostracoda						
Ostracoda sp 1	15.80	0.00	0.00	15.80	0.00	0.00
Ostracoda sp 2	31.59	31.59	47.39	15.80	227.96	239.02
Ostracoda sp3	47.39	15.80	60.56	31.59	143.62	109.27
Ostracoda sp 4	0.00	0.00	0.00	0.00	401.55	36.86
Ostracoda sp 6	0.00	0.00	0.00	0.00	47.39	78.99
Ostracoda spp	0.00	0.00	0.00	0.00	15.80	0.00
Phyllocarida						
Nebalia capensis	15.80	0.00	0.00	0.00	0.00	0.00
Cumacea						
Bodotriidae	123.91	50.02	47.39	15.80	57.92	105.32
Ceratocumatidae	76.73	31.59	31.59	50.55	65.82	69.11
Diastylidae	31.59	47.39	64.73	0.00	245.99	135.93
Gynodiastylidae	108.44	15.80	63.19	23.70	617.83	65.95
Leuconidae	15.80	0.00	0.00	0.00	0.00	15.80
Nannastacidae	129.40	87.22	68.46	21.06	62.66	78.99
Pseudocumatidae	0.00	0.00	0.00	0.00	0.00	31.59
Damaged	55.29	15.80	21.06	0.00	65.17	44.23
Unidentified	0.00	0.00	0.00	0.00	0.00	15.80
Tanaidacea						
Anatanais gracilis	0.00	0.00	0.00	0.00	0.00	15.80
Apseudes cf digitalis	0.00	0.00	0.00	0.00	0.00	15.80
Apseudes minutus	15.80	0.00	0.00	0.00	903.65	93.03
Apseudes sp	0.00	0.00	0.00	0.00	0.00	15.80
Tanais philetaerus	0.00	0.00	0.00	0.00	0.00	15.80
Unidentified	0.00	0.00	0.00	15.80	31.59	31.60
Damaged	0.00	0.00	0.00	0.00	94.79	15.80

Appendix 8A. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Isopoda						
Anthuridae	0.00	0.00	0.00	0.00	0.00	63.19
Amakusanthura africana	47.39	15.80	0.00	15.80	21.72	72.19
Arcturina scutula	39.49	0.00	0.00	0.00	0.00	47.39
Cirolana cf meinerti	0.00	0.00	15.80	0.00	0.00	0.00
Dynamenella sp	0.00	0.00	0.00	0.00	15.80	0.00
Eurydice longicornis	15.80	15.80	47.39	0.00	15.80	0.00
Gnathia africana	98.12	173.64	76.35	0.00	123.03	94.41
Isopod juvenile	0.00	0.00	0.00	0.00	139.28	0.00
Unidentified	0.00	0.00	0.00	0.00	139.28	0.00
Damaged	0.00	0.00	0.00	0.00	15.80	0.00
Amphipoda						
Acanthonotozomatidae sp 1	0.00	0.00	15.80	0.00	0.00	0.00
Amaryllis macrophthalma	0.00	0.00	15.80	0.00	0.00	0.00
Ampeliscidae	0.00	0.00	0.00	0.00	15.80	15.80
Ampelisca anomala	0.00	0.00	0.00	0.00	0.00	15.80
Ampelisca brachyceras	0.00	0.00	52.66	0.00	15.80	0.00
Ampelisca brevicornis	0.00	0.00	15.80	0.00	63.15	47.39
Ampelisca chiltoni	0.00	0.00	0.00	0.00	0.00	15.80
Ampelisca palmata	31.59	0.00	0.00	0.00	0.00	0.00
Ampelisca sp	0.00	0.00	0.00	0.00	15.80	31.59
Aora sp	0.00	0.00	0.00	0.00	15.80	0.00
Aora gibbula	0.00	0.00	15.80	0.00	63.19	0.00
Atylus swammerdami	15.80	0.00	0.00	23.70	36.86	15.80
Bathyporeia sp	247.22	19.75	31.59	0.00	63.19	133.00
Colomastix keiskama	0.00	0.00	0.00	0.00	72.67	0.00
Corophiidae	47.39	0.00	15.80	0.00	110.58	47.39
Cyproidea ornata	0.00	0.00	0.00	0.00	15.80	0.00
Elasmpus affinis	0.00	0.00	0.00	0.00	94.79	0.00
Eusiradae	0.00	0.00	15.80	0.00	0.00	0.00
Gammaridae	0.00	15.80	15.80	0.00	0.00	0.00
Heterophoxus cephalodens	0.00	0.00	57.92	0.00	31.60	0.00
Heterophoxus sp	0.00	71.97	92.15	0.00	31.60	0.00
Hippomedon longimanus	0.00	0.00	0.00	0.00	37.34	69.03
Hippomedon normalis	0.00	0.00	0.00	0.00	15.80	0.00
Hippomedon sp	0.00	0.00	0.00	0.00	0.00	15.80
Hoplopleon sp	0.00	0.00	0.00	0.00	15.80	0.00
Ischyroceridae	0.00	0.00	0.00	0.00	15.80	0.00
Laetmatophilus sp	86.97	340.67	18.43	15.80	54.16	31.59
Lysianassidae	0.00	0.00	0.00	0.00	15.80	39.49
Maera sp 1	0.00	15.80	15.80	0.00	286.99	15.80
cf Mallacoota subcarina	0.00	0.00	0.00	0.00	0.00	15.80
Mandibulophoxus stimpsoni	23.70	130.52	142.61	0.00	197.74	198.25

Appendix 8A. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Megaluropus namaquaeensis	78.99	52.66	47.39	0.00	15.80	31.59
Monoculodopsis longimana	58.45	59.69	51.60	15.80	50.48	53.71
Oedicerotidae	0.00	31.59	31.59	31.60	31.59	15.80
Oediceroides cinderella	0.00	0.00	0.00	0.00	0.00	15.80
Perioculodes longimanus	58.67	31.59	76.40	0.00	54.16	47.39
Perioculodes sp	0.00	0.00	0.00	0.00	15.80	0.00
Phoxocephalidae	0.00	78.99	66.95	0.00	31.59	70.56
Siphonoecetes sp	0.00	0.00	0.00	0.00	15.80	0.00
Stegocephaloides sp	15.80	0.00	0.00	0.00	52.66	80.57
Synchelidium cf tenuimanus	0.00	0.00	15.80	0.00	0.00	0.00
Urothoidae	15.80	0.00	55.29	0.00	63.19	0.00
Urothoe coxalis	0.00	0.00	31.59	31.59	15.80	15.80
Urothoe grimaldi	0.00	0.00	31.59	15.80	31.59	31.59
Urothoe pinnata	125.94	54.41	391.10	0.00	237.20	94.78
Urothoe platypoda	0.00	0.00	0.00	0.00	172.88	100.84
Urothoe cf pulchella	0.00	0.00	0.00	0.00	0.00	15.80
Urothoe cf serrulidactylus	0.00	0.00	0.00	15.80	0.00	31.59
Urothoe tumorosa	126.38	21.06	138.07	21.06	399.88	119.31
Urothoe sp	39.49	0.00	50.40	55.29	47.39	52.66
Urothoe sp 1	0.00	0.00	52.66	0.00	22.12	0.00
Urothoe sp 2	0.00	0.00	53.71	0.00	15.80	15.80
Urothoe sp 3	0.00	0.00	31.59	0.00	0.00	0.00
Urothoe sp 4	0.00	0.00	39.49	0.00	0.00	78.99
Urothoe sp 5	0.00	0.00	15.80	0.00	0.00	0.00
Urothoe sp 6	0.00	0.00	0.00	15.80	0.00	0.00
Unidentified	0.00	31.59	0.00	0.00	47.39	63.19
Damaged	56.87	0.00	31.60	15.80	82.94	63.59
Mysidacea						
Gastrosaccus psammodytes	47.39	31.59	51.34	0.00	47.39	47.39
Mesopodopsis wooldridgei	52.66	31.59	77.94	15.80	31.59	31.60
Mysida larvae	15.80	0.00	0.00	15.80	15.80	221.17
Unidentified	0.00	15.80	0.00	0.00	31.59	0.00
Damaged	0.00	0.00	31.59	0.00	0.00	34.75
Prawns, shrimps, caridea						
Caridea	0.00	0.00	0.00	0.00	15.80	0.00
Pasiphaeidae	0.00	0.00	15.80	0.00	0.00	0.00
Pasiphae (Pasiphae) sp 1	0.00	0.00	15.80	0.00	0.00	0.00
Stenopus sp 1	15.80	0.00	0.00	0.00	0.00	0.00
Unidentified	15.80	0.00	0.00	0.00	0.00	0.00

Appendix 8A. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Decapoda						
Diogenidae	31.59	286.62	15.80	42.13	31.59	31.59
Paguristes cf ciliatus	0.00	0.00	0.00	15.80	0.00	0.00
Philyra punctata	15.80	0.00	15.80	31.59	0.00	0.00
Portunidae	0.00	0.00	0.00	0.00	0.00	15.80
Spiroplax spiralis	0.00	0.00	39.49	15.80	15.80	31.59
Decapod larvae & megalopae	15.80	15.80	15.80	47.39	55.26	31.59
Unidentified	0.00	0.00	0.00	0.00	31.59	0.00
Bivalvia						
Donacidae/Tellinidae	53.97	142.50	75.83	99.07	133.40	60.56
Donax burnupi	0.00	52.66	0.00	0.00	15.80	15.80
Donax cf serra	15.80	0.00	0.00	0.00	0.00	0.00
Donax sordidus	15.80	0.00	0.00	0.00	0.00	0.00
Lucinidae	0.00	0.00	0.00	15.80	0.00	0.00
Lutraria lutraria	0.00	0.00	0.00	0.00	15.80	0.00
Mytilidae	0.00	0.00	0.00	15.80	0.00	0.00
Phaxas decipiens	0.00	15.80	47.39	31.59	47.39	15.80
Tellina cf alfredensis	0.00	0.00	0.00	15.80	0.00	0.00
Tellina cf gilchristi	0.00	0.00	0.00	15.80	0.00	0.00
Tivela cf compressa	15.80	0.00	0.00	0.00	0.00	0.00
Veneridae	15.80	0.00	31.60	15.80	15.80	0.00
Bivalve juvenile	80.83	76.28	114.94	51.34	191.65	102.68
Unidentified	0.00	0.00	0.00	31.59	0.00	0.00
Damaged	0.00	0.00	0.00	0.00	0.00	15.80
Gastropoda						
Bullidae	0.00	0.00	0.00	15.80	0.00	0.00
Bullia annulata	15.80	15.80	0.00	31.59	15.80	15.80
Bullia laevissima	0.00	15.80	0.00	15.80	0.00	0.00
cf Connidae	15.80	0.00	0.00	0.00	0.00	0.00
Gastropod juvenile	15.80	0.00	0.00	0.00	0.00	0.00
Gastropod larvae	47.39	0.00	0.00	0.00	0.00	0.00
Haminoeidae	0.00	0.00	50.55	31.59	15.80	0.00
Nassariidae	15.80	0.00	0.00	0.00	0.00	0.00
Unidentified	31.59	31.60	0.00	0.00	0.00	0.00
Nudibranch	47.39	0.00	0.00	0.00	15.80	0.00
Echinodermata						
Astropecten granulatus	0.00	0.00	0.00	0.00	0.00	15.80
Ophiuroidea sp 1	53.71	53.71	120.16	15.80	88.27	63.19
Echinoidea	31.59	31.59	31.59	0.00	31.59	0.00
Echinocardium cordatum	63.54	78.99	87.28	0.00	52.66	69.96
Holothuroidea	0.00	0.00	0.00	15.80	0.00	0.00
Cephalochordata						
Cephalochordata sp 1	0.00	15.80	15.80	0.00	31.59	31.59
Other/unknown	15.80	0.00	15.80	0.00	31.59	0.00

Appendix 8B. Mean (n = 75) abundance (individuals m^{-2}) for 2009 benthic survey.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Cnidaria						
Hydrozoa	15.80	0.00	0.00	31.59	15.80	0.00
Unsegmented worms						
Nematoda	0.00	0.00	0.00	0.00	0.00	15.80
Nemertea	52.66	0.00	37.34	47.39	61.68	54.50
Platyhelminthes	15.80	0.00	0.00	15.80	51.34	50.55
Sipunculida spp	31.59	0.00	15.80	0.00	0.00	0.00
Sipunculida-like	0.00	0.00	15.80	15.80	0.00	15.80
Oligochaeta	0.00	0.00	0.00	0.00	15.80	15.80
Polychaeta						
Ampharetidae	0.00	0.00	0.00	15.80	55.29	0.00
cf Amphinomidae	0.00	0.00	0.00	15.80	0.00	0.00
Armandia longicaudata	0.00	31.59	15.80	0.00	0.00	36.11
Capitellidae	51.34	15.80	37.91	53.71	136.96	47.39
Chrysopetalidae sp 1	0.00	0.00	0.00	0.00	0.00	15.80
Cirratulidae	207.00	78.99	150.54	51.23	150.29	73.72
Cirratulidae sp 2	0.00	0.00	31.60	86.89	41.75	35.54
Diopatra neopolitana	0.00	0.00	0.00	0.00	63.19	0.00
Eteone sp 1	0.00	0.00	0.00	0.00	35.54	36.86
Glyceridae	31.59	15.80	15.80	73.44	69.58	60.03
Glycera cf longipinis	0.00	0	0	31.59	0.00	0.00
Glycera prashadi	0.00	0.00	0.00	0.00	0.00	31.59
Glycinde capensis	31.60	0.00	0.00	15.80	0.00	0.00
Hesionidae	15.80	0.00	0.00	15.80	15.80	0.00
Lumbrineris sp	0.00	0.00	0.00	0.00	15.80	0.00
Magelona cincta	0.00	0.00	0.00	47.39	60.56	0.00
Magelona papillicornis	75.78	31.59	47.39	73.24	49.65	72.22
Mediomastus capensis	0.00	0.00	0.00	15.80	0.00	0.00
Micronephtys sphaerocirrata	106.39	68.08	76.90	84.25	168.49	95.07
Micronereides cf capensis	0.00	0.00	0.00	0.00	0.00	15.80
Neoleanira tetragona	0.00	0.00	0.00	0.00	0.00	15.80
Nephtyidae	47.39	0.00	0.00	0.00	0.00	0.00
Nephtys capensis	35.54	0.00	0.00	0.00	0.00	0.00
Nereididae	0.00	0.00	0.00	31.60	36.11	31.60
Orbiniidae	15.80	31.59	39.49	15.80	59.24	63.19
Orbinia sp	0.00	0.00	0.00	15.80	15.80	15.80
cf Paranuphis antarctica	0.00	0.00	0.00	0.00	0.00	15.80
Pectinaria capensis	0.00	15.80	18.05	0.00	56.61	47.39
Pherusa sp 1	0.00	0.00	0.00	0.00	36.86	0.00
Pholoe minuta	0.00	0.00	0.00	15.80	86.89	15.80
Phyllodocidae	0.00	0.00	0.00	0.00	0.00	31.60

Appendix 8B. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Pontodora cf pelagica	0.00	0.00	0.00	0.00	0.00	31.60
Prionospio cf cirrifera	0.00	0.00	0.00	15.80	0.00	0.00
Sabellidae sp 1	0.00	0.00	0.00	0.00	0.00	15.80
Sigalionidae	31.59	15.80	31.59	0.00	63.19	53.54
Spionidae	279.39	138.34	56.49	69.11	74.74	423.13
Sthenelais cf boa	53.71	15.80	47.39	0.00	47.39	31.59
Sthenelais sp 1	0.00	15.80	0.00	0.00	0.00	0.00
Sthenelais spp	0.00	0.00	15.80	0.00	31.59	15.80
Syllidae	0.00	0.00	15.80	0.00	31.59	88.47
Unidentified	0.00	0.00	0.00	15.80	59.50	80.57
Pycnogonida						
cf Queubus jamesanus	73.72	0.00	0.00	21.06	0.00	0.00
cf Queubus	35.54	0.00	0.00	15.80	0.00	0.00
Unidentified	15.80	0.00	0.00	0.00	15.80	0.00
Ostracoda						
Ostracoda sp 1	0.00	0.00	0.00	0.00	31.59	36.86
Ostracoda sp 2	15.80	0.00	0.00	0.00	116.88	168.45
Ostracoda sp 3	56.76	55.29	51.34	15.80	120.02	63.19
Ostracoda sp 4	0.00	0.00	15.80	15.80	286.47	75.04
Ostracoda sp 5	15.80	0.00	0.00	15.80	57.92	74.27
Ostracoda sp 6	0.00	0.00	0.00	0.00	37.74	43.44
Ostracoda sp 7	15.80	0.00	0.00	15.80	31.59	0.00
Ostracoda sp 8	15.80	47.39	0.00	0.00	47.39	59.24
Ostracoda sp 9	0.00	0.00	0.00	0.00	0.00	15.80
Ostracoda sp 10	15.80	15.80	0.00	0.00	36.86	31.59
Ostracoda sp 11	0.00	0.00	15.80	0.00	245.58	182.00
Ostracoda sp 12	0.00	0.00	0.00	0.00	0.00	31.60
Ostracoda sp 13	15.80	0.00	0.00	0.00	0.00	0.00
Ostracoda sp 14	0.00	15.80	0.00	0.00	0.00	0.00
Unidentified	0.00	0.00	0.00	0.00	15.80	31.59
Copepoda						
Saphirina sp 2	53.71	0.00	0.00	0.00	0.00	0.00
Cumacea						
Bodotriidae	93.45	61.50	52.66	47.39	34.75	88.31
Diastylidae	15.80	31.59	72.22	47.39	127.08	177.13
Gynodiastylidae	0.00	0.00	15.80	0.00	67.93	15.80
Nannastacidae	134.55	81.45	67.73	71.09	113.40	109.06
Damaged	0.00	0.00	0.00	0.00	31.59	15.80
Unidentified	0.00	0.00	0.00	0.00	0.00	47.39

Appendix 8B. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Tanaidacea						
Apseudes cf cooperi	0.00	0.00	0.00	0.00	0.00	15.80
Apseudes minutus	0.00	0.00	31.60	0.00	1155.66	474.59
Apseudes sp	0.00	0.00	0.00	0.00	15.80	0.00
Leptochelia cf barnadi	0.00	0.00	0.00	0.00	63.19	31.60
Parapseudes cf spongicola	0.00	0.00	0.00	0.00	15.80	0.00
Damaged	0.00	0.00	0.00	0.00	31.60	31.59
Isopoda						
Accalathura laevitelson	0.00	0.00	0.00	0.00	0.00	15.80
Anthuridae	15.80	0.00	0.00	0.00	0.00	15.80
Amakusanthura africana	47.39	0.00	35.54	0.00	31.59	63.19
Apanthura cf sandalensis	0.00	0.00	0.00	0.00	15.80	0.00
Arcturina scutula	82.94	0.00	0.00	0.00	15.80	34.75
Austroarcurus africanus	0.00	0.00	0.00	0.00	0.00	15.80
Cirolana sp	0.00	0.00	0.00	0.00	0.00	15.80
Dynamenella sp	31.60	0.00	0.00	0.00	15.80	15.80
Gnathia africana	47.39	96.98	87.80	15.80	80.49	60.42
Janiridae sp 1	0.00	0.00	0.00	0.00	0.00	15.80
Leptanthura agulhasensis	0.00	0.00	0.00	0.00	0.00	31.59
Leptanthura laevigata	0.00	0.00	0.00	0.00	0.00	15.80
Leptanthura sp	0.00	0.00	0.00	0.00	0.00	15.80
Panathura serricauda	0.00	0.00	0.00	0.00	0.00	15.80
Synidotea hirtipes	0.00	0.00	0.00	110.58	31.59	0.00
Synidotea variegata	47.39	0.00	0.00	47.39	47.39	15.80
Uromuna sheltoni	0.00	0.00	0.00	0.00	46.08	0.00
Unidentified	0.00	0.00	0.00	15.80	0.00	15.80
Amphipoda						
Acanthonotozomatidae	0.00	0.00	0.00	0.00	0.00	15.80
Acanthonotozomatidae sp 1	0.00	0.00	0.00	0.00	0.00	15.80
Ampeliscidae	0.00	0.00	0.00	0.00	39.49	0.00
Ampelisca brachyceras	60.18	31.59	50.46	0.00	57.92	59.99
Ampelisca brevicornis	0.00	0.00	31.59	0.00	143.67	58.17
Ampelisca sp	0.00	0.00	0.00	0.00	15.80	31.59
Aora gibbula	0.00	0.00	15.80	0.00	63.19	0.00
cf Aristia symbiotica	0.00	0.00	0.00	0.00	0.00	15.80
Atylidae	0.00	0.00	0.00	15.80	0.00	94.78
Atylus swammerdami	0.00	0.00	0.00	0.00	47.39	40.17
Bathyporeia sp	120.68	138.26	15.80	0.00	15.80	101.69
Caprella sp	0.00	0.00	0.00	0.00	0.00	15.80
Colomastix keiskama	0.00	0.00	15.80	0.00	41.47	54.41
Corophiidae	0.00	0.00	15.80	47.39	177.05	193.52

Appendix 8B. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Cymus gracilis	0.00	0.00	0.00	0.00	15.80	21.06
Cymadusa sp 1	0.00	0.00	0.00	0.00	0.00	31.60
Ericthonius punctatus	0.00	0.00	0.00	0.00	0.00	31.60
Eusiradae	0.00	0.00	0.00	0.00	82.28	132.70
Gammaridae	15.80	0.00	23.70	0.00	228.86	51.34
Heterophoxus cf opus	31.59	89.30	67.21	0.00	98.49	100.53
Hippomedon longimanus	15.80	0.00	0.00	0.00	72.67	80.20
Hippomedon normalis	0.00	0.00	0.00	0.00	15.80	44.23
Hippomedon cf onconotus	0.00	0.00	0.00	0.00	0.00	15.80
Hippomedon sp	0.00	0.00	0.00	0.00	22.12	47.39
Hoplopleon sp 1	0.00	0.00	0.00	0.00	0.00	15.80
Ischyroceridae	0.00	0.00	0.00	0.00	142.18	94.79
Ischyroceridae sp 1	0.00	0.00	0.00	0.00	0.00	78.99
Laetmatophilus sp	93.57	117.78	47.39	0.00	18.96	100.13
Leucothoe richiardi	0.00	0.00	0.00	0.00	0.00	31.59
Lysianassidae	0.00	0.00	0.00	0.00	23.70	39.49
Maera sp 1	0.00	0.00	0.00	36.86	275.14	73.72
Mandibulophoxus stimpsoni	47.39	163.94	119.62	15.80	168.53	168.63
Megaluropus namaquaeensis	55.29	47.39	47.39	15.80	15.80	31.59
Microdeutopus cf thumbellinus	0.00	0.00	0.00	0.00	0.00	67.14
Monoculodopsis longimana	52.92	52.66	50.55	31.59	67.20	71.09
Oedicerotidae	68.46	15.80	47.39	15.80	15.80	67.14
Perioculodes longimanus	106.60	47.39	42.13	0.00	50.55	47.39
Phoxocephalidae	0.00	31.59	15.80	0.00	48.83	59.50
Stegocephalidae	0.00	0.00	0.00	0.00	47.39	96.76
Stegocephaloides sp	0.00	0.00	0.00	0.00	15.80	123.75
Urothoidae	15.80	31.59	0.00	15.80	93.21	44.76
Urothoe coxalis	0.00	0.00	28.08	21.06	57.27	15.80
Urothoe grimaldi	0.00	0.00	21.06	0.00	53.71	31.59
Urothoe pinnata	175.69	139.26	221.35	21.06	275.67	80.18
Urothoe platypoda	0.00	0.00	0.00	0.00	133.60	113.64
Urothoe tumorosa	0.00	0.00	75.48	15.80	135.16	142.93
Urothoe sp 1	0.00	0.00	54.42	63.19	41.47	47.39
Urothoe sp 2	0.00	15.80	26.33	15.80	19.31	19.75
Urothoe sp 3	0.00	0.00	43.88	0.00	39.49	15.80
Urothoe sp 4	0.00	15.80	28.96	15.80	19.75	19.75
Urothoe sp 5	0.00	0.00	18.96	15.80	34.47	15.80
Urothoe sp 6	0.00	0.00	0.00	0.00	15.80	15.80
Urothoe sp 7	0.00	0.00	0.00	0.00	0.00	15.80
Amphipod juveniles	0.00	0.00	0.00	0.00	0.00	15.80
Unidentified	15.80	0.00	0.00	0.00	39.49	98.73
Damaged	0.00	0.00	0.00	0.00	15.80	39.49

Appendix 8B. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Mysidacea						
Doxomysis algoaensis	0.00	15.80	0.00	0.00	0.00	0.00
Gastrosaccus psammodytes	0.00	0.00	15.80	0.00	15.80	47.39
Mesopodopsis wooldridgei	47.39	34.75	47.39	94.07	47.39	31.59
Mysida larvae	0.00	15.80	55.29	0.00	0.00	0.00
Unidentified	31.59	15.80	15.80	47.39	15.80	31.59
Damaged	0.00	0.00	0.00	15.80	0.00	0.00
Prawns, shrimps, caridea						
Caridea	31.59	31.59	15.80	0.00	23.70	31.59
Unidentified	0.00	0.00	0.00	0.00	0.00	31.59
Decapoda						
Brachyura	0.00	0.00	15.80	0.00	0.00	0.00
Diogenidae	52.66	315.20	31.59	63.19	15.80	75.83
Hymenosoma orbiculare	0.00	0.00	15.80	0.00	15.80	0.00
Paguridae sp 1	0.00	0.00	0.00	15.80	0.00	0.00
Paguristes cf ciliatus	0.00	0.00	0.00	0.00	0.00	15.80
Philyra punctata	47.39	0.00	31.59	15.80	15.80	0.00
Spiroplax spiralis	0.00	15.80	39.49	44.76	60.03	15.80
Decapod larvae & megalopae	0.00	52.66	31.59	31.59	47.39	15.80
Bivalvia						
Arcidae	0.00	0.00	0.00	15.80	0.00	0.00
Donacidae/Tellinidae	47.39	31.59	15.80	51.90	93.35	63.19
Donax burnupi	0.00	0.00	0.00	0.00	0.00	15.80
Lucinidae	31.59	0.00	47.39	15.80	31.59	15.80
Mactridae	0.00	0.00	0.00	0.00	0.00	15.80
Mytilidae	63.19	0.00	0.00	0.00	0.00	0.00
Phaxas decipiens	15.80	0.00	31.59	31.59	49.65	0.00
Solen cylindraceus	0.00	0.00	0.00	50.55	47.39	31.59
Tellina cf alfredensis	0.00	0.00	0.00	0.00	15.80	0.00
Bivalve juvenile	57.92	0.00	31.59	47.39	113.82	79.67
Damaged	15.80	0.00	0.00	0.00	0.00	0.00
Gastropoda						
Acteon cf albus	0.00	0.00	31.60	0.00	0.00	0.00
Ancilla albozonata	0.00	0.00	0.00	0.00	0.00	15.80
Bullia annulata	31.59	31.59	0.00	0.00	0.00	0.00
Bullia laevissima	31.59	15.80	0.00	0.00	0.00	0.00
Bullia sp	15.80	0.00	0.00	47.39	0.00	0.00
Eulimidae	63.19	78.99	0.00	0.00	0.00	0.00
Haminoeidae	15.80	31.59	0.00	0.00	15.80	0.00
Nassariidae	51.34	0.00	0.00	0.00	0.00	0.00
Nassarius sp	0.00	15.80	0.00	47.39	27.65	0.00
Gastropod larvae	0.00	0.00	0.00	0.00	0.00	31.59
Unidentified	31.59	0.00	15.80	0.00	15.80	0.00

Appendix 8B. Continued.

Taxa	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Nudibranch	15.80	0.00	0.00	0.00	15.80	0.00
Echinodermata						
Ophiuroidea sp 1	15.80	31.59	40.37	15.80	82.76	44.23
Ophiuroidea sp 2	0.00	0.00	0.00	0.00	15.80	0.00
Ophiuroidea sp 3	0.00	0.00	0.00	15.80	47.39	31.59
Ophiuroidea sp 4	0.00	0.00	0.00	0.00	0.00	15.80
Echinoidea	47.39	0.00	0.00	0.00	0.00	15.80
Echinocardium cordatum	53.71	31.59	31.59	0.00	43.71	61.22
Holothuroidea	31.59	0.00	0.00	0.00	0.00	0.00
Cephalochordata						
Cephalochordata sp 1	0.00	0.00	0.00	0.00	31.59	31.59
Other/unknown	0.00	0.00	0.00	0.00	31.59	15.80

Appendix 9. Bottom Current Dynamics during summer in Algoa Bay

The purpose of this section is to describe the hydrodynamic regime around the 10 m depth contour in Algoa Bay. Data used to describe this hydrodynamic regime has been kindly offered by Dr. Wayne Goschen of SAEON Egagasini Node in Cape Town (wayne@saeon.ac.za), who reserves the right to publish this information. Reported hereunder are analyses of mean currents measured at three depths by two ADCPs (Acoustic Doppler Current Profiler). One ADCP was deployed in about 30 m water at Cape Recife and the other at Bird Island between December 2008 and February 2009, giving a scenario of the hydrodynamic regimes during the summer months.

The vectors of currents were broken into their north and east components and their principal axes directions determined using the method described by Kundu *et al.* (1976). This allowed the means and standard deviations of the speed along the major and minor axes to be established. The results for the major and minor axes and net currents at three depths at the two sites are shown in Figure 1, from which it can be seen that currents throughout the water column were aligned with the local bottom topography and shoreline orientation at both Bird Island and Cape Recife.

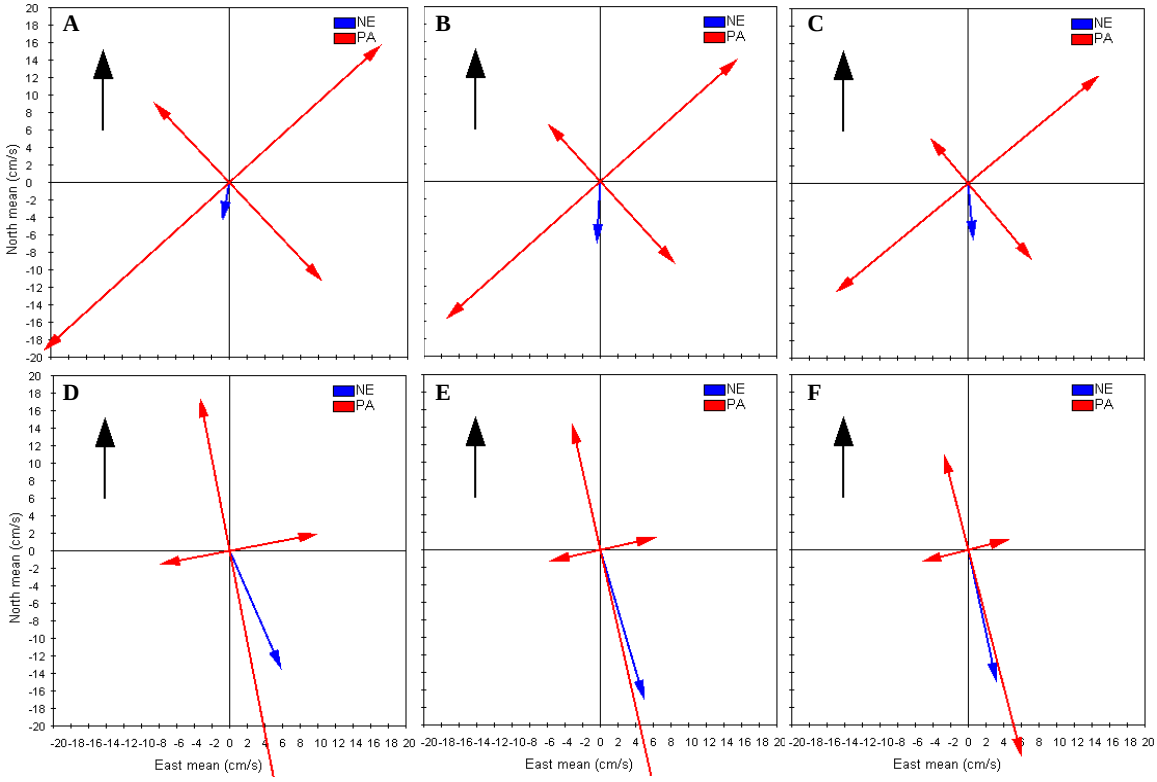


Figure A9.1. Current velocities in the major and minor directions (red arrows) from two ADCP deployments in Algoa Bay. A–C represent ADCP measurements from the Bird Island station measured at 4, 9 and 14 m depths, respectively. D–E represent Cape Recife measurements at 4, 9 and 14 m respectively. Blue lines represent net flow over the deployment period.

Bird Island

The predominant current directions at Bird Island were north-eastward and south-westward (Figure 1 A–C). Current flowing north-eastward ranged from approximately 20 cm s^{-1} to 25 cm s^{-1}. The slowest current was measured at 14 m (near the bottom), while the fastest current was measured at 4 m depths (at the surface). At 9 m depth, water flowed at a velocity of approximately 22 cm s^{-1}. Currents flowing south-westward ranged between 20 cm s^{-1} and 29 cm s^{-1}. These velocities were measured at 14 m and 4 m depth, respectively. At 9 m depth, current flowed at a velocity of approximately 25 cm s^{-1}.

Currents flowing north-westward and south-eastward (minor axis) were the slowest with current velocities flowing north-westward ranging from approximately 7 cm s^{-1} (at 14 m) to 13 cm s^{-1} (at 4 m). At a 9 m depth, currents flowed at approximately 9 cm s^{-1}. Current velocity of south-eastward flows ranged from approximately 12 cm s^{-1} at 14 m to 13 cm s^{-1} at 9 m. The net direction at Bird Island was southward with net velocity ranging from approximately 4 cm s^{-1} at a 4 m depth contour to 8 cm s^{-1} at 9 m.

Cape Recife

Bottom currents in the deeper regions of Algoa Bay have been shown to flow predominantly south-westward (CSIR 1970; Schumann *et al.* 2005), possibly due to entrainment by the Agulhas Current (Schumann *et al.* 2005). From these results, at Cape Recife predominant current directions were northwards and southwards (Figure 1 D–F). Associated velocities ranged between 12 cm s^{-1} at a 14 m depth and 18 cm s^{-1} at a 4 m depth for currents flowing northwards. During the measurement period, mean currents flowed southward, out of the bay, and had velocities ranging from 46 cm s^{-1} at a 14 m depth to >50 cm s^{-1} at 4 and 9 m depths. Westward and eastward velocities (minor axis) were the slowest at Cape Recife. Westward velocity ranged between 6 cm s^{-1} at a 14 m depth and 8 cm s^{-1} at a 4 m depth. The 9 m depth velocity was approximately 6 cm s^{-1}. Eastward velocities ranged between 5 cm s^{-1} at 14 m and 11 cm s^{-1} at 4 m. Velocity at 9 meters was approximately 7 cm s^{-1}. The net direction for the current was southwards out of the bay and ranged between ~15 cm s^{-1} at a 4 m depth and 18 cm s^{-1} at a 9 m depth. Velocity at 14 m depth was approximately 16 cm s^{-1}.

In summary, data presented in this section show that current flow was parallel to the shoreline orientation and is known from previous studies to be mainly driven by wind, tides and Agulhas Current influences (Schumann *et al.* 2005). Bottom currents in the bay have been found to flow predominantly south-westward, at least in the summer months, due to prevalent north-easterly winds during this season (Roberts 1990). This is also supported in other literature (e.g., CSIR 1970; Schumann *et al.* 2005). It is not, however, suggested that this is always the case or the prevailing state in other seasons. This section also reveals that current velocity decreases with depth, due to friction with the bottom and the decrease in the force of the wind with depth (Goschen *pers. comm.*).