Long-term Changes in the Benthic Macrofauna of Saldanha Bay

By

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MASTER OF SCIENCE

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DECLARATION

This thesis reports the results of original research, which I carried out under the auspices of the Marine Biology Research Institute, University of Cape Town. All assistance that I received has been fully acknowledged. This work has not been presented for a degree at any other university.

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Natasha Kruger

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Date

Dedicated to my family

Breslau, Miranda and Nicklaus Kruger

For their encouragement and patience.

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First and foremost I thank Almighty God for carrying me through the length of this project. The key to success can only be found in Him.

"It is the Lord who bestows wisdom and teaches knowledge and understanding." (Proverbs 2:6)

"Commit to the Lord all that you do, and your plans will be successful." (Proverbs 16:3)

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ABSTRACT

Saldanha Bay, which lies on the west coast of South Africa, has undergone major development over the last 30 years, including breakwater and harbour construction, harbour extension, dredging, mining, fishing, fish-processing and mussel culture. The aims of this study were to determine whether the benthic macrofaunal communities in the Bay have been altered over this period and to explore the benthic community patterns within the Bay prior to and after harbour development.

Twelve stations sampled prior to harbour construction were resampled in 2001 (40 years later) with a Day Dredge. Organisms having an average length greater than 1cm were collected from these samples. The species abundances were coded to make the samples comparable. The data were then analysed using PRIMER software. An ANOSIM was performed, which indicated that the benthic communities before harbour development were significantly different from those in 2001 ($p<0.001$). Increases in the abundances of the whelk *Nassarius speciosus* and the crab *Hymenosoma orbiculare* were mostly responsible for these differences. In addition, the benthic communities of the 1960s were divided into two groups, which covered the entire Bay, whereas in 2001 the communities were divided into distinct "Small Bay" and "Big Bay" groups.

In a second parallel analysis, thirteen stations were resampled using a van Veen Grab ($0.2m^2$). All organisms having an average length greater than 1mm were identified and counted. Similar to the dredge data, the grab data were analysed using PRIMER software. The ANOSIM again indicated that the benthic communities before harbour construction were different from those in 2001 ($p<0.001$). A dramatic decrease in the bivalve *Macoma* abundance (369 to 2 individuals per sample) was primarily responsible for the community differences. The analysis of the 1960s data only showed one benthic community, whereas three communities were identified in 2001, an indication that communities had become more diverse. Although one of the groups of 2001 was limited to the Big Bay area, the separation between Small and Big Bays was less distinct. In addition, sediment samples were collected and analysed. These showed that the sediment range in the Bay has narrowed, becoming finer and more dominated by fine sand and mud.

This study revealed an increase in scavenger and predator abundance, but a decrease in that of suspension-feeders, which is probably related to the change in sediment and food availability. Also, there appears to be an increase in species that prefer sheltered habitats, which is presumably due to the sheltering of the Bay by the breakwater. The fauna present before harbour construction is thus distinctly different from that after harbour development.

The methods used in this study were explorative not experimental, so the actual cause of faunal changes could not be ascertained. The communities have obviously changed over the last 40 years and the two possible causes were natural fluctuations and anthropogenic activity. Since no information about natural variation in the benthic communities of Saldanha Bay was available, this could not be excluded as a possibility. However, it is more likely that the considerable anthropogenic activities within Saldanha Bay, which are known to have altered the physical parameters of the Bay, have led to the changes observed in the benthic communities.

CONTENTS

Chapter 1

GENERAL INTRODUCTION AND LITERATURE REVIEW

In benthic ecology, the concept of a community has changed quite drastically over the last 170 years. In 1871, Karl Möbius proposed the idea of "biocoenosis", which considered a community to be a superorganism (Mills 1969), i.e. the same organisms would always be found together. This was, however, refuted and, in 1918, Peterson described different soft-bottom communities, each of which was named after and characterized by one or two dominant species. Working in South African waters, Day (1963) pointed out that benthic communities were more complex than initially thought. He noted that the bulk of the community consisted of smaller organisms, which were easy to miss when using the dredge sampling method, and that samples did not seem to be dominated by just a few species. Such communities did not conform to those previously described. Mills (1969) provided a working definition of a "community". He stated that a community is "a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and separable by means of ecological survey from other groups." This definition allowed scientists to practically distinguish between different communities through statistical analyses.

Since communities consist of species having different environmental tolerances, turnover rates and levels of interaction with other species, they are known to be highly variable in both space and time. Spatially, often samples collected adjacent to each other are often very different. This led to the idea that benthic communities form a mosaic of patches, presumably due to the patchiness of the habitat. Temporally, it is also known that communities exhibit seasonal variation, interannual variation and long-term cycles, which include known cases of 6-7, 20-30 and in some cases 100-year cycles in total abundance and biomass (Gray 1981). Therefore, benthic communities are subject to a large amount of natural variability.

In addition, benthic communities are subject to pressure from anthropogenic activities. Analyses of changes in soft-bottom benthic macrofaunal community structure have also been widely used for detecting and monitoring the biological effects of human activities in the marine environment. The macrobenthos has the advantage that the organisms are relatively non-mobile, and therefore particularly useful for the study of local anthropogenic effects (Clarke & Warwick 1994). In addition a large body of literature exists on the effects of pollution and disturbance on macrobenthic communities, against which particular case histories can be evaluated. An important disadvantage is that the response time of the benthos to a pollution event is slow, the generation times of the species being measured in years (Clarke & Warwick 1994). Thus the communities characteristic of polluted areas may only be fully established years after the pollution event, i.e. a lag-phase is expected. On the other hand, the long generation times results in a more stable community in which the effects of pollution can be distinguished from natural variation.

Agard *et al.* (1993) considered the effects of pollution from oil mining, relative to the effects of natural oil seepage, in the Pointe-à- Pierre to La Brea region on the island of Trinidad, West Indies. This large coastal embayment has one of the world's largest natural oil seeps at La Brea and an oil refinery at Pointe-à- Pierre. Grab samples were collected covering the entire embayment, including the areas of natural oil seepage and oil refinery activity. The benthos in the oil refinery area showed signs of disturbance. However, there was no indication of disturbed benthos near the natural oil seepage, even though levels of polycyclic aromatic hydrocarbons similar to those at the oil refinery were found. This suggests that the benthos may be employed to distinguish the effects of natural processes from those of anthropogenic activities.

Benthic community composition is the result of a combination of natural processes and anthropogenic activities. Long-term monitoring of these communities assists one to determine which of the above processes is responsible for the changes observed in benthic communities. Investigation of long-term changes in benthic communities has revealed the introduction of alien invasive species (Currie & Parry 1999), the long-term effects of sewage outfalls (Hillbig & Blake 2000) and even the combined effects of anthropogenic activities and climate change (Bourcier 1996). In South Africa long-term changes in benthic communities were used to assess whether an effective ecological reserve could be set in the east coast Mhlathuze estuary (Mackay & Cyrus 1999). Since the benthos of Saldanha Bay (which lies on the west coast of South

Africa) has been subject to a history of human disturbances, it provides the opportunity to investigate long-term changes in the benthic macrofauna.

A Brief History of Saldanha Bay

"Elephants and other large animals have made it their home, coming there at low tide from the Anse a Flamens (Riet Bay). Each island has its particular species of birds which live on the fish abounding in the bay, for all sorts of sea creatures live there - whales porpoises, dogfish, mullet and a thousand other kinds."

(Etienne de Flacourt 1648 describing Saldanha Bay in Burman & Levine, 1974)

Saldanha Bay is situated on the west coast of South Africa about 100km north of Cape Town. The kidney-shaped bay includes Langebaan Lagoon, which is a shallow tidal body of water. As is evident from the quote above, the rich biological diversity of Saldanha Bay has been recognised since the seventeenth century.

Although French whalers had been whaling in Saldanha Bay since the early 1600s, the first written mention of the Bay comes from Jan Olafsson, an Icelander, who explored Saldanha Bay in 1623 (Burman & Levine 1974). He found barrels of unrendered whale oil and concluded that they had been left there by the French, who were known to travel far a-field in search of whales. Whaling was continued on and off for the next 300 years, with the first whaling station being built in 1909. Due to a drop in the oil price in 1930, the whale factory was closed. In 1947, just after World War II, the price of whale oil increased and the whale factory was re-opened and remained operational until the end of 1967, when it closed for good. Although fishing was excellent in Saldanha, the fish did not fetch a good price. The rock lobster industry came to Saldanha Bay in 1903. North Bay Canning Company was reasonably established by 1905 and Saldanha Bay Canning Company was built shortly after that (Fig. 1.1). The canning companies expanded their business into canning sardines in 1926. In 1948 the North Bay canning company was absorbed into a new company, Southern Sea Fishing Enterprises. Sea Harvest Corporation was formed in 1964 and is now the largest fishing operation in Saldanha Bay, operating a fleet of deep-sea trawlers and an onshore fish packing and freezing factory. Saldanha Bay therefore has a long history of fishing activity.

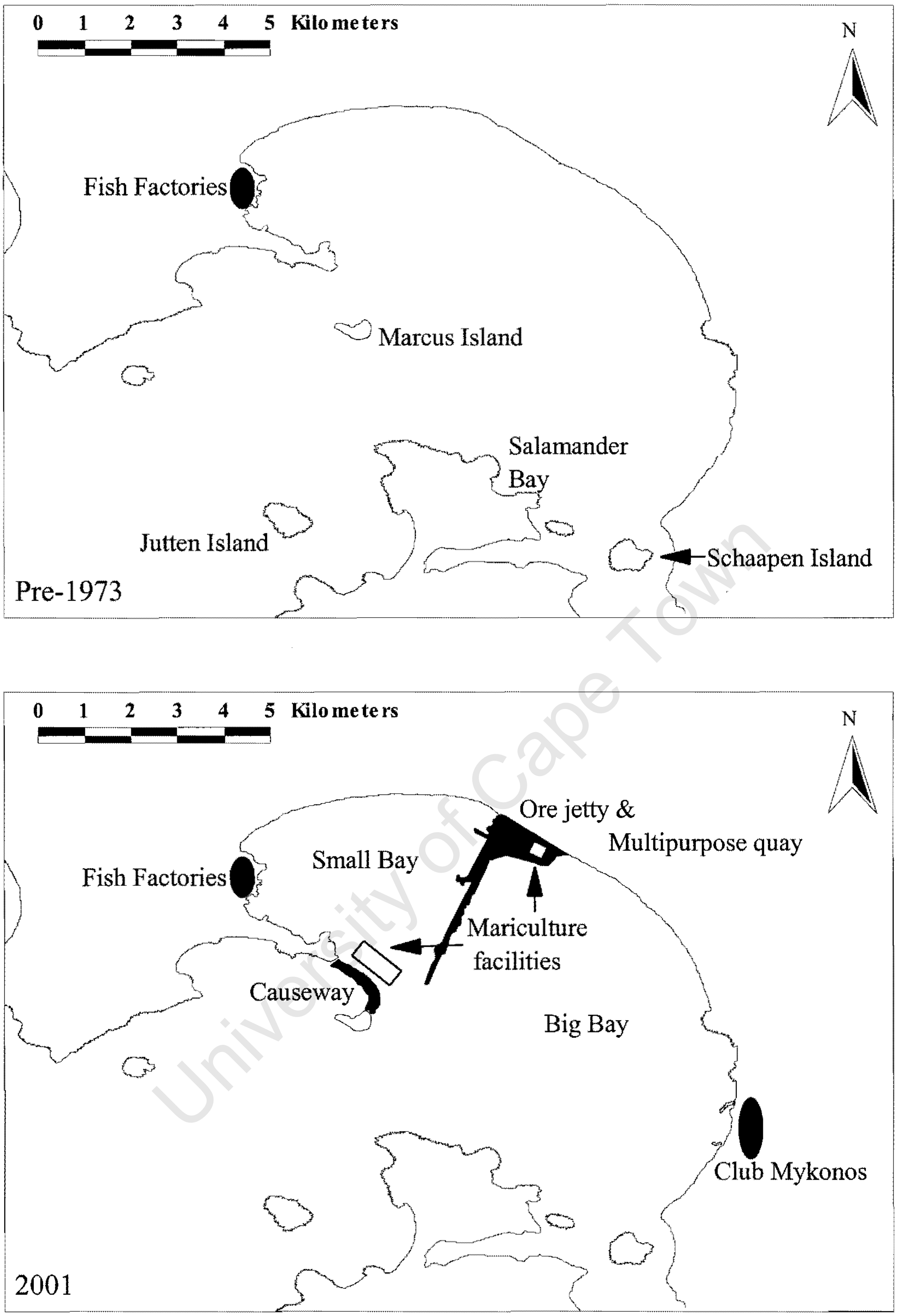


Figure 1.1: Maps of pre- and post-development periods indicating, diagrammatically, the major developments within Saldanha Bay.

Since Saldanha Bay is the only natural harbour of significant size on the west coast of South Africa (Fuggle 1977), it was the natural choice for the development of an international harbour. In 1971 the decision was made to develop an international port in the Bay to facilitate the export of iron ore as part of the Sishen-Saldanha Bay Ore Export Project. The Bay provided a large port area, which had the potential to handle the largest ore carriers. Development commenced in 1973 (ISCOR brochure 1973).

In 1973 a causeway was built linking Marcus Island to the mainland (Fig. 1.1). This shelters the northern area of the Bay and provides shelter for the ore-carriers when they dock at the harbour. During 1973-1974, the General Maintenance Quay and Rock Quay were constructed. The Ore and Oil jetty was completed and the first iron ore loaded in 1976. The ore jetty essentially divides Saldanha Bay into two sections: Big Bay and Small Bay (Fig. 1.1). A Multipurpose Terminal was added to the jetty between 1979 and 1980 to accommodate the export of ore concentrates. Construction of a small-craft harbour was completed in 1984 to cater for the growing marine activities. Expansion then stagnated until the early 1990s when the heavy industries Namakwa Sands, Saldanha Steel and Duferco settled in the Saldanha-Vredenburg area. The increased export as a result of these industries led to the extension of the multipurpose terminal, which was completed in 1998 (Personal communication, Victor Schultz). Dredging inevitably preceded every step of the harbour construction and expansion and submarine blasting was necessary to deepen the approach channels.

The rich faunal and floral diversity of Saldanha Bay as well as its unique geological history made it an important study area for natural scientists. The decision to develop a port in the Bay led to some concern in the scientific community about the fragile lagoon-bay system. A symposium on 'Research in the Natural Sciences of Saldanha Bay and Langebaan Lagoon' was held in 1976 to document the biological, geological, chemical and physical characteristics of the Bay (Fuggle 1977). The proceedings of the symposium summarised the research in Saldanha Bay and Langebaan Lagoon prior to commencement of construction of the harbour, and provided a baseline study of Saldanha Bay against which future studies could be compared to determine the effects of harbour construction on the Bay.

The development of the Bay into a harbour inevitably led to increased economic and industrial growth. New resorts were established in the 1980s, for example Club Mykonos, increasing the recreational use of the Bay. For this purpose, Saldanha had to be aesthetically pleasing or tourism would cease. Also in 1984, the first commercial aquaculture facility, Seafarm, was established in an enclosed dam cut off from Saldanha Bay by a causeway (van Erkom Schurink & Griffiths 1990, Fig.1.1). Atlas Sea Farms and Sea Harvest Corporation began aquaculture in open water in the same area in 1987. For the mussels to be of export quality, the Bay water had to be of a high quality. The development of Saldanha Bay thus became a trade-off between economic growth and environmental health.

Langebaan Lagoon is ecologically significant as it is the only marine lagoon in South Africa. Its high biodiversity and high densities of mudflat birds earned it national park status with the creation of the West Coast National Park in 1984. The lagoon is also listed as a RAMSAR site. Since the water bodies of Saldanha Bay and Langebaan Lagoon are linked, any activities that decrease the water quality of Saldanha Bay would have an effect on the communities in Langebaan Lagoon.

Physical and Chemical Studies Conducted in Saldanha Bay

The developments described above led to a number of environmental impact studies being performed in the Bay and careful monitoring of the environmental effect of every new development. To this end the information from the scientific conference in 1976 provided a good basis from which environmental changes could be discerned. Since the 1970s, many aspects of the environment have been revisited to determine the effect of the harbour development. These include water movement (Weeks *et al.* 1991a, b, Luger *et al.* 1999), sediment distribution patterns and organic loading and metal loading of sediment (Monteiro *et al.* 1999). These are discussed in greater detail below.

Water movement consists of both wave exposure and water circulation patterns, which include current speeds. Before the harbour development in Saldanha Bay, Flemming (1977) distinguished five wave-energy zones in the inner bay. There was a centrally exposed zone, two marginal semi-exposed zones, a sheltered zone in the north and a transitional zone in the south (Fig. 1.2). The division of Saldanha Bay into Small and Big Bay by the iron ore jetty altered the wave energy and exposure patterns within the Bay. The causeway now shelters Small Bay, which has resulted in an increase in the complexity of the wave exposure patterns (Luger *et al.* 1999, Fig. 1.2). Small Bay has western and eastern sheltered areas, separated by a semi-sheltered area. In Big Bay, a northern area near the jetty is semi-sheltered, then a semi-exposed area surrounds the central exposed area and another semi-sheltered area leads into the lagoon. It is therefore evident that the wave exposure patterns in both Big and Small Bays have been altered as a result of the physical structures (i.e. the breakwater and the ore jetty) in the Bay.

Referring to pre-harbour development, Flemming (1977) states: "Sediment distribution seems to be in equilibrium with the prevailing hydrodynamic regime." He described this regime as being controlled by wave action or exposure. The coarsest sediment was found in the centre of the Bay on the abrasion platform of the exposed zone and along the rocky shoreline of North Channel. The South Channel, semi-exposed, sheltered and transitional zones were dominated by fine to very fine sand. The mud fraction was concentrated in the north-western area and in the centre of the Bay (Monteiro *et al.* 1999, Fig. 1.3). After the harbour development, the sediment distribution is still a result of wave energy, but since the wave exposure pattern has been altered, so has the sediment distribution pattern. The mud fraction now dominates the western margin of Small Bay, the eastern margin of Small Bay against the ore jetty, the northern margin of Big Bay against the ore jetty and the Salamander Bay area (Monteiro *et al.* 1999). There is, however, an additional site dominated by mud along the Bay side of Marcus Island causeway, which is linked to the Sea Harvest mussel farm. Not only do the mussels themselves contribute to biodeposition, but the ropes of the mussel rafts also slow down the water movement in the area, creating an area of deposition.

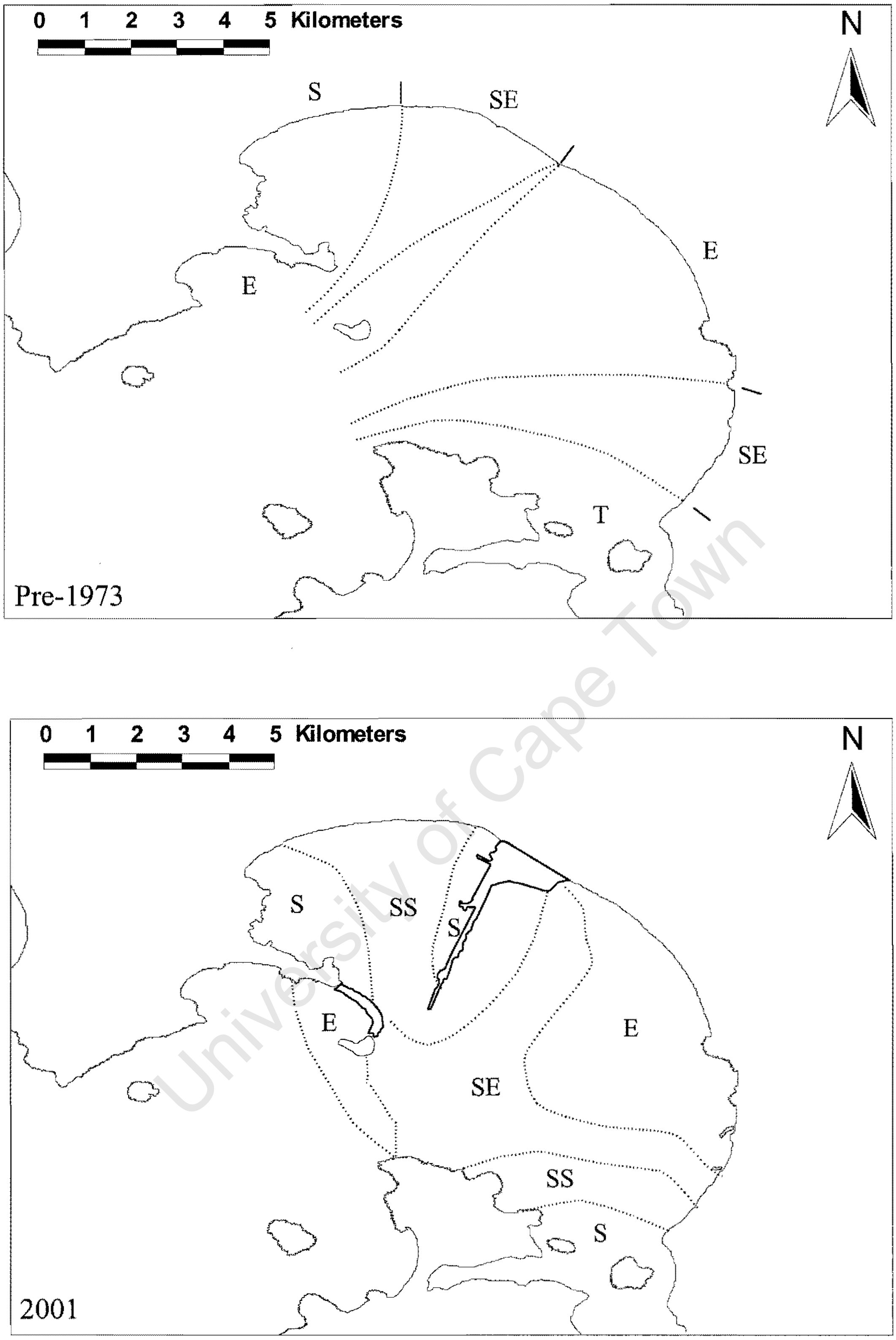


Figure 1.2: The wave exposure patterns pre- and post-development of Saldanha Bay. S=sheltered, SS=semi-sheltered, SE=semi-exposed, E=exposed and T=transitional. (Pre-1973: adapted from Flemming 1977, and 2001: adapted from Luger *et al.* 1999)

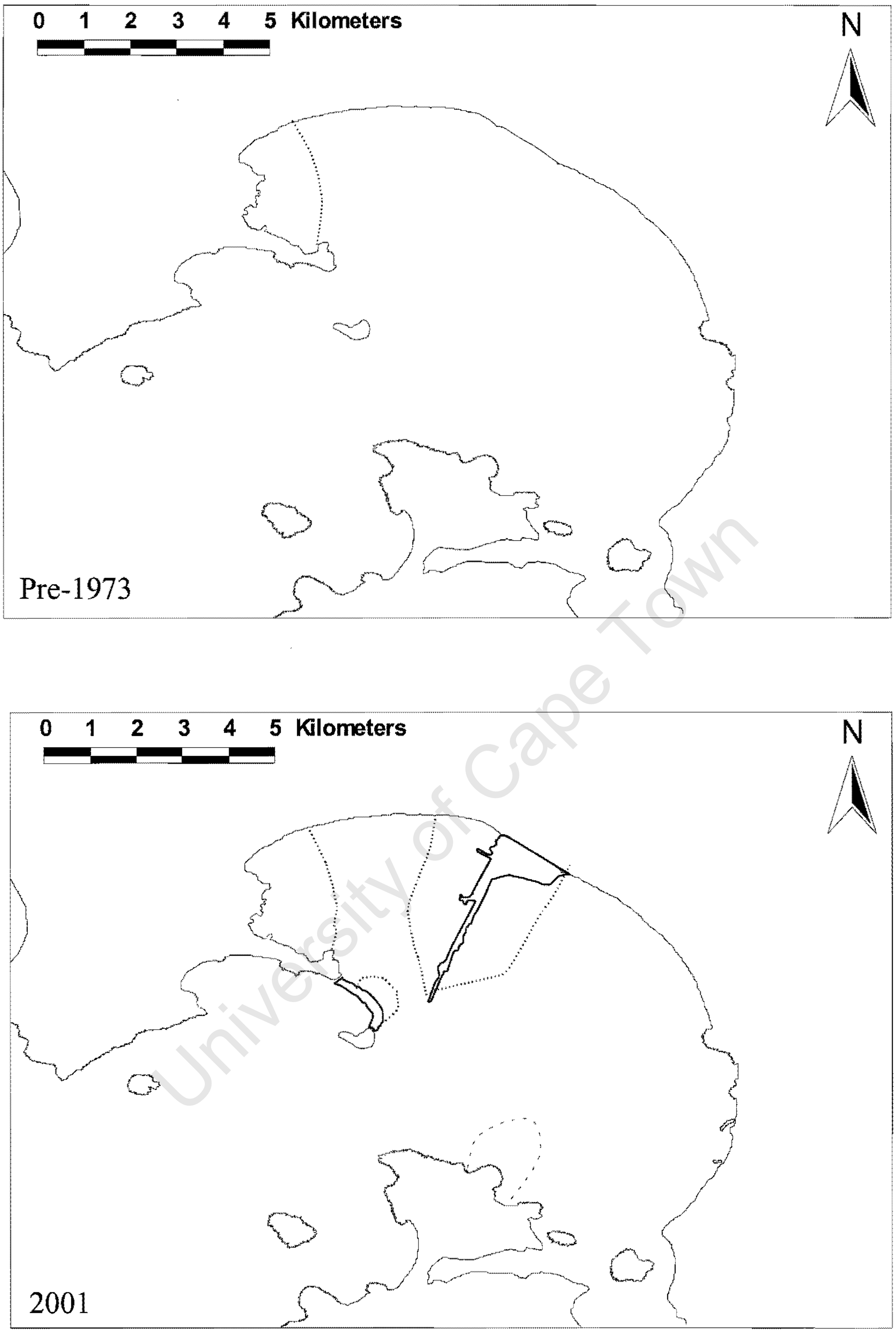


Figure 1.3: The major mud deposit areas in both the pre- and post-development stages of Saldanha Bay. (Both maps adapted from Monteiro *et al.* 1999)

Organic carbon is concentrated in the same areas as the mud fraction (Monteiro *et al.* 1999). The reason for this is that the particle size-range of organic carbon closely resembles that of mud, therefore they will settle out together. In both the pre- and post-harbour development studies, the organic carbon distribution has the same depositional pattern as the mud, since it forms part of the mud fraction. However, the percentage of organic carbon has increased from a maximum value of 1% to 10%, indicating that organic loading is taking place. Similarly the deposition patterns of trace metals (i.e. iron, nickel, copper, zinc, cadmium and lead) follow that of mud, higher values being recorded in areas with large amounts of mud.

These changes in the physical environment have consequences for the biological communities in Saldanha Bay. The habitat of a soft-sediment community is usually characterised by the sediment grain size (Gray 1981). Organic content of the sediment increases with fineness of deposit. The two most important factors in determining grain size distribution are wave action and current velocity. As mentioned above the Bay has become more sheltered from wave action, and this in turn has caused a shift to finer sediment grain sizes, which caused an increase in the organic content.

Biological Studies Conducted in Saldanha Bay

A number of studies conducted in Saldanha Bay have considered the effects of particular developments on benthic community structure. The effects of the fish factory effluent (Christie & Moldan 1977, Newman & Pollock 1973, Bickerton *et al.* 1997a), of dredging during harbour construction (Moldan 1978, Bickerton 1997a, b, Bickerton 2000), of the iron-ore loading terminal (Beckley 1981) and resultant heavy metal concentrations (Henry & Davis 1983) were studied. Since the establishment of mussel culture, its effects on benthos have been monitored (Grant *et al.* 1998, Stenton-Dozey *et al.* 1999, Stenton-Dozey *et al.* 2001). These will be considered in more detail below.

Organic Pollution by Pelagic-Fish Factories

During the early 1970s, pelagic fishing vessels harboured in the sheltered waters of Saldanha Bay (Newman & Pollock 1973) and offloaded their catch using the "wet" system. Seawater was let into the hold and pumped with the catch into installations on the quay. The water then eventually returned to the sea, contaminated with blood and other biological waste. The fish factory effluent also contained other waste from the processing plant. The amount of organic matter released depended on the degree of deterioration of the fish when landed. In May 1972 (Newman & Pollock 1973), large numbers of dead marine animals were washed up on shore in St Helena Bay. At the time of mortality, divers sampled the temperature, salinity and oxygen content of the water on the seabed at various stations. Very low dissolved oxygen values were recorded at all the stations sampled. It was concluded that the extremely calm conditions during the week preceding mortality had resulted in the accumulation of large amounts of organic matter. The degradation of this material resulted in a depletion of oxygen. Shortly after this, large numbers of bivalves washed ashore in Saldanha Bay near the fish factories (Newman & Pollock 1973). Divers were sent to investigate and again measured low oxygen values near the seabed over a large area. Large mortalities of the most common species, including sand-prawns (*Callianassa kraussi*), clams (*Mactra glabrata*) and black mussel (*Choromytilus meridionalis*) were also observed. As in the St Helena Bay investigation (Newman & Pollock 1973), it was found that organic material had built up on the sea floor. The decaying organic matter used oxygen, which deprived the benthic organisms of oxygen and ultimately led to reduction of sulphate into toxic sulphide and free sulphur. Thus, mass mortality of the benthos occurred in the fish factory area. However, if one moved outside the area, the benthic communities were healthy. It was then decided that better waste management practices needed to be applied at the fish processing plants, which commenced in 1974 (Christie & Moldan 1977).

Christie & Moldan (1977) surveyed the area near the Saldanha Bay fish factories to measure the effects of effluent on the benthic macrofauna, and in doing so, assess any improvement in the benthic macrofauna of that area since the study by Newman & Pollock (1973). They collected samples from five stations at increasing distances from the effluent outlet (i.e. 25, 100, 250, 400 and 550 m). Stations were parallel to the shore and at a constant depth of 5m, to eliminate any possible faunal changes with depth, so that any changes observed would be due to the distance from the factory (provided that the sediment texture remained constant). It was found that the sample 25 m away from the effluent outlet had a much lower biomass then the other samples.

Many species absent from the 25 m sample appeared at the other stations. For example, the crab *Hymenosoma orbiculare* was completely absent from the 25 m station and was small in size at the other stations, suggesting a recolonisation of these four stations. The faunal group Amphipoda was almost totally absent from all samples. This group is usually very common in unpolluted sands and often constitute 30-40% of the species present. The absence of these animals therefore suggested that they had a lower tolerance of pollution than other groups and that conditions even 550 m from the factory outlet were still unsuitable for them. The authors concluded that there was a gradation in the effects of pollution. The strongest pollution effects were evident at the station closest to the effluent outlet and gradually improved with distance from the effluent source, although the pollutants were still present. It was, however, noted that the area had improved since the study conducted by Newman & Pollock (1973).

The above studies examined the effects of the effluents of Southern Seas fishmeal and Sea Harvest frozen fish factories in combination, but little attempt was made to assess the possible ecological impact of the effluents of each factory individually. Bickerton *et al.* (1997) investigated the effect of the effluent of the Sea Harvest fish processing plant on the benthic communities of Small Bay. Five stations were clustered in close proximity to the outfall with eight additional stations moving progressively further away from the effluent outlet into Small Bay. At each station three samples were collected by benthic suction sampler and combined for analysis. The stations furthest away from the outfall appeared to be the least disturbed. However, these stations may be impacted by other organic inputs in the Bay. Stations closest to the outfall were more similar to each other than the stations further away. In addition, capitellid polychaetes were present in most of the samples. These polychaetes serve as indicator organisms, as they are opportunistic animals that thrive on organic loading. Bickerton concluded that the restricted water-exchange and flushing, combined with fine sediments, made Small Bay sensitive to organic loading. Perturbation from the Sea Harvest outfall was evident in the benthic macrofauna in the vicinity of the discharge and up to 150 m away from it. Even though disturbance effects were evident beyond this point, it was impossible to pinpoint one specific source as the cause.

It is evident from these studies that the organic loading as a result of fish factory effluent has had a significant effect on benthic communities of Saldanha Bay, particularly in Small Bay. There is no indication that the effluent has had or is having an effect in Big Bay. Organic loading is, however, not restricted to the effluents of the fish factories, as the activities of the mussel farm have also contributed to the organic loading and have been shown to have significant effects on the benthos of Saldanha Bay.

The Effect of Mariculture of Mussels

The 80-ha mussel farm in Saldanha Bay is protected on the seaward side by the causeway (Fig. 1.1). The average water depth in the farm is 11 m and the sediments are fairly consistent (Stenton-Dozey *et al.* 1999). Besides mussels, an abundance of fouling organisms, particularly the sea squirt *Ciona intestinalis*, also inhabit the rafts. There is a fast sedimentation rate from faeces, pseudofaeces, fallen mussels and foulers in the farm. Eutrophication and increases in dissolved nutrients have also been observed. Stenton-Dozey *et al.* (1999) assessed the impact of raft-culture of mussels on benthic ecology. Their study compared the species composition, abundance and biomass under rafts with reference sites. The effects of raft age and position, as well as the recovery after raft removal were also assessed. Samples were collected under nine rafts and along transects to the north, east and south of the mussel farm. The transects were taken from a particular raft outwards for 750 m, a sample being collected every 250 m. Samples were collected under the rafts annually from 1993 to 1996. Most of the rafts showed signs of disturbed macrobenthic communities at least once during the sampling period. The samples were dominated by opportunistic species and scavengers. It was also shown that there was no relationship between the raft age or position and the disturbance of the community. In general the communities under rafts were more disturbed than reference samples. Deposit feeders dominated all samples in terms of biomass and numbers. Under rafts, carnivores were second to deposit-feeders, whereas at reference sites suspension feeders took second place. Due to the high sedimentation rate of organic matter in the farm, the sediment was characterised by high levels of organic carbon and other nutrients, as well as sulphur. The enriched organic matter and dislodged mussels attracted deposit feeders and carnivores, while outside the farm suspension feeders were more prominent than carnivores. Recovery to the baseline community structure outside the mussel farm after the removal of a raft was slow, taking four years or more. It was clear from this study that the mussel rafts were having an impact on the macrobenthic community structure.

A further study of this farm (Stenton-Dozey *et al.* 2001) led to the hypothesis that biodeposition from mussel rafts has had a significant effect on the benthic environment in Saldanha Bay, resulting in organic enrichment and anoxia in sediments, altered oxygen uptake and nutrient flux rates, and led to impoverishment of the macrofauna. Biological and sediment samples were collected under one of the rafts in the farm and compared to reference sites outside of the farm. It was shown that the organic carbon, nitrogen and sulphur contents were higher under the rafts than at the reference sites. As a result of biodeposition the macrofaunal biomass was dramatically reduced to between 5 and 10% of that at reference sites. The samples from beneath the raft were also shown to be disturbed and were dominated by deposit-feeding bivalves and carnivorous/scavenging gastropods that fed upon organic debris. It was therefore concluded that biodeposition from mussel rafts led to the impoverishment of the macrofauna.

Construction Effects

Dredging

Over a two-year period from August 1974, approximately 25 million cubic metres of sediment were dredged from Saldanha Bay. Dredging involved the removal and redistribution of sediment. Moldan (1978) investigated the biological effects of the dredging operation. The most obvious effects of dredging are the physical removal of organisms and resuspension of fine sediments. Organisms sensitive to water flow may also be affected by changes in the water currents. Nutrients such as nitrogen and phosphorus, heavy metals and ammonia are often released during dredging creating an oxygen demand in the water, leading to mortality of the biota. Also, the rate of recolonization of the disturbed area depends in part on the extent of areas left undredged, which may act as reservoirs for that community. Ten stations out of the many sampled between 1963 and 1964 were resampled in 1975 using a 0.2 m^2 van Veen grab. Moldan produced a dendrogram derived from classification analysis of the species abundances, which indicated that the benthic communities before dredging could be divided into four distinct groups. However, after dredging, Moldan noted that all the samples together formed a single group. Moldan (1978) suggested that this was a result of the redistribution of sediment throughout the Bay, with fine sediment particles settling out over a wide area. By the time dredging was completed, the dredged areas were already being recolonized. The larger, more swiftly-moving organisms tended to be the first to recolonize the dredged area. The crabs *Hymenosoma orbiculare* and *Philyra punctata*, the shrimp *Ogyrides saldanhae*, and the errant polychaetes *Glycera tridactyla, Nephtys hombergi* and *N. sphaerocirrata* were the most abundant species present post-dredging. In addition, a few sedentary polychaetes increased in abundance, presumably due to the distribution of finer sediments providing favourable habitats. The conclusion was that although significant changes in the faunal structure had occurred since dredging began, recolonization had already begun towards the end of the operation. It was predicted that faunal assemblages typical of a fine sandy substrate would dominate. In addition it was suggested that the altered circulation patterns resulting from the deepening of the channels and the building of the harbour walls would have a direct influence on the redistribution of the organisms.

One of the few prospective studies conducted in Saldanha Bay was intended to establish the severity and extent of the ecological impact associated with the general cargo quay (GCQ) dredging operation. Bickerton (1997a, 2000) conducted both the pre- and post-dredging surveys. During 1996, 27 pre-dredging samples were collected using a diver-operated suction sampler in Small Bay. Twenty-two of those samples were collected in a grid formation in the proposed dredging area and five samples were collected at a control site 300m away (Bickerton 1997a). The benthos from the area to be dredged, as well as the control sites, was dominated numerically by mud-prawns *Upogebia capensis*, tongue worms *Ochaetostoma capense*, amphipods *Ampelisca brevicornis*, bivalves *Tellina gilchristi*, whelks *Nassarius vinctus* and polychaetes *Eunoe, Nephtys, Mediomastus* and *Polydora* species. The sand-prawn *Callianassa kraussi* occurred at some stations. In terms of biomass, *U. capensis*, *O. capense* and *C. kraussi* contributed largely at some stations, whereas *Nassarius* species contributed largely throughout. The most important result of the study was that prior to dredging the control samples were not different from those in the area to be dredged. This study, therefore, provided a suitable baseline against which the effects of dredging on the benthic macrofauna could be compared.

The objective of the follow-up study (Bickerton 2000) was to establish the extent of recovery of the benthic community 18 months after the completion of dredging. Most of the stations sampled in 1996 were resampled in 1999 and a further five samples were collected in Big Bay, where the sediment had been deposited during dredging operations (i.e. the disposal area). Numerically, the mudprawn *Upogebia capensis*, the tongue worm *Ochaetostoma capense*, the polychaete *Mediomastus capensis* and the crab *Thaumastoplax spiralis* dominated. The disposal area in Big Bay was dominated by opportunistic polychaete species, suggesting a moderate degree of disturbance. The species present in these samples were similar to the dominant species in the 1996 samples. The total biomass had not recovered after 18, months whereas the total number of individuals had recovered. Two general trends emerged from this study. Firstly, the dredged area was characterised by finer sediments, slightly reduced species diversity, slightly lower abundance and a lower biomass (relating to the absence of adult *U. capensis* and *O. capense*). Secondly, the stations in the disposal area in Big Bay were dominated by opportunistic species, which can tolerate low levels of oxygen and organic enrichment. The author emphasized that although the biomass and abundance were recovering, it was likely that the species composition would be altered as a result of the dredging operation. It was therefore concluded that the benthos would not recover to its original state and that the effect of dredging can be considered long-term as a result.

Underwater Blasting

Underwater blasting operations were employed to aid in the extensions to the Port of Saldanha General Cargo Quay. Bickerton (1997b) investigated the effect of the blasting on marine invertebrates. It was hypothesised that marine invertebrates would not be greatly affected, because they do not possess gas-filled bodies, in contrast to many marine teleosts. Mud-prawns were used as a representative benthic invertebrate. Prawns were collected and placed in plastic bags from which all the air had been evacuated underwater. These bags were placed at increasing distances from the blast site above the sea floor. After the blast, the bags were collected and it was found that neither the bags nor the prawns were affected by the blast. Natural populations of the mudprawn live in burrows in the sediment and are not directly exposed to the blasting shock, as the experimental prawns were. It was then concluded that the current level of blasting had no adverse short-term effect on the mudprawn populations of Saldanha Bay. The author believed that this conclusion could be extended to other invertebrates that do not have gas-filled body cavities. The blasting, however, killed large numbers of fish and penguins.

Ore Jetty

Beckley (1981) investigated the marine benthos near the functioning iron-ore loading terminal. She compared four stations near the loading terminal with a station at the mouth of the Bay. The stations under the ore jetty were dominated by a small polychaete *Prionospio sexoculata*, stomatopods and errant polychaetes. Moving 500 m into Small Bay, the samples were dominated by shrimps and tongue-worms. About 1 km away from the ore jetty, in Big Bay, shrimps were absent and tongue worms and whelks dominated. At the mouth of the Bay, errant polychaetes, a whelk and sea-pens were found. The absence of sea-pen *Virgularia schultzei* is commonly associated with polluted areas in Saldanha Bay (Christie & Moldan 1977). *P. sexoculata* is known to be tolerant of adverse conditions (Christie & Moldan 1977), which again indicates a gradient of pollution in the Bay. The strongest pollution was at the ore jetty with effects decreasing away from it.

All the above studies document different gradients of pollutants and disturbance in Saldanha Bay and show that beyond certain distances from the foci of the studies, it is impossible to pinpoint the source of the pollutant or disturbance. Each study concentrated on a particular aspect of anthropogenic activities, but it is known that benthic communities are the result of a combination of all the anthropogenic effects as well as natural processes. These effects are cumulative through time, so temporal comparisons would provide greater insight into the effects humans have had on the environment in addition to natural effects. It is therefore important to consider the combination of these effects on the benthos. Only two studies in Saldanha Bay, that I am aware of, have investigated the cumulative effects of the anthropogenic activities and natural processes, both spatially and temporally (Jackson & McGibbon 1991, Bickerton 1999).

Jackson & McGibbon (1991) compared suction samples collected between 1989 and 1990 with two different sets of historical data. The first set of data, from the South African Museum catalogues, consisted of dredge and grab samples, which meant that the comparison was qualitative because, even though samples from the same stations were compared, the methods of collection were different. The second set of data consisted of suction samples from a survey conducted in Small Bay in 1975. This set of data allowed for a more direct comparison between time periods. However, the survey in 1975 was conducted two years after harbour construction commenced, so the communities were most likely already affected by the construction activity within the bay.

Aims of this study

As a supplement to the 1976 symposium on Saldanha Bay and Langebaan Lagoon, Christie & Moldan (1970) compiled a report containing data from stations sampled prior to the harbour development (1950s-1960s) to provide a baseline for future studies. The current study aimed to determine whether benthic communities had changed since the 1960s and to suggest possible reasons for any changes observed. Stations from the study by Christie & Moldan (1970) were re-sampled and the same sampling methods were applied (i.e. grab and dredge sampling), which resulted in the first direct temporal comparison of communities prior to and post harbour development in Saldanha Bay. In addition the current spatial patterns of benthic communities were examined.

Possible causes for observed changes are put forward. If anthropogenic activities are driving change in the benthic communities of Saldanha Bay, I would forecast the following changes in the Bay:

1) A shift towards finer sediments due to the sheltering of the Bay by the breakwater. The sediment diameter would have a narrower range. The sediment should be finer in Small Bay than Big Bay as Small Bay is more affected by anthropogenic activity than Big Bay.
2) A greater organic load, the result of finer sediments, the mariculture waste input and the reduced flushing time within Small Bay. I would expect this to be most evident in Small Bay.
3) Reduced benthic diversity and abundance.

4) New (different) benthic communities.
5) Greater difference between communities as the physical characteristics of Big and Small Bays diverge.
6) Increases in deposit-feeder, scavenger and predator abundances; and reduced suspension-feeders.

If natural fluctuation were driving change in the communities, the changes would be random. But, it is important to note that even if all the above forecasts were met, it does not prove that anthropogenic activities were driving change, it merely increases the likelihood of it.

The analysis has been divided to separately deal with the samples collected by dredges (Chapter 2) and those collected by grabs (Chapter 3). The reasons for this were, firstly, that the dredge and grab samples were not always collected at the same station and could therefore not be combined and, second, the two methods sample different components of the benthos. Furthermore, dredge sampling was employed at an earlier stage of benthic sampling, so I could go further back with it than with the grab samples. The methods are further discussed in their respective chapters. Lastly, a synthesis (Chapter 4) is provided, which compares the findings in Chapters 2 and 3, and compares the overall findings of my study with international studies on anthropogenic and natural long-term and short-term changes in benthic macrofaunal communities.

Since the data used by Christie and Moldan are not readily available both these and the present data are recorded in appendices in order to facilitate future studies of temporal trends in the benthos of Saldanha Bay.

Chapter 2

CHANGES IN THE BENTHOS OF SALDANHA BAY (1960s – 2001): AN ANALYSIS BASED ON DREDGE SAMPLES.

INTRODUCTION

Qualitative sampling methods are generally used for the investigation of epibenthic communities and large benthic macrofauna, because they are often mobile and can escape sampling equipment, or so widely spread that they are easily missed by quantitative methods, which cover smaller areas. These qualitative sampling methods include video sampling, dredging and trawling. In my study, I used the same dredge used to collect the pre-1973 benthic macrofaunal samples in Saldanha Bay, in order to keep the sampling gear constant and ensure comparability.

Dredging is considered a qualitative or at best semi-quantitative sampling method because the area sampled varies as the dredge is dragged along the ocean floor (Gray 1981). The sample obtained varies with the type of substratum, as the steel frame of the dredge tends to dig into soft mud and bounce over hard substrata. Dredges mainly capture members of the epifauna and to some extent the infauna, depending on the depth of penetration of the dredge (Holme & McIntyre 1971). However, because of their limited penetration of the sediment, dredges are not considered suitable for sampling burrowing infauna.

It is possible to standardize the speed and duration of the tow, in this way obtaining comparative estimates of population density (Holme & McIntyre 1971). However, since dredges only sample a fraction of the animals lying on the surface of the seabed, these represent the minimum densities present on the grounds sampled. It is not easy to control the exact time of the gear on the bottom, as the dredge often continues to be dragged along the bottom while being hauled in. However, hauls of standard duration have been useful for collecting members of invertebrate epifauna not adequately sampled by other methods (Field 1971, Holme & McIntyre 1971). During dredging, the ship usually drifts at 1-2 knots for 5-10 minutes, depending on the substratum (Holme & McIntyre 1971). If the bottom is mud or loose gravel, the dredge fills up quickly and can be hauled up almost immediately. In an effort to make dredging more quantitative, pedometers are sometimes fitted to the dredges to get an accurate measure of the distance covered.

The efficiency (defined as the ability to capture all animals within its sweep) of the dredge is low (Holme & McIntyre 1971). Performance varies with the configuration and nature of the bottom, as mentioned above, because several different bottom types could be encountered in one tow. Complicating factors in dredging include behaviour of the ship, length of the warp, type of warp, and speed of towing. When the speed of towing is increased above a low level, the catch is reduced. The fitting of depressors or diving plates and proper use of the teeth on diving plates can increase the efficiency of the dredge.

The most commonly used dredge is the naturalist's or rectangular dredge, which is usually used for exploratory purposes where the nature of the bottom is not known (Holme & McIntyre 1971). John Day of the University of Cape Town used a variation of the naturalist's dredge (personal communication, J.G. Field) to collect subtidal benthic dredge samples in Saldanha Bay. Sampling commenced in 1946 and was carried out by the University of Cape Town Ecological Survey Unit. These dredge samples were sorted by species, and abundances were recorded or at least estimated as rare, common or abundant. The data were then recorded in the catalogues of the South African Museum in Cape Town. During the 1970s Christie and Moldan (unpublished report, SFRI) reviewed the dredge data series and set up a comprehensive list of 31 stations with reliable dredge data (Appendix 1A & C) to provide a baseline for future studies.

The aim of this chapter was to repeat some of these samples and use these to analyse both temporal and spatial differences in the large benthic macrofauna of Saldanha Bay. The temporal changes were determined through a general comparison of the benthic communities in the 1960s and 2001, whereas the spatial differences were determined by considering the spatial distributions of the benthic communities within each period.

METHODS

Sampling

Twelve of the 31 stations sampled, prior to harbour development (i.e. between 1954 and 1964; Christie & Moldan unpublished report) were resampled in 2001, post harbour development (Fig. 2.1). This allowed for a direct temporal comparison between benthic communities. At each station, a dredge (1 cm^2 mesh) was dragged along the seafloor for 5-10 minutes at 1-2 knots. The conditions were calm during the sampling period. At least half of each sample, depending on size of sample retrieved, was wet-sieved through a 1cm^2-mesh sieve. The organisms retained by the sieve were collected and fixed in 10% formalin. Empty mollusc shells and organisms considered dead at the time of sampling were excluded from the analysis. The macrofauna was sorted, transferred to 1% propylene phenoxytol, identified to the lowest possible taxonomic level and counted. Each dredge sample was labelled with the station number, preceded by either 'O' (old) referring to samples collected between 1954 and 1964 or 'N' (new) referring to samples collected in 2001.

Numerical analysis

In the old samples (pre-1973), it appears as if the entire size range of the faunal sample was sorted and identified. I elected to exclude all organisms with a known average size smaller than 1 cm, because of the likelihood that they would be poorly sampled by the dredge. This procedure also ensured a direct comparison between old and new samples. The species excluded were mostly amphipods, isopods, certain cnidarians and certain polychaetes. These species or taxa groups were better represented in the grab samples (Chapter 3). For both the old and new data, the abundance of species was coded as follows:

0 – absent
1 – present (1-2 individuals)
2 – fairly common (3-5 individuals)
3 – common (6-10 individuals)
4 – very common (11-19 individuals)
5 – abundant (20+ individuals)

This coding tended to have the effect of normalizing data and subsequent transformation was thus unnecessary.

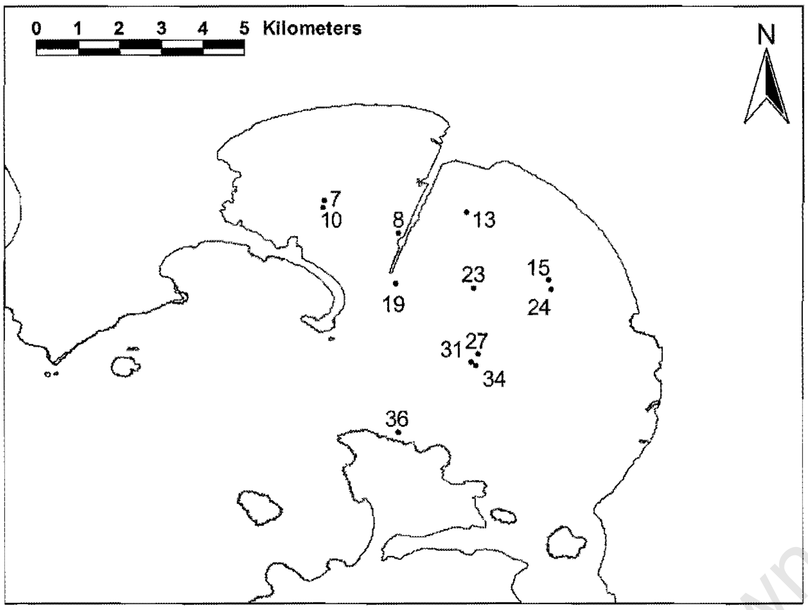


Figure 2.1: Positions of Saldanha Bay dredge stations sampled in both 1960s and 2001.

Non-parametric multivariate statistical analyses and exploratory techniques were applied to the coded data. The analytical procedure was based on that introduced in Field *et al.* (1982) and relies on the PRIMER (Plymouth Routines In Multivariate Ecological Research) software package (Clarke 1993). The coded data were converted into a similarity matrix using the Bray-Curtis similarity measure. This similarity measure was used because it is not affected by joint absences (Field *et al.* 1982). A common feature of marine benthic community survey data is that many of the species are absent from the majority of the samples, meaning that more than half of the data entries are zeros, and Bray-Curtis is sufficiently robust for such marine benthic data (Field *et al.* 1982). This similarity measure also gives more weighting to abundant species and it is completely non-parametric, so it makes no assumptions about normality or equality of variance.

The non-parametric 'analysis of similarity' (ANOSIM) tested the null hypothesis that there was no difference between new and old large benthic macrofaunal community structures. ANOSIM is the non-parametric multivariate analog of the parametric ANOVA (Clarke 1993). The test statistic, R, was calculated based on the average ranked similarity within groups (defined as the old group and the new group) and between groups. R is the measure of average separation between groups and generally ranges from 0-1. R was then recomputed many times under random permutations of the similarity matrix, swapping the labels of the samples. A histogram of all the possible R-values was produced and the probability of obtaining the R-value based on the defined groups was calculated.

To explore the similarities between specific samples and to graphically display the differences between old and new samples, cluster analysis was applied. This analysis consisted of classification and multi-dimensional scaling (MDS) ordination techniques. The advantages of using these methods are that they are flexible with regard to the large number of zeros in the data and no assumptions are made (Field *et al.* 1982). The classification made use of the group average sorting method to link samples on the basis of their similarity. This method joins two groups at the average level of Bray-Curtis similarity between all the samples in one group and all the samples of the other (Field *et al.* 1982). The resultant dendrogram showed the inter-group similarities and identified outliers. However, there are four major disadvantages associated with dendrograms (Field *et al.* 1982). Firstly, they tend to overemphasize discontinuities and may force a graded series into discrete classes. Secondly, the resultant hierarchy is irreversible, as the sample loses its identity once placed in a group. Thirdly, dendrograms only show inter-group relationships, not inter-sample relationships. Lastly, the sequence of samples in a dendrogram is arbitrary; so two adjacent samples are not necessarily the most similar.

For these reasons, MDS ordination was also used to provide a more detailed graphical representation of the similarities between all samples. The distance between the stations on the resulting map is inversely proportional to the Bray-Curtis similarity between the stations. The MDS ordination is an iterative technique. Initially an arbitrary map of stations is plotted in two or more dimensions (Field *et al.* 1982). Then the inter-point distances are regressed against the dissimilarities using monotonic, rank order fit. The poorness-of-fit is minimized, producing a stress value as a measure of poorness-of-fit. The second and third steps are then repeated until the stress settles at the lowest value. The stress value could be thought of as a measure of the difficulty with which the higher-dimensional data are condensed into a 2-dimensional graphical representation. Stress values below 0.2 are considered acceptable, but when values exceed 0.2, the ordination is considered unreliable (Clarke 1993). The advantages of using the MDS technique are that it handles missing data, replication and data with non-uniform reliability, for which it may be desirable to give unequal weights to the dissimilarities in seeking the best graphical representation.

The 'similarity percentages' or SIMPER analysis was used to determine the species responsible for the dissimilarity between the old and new samples as well as the dissimilarity between the groups defined in the cluster analysis. The average Bray-Curtis dissimilarity between all pairs of inter-group samples was calculated, and then this average was broken down into the separate contributions by each species to the average.

The groups determined in the cluster analysis were also related back to the geographical location, to gain insight into possible reasons for the groupings.

The non-parametric Wilcoxon matched pairs test (Zar 1999) was used to determine whether the average number of taxa in each of the old samples was different to that of the new samples and whether the suspension-feeders, scavengers and predators have changed in species abundance between the two periods.

RESULTS

A total of 134 taxa/species was identified from the old and the new samples combined (Fig. 2.2, Appendix 2A), 108 species being found in the old samples and 62 in the new samples. Seventy-two species were recorded exclusively in the 1960s samples and 26 species were exclusive to the 2001 samples, while 36 species were shared between the sampling periods.

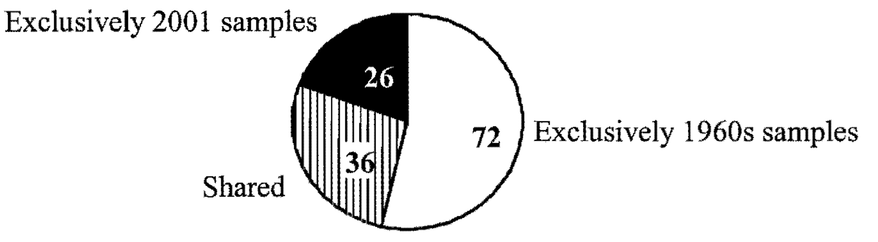


Figure 2.2: Pie chart describing the 1960s and 2001 samples in terms of the number of species shared and not shared between time periods. A total of 134 species was identified.

The greatest decrease in the number of species between the 1960s and 2001 occurred amongst the Polychaeta (Fig. 2.3), which decreased from 38 to 13 species. The decrease in species richness was however not coupled with a major change in species composition. Crustacea and Mollusca both showed a decrease in species number between sampling periods, but this was accompanied by a change in the species composition. Approximately half of the crustacean species present in 2001 were not present in the 1960s as were roughly a third of the molluscan species. Echinodermata showed a decrease in the number of species, but no real change in species composition. The other groups remained similar in number of species, but Pisces showed an increase in the number of species between the 1960s and 2001.

The average number of taxa per dredge in the 1960s samples (20.6) was significantly different from that of the 2001 samples (13.5; Wilcoxon matched pairs, $z=2.31$, $p<0.05$). At most stations the number of species decreased since the 1960s (Fig. 2.4), the greatest decline being observed at Stations 13 and 36. There was an increase in the number of species at Stations 19 and 34, although the increase at Station 19 was minimal. Stations 23, 27 and 31 did not show much difference in species number. The minimum number of species at any station in the 1960s was 13, whereas in 2001 Stations 7, 8, 10, 15 and 24 all had less than 10 species. In sum, richness decreased at nine stations, increased slightly at two, and remained unchanged at one.

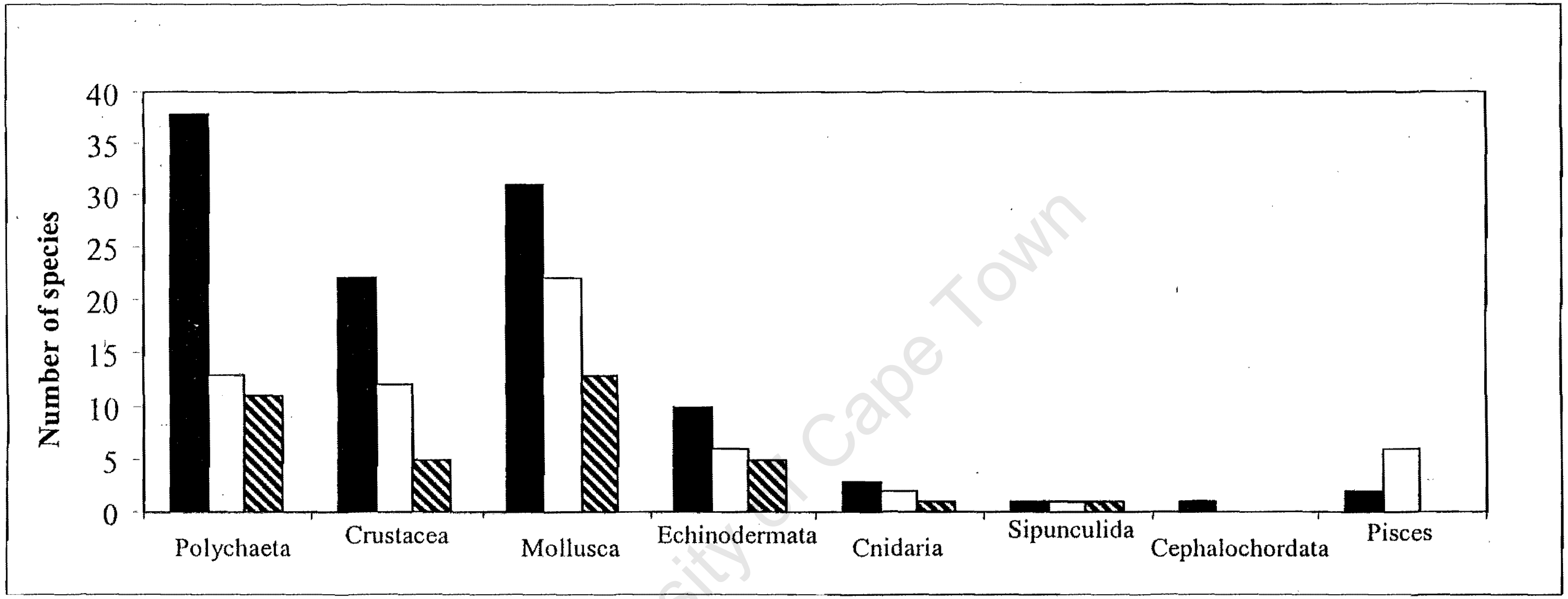


Figure 2.3: The number of species of the major taxa in the 1960s (black bars) and 2001 samples (white bars), and the number of species per taxa shared (striped bars) between time periods.

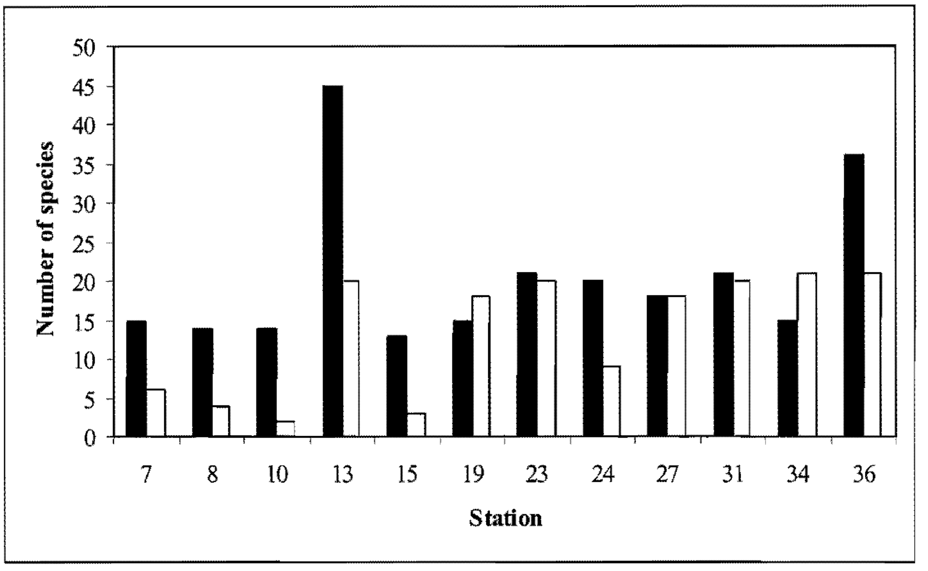


Figure 2.4: Breakdown of the number of species per station sampled in the 1960s (black bars) and 2001 (white bars). The average number of species per sample in the 1960s was 20.6 and in 2001 was 13.5.

The macrobenthic community structure in the old samples was significantly different from that in the new samples (ANOSIM, R=0.36, $p<0.001$). The SIMPER analysis revealed that the whelk *Nassarius speciosus* (4.55%) and the crab *Hymenosoma orbiculare* (4.04%) contributed most to this dissimilarity (= 80.46%) between old and new samples (Table 2.1), both being more abundant in the new samples. Most taxa, including crustaceans, gastropods, bivalves, polychaetes and echinoderms, were more abundant in the old samples than the new samples. There was no difference in the abundances of scavengers and predators or suspension-feeders between the periods (Wilcoxon matched pairs test, $p>0.1$).

The dendrogram (Fig. 2.5) supported the separation of the old and new samples indicated by the ANOSIM, and further revealed the subdivisions within those periods. Four major groups (A-D) and two outliers (N15 and N34) were identified. Groups A and B consisted of old samples and Groups C and D consisted entirely of new samples. Group D had the greatest similarity (approximately 50%), while the other groups had similarities less than 40%. N15, one of the outliers, was a small sample consisting of only three individuals from three different species. The other outlier, N34, was a sample from rocky substratum, which contained very different taxa to the samples collected on soft substrata.

Table 2.1: The percentage contribution of each species to the grouping of the 1959-1964 (old) samples and the 2001 (new) samples. An arbitrary cut-off percentage of 50% was chosen. Average dissimilarity between old and new groups was 80.46%. The average abundance refers to the coded values. Bold values are the greater of the two values. S=suspension-feeders, SP=scavengers and predators and H=herbivore.

Taxon	Taxonomic group	Feeding type	Ave. Abund. 1959-1964	Ave. Abund. 2001	Percent Contrib.	Cum. percent
Nassarius speciosus	Gastropoda	SP	2.67	**3.83**	4.55	4.55
Hymenosoma orbiculare	Brachyura	SP	1.33	**2.00**	4.04	8.59
Bullia laevissima	Gastropoda	SP	**1.67**	0.00	4.01	12.60
Glycera tridactyla	Polychaeta	SP	**1.58**	0.58	3.19	15.79
Thyone aurea	Holothuroidea	S	**1.08**	0.58	2.97	18.76
Ophiothrix fragilis	Ophiuroidea	S	**1.25**	0.25	2.81	21.57
Aulacomya ater	Bivalvia	S	**1.08**	0.50	2.66	24.23
Philyra punctata	Brachyura	SP	**1.08**	0.58	2.64	26.87
Venerupis corrugatus	Bivalvia	S	**1.00**	0.42	2.41	29.28
Nicolea macrobranchia	Polychaeta	S	**0.92**	0.42	2.23	31.51
Annametra occidentalis	Crinoidea	S	0.42	**0.83**	2.20	33.70
Palaemon peringueyi	Macrura	SP	0.08	**1.17**	2.13	35.84
Macoma ordinaria	Bivalvia	S	**0.92**	0.58	2.10	37.94
Bullia annulata	Gastropoda	SP	**0.83**	0.33	2.07	40.01
Parechinus angulosus	Echinoidea	H	**0.83**	0.42	2.01	42.02
Choromytilus meridionalis	Bivalvia	S	0.58	**0.67**	1.85	43.87
Philine aperta	Opisthobranchiata	SP	0.33	**0.58**	1.59	45.46
Sthenelais boa	Polychaeta	SP	0.17	**0.75**	1.56	47.03
Sipunculid spp.	Sipunculida	S	**0.58**	0.50	1.56	48.59
Nassarius vinctus	Gastropoda	SP	**0.67**	0.33	1.56	50.15

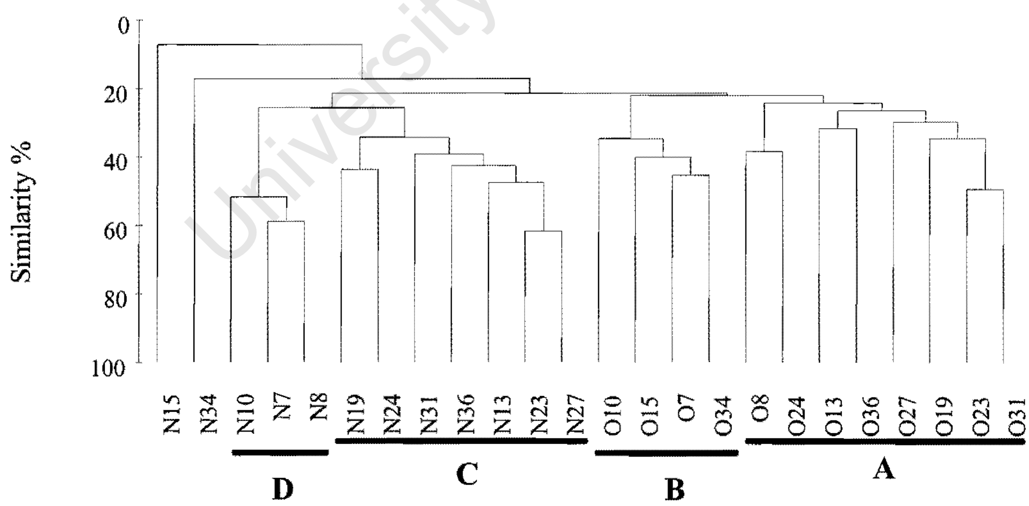


Figure 2.5: Dendrogram of cluster analysis showing the classification of the old (O) samples and new (N) samples at 12 Saldanha Bay stations, based on the coded abundances of large benthic macrofauna.

The MDS ordination (Fig. 2.6) again indicated that the old and new samples were different in that there was no overlap between samples from the different periods. The variation within the old samples seemed to be greater than the variation within the new samples when the outliers were not considered. The dendrogram groupings were supported, as the four groups (A-D) were again distinguishable. The same outliers were not dissimilar to any of the other samples. Groups A and C consisted of equivalent old and new stations, with the exception of station N8, which in 2001 clustered with Group D rather than C. Groups B and D also correspond, except that group D contains the errant N8 (see above) and both new outliers 15 and 34 were in group B of the old samples. Although depth was considered in the analysis, it could not account for the clustering of the samples. As the dredges covered large areas, it was not reasonable to take sediment samples from each sample for analysis; furthermore, the sediment would be partially sieved by the dredge.

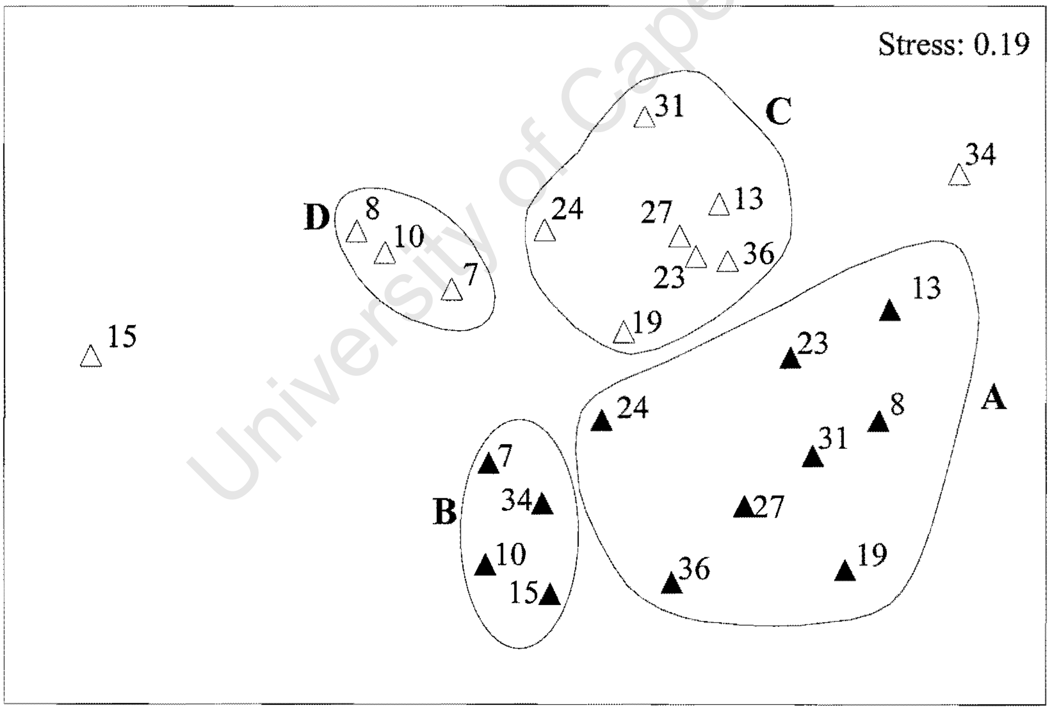


Figure 2.6: MDS ordination of old (closed triangles) and corresponding new (open triangles) dredge samples at 12 Saldanha Bay stations, based on coded abundances of large benthic macrofauna.

The SIMPER analysis comparing old Groups A and B indicated that these groups shared many species (Table 2.2). The dissimilarity (d = 78.11%) between the two groups was mostly due to differences in abundances of those species. The gastropod *Bullia laevissima* (4.21%) made the highest contribution to the dissimilarity, and the brittle star *Ophiotrix fragilis* (3.86%) the next highest contribution. It appeared that Group A consisted of more suspension-feeders (e.g. *O. fragilis* and *Venerupis corrugatus*), whereas Group B consisted of more scavengers (e.g. *B. laevissima* and *B. annulata*).

Table 2.2: The percentage contribution of each species to the average dissimilarity (D = 78.11%) between groups A and B, made up entirely of old samples. An arbitrary cut-off cumulative percentage of 40% was chosen.

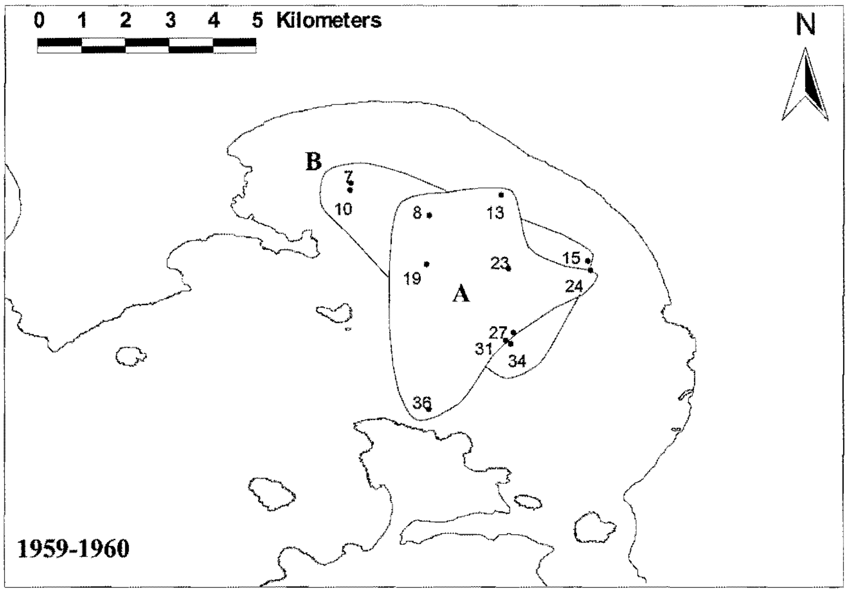
Taxon	**Taxonomic group**	**Ave. Abund. Group A**	**Ave. Abund. Group B**	**Percent Contrib.**	**Cumulative percent**
Bullia laevissima	Gastropoda	1.00	**3.00**	4.21	4.21
Ophiotrix fragilis	Ophiuroidea	**1.88**	0.00	3.86	8.08
Nicolea macrobranchia	Polychaeta	0.75	**1.25**	3.14	11.22
Thyone aurea	Holothuroidea	**1.25**	0.75	3.05	14.27
Diopatra neopolitana capensis	Polychaeta	0.00	**1.50**	3.03	17.31
Venerupis corrugatus	Bivalvia	**1.50**	0.00	3.01	20.31
Virgularia schultzei	Pennatulacea	0.13	**1.50**	2.85	23.16
Nassarius speciosus	Gastropoda	2.25	**3.50**	2.70	25.86
Hymenosoma orbiculare	Brachuyra	**1.75**	0.50	2.70	28.55
Bullia annulata	Gastropoda	0.63	**1.25**	2.61	31.17
Aulacomya ater	Bivalvia	**1.50**	0.25	2.59	33.75
Glycera tridactyla	Polychaeta	1.50	**1.75**	2.56	36.32
Nephtys hombergi	Polychaeta	0.13	**1.25**	2.52	38.83
Philyra punctata	Brachyura	**1.25**	0.75	2.36	41.19

The dissimilarity (d = 74.49%) between Groups C and D appeared to be a result of Group D having relatively few species compared to Group C (Table 2.3), each sample having less than 10 species. The greatest abundances for most species were recorded in Group C, although the mantis shrimp *Pterygosquilla armata capensis* was most abundant in Group D. The species in Group D tended to be mainly scavengers and predators.

Table 2.3: The percentage contribution of each species to the average dissimilarity (d = 74.49%) between groups C and D, made up entirely of new samples. An arbitrary cut-off cumulative percentage of 40% was chosen.

Taxon	**Taxonomic group**	**Ave. Abund. Group C**	**Ave. Abund. Group D**	**Percent Contrib.**	**Cumulative percent**
Hymenosoma orbiculare	Brachyura	**3.14**	0.00	10.79	10.79
Palaemon peringueyi	Caridea	**1.29**	0.00	4.41	15.20
Sthenelais boa	Polychaeta	**1.14**	0.00	3.65	18.84
Syngnathus acus	Pisces	**1.14**	0.00	3.52	22.36
Sepia typica	Cephalopoda	**1.00**	0.00	3.28	25.64
Philyra punctata	Brachyura	**0.71**	0.33	3.24	28.88
Annametra occidentalis	Crinoidea	**1.00**	0.00	3.22	32.10
Pseudocnella insolens	Holothroidea	**0.71**	0.00	3.20	35.30
Glycera tridactyla	Polychaeta	**1.00**	0.00	3.14	38.44
Pterygosquilla armata capensis	Stomatopoda	0.57	**1.00**	3.07	41.52

The groups (A-D) from the dendrogram and MDS were then superimposed onto 1960s and 2001 maps of the stations sampled (Fig. 2.7). In the 1960s, Groups A and B both extended over the length of Saldanha Bay. The middle section of the Bay made up Group A, while the outer edges of the sampling area constituted Group B. In 2001, Groups C and D were clearly confined to specific areas, Group C consisting of samples from Big Bay and Group D consisting of all samples from Small Bay (stations 7, 8 and 10).



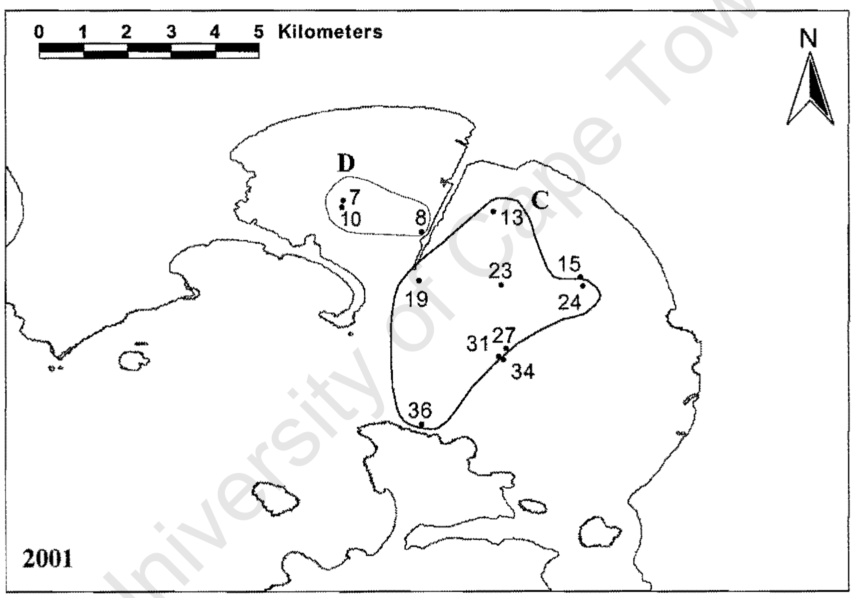


Figure 2.7: Maps of Saldanha Bay showing the spatial distribution of cluster analysis groups (A-D) during the 1960s and 2001, see Figs 2.5-2.6.

DISCUSSION

Benthic communities in Saldanha Bay have undergone a decline in number of species between the 1960s and 2001. This was evident in the total number of species for 1960s to 2001 (Fig. 2.2), the number of species per taxonomic group (Fig. 2.3) and the average number of species per dredge per period (Fig. 2.4). In addition, there was a change in the species composition, as some species were lost or replaced by others (Table 2.1). The replacement or loss of the species from the stations sampled, however, does not necessarily reflect the loss of those species from the entire Bay system. It may only indicate a shift in abundance from common to rare. It was noted that Polychaeta showed the greatest decline in species number (Fig. 2.3). As a result of these changes in species composition and abundance, the benthic communities in 2001 were significantly different from those of the 1960s (Figs. 2.5 and 2.6). Any proposed cause for these changes in the benthic communities should explain all of the observations mentioned above.

The numerical analyses employed in this study were not experimental or predictive, but exploratory. As a result it was not possible to determine conclusively the cause of the changes observed. Three possible causes can however be proposed, these being (1) methodological error, (2) natural environmental and biological variation, or (3) anthropogenic activities within Saldanha Bay.

Methodological error, which results from slight differences in the equipment used or from human error in identification of species, could explain the difference between the benthic communities recorded in the 1960s and 2001. For example the magnitude of the decline in species richness may be exaggerated as a result of under-sampling those species sized 1-2 cm in 2001. Since the emphasis was on individuals greater than 1 cm in length, the size of the sieve used to process the samples in 2001 was greater than that used in the 1960s; so even though species with an average length less than 1 cm were removed from the analysis, it is possible that organisms sized 1-2 cm would not have been as well sampled in 2001. However, I believe that most of the species used in this analysis (Appendix 2) were or would have been easily noticed in the sieve and only a few species would have been difficult to spot. Even if sampling error could account for the loss of certain species, it cannot account for the loss of some of the much larger species (those greater than 2 cm in length), or the gain of some relatively small species (Table 2.1). Also there is the possibility of differences in identification of species, although every effort was made to keep the identification constant and the old species names were updated. Therefore although methodological error could have some effect, I do not believe that this error could have caused the observed differences between the two periods.

Secondly, benthic communities are known to be naturally variable and subject to seasonal, annual and long-term cycles in total biomass and numbers (Gray 1981). There are no publications describing such cycles in Saldanha Bay benthic communities. Thus I cannot dismiss the possibility that natural temporal changes may explain the differences between old and new samples, particularly as there are no equivalent control sites with which comparisons can be made.

The 1960s samples were collected during different seasons (Appendix 1), so seasonal variation may have had an effect on the benthic communities. However, Field (1970) studied the seasonal changes in benthic communities with depth in False Bay. He concluded that although seasonal variation in benthic communities does occur, variation with depth was much greater than the seasonal variation. It can therefore be inferred that spatial variations in environmental factors probably supersede any seasonal variations within the benthic communities. In addition, Gray & Christie (1983) indicated that seasonal changes were not as important as annual changes in benthic communities when conducting long-term studies. Therefore, seasonal variation in benthic communities is unlikely to be the cause of the changes in the benthic communities of Saldanha Bay.

Interannual patterns in benthic communities are the result of the fluctuations or cycles in physical parameters as well as random spawning and settlement of species or individuals. The physical studies in Saldanha Bay emphasize that although the physical parameters or factors in the Bay do fluctuate (Monteiro *et al.* 1990), the current state is far beyond the range of expected natural fluctuation (Weeks *et al.* 1991a, b, Luger *et al.* 1999, Monteiro *et al.* 1999). Since benthic communities are closely linked to their habitats (Gray 1981), it is likely that the present benthic communities may also be transformed beyond their previous natural fluctuations.

The variation among the samples within each period is interesting. The old samples showed greater variation than the new samples (Figs 2.5 & 2.6). As the old samples were collected over a period of 10 years, interannual variation within the communities may explain the variation observed among these samples. This may also be the reason that no apparent pattern was visible among the old samples (noted by Christie and Moldan 1970s). But even though the samples were variable, they were still more similar to each other than to the new samples (Fig. 2.5 & 2.6), suggesting that the interannual differences between samples did not account for the separation of the communities in the 1960s from those in 2001.

Long-term hydrographic data in the North Atlantic Ocean showed evidence of cycles with periods of 3-4, 6-7, 10-11, 18-20 and 100 years (Gray & Christie 1983). Benthic data suggested cycles of 6-7 and 10 –11 year cycles, but not all benthic species show cyclic behaviour (Gray & Christie 1983). Oliver *et al.* (1980) noted that the benthic marine invertebrate communities are organized along a gradient of wave-induced substrate motion on the subtidal high-energy beach in Monterey Bay, California. Two zones were distinguished: a shallow zone (6-14 m), which was commonly disrupted by wave action and was primarily occupied by small, mobile, deposit-feeding crustraceans; and a deeper zone (14-30 m), which was dominated by tube worms and burrowing polychaetes. Community zonation was shown to be strongly influenced by wave-induced bottom disturbance. One of the major natural factors influencing Saldanha Bay is water movement, specifically wave action (Flemming 1977, Monteiro *et al.* 1999). If the wave exposure in the Bay has been altered, then the sediment patterns and the benthic communities within the Bay can also be expected to change.

Although no work has been done on long-term cycles in the benthic communities of Saldanha Bay, physical oceanographers have described changes in environmental parameters immediately after major development events (Weeks *et al.* 1991a; Weeks *et al.* 1991b, Monteiro *et al.* 1999), suggesting that the changes were not the result of natural causes. Also the physical conditions have remained relatively stable within the Bay over the last 30 years since the construction of the harbour. Since benthic communities elsewhere are closely linked to their environments (Gray 1981), it is likely that the communities have not been greatly influenced by natural fluctuations.

The third possible cause of changes in the benthic communities is that conditions within the Bay have changed over the past 30 years due to human activities. Several studies have shown that the physical environment has indeed changed because of human interference (Weeks *et al.* 1991a, b, Luger *et al.* 1999, Monteiro *et al.* 1999). Such changes in habitat have been known to cause major changes in benthic communities (Gray 1981). Therefore, it is logical to conclude that the communities may have changed as a result of human interference. A decline in the number of species is generally associated with disturbance events (Gray 1981), as are increases in scavengers and predators, and decreases in suspension-feeders.

Most suspension-feeding species (80%) declined between the 1960s and 2001, and the average (coded) abundance declined from 0.87 to 0.53, the difference was, however, not significant (Wilcoxon matched pairs test, $p>0.05$). There was also no difference evident when comparing scavengers and predators (Wilcoxon matched pairs test, $p>0.1$). Nevertheless, the species that contributed the most to the 1960s and the 2001 samples, *Nassarius speciosus* and *Hymenosoma orbiculare* (Table 2.1) are both scavengers or predators, and both increased in abundance.

Nassarius speciosus is a scavenger, mostly found in protected or sheltered areas. Since it is known that the organic content of the sediment has increased (Monteiro *et al.* 1999) and that Saldanha Bay has become more sheltered as a result of the breakwater and harbour construction, it is likely that the increase in *N. speciosus* is a result of the harbour construction and organic loading in the Bay. *Hymenosoma orbiculare* is a predator that feeds on small crustaceans and is most common in relatively sheltered areas such as lagoons and estuaries. A large number of amphipod tubes were brought up in the 2001 dredges, indicating considerable food availability for *H. orbiculare*. Evidently the conditions that resulted from the harbour development and subsequent development in the Bay have had an influence on various populations within the communities. *Ophiothrix fragilis, Glycera tridactyla* and *Bullia* species were more abundant in the 1960s (Table 2.1). *O. fragilis* and *Bullia* species share a preference for wave-exposed habitats, and both decreased in abundance since the 1960s. Again, this refers to the difference in wave-exposure between the 1960s and 2001. Wave-exposure patterns are unlikely to change as a result of long-term natural fluctuations, whereas the influence of harbour construction on wave action is obvious. In turn, this is likely to have been responsible for the changes in benthic communities.

There appeared to be two distinct benthic communities present within both the 1960s and 2001(Figs 2.5 and 2.6). Groups A and B in the 1960s were not as distinct as Groups C and D in 2001. Interannual changes in communities could not account for the differences between Groups A and B. Group A had more suspension-feeders, while Group B had a greater abundance of scavengers. When considering the extent of these communities within the Bay, it was evident that each covered a large area of the Bay (Fig. 2.7). Group A was located in the middle of the Bay, in slightly deeper water and in the area of greatest wave exposure (Flemming 1977). Wave exposed areas are generally not considered depositional areas, which means that most of the organic material would remain suspended in the water column, providing greater food availability for suspension-feeders, perhaps explaining their greater abundance in Group A. Group B was found in the semi-exposed zones (Flemming 1977), which could be considered as more of a deposit area than the exposed zone. Relatively, larger amounts of detrital matter would be available for consumption, which may have resulted in the observed abundance of scavengers.

Groups C and D in 2001 were very different. The samples in Group D were made up of six species or less having relatively low abundances and consisting of predators (mainly the stomatopod *Pterygosquilla armata capensis*) and scavengers. *Pterygosquilla armata capensis* is a nocturnal predator that lives in burrows in sandy mud, mainly in sheltered areas. This group was confined to the Small Bay area (Fig. 2.7). It is well known that Small Bay is the area of Saldanha Bay most affected by human activities (Jackson & McGibbons 1991, Stenton-Dozey *et al.* 1999). It is now sheltered from wave exposure because of the breakwater (Monteiro *et al.* 1999), has organic inputs in the form of fish factory effluents and mussel farm waste and has a reduced flushing time, which means that the pollutants emptied into this area are retained longer than would have been the case before the jetty was built. Group C had greater diversity in terms of feeding-groups and taxa. This group was confined to Big Bay, being less affected by the pollutants released into Small Bay. The harbour divides Saldanha Bay into Big Bay and Small Bay. The communities sampled in 2001 are divided into Small Bay and Big Bay communities. Thus, the harbour is probably the major factor dividing the communities within Saldanha Bay.

Anderson *et al.* (1981) studied the environmental effects of harbour construction activities in an estuary at Steveston, British Columbia. They found that the benthic communities were closely related to sediment parameters and that by sampling the sediment type the communities could be predicted. The construction of the harbour merely changed the sediment distribution and the benthic communities shifted their distribution to coincide with that of the sediment. Thus the harbour had the effect of shifting the communities, but did not alter them. This disagrees with what was found in Saldanha Bay. Generally if the communities had just shifted areas or patterns within the Bay, there would be overlap in the communities between the two periods, but there was none (Fig. 2.5 & 2.6). Benthic communities were markedly different between the 1960s and 2001. The habitat has changed rather than shifted so it is likely that the communities should change as well, not simply shift. A possible explanation for the above differences between these conclusions and those of Anderson *et al.* (1981) may be that in their studies the constant flow of the river flushed out pollutants emptied into the harbour area. Since the pollutants would not have the opportunity to settle into sediments, they would have less effect on the benthic communities, which might have been able to shift position rather than being altered.

In conclusion, the results of this analysis show that the species composition of the benthic communities in Saldanha Bay has changed radically, and the number of species has declined. There has been a shift in the feeding groups in that suspension-feeders have decreased, while at least some scavengers and predators have increased in abundance. In addition, organisms that prefer sheltered habitats have become more common at the expense of those that prefer exposed habitats. Although this study cannot exclude the possibility that the changes in benthic communities between the 1960s and 2001 were the result of natural fluctuations, it is more likely that the altered wave exposure and increase in organic matter within Saldanha Bay, which are results of the harbour construction and fish factory and musselfarm outputs, were responsible for those changes.

Chapter 3

CHANGES IN THE BENTHOS OF SALDANHA BAY (1960s-2001): AN ANALYSIS BASED ON QUANTITATIVE GRAB SAMPLES.

INTRODUCTION

In light of the changes in benthos detected by dredge sampling and outlined in Chapter 1, this chapter considers the use of quantitative grab sampling to determine whether the benthic macrofauna (greater than 1mm in size) of Saldanha Bay has changed since the 1960s. Grab samples analysed by Christie and Moldan (1970s, unpublished report) provided the baseline against which these changes could be measured.

Quantitative sampling of soft substrata involves the removal of a known area or volume of sediment, e.g. by means of a core, box corer, suction sampler or grab (Gray 1981). The van Veen grab was used for the current study because it was used in the pre-1973 sampling surveys. Prior to 1970 a 0.1m^2 van Veen grab was used, but since then it has been replaced by the heavier 0.2m^2 grab, the current standard grab sampler (JG Field, UCT, pers. comm.). This causes complications in interpreting the results of comparisons between samples prior to and post-1970, since the 0.2 m^2 grab samples twice the area but probably also penetrates deeper.

The grab is lowered vertically from a stationary ship, capturing slow-moving and sedentary members of the epifauna and infauna down to the depth excavated by the grab (Holme & McIntyre 1971). Its long arms provide leverage, preventing the grab from being jerked off the bottom. The 'bite' of the van Veen grab is quadrangular (Gollardo 1965, Lie & Pamatmat 1965), therefore depth of penetration can be calculated with reasonable accuracy from the total sample volume. Also the shockwave of the grab is negligible (Lie & Pamatmat 1965).

The factors influencing grab sample volume include the movement of the ship relative to the bottom, small-scale topographical features (e.g. hillocks), sediment water content, the presence of objects which prevent initial closing of grab, speed of grab descent onto the substratum and the manner in which the grab is removed from the substratum (Christie 1975). For example, if the sediment water content is high, the sediment is loosely packed, which means that the grab can penetrate deeply, whereas if the sediment is tightly packed, the sediment becomes hard and the grab cannot dig deeply. The depth of penetration and hence the sample volume is, however, influenced mainly by the sediment texture (Holme & McIntyre 1971, Christie 1975). An exponential relationship exists between the sample volume and sediment texture (Christie 1975) until the percentage mud that will give maximum grab volume is reached. In other words, the grab penetrates deeper in mud than in sand or gravel.

Two categories of animals are known to escape the grab: 1) fast-moving animals and 2) deep-burrowing animals. Fast-moving animals can either avoid the samplers actively or they can be washed away by the shockwave (which is negligible in the van Veen grab). Secondly, the maximum depth of penetration of the 0.1 m^2 grab is 15-20 cm (Holme & McIntyre 1971), whereas burrowing organisms can be found at depths of 30 cm or greater. Organisms would therefore be underestimated by the grab if they can burrow below its digging depth. Again, both the penetration depth and the vertical distribution of the organisms are dependent on the substratum.

Benthic communities are known to have patchy distributions (Gray 1981). The way in which the problem of spatial variation is overcome is generally by collecting replicate samples of 0.1-0.2 m^2 area and aggregating them to 0.5 m^2 or $1m^2$ (Holme & McIntyre 1971). This allows one to capture the spatial variation at the station, as well as providing a more accurate idea of the overall abundance and diversity over a larger area of the station, without making assumptions of homogeneity of the community.

In this chapter, 13 of the 23 stations analysed by Christie and Moldan (1970s, unpublished report) prior to the harbour development in Saldanha Bay were resampled. These were used to analyse both temporal and spatial differences in the benthic macrofauna of Saldanha Bay. As in Chapter 2, the temporal changes were determined through a general comparison of the benthic communities in the 1960s and 2001, whereas the spatial differences were determined by considering the spatial distributions of the benthic communities within each period.

METHODS

Sampling

Thirteen stations sampled between 1960 and 1964, before the development of Saldanha Bay harbour (Christie and Moldan unpublished report), were resampled in 2001, after development, to allow for a direct comparison. All sampling in 2001 was conducted in summer under calm oceanic conditions. Two replicate van Veen grab samples were collected at each of the 13 stations (Fig. 3.1). The original samples were collected with a $0.1m^2$ van Veen grab, but this study employed a $0.2m^2$ grab. The difference in size of grab is compensated for in the numerical analysis (see below). The samples were washed through a $1mm^2$-mesh sieve aboard ship to ensure that only macrofauna was collected and to remove fine sediment. The faunal samples were fixed in 10% formalin and kept for analysis. Empty mollusc shells and organisms considered dead at the time of sampling were excluded from the analysis. The macrofauna was sorted, transferred to 1% propylene phenoxytol, identified to the lowest possible taxonomic level and counted. The samples were labelled with an 'O' (old) referring to the samples collected in the 1960s or 'N' (new) referring to the samples collected in 2001, as well as the station number, and paired replicates are indicated by A or B.

Sediment:

Flemming (1977) conducted an extensive study of the distribution of the sediment in Saldanha Bay prior to the harbour development. For the historical samples, proportions of mud, sand and gravel, as well as the mean particle diameter, were estimated from the maps he produced. In addition, percentage organic carbon was read off a map produced by Flemming (reproduced in Monteiro *et al.* 1999). Although the sediment samples were collected at a different time to, and not always at the same location as, the faunal samples, the sediment distribution was relatively stable in the Bay at the time (Pedro Monteiro, CSIR, pers. comm.), so that use of these data is justifiable.

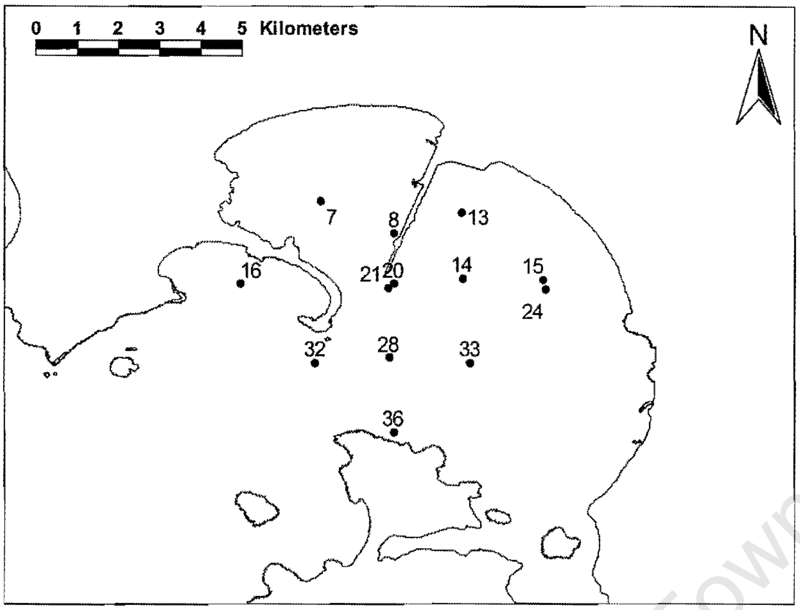


Figure 3.1: Positions of the Saldanha Bay grab stations sampled in the 1960s and again in 2001. Sampling sites are numbered.

A 100 g sediment sample was collected from each of the new grab samples. The sediment was processed as described by Flemming (1977). The interstitial salt was removed from a representative sediment sample (approximately 30-50g) by dialysis. The sample was then wet-sieved through a 63μm mesh sieve, to separate the sand and gravel from the mud fraction. The mud fraction solution was made up to one litre and a subsample taken into a pipette of known volume. The mass of the mud in the subsample was then determined after drying and multiplied up to total mass of mud within the sample. The sand and gravel fraction was also dried, then separated into sand (<2 mm) and gravel (>2 mm) fractions. These were each weighed and the proportions of mud, sand and gravel were calculated. Using a splitter (an instrument that divides the sand in such a way that each half is representative of the entire sample), a sample of 2-3 g was split off. This was then run through a settling tube to determine mean particle diameter. Percentage of organic carbon was derived from a recent study by Monteiro *et al.* (1999).

Numerical Analysis:

Since historical data were collected by a 0.1 m^2 van Veen grab and the new data were collected by a 0.2 m^2 van Veen grab, the old data for numbers of individuals per species were multiplied by two to make them comparable to the new data (closest approximation). The average depth of penetration of the grab was calculated for the new samples (6.25 ± 4.33 cm) and five of the old samples (4.9 ± 1.24 cm), for which the volume of the grab was known. Since the depths were not very different, it was considered unnecessary to compensate for differences in depth of penetration between the old and new samples. The old data for the number of species (species richness) could not validly be scaled up in this way and may have been underestimated relative to those of the new data, according to the species richness-area hypothesis (Begon *et al.* 1990).

Non-parametric multivariate analyses were applied to the species abundance data using the PRIMER (Plymouth Routines in Multivariate Ecological Research) software (Clarke 1993). The raw data were transformed using a "root-root" transformation, which reduces the weighting of abundant species, scaling down their scores so that they do not swamp the rest of the data (Field *et al.* 1982). The transformed data were then converted into a similarity matrix using the Bray-Curtis similarity measure.

An ANOSIM was performed on the similarity matrix, testing the null hypothesis that there was no difference in the macrobenthic community structure of Saldanha Bay between the 1960s and 2001. Exploratory cluster analyses, viz. classification and MDS ordination, were undertaken to produce graphical presentations of the similarities between the old and new samples. SIMPER analysis was performed on the data to determine which species contributed most to the dissimilarity between groups (Clarke 1993). Feeding types of these species were defined from the literature and the average abundance of each feeding type was calculated. This was based on the species most important species identified in the SIMPER analysis. Wilcoxon matched pairs tests were applied to the 1960s and 2001 species abundances to provide a before and after value for each species (Zar 1999).

Sediment data, including sediment grain size and organic carbon content, as well as depth, were superimposed onto the MDS ordination to determine whether groups were characterised by particular physical characteristics (viz. sediment parameters and depth). Non-parametric Wilcoxon matched pairs tests (Zar 1999) were applied to determine whether there was a difference in the sediment characteristics between old and new samples.

Wilcoxon matched pairs tests were also used to compare the species richness and number of individuals between the old and new samples. Since diversity indices are dependant on the combination of species richness and number of individuals, these were not calculated because although the difference in area of grab has been compensated in the number of individuals, this has not been done for the species richness, which would render the results of any statistical tests conducted on them invalid. For the matched pairs tests, the abundance and species numbers for the replicate new samples were averaged to allow direct comparison with the single samples taken for the old data.

In addition, the geographical locations of the defined groups in the 1960s and 2001 were plotted in an attempt to relate groups to location.

RESULTS

General Analysis

In total, 141 taxa were identified, the old samples having a total of 93 taxa, and the new samples 89 taxa (Appendix 2B). Fifty-two taxa were found only in the old samples and 48 were exclusive to the new samples (Fig. 3.2). Forty-one species were shared between the two periods. Thus, approximately half the species in each period were exclusive to that period. Polychaeta, Crustacea and Mollusca had the greatest number of species in both periods (Fig. 3.3). The total number of species of Mollusca and Crustacea had increased marginally while the total number of species of Polychaeta had decreased. Up to 50% or 60% of the species present in the 1960s had disappeared from the sampled stations, or at least become rare in 2001, and similar numbers of species had appeared or become more common in 2001.

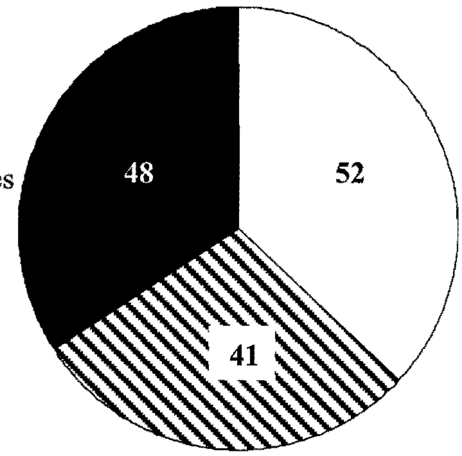


Figure 3.2: Pie chart indicating the number of species shared between and exclusive to the two periods, 1960s and 2001.

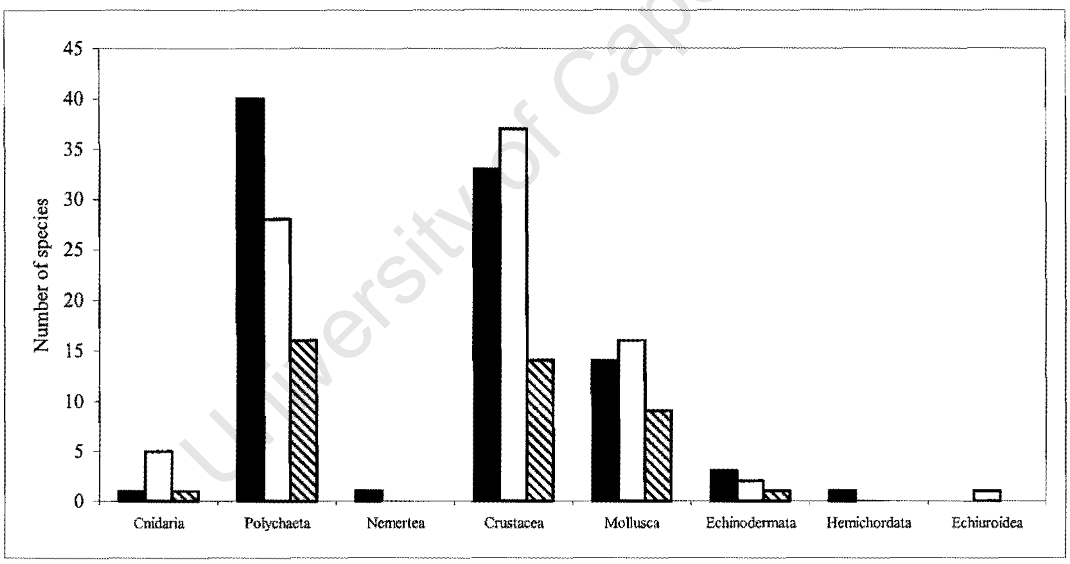


Figure 3.3: The total number of species of the major taxa in the 1960s (black bars) and 2001 (white bars) as well as the number of species shared (striped bars) between the two periods.

There was no significant difference in the number of species in the old and new samples (Wilcoxon matched pairs, Z=1.50, p>0.05). The number of individuals per sample (Fig. 3.4) in the 1960s samples was significantly greater than that of 2001

(Wilcoxon matched pairs, Z=2.76, p<0.01). Furthermore, the average number of individuals decreased from 719 (± 522 SD) to 257 (± 210 SD). The doubling of the abundances in the old samples provides a relatively good approximation to number of individuals in the larger area, as the number of individuals probably increases linearly with area, which suggests that the difference observed between the old and new samples is real. The 1960s samples were dominated by Pelecypoda (54%) and had a very small percentage of Prosobranchiata (<1%). Crustacea made up 10% (including amphipods) and Polychaeta made up 35% of the individuals. In 2001, Polychaeta made up the largest proportion of the individuals (45%). Crustacea made up the second largest proportion of individuals (38%), the majority of which were amphipods (30%). Mollusca only contributed 14% of the individuals; Pelecypoda a mere 2%, and Prosobranchiata 12%. It should be noted that the changes in percentages did not necessarily indicate an absolute increase or decrease in the abundance of any taxonomic group, because the total number of individuals was different.

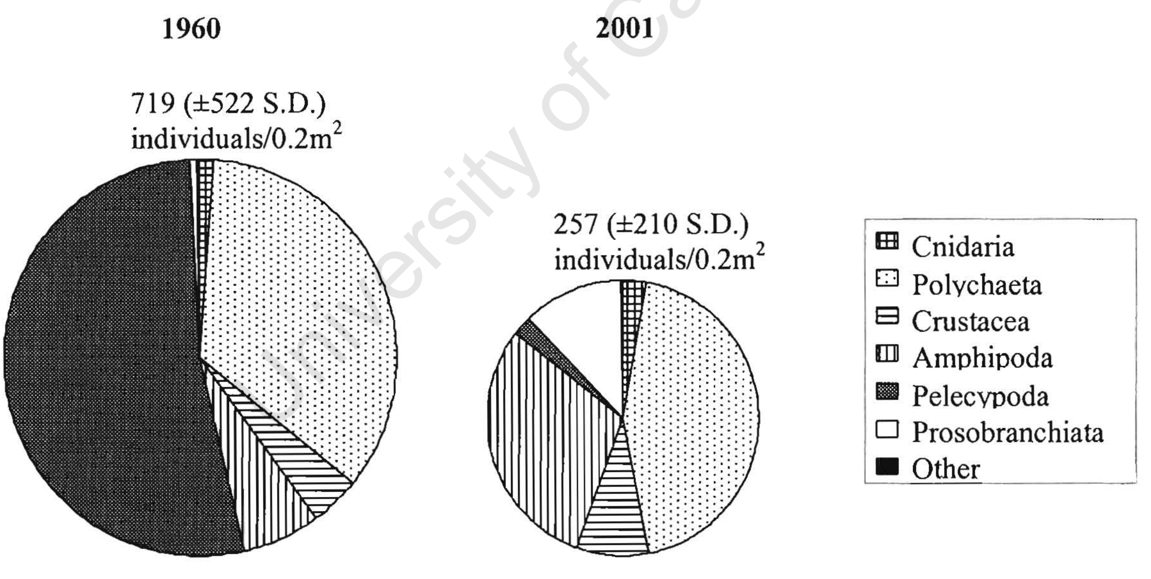


Figure 3.4: Pie charts indicating the percentage contribution of the major taxa to the total number of individuals per sample for both the 1960s and 2001. The size of the pie charts indicate the relative numbers of individuals per sample (mean with standard deviation indicated in brackets).

Multivariate Analysis

General comparison between the benthic communities of the 1960s and 2001

The benthic species composition of the old and new samples were significantly different (ANOSIM, R = 0.599, p<0.001), although the validity of this test may be questioned, because of the different sampling gear used and the doubling of old sample species abundances. The pelecypod genus *Macoma* contributed most (5.65%) to the dissimilarity (D=80.70%) between old and new samples (Table 3.1), its abundance in 2001 being less than 1% of that found in the 1960s. The polychaetes *Prionospio saldanha*, *Magelona capensis*, *Mediomastus capensis* and *Ampharete capensis*, as well as amphipods of the genus *Bathyporeia* were virtually absent from the 2001 samples, each contributing less than 4% to the dissimilarity. The whelk *Nassarius plicatellus* and the amphipod *Ampelisca diadema* were absent from the 1960s samples. The whelks *Nassarius vinctus* and *N. speciosus* showed an increase in abundance between the 1960s and 2001, together contributing 6.46% to the dissimilarity. The amphipods *Ampelisca brevicornis* and *Paramoera capensis* also increased in abundance, whereas *Bathyporeia* spp. and *Megaluropus namaquensis* decreased in abundance between the 1960s and 2001. Cumaceans were abundant in the 1960s, but few were found in the 2001 samples. The polychaete *Orbinia angrapequensis* showed an increase in abundance. The delicate polychaete *Nephtys sphaerocirrata* decreased in abundance, while the more robust congener *N. hombergi* increased in abundance.

The most common feeding types represented in the samples were suspension-feeders, deposit-feeders, scavengers and predators (Table 3.1). Although the total abundances of the scavenger and predators increased and that of the suspension-feeders and deposit-feeders decreased, the differences were not statistically significant (Table 3.2). In terms of number of species, similar numbers of species within each feeding type increased and decreased in abundance.

Table 3.1: SIMPER analysis: The percentage contribution of each species to the grouping of the 1960-1964 (old) samples and the 2001 (new) samples. The arbitrary cut-off percentage of 50% was chosen. Average dissimilarity between old and new groups = 80.70%.

Taxon	Taxonomic group	Feeding type	Ave. Abund. ($0.2m^2$) 1960-1964	Ave. Abund. ($0.2m^2$) 2001	Percent Contrib.	Cum. percent
Macoma spp.	Bivalvia	S	**368.62**	2.00	5.65	5.65
Prionospio saldanha	Polychaeta	D	**76.31**	0.00	3.19	8.84
Orbinia angrapequensis	Polychaeta	D	10.46	**29.81**	3.01	11.85
Nassarius plicatellus	Gastropoda	SP	0.00	**19.38**	2.92	14.77
Cumacea	Cumacea	S	**26.31**	0.69	2.84	17.60
Ampelisca diadema	Amphipoda	S	0.00	**44.96**	2.79	20.39
Phaxas decipiens	Bivalvia	S	**7.23**	0.42	2.35	22.74
Virgularia schultzei	Pennatulacea	S	**8.92**	6.23	2.20	24.95
Magelona capensis	Polychaeta	D	**17.38**	0.00	2.17	27.11
Mediomastus capensis	Polychaeta	D	**8.00**	0.00	2.13	29.24
Ampelisca brevicornis	Amphipoda	S	8.15	**9.27**	2.12	31.37
Nephtys sphaerocirrata	Polychaeta	SP	**10.62**	1.96	2.08	33.44
Timarete tentaculata	Polychaeta	D	0.15	**47.23**	1.96	35.40
Paramoera capensis	Amphipoda	D	0.77	**17.77**	1.96	37.36
Nassarius vinctus	Gastropoda	SP	0.92	**4.35**	1.80	39.16
Nassarius speciosus	Gastropoda	SP	1.85	**5.15**	1.74	40.90
Nephtys hombergi	Polychaeta	SP	2.77	**3.85**	1.74	42.64
Glycera tridactyla	Polychaeta	SP	**8.15**	3.46	1.72	44.36
Bathyporeia spp.	Amphipoda	D	**5.69**	0.00	1.64	46.00
Hymenosoma oriculare	Brachyura	SP	**2.31**	1.88	1.62	47.62
Megaluropus namaquensis	Amphipoda	D	**11.69**	0.04	1.60	49.22
Ampharete capensis	Polychaete	D	**69.23**	0.00	1.60	50.83

Table 3.2: Comparison of the feeding types of the 1960s and 2001 samples. Only species represented in the SIMPER table (Table 3.1) were used. The total abundance is the sum of the average abundances of all species belonging to a feeding category. The increase or decrease in the number of species refers to the change that has been observed since the 1960s.

Feeding type	Number of individuals			Number of species	
	1960s (total abundance)	2001 (total abundance)	Significance (Wilcoxon matched pairs test)	Increased in abundance	Decreased in abundance
Scavengers & Predators	26.62	40.03	$P > 0.1$	4	3
Suspension-feeders	419.23	63.57	$P > 0.1$	3	4
Deposit-feeders	199.68	94.85	$P > 0.1$	4	5

Detailed comparison of benthic communities

Old and new samples separated at just above the 20% similarity level of the dendrogram (Fig. 3.5) and two outliers were identified, i.e. the samples from stations 8 and 14 in the 1960s. Four main groups could be distinguished at the 30% similarity level. Group 1 consisted of all the old samples excluding the outliers and Groups 2-4 consisted entirely of new samples. Group 4 could be further divided into three subgroups with average similarities greater than 50%. At 11 of the 13 stations, the replicate pairs of samples were very similar to each other. Only at stations 20 and 33 were the replicates dissimilar in composition.

There was a clear distinction between the old and new samples on the MDS ordination plot, apart from two outliers (Fig. 3.6). Out of the three new sample groups, the samples from Group 4 were most similar to the samples in Group 1 and the samples in Groups 2 and 3 were most similar to each other. The MDS shows that Group 4 should not be further divided.

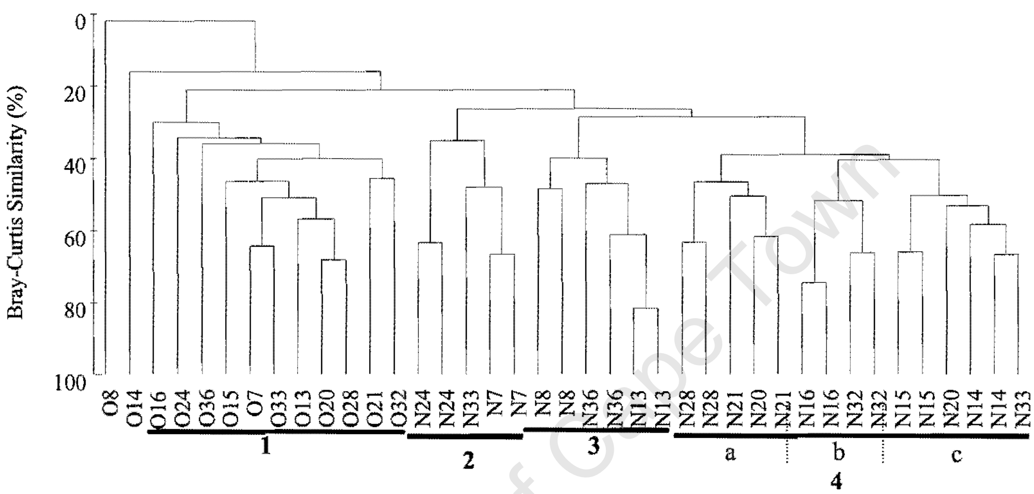


Figure 3.5: Dendrogram of cluster analysis showing the classification of the old (O) and new (N) grab samples at 13 Saldanha Bay stations, based on the abundances of small benthic macrofaunal taxa. Groups 1-4 are indicated, with Group 4 being subdivided into a, b and c subgroups.

Group 1 had the greatest abundances of the bivalves *Macoma ordinaria* and *Phaxas decipiens*, the polychaetes *Glycera tridactyla* and *Prionospio saldanha* and cumaceans, which made it different from Groups 2-4 (Table 3.3). *Upogebia africana* (Anomura), *Paramoera capensis* (amphipod), *Nassarius speciosus* (whelk) and *Polydora* spp. (polychaetes) were most responsible for separating Group 2. The whelk *Nassarius plicatellus* and the amphipod *Ampelisca diadema* defined Group 3. Group 4 was defined by the polychaetes *Orbinia angrapequensis* and *Glycera tridactyla*, the sea-pen *Virgularia schultzei* and the amphipod *Ampelisca brevicornis*. Groups 1 and 4 had similar abundances of *Virgularia schultzei* and *Ampelisca brevicornis*.

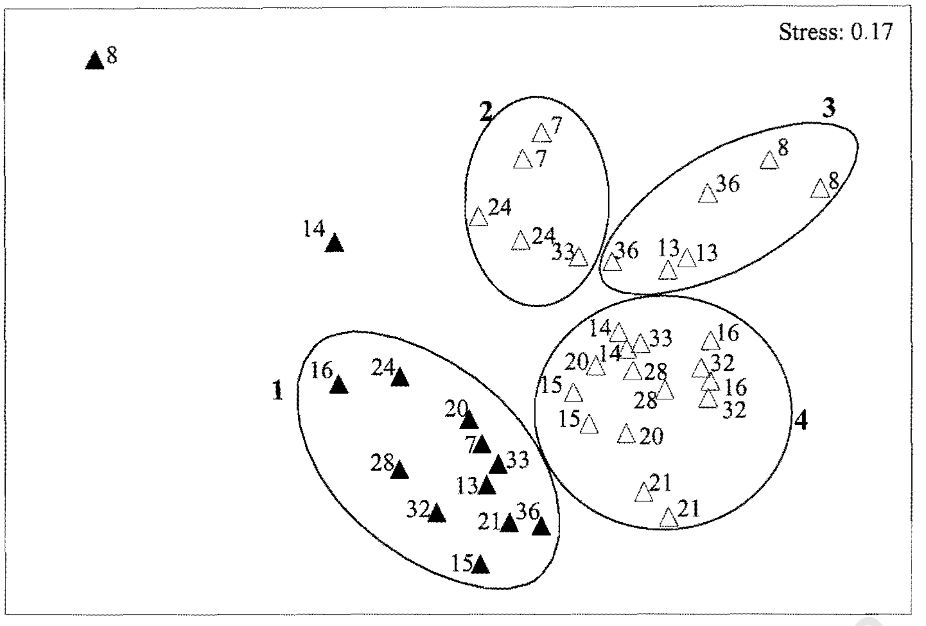


Figure 3.6: MDS ordination of old (closed triangles) and corresponding new (open triangles) grab samples at 13 Saldanha Bay stations, based on the abundances of small benthic macrofaunal taxa. Groups 1-4 from Fig. 3.5 are marked on the diagram and encircled.

Table 3.3: SIMPER analysis: A comparison of abundances of the species contributing most to the similarity (indicated by *) within each of Groups 1-4. Similarities were all greater than 35%. The arbitrary cut-off was 45% of the similarities.

Taxon	**Taxonomic group**	**Average Abundance (0.2 m^2)**			
		Group 1	**Group 2**	**Group 3**	**Group 4**
Macoma ordinaria	Bivalvia	**429.45***	3.80	2.33	1.27
Glycera tridactyla	Polychaeta	**6.18***	4.80	0.67	4.13*
Phaxas decipiens	Bivalvia	**8.55***	0.40	0.00	0.60
Prionospio saldanha	Polychaeta	**90.18***	0.00	0.00	0.00
Cumacea		**22.91***	0.00	0.00	1.20
Upogebia africana	Anomura	0.00	**65.20***	7.17	0.07
Nassarius speciosus	Gastropoda	1.82	**15.40***	4.17	2.13
Polydora spp.	Polychaeta	6.36	**82.20***	0.00	0.00
Paramoera capensis	Amphipoda	0.91	**68.60***	15.33	1.80
Nassarius plicatellus	Gastropoda	0.00	2.80	**39.00***	17.07
Ampelisca diadema	Amphipoda	0.00	3.8	**186.50***	2.07
Orbinia angrapequensis	Polychaeta	12.18	25.40	3.50	**41.80***
Virgularia schultzei	Pennatulacea	9.82	0.20	0.00	**10.73***
Ampelisca brevicornis	Amphipoda	9.45	0.00	6.83	**13.33***

Comparison of environmental factors

The sediment parameters that showed a significant difference between the old and new samples were percentage gravel, percentage mud and mean particle size (Wilcoxon matched pairs, $p<0.05$), whereas there was no significant difference in percentage sand and percentage organic carbon ($p>0.05$). There seemed to be a higher percentage of gravel in the old samples than in the new, although the Group 1 (old) samples did have considerable variation in gravel content. Gravel was virtually absent from all Groups 4 stations, and many Group 3 stations (Fig. 3.7a).

The new samples generally had > 50% sand except for Station 8 (5%), whereas the old samples had from 25-99% sand (Fig. 3.7b). Within the new samples (Groups 2-4), the sand fraction was consistently high in Group 4. The mean sand particle size (in phi units, Fig. 3.8a) of the old samples (Group 1) ranged from 1-3 Φ (medium to fine sand), whereas in the new samples the values were concentrated between 2.5 and 3 Φ (fine sand), the only exception being Station 24 (2 Φ). The outliers had mean particle sizes greater then 3 Φ. Within the new samples, the sediment tended to be more uniformly fine sand, whereas the old samples had great variation in particle size.

The percentage mud was always consistently low in the old samples (see Group 1 in Fig. 3.7c). Values were more variable in the new samples, being low in Group 4 but higher in Groups 2 and 3, with much greater values in two of the samples in Group 3, namely the replicates at Station 8. Some new samples appeared to have higher percentage organic carbon, but high percentages were not characteristic of all the new samples (Fig. 3.7d). Values were always moderately low in all old samples (Group 1) but variable among new samples, being consistently low in Group 2, often high in Group 4 and always high in Group 3. Again Station 8 (in group 3) stood out as having very high values, parallel with its high percentage mud.

In summary, old (Group 1) samples had high percentage gravel, low percentage mud and moderately low percentage organic carbon. New samples (Groups 2-4) were more variable but always had less gravel. Within Groups 2-4, Group 2 was distinguished by having relatively more gravel and very low levels of organic carbon, Group 3 by a combination of high levels of percentage mud and percentage organic carbon, and Group 4 by low levels of mud. Particle size of the sand component was generally greater in the old samples (mostly 1-2 Φ) than in new samples (generally greater than 2.5 Φ).

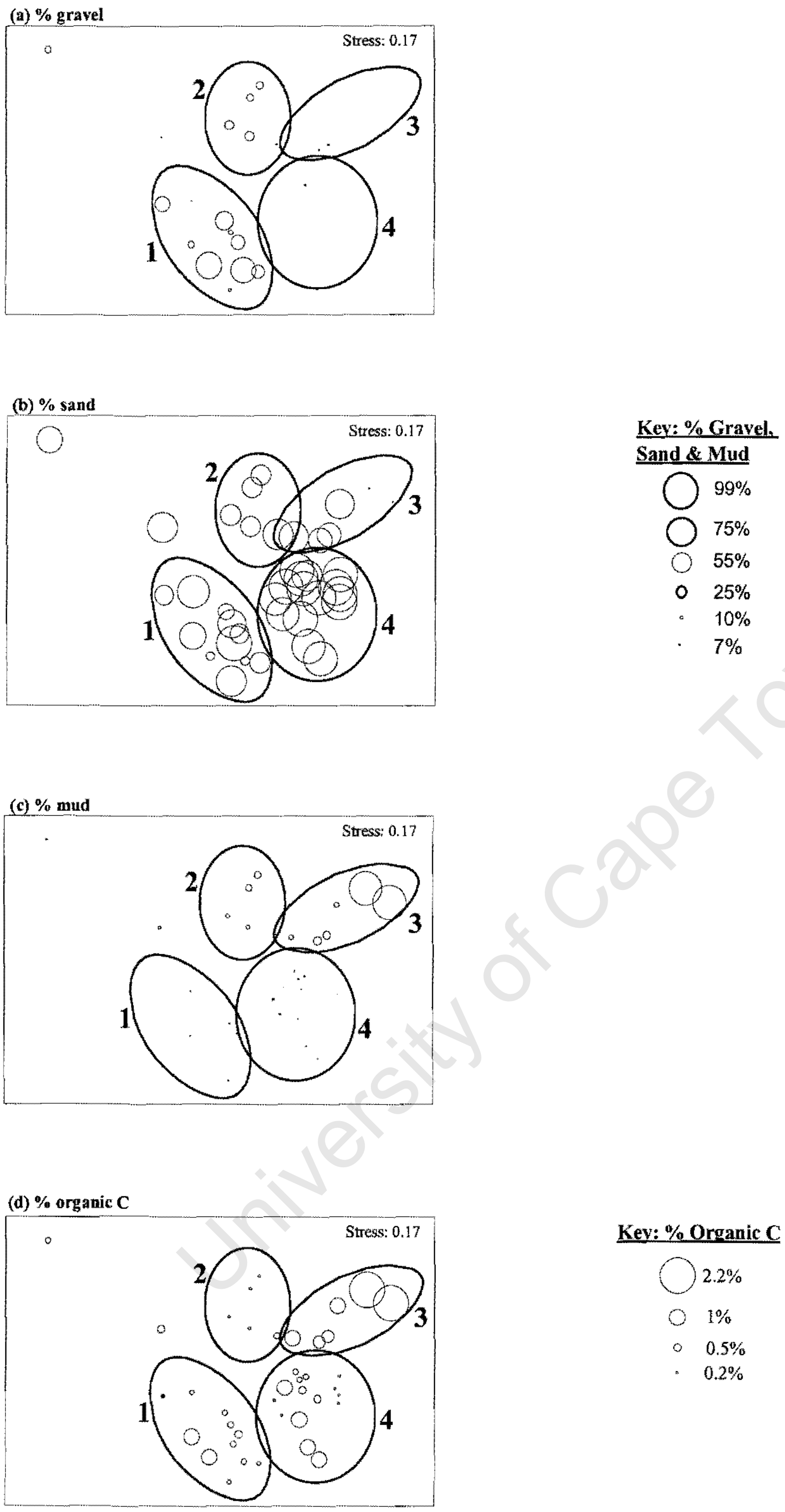
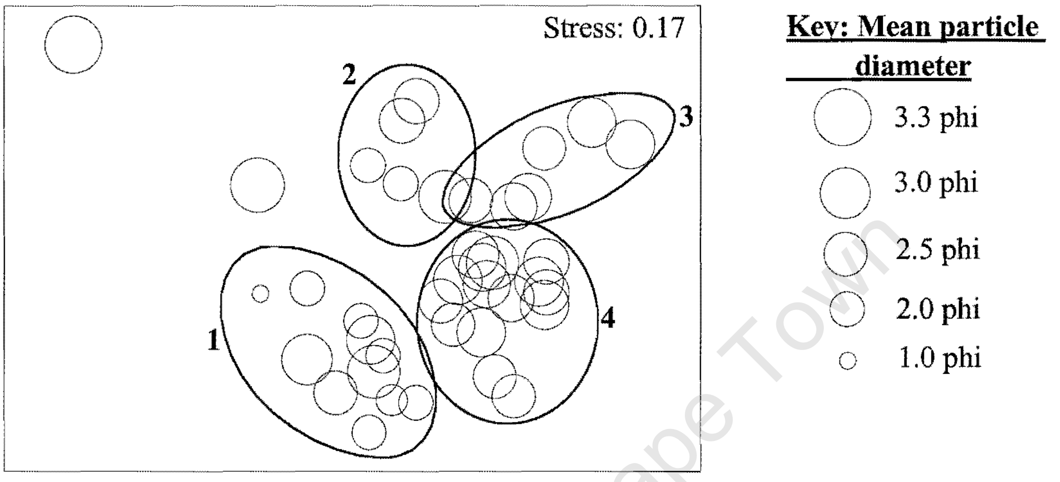


Figure 3.7: Sediment characteristics: % gravel, sand, mud and organic carbon, superimposed on the MDS ordination plot (Fig. 3.6), based on species-abundance data. Groups were as in Figure 3.6. Bubbles for % organic carbon differ in dimension from those of other sediment parameters.

The average depth at which samples were taken was not significantly different between old and new samples (Wilcoxon matched pairs, $p>0.05$; Fig. 3.8b). The old samples (Group 1) ranged from depths of 10 to 26m, very similar to the depths at which the new samples were collected (10-27m). Depth could also not be used to distinguish among the new sample groups (Groups 2-4).

(a) mean particle diameter (phi)



(b) depth (m)

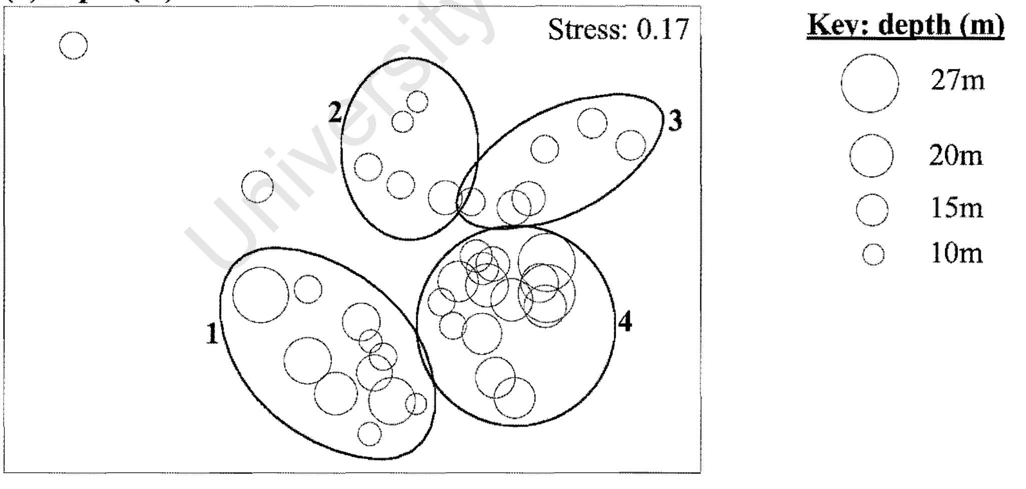


Figure 3.8: Sediment mean particle diameter (phi) and depth (m) values superimposed on the MDS ordination plot based on species-abundance data (Fig. 3.6). Groups indicated by bold numbers 1-4.

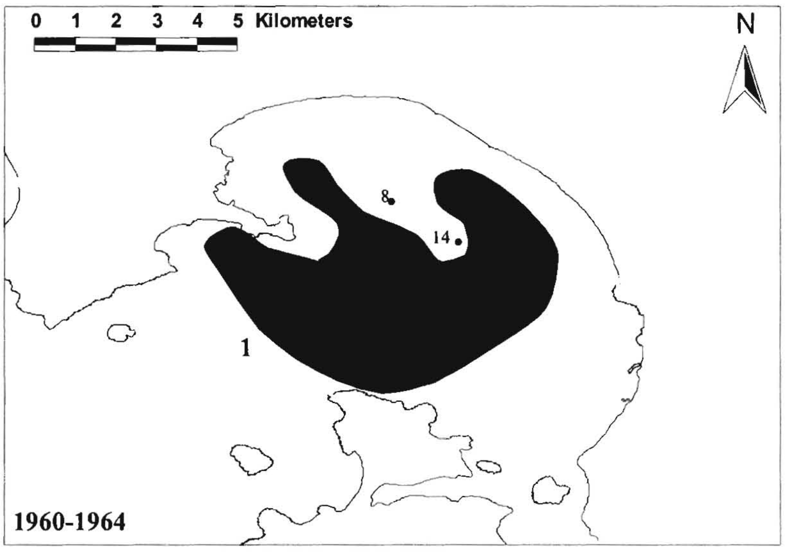
Geographically, the old samples formed one large group, which covered the entire area sampled (Fig. 3.9). In 2001, Group 3 consisted of Stations 8, 13 and 36, all of which are situated near to the coast where major human activity takes place. Group 4 consisted of stations situated outside Saldanha Bay (4b), the area leading up to the ore jetty (4a) or in Big Bay (4c). Group 2 consisted of stations 7, 33 and 24, which are possibly far enough away from the ore jetty not to be too greatly influenced by the activities surrounding it.

DISCUSSION

The main changes observed in Saldanha Bay during this study were: (1) radically different benthic community composition between the 1960s and 2001; (2) an increase in the total abundance (Table 3.2) of scavengers and predators, and a decrease in suspension-feeders and deposit-feeders; (3) a decrease in the number of individuals (based on corrected values for 0.1 m^2 grab); (4) greater differences between stations in 2001 than in the 1960s (3 groups vs 1 group); (5) a shift to less gravel, more mud, finer sand and (possibly) more organic carbon, at least at some of the stations.

As in Chapter 2, three possible causes provide plausible explanations for the differences between the 1960s and 2001. Firstly, the methodology, referring specifically to the conversion of old sample abundances by multiplication, could have caused differences between samples. Secondly, natural variations in communities, in terms of long-term fluctuations or cycles, could have accounted for the observed differences. Thirdly, the changes could have been a result of anthropogenic activities in Saldanha Bay.

As mentioned above, the standard grab-size changed from $0.1m^2$ to $0.2m^2$ around 1970. For this reason, different sized grabs were used to sample in the 1960s and 2001. The larger grab was more likely to sample rare species than the small grab, because it covered a larger area, although the depth of penetration was not significantly different between the grab sizes. The larger grab was also less likely to allow the escape of more mobile species. The number of individuals per species in the old samples was multiplied up to compensate for the difference in area, but it was not possible to validly compensate for species numbers in this manner.



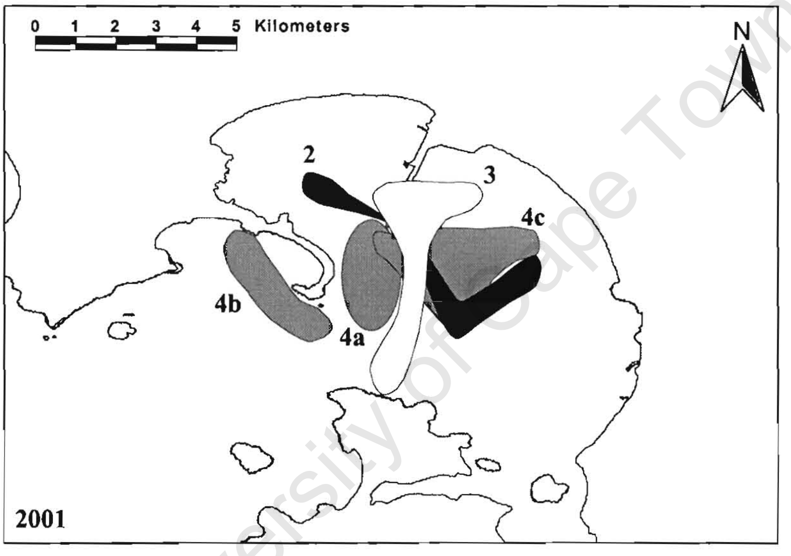


Figure 3.9: Maps of Saldanha Bay showing spatial distribution of the cluster analysis Groups 1-4 during the 1960s and 2001. Shading was used to clearly delimit Groups 1-4.

Another issue is that the benthic communities are known to have patchy distributions (Gray 1981), so the larger grab may capture more of the community heterogeneity. Due to the patchy distribution, at least two replicate samples are generally collected at a site or station, to better capture the diversity. In this study the old samples had no replicates, which limited the interpretation, since we have no idea of the natural variation at each station. It could be that we are forcing differences in communities where none exist. However, since replicates of new samples were generally very similar to each other, it is likely that the differences between old and new samples are real, and not attributable to lack of replication of old samples. Furthermore, using identical robust analytical methods, the old samples fell into a single group at approximately 30% Bray-Curtis similarity, whereas the new samples were divided into three groups at this level (Figs 3.5 & 3.6). This suggests strongly that the old samples were no more variable than the new ones, in spite of being multiplied up.

The methodological differences may account for the fact that the number of species (Fig. 3.2) recorded in the 1960s was not significantly different to that in 2001. Since species diversity measures are dependant on species number and abundance, the conversion may have obscured significant differences in diversity between the two periods. However, it must be pointed out that by taking smaller samples in the 1960s, any error can only be in the direction of underestimating the number of species in the old samples. If any change had taken place (but was not detected due to methodological differences), it can only have been in the direction of a decrease in the number of species.

Species composition and relative abundance were, however, clearly different between the two periods (Figs 3.2, 3.3 and 3.4; Tables 3.1 and 3.3), to the point that the communities of the two periods were significantly different (ANOSIM, $p<0.001$; Figs 3.5 and 3.6). Even though the ANOSIM results are questionable, the fact that some species, in the SIMPER analysis, increase in abundance in the new samples suggests that the differences observed were not the result of methodological differences. Therefore methodological differences cannot, by themselves explain the differences in benthic communities between the 1960s and 2001. They could also not explain the changes observed in the sediment parameters (Fig. 3.7 and 3.8a).

Seasonal, interannual, interdecadal or longer cycles in the abundance of benthic macrofaunal species may explain the difference between old and new samples. Not all species undergo long-term fluctuations. Interestingly, the samples at Stations 16 and 32, which are situated outside Saldanha Bay, had undergone as much change as the stations inside the Bay. It was assumed that these stations would be least affected by anthropogenic factors, so the dramatic change in community structure leads to the idea that natural fluctuations may be responsible for the changes observed. However, the construction of the breakwater between the mainland and Marcus Island would have altered wave forces at both these sites, so human effects cannot be discounted. The problem is that no studies have been conducted into the temporal cycles in benthic communities in Saldanha Bay. But seasonal change in False Bay was minimal (Field 1971). Since the nature of the change in benthic communities in South Africa is not fully understood, it would be unwise to disregard the possibility of natural cycles being responsible for the changes observed.

Sediment composition in the Bay has clearly changed since the 1960s. Since sediment texture is dependant on wave exposure (Personal communication P.M.S. Monteiro), this was not unexpected. As far as I am aware, the background wave exposure regime has been relatively stable and only intensifies with seasonal storms. Given that sampling in the 1960s was spread over all seasons and over more than one year (Flemming 1977), natural temporal variations in wave action are unlikely to explain the changes in sediment composition.

Lastly, anthropogenic effects may be responsible for the changes observed. The building of the causeway and ore jetty restricted water flow and sheltered the Bay from wave exposure (Fig. 1.2). Water movement is responsible for sediment deposition. Therefore the changes in sediment distribution patterns may be attributed to the sheltering of the Bay by the construction of the ore jetty and causeway. The sediment texture would therefore tend towards finer sand and mud, as was observed in the 2001 samples (Figs 3.7 and 3.8). The fish factory and the mariculture farms also release relatively large amounts of organic matter. Therefore one would expect an increase in the organic content of the sediment. This is not supported by the present study, with some sites increasing and others decreasing in organic content (Fig. 3.7), but has been shown to be true in other studies (Monteiro *et al.* 1999). It was not possible to test other organic constituents, as these were not measured before the harbour was developed. It is, however, known that the heavy metal content of the sediment has increased as a result of ore shipping (Monteiro *et al.* 1999). The change in habitat, as a result of changes in hydrodynamics and sediment texture and composition, is believed to be the most likely cause of the changes observed in the benthic communities of Saldanha Bay.

Indicator species and Feeding types

Indicator species and feeding types may be examined to investigate whether the habitat change is responsible for the striking changes in community composition observed during this study. The general trend found in earlier studies in Saldanha Bay (Jackson & McGibbon 1991, Stenton-Dozey *et al.* 1999, 2001), was a decrease in the numbers of suspension-feeders and an increase in deposit-feeders. Deposit-feeders are known to prefer fine sand with a high organic content (Gray 1981). Although suspension-feeders decreased in this study, the deposit-feeders did not increase as predicted by previous studies. This may be due to natural fluctuation in the benthic communities, which results from random settlement of larvae.

Virgularia schultzei, a filter-feeder, was considered an indicator of unpolluted or undisturbed areas in Saldanha Bay (Christie & Moldan 1977, Jackson & McGibbon 1991). Overall, it was most abundant in the old samples (Table 3.2), which suggests that the system in 2001 was more disturbed than in the 1960s. However, this species was also abundant in Group 4 of the 2001 samples (Table 3.4), which implied that the area covered by Group 4 (most of Big Bay; Fig. 3.9) was relatively unpolluted or undisturbed when compared to Small Bay. This is supported by a study conducted by Jackson & McGibbon (1991), in which *Virgularia schultzei* was found to be concentrated in the Big Bay area.

Polydora, a deposit-feeding species, was absent from studies conducted in 1975 (Christie & Moldan 1977, Jackson & McGibbon 1991). Jackson & McGibbon (1991) noted that *Polydora* had rapidly increased in abundance towards the end of the 1980s, especially around the fish factory outfall. Although present across Saldanha Bay in low abundance since the 1940s, its range had become restricted to Small Bay by 1990 (Jackson & McGibbon 1991). The major increase in this species was attributed to the changes in patterns of food availability (Jackson & McGibbon 1991). In this study, *Polydora* was abundant in Group 2 samples (Table 3.4), which consisted of stations in both Small and Big Bays.

Even though *Upogebia*, a sand-prawn, was absent from the 1975 survey (Christie & Moldan 1977), it was dominant in both numbers and biomass in Small Bay during 1989-1990 (Jackson & McGibbon 1991). These prawns are typical of sheltered areas, and their increase was attributed to the reduction of water movement resulting from the construction of the causeway and ore jetty. *Upogebia* was abundant in Group 2, which was made up of stations in Big and Small Bay. The disruption of water circulation (Weeks *et al.* 1991a,b) may have produced relatively sheltered areas, in which the species settled.

The amphipod *Ampelisca* builds tubes, which form mats. These mats support specific organisms and trap sediment particles of particular size. This process is thought to stabilise and decrease the amount of natural variability within the area. These amphipods prefer sheltered areas, so Saldanha Bay is the ideal place for them to settle, since the wave exposure has now been reduced. *Ampelisca* was not abundant in the 1960s although present, and no mention of it was made in the 1989-1990 survey (Jackson & McGibbon 1991), but by the late 1990s Bickerton (1999) noted that *Ampelisca brevicornis* was common in both Big and Small Bay. Group 3 of my study was dominated by *Ampelisca diadema* and *Nassarius plicatellus* (Table 3.1). Gray (1981) noted that there was a cyclic negative relationship between *Nassarius* and *Ampelisca* species. This was, however, not supported by the current study, since they co-occur in most of the samples.

The examination of feeding types and indicator species reveals that the abundant species in the 2001 samples prefer sheltered areas dominated by fine sand and high organic sediment content, to the detriment of those species abundant in the 1960s samples, which preferred wave-exposed, undisturbed or unpolluted areas. Thus habitat changes due to anthropogenic activities are likely to have caused the changes observed in the benthic communities of Saldanha Bay. However, the species commonly associated with polluted areas, namely the polychaetes *Prionospio* and

Mediomastus capensis (Bickerton 1999), were virtually absent from the 2001 samples, but abundant in the old samples. This could be a result a natural fluctuation.

Comparison of sediment content between groups of new samples

The three groups of new samples had slight, but quite definite differences in sediment texture. Group 2 had a mixture of gravel, sand and mud, Group 3 had a high percentage of mud and sand, but not much gravel, and Group 4 had mostly sand with very little mud or gravel. Group 1 (old samples) had relatively high sand and gravel content, so the habitat characterising the stations of Group 4 were most similar to those of the 1960s. The new samples had greater mud content in Group 2 and 3 samples. Station 8 in particular had mostly mud and very little sand or gravel. Interestingly, the sand fraction of Station 8 consisted mainly of shell and faecal pellets. It was most similar to Stations 13 and 36 in species composition, but very different from any other station in terms of sediment composition. This station was located closest to the ore jetty, an area that has undergone major physical changes, mainly a major increase in mud and organic content as well as trace metal content (Monteiro *et al.* 1999).

The community patterns in Saldanha Bay showed clearer grouping in 2001, three clear groups being defined, whereas in the 1960s the variation between stations was less and they made just one group. It seemed that anthropogenic activities served to diversify and more clearly define communities.

In conclusion, the benthic communities have substantially changed since the 1960s, as have the wave exposure and sediment distribution. Although natural fluctuations cannot be disregarded as a possible explanation for some of these changes, the more likely explanation is changes in habitat, caused by anthropogenic activities within Saldanha Bay.

Chapter 4

SYNTHESIS AND GENERAL DISCUSSION

Over the last 30 years many developments have taken place in Saldanha Bay. The harbour and breakwater were built between 1973 and 1976, with extensions continuing into the 1990s. The construction and maintenance of the harbour required underwater blasting and dredging. The mussel farms were established around 1984. Recreational use of the Bay has increased as a result of increased development, for example Club Mykonos, with its small craft harbour. Other activities, such as the fishing industry and fish processing factories in the area continued throughout the 30 years.

It is known that these developments have altered the physical processes operating in the Bay. These include water movement (Weeks *et al.* 1991a, b, Luger *et al.* 1999), sediment distribution patterns, organic loading and metal loading of sediment (Monteiro *et al.* 1999). It was also suggested by other studies that the benthic communities had changed since the developments in Saldanha Bay, particularly of the harbour, breakwater and mussel farms (Jackson & McGibbon 1991, Bickerton 1999). The aims of this thesis were to determine whether benthic communities had changed since the 1960s and to suggest possible reasons for changes observed.

For both sampling strategies (i.e. dredge and grab), a subsample of stations considered in the study by Christie & Moldan in the 1970s was resampled in 2001. The dredge provides semi-quantitative data because the speed and duration of dredging was standardized, whereas the grab is more truly quantitative, sampling a fixed area.

Possible methodological problems arose due to slight modifications of the sampling methods between the 1960s and 2001. The old dredge samples contained organisms covering the entire faunal size range, whereas only the species with an average length greater than 1cm were considered in the 2001 samples. The species with an average length less than 1cm were therefore removed from the old data during analysis. In terms of the grab sampling, the old samples were collected with a smaller van Veen grab ($0.1m^2$) than the current standard-sized grab ($0.2m^2$), used to collect the new samples. The difference in area was accounted for by the multiplication of the old sample species abundances by a factor of two, but no valid compensation could be made for the species number.

COMBINED RESULTS FROM GRAB AND DREDGE SAMPLING

Three physical characteristics of Saldanha Bay are considered: sediment parameters, depth at station and the wave exposure of the Bay. Since the dredge can sample across different habitats in one haul, sediment samples were not collected for dredge samples. Analysis of the sediment samples from the grab stations showed that the percentage gravel had decreased and the percentage mud had increased (Table 4.1, Fig. 3.7), particularly at the stations falling in Groups 2 and 3 surrounding the ore jetty and Salamander Bay. The percentage sand was relatively unchanged. The range of mean sand particle diameter had narrowed towards the finer sediment (2.5-3.0 Φ, Fig. 3.8). Percentage organic carbon had also increased, although not significantly (Fig. 3.7). The depths of the stations were not significantly different between the 1960s and 2001 for either the grab or the dredge (Table 4.1, Fig. 3.8). A greater amount of sheltered habitat is, however, available within the Bay in 2001 when compared to the 1960s (Fig 1.2).

Several changes were evident in terms of benthic macrofaunal community structure. The total species richness decreased in both dredge and grab analyses (Table 4.1), although only marginally so in the grab analyses. The greatest decrease in the number of species was in Polychaeta. In the dredge samples the number of species per sample decreased, but not in the grab samples. This was thought to be the result of using grabs of different sizes and being unable to compensate for that difference in terms of number of species. A comparison of abundance measures was only possible in the grab analysis because only this method was quantitative. Both total abundance and number of individuals per sample decreased from the 1960s to 2001.

Table 4.1: Comparison of results of Chapters 2 and 3, indicating the main changes in the benthic communities between the 1960s and 2001

	Results	
	Dredge	**Grab**
Physical Characteristics		
Sediment		
% Gravel	----------	Decreased
% Sand	----------	Unchanged
% Mud	----------	Increased
Mean sand particle	----------	Shift to finer sediment
diameter range		Range narrowed
% Organic Carbon	----------	Increased (not stat. sign.)
Depth range sampled	Unchanged	Unchanged
Habitat categories		
Sheltered	Increased	Increased
Exposed	Decreased	Decreased
Biological characteristics		
Diversity and abundance		
Total species richness	Decreased	Decreased
Total abundance	----------	Decreased
# species per sample	Decreased	Unchanged
# indivs per sample	----------	Decreased
Feeding categories		
Scavengers and Predators	Unchanged	Increased (not stat. sign.)
Suspension-feeders	Unchanged	Decreased (not stat. sign.)
Deposit-feeders	----------	Decreased (not stat. sign.)
Communities	Old distinctively different from new	Old distinctively different from new
Cluster Grouping		
1960s	2 groups - cover entire sampling area	1 group - covers entire sampling area
2001	2 groups – divided into Big Bay and Small Bay	3 groups- cover specific areas of the Bay Group 4 covers Big Bay and the area outside Saldanha Bay Groups 2 & 3 cover both Small and Big Bays

The abundance of scavengers and predators remained unchanged over the time span in the dredge analysis, but increased in the grab analysis (Table 4, Table 3.2). Suspension-feeder abundance remained unchanged in the dredge analysis, but decreased in abundance in the grab analyses. Deposit-feeders were poorly represented in the dredge analyses, decreased in abundance in the grab analyses. Most distinguishing species differ between grab and dredge analyses; only four species were shared between the two techniques (highlighted by the SIMPER analyses). Two of these showed the same trend and two showed opposite trends.

Benthic communities clearly differed between the 1960s and 2001 in both the dredge and grab analysis (Table 4.1, Figs 2.5, 2.6, 3.5 and 3.6). There was no overlap in the communities from the two time periods and ANOSIM recorded that the difference was highly significant ($p<0.001$). The community grouping in the 1960s tended to include stations from both Small and Big Bays (Fig. 3.9, Table 4.1). The dredge samples in 2001, however, clearly indicated a separation of the communities of Big Bay from those of Small Bay (Fig. 2.7). This was, however, not the case for the grab samples. Although one group was limited to Big Bay and the area next to the causeway facing the open ocean, the other two groups contained samples from both Big and Small Bays.

SALDANHA BAY DISCUSSION

The overall results will now be discussed in terms of the postulates above (see Chapter 1):

Postulate 1: A shift towards finer sediments (i.e. a narrowing of the range of sediment particle diameter)

Finer sediment was observed in 2001 than in the 1960s, the mean sand particle diameter having a narrower range (2.5-3.0Φ) than before (1.0-3.0 Φ). The percentage gravel decreased considerably, while the percentage mud increased, particularly at Station 8 next to the ore jetty in Small Bay.

Postulate 2: A greater organic load

In general the percentage organic carbon increased in 2001, although not significantly so. The greatest increase appeared to be around the ore jetty. This shift towards finer sand and mud, and the increase in organic carbon has been observed in a previous study by Monteiro *et al.* (1999).

Postulate 3: Reduced diversity and abundance of the benthos

In terms of the biology and ecology of the benthic communities, the diversity in dredges and abundance in both dredges and grabs were clearly reduced in 2001.

Postulate 4: New (different) benthic communities

The benthic communities were dramatically different between the 1960s and 2001 as a result of the different species composition.

Postulate 5: Greater differences between communities as Small and Big Bays diverged

A greater spatial differentiation between communities was observed in 2001 than in the 1960s. In the grab analysis, a single community existed in the 1960s, but in 2001, the same stations formed three very different communities. Similarly, the dredge analysis indicated two communities in the 1960s, each covering the entire span of Saldanha Bay, whereas in 2001, two communities were observed, but one was restricted to Small Bay and the other to Big Bay.

Postulate 6: Increased abundances of deposit-feeders, scavengers and predators and decreased abundances of suspension-feeders.

A shift was also observed in the feeding types in the form of increased abundance of scavengers and predators, and a decrease in the suspension-feeders and deposit-feeders. The deposit-feeders did not conform to postulate 6, contradicting the findings of previous studies, but the decrease in suspension-feeders is in agreement with previous studies (Jackson & McGibbon 1991, Bickerton 1999, Stenton-Dozey *et al.* 1999, 2000).

Thus all six postulates were, mostly, supported by the results of this study.

The methods used in this study are exploratory, not experimental, thus the cause of the observed changes cannot be ascertained. Three possible explanations have, however, been proposed for the changes observed during this study, namely methodological error, natural fluctuations and random settlement, and anthropogenic activities. In light of the overall changes observed above, the likelihood of each explanation will be discussed in further detail below.

Methodological error could not explain the marked changes observed during this study, as the error would have affected only a few of the smaller species in the dredge samples, and could only have resulted in an underestimate of the species diversity in the old grab samples. The results, therefore, are conservative.

Although all the postulates were met, it is not possible to disregard natural fluctuation as a possible explanation, because no studies have been done to investigate the natural fluctuations in the subtidal benthic communities of Saldanha Bay. Benthic communities are known to fluctuate with environmental changes, in addition to the variation that results from recruitment and settlement (Gray 1981). Random recruitment and settlement would add to the patchy distribution of communities within a particular period, but it is unlikely that it would be the cause of the differences in community over the 30-year period. It is known that the temperature and salinity in the Bay fluctuate annually and seasonally (Monteiro *et al.* 1990), but it has not been established if the benthic communities in the Bay follow similar cycles. Since this is a long-term study, long-term cycles may also be affecting the benthic communities, but there is no way to determine if that is the case.

The main physical process that affects the sediment in Saldanha Bay is the wave action (Monteiro *et al.* 1999). The wave action regime in Saldanha Bay has clearly changed in a manner that can be directly linked to the creation of the harbour, rather than being attributable to any natural fluctuation. Changes in the sediment between the 1960s and 2001 are most parsimoniously explained as being due to the changed wave regime. Before the development of the harbour the wave dispersal and sediment composition were in a stable equilibrium (Flemming 1977), which was disturbed by the harbour. After the construction of the harbour the sediment is believed to have evolved a new equilibrium and to be stable again (PMS Monteiro, pers. comm.). Other changes in the sediment, including organic loading have been clearly linked to the development of mariculture (Monteiro *et al.* 1999, Stenton-Dozey *et al.* 1999, 2001), fish factories (Newman & Pollock 1973, Christie & Moldan 1977), and metal processing and export (Monteiro *et al.* 1999). Thus, physical changes on the Bay are most obviously explained by anthropogenic effects, not natural fluctuations. There are no known natural fluctuations in physical conditions that would have altered the wave regime or sediment composition in the Bay to the extent that has occurred over the time span considered. As benthic communities are closely linked to the sediment (Gray 1981), changes in their composition can logically be associated with changes in the wave regime and sediment.

GENERAL DISCUSSION

Comparison of sampling resolutions

It was interesting to note that the dredge- and grab analyses showed the same patterns in most aspects of diversity, benthic communities and feeding types. However, a more in-depth study was possible with the grab data than the dredge, because of the semi-quantitative nature of dredge sampling. Consequently, certain biological and sedimentary characteristics were only considered for the grab samples. For instance, environmental factors were superimposed on grab MDS ordinations (Figs 3.7 and 3.8), because there was a close link between the grab samples and the sediment samples. The communities were different between the 1960s and 2001 as sampled by both methods, but the grouping of the stations also differed between the periods. Although the dredge sampling method gives a more general overview of the changes in the Bay, the grab samples provide a more site-specific perspecitive.

Field (1971) suggested that dredge sampling would be more useful for zoogeographical studies in defining faunistic regions over a wide area, whereas quantitative grab sampling would be more useful if detailed study was required. Field proposed that grab and dredge samples from a single station should be used together to provide a clearer idea of benthic communities. Because the dredge samples mostly epifauna and the grab samples mostly infauna (Holme & McIntyre 1971) the two methods compliment each other, giving us fuller knowledge of the benthic macrofauna. The combination of the two methods was, for instance, used in a study of the benthos off North Carolina (Day *et al.* 1971).

Recently, Hewitt *et al.* (1998) investigated the effect of increasing sampling resolution on the ability to detect the effects of large-scale processes on marine benthos. The sampling resolutions were, in ascending order, video transects, grab sampling and core sampling. Three hypotheses were proposed. Firstly, the loss of information at the finer scale inhibits our ability to detect relationships between large-scale (e.g. environment) processes and communities at coarser resolutions. Secondly, the information collected at the finer scale is noisy and obscures detection of large-scale relationships. Lastly, the same information is available from all three resolutions. Areas were sampled by all three methods and sediment samples were collected and analysed. The first two hypotheses were supported, but no support was found for the third hypothesis. It was found that the fine-scale dynamics could be irrelevant for detecting large-scale impacts but often they revealed relationships between the communities and physical variables. Results of ecological studies were found to be scale dependent. The results suggested that low-resolution sampling should not be undertaken alone, since information is lost when the resolution coarsens. The authors suggested that the best sampling regime would entail a combination of the sampling methods. The coarser resolutions would provide an overview, from which areas that needed more detailed sampling could be identified. Hewitt *et al.* (1998) therefore echoed the findings of Field (1971) in that the coarser resolution (namely dredge sampling) was thought to provide an overall idea of patterns, without focussing on the details.

Since the grab and dredge samples were not always collected at the same stations, a direct comparison of the effects of the resolutions is not possible. But one could consider whether the same areas generally clustered together. In the 1960s, two general communities arose out of the dredge samples, but only one group could be identified from the grab samples. The grab samples were not exceptionally similar to but also not particularly different from each other, thus all the samples were grouped together in the 1960s (Fig. 3.5, 3.6 & 3.9). The dredge samples of 2001 separated the Big Bay samples from the Small Bay samples, giving rise to two clear groups, whereas the grab samples of 2001 gave rise to three groups but the groups overlapped both Big and Small Bays. One grab sample group (Group 4, Fig. 3.9) consisted mostly of Big Bay samples. Since this group contained samples outside of Saldanha Bay, it may be assumed that those samples were the least affected by the anthropogenic activities within the Bay. I suspect that the other two groups, which cross Small and Big Bays, were a result of the similarity in sediment parameters and the patchy spatial distribution of communities. Thus, in the current study, it was found that the dredge samples more clearly showed a separation of Saldanha Bay benthic communities into Big and Small Bay communities than did the grab samples. Maybe the best way to consider overall effects is not to focus on the detail provided by the grabs, because the patchy distribution will affect the interpretation of those results. This fits in with the hypothesis proposed by Hewitt *et al.* (1998), which states that the information collected at the finer scale is noisy and may obscure detection of large-scale relationships.

Comparison of Saldanha Bay study with other long-term studies

In an attempt to unravel the link between the natural fluctuations of benthic communities and the changes caused by anthropogenic activities, it is important to compare my results with those of previous long-term studies, which take into consideration both natural and anthropogenic changes to communities.

Some studies have shown that as in the case of Saldanha Bay, the construction of a barrier, such as a harbour or a seawall, changes the hydrodynamics of the area (Bourcier 1996), and as a result changes the sedimentary environment (Ahn & Choi 1998). This then leads to changes in abundance and biomass as well as species numbers (Bourcier 1996, Ahn & Choi 1998). These barriers are usually permanent structures and once completed, the benthic communities surrounding it can establish a new stable equilibrium (Bourcier 1996). The expectation would then be that all samples collected before and after the harbour development in Saldanha Bay would differ in species composition and abundance. Previous studies have alluded to the differences between the benthic communities from before and after the Saldanha Bay harbour construction (Jackson & McGibbon 1991, Bickerton 1999). These studies have also shown that the benthic communities of Small and Big Bays were different. Since the period of harbour construction and the ore jetty and breakwater structures seem to be important in separating communities, it increases the likelihood that the shift in benthic community structure is mostly due to the harbour construction, not simply a natural cyclical change. However, most harbours were established long before environmental impact assessments became obligatory, so the extent of the changes in the benthic communities of those harbours are often unknown.

Studies of the effects of harbour construction activities in estuaries have failed to detect any changes in benthic communities (Anderson *et al.* 1981, Marques *et al.* 1993) because naturally variable physical conditions such as rapid water flow or siltation overshadowed the effects of development. This contradicts the results of the Saldahna Bay study. Since Saldanha Bay fauna are adapted to a narrow range of environmental conditions (e.g. temperature and salinity; Monteiro *et al.* 1990), not extremely variable physical conditions, as in the case of an estuarine environment, the anthropogenic activities are more likely to have a greater influence on the environment and benthic communities of the Bay.

It appears as though anthropogenic activities in themselves do not always have a negative effect on the environment, particularly when natural disturbance is great. Bourcier (1996) considered the combined effects of anthropogenic and climatic action on the benthic macrofauna in the Mediterranean. He found that the effects of anthropogenic factors were magnified by climatic changes. It therefore becomes imperative to understand the natural cycles in an environment before developing an area.

In other cases, attempts have been made to study the effects of more recent developments within the harbour such as pollution (Shim & Singh 1988, Wilson *et al.* 1998, Currie & Parry 1999). For instance, a study in Richards Bay Harbour, South Africa (Mackay & Cyrus 1998) indicated that the industrialisation of the area was responsible for the changes in the benthic communities. This study incorporated all anthropogenic effects in the harbour. It was difficult to pinpoint the major factor responsible for the changes observed within the harbour. Similarly in Saldanha Bay the rapid development of the Bay makes it difficult to pinpoint the major factor responsible for the observed changes.

Long-term studies in Port Phillip Bay, Australia indicated that the communities in two different habitats within the harbour became less distinctive over a 20-year period (Wilson *et al.* 1998, Currie & Parry 1999). In Saldanha Bay there seemed to be a more distinct separation between areas within the Bay, but the habitats were fairly similar in the 1960s.

At least three infaunal species were introduced in Port Phillip Bay, Australia over a 20-year period (Wilson *et al.* 1998, Currie & Parry 1999). One way of definitively deciding whether a change in a community is natural or due to anthropogenic activity is when introduced species are mainly responsible for those community changes. These are obviously a result of human activity, therefore it can conclusively be stated that human activity is responsible for the community changes. In Saldanha Bay the alien mussel species *Mytilus galloprovincialis* has been introduced (van Erkom Schurink & Griffiths 1990), which has invaded the rocky intertidal shore of most of the west coast, partially displacing the indigenous ribbed mussel *Aulacomya ater*. As yet no alien species have been identified in the soft sediment, although the International Maritime Organisation (IMO) is currently completing a study carried out in Saldanha Bay aimed at identifying any alien species in the Bay.

Another way of distinguishing between anthropogenic and natural effects is by observing the interannual fluctuations over the longest period available. Wilson *et al.* (1998) observed interannual fluctuations in community parameters (e.g. density and species richness) during the longest single data series available for Port Phillip Bay. They found that the magnitude of variation in community parameters across the 20-year time period was no greater than the variation observed in the longest single data series. The authors stated that the variability common to marine benthic communities raise problems for identifying possible causes, estimating ecological consequences and for designing monitoring strategies. As mentioned above, no studies have considered the natural variation within the communities of Saldanha Bay. However, the longest data series available was the old data, which covered a period of between 4 and 10 years. The results of this study have shown that the current benthic communties fall outside of the interannual fluctuations in the old data. Therefore, anthropogenic activities are the more likely cause of the observed changes. However, the natural temporal change cannot be excluded as a possible cause of the changes in Saldanha Bay benthic communities. Wilson *et al.* (1998) also provided a comparative table to show how their findings compared with other long-term studies. The comparison indicated that natural variation could easily account for massive changes in the biomass, abundance and species richness. The change could be as great as or even greater than that caused by anthropogenic activity. This variation makes the detection of long-term changes in benthic communities extremely difficult.

This theme was picked up by Gray & Christie (1983). They observed that 50% of general long-term trends was accounted for by the cyclic character of temperature variations and that many benthic species responded to long-term hydrographic cycles. Not all species showed a response though. Prediction of data may be incorrect if long-term cycles are not taken into account. But if cycles in excess of 100 years exist, then it becomes impossible to predict future trends in marine data. The conclusion drawn by Gray & Christie was that predicting long-term changes in benthic communities is an unattainable goal due to long period cycles. Cycles of different periods may interfere with each other, making the prediction virtually impossible.

From this it seems that historical ecological studies can only provide scenarios of changes that have occurred and have very little predictive power. This is however, not a negative thing. These historical case studies provide us with a wealth of knowledge of what could happen, so that precautions can be taken in designing for example harbours or sewage works or even mussel culture farms. This will promote a more environmentally friendly perspective in future anthropogenic activities affecting the ocean and many problems could be avoided. In addition to the historical case studies, a solid understanding of the natural variation in benthic communities within an area (i.e. in terms of interannual and seasonal variation) is imperative in distinguishing between anthropogenic and natural effects. Ideally a combination of before/after and control/impact sampling should allow us to disentangle anthropogenic effects from those of natural fluctuations.

In conclusion, it has been shown that over the last 30-40 years Saldanha Bay benthic macrofaunal communities have changed considerably. The cause could not be conclusively determined as the methods used were not investigative but explorative and there is not enough experimental evidence to distinguish between the two main possible causes, namely natural variation and anthropogenic activity. However, it is most likely that the changes observed in the benthos were the result of the anthropogenic activities, which continue to impact the Bay even today.

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Appendices

Appendix 1 A: Macrofaunal abundance data for dredge samples collected prior to harbour development (Christie & Moldan 1970s)

		Stations																														
Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
CNIDARIA																																
HYDROZOA																																
Bougainvillia maclovian		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Clytia hemisphaerica		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Nemertesia cymodocea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Podocoryne carnea		0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	0	1	1	0	0	1	0	0	0	0	0
ACTINARIA																																
Anthothoe stimpsoni		0	0	0	0	0	0	0	0	0	1	0	0	5	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Anthopleura michaelseni		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Bunodosoma capensis		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pseudactinia flagellifera		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
OCTOCORALIA																																
Virgularia schultzei		0	0	0	0	9	0	5	0	1	0	0	0	0	10	0	2	0	0	4	0	0	7	10	0	2	0	4	0	0	0	0
ANNELIDA																																
POLYCHAETA																																
Antinoe lactea		0	0	0	0	0	5	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampharete capensis		0	0	0	0	0	0	0	2	1	90	0	0	0	0	65	0	10	10	0	0	4	0	0	12	0	0	0	0	0	0	0
Aonides oxycephala		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asychis capensis		0	0	0	0	1	0	0	0	0	0	0	7	0	0	0	0	0	3	0	0	0	0	7	0	4	0	0	0	0	0	0
Timarete tentaculata	Cirriformia tentaculata	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timarete capensis	Cirriformia capensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	0
Caulleriella acicula		1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dorvillea neglecta		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra neopolitana capens		0	0	0	0	0	0	1	0	0	0	1	0	0	3	0	0	0	0	1	0	0	0	1	0	8	0	0	0	0	0	0
Euclymene sp.		0	0	0	0	0	1	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone foliosa		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Exogone dispar		0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerodorum gracile		0	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera tridactyla		0	0	3	1	9	4	4	0	6	2	0	0	3	10	1	0	1	4	0	0	14	0	20	1	1	0	6	0	0	0	0
Harmothoe aequiseta		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harmothoe fraser-thompson		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Harmothoe goreensis		0	0	0	0	0	0	0	0	1	3	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris heteropoda		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Lumbrineris meteorana		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Lumbrineris tetraura		2	1	3	0	0	0	0	0	10	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
POLYCHAETA (cont.)																																
Harmothoe waahli		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Mediomastus capensis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0
Marphysa purcellana		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myxicola infundibulum		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Marphysa capensis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys hombergi		8	2	0	0	4	5	0	0	0	3	0	0	0	6	0	0	0	0	0	0	0	1	4	0	0	0	2	0	0	0	0
Nephtys spaerocirrata		0	6	0	0	3	0	0	0	0	0	0	2	0	6	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Nereis operta		0	0	4	0	1	0	0	2	15	0	1	0	2	0	0	0	2	3	0	0	0	0	0	1	0	0	0	0	0	0	1
Nicolea macrobranchia		20	8	0	2	0	6	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	20	0	0	3	0	7	0
Nicolea venustuca		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notophylum splendens		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophelia agulhana		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orbinea angrapequensis		1	0	0	0	0	6	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Onuphis holobranchiata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Owenia fusiformis		0	0	0	0	0	0	3	0	0	0	0	0	12	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
Orbinia dubia		0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Paradoneis lyra		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Paralaeospira levinseni		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pectinaria capensis		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pherusa laevis		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa saldanha		0	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
Pherusa monroi		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa swakopiana		0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pholoe minuta		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pista foliigera		0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pista quadrilobata		0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Phyllochaetopterus socialis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodoce castanea		0	0	1	0	1	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platynereis dumerilii		0	0	0	4	0	0	0	0	0	2	2	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Platynereis australis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
Polynoe erythrotaenia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Polydora ciliata		0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora colonia		0	0	6	0	1	0	0	0	6	0	0	0	0	0	0	0	6	0	0	0	6	0	0	10	0	0	35	0	0	0	0
Potamilla reniformis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio sexoculata		0	6	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Prionospio saldanha		0	0	0	0	2	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Protomystides capensis		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterampharete luderitzi		0	0	0	0	14	0	0	0	0	0	0	1	0	10	0	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0	0
Scalisetosus pellucidus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Scolopolos dayi		0	0	0	0	17	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
POLYCHAETA (cont.)																																
Spermosyllis capensis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sthenelais boa		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Syllidia armata		0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syllis ferrugina		0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syllis variegata		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terebella pterochaeta		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Thalenessa oculata		0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trypanosyllis gemmulifera		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
SIPUNCULIDS + ECHIUROIDEA																																
Golfingia capensis		0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Phascolosoma japonicum		0	0	0	0	0	0	0	2	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Themiste stephensoni		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
CRUSTACEA																																
CIRRIPEDIA																																
Balanus algicola		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Balanus maxillaris		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
AMPHIPODA																																
Ampelisca anomala		0	0	12	0	0	0	0	0	35	0	0	7	11	12	3	0	879	0	0	0	12	0	0	12	0	0	0	0	0	0	0
Ampelisca brachyceras		0	0	8	0	0	0	2	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Ampelisca brevicornis		1	2	18	8	20	3	0	0	4	513	0	2	1	35	0	0	1	0	0	0	0	0	22	0	3	0	5	0	0	0	0
Ampelisca spinimana		0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aora kergueleni		0	0	0	0	0	0	0	0	0	11	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atylus guttatus		0	0	0	0	1	0	2	0	0	0	0	6	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Bathyporeia		0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	11	0	0	0	0	0	0
Caprella equilibra		0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceradocus rubromaculatus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cheiriphotus megacheles		0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chevalia aviculae		0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Corophium ascherusicum		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Cymadusa filosa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Euphridosine capensis		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hippomedon onconotus		0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	9	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hoplopleon medusarum		0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lembos hirsutipes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lembos jassopsis		0	0	1	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leucothoe richiardi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liljeborgia epistomata		0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
AMPHIPODA (cont.)																																
Lysianassa ceratina		3	13	0	0	0	1	0	0	0	3	0	0	2	0	6	5	2	5	0	0	0	0	4	1	1	0	0	12	0	5	0
Macra hamigera		0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macra inaequipes		0	0	0	0	0	0	0	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaluropus namaquensis		0	0	3	0	0	0	5	0	1	1	0	2	3	2	0	1	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0
Melita orgasmos		0	0	0	0	0	0	0	0	0	1	0	0	0	0	10	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Melita subchelata		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microlysias		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monoculodopsis longimana		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Orchomene plicata		4	1	0	0	1	250	0	0	0	33	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0
Paramoera capensis		13	0	3	1	3	20	0	0	0	46	0	11	1	15	63	70	1	0	0	0	0	0	80	4	9	10	0	8	0	0	0
Periocolodes longimanus		0	0	1	0	1	2	4	0	0	0	0	0	8	0	0	0	1	0	0	0	0	0	160	0	12	0	0	0	0	0	0
Photis longidactylus		0	0	0	0	0	0	0	0	0	0	0	0	0	59	0	0	1	0	0	0	0	0	65	2	12	0	0	0	0	0	0
Photis longimanus		0	0	0	0	0	0	0	12	21	0	0	0	0	0	0	0	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Photis uncinata		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phtiscia marina		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platyichnopos herdmani		0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
Polycheria atolli		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonoectes dellavallei		0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tryphosella africana		0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urothoe grimaldi		3	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
ISOPODA																																
Apanthura africana		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	0	0	0	0	0	0
Cirolana sulcata		0	0	0	0	0	0	0	0	0	6	0	0	0	0	3	3	6	0	0	0	0	0	0	0	0	0	0	10	0	0	0
Cirolana hirtipes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymodoce valida		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Exosphaeroma pallidum		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Exospaeroma varicolor		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Holidotea unicornis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Iais pubescens		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lanocira gardineri		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
Leptanthura laevigata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paridotea ungulata		1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6	4
Pontogeloides latipes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synidotea hirtipes		4	5	6	1	26	3	15	0	3	2	11	1	1	4	3	1	2	0	0	0	0	0	8	0	8	0	0	0	0	0	0
OSTRACODA																																
Euphilomedes sp. A		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphilomedes sp. B		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclasterope lobiancoi		0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
OSTRACODA (cont.)																																
Cylindroleberis kliei		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprindina sp.		0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprindina vanhoeffeni		0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	8	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Paradolaria dorsoserrata		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parasterope beta		0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rutiderma compressa		0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synasterope		0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PYCNOGONIDS																																
Discoarachne brevipes		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hannonia typica		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nymphon phasmatodes (Bohm)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Pycnogonium microps		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Tranystylum brevipes		0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
MACRURA																																
Palaemon pacificus	Palaemon peringueyi	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	10	3	0	0
Ogyrides saldanhae		0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jasus lalandii		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANOMURA																																
Anapagurus hendersoni		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Dardanus arrosor		0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diogenes brevirostris		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Diogenes costatus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porcellana streptocheles		1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia capensis		0	0	1	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
BRACHYURA																																
Atelecyclus rotundatus		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptodromiopsis spongiosa		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Dromidia hirsutissima		0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eudromidia hendersoni		0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Hymenosoma orbiculare		1	5	2	0	0	1	2	2	1	0	0	4	15	0	8	1	9	0	0	0	0	0	0	6	1	4	0	0	0	4	1
Nautilocorystes ocellata		0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philyra punctata		1	0	1	0	0	0	2	8	0	0	0	0	1	1	0	0	0	4	0	0	3	0	1	0	1	1	0	1	0	0	0
Pilumnoides perlatus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pseudodromia latens		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Zoacae larvae		0	0	0	0	0	0	7	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thaumastoplax spiralis		0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
CUMACEA																																
Bodotria sp.		0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Iphinoe africana		4	70	15	0	537	110	23	0	15	24	0	46	0	12	0	0	0	0	0	0	0	1	52	0	0	0	1	0	0	0	0
MYCIDACEA																																
Mycidopsis schultzei		0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCA																																
AMPHINEURA																																
Chaetpopleura papilio		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Chiton tulipa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OPISTHOBRANCHIATA																																
Arminia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philine aperta		1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0
PELECYPODA																																
Aulacomya ater		0	2	0	0	0	0	0	2	0	0	0	0	6	1	7	5	4	5	0	2	0	0	0	0	0	2	0	0	0	0	0
Carditella similis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Choromytilus meridionalis		2	0	0	0	0	0	0	0	0	0	0	0	4	0	1	3	0	0	0	3	0	0	3	0	2	2	0	3	8	0	6
Lasea rubra		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma juvs		0	0	0	0	0	12	3	0	1	2	0	2	0	0	0	6	2	2	0	0	2	0	0	2	2	0	0	0	0	0	0
Macoma ordinaria		0	1	3	0	3	0	0	0	0	0	0	0	6	6	0	0	0	0	0	1	0	0	8	1	0	0	19	0	0	0	0
Nucula nucleus		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phaxas decipiens	Phaxas pellucidus	0	0	0	0	2	0	0	0	2	2	0	2	0	2	0	0	0	0	0	0	0	0	2	0	0	0	6	0	0	0	0
Venerupis corrugatus	Tapes corrugatus	0	0	3	0	0	0	0	1	1	0	0	0	6	0	0	0	1	2	0	0	6	0	0	8	0	0	0	0	0	0	0
Tellina gilchristi		0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thracia alfredensis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Atrina squamifera		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PROSOBRANCHIATA																																
Afrocominella capensis		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amblychilepas scutella		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	1	0	3
Argobiccinum pustulosum	Argobuccinum argus	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	0	4	0	0	0	1	0	0	1	0	2	0	4	2	0	4
Bullia annulata		0	0	3	10	0	0	4	0	0	8	1	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0	0	0	0	0	0
Bullia laevissima		7	0	8	4	6	0	6	1	2	8	3	1	0	8	0	0	0	1	1	1	0	4	5	10	6	0	0	0	1	0	0
Calyptraea capensis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Calyptraea chinensis		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crepidula porcellana		0	0	1	0	0	0	0	1	0	0	0	0	4	0	2	0	0	0	4	0	0	0	0	0	0	0	0	3	0	0	1
Granula bensoni	Diluculum inopinatum	0	1	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Demoulia abbreviata		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
PROSOBRANCHIATA (cont.)																																
Dendrofissurella mutabilis	Fissurella mutabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Fusus verruculatus		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Gibbula zonata	Gibbula rosea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marginella bensoni		0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nassarius vinctus	Nassa analogica	0	0	0	0	0	0	0	0	0	0	0	1	6	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Nassarius speciosus	Nassa speciosa	8	1	12	0	6	0	30	2	8	8	8	6	4	6	8	4	8	6	59	39	8	6	18	2	8	0	0	0	0	1	1
Natica saldontiana		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Natica tecta	Natica genuana	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	7	0	0	1	0	0	0	1	0	0	0
Thais cingulata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Tricolia capensis		0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turritella carinifera		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turritella sanguinea		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOPODA																																
Sepia typica	Hemisepius typicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0	4	2	0
Inioteuthis capensis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHINODERMATA																																
ASTEROIDEA																																
Henricia ornata		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
OPHIUROIDEA																																
Amphiura capensis		0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0
Ophiotrix triglochis		0	0	3	0	0	0	0	2	0	0	0	0	0	0	0	14	4	0	0	0	4	0	0	8	0	6	0	2	0	0	1
Ophioderma leonis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
ECHINOIDEA																																
Parechinus angulosus		1	0	0	0	0	0	0	0	1	0	0	0	4	0	8	8	4	0	0	1	0	0	0	4	1	3	0	1	6	4	4
CRINOIDEA																																
Annametra occidentalis		0	0	12	0	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	14
HOLOTHUROIDEA																																
Penctata doliolum		1	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
Trychythyone insolens		2	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8	8	8	6
Taeniogyrus dayi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Thyone aurea		1	0	1	0	0	0	0	0	8	8	0	0	0	0	8	11	8	0	0	1	0	0	0	8	0	3	0	1	5	1	1
Epitonium kraussi		0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	4	5	6	7	8	9	10	11	12	13	15	17	19	23	24	25	26	27	29	30	31	34	35	36	38	39	40	41
TUNICATA																																
Trididemnum cerebriforme		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pyura stolonifera		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOCHORDATA																																
Branchiostoma		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
VERTEBRATA																																
PISCES																																
Chorisochismus dentex		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Clinus agilis		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Coryphopterus agulhensis		0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Torpedo marmorata		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Syngnathus acus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Appendix 1 B: Macrofaunal abundance data for grab samples collected prior to harbour development (Christie & Moldan 1970s)

Species	Previous species name	Stations 1	2	3	5	6	7	8	13	14	15	16	18	20	21	24	28	29	30	32	33	36	37
CNIDARIA																							
HYDROZOA																							
Obelia geniculata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
OCTOCORALIA																							
Virgularia schultzei		0	0	0	57	1	10	0	0	0	1	0	0	0	20	4	0	1	44	9	10	0	1
TURBELLARIA																							
Prosthiostomum drygalskii		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
ANNELIDA																							
POLYCHAETA																							
Ampharete capensis		0	0	0	0	0	0	2	0	446	0	0	255	0	0	1	1	0	0	0	0	0	0
Antinoe lactea		0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabella		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Aricidea longobranchiata		0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asychis capensis		0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	1	0	0	0
Caulleriella acicula		0	0	0	0	0	0	0	0	0	1	0	0	12	8	1	19	0	1	4	0	0	0
Timarete capensis	Cirriformia capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	3	0
Timarete tentaculata	Cirriformia tentaculata	0	0	0	0	0	0	0	0	1	0	0	52	0	0	0	0	0	0	0	0	0	0
Cirratulus gilchristi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Diopatra monroi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Diopatra neopolitana		0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0
Dorvillea rudolphi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Dorvillea neglecta		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone foliosa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Euclymene sp.		0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Eulalia sanguinea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Exogone dispar		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera tridactyla		0	0	1	4	0	1	0	2	3	2	6	0	5	2	19	0	0	7	3	4	4	0
Lepidonotus clava		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Lumbrineris tetraura		0	0	0	0	0	1	0	0	0	0	0	3	0	0	1	0	0	0	0	0	1	0
Lumbrineris heteropoda		0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Magelona capensis		0	0	0	0	0	4	0	6	0	9	0	0	16	0	0	66	4	1	8	4	0	0
Magelona papillicornis		0	0	0	1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus capensis		0	0	0	12	0	10	0	5	0	3	0	0	0	0	5	3	0	1	0	13	0	0
Myxicola infundibulum		0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naineris laevigata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
Nephtys spaerocirrata		0	1	0	1	7	9	0	21	0	1	0	0	5	0	0	14	4	0	0	19	12	0

Species	Previous species name	1	2	3	5	6	7	8	13	14	15	16	18	20	21	24	28	29	30	32	33	36	37
POLYCHAETA (cont.)																							
Nephtys capensis		0	0	0	0	0	1	0	2	0	0	0	0	2	0	0	0	0	0	2	0	0	0
Nereis lamellosa		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Nephtys hombergi		0	4	2	5	4	1	0	2	0	8	0	0	2	2	0	0	0	1	1	0	1	0
Nicolea macrobranchia		2	2	0	0	0	0	14	0	0	0	0	0	0	0	8	0	0	0	0	0	5	0
Nereis operta		0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0
Nerinides gilchristi		0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0	0	0	0
Orbinea angrapequensis		7	0	0	0	13	0	0	19	0	0	0	0	2	4	1	0	0	0	5	37	2	0
Owenia fusiformis		0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Paraonis lyra		0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
Pectinaria capensis		1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Pherusa swakopiana		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodoce castanea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Platynereis dumerilii		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	7	0
Polycirrus haematodes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Polydora hoplura		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polynoe scolopendrina		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Prionospio saldanha		1	0	0	64	0	317	0	13	0	106	0	0	14	3	0	25	20	13	3	15	0	0
Prionospio sexoculata		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Protomystides capensis		0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Sabellides luderitzi		0	0	0	15	0	0	0	0	0	94	0	0	0	0	0	3	0	13	0	0	0	0
Scolaricia dubia		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Scalisetosus pellucidus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Scolopolos dayi		0	0	0	46	0	0	0	0	0	28	0	0	0	0	0	0	0	6	0	0	0	0
Sigalion capense		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerodorum gracile		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Syllis armillaris		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0
Syllis prolifera		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Terebella schmardai		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	5	0
Tharyx dorsobranchialis		0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Thelepus pequenianus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Trypanosyllis gemmulifera		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0
NEMERTEA																							
Cerebratulus fuscus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	3	0	0	0
CRUSTACEA																							
CUMACEA																							
Bodotria vertebrata semicarinata		0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	4	0	0	0
Iphinoe africana		14	23	5	18	120	75	0	0	0	4	0	0	3	0	45	2	0	8	1	27	11	1
Iphinoe crassipes		0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	4	0	2	0

Species	Previous species name	1	2	3	5	6	7	8	13	14	15	16	18	20	21	24	28	29	30	32	33	36	37
MYSIDS																							
Gastrosaccus sp.		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
OSTRACODA																							
Cyclsterope lobiancoi		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0
Cypridina sp.		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Cycloleberis galatheae		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
AMPHIPODA																							
Ampelisca anomala		0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ampelisca brachyceras		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ampelisca brevicornis		0	3	0	21	3	1	0	24	0	5	0	0	13	1	1	2	0	5	0	1	180	4
Ampelisca diadema		0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampelisca palmata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	0
Ampelisca spinimana		0	0	0	4	0	0	0	10	0	1	0	0	0	2	0	0	0	0	0	0	0	0
Bathyporeia		1	0	0	0	0	0	0	2	0	1	0	0	18	0	2	6	0	0	7	1	0	0
Bathyporeia gracilis		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Caprella equilibra		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceradocus rubromaculatus		0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Euphariambus fallax		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hippomedon onconotus		0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Lembos jassopsis		0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liljeborgia epistomata		0	0	0	1	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1	2
Listriella saldanha		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lysianassa ceratina		0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	16	0	0	1
Lysianassa variegata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Maera grossimana		0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0
Maera vagans		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Megaluropus namaquensis		0	0	0	0	0	0	0	1	0	0	0	0	28	24	0	16	0	1	7	0	0	0
Melita orgasmos		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Melita subchelata		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Monoculodopsis longimana		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Orchomene plicata		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paramoera capensis		0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	2	0	2	1	0	70	0
Perioculodes longimanus		0	0	0	0	1	0	0	1	0	0	1	0	12	9	0	3	0	6	0	1	1	1
Photis longidactylus		0	0	0	0	0	0	0	0	8	0	0	0	0	3	1	0	0	0	3	0	0	0
Photis longimanus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Photis uncinata		0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	10	0	0	0	0
Platyichnopos herdmani		0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	1	0	0	0
Podocerus inconspicuus		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Siphonoetes dellavallei		0	0	0	26	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0
Tryphosella africana		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0

Species	Previous species name	1	2	3	5	6	7	8	13	14	15	16	18	20	21	24	28	29	30	32	33	36	37
AMPHIPODA (cont.)																							
Urothoe coxalis		0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Urothoe grimaldi		37	15	0	13	25	2	0	5	0	2	0	0	0	0	0	4	0	3	0	2	0	0
Urothoe pulchella		0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ISOPODA																							
Apanthura africana		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Cirolana sulcata		0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	1	0
Hollidotea sp.		0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Leptanthura laevigata		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Microarcturus similis		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Paradotea ungulata		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synidotea hirtipes		7	0	0	0	0	1	0	0	0	0	0	0	3	0	0	1	0	0	0	0	2	0
PYCNOGONIDS																							
Tanystylum brevipes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
MACRURA																							
Ogyrides saldanhae		0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BRACHYURA																							
Hymenosoma orbiculare		3	2	0	0	3	9	0	0	3	0	1	11	1	0	0	1	0	0	0	0	3	0
Nautilocorystes ocellata		0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Philyra punctata		0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	3	0
Pilumnoides perlatus		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Thaumastoplax spiralis		0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANOMURA																							
Anapagurus hendersoni		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Upogebia africana		2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MOLLUSCA																							
OPISTHOBRANCHIATA																							
Philine aperta		0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Arminia		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
PELECYPODA																							
Anomia monia squama		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Aulacomya ater		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Choromytilus meridionalis		3	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	8	0
Lasaea		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Lutraria lutraria		0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	5	6	7	8	13	14	15	16	18	20	21	24	28	29	30	32	33	36	37
PELECYPODA (cont.)																							
Macoma juvs		0	0	0	0	2	2	0	700	40	0	700	7	460	0	34	255	0	0	132	13	0	1
Macoma ordinaria		0	1	6	15	0	0	0	0	9	22	0	0	0	10	0	0	0	87	0	0	5	0
Phaxas decipiens	Phaxus pellucidus	0	0	0	0	0	3	0	4	0	4	1	0	18	2	0	2	0	0	4	3	0	0
Venerupis corrugatus	Tapes corrugatus	0	0	0	0	0	0	1	0	2	0	0	2	0	0	1	0	0	0	0	0	0	0
Tellina analogica		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Tellina gilchristi		1	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	4	1	0	0
PROSOBRANCHIATA																							
Argobuccinum pustulosum	Argobuccinum argus	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Bullia annulata		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Bullia laevissima		0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	1	1	8	0
Calyptraea chinensis		0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0
Crepidula porcellana		0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Granula bensoni	Diluculum inopinatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Fusinus ocelliferus	Fusus occelliferus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Nassarius vinctus	Nassa analogica	0	0	0	0	0	0	0	5	0	0	0	0	1	0	0	0	0	0	0	0	5	0
Nassarius speciosus	Nassa speciosa	1	0	1	4	0	2	0	0	1	0	2	1	2	0	2	1	0	6	0	2	10	0
Nassa muiri		0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natica tecta	Natica genuana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Natica saldontiana		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Gibbula zonata	Gibbula rosea	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHINODERMATA																							
OPHIUROIDEA																							
Amphipholis squamata		0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0
Amphiura capensis		0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
Ophiothrix triglochis		0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	10	0
ECHINOIDEA																							
Parechinus angulosus		0	0	0	0	0	0	0	0	1	0	0	7	0	0	0	0	0	0	0	0	0	0
HOLOTHUROIDEA																							
Penctata doliolum		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Thyone aurea		0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0	0	0	0	0	0	0
Pseudocnella insolens	Thyone insolens	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA																							
Branchiostoma		0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Species	Previous species name	1	2	3	5	6	7	8	13	14	15	16	18	20	21	24	28	29	30	32	33	36	37
VERTEBRATA																							
PISCES																							
Chorismochismus dentex		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Diplelogaster megalops		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Appendix 1C: Station data for Saldanha Bay dredge (D) and grab (G) samples prior to harbour development (Christie and Moldan 1970s).

Station No.	Cat. No.	Sampling Method	Date	Position	Depth (m)	Substrate	Grab volume (L)
1	336-337 338	D G	26/4/64	33° 0.3' S / 17° 57.9' E	6	Fine sand and shell	 9
2	222 223-224	G D	2/5/60	33° 0.5' S / 17° 57.5' E	6	Mud and stones	
3	229 230-231	G D	4/5/60	33° 0.6' S / 17° 59.6' E	8	Sand and Rock	
4	193	D	30/4/59	33° 0.7' S / 17° 58.4' E	8	Medium sand	
5	238-239 240-241	G D	5/5/60	33° 0.7' S / 18° 0.4' E	7	Medium sand	
6	290-291 292	D G	29/4/63	33° 1.0' S / 17° 57.9' E	9	Fine sand	 8
7	300-301 302-303	D G	30/4/63	33° 1.0' S / 17° 58.9' E	11	Shell	
8	332-333 334-335	D G	25/4/64	33° 1.25' S / 17° 59.7' E	13	Rock	
9	185+189	D	30/4/64	33° 1.1' S / 18° 0.3' E	9	Sand	
10	184+188	D	29/4/59	33° 1.5' S / 17° 58.8' E	13	Sand	
11	181	D	28/4/59	33° 1.6' S / 17° 59.3' E	13	Shell and sand	
12	199-200	D	1/5/59	33° 1.7' S / 18° 1.4' E	9	Sand	
13	276-279 280	D G	1/5/63	33° 1.9' S / 18° 00' E	17	Fine sand	 4
14	270-271	G	25/4/62	33° 2.1' S / 18° 0.1' E	15	Mud and shell	

Station No.	Cat. No.	Sampling Method	Date	Position	Depth (m)	Substrate	Grab volume (L)
15	225-226 227-228	G D	3/5/60	33° 2.2'S / 18° 1.4' E	11	Fine sand	
16	299	G	30/4/63	33° 2.5' S / 17° 57.6' E	26	Sand and shell	
17	182,183+187	D	29/4/59	33° 2.5' S / 17° 58.7' E	13	Coarse sand and shell	
18	304-305	G	30/4/63	33° 2.5' S / 17° 58.9' E	20	Coarse shell	2
19	190-192	D	30/4/59	33° 2.5' S / 17° 59.5' E	18	Shell and coarse sand	
20	293-294	G	29/4/63	33° 2.5' S / 17° 59.7' E	18	Sand	6
21	255-256	G	22/4/62	33° 2.8' S / 17° 59.2' E	22	Fine sand	
22	275	D	22/4/62	33° 2.8' S / 18° 0.1' E	17	Sand	
23	174,175+186	D	27/4/59	33° 2.8' S / 18° 0.6' E	15	Shell, sand and rocks	
24	348-349 350-351	D G	29/4/64	33° 2.9' S / 18° 1.6' E	13	Shell and coarse sand	 8
25	135	D	6/5/54	33° 3' S / 17° 58.6' E	11	Sand	
26	136	D	6/5/54	33° 3' S / 18° 0.5' E	8	Sand	
27	176-177	D	27/4/59	33° 3' S / 18° 0.9' E	15	Shelly sand and rocks	
28	311-312	G	1/5/63	33° 3.3' S / 17° 59.3' E	22	Fine sand	6
29	339 340	D G	27/4/63	33° 3.4' S / 18° 2.0' E	7.5	Fine sand and shell	 4
30	210-211 212-213	G D	1/5/60	33° 3.5' S / 18° 1.5' E	9	Fine sand	
31	178-179	D	28/4/59	33° 3.6' S / 18° 0.4' E	15	Shelly sand and rocks	
32	306-307	G	30/4/63	33° 3.7' S / 17° 58.5' E	20	Fine sand	4
33	308-309	G	30/4/63	33° 3.7' S / 18° 0.7' E	13	Mud	
34	346-347	D	28/4/64	33° 3.9' S / 18° 0.8' E	11	Fine sand	
35	132-133	D	26/3/53	33° 4.0' S/ 17° 59.3' E	8	Rock	

Station No.	Cat. No.	Sampling Method	Date	Position	Depth (m)	Substrate	Grab volume (L)
36	232 233-235,246	D G	4/5/60	33° 4.1' S / 17° 59.7' E	7-13	Sand	
37	272	G	21/4/62	33° 4.2' S / 18° 1.4' E	9	Fine sand	
38	130-131	D	9/4/53	33° 4.6' S / 18° 0.6' E	4	Sand	
39	137	D	6/5/55	33° 4.8'S / 18° 0.3' E	8	Sand and rock	
40	143 258	D G	28/4/57	33° 5.2' S / 18° 1.1'E	3-4	Sand	
41	145	D	28/4/57	33° 5.0' S / 18° 0.4' E	4	Sand	

Appendix 2 A: Coded macrofaunal abundance data of dredge samples from the 1960s and 2001 surveys, used in this study.

Species	O7	O8	O10	O13	O15	O19	O23	O24	O27	O31	O34	O36	N7	N8	N10	N13	N15	N19	N23	N24	N27	N31	N34	N36
CNIDARIA																								
Anthothoe stimpsoni	0	0	1	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Anthopleura michaelseni	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bunodactis reynaudi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Virgularia schultzei	2	0	0	0	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
POLYCHAETA																								
Antinoe lactea	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timarete tentaculata	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timarete capensis	0	0	0	0	0	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Cirratulus gilchristi	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra monroi	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra neopolitana capens	1	0	0	0	2	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerodorum gracile	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycera tridactyla	2	0	1	2	3	0	1	2	4	1	1	2	0	0	0	0	0	2	2	0	1	0	0	2
Harmothoe goreensis	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidonotus clava	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris heteropoda	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris meteorana	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris tetraura	0	0	0	0	0	0	0	2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Marphysa purcellana	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marphysa capensis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Naineris laevigata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys hombergi	0	0	2	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
Nephtys spaerocirrata	0	0	0	0	3	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Nereis operta	0	1	0	1	0	0	1	2	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Nereis pelagica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Nicolea macrobranchia	0	0	0	2	0	0	0	1	0	0	5	3	0	0	0	1	0	2	1	0	0	0	0	1
Nicolea venustula	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orbinea angrapequensis	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Onuphis holobranchiata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Scolaricia dubia	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectinaria capensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa laevis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa saldanha	0	0	0	3	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	O7	O8	O10	O13	O15	O19	O23	O24	O27	O31	O34	O36	N7	N8	N10	N13	N15	N19	N23	N24	N27	N31	N34	N36
POLYCHAETA (cont.)																								
Pherusa monroi	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa swakopiana	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Platynereis dumerilii	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Polycirrus haematodes	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Potamilla reniformis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Sigalion capense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Sthenelais boa	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	3	0	2	0	1	1
Syllidia armata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terebella pterochaeta	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thalenessa oculata	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0
Thelepus pequenianus	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Terebella schmardai	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
SIPUNCULIDA	0	1	0	3	0	0	1	1	0	1	0	0	0	0	0	2	0	0	1	0	0	2	0	1
CRUSTACEA																								
Balanus algicola	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanus maxillaris	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paridotea ungulata	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Paridotea reticulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0
Discoarachne brevipes	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hannonia typica	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nymphon phasmatodes (Bohm)	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pycnogonium microps	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tranystylum brevipes	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Palaemon peringueyi	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	1	4	5	0
Jasus lalandii	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	1	3	3
Anapagurus hendersoni	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diogenes costatus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upogebia capensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paguristes gamianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Callianassa rotundicaudata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Atelecyclus rotundatus	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptodromiopsis spongiosa	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dromidia hirsutissima	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1
Eudromidia hendersoni	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	O7	O8	O10	O13	O15	O19	O23	O24	O27	O31	O34	O36	N7	N8	N10	N13	N15	N19	N23	N24	N27	N31	N34	N36
CRUSTACEA (cont.)																								
Hymenosoma orbiculare	1	1	0	4	0	1	3	0	0	3	1	2	0	0	0	4	0	3	4	4	4	0	2	3
Nautilocorystes ocellata	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philyra punctata	1	3	0	1	1	0	0	2	2	0	1	2	1	0	0	0	0	2	0	3	0	0	1	0
Pilumnoides perlatus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Crab sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Ovalipes trimaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Goniplax angulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1
Mycidopsis schultzei	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterygosquilla armata capensis	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	1	0	0	0	1	0	2
MOLLUSCA																								
Chaetpopleura papilio	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armina	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Philine aperta	0	0	0	0	0	0	3	1	0	0	0	0	1	0	0	2	0	1	0	1	1	0	0	1
Nudibranch sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Anomia monia squama	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Aulacomya ater	0	1	0	3	1	2	2	2	0	0	0	2	0	0	0	5	0	0	0	0	1	0	0	0
Choromytilus meridionalis	0	0	0	2	0	2	0	0	0	0	1	2	1	0	0	1	0	3	0	0	0	0	3	0
Macoma ordinaria	0	0	0	3	3	0	0	0	0	1	0	4	0	0	0	1	0	0	1	0	0	2	0	3
Mytilus galloprovincialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Nucula nucleus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phaxus pellucidus	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Venerupis corrugatus	0	1	0	3	0	0	1	1	3	3	0	0	0	0	0	0	0	2	0	0	0	0	0	3
Tellina gilchristi	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thracia alfredensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atrina squamifera	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kraussina rubra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Carditella rugosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Afrocominella capensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Argobuccinum pustulosum	0	0	0	2	0	0	2	0	1	1	0	0	0	0	0	1	0	0	1	0	1	2	2	0
Bullia annulata	2	0	3	0	0	0	0	1	0	2	0	2	0	0	0	0	0	1	1	1	0	1	0	0
Bullia laevissima	3	1	3	0	3	0	0	1	0	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Burnupena papyracea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Calyptraea chinensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clionella sinuata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0
Crepidula porcellana	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	4	0

Species	O7	O8	O10	O13	O15	O19	O23	O24	O27	O31	O34	O36	N7	N8	N10	N13	N15	N19	N23	N24	N27	N31	N34	N36
MOLLUSCA (cont.)																								
Granula bensoni	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Demoulia abbreviata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fusus verruculatus	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fusinus occelliferus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Gibbula rosea	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nassarius vinctus	0	0	0	3	0	1	0	0	0	0	1	3	0	0	2	1	0	0	0	0	0	0	0	1
Nassarius plicatellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Nassarius speciosus	5	1	3	2	3	2	3	3	3	1	3	3	4	4	5	4	1	5	5	5	5	5	0	3
Natica saldontiana	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natica tecta	0	0	0	0	0	0	1	0	3	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Nucella squamosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Nucella cingulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Turritella carinifera	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turritella sanguinea	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sepia typica	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	2	2	0	2
ECHINODERMATA																								
Henricia ornata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipholis squamata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Amphiura capensis	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiothrix fragilis	0	1	0	0	0	4	2	0	2	3	0	3	0	0	0	0	0	0	0	0	0	0	2	1
Parechinus angulosus	0	0	0	2	0	3	2	0	0	2	1	0	1	0	0	1	0	1	0	0	0	0	2	0
Annametra occidentalis	0	2	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	5	0	2	0	3	0
Penctata doliolum	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0
Pseudocnella insolens	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0	0
Thyone aurea	0	0	3	0	0	4	3	0	0	3	0	0	0	0	0	0	0	0	2	0	2	0	2	1
Epitonium kraussi	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CEPHALOCHORDATA																								
Branchiostoma	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PISCES																								
Chorisochismus dentex	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Coryphopterus agulhensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caffrogobius saldanha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Caffrogobius agulhensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1

Species	O7	O8	O10	O13	O15	O19	O23	O24	O27	O31	O34	O36	N7	N8	N10	N13	N15	N19	N23	N24	N27	N31	N34	N36
PISCES (cont.)																								
Syngnathus acus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	5
Cancelloxus burrelli	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Parablennius cornutus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Narke capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Appendix 2 B: Macrofaunal abundance data of grab samples from the 1960s and 2001 surveys used in this study (old data was multiplied by two).

Species	O7	O8	O13	O14	O15	O16X	O20	O21	O24	O28	O32X	O33	O36	N7A	N7B	N8A	N8B	N13A	N13B	N14A	N14B
OCTOCORALIA Pennatulacea																					
Virgularia schultzei	20	0	0	0	2	0	0	40	8	0	18	20	8	0	1	0	0	0	0	14	3
ACTINARIA																					
Anthothoe stimpsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0
Anthopleura michaelsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anemone sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Burrowing anemone sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POLYCHAETA																					
Ampharete acutifrons	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0	0	0	0	77
Ampharete capensis	0	4	0	892	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Ampharete sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Antinoe lactea	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aphroditidae sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aphroditidae sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabella iricolor	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Asychis capensis	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Caulleriella acicula	0	0	0	0	2	0	24	16	2	38	8	0	0	0	0	0	0	0	0	0	0
Timarete capensis	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Timarete tentaculata	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra monroi	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0
Diopatra neopolitana	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Dorvillea neglecta	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Dorvillea rudolphi	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Eteone foliosa	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Euclymene sp.	2	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0
Glycera tridactyla	2	0	4	6	4	12	10	4	38	0	6	8	12	1	0	0	0	0	1	1	11
Lumbrineris tetraura	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris heteropoda	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelona capensis	8	0	12	0	18	0	32	0	0	132	16	8	0	0	0	0	0	0	0	0	0
Magelona papillicornis	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mediomastus capensis	20	0	10	0	6	0	0	0	10	6	0	26	26	0	0	0	0	0	0	0	0
Myxicola infundibulum	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naineris laevigata	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Nephtys spaerocirrata	18	0	42	0	2	0	10	0	0	28	0	38	0	0	4	2	0	0	0	2	6
Nephtys capensis	2	0	4	0	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Nereis lamellosa	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Nephtys hombergi	2	0	4	0	16	0	4	4	0	0	2	0	4	1	3	0	2	4	2	6	4

Species	O7	O8	O13	O14	O15	O16	O20	O21	O24	O28	O32	O33	O36	N7A	N7B	N8A	N8B	N13A	N13B	N14A	N14B
POLYCHAETA (cont.)																					
Nerinides gilchristi	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orbinea angrapequensis	0	0	38	0	0	0	4	8	2	0	10	74	0	0	0	0	0	5	9	145	0
Owenia fusiformis	0	0	0	20	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Paraonis lyra	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0
Pectinaria capensis	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa swakopiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodoce castanea	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Platynereis dumerilii	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora sp.	0	0	0	0	0	0	0	0	0	0	0	0	70	171	176	0	0	0	0	0	0
Prionospio saldanha	634	0	26	0	212	0	28	6	0	50	6	30	0	0	0	0	0	0	0	0	0
Prionospio sexoculata	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	5	0	0	0	0
Protomystides capensis	0	0	2	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Sabellides luderitzi	0	0	0	0	188	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Scolaricia dubia	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scolopolos dayi	0	0	0	0	56	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
Sigalion capense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tharyx dorsobranchialis	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Terebellid	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Polychaete sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	0	0	0	0	0	0
Polychaete sp. F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEMERTEA																					
Cerebratulus fuscus	0	0	0	0	0	0	0	0	0	6	6	0	0	0	0	0	0	0	0	0	0
CRUSTACEA																					
CUMACEA	150	0	0	0	8	6	8	0	90	6	18	54	2	0	0	0	0	0	0	0	0
MYSIDS																					
Gastrosaccus sp.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
OSTRACODA	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0
AMPHIPODA																					
Ampelisca anomala	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampelisca brachyceras	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Ampelisca brevicornis	2	0	48	0	10	0	26	2	2	4	0	2	10	0	0	0	0	8	8	13	14
Ampelisca diadema	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	3	35	512	496	3	9
Ampelisca spinimana	0	0	20	0	2	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Aora gibbula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7	0	0
Atylus guttatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bathyporeia	0	0	4	0	2	0	36	0	4	12	14	2	0	0	0	0	0	0	0	0	0
Bathyporeia gracilis	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium acherusicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	O7	O8	O13	O14	O15	O16	O20	O21	O24	O28	O32	O33	O36	N7A	N7B	N8A	N8B	N13A	N13B	N14A	N14B
AMPHIPODA (cont.)																					
Ceradocus rubromaculatus	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphariambus fallax	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hippomedon normalis	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	1	0	0	0	0
Hippomedon onconotus	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lembos jassopsis	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leucothoe richiardi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liljeborgia epistomata	10	0	4	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	4	0	0
Listriella saldanha	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Lysianassa ceratina	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0
Maera grossimana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Megaluropus namaquensis	0	0	2	0	0	0	56	48	0	32	14	0	0	0	0	0	0	0	0	0	0
Monoculodopsis longimana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paramoera capensis	0	0	0	0	0	0	4	0	0	4	2	0	0	0	6	0	0	0	0	0	0
Perioculodes longimanus	0	0	2	0	0	2	24	18	0	6	0	2	0	0	0	0	0	0	0	0	0
Photis longidactylus	0	0	0	16	0	0	0	6	2	0	6	0	0	0	0	0	0	0	0	0	0
Photis uncinata	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platyichnopos herdmani	0	0	0	0	0	2	2	2	0	0	2	0	0	0	0	0	0	0	0	0	0
Podocerus inconspicuus	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonoetes dellavallei	0	0	0	0	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Tryphosella africana	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Urothoe coxalis	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urothoe grimaldi	4	0	10	0	4	0	0	0	0	8	0	4	0	0	0	0	0	0	0	0	0
Corophiidae sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
ISOPODA																					
Anthelura remipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirolana hirtipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hollidotea sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microarcturus similis	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synidotea hirtipes	2	0	0	0	0	0	6	0	0	2	0	0	0	0	0	0	0	0	0	0	1
STOMATOPODA																					
Pterysquilla armata capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Prawn sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Prawn sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prawn sp. C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BRACHYURA																					
Hymenosoma orbiculare	18	0	0	6	0	2	2	0	0	2	0	0	0	3	6	1	0	3	1	6	10
Nautilocorystes ocellata	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	4	3
Philyra punctata	0	0	0	2	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Species	O7	O8	O13	O14	O15	O16	O20	O21	O24	O28	O32	O33	O36	N7A	N7B	N8A	N8B	N13A	N13B	N14A	N14B
BRACHYURA (cont.)																					
Goniplax angulosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ovalipes trimaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crab sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	9	6	0	0
Crab sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
ANOMURA																					
Upogebia africana	0	2	0	0	0	0	0	0	0	0	0	0	0	105	120	0	0	0	0	0	0
Upogebia capensis	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
COPEPOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
PELECYPODA / Bivalves																					
Anomia monia squama	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Choromytilus meridionalis	0	0	0	0	0	0	0	2	0	0	0	0	0	3	9	0	0	0	0	0	0
Lutraria lutraria	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma spp.	4	0	1400	98	44	1400	920	20	68	510	264	26	38	14	2	0	0	1	2	0	0
Phaxas decipiens	6	0	8	0	8	2	36	4	0	4	8	6	12	0	0	0	0	0	0	5	2
Venerupis corrugatus	0	2	0	4	0	0	0	0	2	0	0	0	0	18	1	0	0	0	0	0	0
PELECYPODA (cont.)																					
Tellina analogica	0	0	0	0	0	0	0	0	0	0	0	0	0	6	3	0	0	0	0	1	0
Tellina gilchristi	0	0	0	12	0	0	0	0	0	0	8	2	0	0	0	0	0	0	0	0	0
Tellinid sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bivalve sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PROSOBRANCHIATA / Gastropods																					
Bullia annulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bullia laevissima	0	0	0	0	0	2	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
Calyptraea chinensis	0	0	0	0	0	0	0	0	2	0	0	0	0	5	0	0	0	0	0	0	0
Crepidula porcellana	0	0	0	0	0	0	0	0	2	0	0	0	0	0	16	0	0	0	0	0	0
Nassarius vinctus	0	0	10	0	0	0	2	0	0	0	0	0	0	38	1	1	0	10	10	2	0
Nassarius speciosus	4	0	0	2	0	4	4	0	4	2	0	4	0	18	25	0	2	6	5	6	2
Nassarius plicatellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	54	51	45	9	18
Nassa muiri	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gibbula zonata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropod sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	7	15	0	0	0	0	0	0
Gastropod sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OPHIUROIDEA / Echinodermata																					
Ophiothrix fragilis	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0

Species	O7	O8	O13	O14	O15	O16	O20	O21	O24	O28	O32	O33	O36	N7A	N7B	N8A	N8B	N13A	N13B	N14A	N14B
ECHINOIDEA /Echinodermata																					
Parechinus angulosus	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
HOLOTHUROIDEA /Echinodermata																					
Thyone aurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thyone insolens	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA																					
Branchiostoma	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHIUROIDEA																					
Ochaetostoma capense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	7	0	0

Species	N15A	N15B	N16A	N16B	N20A	N20B	N21A	N21B	N24A	N24B	N28A	N28B	N32A	N32B	N33A	N33B	N36A	N36B
OCTOCORALIA																		
Virgularia schultzei	25	24	3	6	2	2	4	8	0	0	34	4	11	19	2	0	0	0
ACTINARIA																		
Anthothoe stimpsoni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthopleura michaelsoni	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anemone sp. A	0	0	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	0
Burrowing anemone sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
POLYCHAETA																		
Ampharete acutifrons	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	4	0	0
Ampharete capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampharete sp. B	0	0	0	0	0	2	0	0	0	0	0	0	11	6	0	0	0	0
Antinoe lactea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aphroditidae sp. A	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Aphroditidae sp. B	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Arabella iricolor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Asychis capensis	0	0	0	0	0	0	0	0	0	0	1	4	0	0	1	0	0	0
Caulleriella acicula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Timarete capensis	0	0	0	0	0	0	0	6	0	0	0	2	0	5	0	0	0	0
Timarete tentaculata	0	0	315	696	2	2	3	0	60	34	2	0	13	101	0	0	0	0
Diopatra capensis	0	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra monroi	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	1	1
Diopatra neopolitana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dorvillea neglecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dorvillea rudolphi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eteone foliosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euclymene sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Glycera tridactyla	3	2	1	4	6	8	4	4	8	8	0	14	0	2	2	7	0	3
Lumbrineris tetraura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lumbrineris heteropoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelona capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Magelona papillicornis	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Mediomastus capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myxicola infundibulum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naineris laevigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys spaerocirrata	0	15	0	0	0	0	9	2	0	0	2	4	0	4	0	0	0	1
Nephtys capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereis lamellosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys hombergi	17	16	10	6	0	3	0	0	0	0	0	1	5	11	2	3	1	3
Nicolea macrobranchia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereis operta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nerinides gilchristi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	N15A	N15B	N16A	N16B	N20A	N20B	N21A	N21B	N24A	N24B	N28A	N28B	N32A	N32B	N33A	N33B	N36A	N36B
POLYCHAETA (cont.)																		
Orbinea angrapequensis	57	225	2	16	26	9	24	27	25	36	19	16	10	7	44	66	0	7
Owenia fusiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Paraonis lyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectinaria capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pherusa swakopiana	1	0	3	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Phyllodoce castanea	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0
Platynereis dumerilii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polydora sp.	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	50	0	0
Prionospio saldanha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prionospio sexoculata	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Protomystides capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sabellides luderitzi	0	0	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scolaricia dubia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scolopolos dayi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigalion capense	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Tharyx dorsobranchialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	8	0
Terebellid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Polychaete sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polychaete sp. F	0	0	0	0	0	0	0	2	0	0	0	0	14	10	0	0	0	0
NEMERTEA																		
Cerebratulus fuscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUSTACEA																		
CUMACEA	8	3	0	0	0	2	0	0	0	0	0	0	0	0	5	0	0	0
MYSIDS																		
Gastrosaccus sp.																		
OSTRACODA	0	0	0	0	0	0	0	0	1	3	0	0	1	1	0	2	0	1
AMPHIPODA																		
Ampelisca anomala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ampelisca brachyceras	0	0	1	2	1	0	0	0	0	0	0	1	0	1	0	0	0	0
Ampelisca brevicornis	6	4	1	2	25	3	2	0	0	0	11	10	4	25	80	0	0	25
Ampelisca diadema	0	0	1	0	1	6	0	0	0	0	1	1	1	3	5	3	37	36
Ampelisca spinimana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aora gibbula	0	0	0	0	0	0	0	0	0	0	9	1	0	0	0	0	0	10
Atylus guttatus	0	0	0	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Bathyporeia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bathyporeia gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corophium acherusicum	0	0	3	1	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Ceradocus rubromaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	N15A	N15B	N16A	N16B	N20A	N20B	N21A	N21B	N24A	N24B	N28A	N28B	N32A	N32B	N33A	N33B	N36A	N36B
AMPHIPODA (cont.)																		
Euphariàmbus fallax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hippomedon normalis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	10
Hippomedon onconotus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lembos jassopsis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leucothoe richiardi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Liljeborgia epistomata	0	0	0	0	0	0	1	0	0	0	0	4	0	0	5	0	0	0
Listriella saldanha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lysianassa ceratina	0	0	1	0	0	0	2	0	0	0	4	0	0	0	0	1	0	0
Macra grossimana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megaluropus namaquensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Monoculodopsis longimana	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Paramoera capensis	1	0	0	2	2	0	1	3	181	145	6	7	3	2	0	11	0	92
Perioculodes longimanus	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0
Photis longidactylus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Photis uncinata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Platyichnopos herdmani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Podocerus inconspicuus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonoetes dellavallei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tryphosella africana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urothoe coxalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urothoe grimaldi	0	4	0	0	4	0	5	0	0	0	1	0	3	1	0	0	0	0
Corophiidae sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ISOPODA																		
Anthelura remipes	0	0	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cirolana hirtipes	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Hollidotea sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microarcturus similis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synidotea hirtipes	1	4	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	1
STOMATOPODA																		
Pterysquilla armata capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Prawn sp. A	0	0	0	0	2	2	0	1	0	0	6	1	0	0	0	0	0	0
Prawn sp. B	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Prawn sp. C	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
BRACHYURA																		
Hymenosoma orbiculare	4	0	0	0	2	2	0	0	1	6	0	0	0	0	1	1	0	2
Nautilocorystes ocellata	7	5	0	1	0	3	0	0	0	0	1	1	0	0	1	0	0	0
Philyra punctata	0	0	0	0	0	0	0	0	5	10	2	1	0	0	0	0	0	0
Thaumastoplax spiralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Goniplax angulosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Species	N15A	N15B	N16A	N16B	N20A	N20B	N21A	N21B	N24A	N24B	N28A	N28B	N32A	N32B	N33A	N33B	N36A	N36B
BRACHYURA (cont.)																		
Ovalipes trimaculatus	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crab sp. A	0	1	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	1
Crab sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANOMURA																		
Upogebia africana	0	0	0	0	0	0	0	0	51	19	0	1	0	0	0	31	0	43
Upogebia capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COPEPOD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PELECYPODA																		
Anomia monia squama	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Choromytilus meridionalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lutraria lutraria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macoma spp.	0	6	1	0	1	0	1	3	1	0	3	4	0	0	0	2	8	3
Phaxas decipiens	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0
Venerupis corrugatus	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Tellina analogica	0	0	7	22	0	2	0	0	0	0	2	1	1	0	0	0	2	5
Tellina gilchristi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tellinid sp. A	0	0	0	0	0	0	2	0	0	1	0	0	0	3	0	0	0	0
Bivalve sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
PROSOBRANCHIATA																		
Bullia annulata	0	0	0	0	5	0	2	0	0	1	1	1	1	0	1	0	1	0
Bullia laevissima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calyptraea chinensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crepidula porcellana	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Nassarius vinctus	0	0	2	2	0	0	0	0	0	0	1	1	3	6	3	7	13	13
Nassarius speciosus	3	6	1	2	0	3	0	0	5	11	1	0	1	0	7	18	2	10
Nassarius plicatellus	0	0	24	91	0	0	0	0	1	0	2	8	4	94	6	13	24	48
Nassa muiri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gibbula zonata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropod sp. A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gastropod sp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
OPHIUROIDEA																		
Ophiothrix fragilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHINOIDEA																		
Parechinus angulosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	N15A	N15B	N16A	N16B	N20A	N20B	N21A	N21B	N24A	N24B	N28A	N28B	N32A	N32B	N33A	N33B	N36A	N36B
HOLOTHUROIDEA																		
Thyone aurea	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Thyone insolens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEMICHORDATA																		
Branchiostoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ECHIUROIDEA																		
Ochaetostoma capense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Appendix 2 C: Station data for Saldanha Bay dredge (D) and grab (G) samples collected in 2001 corresponding to those in Appendix 1C (Christie and Moldan 1970s).

Station No.	Sampling Method	Date	Position	Depth (m)	Substrate	Grab volume (L)
7	D G	14/2/2001	33° 1.0' S / 17° 58.9' E	10	Fine sand	18 + 20
8	D G	14/2/2001	33° 1.25' S / 17° 59.7' E	14	Fine sand	35
10	D	14/2/2001	33° 1.5' S / 17° 58.8' E	15	Fine sand	
13	D G	14/2/2001	33° 1.9' S / 18° 00' E	16	Fine sand	22
14	G	14/2/2001	33° 2.1' S / 18° 0.1' E	15	Fine sand	9 + 12
15	D G	14/2/2001	33° 2.2'S / 18° 1.4' E	13	Fine sand	7 + 10
16	G	14/2/2001	33° 2.5' S / 17° 57.6' E	27	Fine sand	3
19	D	14/2/2001	33° 2.5' S / 17° 59.5' E	20	Limestone lumps, shelly sand	
20	G	14/2/2001	33° 2.5' S / 17° 59.7' E	19	Fine sand	5 + 11
21	G	12/2/2001	33° 2.8' S / 17° 59.2' E	19	Fine sand	6 + 10
23	D	14/2/2001	33° 2.8' S / 18° 0.6' E	15	Sandy mud	
24	D G	13/2/2001	33° 2.9' S / 18° 1.6' E	13	Medium sand	13 + 6
27	D	14/2/2001	33° 3' S / 18° 0.9' E	14	Sand	
28	G	13/2/2001	33° 3.3' S / 17° 59.3' E	20	Fine sand	4 + 5
31	D	14/2/2001	33° 3.6' S / 18° 0.4' E	16	Limestone, rock	
32	D G	12/2/2001	33° 3.7' S / 17° 58.5' E	18-20	Fine sand	7
33	G	14/2/2001	33° 3.7' S / 18° 0.7' E	16	Fine sand	11 + 12
34	D	14/2/2001	33° 3.9' S / 18° 0.8' E	15	Rock	
36	D G	12/2/2001	33° 4.1' S / 17° 59.7' E	13-17 13	Fine sand	15 + 17

Appendix 2 D: Sediment data for Saldanha Bay grab samples for both the 1960s and 2001.

Station no.	Percentage Gravel		Percentage Sand		Percentage Mud		Mean Particle Diameter		Percentage Organic Carbon	
	1960s	2001	1960s	2001	1960s	2001	1960s	2001	1960s	2001
7	15.00	22.16	80.00	58.11	5.00	19.72	3.00	2.60	0.40	0.20
8	20.00	0.00	75.00	5.00	5.00	95.00	3.00	2.79	0.40	2.20
13	0.00	7.07	99.00	68.58	1.00	24.35	3.00	2.74	0.40	0.80
14	5.00	0.08	85.00	95.55	10.00	4.37	2.00	2.69	0.50	0.40
15	10.00	0.10	85.00	91.79	5.00	8.12	2.00	2.54	0.30	0.20
16	43.50	0.01	56.00	97.79	0.50	2.20	1.00	2.64	0.30	0.20
20	53.00	0.06	46.00	97.71	1.00	2.22	2.00	2.78	0.40	1.00
21	72.00	0.09	27.00	96.42	1.00	3.49	1.00	2.53	0.40	1.00
24	5.00	27.66	90.00	58.56	5.00	13.78	2.00	1.95	0.30	0.20
28	20.00	1.44	75.00	96.48	5.00	2.08	3.00	2.67	1.00	0.50
32	74.00	0.00	25.00	98.80	1.00	1.20	2.00	2.79	1.00	0.20
33	40.00	7.31	55.00	85.48	5.00	7.20	2.00	2.97	0.50	0.40
36	39.00	0.30	60.00	84.26	1.00	15.44	2.00	2.49	0.30	1.00