



Saldanha Bay
Water Quality Trust

THE STATE OF SALDANHA BAY AND LANGEBAAN LAGOON 2015

**Technical Report
September 2015**

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FOREWORD

*"I think I first fell in love with Saldanha Bay as a schoolboy studying maps of South Africa.
It appeared such a uniquely wonderful place."*

(The late Dr. Martin Fourie, 2001)

Unlike the late Dr. Fourie, in our modern technical age, one can view the area on Google Earth and it is probably even more impressive than what he would have experienced by perusing a map or school atlas.

History

Concerns were initially raised by the Department of Water Affairs (DWA) relating to water quality in Small Bay and specifically discharge of waste by-products by the fishing industry into the bay. It was pointed out that although willing to be part of a monitoring programme, they were not the only impactors and therefore should not be required to carry the costs alone.

Today we can proudly state that our contributors represent a broad cross section of local industries, as well as local government, all of whom are impactors to a greater or lesser degree.

These entities contribute to the Trust on a purely voluntary basis and are to be commended for their commitment to our better understanding and management of this fragile environment (See cover page).

The Trust was formally established in June 1996 thanks to the tireless efforts of the late Dr Martin Fourie, (Langebaan resident), Mr Malcolm McGregor, (Sea Harvest) and Mr Christo van Wyk (Then of the DWA and currently the Chairperson).

The Trust undergoes an annual financial audit and is run on a day to day basis by the Chairman, assisted by a part-time Operations Manager and overseen by a Board of Trustees who meets every second month.

Over the years the Trust has strived to better understand and therefore influence the management of this unique system.

As alluded to last year, there were some positive inroads made. At our instigation an Inter-governmental Task Team has been formed and they have had a couple of meetings already this year. Our goal was to achieve the status of a "Special Management Area" for the area, as per section 23 of the Integrated Coastal Management Act. Unfortunately as this body is an "Intergovernmental body", the Chairman and I have been excluded from attending to date, but have made all the Trust's research and monitoring data available to them.

We have often been the catalyst as whistle blowers when there have been environmental transgressions in our area. Despite this, we have forged good working relationships with all three tiers of government and industry and always strive to handle such environmental incidents factually and unemotionally as well as trying to find solutions.

We have also managed to spread our monitoring footprint outside our immediate area to include Danger Bay, which I believe is a very positive inclusion to our current data base.

Challenges

We currently only face three challenges, namely finance, finance and finance! Every year we are on an absolute knife edge as to whether or not we will be able to go ahead with the monitoring and compilation of the State of the Bay Report. To this end, I can only ask all businesses in the area to become contributors. Believe me, every bit adds to the whole. I must also thank Anchor Environmental for their patience with us and their commitment to this project, particularly Dr. Barry Clark who is always willing to assist or advise.

I would like to thank the present Board of Trustees for their regular input and guidance. Special thanks go to the Chairperson, Mr. Christo van Wyk, who is always so passionate and committed to what we do.

See you on the water,

Jimmy Walsh

Operations Manager

Saldanha Bay Water Quality Forum Trust



Figure i SBWQFT Trustees. Top row (from left) Pierre Nel (SANParks), Andre Kruger (Saldanha Bay Municipality Councillor), Jan Cillie (Saldanha Bay Municipality Councillor), Frank Hickley (Sea Harvest); Bottom row (from left): Elmien de Bruyn (Duferco) Christo van Wijk (Metsal), and Nicole Abrahams (Transnet National Port Authority).

EXECUTIVE SUMMARY

Regular, long-term environmental monitoring is essential to identify and to enable proactive mitigation of negative human impacts on the environment (e.g. pollution), and in so doing maintain the beneficial value of an area for all users. This is particularly pertinent for an area such as Saldanha Bay and Langebaan Lagoon, which serves as a major industrial node and port while at the same time supporting important tourism and fishing industries. The development of the Saldanha Bay port has significantly altered the physical structure and hydrodynamics of the Bay, whilst all developments within the area (industrial, residential, tourism etc.) have the potential to negatively impact on ecosystem health.

Saldanha Bay and Langebaan Lagoon have long been the focus of scientific study and interest, owing to its conservation importance as well as its many unique features. The establishment of the Saldanha Bay Water Quality Forum Trust (SBWQFT) in 1996, a voluntary organization representing various organs of State, local industry and other relevant stakeholders and interest groups, gave much impetus to the monitoring and understanding of changes in the health and ecosystem functioning of this unique bay-lagoon ecosystem. Direct monitoring of a number of important ecosystem indicators was initiated by the SBWQFT in 1999, including water quality (faecal coliform, temperature, oxygen and pH), sediment quality (trace metals, hydrocarbons, total organic carbon (TOC) and nitrogen) and benthic macrofauna. The range of parameters monitored has expanded since then to include surf zone fish and rocky intertidal macrofauna (both initiated in 2005) and led to the commissioning of a “State of the Bay” technical report series in 2006. This report has been produced annually since 2008, presenting data on parameters monitored directly by the SBWQFT as well as those monitored by others (government, private industry, academic establishments and NGOs).

In this 2015 State of the Bay report, available data on a variety of physical and biological parameters are presented, including activities and discharges affecting the health of the Bay (residential and industrial development, dredging, coastal erosion, shipping, and sewage and other wastewaters), water quality in the Bay itself (temperature, oxygen, salinity, nutrients, and pH), sediment quality (particle size, trace metal and hydrocarbon contaminants, TOC and nitrogen) and ecological indicators (Chlorophyll a, aquatic macrophytes, benthic macrofauna, fish and birds). Where possible, trends and areas of concern are identified and recommendations for future monitoring are made, with a view to further improving the existing environmental monitoring program for the area. Key findings for each of the major parameters in the State of the Bay monitoring are summarised below.

Sampling of sediments, benthic macrofauna and fish is now undertaken in Danger Bay, an open coast bay directly west of Saldanha town. This represents the second year of baseline data collection prior to the construction of the proposed Saldanha Regional Marine Outfall, which when operational, will discharge approximately 8-9 Mega litres per day of treated effluent (predominantly brine with trace levels of other elements generated from the various sources) into Danger Bay. It was deemed prudent to initiate monitoring in 2014 to develop a comprehensive baseline that captures natural variability prior to the commissioning of the pipeline (anticipated to be 2020). The results of the Danger Bay baseline sampling are included in the sediment, benthic macrofauna and

fish chapters of the main report but key findings of all three aspects are summarized separately in this section of the report as well.

Activities and Discharges Affecting the Bay

Human settlements surrounding Saldanha Bay and Langebaan Lagoon have expanded tremendously in recent years. This is brought home very strongly by population growth rates of 2.66% per annum in Saldanha and 9.24% in Langebaan over the period 2001 to 2011. Numbers of tourists visiting the Saldanha Bay and Langebaan Lagoon area are constantly increasing, especially those visiting the West Coast National Park (WCNP) (13% increase per annum since 2005). This rapid population growth translates to corresponding increases in the amounts of infrastructure required to house and accommodate these people and also in the amounts of waste and wastewater that is produced and has to be treated and disposed of.

Major developments in the Bay itself over the last 50 years include the development of the Port of Saldanha (construction of the Marcus Island causeway and the iron ore terminal and associated infrastructure), the establishment of a three small craft harbours, mariculture farms and several fish processing factories. Extensive industrial and residential development has also become established on the periphery of the Bay. Anthropogenic pollutants and wastes find their way into the Bay from a range of activities and developments within the study area. These include dredging and port expansion, port activities, shipping, ballast water discharges and oil spills, municipal (sewage) and household discharges, discharge from fish processing factories, biological waste associated with mariculture and storm water runoff.

Coastal developments in Langebaan and Saldanha extend right to the water's edge. The impact of shoreline erosion on existing development in the Saldanha and Langebaan area is being managed by means of two Environmental Management and Maintenance Plans (EMMP) but the lack of sufficient funding for the implementation of some of these measures has been problematic. Human induced changes within Saldanha Bay (mostly changes in current circulation and wave activity) have also contributed to the erosion of Langebaan beach and Paradise beach. In order to mitigate this and to alter wave dynamics and reduce erosion, groynes have been constructed at the mouth of Langebaan Lagoon, which required dredging of marine sands.

A number of major dredging events have occurred in Saldanha Bay to facilitate the development of the commercial port. Dredging of the seabed has significantly altered sediment composition and had a devastating effect on the Saldanha Bay marine environment in the past, principally through the loss of benthic species. The impacts of dredging are mostly observed in the vicinity of the iron ore terminal and within Small Bay. Most recently, Transnet have commenced with upgrades to the General Maintenance Quay and Rock Quay in Saldanha. Construction commenced in 2015 and is estimated to be completed in 2016. Transnet has also proposed a Phase 2 expansion of the Iron Ore Terminal (Big Bay side) to increase its holding capacity, which will require the dredging of sediment and removal of hard material in the navigation channel near the proposed berth.

Other recent developments that have been implemented in and around the Bay include a reverse-osmosis desalination plant which has been constructed at the Iron Ore Terminal in Big Bay (operational since August 2012) and the refurbishment and expansion of the small craft harbour at

Salamander Bay in Langebaan Lagoon. Environmental Authorisation (EA) has recently been granted for a new Liquid Petroleum Gas terminal in the bay and a land-based gas storage facility in Saldanha.

The Saldanha Bay Industrial Development Zone (SBIDZ) was declared on 13 October 2013 and the Operator Permit was granted to the SBIDZ licensing Company (Saldanha Bay Industrial Development Zone LiCo). The SBIDZ is envisioned to provide services in maintenance and repair fabrication as well as communal and supply services to various industrial sectors in Saldanha. The Saldanha Bay IDZ Licensing Company (LiCo) appointed CCA Environmental (Pty) Ltd to undertake the Scoping and EIA process for the proposed oil and gas offshore service complex (OSC) at the Saldanha Bay IDZ. The Final EIR is currently subject to a commenting period from 1 September to 2 October 2015.

A new desalination plant has been proposed by the WCDM, for which EA was granted in August 2013, and if implemented, effluent from this plant will be discharged into Danger Bay. Frontier Saldanha Utilities (Pty) Ltd. have also proposed a regional marine outfall project, which will direct effluent from at least three sources (Rare Earth Elements Separation Plant, Chlor-Alkali Production Facility and the Regional Wastewater Treatment Plant proposed by the Saldanha Bay Municipality (SBM) into Danger Bay.

Metals exported from the Port of Saldanha Bay include lead, copper, zinc, iron and manganese, of which iron ore exports comprise the largest proportion with just over 50 million tons exported per annum. Overall metal exports are increasing steadily, impacting on air and water quality in the Bay, as well as contributing to the steady increase in shipping traffic.

Ships entering the port of Saldanha take up and discharge large volumes of ballast water when offloading and loading cargo, respectively. Water from foreign ports is thus introduced to Saldanha Bay and presents risks such as the introduction of alien species and the release of water containing high concentrations of contaminants into the Bay. The average size and number of vessels in use has also increased over the years, and as a result, the volume of ballast water discharged to the Bay has doubled since 2004, with almost 23 million tons of ballast water being discharged in 2014. Historical measurements suggest that the concentrations of the trace metals in ballast water discharged into Saldanha Bay exceeds the South African Water Quality Guidelines, indicating that ballast water discharges may also contribute significantly to metal contamination within the Bay. To address environmental impacts and risks, the International Convention for the Control and Management of Ship's Ballast Water and Sediments of 2004 (BWM Convention) was ratified by 30 states, including South Africa. It took almost a decade until the Draft Ballast Water Management Bill was published in the *Government Gazette* in April 2013 (Notice 340 of 2013), designed to give effect to the BWM Convention. The Bill sets out how ballast water is to be discharged, all ships are expected to have a ballast water management plan, and to keep an up to date ballast water record book. Vessels constructed after 2009 are required to be designed such that accumulation of sediments is prevented and removal of sediments is facilitated.

Storm water enters Saldanha Bay/Langebaan Lagoon via multiple storm water drains and tarred surfaces. Storm water is a major potential source of pollutants in the Bay as it typically contains contaminants such as metals, bacteria, fertilizers (nutrients), hydrocarbons, plastics, pesticides and solvents. Increased volumes of storm water runoff (as a result of development) are associated with degradation of aquatic environments. Studies conducted by the Council for Scientific and Industrial Research (CSIR) indicate that the concentrations of several contaminants (nitrate, ammonia, metals

and faecal coliforms) in Saldanha Bay storm water runoff are well above accepted guideline limits. More coordinated storm water management is now under way in Langebaan and a Stormwater Management Master Plan is currently being drafted and may contribute to addressing some of these concerns.

Three fishing companies currently discharge land-derived wastewater into Saldanha Bay: SA Lobster Exporters (Marine Products), Live Fish Tanks (West Coast) and Sea Harvest. Premier Fishing is currently in the process of upgrading their fish processing plant for which EA was issued in June 2013. Long term data for effluent volume and quality is available for the Sea Harvest factory, and it is evident from these data that their effluent contains significant quantities of organic material (suspended solids, ammonia and other nitrogenous compounds) and may be contributing to poor water quality conditions in Small Bay. No information is available on effluent discharged by SA Lobster Exporters and Live Fish Tanks, or whether their discharges are authorised in terms of the National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) (ICMA).

Saldanha Bay is the only natural sheltered embayment in South Africa and as a result it is regarded as the major area for mariculture. There are currently seven mariculture operators that farm mussels, oysters, and various other species in the Bay. A total area of approximately 150 ha has been allocated to these operators. Historic studies as well as the State of the Bay surveys have shown that these culture operations can lead to organic enrichment and anoxia in sediments under the culture rafts and ropes. The source of the contamination is believed to be mainly faeces, decaying mussels and fouling species. Mariculture production in Saldanha has been static for many years but bivalve production is now clearly increasing again and there is much recent interest in fin fish farming in the Bay as well.

Management and Policy Development

Continuously accelerating urban and industrial development is a major cause of fragmentation and loss of ecological integrity of remaining marine and coastal habitats in Saldanha Bay and Langebaan. The challenge of addressing cumulative impacts in an area such as Saldanha is immense. The current and future desired state of the greater Saldanha Bay area is polarised, where industrial development (Saldanha Bay IDZ and associated industrial development) and conservation areas (Ramsar Site, MPAs and National Parks) are immediately adjacent to one another. Furthermore, the Saldanha Bay environment supports conflicting uses including industry, fishery, mariculture, recreation and the natural environment itself. This situation necessitates sustainable development that is steered towards environmentally more resilient locations and away from sensitive areas.

Inefficiencies arising from fragmented, activity-based EIA procedures can be countered by means of a strategic environmental management approach, which places a proposed activity within the environmental context of a particular geographical area. The Department of Environmental Affairs and Development Planning (DEADP) commissioned an Environmental Management Framework (EMF) for the Greater Saldanha Bay Area, which aims to promote sustainability, secure environmental protection and promote cooperative governance. If adopted by the competent authority, EMFs must be considered in all Environmental Authorisation applications and taken into account by every competent authority during the decision-making process. Finally, an EMF also

provides applicants with a preliminary indication of the areas in which it would be potentially inappropriate to undertake an activity listed in terms of the NEMA EIA regulations.

Historically, development in the coastal zone has been controlled largely through the EIA regulations published in terms of the NEMA, which require that an EIA be conducted for the development of any infrastructure within 100 m of the high-water mark. Recognising, however, that as well as being sensitive, vulnerable, and often stressed ecosystems, coastal areas are also highly dynamic in both space and time, and cannot be boxed within fixed boundaries, the approach to controlling development in coastal areas has changed dramatically in recent years. This is particularly pertinent in the light of climate change where rising sea-levels and potential increases in the frequency and intensity of storm events are upping the stakes even further. These changes are being implemented through the ICMA (as amended in 2014) which calls for coastal management lines to be determined for all coastal areas. Coastal management lines and overlay zones (designed to cater for short, medium and long term storm events) for the West Coast District Municipality (WCDM) are currently in draft form and will soon be published in the *Government Gazette* for public comment. While ensuring the protection of coastal property and infrastructure in future, it is also hoped that these interventions will also afford greater protection to the marine environment by limiting coastal erosion, trampling and habitat loss.

Water Quality

Aspects of water quality (temperature, salinity and dissolved oxygen, nutrients and chlorophyll concentrations) are measured in an attempt to understand the health of the environment. Regional oceanographic processes appear to be driving much of the variation in water temperature, salinity, dissolved oxygen, nutrients and chlorophyll concentrations observed in Saldanha Bay. However, there is clear evidence of altered current strengths, circulation patterns and wave energy within Saldanha Bay, which are ascribed to the construction of the ore terminal and causeway. These changes have also contributed to the deterioration in water quality in Small Bay in particular. The water entering Small Bay appears to remain within the confines of the Bay for longer periods than was historically the case. There is also an enhanced clockwise circulation and increased current strength flowing alongside unnatural obstacles (i.e. enhanced boundary flow, for example alongside the ore terminal). The wave exposure patterns in Small Bay and Big Bay have also been altered as a result of harbour developments in Saldanha Bay. The extent of sheltered and semi-sheltered areas has increased particularly in Small Bay, but also in Big Bay.

Regular monitoring of microbiological indicators at 20 stations in the Bay (10 in Small Bay, 5 in Big Bay and 5 in Langebaan Lagoon) was initiated by the SBWQFT in 1999 and has continued since this time with the assistance of the Saldanha Bay Municipality. These data indicate that chronic problems with faecal coliform pollution were present in the early parts of the record but that conditions have improved considerably since this time. Currently, 18 of the 20 monitoring stations in the Bay are rated as having 'Excellent' water quality. The remaining two sites at the Bok River Mouth and Hoedjiesbaai (both of which are located in Small Bay) are rated as 'Good' and 'Poor/Unacceptable' respectively.

There is also a concerning trend of increasing faecal coliform levels at two popular recreational sites in Big Bay (Leentjiesklip and Langebaan Main Beach). The authorities are advised to remain vigilant

and take immediate mitigating action if water quality at these two sites worsens. Guideline limits for mariculture are much stricter than the recreational guideline limits, thus levels of compliance for mariculture are predictably much lower. Data for 2015 did, however, indicate substantial improvements relative to previous years. Six of the ten sites in Small Bay (Sites 4 - 9) were not compliant in respect of the 80th percentile limits for mariculture, and five of these were also not compliant with the 95th percentile limits. Noticeable improvements were evident at the Small Quay-Sea Harvest, the Saldanha Bay Yacht Club and both the Pepper Bay sites. Faecal coliform counts at all four sites in Big Bay were well within both the 80th and 90th percentile limits for mariculture in 2015.

Given the current importance and likely future growth of both the mariculture and tourism industries within Saldanha Bay, it is imperative that whatever efforts have been taken in recent years to combat pollution by faecal coliforms in Small Bay (e.g. upgrading of sewage and storm water facilities to keep pace with development and population growth) should be increased and applied more widely. Continued monitoring of bacterial indicators (intestinal *Enterococci* in particular), to assess the effectiveness of adopted measures, is also required and should be undertaken at all sites on a bimonthly basis.

Concentrations of trace metals in marine organisms (mostly mussels) in Saldanha Bay have historically been monitored on a routine basis by the Department of Environmental Affairs (DEA) and by mariculture farm owners. DEA discontinued mussel watch programme in Saldanha Bay in 2007, but this has now been incorporated into the State of the Bay surveys. Data suggest that concentrations of trace metals are high along the shore (particularly for lead near the Multipurpose Quay) and are consistently above published regulatory limits for foodstuffs at many sites. Concentrations of trace metals in the cultured mussel in the Bay offshore are much lower though, and are currently not of concern. The reasons for the lower concentrations of trace metals in farmed mussels compared with those on the shore may be linked with higher growth rates for the farmed mussels, and the fact that the cultured mussels are feeding on phytoplankton blooms in freshly upwelled water that has only recently been advected into the Bay from outside and is thus relatively uncontaminated. The high concentrations of trace metals along the shore points to the need for management interventions to address this issue, as metal contamination poses a serious risk to the health of people harvesting mussels from the shore. It is vitally important that this monitoring continues in the future and that data are made available to the public for their own safety.

Sediment quality

The distribution of mud, sand and gravel within Saldanha Bay is influenced by wave action, currents and mechanical disturbance (e.g. dredging). Under natural circumstances, the prevailing high wave energy and strong currents would have flushed fine sediment and mud particles out the bay, leaving behind the heavier, coarser sand and gravel fractions. However, obstructions to current flow and wave energy can result in increased deposition of finer sediment (mud). Large-scale disturbances (e.g. dredging) of sediments re-suspends fine particles that were buried beneath the sand and gravel. Contaminants (trace metals and toxic pollutants) associate with the mud component of the sediment and can have a negative impact on the environment when they are re-suspended. Accumulation of organic matter in benthic sediments can also give rise to problems as it depletes

oxygen both in the sediments and surrounding water column as it decomposes. Historically, it was reported that the proportion of mud in the sediments of Saldanha Bay was very low, to the extent that it was considered negligible. Reduced water circulation in the Bay and dredging activities have resulted in an overall increase in the mud fraction in sediments in the Bay. The most significant increases in mud content in the surface sediments have been observed following dredging events. In between these events, mud tends to be flushed out or re-buried beneath sand and gravel, and the sediment composition starts reverting to one mostly dominated by sand although the mud fraction always remains greater than pre-port development. Data collected as part of the State of the Bay surveys since 1999 has shown a progressive decline in the amount of fine sediment (mud) at most sites in the Bay. However, despite these overall encouraging trends, the sediment at several deeper or more sheltered sites within Small and Big Bay still have elevated mud fractions. Areas most significantly affected in this way are all located in the vicinity of the Ore terminal the mussel rafts and the Yacht Club Basin.

Levels of total organic carbon (TOC) and total organic nitrogen (TON) remain elevated in the more sheltered and deeper areas of the bay, notably near the Yacht Club Basin and Ore terminal. Phytoplankton production is still considered to be the dominant natural source of organic matter in sediments in the Bay but is greatly augmented by anthropogenic inputs of TOC and TON associated with waste discharge from the fish factories, faecal waste from the mussel rafts, sewage effluent and storm water runoff. In the past, accumulation of organic waste, especially in sheltered areas where there is limited water flushing, has led to hypoxia (reduced oxygen) in these areas with negative impacts on benthic communities (e.g. the Saldanha yacht club). Data collected since 1999 have indicated an overall decline in TON and TOC levels at most sites despite the slight increases recorded in the 2015 survey. Sites where TOC and TON levels are still elevated include the Multi-purpose Quay and Yacht Club Basin in Small Bay where concentrations have remained elevated since 2008.

In areas of the Bay where muddy sediments tend to accumulate, trace metals and other contaminants often exceed acceptable threshold levels. This is believed to be due either to naturally-occurring high levels of the contaminants in the environment (e.g. in the case of cadmium) or due to impacts of human activities (e.g. lead, copper, manganese and nickel associated with ore exports). While such trace metals are generally biologically inactive when buried in the sediment, they can become toxic to the environment when re-suspended as a result of mechanical disturbance. On average, the concentrations of all metals were highest in Small Bay, lower in Big Bay and below detection limits in Langebaan lagoon. Following the major dredging event in 1999, Cadmium concentrations in certain areas in Small Bay exceeded internationally accepted safety levels, while concentrations of other trace metals (e.g. lead, copper and nickel) approached threshold levels. Subsequent to this time, there have been a number of smaller spikes in trace metal levels, mostly as a result of dredging operations. For example, trace metals in the entrance to Langebaan Lagoon were significantly elevated in 2011 following dredging operations that were conducted as part of the expansion of the Naval Boat Yard in Salamander Bay. Currently, trace metal levels are mostly well within safety thresholds with the exceptions of a few sites in Small Bay where thresholds were exceeded in 2015. Key areas of concern regarding trace metal pollution within Small Bay include the Yacht Club Basin where cadmium and copper exceeded recommended thresholds and adjacent to the Multi-purpose terminal where levels of cadmium were in excess of internationally accepted guidelines. Recent increases in the concentration of manganese around the

ore terminal are also a little concerning. Regular monitoring of trace metal concentrations is strongly recommended to provide an early warning of any future increases.

Poly-aromatic hydrocarbons (PAH) contamination measured in the sediments of Saldanha Bay since 1999 have been well below ERL values stipulated by NOAA and not considered an environmental risk. Total petroleum hydrocarbon (TPH) levels however, have fluctuated considerably in the vicinity of the ore terminal in recent years. In 2014 TPH Levels were found to be exceptionally high at some sites indicating heavily polluted conditions. The most likely explanation for the high observed TPH contamination levels is that a pollution incident associated with shipping activities took place. Alternatively, a pollution incident or routine operational activities on the jetty itself could be the cause of this contamination. While TPH and PAH finding in 2015 presented no major concern, it is recommended that TPH monitoring within the vicinity of the ore terminal is continued to identify the occurrence of pollution incidents, like that recorded in 2014.

Aquatic macrophytes (eelgrass and saltmarshes)

Three distinct intertidal habitats exist within Langebaan Lagoon: seagrass beds, such as those of the eelgrass *Zostera capensis* (a type of seagrass); saltmarsh dominated by cordgrass *Spartina maritime* and *Sarcocornia perennis*; and unvegetated sandflats dominated by the sand prawn, *Callinassa krausii* and the mudprawn *Upogebia capensis*. Eelgrass and saltmarsh beds are extremely important as they increase habitat diversity in the lagoon, provide an important food source, increase sediment stability, provide protection to juvenile fish and invertebrates from natural predators and generally support higher species richness, diversity, abundance and biomass of invertebrate fauna compared to unvegetated areas. Eelgrass and saltmarsh beds are also important for waterbirds which feed directly on the shoots and rhizomes, forage amongst the leaves or use them as roosting areas at high tide. Recent studies show that the aerial extent of seagrass beds in Langebaan Lagoon has declined by an estimated 38% since the 1960s, this being more dramatic in some areas than others (e.g. seagrass beds at Klein Oesterwal have declined by almost 99% over this period). Corresponding changes have been observed in densities of benthic macrofauna. At sites where eelgrass cover has declined, species commonly associated with eelgrass have declined in abundance, while those that burrow predominantly in unvegetated sand have increased in density. Fluctuations in the abundance of wading birds such as Terek Sandpiper, which feeds exclusively in *Zostera* beds have also been linked to changes in eelgrass, with population crashes in this species coinciding with periods of lowest seagrass. The loss of eelgrass beds from Langebaan Lagoon is a strong indicator that the ecosystem is undergoing a shift, most likely due to anthropogenic disturbances. It is critical that this habitat and the communities associated with it be monitored in future as further reductions are certain to have long term implications, not only for the invertebrate fauna but also for species of higher trophic levels. In contrast, little change has been reported in the extent of saltmarshes in Langebaan Lagoon, these having declined by no more than 8% since the 1960s.

Benthic macrofauna

Soft-bottom benthic macrofauna (animals living in the sediment that are larger than 1 mm) are frequently used as a measure to detect changes in the health of the marine environment resulting from anthropogenic impacts. This is largely because these species are short lived and, as a consequence, their community composition responds rapidly to environmental changes. Monitoring

of benthic macrofaunal communities over the period 1999-2015 has revealed a relatively stable situation in most parts of the Bay and Lagoon with the exception of 2008 when a dramatic shift in benthic community composition occurred at all sites. This shift involved a decrease in the abundance and biomass of filter feeders and an increase in shorter lived opportunistic detritivores. This was attributed to the extensive dredging that took place during 2007-2008. Filter feeding species are typically more sensitive to changes in water quality than detritivores or scavengers and account for much of the variation in overall abundance and biomass in the Bay.

Aside from this Bay-wide phenomenon, localised impact on and subsequent improvements in health have been detected in the yacht club basin and at Salamander Bay following construction of the boat dock. At one point (2008) benthic fauna have been almost entirely eliminated from the Yacht Club basin in Small Bay, owing to very high levels of trace metals and other contaminants at this site (TOC, Cu, Cd and Ni). Benthic macrofauna communities in this area have, however, recovered steadily year-on-year since this time and are now almost on a par with the other sites in Small Bay. Impacts of the dredging activities in Salamander Bay for the expansions of the Naval Boatyard in this area (2010) were also clearly evident in the data from these sites for several years following this development but have now finally returned to more natural levels.

Notable improvements in the health of benthic communities include the return of the suspension feeding sea-pen *Virgularia schultzei* to Big Bay and Langebaan Lagoon since 2004, as well as an increase in the percentage biomass of large, long lived species such as the tongue worm *Ochaetostoma capense*, and several gastropods. Certain areas of Small Bay that experience reduced water circulation patterns in (e.g. base of the ore jetty, near the Small Craft Harbour and near mussel rafts) which results in the accumulation of fine sediment, organic material and trace metals (aggravated by anthropogenic inputs) still have impoverished macrofauna communities.

Rocky intertidal

As a component of the ongoing State of the Bay evaluation, baseline conditions relating to rocky intertidal biota present at eight sites in Saldanha Bay were first surveyed in 2005 and have been resurveyed annually since 2008. In the 2015 survey, a total of 116 taxa were recorded from the eight study sites, most of which had also been found in the previous surveys. The faunal component was represented by 23 species of filter-feeders, 28 species of grazers, and 17 species of predators/scavengers. The algal component comprised 35 corticated (foliose) seaweeds, six ephemerals, five species of encrusting algae, and two species of kelp. These species are common along much of the South African West Coast and many have been recorded by other studies conducted in the Saldanha Bay area. Rocky shore species found included four alien invasive species, the Mediterranean mussel *Mytilus galloprovincialis* and three alien barnacle species; *Balanus glandula*, *Amphibalanus amphitrite amphitrite* and *Menesiniella regalis*.

The most important factor responsible for community differences among sites remains exposure to wave action and to a lesser extent shoreline topography. Within a site, the vertical emersion gradient of increasing exposure to air leads to a clear zonation of flora and fauna from low shore to high shore. Species composition and abundance has remained similar between years and any differences that were evident are considered most likely to be natural seasonal and inter-annual

phenomena, rather than anthropogenically-driven changes. Exceptions are the alien species introduced by hull fouling, ballast water or mariculture.

Fish

Long-term monitoring of juvenile fish assemblages by means of experimental seine-netting in the surf zone has revealed some concerning trends in recent years. The significant declines in white stumpnose abundance at all sites throughout the system in recent years suggest that the protection afforded by the Langebaan MPA may not be enough to sustain the fishery at the current high effort levels. Commercial fishing effort and white stumpnose catch has increased dramatically over the period 2003-2015, particularly in the recent part of this period. It is likely that recreational fishing effort for white stumpnose has also increased. The low white stumpnose abundance in recent years may simply be a result of natural variability in recruitment strength (possibly at decadal time scales greater than the monitoring record). However, given the findings of Arendse (2011) who assessed the adult stock to be overexploited using data collected during 2006-2008 already, this could indicate that recruitment overfishing is occurring and precautionary management interventions are warranted. The consistent declining trend in juvenile white stumpnose abundance in the nursery surf-zone habitats since 2007, with the three lowest abundance estimates emanating from the last three annual surveys, strongly supports the implementation of the harvest control measures recommended by Arendse (2011); namely a reduction in bag limit from 10 to 5 fish per person per day and an increase in size limit from 25 cm TL to 30 cm TL.

The 2013-2015 sampling events recorded average recruitment of common species such as harders, gobies and silversides within Big Bay and Langebaan Lagoon sites that are comparable with data from earlier surveys. In Small Bay, however, with the exception of harders and silversides, estimated abundance of key species was well below average, with very low white stumpnose density and a complete absence of black tail for the first time in the 11 year sampling record. This follows the trend observed since 2010/11 and it is somewhat concerning that the estimated abundance of some key species is decreasing in the areas of maximum anthropogenic disturbance within Small Bay, whilst they are stable or increasing in other less disturbed areas of Big Bay and Langebaan Lagoon.

In the data set collected to date, the average density of commercially important fish, such as white stumpnose and harders, was much higher at Small Bay sites compared to Big Bay and Lagoon sites. Since 2011, however, estimated densities of these species were similar and low in both Big Bay and Small Bay. Over the period 2005-2010, the average white stumpnose density calculated from all seine net surveys was 1.2 fish per m² in Small Bay, over the period 2011-2015 this dropped to 0.03 fish.m⁻² compared with the long term average of 0.09 fish per m² in Big Bay and 0.05 fish per m² in Langebaan lagoon. The juveniles of other species were historically also more abundant in Small Bay. This gives an indication of the importance of Small Bay as a nursery habitat for the fish species that support the large and growing fisheries throughout the Bay. Small Bay is often viewed as the more developed or industrialized portion of the Bay and is considered by many as a 'lost cause'. These data provide a strong argument to stamp out such negative thinking and to continue lobbying strongly for enhanced protection of this portion of the Bay. The concerning trend in decreasing white stumpnose recruitment throughout the Bay makes it even more critical that the quality of what is demonstrably the most important white stumpnose nursery habitat is improved. With the

exception of white sturgeon, the current status of fish and fisheries within Langebaan Lagoon appear to be satisfactory.

Birds

Saldanha Bay, Langebaan Lagoon and the associated islands provide important shelter, feeding and breeding habitat for at least 53 species of seabirds, 11 of which are known to breed on the islands. The islands of Malgas, Marcus, Jutten, Schaapen, Caspian and Vondeling support breeding populations of African Penguin (a red data species), Cape Gannet, four species of marine cormorants, Kelp and Hartlaub's Gulls, and Swift Terns. The islands also support important populations of the rare and endemic African Black Oystercatcher. Saldanha Bay and its islands support substantial proportions of the total populations of several of these species.

There has been an overall decrease in the breeding population of African Penguin at all four islands in the Bay. This decrease in numbers has been attributed to migration to other islands (particularly Dyer, St Croix and Bird Islands) and a reduced availability of sardines and anchovy along the west coast. In Saldanha Bay the population initially grew from 552 breeding pairs in 1987 to a peak of 2 156 breeding pairs in 2001 and then underwent a severe decline to just 314 breeding pairs in 2014. This reduction in numbers is consistent with the overall downward trend evident since 2002 and strongly reinforces the argument that immediate conservation action is required to prevent further losses of these birds.

Populations of Kelp Gull have showed steady year-on-year increases in the Saldanha Bay region until 2000, most likely due to the increase in availability of food as a result of the introduction and spread of the invasive alien mussel *Mytilus galloprovincialis*. Since 2000, however, populations on the islands have been steadily decreasing, following large-scale predation by Great White Pelicans *Pelecanus onocrotalus*.

Hartlaub's Gull and Swift Tern populations vary erratically, with numbers fluctuating widely each year. Swift terns bred in numbers on several of the islands in Saldanha Bay in 2012-2014, after being completely absent for several years. A total of with 543 breeding pairs were recorded on Malgas , Jutten and Schaapen Islands in 2014. Cape Gannets on the West Coast have been declining since the start of an eastward shift of pelagic fish stocks in the late 1990's. This is, to some extent, compensated for by an increase in the numbers of breeding birds on the east coast (Bird Island). The Saldanha Bay Cape Cormorant population has been quite variable since the start of monitoring in 1988, with overall numbers down 90% since 2009.

Bank Cormorant numbers in Saldanha Bay have declined by approximately 80% since 1990. Numbers dropped as low as 22 pairs in 2013 and have since increased slightly to 50 breeding pairs in 2014. In Saldanha Bay the declines are mainly attributed to scarcity of their main prey, the rock lobster, which in turn has reduced recruitment to the colonies. Overall numbers of both white-breasted cormorants and crowned cormorants in Saldanha Bay have been relatively constant with no evidence of a long term decline.

The islands in Saldanha Bay support an important number of African Black Oystercatchers. In the last 35 years the population has grown by 100 breeding pairs on the three main breeding islands in Saldanha Bay most likely due to the introduction and proliferation of the alien mussel *Mytilus*

galloprovincialis, which is a major food item for this species. Consideration should be given to reviving oyster catcher counts in order to maintain this valuable long-term data series.

Langebaan Lagoon and its associated warm, sheltered waters and abundance of prey, provides an important habitat for migrant waterbirds. About two thirds of the waterbird species are waders, of which 20 species are regular migrants from the Palaearctic region of Eurasia; these make up 83% of the summer wader population by numbers. Important non-waders which utilise the system are Kelp and Hartlaub's Gulls, Greater Flamingo, Sacred Ibis and Common Tern. Langebaan Lagoon has been identified as the most important wetlands for waders on the west coast of southern Africa. Since 1980, there has been a dramatic downward trend in the numbers of Palaearctic waders at the lagoon, which is at least in part attributed to population declines as a result of disturbances to their breeding grounds. There has also been a dramatic decline in numbers of resident waders, which indicates that disturbances at the lagoon, such as habitat changes and human disturbance are significant. It is highly recommended that the status of key species continue to be monitored in future and that these data be made available and used as an indication of environmental conditions in the area.

Alien Invasive Species

To date, 92 marine species have been recorded as introduced to South African waters, mostly through shipping activities or mariculture. Seventy of these occur on the South Africa west coast, and at least 30 of these are known to occur in Saldanha Bay and/or Langebaan Lagoon. The presence of one new alien species – the European porcelain crab *Porcellana platycheles* - has been confirmed in Saldanha Bay in the last year. It was first found on Schaapen Island in 2012 but its identity was confirmed only recently. Many of these alien species are considered invasive, including the Mediterranean mussel *Mytilus galloprovincialis*, the European green crab *Carcinus maenas* and the recently detected barnacle *Balanus glandula*. An additional 39 species are currently regarded as cryptogenic (of unknown origin) but very likely introduced, 20 of which have been recorded from Saldanha Bay. Most of the introduced species in this country have been found in sheltered areas such as harbours, and are believed to have been introduced through shipping activities, mostly ballast water. Because ballast water tends to be loaded in sheltered harbours the species that are transported originate from these habitats and have a difficult time adapting to South Africa's exposed coast. The status of some of the more common alien species in the bay are presented in the main body of the report along with trends in their distribution and abundance where these data are available.

Populations of the Western Pea crab *Pinnixa occidentalis*, first detected in the Bay in 2004, seem to have stabilised in terms of its abundance in the Bay but seems to be expanding its distribution outside of the Bay. The preferred range of this species in its native waters on the Pacific coast of the USA is waters deeper than 10 m. This species made a brief incursion into Langebaan Lagoon in 2009 and was absent from this area until this year. Previously it was suspected that the population may have expanded outside of the Bay and this has now been confirmed by its presence at least one station in Danger Bay.

Populations of the Mediterranean mussel *Mytilus galloprovincialis* and acorn barnacle *Balanus glandula* (which originate from European waters the Pacific coast of North America, respectively) are

by far the most dominant animal species on rocky shores in the Bay. Populations of *Mytilus* grew rapidly from an average of 5.4% cover in 2005 to 7.8-11.1% in 2012, but have since decreased again to around 7% in 2015. Populations of *Balanus* also seem to be declining, after peaking in 2009. Abundance (% cover) of this species has declined from a peak of around 7.5% in 2009 to around 3.4% in 2015..

Recent updates on the distribution of brooding anemone *Sagartia ornate*, known only from Langebaan Lagoon, indicates that this has changed somewhat, with this species now inhabiting eelgrass instead of spiky cord grass beds as it had in the past. This change has not resulted in any expansion in the range occupied by this species, however.

Aliens are considered to represent one of the greatest threats to rocky shore communities in Saldanha Bay, owing to their potential to become invasive thereby displacing naturally occurring indigenous species. Thus, changes in the population of these species in Saldanha Bay will be carefully monitored in future to see what impacts they will have on the local biota.

Danger Bay

Sediment and benthic macrofauna samples were collected from 14 subtidal sites (7-20 m depth) in the vicinity of the options for the proposed regional marine outfall pipe end (the northern half of Danger Bay), whilst seine net hauls were conducted at three sites within the surf zone in this area. In contrast to sediments within Saldanha Bay, Danger Bay sediments comprised almost entirely sand (>99%) with an extremely low mud fraction (average = 0.14%). Consequently organic matter concentrations (total organic carbon and total organic nitrogen) in these sediments were also very low. Concentrations of trace metals in the sandy Danger Bay sediment samples were also low relative to sites with anthropogenic impacts and muddy sediments collected within Saldanha Bay. These differences are attributed to the much higher wave exposure of Danger Bay, compared to sites within Saldanha Bay, and much reduced inputs of wastewater.

Reflecting these habitat differences, the benthic macrofauna community in Danger Bay is distinct from that found within Saldanha Bay and Langebaan Lagoon. Average macrofauna biomass at Danger Bay sites was an order of magnitude lower than that found within Saldanha Bay and Langebaan Lagoon during 2015 and the community was dominated by small crustaceans (mostly amphipods), polychaetes and gastropods. These taxa are mostly short lived R-selected species that are predominantly detritivores and scavengers in contrast to sites within Saldanha Bay and Langebaan Lagoon, where filter feeders are the dominant functional group. The absence of large crustaceans such as the mud prawn *Upogebia capensis* and associated commensal species (e.g. *Spiroplax spiralis*) and the crown crab *Hymenosoma orbiculare*, and the abundance of a small amphipod *Urothoe coxalis* found only in Danger Bay, were the main causes of dissimilarity between Danger Bay and the Saldanha Bay and Langebaan Lagoon samples.

Surf zone fish diversity at Danger Bay was low compared with catches made at most sites within the Saldanha Bay, and reflects the less sheltered, cooler and cleaner water found on the more exposed coast. These conditions are less suitable as a nursery area for many fish species in that they do not offer the increased turbidity, temperature and food availability found within the Bay. Indeed three of the four species caught at Danger Bay, False Bay klipvis, sand sharks, and sand snake eels were

adults, whilst the harders were nearly double the average size of those sampled within Saldanha Bay- Langebaan.

The significant difference in physical habitat and biota found in Danger Bay compared to that within Saldanha Bay reflects a more exposed and dynamic environment that does suggest that this site is far more suitable for a regional marine outfall. Discharge of organically and chemically enriched effluent from the proposed regional marine outfall is still expected to have a discernable impact on the physical environment and biological communities within a zone of impact. Ongoing collection of comprehensive baseline data on macrobenthic communities in Danger Bay to capture the natural variability is essential for objective and quantitative assessment of potential impacts.

Summary

In summary, developments in Saldanha Bay and Langebaan Lagoon during the past thirty years have inevitably impacted on the environment. Most parameters investigated in this study suggest a considerable degree of negative impact having occurring over the last few decades. Long term decreases in populations of fish (e.g. white stumpnose) and many bird species in Saldanha Bay and Langebaan Lagoon are of particular concern. These most likely reflect long term changes in exploitation levels (fish) and habitat quality (sediment and water quality, and also increasing levels of disturbance) and also in important forage species (e.g. benthic macrofauna). Recent improvements in some of these underlying indicators (e.g. sediment quality and macrofauna abundance and composition) are very encouraging, though, and will hopefully translate into improvements in the higher order taxa as well. There remains considerable work to be done in maintain and restoring the health of the Bay, especially in respect of the large volumes of effluent that are discharged to the Bay, very little of which is compliant with the existing effluent quality standards. A holistic approach in monitoring and assessing the overall health status of the Bay is essential, and regular (in some cases increased) monitoring of all parameters reported on here is strongly recommended.

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GLOSSARY

Alien species	An introduced species that has become naturalized
Articulated coralline algae	Branching, tree-like plants which are attached to the substratum by crustose or calcified, root-like holdfasts.
Biodiversity	The variability among living organisms from all terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems.
Biota	All the plant and animal life of a particular region.
Colony-forming unit	A colony-forming unit (CFU) is a unit used to estimate the number of viable bacteria or fungal cells in a sample.
Community structure	Taxonomic and quantitative attributes of a community of plants and animals inhabiting a particular habitat, including species richness and relative abundance structurally and functionally.
Coralline algae	Coralline algae are red algae in the Family Corallinaceae of the order Corallinales characterized by a thallus that is hard as a result of calcareous deposits contained within the cell walls.
Corticated algae	Algae that have a secondarily formed outer cellular covering over part or all of an algal thallus. Usually relatively large and long-lived.
Crustose coralline algae	Slow growing crusts of varying thickness that can occur on rock, shells, or other algae.
Ephemeral algae	Opportunistic algae with a short life cycle that are usually the first settlers on a rocky shore.
Fauna	General term for all of the animals found in a particular location.
Flora	General term for all of the plant life found in a particular location.
Foliose algae	Leaf-like, broad and flat; having the texture or shape of a leaf.
Filter-feeders	Animals that feed by straining suspended matter and food particles from water.
Functional group	A collection of organisms of specific morphological, physiological, and/or behavioural properties.
Grazer	An herbivore that feeds on plants/algae by abrasion from the surface.
Indigenous	Native to the country not introduced.

Intertidal	The shore area between the high- and the low-tide levels.
Invertebrate	Animals that do not have a backbone. Invertebrates either have an exoskeleton (e.g. crabs) or no skeleton at all (worms).
Kelp	A member of the order Laminariales, the more massive brown algae.
Opportunistic	Capable of rapidly occupying newly available space.
Rocky shore community	A group of interdependent organisms inhabiting the same rocky shore region and interacting with each other.
Scavenger	An animal that eats already dead or decaying animals.
Shore height zone	Zone on the intertidal shore recognizable by its community.
Thallus	General form of an alga that, unlike a plant, is not differentiated into stems, roots, or leaves.
Topography	The relief features or surface configuration of an area

LIST OF ABBREVIATIONS

AOU	Apparent oxygen utilization
BA	Basic Assessment
BCLME	Benguela Current Large Marine Ecosystem
CBA	Critical Biodiversity Area
COD	Chemical oxygen demand
CFU	Colony-forming unit
CSIR	Council for Scientific and Industrial Research
CWAC	Co-ordinated Waterbird Counts
CWDP	Coastal Water Discharge Permit
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEA&DP	Western Cape Department of Environmental Affairs & Development Planning
DWA	Department of Water Affairs
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
EMF	Environmental Management Framework
EMMP	Environmental Management and Maintenance Plan
EMPr	Environmental Management Programme
ICMA	National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008)
LPG	Liquid petroleum gas
MLRA	Marine Living Resources Act (No. 18 of 1998)
MPA	Marine Protected Area
NEMA	National Environmental Management Act (No. 107 of 1998)
NEMBA	National Environmental Management: Biodiversity Act (No. 10 of 2004)
NOAA	National Oceanic and Atmospheric Administration
NWA	National Water Act (No. 36 of 1998)
PAH	Poly-aromatic hydrocarbons
TOC	Total organic carbon
TON	Total organic nitrogen
RWQO	Receiving Water Quality Objectives approach
SBIDZ	Saldanha Bay Industrial Development Zone
SBM	Saldanha Bay Municipality
SBWQFT	Saldanha Bay Water Quality Forum Trust
TNPA	Transnet National Ports Authority
TPH	Total petroleum hydrocarbon
TSS	Total suspended solids
WCDM	West Coast District Municipality
WWTW	Wastewater Treatment Works

1 INTRODUCTION

1.1 Background

Saldanha Bay is situated on the west coast of South Africa, approximately 100 km north of Cape Town and is directly linked to the shallow, tidal Langebaan Lagoon. The Bay and Lagoon are considered to be one of the biodiversity “hot spots” in the country and an area of exceptional beauty. A number of marine protected areas have been proclaimed in and around the Bay, while Langebaan Lagoon and much of the surrounding land falls within the West Coast National Park (Figure 1.1). Langebaan Lagoon was also declared a Ramsar Site in 1988, along with a series of islands within Saldanha Bay (Schaapen, Marcus, Malgas, Jutten and Vondelig).



Figure 1.1. Regional map of Saldanha Bay and Langebaan Lagoon and Danger Bay showing development (grey shading) and conservation areas.

In spite of these noteworthy successes, the history of the area has been one that is also tainted with overexploitation and abuse, the environment generally being the loser in both instances.

Saldanha Bay and Langebaan Lagoon have long been the focus of scientific study and interest largely owing to the conservation importance and its many unique features. A symposium on research in the natural sciences of Saldanha Bay and Langebaan Lagoon was hosted by the Royal Society of South Africa in 1976 in an attempt to draw together information from the various research studies that had been and were being conducted in the area. The symposium served to focus the attention of scientific researchers from a wide range of disciplines on the Bay and resulted in the development of a large body of data and information on the status of the Bay and Lagoon at a time prior to any major developments in the Bay.

More recently (in 1996), the Saldanha Bay Water Quality Forum Trust (SBWQFT), a voluntary organization representing various organs of State, local industry and other relevant stakeholders and interest groups, was inaugurated with the aim of promoting an integrated approach to the management, conservation and development of the waters of Saldanha Bay and the Langebaan Lagoon, and the land areas adjacent to, and influencing it. Since its inauguration the SBWQFT has played an important role in guiding and influencing management of the Bay and in commissioning scientific research aimed at supporting informed decision making and sustainable management of the Saldanha Bay/Langebaan Lagoon ecosystem. Monitoring of a number of important ecosystem indicators was initiated by the SBWQFT in 1999 including water quality (faecal coliform, temperature, oxygen and pH), sediment quality (trace metals, hydrocarbons, Total organic carbon (TOC) and nitrogen) and benthic macrofauna. The range of parameters monitored has since increased to include surf zone fish and rocky intertidal macrofauna (both initiated in 2005) and has culminated in the commissioning of a “State of the Bay” report series that has been produced annually since 2008.

The first State of the Bay report was produced in 2006 by Anchor Environmental Consultants (Pty) Ltd. and served to draw together all available information on the health status and trends in a wide range of parameters that provide insights into the health of the Saldanha Bay/Langebaan Lagoon ecosystem. The 2006 report incorporated information on trends in a full range of physico-chemical indicators including water quality (temperature, oxygen, salinity, nutrients, and pH), sediment quality (particle size, trace metal and hydrocarbon contaminants, TOC and nitrogen) and ecological indicators (chlorophyll a, benthic macrofauna, fish and birds). This information was drawn from work commissioned by the SBWQFT as well as a range of other scientific monitoring programmes and studies. The 2006 report was presented in two formats – one data rich form that was designed to provide detailed technical information in trends in each of the monitored parameters and the second in an easy to read form that was accessible to all stakeholders.

The success of the first State of the Bay report and the ever increasing pace of development in and around the Saldanha Bay encouraged the SBWQFT to produce the second State of the Bay report in 2008, and then annually from this time onwards. This (2015) report is the 9th in the series and provides an update on the health of all monitored parameters in Saldanha Bay, Langebaan Lagoon and Danger Bay in the time since the last State of the Bay assessment (2014), and includes information on trends in all of the parameters reported on in the previous reports (2006, 2008, 2009, 2010, 2011 and 2012, 2014).

This annual report also incorporates a number of additional indicators not previously covered by the State of the Bay reports (focussing mostly on activities and discharges that affect the health of the system). Readers that are familiar with the State of the Bay report series are encouraged to consult Section 1.3 of this report which highlights new and updated information that has been included in this edition.

1.2 Structure of this report

This report draws together all available information on water quality and aquatic ecosystem health of Saldanha Bay and Langebaan Lagoon, and on activities and discharges affecting the health of the Bay. The emphasis has been on using data from as wide a range of parameters as possible that are comparable in both space and time and cover extended periods which provide a good reflection of the long term environmental health in the Bay as well as recent changes in the health status of the system. The report is composed of twelve chapters each of which addresses different aspects of the health of the system.

Chapter One introduces the State of the Bay Reporting programme and explains the origin of and rationale for the programme, and provides the report outline.

Chapter Two provides background information to anthropogenic impacts on the environment and the range of different approaches to monitoring these impacts, which captures the differences in the nature and temporal and spatial scale of these impacts.

Chapter Three provides a summary of available information on historic and on-going activities, discharges and other anthropogenic impacts to the Bay that are likely to have had or are having some impact on environmental health.

Chapter Four outlines the coastal and environmental management measures in the greater Saldanha Bay area developed/implemented to facilitate sustainable development in an area where industrial development (Saldanha Bay IDZ and associate industrial development), residential and conservation areas (Ramsar Site, MPAs and National Parks) are immediately adjacent to one another.

Chapter Five summarises available information on water quality parameters that have historically been monitored in the Bay and Lagoon and reflects on what can be deduced from these parameters regarding the health of the Bay.

Chapter Six summarises available information on sediment monitoring that has been conducted in Saldanha Bay, Danger Bay and Langebaan Lagoon with further interpretation of the implication of the changing sediment composition over time and/or related to dredging events.

Chapter Seven summarises available information on long-term trends in aquatic macrophytes (seagrasses and salt marshes) in Langebaan Lagoon.

Chapter Eight presents data on changes in benthic macrofauna in Saldanha Bay and Langebaan Lagoon from the 1970's to the present day and provides the first baseline data for Danger Bay.

Chapter Nine addresses changes that have occurred in the rocky intertidal zones in and around Saldanha Bay over the past 20 years and presents results from a rocky intertidal monitoring survey initiated in 2005.

Chapter Ten summarises all available information on the fish community and composition in the Bay and Lagoon, as deduced from both seine and gill net surveys, and presents results from a surf zone fish monitoring survey initiated in 2005. In 2014 this survey was expanded to include Danger Bay.

Chapter Eleven provides detailed information on the status of key bird species utilising the offshore islands around Saldanha Bay and both resident and migrant waders utilising the feeding grounds in Langebaan Lagoon as well as providing an indication of the national importance of the area for birds.

Chapter Twelve summarise available information of marine alien species known to be present in Saldanha Bay and Langebaan Lagoon as well as trends in their distribution and abundance.

Chapter Thirteen provides a tabulated summary of the key changes detected in each parameter covered in this report and assigns a health status rank to each. This chapter also provides recommendations for future environmental monitoring for the Bay and of management measures that ought to be adopted in the future.

1.3 What's new in the 2014 Edition of the State of the Bay report

Readers who are familiar with the State of the Bay report series will know that while the various chapters of this report are updated each year with new data and information that has been collected during the course of the preceding year, either through dedicated surveys commissioned by the SBWQFT or other dedicated individuals and agencies, much of the background or contextual information pertinent to the State of the Bay remains the same. While this background and contextual information is important, it can be a little tedious to wade through for those who have seen it all before. This section of the report thus serves to highlight what new data and information has been included in each of the chapters of this report to make it easier for those readers to home in on the material that is of greatest interest to them.

Chapter 3: Activities and Discharges Affecting the Health of the Bay

Only developments and activities which have experienced changes since the last State of the Bay report (2014) are retained in this chapter. Completed, stagnated or pending developments are briefly summarised in the relevant section and the reader is referred to the previous report of 2014 for more details. Additional and updated sections are listed below:

- New updated information on numbers of visitors to the West Coast National Park;
- New and updated information on new and existing development proposals for Saldanha (the Saldanha Bay Industrial Development Zone, the Transnet-NPA port expansion programme, the Sishen-Saldanha Orelane expansion project, Sunrise Energy Liquid Petroleum Gas (LPG) Facility and Oil Tanking MOGS Saldanha crude oil storage facility);
- New information on metal exports from the Saldanha Bay Multipurpose and Iron Ore Terminals;
- New and updated information on shipping traffic and ballast water discharges; and
- New and updated information on the Transnet-NPA Desalination Plant, updated information on effluent volumes and quality discharged by the Saldanha and Langebaan Water Treatment Works, new and updated data on volumes and quality of effluent discharged by fish processing establishments in Saldanha, and new developments in the mariculture industry in Saldanha.

Chapter 4: Coastal and Environmental Management

- New developments pertaining to how development in the coastal zone surrounding the Bay will be managed and controlled in future, including details on:
 - The Environmental Management Framework (EMF) for the Greater Saldanha Bay Area;
 - The proposed Saldanha Bay Special Management Area;
 - The adoption of coastal management lines in the West Coast District Municipality

Chapter 5: Water quality

- New information on variations in temperature, salinity, dissolved oxygen and turbidity in the Bay.

- New updated information on levels of microbial indicators (faecal coliforms and *E. coli.*) in the Bay.
- New updated information on levels of trace metals in mussels on the shoreline and in farmed oysters and mussels in the Bay.

Chapter 6: Sediments

- New updated information on grain size composition and health of benthic sediment in Saldanha Bay (TOC and Nitrogen, Trace metal and hydrocarbon content).
- New information on sediment composition from 14 stations sampled in Danger Bay, including particle size composition, TOC and organic nitrogen content.

Chapter 8: Benthic macrofauna

- New updated information on species composition, abundance, biomass and health of benthic macrofauna communities in Saldanha Bay and Langebaan Lagoon.
- First baseline information on the benthic macrofauna community inhabiting soft sediments in Danger Bay.

Chapter 9: Intertidal invertebrates (Rocky Shores)

- New updated information on species composition, abundance, biomass and health of rocky intertidal invertebrate communities in Saldanha Bay and Langebaan Lagoon.

Chapter 10: Fish

- New updated information on species composition, abundance, biomass and health of fish communities in Saldanha Bay and Langebaan Lagoon.

Chapter 11: Birds

- New updated information on species composition, abundance and health of birds breeding on islands within Saldanha Bay, Danger Bay and Langebaan Lagoon.

Chapter 12: Alien invasive species

New updated information on the number, distribution and abundance of alien invasive marine species in Saldanha Bay and Langebaan Lagoon.

2 BACKGROUND TO ENVIRONMENTAL MONITORING AND WATER QUALITY MANAGEMENT

2.1 Introduction

Pollution is defined by the United Nations Convention on the Law of the Sea as ‘the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of the sea water and reduction of amenities’. A wide variety of pollutants are generated by man, many of which are discharged to the environment in one form or another. Pollutants or contaminants can broadly be grouped into five different types: trace metals, hydrocarbons, organochlorines, radionuclides, and nutrients. Certain metals, normally found in very low concentrations in the environment (hence referred to as trace metals) are highly toxic to aquatic organisms. These include for example Mercury, Cadmium, Arsenic, Lead, Chromium, Zinc and Copper. These metals occur naturally in the earth’s crust, but mining of metals by man is increasing the rate at which these are being mobilised which is enormously over that achieved by geological weathering. Many of these metals are also used as catalysts in industrial processes and are discharged to the environment together with industrial effluent and wastewater. Hydrocarbons discharged to the marine environment include mostly oil (crude oil and bunker oil) and various types of fuel (diesel and petrol). Sources of hydrocarbons include spills from tankers, other vessels, refineries, storage tanks, and various industrial and domestic sources. Hydrocarbons are lethal to most marine organisms due to their toxicity, but particularly to marine mammals and birds due to their propensity to float on the surface of the water where they come into contact with seabirds and marine mammals. Organochlorines do not occur naturally in the environment, and are manufactured entirely by man. A wide variety of these chemicals exists, the most commonly known ones being plastics (e.g. polyvinylchloride or PVC), solvents and insecticides (e.g. DDT). Most organochlorines are toxic to marine life and have a propensity to accumulate up the food chain. Nutrients are derived from a number of sources, the major one being sewage, industrial effluent, and agricultural runoff. They are of concern owing to the vast quantities discharged to the environment each year which has the propensity to cause eutrophication of coastal and inland waters. Eutrophication in turn can result in proliferation of algae, phytoplankton (red tide) blooms, and deoxygenation of the water (black tides).

It is important to monitor both the concentration of these contaminants in the environment and their effects on biota such that negative effects on the environment can be detected at an early stage before they begin to pose a major risk to environmental and/or human health.

2.2 Mechanisms for monitoring contaminants and their effects on the environment

The effects of pollutants on the environment can be detected in a variety of ways as can the concentrations of the pollutants themselves in the environment. Three principal ways exist for assessing the concentration of pollutants in aquatic ecosystems - through the analysis of pollutant concentrations in the water itself, in sediments or in living organisms. Each has their advantages and disadvantages. For example, the analysis of pollutant concentrations in water samples is often problematic owing to the fact that even at concentrations lethal to living organisms, they are difficult to detect without highly sophisticated sampling and analytical techniques. Pollutant concentrations in natural waters may vary with factors such as season, state of the tide, currents, extent of freshwater runoff, sampling depth, and the intermittent flow of industrial effluents, which complicates matters even further. In order to accurately elucidate the degree of contamination of a particular environment, a large number of water samples usually have to be collected and analysed over a long period of time. The biological availability of pollutants in water also presents a problem in itself. It must be understood that some pollutants present in a water sample may be bound chemically to other compounds that renders them unavailable or non-toxic to biota (this is common in the case of trace metals).

Another way of examining the degree of contamination of a particular environment is through the analysis of pollutant concentrations in sediments. This has several advantages over the analysis of water samples. Most contaminants of concern found in aquatic ecosystems tend to associate preferentially with (i.e. adhere to) suspended particulate material rather than being maintained in solution. This behaviour leads to pollutants becoming concentrated in sediments over time. By analysing their concentrations in the sediments (as opposed to in the water) one can eliminate many of the problems associated with short-term variability in contaminant concentrations (as they reflect conditions prevailing over several weeks or months) and concentrations tend to be much higher which makes detection much easier. The use of sediments for ascertaining the degree of contamination of a particular system or environment is thus often preferred over the analysis of water samples. However, several problems still exist with inferring the degree of contamination of a particular environment from the analysis of sediment samples.

Some contaminants (e.g. bacteria and other pathogens) do not accumulate in sediments and can only be detected reliably through other means (e.g. through the analysis of water samples). Concentrations of contaminants in sediments can also be affected by sedimentation rates (i.e. the rate at which sediment is settling out of the water column) and the sediment grain size and organic content. As a general rule, contaminant concentrations usually increase with decreasing particle size, and increase with increasing organic content, independent of their concentration in the overlying water. Reasons for this are believed to be due to increases in overall sediment particle surface area and the greater affinity of most contaminants for organic as opposed to inorganic particles (Phillips 1980, Phillips & Rainbow 1994). The issue of contaminant bioavailability remains a problem as well, as it is not possible to determine the biologically available portion of any contaminant present in sediments using chemical methods of analysis alone.

One final way of assessing the degree of contamination of a particular environment is by analysing concentrations of contaminants in the biota themselves. There are several practical and theoretical

advantages with this approach. Firstly, it eliminates any uncertainty regarding the bioavailability of the contaminant in question as it is by nature 'bio-available'. Secondly, biological organisms tend to concentrate contaminants within their tissues several hundred or even thousands of times above the concentrations in the environment and hence eliminate many of the problems associated with detecting and measuring low levels of contaminants. Biota also integrates concentrations over time and can reflect concentrations in the environment over periods of days, weeks, or months depending on the type of organism selected. Not all pollutants accumulate in the tissues of living organisms, including for example nutrients and particulate organic matter. Thus, while it is advantageous to monitor contaminant concentrations in biota, monitoring of sediment and water quality is often also necessary.

Different types of organisms tend to concentrate contaminants at different rates and to different extents. In selecting what type of organism to use for bio monitoring it is generally recommended that it should be sedentary (to ensure that it is not able to move in and out of the contaminated area), should accumulate contaminants in direct proportion with their concentration in the environment, and should be able to accumulate the contaminant in question without lethal impact (such that organisms available in the environment reflect prevailing conditions and do not simply die after a period of exposure). Giving cognisance to these criteria, the most commonly selected organisms for bio monitoring purposes include bivalves (e.g. mussels and oysters) and algae (i.e. seaweed).

Aside from monitoring concentrations of contaminant levels in water, sediments, and biota, it is also possible, and often more instructive, to examine the species composition of the biota at a particular site or in a particular environment to ascertain the level of health of the system. Some species are more tolerant of certain types of pollution than others. Indeed, some organisms are extremely sensitive to disturbance and disappear before contaminant concentrations can even be detected reliably whereas others proliferate even under the most noxious conditions. Such highly tolerant and intolerant organisms are often termed biological indicators as they indicate the existence or concentration of a particular contaminant or contaminants simply by their presence or absence in a particular site, especially if this changes over time. Changes in community composition (defined as the relative abundance or biomass of all species) at a particular site can thus indicate a change in environmental conditions. This may be reflected simply as: (a) an overall increase/decrease in biomass or abundance of all species, (b) as a change in community structure and/or overall biomass/abundance but where the suite of species present remain unchanged, or (c) as a change in species and community structure and/or a change in overall biomass/abundance (Figure 2.1.). Monitoring abundance or biomass of a range of different organisms from different environments and taxonomic groups with different longevities, including for example invertebrates, fish and birds, offers the most comprehensive perspective on change in environmental health spanning months, years and decades.

The various methods for monitoring environmental health all have advantages and disadvantages. A comprehensive monitoring programme typically requires that a variety of parameters be monitored covering water, sediment, biota and community health indices.

2.3 Indicators of environmental health and status in Saldanha Bay and Langebaan Lagoon

For the requirements of the Saldanha Bay and Langebaan Lagoon State of the Bay monitoring programme a ranking system has been devised that incorporates both the drivers of changes (i.e. activities and discharges that affect environmental health) and a range of different measures of ecosystem health from contaminant concentrations in seawater to change in species composition of a range of different organisms (Figure 2.1. and Table 2.1.). Collectively these parameters provide a comprehensive picture of the State of the Bay and also a baseline against which future environmental change can be measured. Each of the threats and environmental parameters incorporated within the ranking system was allocated a health category depending on the ecological status and management requirements in particular areas of Saldanha Bay and Langebaan Lagoon. An overall Desired Health category is also proposed for each environmental parameter in each area, which should serve as a target to be achieved or maintained through management intervention.

Various physical, chemical and biological factors influence the overall health of the environment. Environmental parameters or indices were selected that can be used to represent the broader health of the environment and are feasible to measure, both temporally and spatially. The following environmental parameters or indices are reported on:

Activities and discharges affecting the environment: Certain activities (e.g. shipping and small vessel traffic, the mere presence of people and their pets, trampling) can cause disturbance in the environment especially to sensitive species, that, along with discharges to the marine environment (e.g. effluent from fish factories, treated sewage, and ballast water discharged by ships) can lead to degradation of the environment through loss of species (i.e. loss of biodiversity), or increases in the abundance of pest species (e.g. red tides), or the introduction of alien species. Monitoring activity patterns and levels of discharges can provide insight into the reasons for any observed deterioration in ecosystem health and can help in formulating solutions for addressing negative trends.

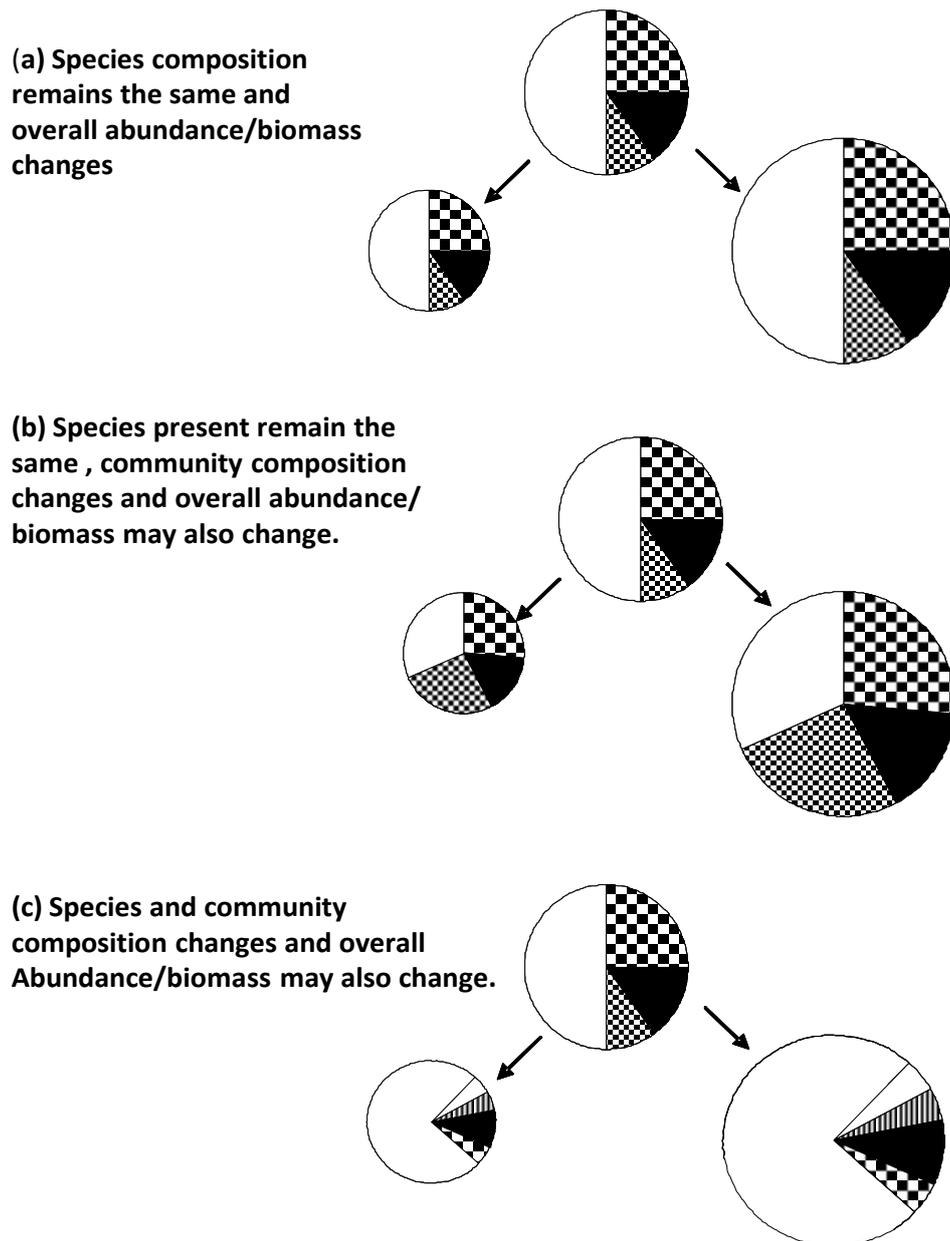


Figure 2.1. Possible alterations in abundance/biomass and community composition. Overall abundance/biomass is represented by the size of the circles and community composition by the various types of shading. After Hellowell (1986).

Water Quality: Water quality is a measure of the suitability of water for supporting aquatic life and the extent to which key parameters (temperature, salinity, dissolved oxygen, nutrients and chlorophyll a, faecal coliforms and trace metal concentrations) have been altered from their natural state. Water quality parameters can vary widely over short time periods and are principally affected by the origin of the water, physical and biological processes and effluent discharge. Water quality parameters provide only an immediate (very short term – hours to days) perspective on changes in the environment and do not integrate changes over time.

Sediment quality: Sediment quality is a measure of the extent to which the nature of benthic sediments (particle size composition, organic content and contaminant concentrations) has been altered from its natural state. This is important as it influences the types and numbers of organisms inhabiting the sediments and is in turn, strongly affected by the extent of water movement (wave action and current speeds), mechanical disturbance (e.g. dredging) and quality of the overlying water. Sediment parameters respond quickly to changes in the environment but are able to integrate changes over short periods of time (weeks to months) and are thus good indicators or short to very short-term changes in environmental health.

Coastal development: Coastal development includes development activities such as infrastructure (harbours and launch sites, cities, towns, housing, roads and tourism), as well as dredging and the disposal of dredge spoil. Coastal developments pose a major threat to many components of marine and coastal environments, owing to their cumulative effects, which are often not taken into account by impact assessments. Associated impacts include organic pollution of runoff and sewerage, transformation of the supratidal environment, alteration of dune movement, increased access to the coast and sea, and the negative impacts on estuaries.

Shoreline erosion: Anthropogenic activities, particularly structures erected in the coastal zone (e.g. harbours, breakwaters, buildings) and dredging activities, can also profoundly influence shorelines composed of soft sediment (i.e. sandy beaches) leading to erosion of the coast in some areas and the accumulation of sediment in others. Many of the beaches in Saldanha Bay have experienced severe erosion in recent decades to the extent that valuable infrastructure is severely threatened in some areas.

Macrofauna: Benthic macrofauna are mostly short lived organisms (1-3 years) and hence are good indicators of short to medium term (months to years) changes in the health of the environment. They are particularly sensitive to changes in sediment composition (e.g. particle size, organic content and trace metal concentrations) and water quality.

Rocky intertidal: Rocky intertidal invertebrates are also mostly short lived organisms (1-3 years) and as such are good indicators of short to medium term changes in the environment (months to years). Rocky intertidal communities are susceptible to invasion by exotic species (e.g. Mediterranean mussel), deterioration in water quality (e.g. nutrient enrichment), structural modification of the intertidal zone (e.g. causeway construction) and human disturbance resulting from trampling and harvesting (e.g. bait collecting).

Fish: Fish are mostly longer lived animals (3-10 years +) and as such are good indicators of medium to long term changes in the health of the environment. They are particularly sensitive to changes in water quality, changes in their food supply (e.g. benthic macrofauna) and fishing pressure.

Birds: Birds are mostly long lived animals (6-15 years +) and as such are good indicators of long term changes in the health of the environment. They are particularly susceptible to disturbance by human presence and infrastructural development (e.g. housing development), and changes in food supply (e.g. pelagic fish and intertidal invertebrates).

Alien species: A large number of alien marine species have been recorded as introduced to southern African waters. South Africa has at least 85 confirmed alien species, some of which are considered

invasive, including the Mediterranean mussel *Mytilus galloprovincialis*, the European green crab *Carcinus maenas*, and the barnacle *Balanus glandula*. Most of the introduced species in South Africa have been found in sheltered areas such as harbours, and are believed to have been introduced through shipping activities, mostly ballast water. Ballast water tends to be loaded in sheltered harbours, thus the species that are transported often originate from these habitats and have a difficult time adapting to the more exposed sections of the southern African coastline, but are easily able to gain a foothold in sheltered bays such as Saldanha Bay.

Table 2.1. Ranking categories and classification thereof as applied to Saldanha Bay and Langebaan Lagoon for the purposes of this report.

Health category		Ecological perspective	Management perspective
Natural		No or negligible modification from the natural state	Relatively little human impact
Good		Some alteration to the physical environment. Small to moderate loss of biodiversity and ecosystem integrity.	Some human-related disturbance, but ecosystems essentially in a good state, however, continued regular monitoring is strongly suggested
Fair		Significant change evident in the physical environment and associated biological communities.	Moderate human-related disturbance with good ability to recover. Regular ecosystem monitoring to be initiated to ensure no further deterioration takes place.
Poor		Extensive changes evident in the physical environment and associated biological communities.	High levels of human related disturbance. Urgent management intervention is required to avoid permanent damage to the environment or human health.

3 ACTIVITIES AND DISCHARGES AFFECTING THE HEALTH OF THE BAY

3.1 Introduction

Industrial development of Saldanha Bay dates back to the early 1900's with the establishment of a commercial fishing and rock lobster industry in the Bay. By the mid-1900's Southern Seas Fishing Enterprises and Sea Harvest Corporation had been formed, with Sea Harvest becoming the largest fishing operation in Saldanha Bay to date. Human settlement and urbanization grew from village status in 1916, to an important city today with a population of more than 40 000 today. With increasing numbers of fishing vessels operating in Saldanha Bay, and to facilitate the export of iron ore from the Northern Cape, the bay was targeted for extensive development in the early 1970's. The most significant developments introduced at this time were the causeway linking Marcus Island to the mainland, to provide shelter for ore-carriers, and the construction of the iron ore terminal. These two developments effectively separated the Bay into two separate compartments – Small Bay and Big Bay. By the end of the 1970's Saldanha Bay harbour was an international port able to accommodate large ore-carriers and deep-sea trawlers. During the 1980's a multi-purpose terminal was added to the ore terminal and a small-craft harbour was built in the western corner of Small Bay to accommodate increasing recreational and tourism activities in the bay.

A reverse osmosis desalination plant for dust control at the iron ore terminal has been operational since August 2012 and an expansion to total a capacity of 3600 m³/day of potable water is envisioned in the foreseeable future. Development of the port is expected to increase dramatically with the establishment of the Saldanha Bay Industrial Development Zone (SBIDZ), a process that was initiated in 2013. Other projects that are close to the implementation phase include the upgrade of the General Maintenance Quay and Rock Quay as well as new infrastructure to support import of liquid petroleum gas. Further proposed developments include the expansion of the iron ore terminal, the construction of a proposed oil and gas offshore service complex (OSC) at the Saldanha Bay IDZ, a breakwater in Salamander Bay, and potentially if sufficient funds are available, a new municipal reverse osmosis desalination plant.

Concerns have been raised that cumulative impacts on the marine environment in Saldanha Bay have not been adequately addressed by many of the recent development proposals. This applies especially to the cumulative impacts that will arise from future development within the Saldanha Bay IDZ. Furthermore, the impact on the Saldanha Bay marine environment by land-based projects such as storage facilities for crude oil and liquid petroleum gas has generally been underestimated. It was proposed that a more holistic management strategy was needed to deal with the piece meal Environmental Impact Assessments (EIA) and the solution was presented in form of a generic Environmental Management Programme (EMPr), which will become a requirement for every development that can be linked to the marine environment. More importantly though, an Environmental Management Framework (EMF) has been drafted for the greater Saldanha Bay Area and must be considered by the competent authority and the applicant if it is adopted in terms of NEMA by the provincial government (DEA&DP, Refer to Chapter 4). The Saldanha Bay Water Quality Forum Trust (SBWQFT) is also currently lobbying the relevant Provincial and National authorities to have Saldanha Bay declared a "Special Management Area" under the ICMA. If this is realised,

measures for the conservation alongside rapid development of the Saldanha Bay area will be addressed more effectively (Refer to Chapter 4).

Disposal of wastewater is a major problem in the region, and much of it finds its way into the Bay as partially treated sewage, storm water, industrial effluent (brine, cooling water discharges and fish factory effluent) and ballast water. Sewage discharge is arguably the most important waste product that is discharged into Saldanha Bay in terms of its continuous environmental impact. Sewage is harmful to biota due to its high concentrations of nutrients which stimulate primary production that in turn leads to changes in species composition, decreased biodiversity, increased dominance, and toxicity effects. The changes to the surrounding biota are likely to be permanent depending on distance to outlets and are also likely to continue increasing in future given the growth in industrial development and urbanisation in the area.

Ballast water discharges are by far the highest in terms of volume and also continuous due to constant and increasing shipping traffic. Ballast water often includes high levels of contaminants such as trace metals and hydrocarbons, and, along with the vessels that carry the ballast water, serves to transport alien species from other parts of the world into Saldanha Bay. Ballast water discharges can, however, be effectively managed and the remit of the International Maritime Organisation (IMO) is to reduce the risks posed by ballast water to a minimum through the direct treatment of the water while on board the ship, as well as by regulating the way in which ballast water is managed while the ship is at sea.

Storm water discharges are a seasonal concern and can introduce large volumes of surface water containing pesticides, trace metals and hydrocarbons into the Bay during the rainy season, which can, in turn, be harmful to the environment and Storm water discharges are very difficult to manage and are bound to increase with increasing urbanization and industrial development in the areas surrounding the Bay.

Dredging in Saldanha Bay has had tremendous immediate impact on benthic micro and macrofauna, as particles suspended in the water column kill suspension feeders like fish and zooplankton. It also limits the penetration of sunlight in the water column and causes die offs of algae and phytoplankton. The damage caused by dredging is generally reversible in the long term, and although the particle composition of the settled material is likely to be different, ecological functions as well as major species groups generally return in time.

The final important type of discharge to the Bay is oil spills. Although, extremely harmful to all biota, large oil spills are fortunately rare, and Saldanha Bay has never experienced a major spill to date. The management options in place in Saldanha are the best in South Africa with prevention being the primary focus.

Each of these aspects and their potential threat to the bay is addressed in more detail in the various subsections below. In some instances, however, proposed developments (including environmental impacts and proposed mitigation measures) detailed in previous State of the Bay reports have been omitted and the reader is referred to these reports (Anchor Environmental 2012, 2014) for further information on these development proposals. This only applies to those developments and activities that have not changed significantly in the past year.

3.2 Urban and industrial development

The first mention of Saldanha Bay in recorded history dates to 1601 when Joris van Spilbergen mistook the present Saldanha Bay for Table Bay. Since then the name has remained, while the original Aguada de Saldanha “watering place of Saldanha” has become known as Table Bay (Axelson 1977). In 1623, an Icelander by the name of Jon Olaffsson entered Saldanha Bay in search of whaling opportunities, only to find that French sailors had already commenced with such lucrative activities in the Bay.

Shortly after his arrival in Table Bay in 1652, Jan van Riebeeck sent a small vessel to explore the possibility of local trade opportunities in Saldanha Bay (Axelson 1977). At this stage the French had virtually hunted out the seal population, which fetched a high price for their skins. However, the abundance of sheep, fish (4 000 harders being caught in a single day) and bird’s eggs rendered the Bay sufficiently valuable for the Dutch East India Company to erect markers denoting their possession of the Bay in 1657. A shortage of freshwater, however, limited development or permanent European colonization in Saldanha Bay, although four small communities eventually became established near Langebaan Lagoon.

Saldanha Bay was reported to be “rich in fish” and although the price for fish was deemed “poor”, there are records of a fish trading post being established at Oostewal, Langebaan Lagoon in the early 1700’s (Axelson 1977). Initially, commercial fishing interests were slow to develop in Saldanha Bay, however, by the early 1900’s fishing was considered a growing industry. In 1903, a rock lobster fishery was introduced in Saldanha Bay with the North Bay Canning Company and the Saldanha Bay Canning Company being established in the early 1900’s (Axelson 1977). With increasing catches of sardines in the vicinity of the Bay, canning companies soon expanded their business to incorporate sardine canning. In 1948 the North Bay Canning Company was absorbed into Southern Seas Fishing Enterprises, while in 1964 Sea Harvest Corporation was formed, subsequently becoming the largest fishing operation in Saldanha Bay, operating a fleet of deep-sea trawlers and purse seiners and providing an onshore fish packing and freezing facility.

The first whaling factory was built in 1909 at Donkergat, followed by a second in 1911 at Salamander Bay. In 1930 however, the international price for whale oil plummeted, resulting in the closure of both these factories. Whaling activities were re-established for a short period between 1960 and 1967, after which no further whaling took place in Saldanha Bay (Axelson 1977).

The establishment of fish processing factories and the substantial growth of the fishing industry in Saldanha Bay resulted in an ever increasing number of pelagic fishing vessels harbouring in the Bay and offloading their catch. During the early 1970’s, the methods employed to offload the catch involved releasing substantial amounts of water, loaded with organic matter (biological waste and fish factory effluent), back into the Bay (known as “wet offloading”). Within a short period of time the marine environment within the Bay began showing severe signs of organic overloading and in 1972 a mass mortality event of marine organisms (fish and shellfish) brought the pollution situation to attention. By 1974, official waste management practices (primarily “dry offloading” of the catch) were being implemented by the fish factories to reduce the amount of organic loading in the Bay (Christie & Moldan 1977).

Saldanha Bay, being the only natural harbour of significant size on the west coast of South Africa, was targeted for development of an industrial port at an early stage, and in 1971 was upgraded into an international port (Fuggle 1977). The primary purpose of the port at that stage was to facilitate the export of iron ore as part of the Sishen-Saldanha Bay Ore Export Project. The first major development in the Bay towards the realisation of these goals was the construction of the iron ore terminal and a causeway, built in 1973, that linked Marcus Island to the mainland, providing shelter for ore-carriers. During 1973 and 1974 the General Maintenance Quay and Rock Quay were added to the iron ore terminal. Between 1974 and 1976 extensive dredging was conducted to accommodate a deep-water port for use by large ore-carriers. The iron ore terminal was built with the initial intention of being used for export of ore, however, was later extended to provide for the import of oil. The construction of the iron ore terminal essentially divided Saldanha Bay into two sections: a smaller area bounded by the causeway, the northern shore and the ore terminal (called Small Bay); and a larger, more exposed area adjacent called Big Bay, leading into Langebaan lagoon (Figure 3.3.). A multi-purpose terminal had been added to the ore terminal by 1980 and a small-craft harbour was built in 1984 to cater for the increase in recreational and tourism activities in the Bay. Due to the increase in heavy industries in the area in the 1990's (Namakwa Sands, Saldanha Steel), the Multi-Purpose Terminal was extended in 1998. During each phase of development undertaken in Saldanha Bay, dredging and submarine blasting has been necessary. Development of the causeway and iron-ore terminal in Saldanha Bay greatly modified the natural water circulation and current patterns (Weeks *et al.* 1991b) in the Bay. This led to reduced water exchange and increased nutrient loading of water within the Bay.

In addition to the increasing fish factory effluent and the structural modifications of the Bay, the establishment of mussel mariculture ventures (of the Mediterranean mussel *Mytilus galloprovincialis*) in the sheltered waters of Small Bay in 1984, exacerbated the pollution and organic loading problems in the area (Stenton-Dozey *et al.* 1999). Aerial photographs taken in 1960 (Figure 3.1), 1989 (Figure 3.2) and in 2007 (Figure 3.3.) clearly show the extent of development that has taken place within Saldanha Bay over the last 50 years. The current layout of the Port of Saldanha is shown in Figure 3.4. Future plans, including short term (2019) and long-term goals for the development of the bay are shown in Figure 3.5 and Figure 3.6.



Figure 3.1 Composite aerial photo of Saldanha Bay and Langebaan Lagoon taken in 1960. (Source Department of Surveys and Mapping). Note the absence of the ore terminal and causeway and limited development at Saldanha and Langebaan.

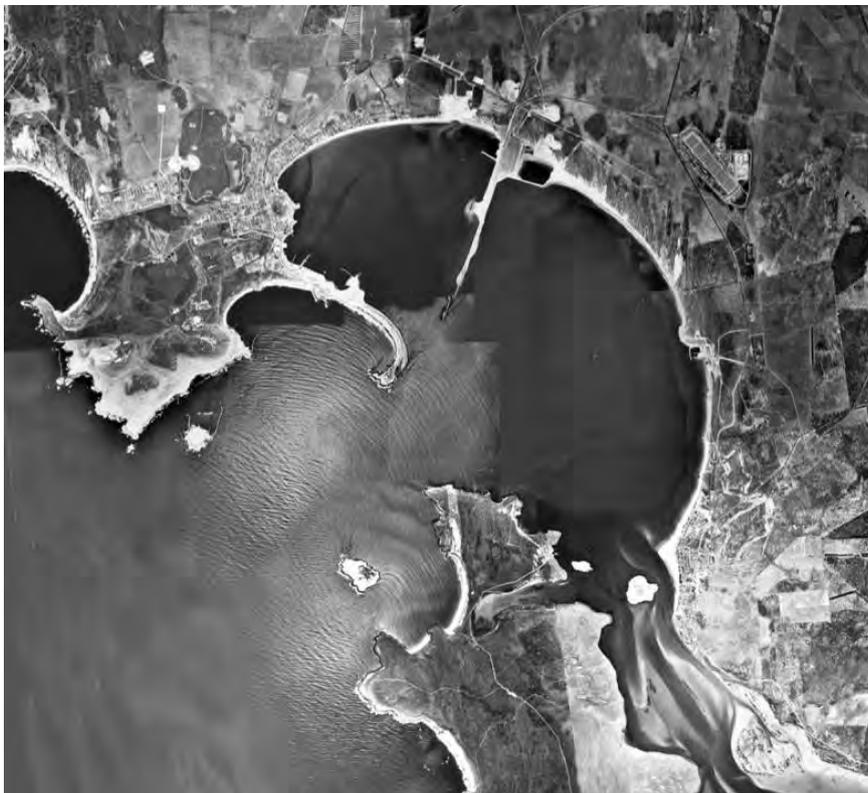


Figure 3.2. Composite aerial photo of Saldanha Bay and Langebaan Lagoon taken in 1989 (Source Department of Surveys and Mapping). Note the presence of the ore terminal, the causeway linking Marcus Island with the mainland, and expansion of settlements at Saldanha and Langebaan.



Figure 3.3. Composite aerial photo of Saldanha Bay and Langebaan Lagoon taken in 2007. (Source Department of Surveys and Mapping). Note expansion in residential settlements particularly around the town of Langebaan.

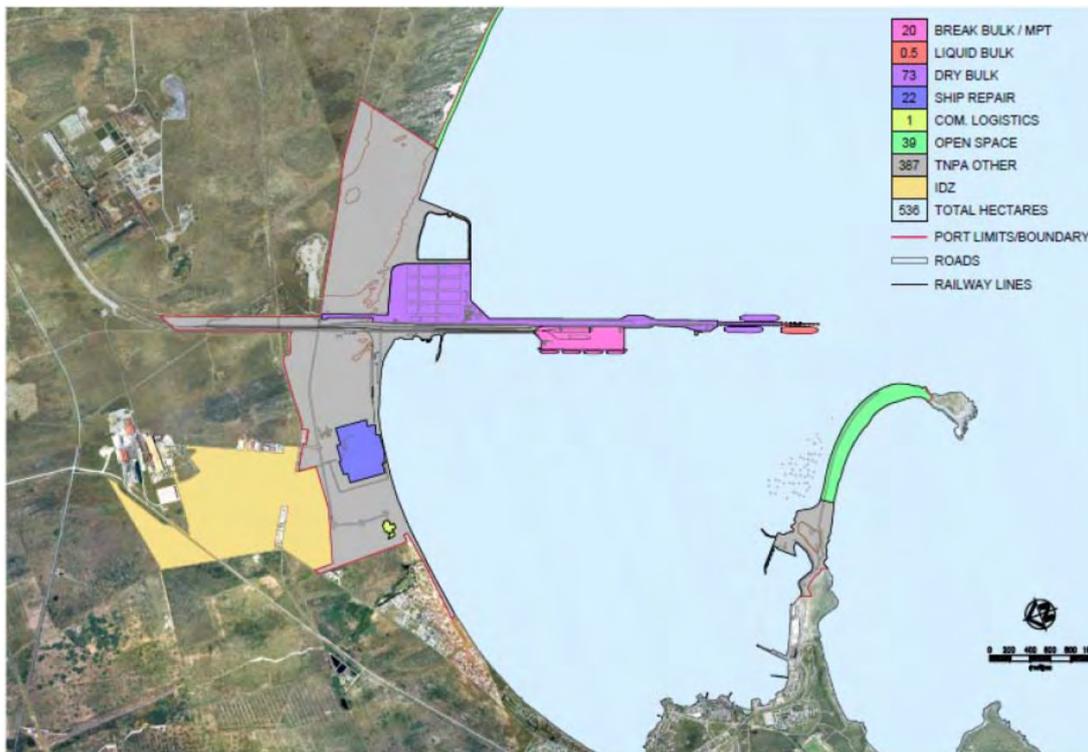


Figure 3.4. Current layout of Transnet Saldanha Bay Port (Source: Transnet National Port Authority 2013, Port Development Framework Plans).

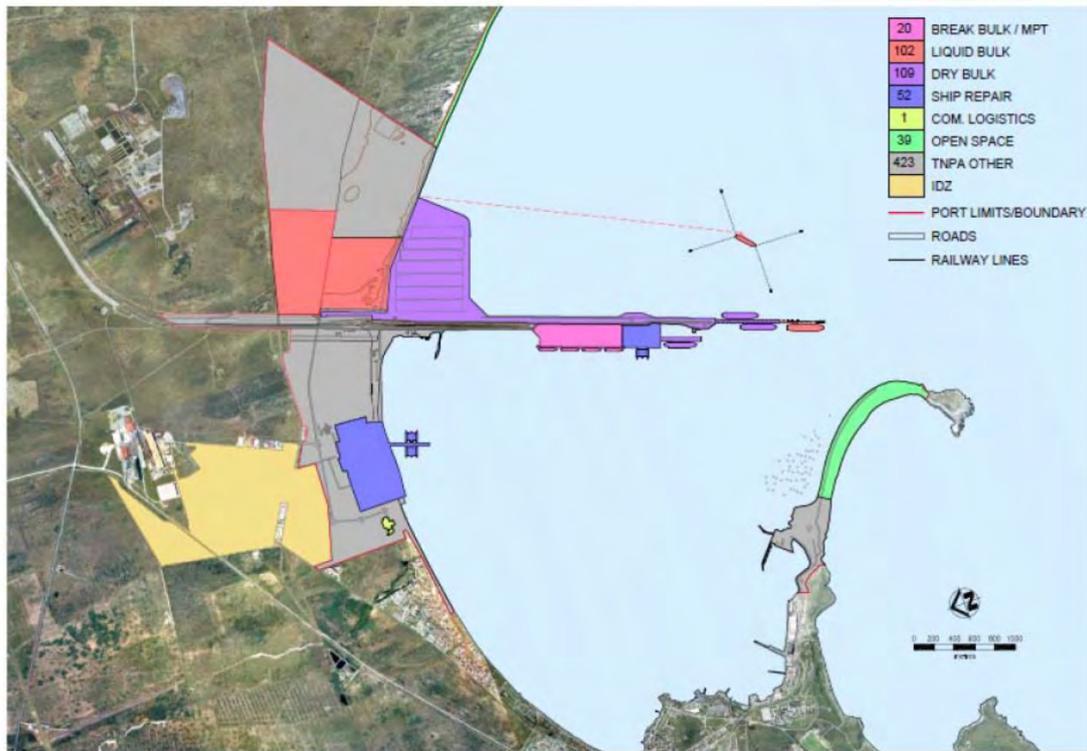


Figure 3.5. Short term layout (2019) of Transnet Saldanha Bay Port (Source: Transnet National Port Authority 2013, Port Development Framework Plans).

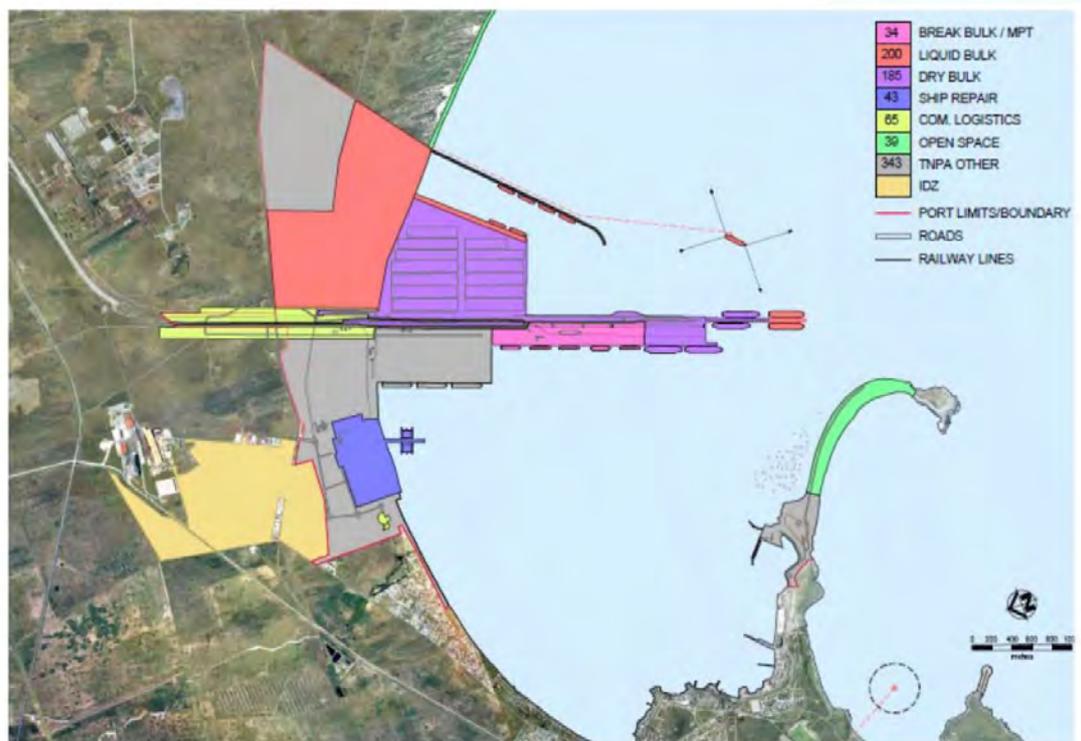


Figure 3.6. Long term layout of Transnet Saldanha Bay Port (Source: Transnet National Port Authority 2013, Port Development Framework Plans).

Data on population growth in the town of Saldanha and Langebaan Lagoon are available from the 1996, 2001 and 2011 census data. The population of Saldanha increased from 16 820 in 1996 to 21 636 in 2001 and to 28 135 in 2011, growth slowing from an initial rate of 5.7% per year in the first period to just 2.7%/yr in the second (Statistics South Africa 2014). In contrast, the Langebaan population increased from 2 735 to 3 428 between 1996 and 2001 (2.5% per year), and rapidly from there up to 8 294 in 2011 (a growth rate of 9.24%/yr) (Table 3.1.) (Statistics South Africa 2014). The human population in Saldanha Bay, particularly that in Langebaan Village, is thus expanding rapidly, which has been attributed to the immigration of people from surrounding municipalities in search of real or perceived jobs (Saldanha Bay Municipality 2011). These population increases are no doubt increasing pressure on the marine environment and the health of the Bay through increased demand for resources, trampling of the shore and coastal environments, increased municipal (sewage) and household discharges (which are ultimately disposed of in Saldanha Bay) and increased storm water runoff due to expansion of tarred and concreted areas.

Urban development around Langebaan Lagoon has encroached right up to the coastal margin, leaving little or no coastal buffer zone (Figure 3.7. and Figure 3.8.). Allowing an urban core to extend to the waters' edge places the marine environment under considerable stress due to trampling and habitat loss. It also increases the risks of erosion due to removal of vegetation and interferes with certain coastal processes such as sand deposition and migration. Expansion of tarred areas also increases the volumes of storm water entering the marine environment, which ultimately can have a detrimental effect on ecosystem health via the input of various contaminants and nutrients (See Section 3.4).

Table 3.1. Total human population and population growth rates for the towns of Saldanha and Langebaan from 2001 to 2011 (Statistics South Africa, 2014).

Location	Total Population 1996	Total Population 2001	Total Population 2011	Growth 2001-2011 (%/yr.)
Saldanha	16 820	21 363	28 135	2.66
Langebaan	2 735	3 428	8 294	9.24



Figure 3.7. Satellite image of Saldanha (Small Bay) showing little or no set-back zone between the town and the Bay. Source: Google Earth.

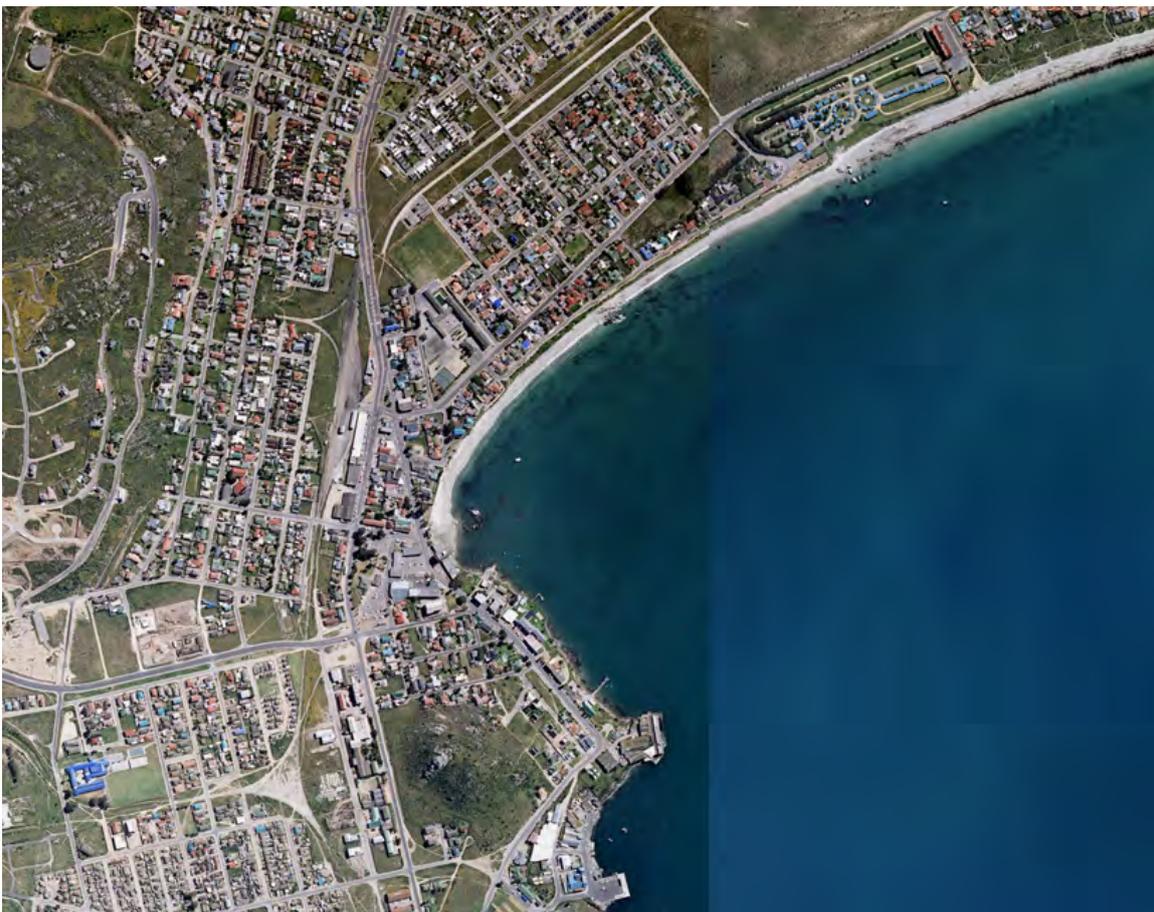


Figure 3.8. Composite aerial photograph of Langebaan showing absence of development set-back zone between the town and the lagoon. Source: Department of Surveys & Mapping, South Africa.

Industrial and urban development in and around Saldanha Bay has been matched with increasing tourism development in the area, specifically with the declaration of the West Coast National Park, Langebaan Lagoon being declared a National Wetland RAMSAR site and establishment of holiday resorts like Club Mykonos and Blue Water Bay. The increased capacity for tourism results in higher levels of impact on the environment in the form of increased pollution, traffic, fishing and disturbance. Long term data (2005-2015) on numbers of visitors to the West Coast National Park (WCNP) indicate strong seasonal trends in numbers of people visiting the park, peaking in the summer months and during the flower season in August and September (Figure 3.9.). Paying day guests (excluding international visitors) contribute the most to this seasonal pattern, while free guest¹ numbers are relatively constant throughout the year with a small peak in September. International and overnight guest numbers are considerably lower than the visitor categories. Visitor numbers have been increasing at an average rate of 13% per annum since 2005², peaking in the 2014-2015 period with a total of almost 240 thousand visitors (Figure 3.10). Historically, domestic day guests have made up the largest proportion but have been decreasing since peaking in 2009/2010. In contrast, the number of free guests has been increasing steadily over time and now equals the proportion of day guests. The number of international visitors has stayed relatively constant over time while popularity of overnight stays inside the park has decreased substantially since 2005/2006 and reached lowest numbers in 2014/2015 with 2053 guests.

¹ These include Wild Card, school class, military personnel, official visit, staff, residents and 'other' entries.

² The average annual growth rate was calculated from the data reflecting the total numbers of tourists entering the West Coast National park in a rolling 12 month periods from July 2005 until June 2015.

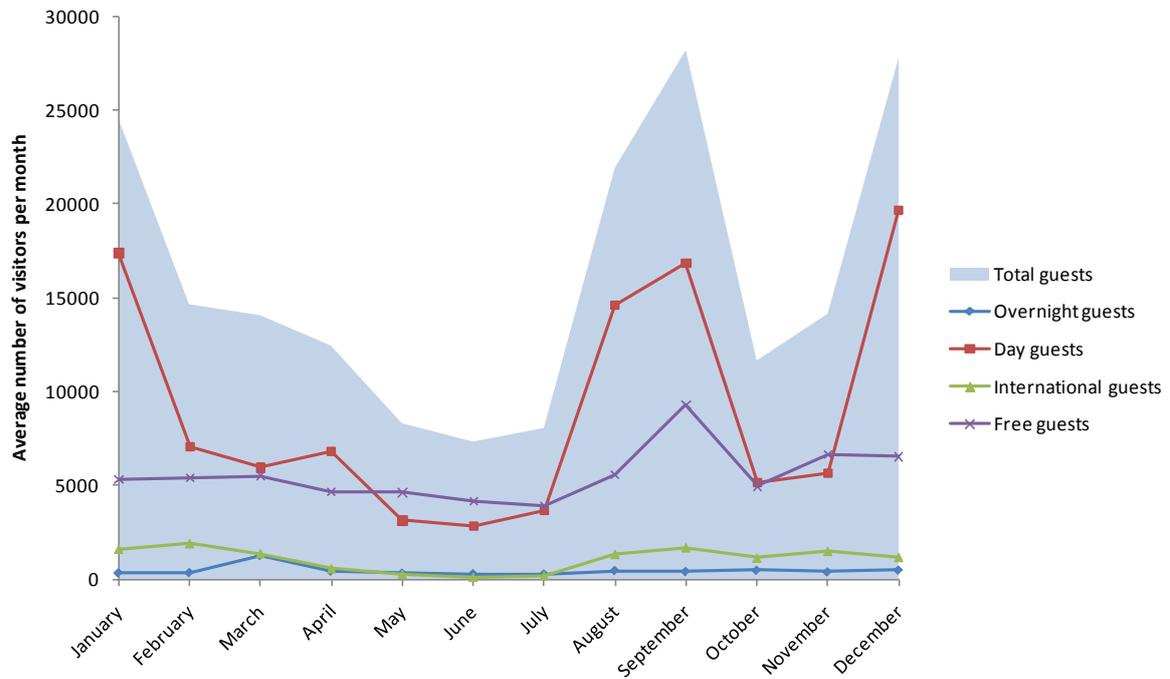


Figure 3.9. Monthly average tourist numbers visiting the West Coast National Park since 2005. Day guests include all South African visitors (adults and children) while Overnight guests refer to those staying in SANPARK accommodation. International guests include all SADC and non-African day visitors (adults and children) while the category ‘Other’ includes residents, staff, military, school visits, etc. (Source: Pierre Nel, WCNP).

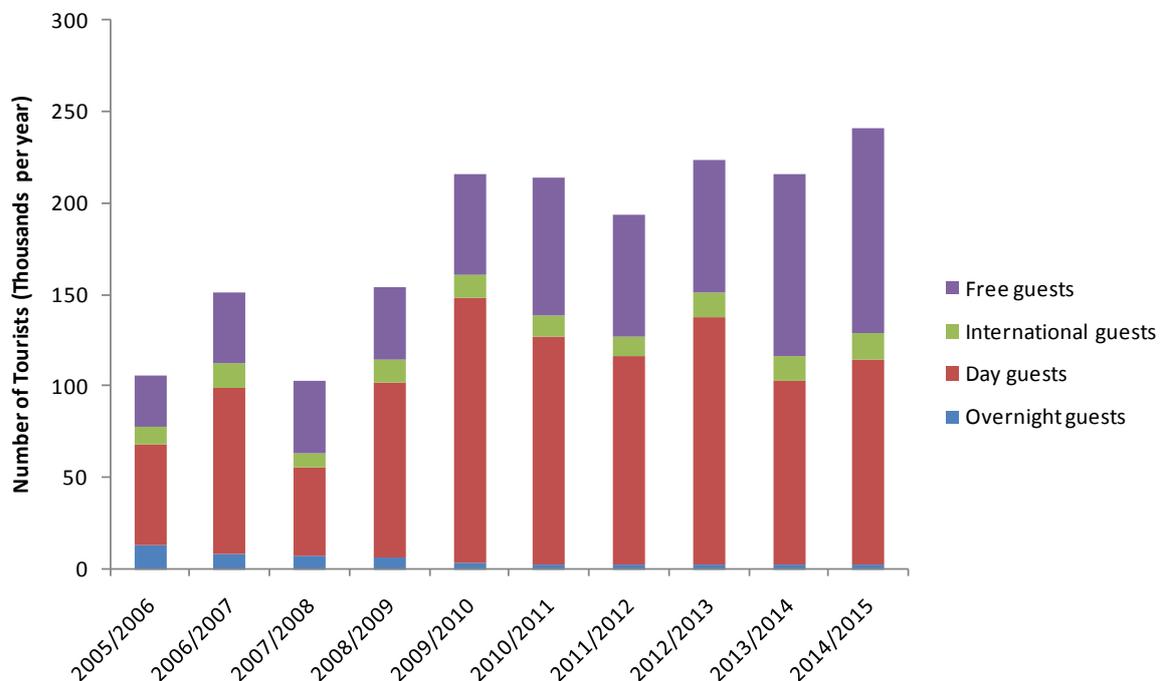


Figure 3.10. Numbers of tourists visiting the West Coast National Park in a rolling 12 month periods from July 2005 until June 2015. Day guests include all South African visitors (adults and children) while Overnight guests refer to those staying in SANPARK accommodation. International guests include all SADC and non-African day visitors (adults and children) while the category ‘Other’ includes residents, staff, military, school visits, etc. (Source: Pierre Nel, WCNP).

In terms of the Municipal Systems Act 2000 (Act 32 of 2000) every local municipality must prepare an Integrated Development Plan (IDP) to guide development, planning and management over the five year period in which a municipality is in power. A core component of an IDP is the Spatial Development Framework (SDF) which is meant to relate the development priorities and the objectives of geographic areas of the municipality and indicate how the development strategies will be co-ordinated. An SDF aims to guide decision making on an on-going basis such that changes, needs and growth in the area can be managed to the benefit of the environment and its inhabitants. The 2006 Saldanha Municipality IDP has recently been revised and replaced with the 2011/2012 IDP. The revised SDF for the Saldanha Bay Municipality (SBM) was produced in 2011 and is available on the municipality website. The revised version has adopted a holistic approach, ensuring that the municipal spatial planning of the rural and urban areas is integrated for the first time since the establishment of the municipality.

A study by Van der Merwe *et al.* (2005) assessing the growth potential of towns in the Western Cape (as part of the provincial SDF) identified Langebaan and Saldanha as towns with high growth potential. It was estimated that, given the projected population figures, there would be a future residential demand of 9 132 units in Saldanha and 3 781 units in Langebaan. The SDF proposes addressing these demands by increasing the residential density in specified nodes in both towns and by extending the urban edge of Saldanha in a northerly direction towards Vredenberg, and that of Langebaan inland towards the North-East.

3.2.1 The Saldanha Bay Industrial Development Zone

Saldanha Bay has long been recognised as a strategically important industrial centre in the Western Cape. This provided a strong foundation for the establishment of an Industrial Development Zone (IDZ) in October 2013. IDZs are designated in terms the Industrial Development Zone Programme Regulations (R.1224 of the Manufacturing Development Act (no. 187 of 1993) which provide in Regulation 3 that:

- (1) The Minister may identify an area as suitable for development of an Industrial Development Zone by notice in the Gazette if the Minister is satisfied that designation of the area as an Industrial Development Zone will –
 - a. facilitate the creation of an industrial complex having strategic economic advantage;
 - b. provide the location for the establishment of strategic investments;
 - c. enable the exploitation of resource-intensive industries;
 - d. take advantage of existing industrial capacity, promote integration with local industry and increase value-added production;
 - e. create employment and other economic and social benefits in the region in which it is located; and
 - f. be consistent with any applicable national policies & law, as determined by appropriate environmental, economic and technical analyses.

In 2008, the Western Cape Department of Economic Development and Tourism (DEDT), through Wesgro (the official Investment and Trade Promotion Agency of the Western Cape) appointed Demacon Consulting to conduct a pre-feasibility study to identify and assess the opportunities

available in the industrial and business market and ascertain whether there are any binding constraints to establishing an IDZ programme at Saldanha Bay. This pre-feasibility study (completed in October 2009) was followed shortly by a more detailed feasibility study (Wesgro 2011) which culminated in an application from the Provincial Government of the Western Cape (PGWC) and SBM to the Department of Trade and Industry (DTI) for the designation of an IDZ within the Saldanha Bay area (Wesgro 2011).

On 13 October 2013, the Minister of Trade and Industry promulgated the IDZ at Saldanha Bay and granted the Operator Permit to the SBIDZ licensing Company (Saldanha Bay Industrial Development Zone LiCo) (Notice 1081 of 2013). The SBIDZ is intended as an Oil and Gas Marine Repair engineering and logistics services complex. The designation of the IDZ provides a contiguous customs-free area, designed to facilitate international investment in the area. The SBIDZ Licencing Company (LiCo) (a subsidiary of Wesgro) was assigned the responsibility for the promotion, management and marketing of the SBIDZ. The SBIDZ is envisioned to provide services in maintenance and repair fabrication as well as communal and supply services (Table 3.2.). Proposed first phase developments that form part of the SBIDZ are described in Section 3.4. Concern has been expressed over the fact that the impacts of the SBIDZ on the marine environment have not been adequately assessed or addressed, considering the likely impacts of increased vessel traffic on underwater noise and invasive alien species transfer; increased pollution of the Saldanha Bay through maintenance and repair activities; additional storm water runoff; and added pressure on the already regularly overflowing sewage works (Section 3.4.3) in Saldanha.

Table 3.2. Overview of the planned activities in the Saldanha Bay Industrial Development Zone (Adapted from Wesgro 2012)

Maintenance & Repair Services	Fabrication Services
<ul style="list-style-type: none"> Maintenance, repair, upgrade and conversion of rigs and other vessels (floating repairs, dry docking) Repair of parts and structures Inspection, certification 	<ul style="list-style-type: none"> Structures, subsea manifolds Spare parts
Communal Services	Supply & other Services
<ul style="list-style-type: none"> Property development Customs clearance Marketing & administrative functions Security, medical, food & retail Utilities, waste management, transport Road and quay access 	<ul style="list-style-type: none"> Bonded warehousing / storage - Scheduling & forecasting Logistics and transport – sourcing and forwarding (air, ship, rail and road) Lifting, stacking, moving Fuel bunkering Pipe coating & upsetting Tugging / piloting Project and engineering services (e.g. EPC)

The Saldanha Bay IDZ Licensing Company (LiCo) appointed CCA Environmental (Pty) Ltd to undertake the Scoping and EIA process for the proposed oil and gas offshore service complex (OSC) at the Saldanha Bay IDZ. This S&EIA process is only applicable to the southern side of the Saldanha IDZ

(Portion 2, Figure 3.11) and the Final EIR is currently subject to a commenting period from 1 September to 2 October 2015.

The project includes the following components:

- Maintenance and repair of offshore drilling units covering an initial 10 ha, potentially expanding to 14 ha in future;
- A 3 ha small ship repair yard that will service smaller ships 100-150 m in size in four repair bays;
- A regional service base for ports and offshore supply bases for oil and gas activities (16 ha);
- Multi-user fabrication and storage yard for the manufacturing and storage of equipment and associated items for the oil and gas industry. Several operators specialising in different products (25 ha short term, 100 ha long-term);
- Regional oil disaster response base for the storage of major oil spill remediation equipment (1 ha); and
- Communal / support services (unknown area).

Upgrades to the Saldanha Bay WWTW are currently underway and are subject to substantial increases treatment capacity to cater for the proposed activities related to the Saldanha Bay IDZ (Section 3.4.3.3). The total water demand of the entire OSC was calculated as 1453 kilolitre per day and is characteristic of general office demand as opposed to that of a wet industry. Water will initially be provided by the WCDM bulk water distribution system supplied by the Miswaterstand Water Scheme. Water shortages in the near future are predicted and alternative options are under discussion including water transfer from the Berg River system as well supplies from a proposed regional RO plant situated in Danger Bay (Section 3.4.2). A waste transfer facility on Portion 1 of the Saldanha Bay IDZ is also required, which will be subject to a Waste Management License and associated EIA.

The draft EIR included description and assessment of environmental impacts on terrestrial ecosystems and biodiversity but failed to address impacts on the marine environment. Comments provided by Interested and Affected Parties resulted in the inclusion of a short marine risk assessment which dealt with the possible impacts of increased vessel traffic as well as stormwater runoff from the proposed OSC. However, it was also clarified that potential impacts that may occur as a result of the construction and operation of marine infrastructure associated with the OSC will be investigated in a separate EIA process undertaken by the TNPA at a later stage.

The direct impact of additional vessels on marine ecology of the bay (i.e. oil and alien species transfer) was rated to be of low significance due to the very small increase (1-3%) in cargo volume expected over the next 30 years. Furthermore, the risk of alien biota transfer into the port was claimed to be low as shallow berth vessel types will not require deballasting within the port and high pressure blasting of vessel hulls to clear hull fouling is not permitted. Large oil spills would also be unlikely as the proposed complex is not associated with oil tankers. The following mitigation measures applicable to the marine environment were listed in the final EIR:

- LiCo should participate in long term water quality monitoring within the Saldanha Bay area as part of the Saldanha Bay Water Quality Forum Trust's State of the Bay monitoring process. Participation could include making data available to the SBWQFT and providing a financial contribution for setting up further monitoring stations within the Port of Saldanha;
- It must be ensured that all operators are aware of and implement existing measures for the management of marine impacts within the Port of Saldanha. These include:
 - Ballast Water Performance Standards as specified in the new Draft Ballast Water Management Bill, 2013.
 - All vessels entering the Port of Saldanha must undergo inspection by a Pollution Control Officer to minimise the risks of pollution in the port
 - Standard Terms and Conditions for Ship Repair Operators which details the Safety, Health and Environmental (SHE) process to be followed for rig/vessel repair within the Port of Saldanha and also includes a Code of Practice for Ship Repair Operators.
 - Onshore stormwater management at the proposed OSC are expected to comply with TNPA's Draft Stormwater Management Plan which requires that all stormwater on-site is collected for infiltration and evaporation in detention ponds of sufficient capacity to retain a 1:50 year rain event.
- An updated Operational EMP must be compiled once it is known which businesses will be established within the OSC. The Operational EMP must address activities as part of all components of the OSC, both onshore and offshore. This Operational EMP should be made available for public review prior to submission to DEA&DP for approval; and
- Sufficient capacity is absolutely necessary in the stormwater planning of the site in order to efficiently manage stormwater in line with TNPA and municipal requirements. No stormwater from onshore facilities is to be discharged to the sea as per TNPA policy (Section 3.4.5.1).



Figure 3.11 Google Earth image showing the location of the proposed site (red shading) within the Saldanha Industrial Development Zone indicated by the and black outline (Source: Final EIR for the proposed oil and gas offshore service complex at the Saldanha Bay IDZ, CCA Environmental (Pty) Ltd. 2015).

3.2.2 Export of metal ores from the Port of Saldanha

Metal ores exported from the Port of Saldanha Bay include lead, copper, zinc, iron and manganese. Most of the iron is exported from the iron ore terminal, while a proportion is also exported from the multipurpose terminal (Figure 3.13). The Port of Saldanha currently has the capacity to export up to 60 million tons of iron ore per year but is in the process of upgrading the infrastructure to support an annual export of 80 million tons (Section 3.2.4). Iron ore exports have increased steadily from 19.89 to 52.2 million tonnes between the years 2013 and 2014 and it is likely that 2015 exports will be closer to the maximum capacity of the current infrastructure (28.4 million tons in June, extrapolated to 56.9 million tonnes) (Figure 3.12, data provided by Rejean Viljoen, Transnet Port Authority 2015). Iron ore exports departing from the Multi Purpose Terminal in the Port of Saldanha comprise the greatest proportion of metal exports from this terminal and have increased continuously from 252 000 tons in 2011 to 328 000 tons per annum in 2014 (note that annual export is calculated based on the fiscal year, i.e. April-March). Lead exports in contrast remained stable between 2010 and 2013 before dropping by almost half in 2014. Zinc exports show inter-annual fluctuation where exports peaked in 2013 with 87 000 tons. Copper is exported in small quantities compared to iron ore and exports have steadily increased since 2011, peaking in 2014 at 23 000 tons.

Manganese exports via the port of Port Elizabeth account for approximately 65% of total exports (5.9 million tonnes in 2013/2014), followed by the Port of Durban with 33% and a very small quantity from Saldanha Bay and Richards Bay (Ports Regulator of South Africa 2015). Manganese exports from the MPT in Saldanha Bay commenced recently. Total exports by February 2015 were close to 800 000 tonnes, comparing to a 600 000 tonne budget for the financial year 2014/2015 (TNPA 2015). Although it is unknown when exactly manganese exports commenced, FerroMarine Africa Pty Ltd

saw manganese export activities at the MPT in Saldanha Bay for the first time in September 2014 (FerroMarine Africa Pty Ltd, *pers. comm.* 2015). The Transport Port Terminals (TPT) ensured that the manganese ore would be containerised and would hence not introduce any dust into the environment. However, it has been observed that manganese ore is arriving in open rail wagons and is loaded by open skips into bulk cargo vessels (FerroMarine Africa Pty Ltd, *pers. comm.* 2015). Concerns have been submitted to the West Coast District Municipality that the listed threshold of 100 000 tonnes storage and handling capacity as per the National Environmental Management Air Quality Act (Act 39 of 2004) is likely to have been exceeded through additional exports of manganese ore at the MTP (FerroMarine Africa Pty Ltd, *pers. comm.* 2015). It is clearly evident that manganese contamination of sediments has quadrupled at some sampling sites in Saldanha Bay (Section 6.1.3). Congruently, analysis of bivalve tissue at five sites in Saldanha Bay show a marked increase in 2014 and 2015 (Section 5.10).

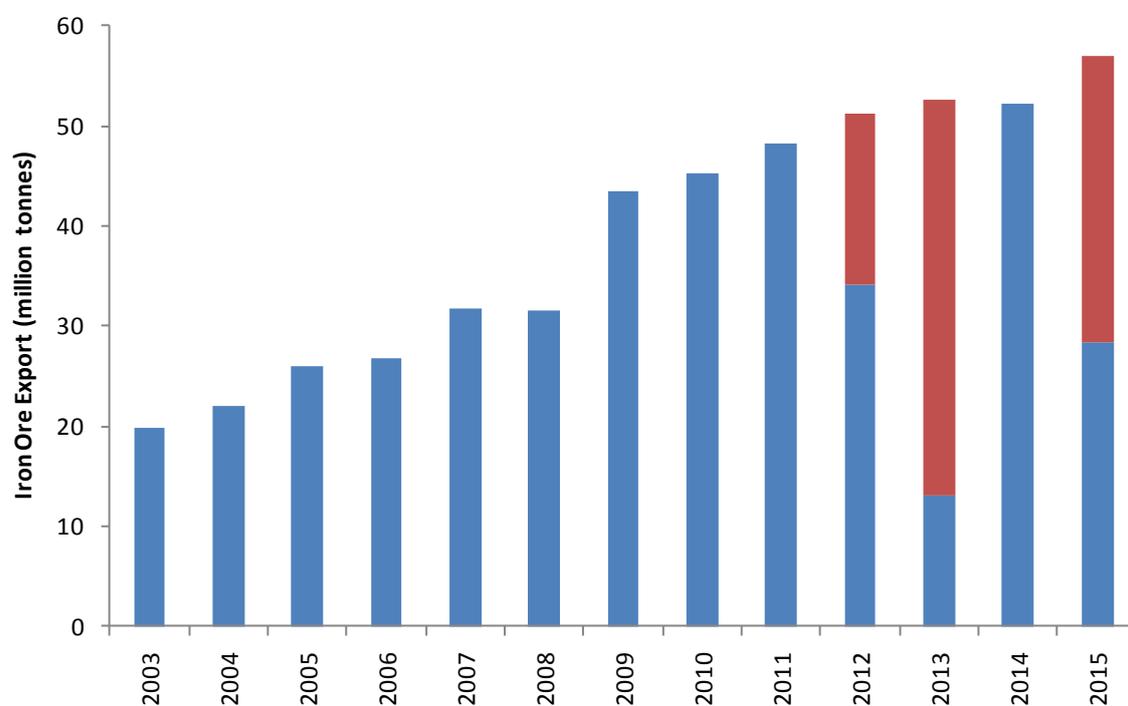


Figure 3.12 Annual exports of iron ore from the from the Iron Ore Terminal at the Port of Saldanha. Red indicates the extrapolation made for that year from existing data (Data provided by Rejean Viljoen, Transnet Port Authority 2015).

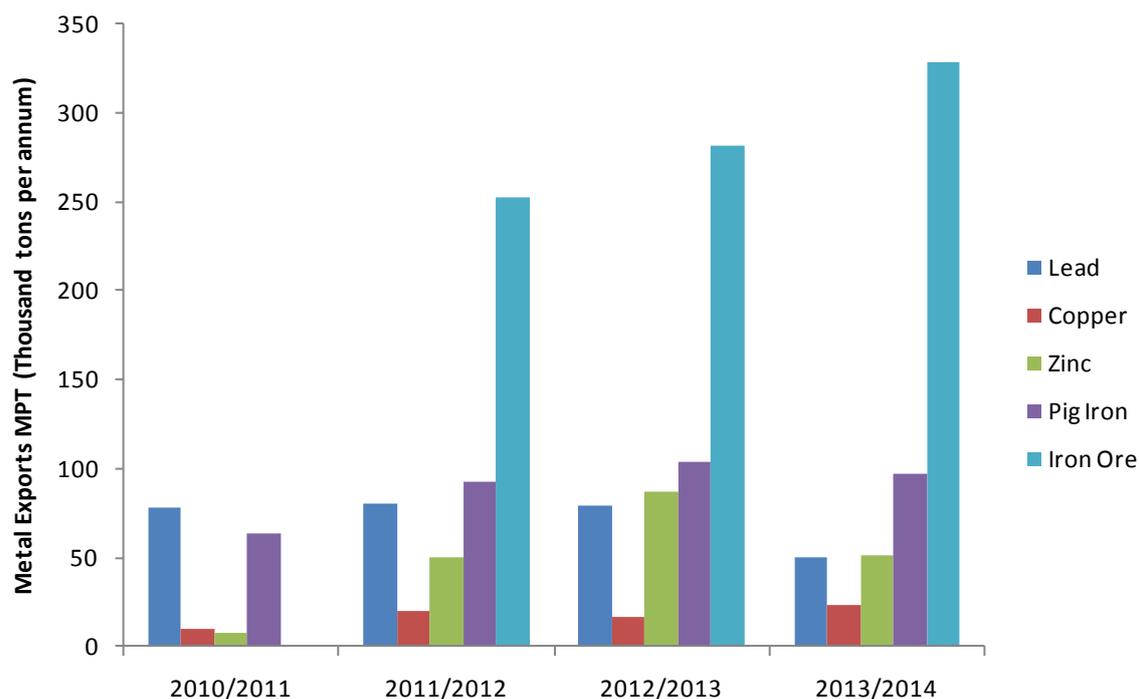


Figure 3.13 Annual exports of lead, copper, zinc, pig iron and iron ore from the Multipurpose Terminal at the Port of Saldanha Bay (Data provided by Rejean Viljoen, Transnet Port Authority 2015).

3.2.3 Dredging and port expansion

Dredging of the seabed is performed worldwide in order to expand and deepen existing harbours/ports or to maintain navigation channels and harbour entrances (Erftemeijer & Lewis 2006), and has thus been touted as one of the most common anthropogenic disturbance of the marine environment (Bonvicini Pagliai *et al.* 1985). The potential impacts of dredging on the marine environment can stem from both the removal of substratum from the seafloor and the disposal of dredged sediments, and include:

- Direct destruction of benthic fauna populations due to substrate removal;
- Burial of organisms due to disposal of dredged sediments;
- Alterations in sediment composition which changes nature and diversity of benthic communities (e.g. decline in species density, abundance and biomass);
- Enhanced sedimentation;
- Changes in bathymetry which alters current velocities and wave action;
- Increase in concentration of suspended matter and turbidity due to suspension of sediments. The re-suspension of sediments may give rise to:
 - Decrease in water transparency
 - Release in nutrients and hence eutrophication
 - Release of toxic metals and hydrocarbons due to changes in physical/chemical equilibria
 - Decrease in oxygen concentrations in the water column
 - Bioaccumulation of toxic pollutants

- Transport of fine sediments to adjacent areas, and hence transport of pollutants
- Decreased primary production due to decreased light penetration to water column

Aside from dredging itself, dredged material may be suspended during transport to the surface, overflow from barges or leaking pipelines, during transport to dump sites and during disposal of dredged material (Jensen & Mogensen 2000 in Erftemeijer & Lewis 2006).

Saldanha Bay is South Africa's largest and deepest natural port and as a result has undergone extensive harbour development and has been subjected to several bouts of dredging and marine blasting (refer to AEC 2014 for more information on the dredging events prior to 2012). In 2012, Transnet-NPA proposed an upgrade of the existing General Maintenance Quay and the Rock Quay in Saldanha Bay. This allows for the docking of larger vessels involved in cargo handling, thus potentially increasing the throughput capacity of the Port of Saldanha (refer to AEC 2014 for more information regarding the project design and impact mitigation). Environmental authorisation for this project was granted and the Draft EMPr was approved on 3 September 2013 (SRK Consulting, *pers. comm.* 2014). Construction commenced at the beginning of 2015 and is estimated to be completed just over a year later (PRDW, Project Engineer, Shaun Hayes, *pers. comm.* 2014). Maintenance dredging has taken place in accordance with the Environmental Management Programme, which includes turbidity monitoring.

3.2.4 The Sishen-Saldanha oreline expansion project

Currently, iron ore is mined in Hotazel, Postmasburg and Sishen before being transported on a freight train 861 km to Saldanha Bay. From the train, it is loaded onto conveyor belts and then placed in stockpiles to be loaded into the holds of cargo ships. Transnet is currently installing a third iron ore tippler to ensure that 60 million tons per annum of iron ore can continue to be exported (GIBB 2013b) (refer to AEC 2014 for more information on this project).

Transnet in conjunction with six mining companies (Aquila Steel, Assmang, Kumba Iron Ore, PMG, Tshipi e Ntle and UMK) are now proposing an oreline expansion project. This would increase the capacity of the current Sishen-Saldanha railway and port from 60 to 88 million tonnes per annum by 2017 in order to satisfy the global demand for iron ore (GIBB 2013). The Sishen-Saldanha oreline expansion project has three major components, namely a facility for emerging miners (mine-side ore loading), iron ore rail and a port iron ore terminal (GIBB 2013). The three components of this project are currently still in the planning phase (refer to AEC 2014 for more information and time frames of this project).

An increase in rail capacity will result in a greater volume of ore arriving in Saldanha and accordingly an increase in ship traffic will be necessary in order to transport this product globally. In 2014, 306 iron ore ships arrived and departed from the iron ore terminal in the Port of Saldanha, exporting 52.2 million tons of iron ore (Section 3.2.2).

3.2.5 Development of liquid petroleum gas facilities in Saldanha Bay

Liquid Petroleum Gas (LPG) is a fuel mix of propane and butane which is in a gaseous form at ambient temperature, but is liquefied under increased pressure or by a temperature decrease. The LPG industry is currently expanding to provide an alternative energy source in South Africa and to reduce the pressure on South Africa's electricity grid. In line with the National LPG Strategy (DEA&DP 2014), 1.5 million households are aimed to convert to LPG over the next five years. These new developments will contribute cumulatively to existing impacts in Saldanha Bay such as stormwater runoff and increased vessel traffic. The offloading of imported LPG in the harbour poses an additional pollution risk to the Saldanha harbour.

Sunrise Energy (Pty) Ltd is currently building an LPG import facility in the Saldanha Bay Harbour and is scheduled to be completed in mid-2016 (Sunrise Energy (Pty) Ltd, Janet Barker, *pers. comm.* 2014). This development aims to supplement current LPG refineries and distributors in the Western Cape and ensure that industries dependant on LPG can remain in operation. An EIA process in terms of section 24 of the NEMA was initiated by ERM Southern Africa in 2012 and EA was granted on 13 May 2013 by the DEA&DP (refer to AEC 2014 for more information). The Draft EMP for the project requires that environmental/sediment monitoring be undertaken prior to and during installation of marine infrastructure to monitor effects on the surrounding environment, and that annual monitoring of environment/sediment in the vicinity of the marine facilities to assess any potential operational impacts on water quality. It was recommended that such monitoring be undertaken as part of the Saldanha Bay Water Quality Forum Trust's monitoring program. The bulk earthworks and construction commenced in January 2014, but the installation of infrastructure in the marine environment has not yet begun and is scheduled to start in September 2015 (Sunrise Energy (Pty) Ltd, Janet Barker, *pers. comm.* 2015).

Avedia Energy is in the process of developing a land based liquid petroleum gas storage facility on Portion 13 of Farm Yzervarkensrug No. 127 in Saldanha. The storage facility will include 16 mounded bullet tanks with a storage capacity of 250 metric tons each. So far, site clearance and the first four bullets have been installed and further construction will commence as soon as tenders have been adjudicated and awarded (Frans Lesch, ILF Consulting Engineers, Project Manager at Avedia Energy Saldanha LPG plant, *Pers. Comm.* 2015) (refer to AEC 2014 for more information).

3.2.6 Crude oil storage facility

The Port of Saldanha reportedly represents an excellent strategic location to receive, store process and distribute crude oil from West Africa and South America (SouthAfrica.info 2013). Oil tanking MOGS Saldanha (RF) (Pty) Ltd (OTMS), a joint venture between MOGS (Pty) Ltd and OTGC Holdings (Pty) Ltd, intend to construct and operate a commercial crude oil blending and storage terminal with a total capacity of 13.2 million barrels, comprising twelve 1.1 million barrel in-ground concrete tanks in Saldanha Bay. The construction phase commenced at the beginning of 2015 but it is currently unknown when this project will be completed (refer to AEC 2014 for more information).

3.2.7 Development of the Salamander Bay Boat yard

The Special Forces Regiment of the South African National Defence Force (SANDF) commenced with the construction of a boat park in Salamander Bay at the entrance of Langebaan Lagoon in 2009, designed to house boats belonging to the regiment. Impacts caused by dredging and excavation resulted in localised permanent loss of habitat and organisms. Details regarding this project and impact mitigation measures are explained in more detail in the AEC 2014 report.

The Department of Public Works has recently proposed constructing a breakwater at the same site (Special Forces Regiment 4 Boat Park in Salamander Bay). The upgrade will entail lengthening the existing rocky point to form a new breakwater which will extend 50 m out from the shore (Figure 3.14.). Greenminded Environmental has been appointed to conduct the required basic assessment in terms of the NEMA. The Basic Assessment (BA) Report has not yet been submitted to the Department of Environmental Affairs (DEA) as the project scope has not been finalised yet.

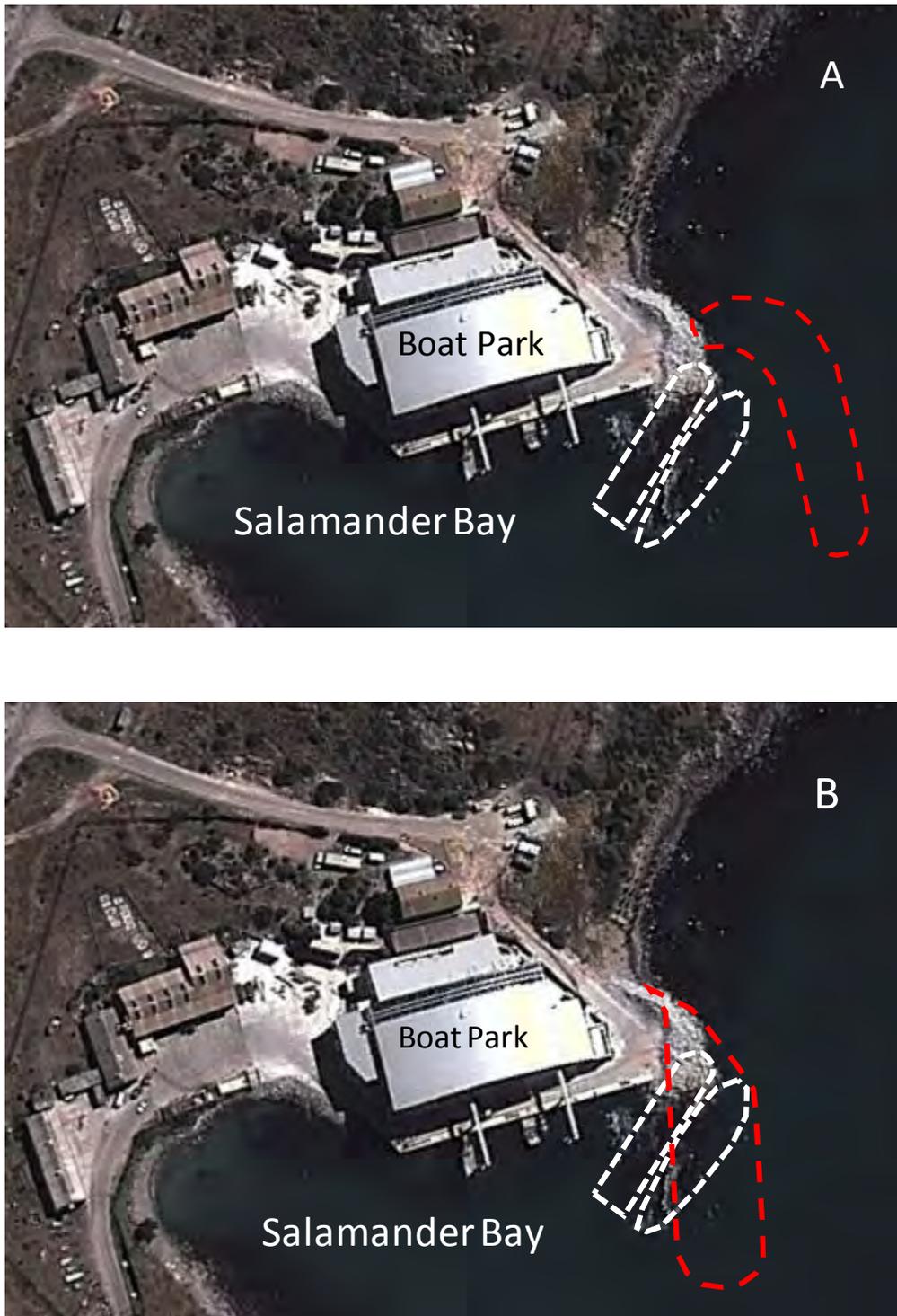


Figure 3.14. Bird's eye view image of Salamander Bay showing the existing boat park, the two shipwrecks (white) and the site of the proposed breakwater (red). The breakwater may either be positioned A) on the outside of the two shipwrecks, or B) on top of sections of the shipwrecks (Anchor Environmental Consultants 2013a).

3.3 Shipping, ballast water discharges, and oil spills

Shipping traffic comes with a number of associated risks, especially in a port environment, where the risks of collisions and breakdowns increase owing to the fact that shipping traffic is concentrated, vessels are required to perform difficult manoeuvres, and are required to discharge or take up ballast water in lieu of cargo that has been loaded or unloaded. Saldanha Bay is home to the Port of Saldanha, which is one of the largest ports in South Africa receiving close to 500 ships per annum. The Port is comprised of an Iron export terminal for export of iron ore, an oil terminal for import of crude oil, a multi-purpose terminal dedicated mostly for export of lead, copper and zinc concentrates, and the Sea Harvest/Cold Store terminal that is dedicated to frozen fish products (Figure 3.4). There are also facilities for small vessel within the Port of Saldanha including the Government jetty used mostly by fishing vessels, the Transnet-NPA small boat harbour used mainly for the berthing and maintenance of Transnet-NPA workboats and tugs, and the Moss gas quay. Discharge of ballast by vessels visiting the iron ore terminal in particular poses a significant risk to the health of Saldanha Bay and Langebaan Lagoon.

3.3.1 Shipping and ballast water

Ships carrying ballast water have been recorded since the late nineteenth century and by the 1950s had completely phased out the older practice of carrying dry ballast. Ballast is essential for the efficient handling and stability of ships during ocean crossings and when entering a port. Ballast water is either freshwater or seawater taken up at ports of departure and discharged on arrival where new water can be pumped aboard, the volume dependant on the cargo load. The conversion to ballast water set off a new wave of marine invasions, as species with a larval or planktonic phase in their life cycle were now able to be transported long distances between ports on board ships. Furthermore, because ballast water is usually loaded in shallow and often turbid port areas, sediment is also loaded along with the water and this can support a host of infaunal species (Hewitt *et al.* 2009). The global nature of the shipping industry makes it inevitable that many ships must load ballast water in one area and discharge it in another, which has an increasing potential to transport non-indigenous species to new areas. It has been estimated that major cargo vessels annually transport nearly 10 billion tonnes of ballast water worldwide, indicating the global dimension of the problem (Gollasch *et al.* 2002). It is estimated that on average, 3,000-4,000 species are transported between continents by ships each day (Carlton & Geller 1993). Once released into ports, these non-indigenous species have the potential to establish in a new environment which is potentially free of predators, parasites and diseases, and thereby out compete and impact on native species and ecosystem functions, fishing and aquaculture industries, as well as public health (Gollasch *et al.* 2002). Invasive species include planktonic dinoflagellates and copepods, nektonic Scyphozoa, Ctenophora, Mysidacea, benthos such as annelid oligochaeta and polychaeta, crustacean brachyura and molluscan bivalves, and fish (Carlton & Geller 1993). Carlton & Geller (1993) record 45 'invasions' attributable to ballast water discharges in various coastal states around the world. In view of the recorded negative effects of alien species transfers, the International Maritime Organisation (IMO) considers the introduction of harmful aquatic organisms and pathogens to new environments via ships ballast water as one of the four greatest threats to the world's oceans (Awad *et al.* 2003).

To address the above environmental impacts and risks, the International Convention for the Control and Management of Ship's Ballast Water and Sediments of 2004 (BWM Convention) was ratified by 30 states representing 35% of the world merchant shipping tonnage (IMO 2015). The BWM Convention provides for standards and procedures for the management and control of ballast water and sediments carried by ships, which are aimed at preventing the spread of harmful aquatic organisms from one region to another.

Under the BWM Convention all vessels travelling in international waters must manage their ballast water and sediment in accordance with a ship-specific ballast water management plan. It is required that every ship maintains a ballast water record book and holds an international ballast water management certificate. Ballast water management standards and treatment technology are slowly being implemented, but in the interim ships are required to exchange ballast water mid-ocean. Parties to the BWM Convention are given the option to take additional measures to those described above and which are subject to criteria set out in the BWM Convention and to the guidelines that have been developed to facilitate implementation of the Convention.

South Africa ratified to this Convention but it took almost a decade until the Draft Ballast Water Management Bill was published in the *Government Gazette* in April 2013 (Notice 340 of 2013) aimed to implement the BWM Convention. The objectives of the proposed legislation include:

- Minimise or prevent harmful impacts by invasive species on the biological diversity within South African waters;
- Minimise or prevent harmful impacts by invasive species on the environment, human health property or resources of South Africa;
- Provide for cooperative governance in both the management of alien and invasive species introduced by ship's ballast water and the conservation of biological diversity; and
- Meet South Africa's obligations in terms of the Convention.

The bill sets out how ballast water is to be discharged, but specifies that these requirements are not applicable in emergency situations or when ballast water is discharged as a result of a collision. All ships are expected to have a ballast water management plan and to keep an up to date ballast water record book. Vessels constructed after 2009 are required to be designed such that accumulation of sediments is prevented and removal of sediments is facilitated. The bill also contains provisions pertaining to:

- Prototype ballast water treatment technologies
- Sediment management for ships
- Sediment reception facilities
- Duties of officers and crew
- Equivalent compliance
- Port ballast water management plans
- Surveys
- Issuance of certificate
- Report of accidents and defects
- Maintenance requirements
- Offences and penalties

The Department of Transport is the authority responsible for administration of this Act. Implementation of the BWM Convention remains slow and it is not known when this bill will be promulgated.

In South Africa to date, an estimated total of 91 marine species (Zsilavec 2007, Mead *et al.* 2011a, Anchor Environmental Consultants 2011, Peters *et al.* 2014, *Pers. obs.* Prof. George Branch and Prof. Charles Griffiths, 2015) are recorded as introduced mostly through shipping activities or mariculture and at least 62 of these are thought to occur in Saldanha Bay-Langebaan Lagoon (Mead *et al.* 2011a). Three of the species recorded in Saldanha Bay are considered invasive: the Mediterranean mussel *Mytilus galloprovincialis*, the European green crab *Carcinus maenas* (Griffiths *et al.* 1992, Robinson *et al.* 2005) and the barnacle *Balanus glandula* (Laird & Griffiths 2008). Recently, Peters *et al.* (2014) established that the brachiopod *Disciniscus tenuis*, previously only known to occur in aquaculture facilities, has spread into the port of Saldanha and on the leeward side of Schaapen Island (Peters *et al.* 2014). Most of the introduced species are found in sheltered areas such as harbours and because ballast water is normally loaded in sheltered harbours, the species that are transported also originate from these habitats and thus have a difficult time adapting to South Africa's exposed coast. This might, in part, explain the low number of introduced species that have become invasive along the coast (Griffiths *et al.* 2008). Most introduced species in South Africa occur along the west and south coasts, very few having been recorded east of Port Elizabeth. This corresponds with the predominant trade routes being between South Africa and the cooler temperate regions of Europe, from where most of the marine introductions in South Africa originate (Awad *et al.* 2003). More detail on alien invasive species in Saldanha Bay is provided in Chapter 12 of this report.

Other potentially negative effects of ballast water discharges are contaminants that may be transported with the water. Carter (1996) reported on concentrations of trace metals such as cadmium, copper, zinc and lead amongst others that have been detected in ballast water and ballast tank sediments from ships deballasting in Saldanha Bay. Of particular concern are the high concentrations of copper and zinc that in many instances exceeded the South African Water Quality Criteria (DWA 1995a) (Table 3.3.). These discharges are almost certainly contributing to trace metal loading in the water column and are indicated by their concentration in filter-feeding organisms in the Bay (refer to Chapter 5).

Table 3.3. Mean trace metal concentrations in ballast water (mg/l) and ballast tank sediments from ships deballasting in Saldanha Bay (Source: Carter 1996) and SA Water Quality Guideline limits (DWA 1995a). Those measurements in red denote exceedance of these guidelines.

	Water	Sediment	SA WQ Guideline limit
Cd	0.005	0.040	0.004
Cu	0.005	0.057	0.005
Zn	0.130	0.800	0.025
Pb	0.015	0.003	0.012
Cr	0.025	0.056	0.008
Ni	0.010	0.160	0.025

Ballast water carried by ships visiting the Port of Saldanha is released in two stages - a first release is made upon entering Saldanha Bay (i.e. Big Bay) and the second once the ship is berthed and loading (Awad *et al.* 2003). As a result as much as 50% of the ballast water is released in the vicinity of the iron ore quay on either the Small Bay side or Big Bay side of the quay depending on which side the ship is berthed.

The total number of ships entering the Port of Saldanha has doubled in the last two decades with 517 ships visiting the port in 2014 (Figure 3.15.). The average size of vessels in use has also increased over the years, and as a result, the volume of ballast water discharged to the Bay has doubled since 2004, with almost 23 million tons of ballast water being discharged in 2014 (Figure 3.16). Overall, Iron ore tankers contributed 59% to the observed vessel traffic and 94% to the total water discharged in 2013 (Figure 3.15. and Figure 3.16).

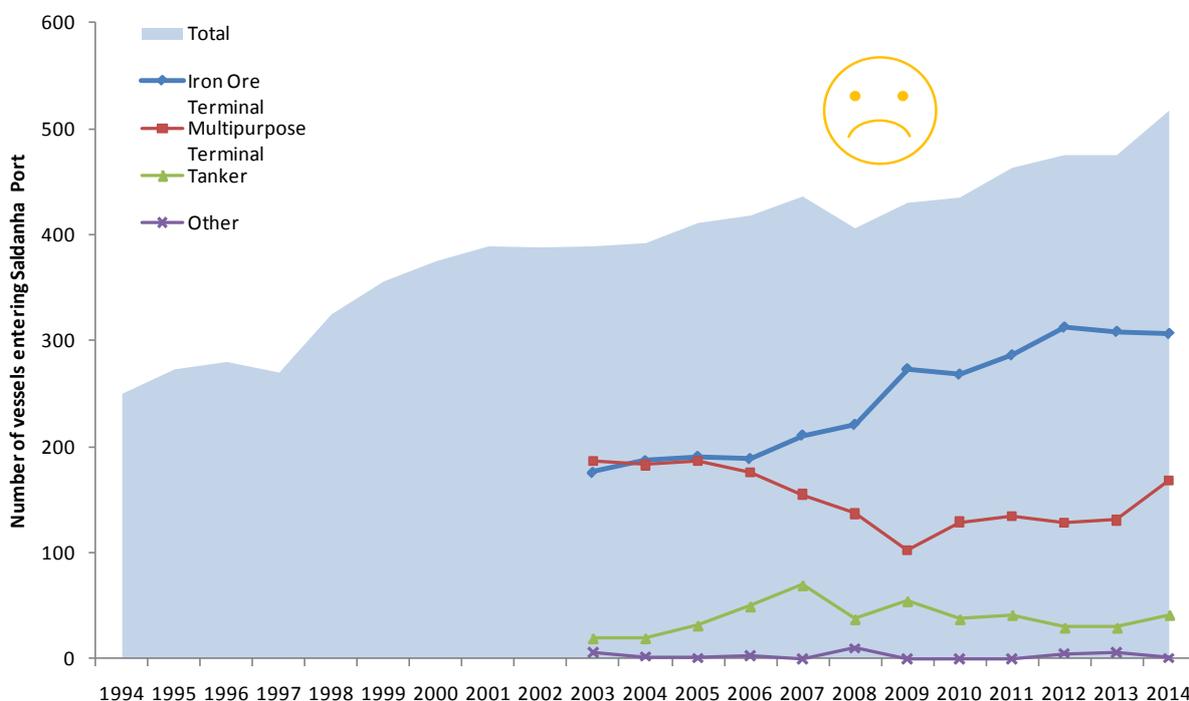


Figure 3.15. The number and type of vessels entering Saldanha Port. The total number of vessels entering Saldanha Port between the years 1994 and 2013 is shown as the blue area. The numbers of vessels docking at the iron ore terminal, the multipurpose terminal, tankers and other vessels are shown in blue, red, green and purple respectively. Data for the different types of vessels is only available from 2003 to 2013 (Sources: Marangoni 1998, Awad *et al.* 2003, Transnet-NPA unpublished data 2003-2013).

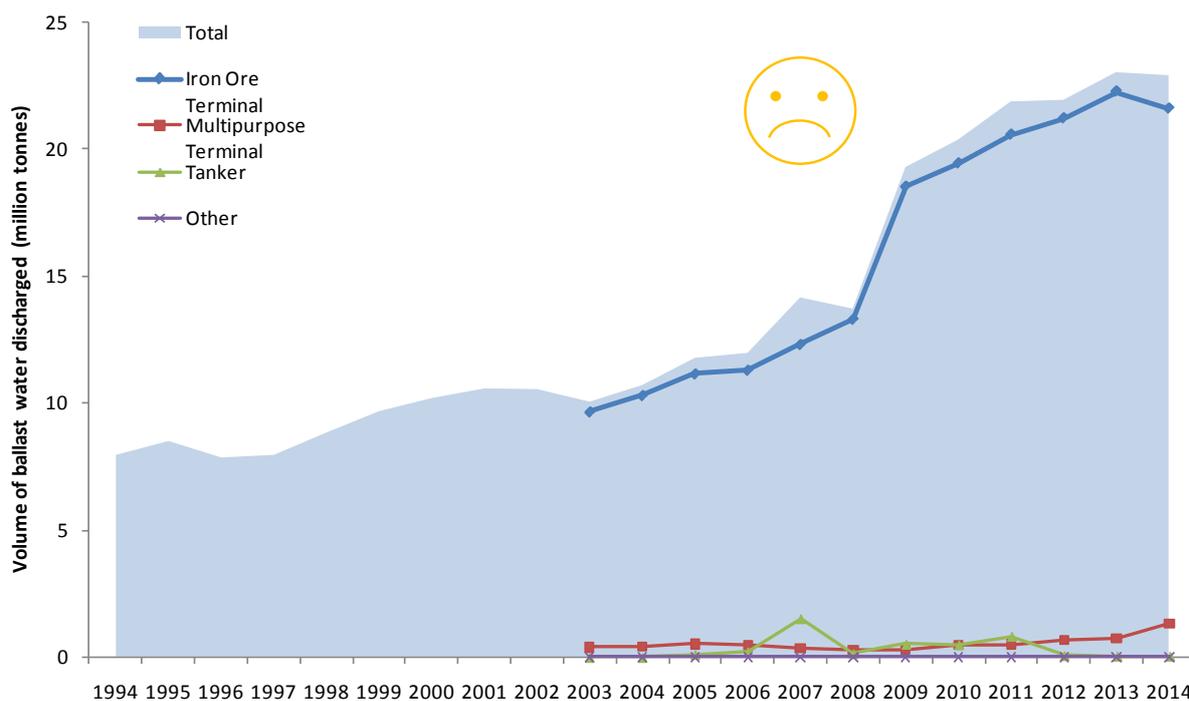


Figure 3.16 Volumes of ballast water discharge in tonnes in Saldanha Port. The total amount of ballast water discharged in Saldanha Port between the years 1994 and 2013 is shown as the blue area. Ballast water discharged by vessels docking at the iron ore terminal, the multipurpose terminal, tankers and other vessels are shown in blue, red, green and purple respectively. Data for the different types of vessels is only available from 2003 to 2013 (Sources: Marangoni 1998, Awad *et al.* 2003, Transnet-NPA unpublished data 2003-2012).

3.3.2 Oil spills

Also associated with this increase in shipping traffic, is an increase in the incidence and risk of oil spills. In South Africa there have been a total of five major oil spills, two off Cape Town (1983 and 2000), one in the vicinity of Dassen Island (1994), one close to the St. Lucia estuary in KwaZulu-Natal (2002) and one in the Goukamma Nature Reserve (2013). No comparable oil spills have occurred in Saldanha Bay to date (SAMSA, Martin Slabber *pers. comm.*). Minor spills do occur however, which have the potential to severely impact the surrounding environment. In April 2002, about 10 tons of oil spilled into the sea in Saldanha Bay when a relief valve malfunctioned on a super-tanker. Booms were immediately placed around the tanker and the spill was contained. More recently in July 2007, a Sea Harvest ship spilled oil into the harbour while re-fuelling, the spill was managed but left oil on rocks and probably affected small invertebrates living on the rocks and in the surrounding sand.

In 2007 Transnet National Ports Authority and Oil Pollution Control South Africa (OPC), a subsidiary of CEF (Central Energy Fund) signed an agreement which substantially improved procedures in the event of oil spills and put in place measures to effectively help prevent spills in the Port of Saldanha. These are laid out in detail in the “Port of Saldanha oil spill contingency plan” (Transnet National Ports Authority 2007). The plan is intended to ensure a rapid response to oil spills within the port itself and by approaching vessels. The plan interfaces with the “National oil spill contingency plan” and with the “Terminal oil spill contingency plan” and has a three tiered response to oils spills:

Tier 1: Spill of less than approximately 7 tonnes

Response where the containment, clean up and rescue of contaminated fauna can be dealt with within the boundaries of the vessel, berth or a small geographical area. The incident has no impact outside the operational area but poses a potential emergency condition.

Tier 2: Spill between 7-300 tonnes

Response where the nature of the incident puts it beyond the containment, clean up and rescue of contaminated fauna capabilities of the ship or terminal operator. The containment of clean up requires the use of some of or the government and industry resources.

Tier 3: Spill in excess of 300 tonnes.

Response where the nature of the incident puts it beyond containment, clean up and rescue of contaminated fauna capabilities of a national or regional response. This is a large spill which has the probability of causing severe environmental and human health problems.

Upon entry to the port, all vessels undergo an inspection by the Pollution Control Officer to minimise risks of pollution in the port through checking overboard valves and ensuring the master and crew of the vessel are familiar with the Port's environmental requirements. Every tanker is contained by booms while oil is being pumped. Immediate containment of any minor spills is thereby ensured (SAMSA, Martin Sabber, *pers. comm.*). The OPC has facilities and equipment to effectively secure an oil spill as well as for the handling of shore contamination including oiled sea birds and beach-cleaning equipment. However, given the environmental sensitivity of the Saldanha Bay area, particularly Langebaan Lagoon, prevention is the most important focus (CEF 2008).

3.3.3 Noise

A variety of noises are produced in the coastal underwater world, including short and high intensity sounds that are generated by underwater construction activities (for example pile driving) (Popper & Hastings 2009) as well as noise produced by shipping vessels which is characterised in wide spread and prolonged low frequency noise (Slabberkorn *et al.* In Press).

Impacts of noises in the coastal environment on fish behaviour and physiology have received a good deal of attention in recent years. For example Bregman (1990) described the 'auditory scene' of fishes which provides information from great distances or information at night for navigation, predator avoidance and prey detection. Consequences of a disturbance in the 'auditory scene' of fishes have been shown in captive three-spined sticklebacks (*Gasterosteus aculeatus*) (Purser & Radford 2011). Foraging efficiency was significantly reduced when subjected to brief as well as prolonged noise, as more time was spent on attacking their prey due to a shift in attention. Several published studies have demonstrated the importance of sound in predator avoidance and prey detection (Knudsen *et al.* 1997, Konings 2001). Reproductive efficiency can also be affected as more than 800 fish species are known to produce sounds when spawning (Aalbers 2008) and during courtship (McKibben & Bass 1998). It has been suggested that entire fish assemblages in very noisy environments might be impacted by noise through reduced reproductive efficiency, thereby affecting number of individuals. For example, roach (*Rutilus rutilus*) and rudd (*Scardinius*

erythrophthalmus) showed an interruption of spawning in the presence of noise produced by speed boats (Boussard 1981). Impacts of sound waves on fish physiology were investigated in controlled experiments where pile driving was lethal to some fish species (Caltrans 2001) but not for others (Abbot *et al.* 2005). The examination of dead and fatally injured fish revealed damaged and bleeding swim bladders (Caltrans 2001).

It appears that not all fish species respond to noise in the same way (Voellmy *et al.* 2014) and current research is insufficient to successfully predict the effects of noise on fish in the marine environment. It is recommended that a precautionary approach be adopted and that impacts of sound, especially future construction of infrastructure in the Port of Saldanha are mitigated. An air bubble curtain around piling operations is commonly cited as an effective mitigation measure to reduce the sound transmission (Abbott & Bing-Sawyer, 2002, Bellmann & Remmers 2013). Producing bubbles around the noise source prevents transmission of sound due to the reflection and absorption of sound waves (Würsig *et al.* 2000).

3.4 Wastewater disposal

Contemporary coastal water management strategies around the world focus on maintaining or achieving receiving water quality such that the water body remains or becomes fit for other designated uses. Designated uses of the marine environment includes aquaculture, recreational use, industrial use, as well as the protection of biodiversity and ecosystem functioning. This goal oriented management approach arose from the recognition that enforcing end of the pipe effluent limits in the absence of an established context, i.e. not recognising the assimilative capacity and requirements of receiving environments, would reach a point where water bodies would only be marginally fit for their recognised uses. This management approach is referred to as the receiving water quality (RWQ) framework (AEC 2015) and it appears that most countries have adopted this framework and have developed water quality guidelines for a variety of uses, which include target values for a range of contaminants that must be met in the receiving environment. Furthermore, in most countries water quality guidelines are legislated standards and are thus a legal requirement to be met by every user/outfall. Although the importance of managing water quality through the RWQ framework is undisputed, the degree to which this is implemented differs widely between countries.

There are a wide variety of legal instruments that are utilised by countries to maintain and/or achieve water quality guidelines in the receiving environment. These include setting appropriate contaminant limits, the banning or restricting of certain types of discharges in specified areas, prohibiting or restricting discharge of certain substances, as well as providing financial incentives to reduce pollution at the source alongside the implementation of cleaner treatment technology. The only effective method however, that ensures compliance of an effluent with water quality guidelines/standards is to determine site-specific effluent limits which are calculated based on the water quality guidelines/standards of a given water body, the effluent volume and concentration, as well as the site-specific assimilative capacity of the receiving environment. This method is also identified as the water quality based effluent limits (WQBEL) approach (AEC 2015) and recognises that effluent (and its associated contaminants) is rapidly diluted by the receiving waters as it enters the environment. In order to take advantage of this beneficial effect, allowance is generally made for a “mixing zone” which extends a short distance from the outfall point (or pipe end) and is an area

in which contaminant levels are “allowed” to exceed the established water quality standards (or guidelines) for the receiving environment. The magnitude of the “mixing zone” should, in theory, vary in accordance with the sensitivity and significance of the receiving environment and the location of the outfall point in the environment, but in practice is usually set at a distance of around 100 m from the pipe end for marine systems. The WQBEL approach differs from the Uniform Effluent Standard (UES) approach in which fixed maximum concentrations or loads are applicable for contaminants in wastewater discharges for all users or outfalls, irrespective of where they are located (AEC 2015).

3.4.1 Legislative context for pollution control in South Africa

South Africa has adopted the RWQ framework for the management of water quality in both inland (freshwater) and marine water bodies and uses both, the WQBEL and the UES approaches to implement the framework. Receiving water quality guidelines have thus been published for the full range of beneficial uses for inland water (human consumption, aquaculture, irrigation, recreational use, industrial use, and protection of biodiversity and ecosystem functioning) and also for the marine environment (aquaculture, recreational use, industrial use, and protection of biodiversity and ecosystem functioning, Table 3.4.). In the case of Saldanha Bay, which is extremely important for biodiversity conservation (there are several Marine Protected Areas (MPAs) in the Bay), is also an important regional centre for aquaculture (mussels, oysters, finfish), is important for recreation (swimming, kite surfing, windsurfing, etc.), and an area from where water is abstracted for industrial purposes (cooling water and desalination), the most stringent receiving environment water quality guidelines should be applicable.

In terms of the National Water Act (Act No 36 of 1998), discharging of waste or water containing waste into a “water resource through a sea outfall or other conduit” is listed as a “water use” for which a “licence” is required, unless such use was authorised through a “general authorisation” indicated by a notice published in the *Government Gazette*. The Revised General Authorisation of 2013 (No. 36820 of 2013) exempts users from having to apply for water use licences for the discharge of water containing waste into a water resource provided that the discharge was within certain specified limits and conditions.

With the promulgation of the National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) (ICMA) (as amended³), responsibility for regulating land-derived

³ ICMA was amended by the National Environmental Management: Integrated Coastal Management Amendment Act, 2014 (Act No. 36 of 2014) (ICMAA).

effluent discharges into coastal waters was transferred to the Department of Environmental Affairs (DEA). In terms of Section 69 of ICMA, no person is permitted to discharge effluent originating from a source on land into coastal waters except in terms of a General Discharge Authorisation (GDA) or a Coastal Waters Discharge Permit (CWDP). Exemptions were issued to proponents who, at the time of promulgation, were discharging effluent into coastal waters in terms of permits issued under the NWA, provided that the effluent was treated to meet the *General and Special Standard* (Government Gazette No. 20526, 8 October 1999⁴), and required that they applied for a CWDP within three years of promulgation of the ICMA. In practice though, not all operations that discharge wastewater into the Bay have applied for a CWDPs even though five years has elapsed since the promulgation of the ICMA. New operators wishing to discharge effluent to coastal waters are required to apply for a CWDP before commencing and are also required to comply with the applicable water quality guidelines. Applications for CWDP are expected to include data on contaminant levels in the effluent to be discharged, as well as results of dilution and dispersion model studies indicated maximum expected levels for the same contaminants at the edge of the defined mixing zone. These levels are of course expected to comply with published guideline levels as defined by other existing, or potential, beneficial uses of the receiving environment.

The DEA is currently in the process of developing a permitting system for such effluent discharges and for this purpose, the Assessment Framework for the Management of Effluent from Land Based Sources Discharged to the Marine Environment was recently developed (AEC 2015). This framework recognises that discharges differ in effluent characteristics (volume and quality) and discharge locality (i.e. biophysical conditions, use of the receiving environment), which ultimately determines the risk a particular discharge poses to the receiving environment. It was recommended that the potential scope of a General Discharge Authorisation, the level of assessment during the application process for a CWDP, as well as licensing conditions should be based entirely on the environmental risk posed by a particular effluent. Accordingly, the guidelines provide a framework within which an effluent can be characterised (effluent components and properties) and its potential impacts be assessed within the context of the receiving environment (i.e. sensitive versus robust receiving environments).

None of outfalls that discharge into Saldanha Bay have yet been issued with a CWDP and are thus all still required to comply with the General Standards in terms of the NWA (Table 3.5).

⁴ The latest revision of the General Authorisation was promulgated on 6 September 2013 (Government Gazette No. 36820).

Table 3.4. South African Water Quality Guidelines for Coastal Marine Waters (1995, 2012): Natural Environment, Industrial Use, Mariculture and Recreational Use

	Natural Environment	Industrial Use	Mariculture	Recreational Use
PHYSICO-CHEMICAL PROPERTIES				
Temperature (°C)	The maximum acceptable variation in ambient temperature is ± 1 °C			For prolonged exposure, temperatures should be in the range 15-35°C
Salinity (ppt)	33-36			N/A
pH	7.3-8.2			pH of water should be within the range 5.0–9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits.
Floating matter including oil and grease (Listed as Objectionable Matter in DEA 2012)	<p>Water should not contain floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance;</p> <p>Water should not contain materials from non-natural land-based sources which will settle to form putrescence;</p> <p>Water should not contain submerged objects and other subsurface hazards which arise from non-natural origins and which would be a danger, cause nuisance or interfere with any designated/recognized use</p>			Water should not contain litter, floating particulate matter, debris, oil, grease, wax, scum, foam or any similar floating materials and residues from land-based sources in concentrations that may cause nuisance. Water should not contain materials from non-natural land-based sources which will settle to form objectionable deposits. Water should not contain submerged objects and other subsurface hazards which arise from non-natural origins and which would be a danger, cause nuisance or interfere with any designated/recognized use. Water should not contain substances producing objectionable colour, odour, taste, or turbidity.
Colour/turbidity/ clarity	<p>Should not be more than 35 <i>Hazen units</i> above ambient concentrations (colour)</p> <p>Should not reduce the depth of the euphotic zone by more than 10 % of ambient levels measured at a suitable control site (turbidity)</p>			N/A
Suspended solids	Should not be increased by more than 10 % of ambient concentrations			N/A
Dissolved -Oxygen	For the west coast, the dissolved oxygen should not fall below 10 % of the established oxygen - natural variation. For the south and east coasts the dissolved oxygen should not fall below 5 mg l ⁻¹ (99 % of the time) and below 6 mg l ⁻¹ (95% of the time)	-	For the west coast, the dissolved oxygen should not fall below 10 % of the established oxygen - natural variation. For the south and east coasts the dissolved oxygen should not fall below 5 mg l ⁻¹ (99 % of the time) and below 6 mg l ⁻¹ (95% of the time)	N/A

	Natural Environment	Industrial Use	Mariculture	Recreational Use
NUTRIENTS				
Ammonium	600 (NH ₃ plus NH ₄ ⁺)	Waters should not contain concentrations of dissolved nutrients that are capable of causing excessive or nuisance growth of algae or other aquatic plants or reducing dissolved oxygen concentrations below the target range indicated for <i>Dissolved oxygen</i>		N/A
Nitrite	Waters should not contain concentrations of dissolved nutrients that are capable of causing excessive or nuisance growth of algae or other aquatic plants or reducing dissolved oxygen concentrations below the target range indicated for <i>Dissolved oxygen</i>			
Nitrate				
Reactive phosphate				
Reactive silicate				
INORGANIC CONSTITUENTS				
Ammonia	20 µg N l ⁻¹ (as NH ₃) 600 µg N l ⁻¹ (as NH ₃ plus NH ₄ ⁺)	-	20 µg N l ⁻¹ (as NH ₃) 600 µg N l ⁻¹ (as NH ₃ plus NH ₄ ⁺)	N/A
Cyanide	12 µg l ⁻¹	-	12 µg l ⁻¹	
Fluoride	5000 µg l ⁻¹	-	5 000 µg l ⁻¹	
Chlorine	-	-	-	
Hydrogen sulphide	-	-	-	
Arsenic	12 µg l ⁻¹	-	12 µg l ⁻¹	
Cadmium	4 µg l ⁻¹	-	4 µg l ⁻¹	
Chromium	8 µg l ⁻¹	-	8 µg l ⁻¹	
Copper	5 µg l ⁻¹	-	5 µg l ⁻¹	
Lead	12 µg l ⁻¹	-	12 µg l ⁻¹	
Mercury	0.3 µg l ⁻¹	-	0.3 µg l ⁻¹	
Nickel	25 µg l ⁻¹	-	25 µg l ⁻¹	
Silver	5 µg l ⁻¹	-	5 µg l ⁻¹	

	Natural Environment	Industrial Use	Mariculture	Recreational Use
Tin	-	-	-	
Zinc	25 µg l ⁻¹	-	25 µg l ⁻¹	
ORGANIC CONSTITUENTS				
Organotins (Tributyltin)	-	-	-	N/A
Total petroleum hydrocarbons	-	-	-	
Polycyclic aromatic - hydrocarbons	-	-	-	
MICROBIOLOGICAL INDICATOR ORGANISMS				
Faecal coliforms (including <i>E. coli</i> .)	-	-	Maximum acceptable count per 100 ml: 20 in 80 % of the samples 60 in 95 % of the samples	
Intestinal Enterococci ¹				
Excellent (2.9% gastrointestinal illness risk)				≤ 100 Colony-forming units (CFU)/100 ml (95 percentile)
Good (5% GI illness risk)				≤ 200 CFU/100 ml (95 percentile)
Sufficient or Fair (minimum requirement) (8.5% GI illness risk)				≤ 185 CFU /100 ml (90 percentile)
Poor (unacceptable) (>8.5% GI illness risk)				≤ 185 CFU /100 ml (90 percentile)
<i>Escherichia coli</i> ¹				
Excellent (Excellent 2.9% gastrointestinal illness risk)				≤ 250 CFU (95 percentile)
Good (5% GI illness risk)				≤ 500 CFU (95 percentile)
Sufficient or Fair (minimum requirement) (8.5% GI illness risk)				≤ 500 CFU (90 percentile)

	Natural Environment	Industrial Use	Mariculture	Recreational Use
risk)				
Poor (unacceptable) (>8.5% GI illness risk)				> 500 (90 percentile)
Clostridium perfringens ²				Geometric mean ≤5 counts per 100 ml
Toxic substances				Consult South Africa's drinking water quality guidelines (e.g. SANS 2005) taking account of the fact that recreational exposure may result in an intake of 200 ml and not 2000 ml/day as is generally assumed for these guidelines

1. Note that a number of different methods are available for calculation of percentiles for bacterial counts. RSA Department of Environmental Affairs (2011) recommend using the non-parametric Hazen method (i.e. using data ranking) for this purpose but indicate that the Excel spreadsheet method can also be applied where users do not have access to a suitable Hazen template.
2. Only applicable in tropical waters

Table 3.5. General Limit as specified in the revised general limit for general authorisation (6 September 2013) under the National Water Act (No. 36 of 1998)

Substance/parameter	General limit as specified in the Revision of General Authorisations in terms of Section 39 of the National Water Act (Government Gazette No. 36820, 6 September 2013)
Temperature	-
Faecal Coliforms (per 100 ml)	1000
Electrical Conductivity measured in milliSiemens per meter (mS/m)	70 above intake to a maximum of 150*
pH	5.5-9.5
Chemical oxygen demand (mg/l)	75 (after removal of algae)
Suspended Solids (mg/l)	25
Soap, oil or grease (mg/l)	2.5
Ortho-Phosphate as P (mg/l)	10
Nitrate/Nitrite as Nitrogen (mg/l)	15
Ammonia (ionised and un-ionised) as N (mg/l)	6
Fluoride (mg/l)	1
Chlorine as Free Chlorine (mg/l)	0.25
Dissolved Cyanide (mg/l)	0.02
Dissolved Arsenic (mg/l)	0.02
Dissolved Cadmium(mg/l)	0.005
Dissolved Chromium (VI) (mg/l)	0.05
Dissolved Copper (mg/l)	0.01
Dissolved Iron (mg/l)	0.3
Dissolved Lead (mg/l)	0.01
Dissolved Manganese (mg/l)	0.1
Mercury and its compounds (mg/l)	0.005
Dissolved Selenium (mg/l)	0.02
Dissolved Zinc (mg/l)	0.1
Boron (mg/l)	1
Phenolic compounds as phenol (mg/l)	-

*Electrical conductivity is only applicable to wastewater discharges into freshwater.

3.4.2 Reverse osmosis desalination plants

Desalination refers to a water treatment process whereby salts are removed from saline water to produce fresh water. Reverse Osmosis involves forcing water through a semi-permeable membrane under high pressure, leaving the dissolved salts and other solutes behind on the surface of the membrane. Water is relatively scarce in the West Coast District Municipality (WCDM) and the rapidly developing industry in Saldanha Bay requires vast quantities of potable water for their operations. Construction of reverse osmosis desalination plants has been identified as a potential solution to reduce dependency of industry on municipal water supplies.

RO plants can have severe impacts on the receiving marine environment due to the highly saline and negatively buoyant brine water that is discharged by these plants, which often contains biocides that serve to limit marine growth in their intake pipe work. Potential environmental impacts associated with the operation of RO plants are listed below:

- Altered flows at the discharge resulting in ecological impacts (*e.g.* flow distortion/changes at the discharge, and effects on natural sediment dynamics);
- The effect of elevated salinities in the brine water discharged to the bay;
- Biocidal action of non-oxidising biocides such as dibromonitrilopropionamide in the effluent;
- The effects of co-discharged wastewater constituents, including possible tainting effects affecting both mariculture activities and fish factory processing in the bay;
- The effect of the discharged effluent having a higher temperature than the receiving environment;
- Direct changes in dissolved oxygen content due to the difference between the ambient dissolved oxygen concentrations and those in the discharged effluent; and
- Indirect changes in dissolved oxygen content of the water column and sediments due to changes in phytoplankton production as a result of altered nutrient dynamics (both in terms of changes in nutrient inflows and vertical mixing of nutrients) and altered remineralisation rates (with related changes in nutrient concentrations in near bottom waters) associated with near bottom changes in seawater temperature due to the brine discharge plume.

3.4.2.1 Transnet NPA Desalination Plant

Transnet NPA recently built a RO plant in Saldanha Bay to produce freshwater for dust mitigation during the loading and offloading of iron ore. The RO plant has been operational since obtaining a water use license from the DWA and subsequent performance tests in 2012 (Membrane Technology 2013) (refer to AEC 2014 for more details on the project design and EIA).

A marine baseline monitoring study was conducted by Anchor Environmental Consultants prior to the commissioning of the RO plant to ensure that impacts in the marine environment are such that the beneficial uses of the potentially impacted area are considered (Hutchings and Clark 2011). Monitoring of the physical and chemical characteristics of the receiving environment were also conducted during the period June 2010 to March 2011 in order to establish a baseline prior to the RO plant coming into operation (van Ballegooyen *et al.* 2012).

The monitoring requirements as specified by the Water Use License and the Record of Decision issued by the Department of Environmental Affairs for the RO plant (these are also reflected in the Transnet Specification No. 1243487-SP-0001) were as follows:

- (a) Monthly monitoring of temperature, salinity, dissolved oxygen, turbidity, concentrations in the brine basin;
- (b) Continuous (hourly) monitoring of temperature, salinity, dissolved oxygen, and turbidity at representative outfall monitoring station and a reference station for at least 1 year; and
- (c) Surveys of trace metals and benthic macrofauna to be conducted bi-annually for an unspecified period.

The Council for Scientific and Industrial Research (CSIR) was recently appointed to conduct the Environmental Monitoring Programme for the Transnet RO plant and three surveys have so far been performed in Saldanha Bay (CSIR 2015). The first survey took place in September 2014 while the RO plant was operational, while the second and third surveys took place while the plant was not operational (December 2014 and February 2015). Benthic macrofauna and trace metals samples (sediment) were collected in September 2014 at five stations situated between 25 and 215 m of the brine discharge point. Benthic macrofauna communities reportedly varied markedly between stations, but this was considered to be a function of variations in sediment grain size rather than impacts of brine discharge. Trace metal analysis showed that out of 15 metals analysed in the sediment samples, copper, iron, zinc and barium were identified as contaminants (i.e. higher than baseline concentrations) at several sampling stations. The report concluded that it was impossible to determine whether elevated trace metal levels can be attributed to the brine discharge. Finally, water quality monitoring indicated that no brine signal could be detected at five stations between 5 and 215 m of the brine discharge points in the receiving environment, although CSIR (2015) concede that there was no certainty that the sampling stations were indeed positioned in the brine dispersion plume at the time of monitoring. Based on the findings of the first three surveys, the report included recommendations for future monitoring as follows:

- Collection of temperature, salinity, pH, dissolved oxygen profile data at three stations each 50 m from the outfall over a neap tide (one day);
- Collection and analysis of water samples from mid-water and at the bottom from the same three stations for salinity, pH, TSS, trace metal content and toxicity;
- Monitoring of salinity at various depths in the water column at caissons 2,3,4, and 5 for periods of 2 minutes at a time, four times in a ten month period; and
- Assessment of trace metal levels in sediments at 5 stations surrounding the outfall on an annual basis; and
- Annual monitoring of benthic macrofauna assemblages at six stations (two within the immediate impact area and four reference sites beyond the immediate impact area) using a benthic grab.

Our assessment of the monitoring actions that have been undertaken to date, as well as proposed monitoring activities for future surveys suggest that these efforts will most likely meet the requirements of the Water Use Licence (WUL) issued by DWS (which are largely non-specific) but do not meet requirements of the ROD for the RO plant issued by DEA (see AEC 2014 for details on this). Furthermore, we are of the opinion that taking water quality measurements at three localities over

the course of a single day (the bulk of the water quality monitoring proposed) or even at quarterly intervals at four localities (the salinity monitoring component) will not enable the full impacts of the RO plant on water quality in Saldanha Bay to be assessed. Similarly, we do not consider that the number of monitoring stations and the monitoring frequency for other aspects of the monitoring programme (water quality, sediment quality and benthic macrofauna) to be sufficient to adequately characterise impacts from the RO plant in what is acknowledged to be a highly variable environment, both spatially and temporally. Recommendations for a benthic monitoring programme that were included in the EIA report and that were followed for the original baseline survey have largely been ignored in follow-up monitoring surveys. Furthermore, instead of using a diver operated suction sampler for collecting the benthic samples, as was done for the baseline survey and for all the State of the Bay surveys, samples have (and presumably will in future) be collected using a benthic grab which means that these different sets of data are not directly comparable with one another. Changes to the sampling methodology were in part motivated by the assertion that the baseline samples were collected from the incorrect position but an examination of the coordinates of the various sampling sites suggests that this was not the case. It is recommended that the monitoring programme for the RO plant and all data that have been collected be carefully reviewed by an independent third party and that the programme be bolstered or revised if necessary.

3.4.2.2 West Coast District Municipality Desalination Plant

The West Coast District Municipality (WCDM) has proposed the construction of an additional RO plant in the Saldanha Bay area, intended as a long-term sustainable alternative water source. The WCDM has limited water resources (due to its semi-arid nature) but yet is required to supply 22 towns and 876 farms across the region with potable water. Currently water is supplied by the Voëlvllei and Misverstand dams on the Berg River, and the Langebaan road aquifer, however, the volume allocated from these sources for this is close to the maximum possible. This is clearly evidenced by the fact that the WCDM has exceeded its water allocation for the last six years. In the financial year 2012/2013, abstractions for the WCDM exceeded allocation by 3.6 million m³ (DWA 2013). A feasibility study conducted in 2007 to assess the most viable solution to the water scarcity issue in the WCDM identified the following potential additional water resources:

- The Twenty-four Rivers Scheme
- Lowlift pumps at the Misverstand Dam
- The Michel's pass Diversion
- Groundwater potential
- Water Quality Management
- Alien vegetation clearing

The most cost-effective solution was identified as a 25 500 m³/day sea water desalination plant. EA was granted on 13 August 2013 for the preferred location for the RO plant, which will be situated on the farm Klipdrift at Danger Bay on a portion of municipal owned land (Please refer to section 3.4.4 and AEC 2013/2014 for more information).

Subsequent costs estimates suggest, however, that the proposed desalination plant and bulk infrastructure will cost R500 million, which is more than double the initial estimated cost. As a result, funding is currently a major challenge for the WCDM. Should funds become available, construction of this RO plant is planned to be executed in three phases, with an initial capacity of 8.5 million litres later building up to a final capacity of 25.5 million litres. Alternatively, a recent revision of the feasibility study revealed that the Berg River may have surplus water and an application for additional allocation of water sourced from the Berg River was submitted by the WCDM. In the event that this additional allocation is granted to the WCDM, the desalination plant will be put on hold for the next ten years. A number of options for recycling wastewater from the region are also being considered, mostly for industrial use.

3.4.3 Sewage and associated wastewaters

3.4.3.1 Environmental impacts

Sewage is by far the most important waste product discharged into rivers, estuaries and coastal waters worldwide. However, sewage is not the only organic constituent of wastewater, received by sewage treatment plants, other degradable organic wastes, which can result in nutrient loading, include:

- Agricultural waste
- Food processing wastes (e.g. from fish factories and slaughter houses)
- Brewing and distillery wastes
- Paper pulp mill wastes
- Chemical industry wastes
- Oil spillages

Our present knowledge of the impacts of wastewaters on water systems has, until recently, largely been based on lake-river eutrophication studies. However, recent focus on how anthropogenic nutrient enrichment is affecting near-shore coastal ecosystems is emerging (for a review see Cloern 2001, Howarth *et al.* 2011). In general, the primarily organic discharge in wastewater effluents contains high concentrations of nutrients such as nitrates and phosphates (essentially the ingredients in fertilizers). Existing records provide compelling evidence of a rapid increase in the availability of nitrogen and phosphorus to coastal ecosystems since the mid-1950's (Cloern 2001). These nutrients stimulate the growth and primary production of fast-growing algae such as phytoplankton and ephemeral macroalgae, at the expense of slower-growing vascular plants and perennial macroalgae (seagrasses) which are better adapted to low-nutrient environments. This process requires oxygen, and with high nutrient inputs, oxygen concentrations in the water can become reduced which can lead to deoxygenation or hypoxia in the receiving water (Cloern 2001).

When phytoplankton die and settle to the bottom, aerobic and anaerobic bacteria continue the process of degradation. However, if the supply rate of organic material continues for an extended period, sediments can become depleted of oxygen leaving only anaerobic bacteria to process the organic matter. This then generates chemical by-products such as hydrogen sulphide and methane, which are toxic to most marine organisms (Clark 1986). The sediments and the benthic communities they support are thus amongst the most sensitive components of coastal ecosystems to hypoxia and

eutrophication (Cloern 2001). The ecological responses associated with decreasing oxygen saturation in shallow coastal systems include the initial escape of sensitive demersal fish, followed by mortality of bivalves and crustaceans, and finally mortality of other molluscs, with extreme loss of benthic diversity (Vaquer-Sunyer & Duarte 2008, Howarth *et al.* 2011). Vaquer-Sunyer & Duarte (2008) propose a precautionary limit for oxygen concentrations at 4.6 mg O₂/litre equivalent to the 90th percentile of mean lethal concentrations, to avoid catastrophic mortality events, except for the most sensitive crab species, and effectively conserve marine biodiversity.

Some of the indirect consequences of an increase in phytoplankton biomass and high levels of nutrient loading are a decrease in water transparency and an increase in epiphyte growth, both of which have been shown to limit the habitat of benthic plants such as seagrasses (Orth & Moore 1983). Furthermore, there are several studies documenting the effects that shifts in natural marine concentrations and ratios of nitrates, phosphates and elements such as ammonia and silica, have on marine organisms (Herman *et al.* 1996, van Katwijk *et al.* 1997, Hodgkiss & Ho 1997, Howarth *et al.* 2011). For instance, the depletion of dissolved Silica in coastal systems, as a result of nutrient enrichment, water management and the building of dams, is believed to be linked to worldwide increases in flagellate/ dinoflagellate species which are associated with harmful algal blooms, and are toxic to other biota (Hodgkiss & Ho 1997, Howarth *et al.* 2011). The toxic effect that elevated concentrations of ammonia have on plants has been documented for *Zostera marina*, and shows that plants held for two weeks in concentrations as low as 125 µmol start to become necrotic and die (van Katwijk *et al.* 1997).

The effects of organic enrichment, on benthic macrofauna in Saldanha Bay, have been well documented (Jackson & McGibbon 1991, Stenton-Dozey *et al.* 2001, Kruger 2002, Kruger *et al.* 2005). Tourism and mariculture are both important growth industries in and around Saldanha Bay, and both are dependent on good water quality (Jackson & McGibbon 1991). The growth of attached algae such as *Ulva sp.* and *Enteromorpha sp.* on beaches is a common sign of sewage pollution (Clark 1986). Nitrogen loading in Langebaan Lagoon associated with leakage of conservancy/septic tanks and storm water runoff has resulted in localised blooms of *Ulva sp.* in the past. In the summer 1993-94, a bloom of *Ulva lactuca* in Saldanha Bay was linked to discharge of nitrogen from pelagic fish processing plants (Monteiro *et al.* 1997). Dense patches of *Ulva sp.* are also occasionally found in the shallow embayment of Oudepos (CSIR 2002). Organic loading is a particular problem in Small Bay due to reduced wave action and water movement in this part of the Bay caused by harbour structures such as the Ore Terminal and the Causeway, as well as the multitude of organic pollution sources within this area (e.g. fish factories, mariculture farms, sewage outfalls, sewage overflow from pump stations, and storm water runoff). Langebaan Lagoon is also sheltered from wave action but strong tidal action and the shallow nature of the lagoon make it less susceptible to the long term deposition of pollutants and organic matter (Monteiro & Largier 1999).

Treatment of effluent is pivotal in reducing the environmental impacts described above. However, the side effects of treating effluent with chlorine have been well established in the literature. Chlorine gas, generated through a process of electrolysis, is toxic to most organisms and is used to sterilise the final effluent (i.e. kill bacteria and other pathogens present in the effluent) before it is released into settling ponds or the environment. Chlorine breaks down naturally through reaction with organic matter and in the presence of sunlight, but should not exceed a concentration 0.25 mg/l in terms of the revised General and Special Standard (Government Notice No. 36820 –6

September 2013) promulgated under the NWA. Furthermore, chlorine, while disinfecting the effluent, produces a range of toxic disinfection by-products (DBPs) through its reactions with organic compounds (Richardson *et al.* 2007, la Farré *et al.* 2008, Sedlak & von Gunten, 2011).

3.4.3.2 Management of treated effluent in Saldanha Bay

There are two wastewater treatment works (WWTW) that release treated effluent into rivers which drain into the Saldanha/Langebaan marine environment, namely the Saldanha WWTW and the Langebaan WWTW (Figure 3.18.). Twenty seven sewage pump stations in Langebaan are situated throughout the town, many of which are near the edge of the lagoon and 16 sewage pump stations are located in Saldanha Bay (Figure 3.18.). Problems are encountered when pump stations in Saldanha Bay overflow due to malfunction or power failures and raw sewage is released directly into Saldanha Bay. This is particularly dangerous to human health and also damaging to the sea-based mariculture sector in Saldanha, which relies on good water quality in the Bay. To address this issue mechanical and electrical equipment upgrades to the pump stations in Saldanha Bay commenced in 2012 and thus far nearly all pump stations have been upgraded. Furthermore, the Saldanha main pump station, as well as two other stations situated along the coast have been fitted with emergency generators. Unfortunately these interventions have not solved the problem entirely as evidenced by a major spill event that occurred at the time this report was being finalised (Sep 2015, Figure 3.17) As part of this current financial year, upgrades will be done to the White City pump station in Saldanha as well as the main line in the White City area (SBM, Gavin Williams, *pers. comm.* 2015).

There are approximately 200 conservancy tanks in Langebaan, east of Club Mykonos (SBM, Elmi Pretorius, *pers. comm.* 2014). Seepage or overflow from these septic or conservancy tanks has also contributed to the pollution of the Saldanha/Langebaan marine environment in the past. However, overflow of these tanks is considered an unlikely event today, as the municipality empties these tanks on a regular basis (SBM, Gavin Williams, *pers. comm.* 2014).

Details on the two WWTW are provided below, which present data on monthly trends in the effluent discharged by the WWTWs. Data was provided by the SBM and water quality parameters recorded as “trace”, “less than” or “greater than” was adjusted in accordance with the following standard international convention:

- “trace” = half the detection limit
- “less than” = half the detection limit
- “greater than” = detection limit multiplied by a factor of three

Concentrations of contaminants in the effluent are compared with the General Discharge Limits of the revised General and Special Standard (Government Notice No. 36820 –6 September 2013) promulgated under the NWA (Table 3.5.).



Figure 3.17. Partially treated sewage spill entering Small Bay via the Bok River due to problems at the Saldanha WWTW (Photo: Jimmy Walsh).

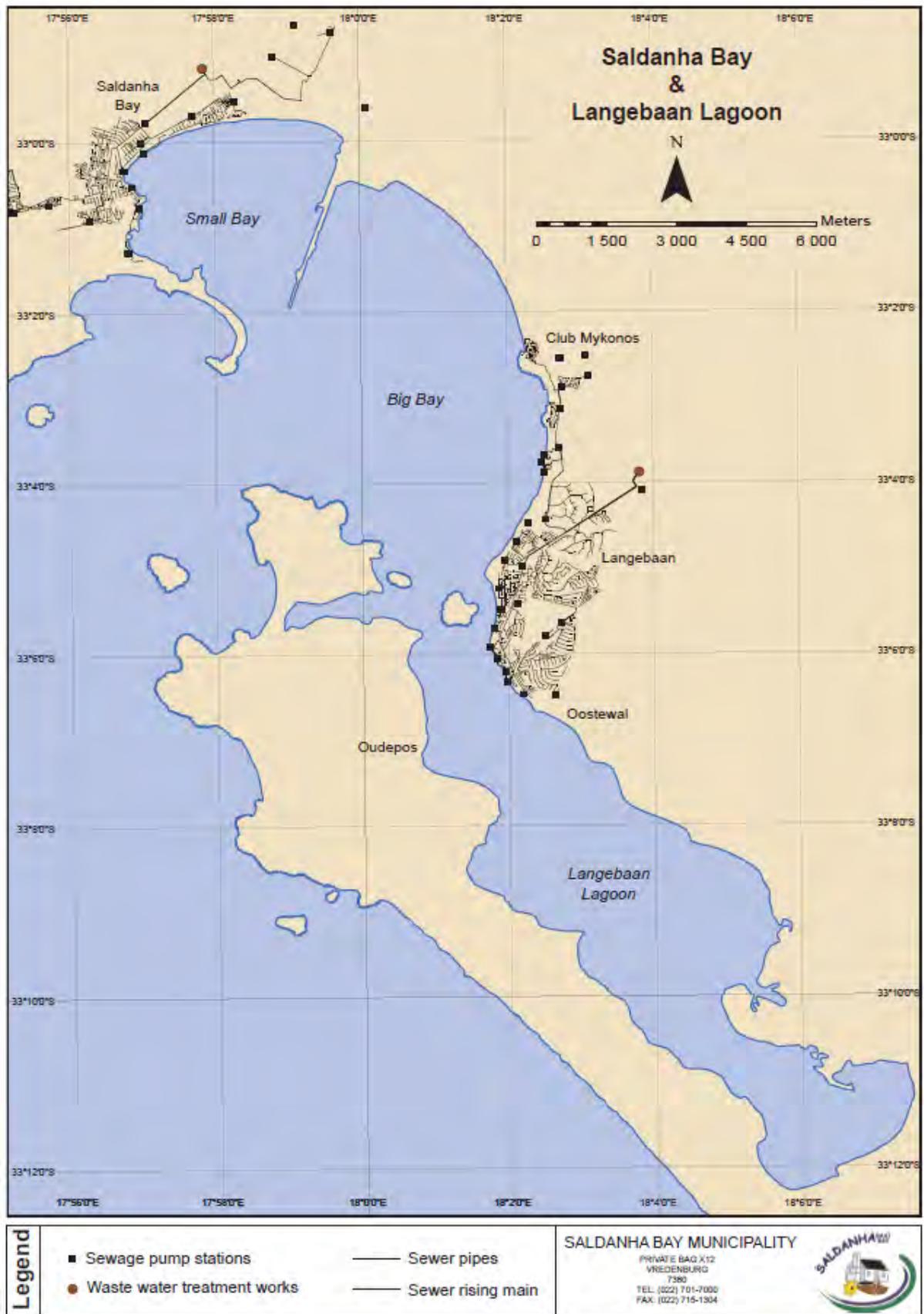


Figure 3.18. Location of wastewater treatment works, sewage pump stations and sewer pipes in the Saldanha and Langebaan area in 2014 (Source: Saldanha Bay Municipality, Elmi Pretorius 2014).

3.4.3.3 Saldanha Wastewater Treatment Works

The WWTW in Saldanha disposes of treated effluent into the Bok River where it drains into Small Bay adjacent to the Blouwaterbaai Resort. In addition to sewage waste, the WWTW in Saldanha also receives and treats industrial wastewater from a range of industries in Saldanha:

- Sea Harvest
- Hoedtjiesbaai Hotel
- Protea Hotel
- Bongolethu Fishing Enterprises
- SA Lobster
- Cape Reef Products
- Transnet Port Authority
- Arcelor Mittal
- Namaqua Sands
- Abattoir
- Duferco

These discharges reportedly often place the plant under considerable stress and result in the discharge of substandard effluent (CSIR 2002). The effective functioning of WWTW is largely dependent on the quality of sewage that is directed into the plant by the industry. Local by-laws are utilised to control the extent to which industries have to treat their effluent before it is directed into municipal wastewater treatment works. These by-laws were found to be not sufficient in regulating wastewater received from the industries and it has been suggested that regulatory standards should be determined on a national level (Eddy 2003).

The Saldanha WWTW was issued an exemption under the NWA section 21(f) and (g), provided that the effluent volume does not exceed 958 000 m³ per year and that the water quality of the treated effluent is compliant with the General Discharge Limits of the revised General and Special Standard (Government Notice No. 36820 –6 September 2013) promulgated under the NWA (Table 3.5.). The Saldanha Bay WWTW is now part of the IDZ and upgrades to double the capacity for treating effluent from the IDZ started this year in June and are projected to finish in July 2016 (Saldanha Bay Municipality, *pers. comm.* 2015). The Saldanha Bay WWTW treats raw sewage by means of activated sludge with mechanical aeration and drying beds. Thirty six million Rand have been set aside for the upgrades to this plant which include (SBM, Gavin Williams, *pers. comm.* 2015):

- Minor alterations to the motor control centre building;
- Installation of new pipe work;
- Construction of new reinforced concrete reactor;
- Construction of division chambers;
- Repair and enlargement of chlorine contact channel;
- Construction of new sludge thickener;
- Refurbishment of existing sludge beds and connecting pipe work;
- Associated site works and temporary works;
- Installation of new drum-type screen and screening press;
- Refurbishment of existing degritter equipment and installation of new degritter;

- Refurbishment of surface aerators in existing reactor and installation of new aerators, mixers and pumps in new reactor;
- Upgrade of chlorination equipment; and
- Installation of rotating bridge in sludge thickener.

The SBM has submitted an application for a new water use licence, as daily discharge volumes of the current and upgraded plant exceed the limits prescribed by the general authorisation (Saldanha Bay Municipality, *pers. comm.* 2015). Before 2008, the average daily volume discharged never exceeded the average daily limit of 2625 m³, but volumes of effluent released have subsequently been increasing steadily over time (Figure 3.19.). Between the years 2008-2012, the Saldanha WWTW was non-compliant only during the winter months. However, the average daily limit was exceeded 69% of the time since January 2013, reaching unprecedented levels of 3363 m³ effluent in June 2014.

Concentrations of faecal coliforms in the effluent from the WWTW exceeded the allowable limit of 1000 org/100 ml on 26 occasions since 2003 (18% of the time) (Figure 3.43). The frequency of non-compliance increased dramatically in 2008, although at a lower concentration (3000 org/100 ml) than previously recorded. Congruent with the consistently higher effluent volumes discharged since January 2013, allowable limits for faecal coliforms in the effluent were exceeded on nine occasions, frequently reaching an all-time estimated high of 7257 org/100ml (maximum detectable limit 2419 org/100ml multiplied by 3). Furthermore, faecal coliform measurements below the allowable limit are generally higher. This is cause for concern, as it appears that Saldanha WWTW is unable to adequately process the ever increasing volumes of wastewater generated in the area.

Allowable limits for total suspended solids (TSS) of 25 mg/l were exceeded on 11% of the occasions on which measurements were made since April 2003 (Figure 3.29). While compliance had clearly improved between 2008 and 2014, the allowable limit has been exceeded on almost all occasions since December 2014.

Chemical oxygen demand (COD) in filtered effluent exceeded the allowable limit of 75 mg/l 17% of the time since April 2003 (Figure 3.22). COD is commonly used to indirectly measure the amount of organic material in water. COD was highest from June-October 2008 peaking at 260 mg/l in July 2008. This trend roughly coincided with the high faecal coliform counts in the effluent over the same period. Overall, as observed for TSS, compliance has improved substantially since the beginning of 2009, where the allowable limit was only exceed on five occasions at a much lower magnitude than in 2008 (<80 mg/l).

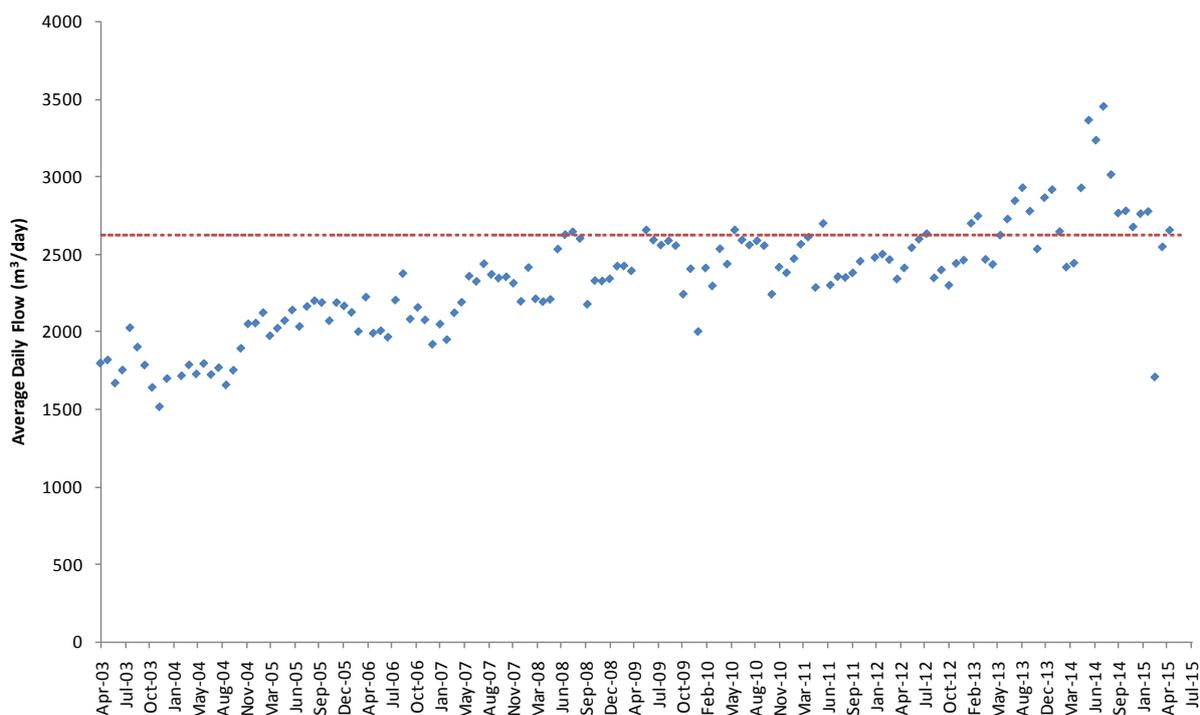


Figure 3.19. Trend in effluent (m³/month) released from the Saldanha Wastewater Treatment Works, April 2003-May 2015. Allowable discharge limits in terms of the exemption issued by DWAF under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

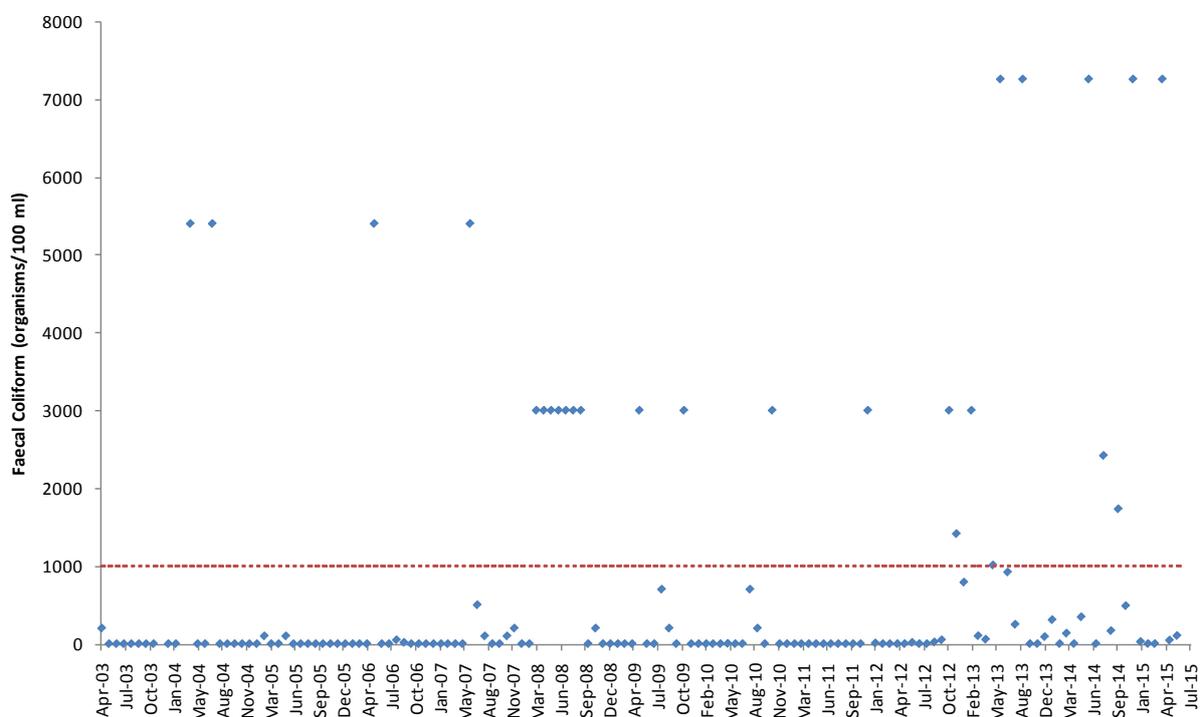


Figure 3.20 Monthly trend in Faecal Coliforms (org/100ml) in effluent released from the Saldanha Wastewater Treatment Works, April 2003-June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

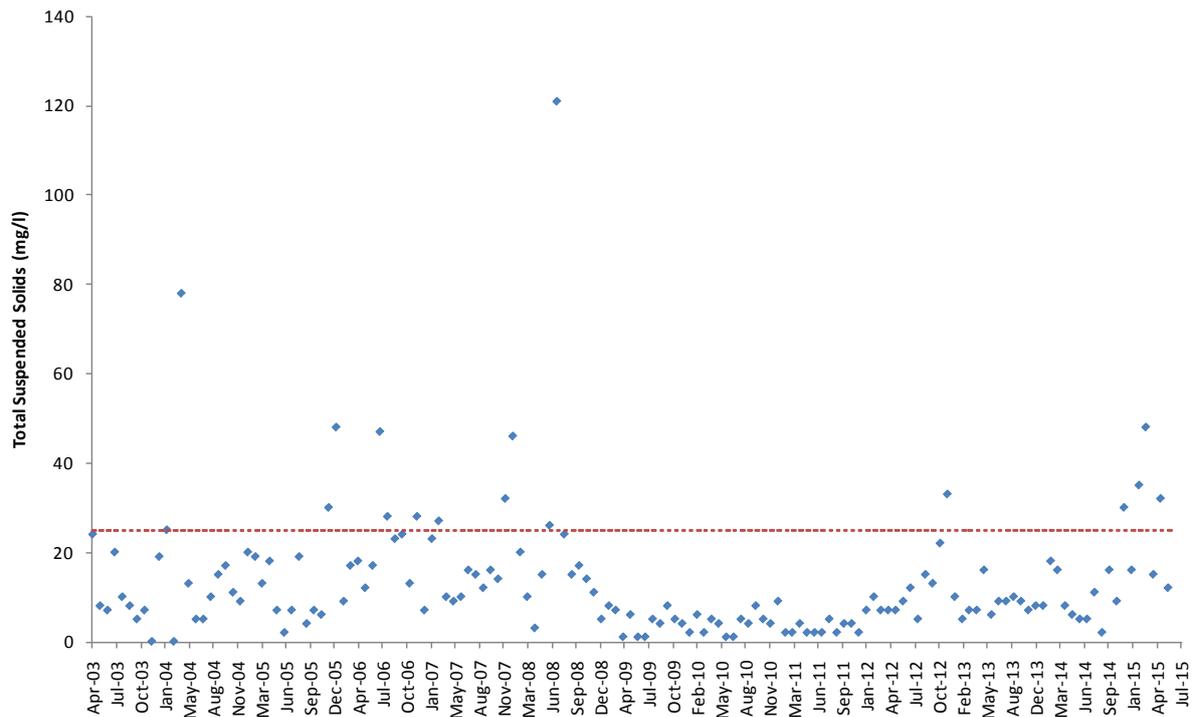


Figure 3.21 Monthly trend in total suspended solids (mg/l) in effluent released from the Saldanha Wastewater Treatment Works, April 2003 – June 2015. Allowable limits as specified in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

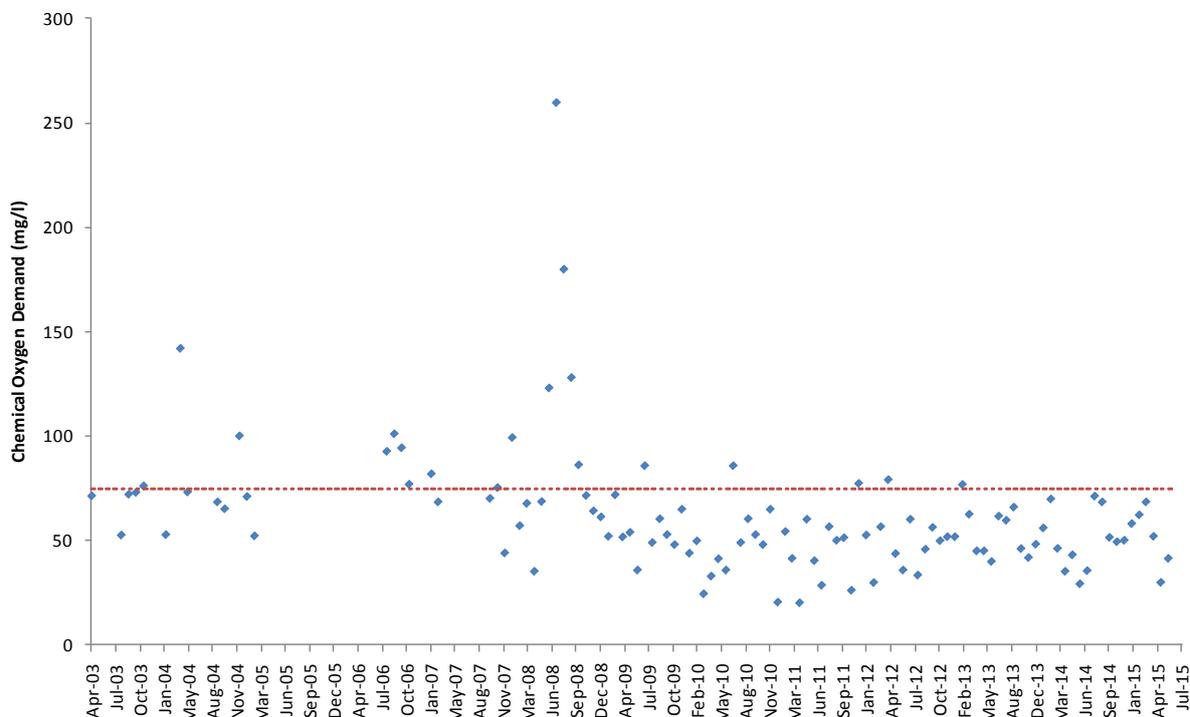


Figure 3.22 Monthly trends in chemical oxygen demand (mg/l filtered) in effluent released from the Saldanha Wastewater Treatment Works, April 2003-June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

Levels of Ammonia-Nitrogen (mg/l as N) are of great concern in the effluent discharged by the Saldanha WWTW as this water quality parameter exceeds the allowable limit of 6 mg/l 81% of the time (Figure 3.23.). Overall, the degree of compliance has increased substantially since the highest values were recorded in the winter of 2006 (58.8 mg/l). However, more drastic mitigation measures are clearly required to lower Ammonia Nitrogen levels to meet the legal limit.

The Nitrate-Nitrogen limit of 15 mg/l was exceeded 17% of time. Overall, compliance has improved since 2010 where measurements have been consistently very low since beginning of 2014 (Figure 3.24).

The concentration of orthophosphate in the effluent has only been measured since October 2007 showing a distinct seasonal pattern, with the highest values occurring during the summer months and lowest values in winter. This is consistent with the higher influx of visitors during summer. Similar to TSS and DOD, orthophosphate levels have dropped since February 2013 and the allowable limit of 10 mg/l was only exceeded on two occasions (Figure 3.25).

Permissible chlorine levels of 0.25 mg/l have been exceeded 58% of the time (Figure 3.26). Overall, the amount of free chlorine has decreased since August 2014, a recent improvement compared to the preceding years. The data shows that chlorine gas always peaks shortly after a high count of faecal coliform in the effluent. For example, chlorine gas was measured as 3.2 mg/l in October 2013, a month after faecal coliform numbers peaked at 7257 org/100ml (i.e. 2419 multiplied by a factor of three). In January 2008, chlorine levels were measured at 12 mg/l but this data point was removed from the graph such that the pattern could be demonstrated more clearly.

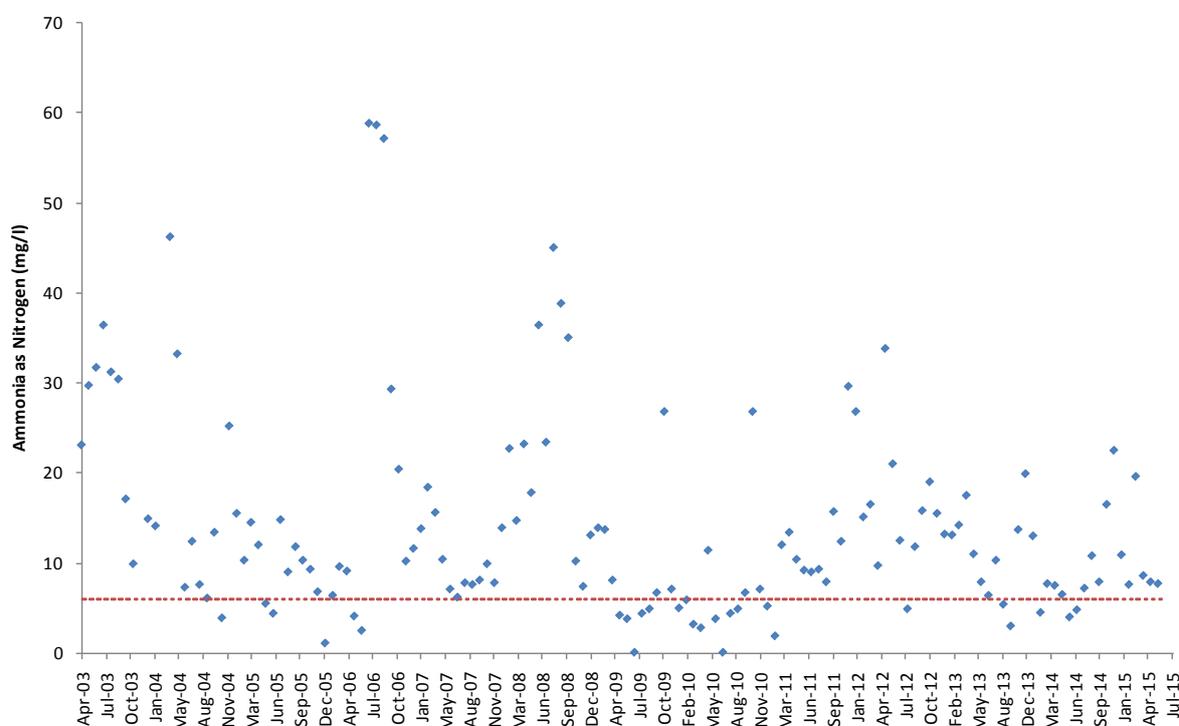


Figure 3.23. Monthly trends in Ammonia Nitrogen (mg/l as N) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

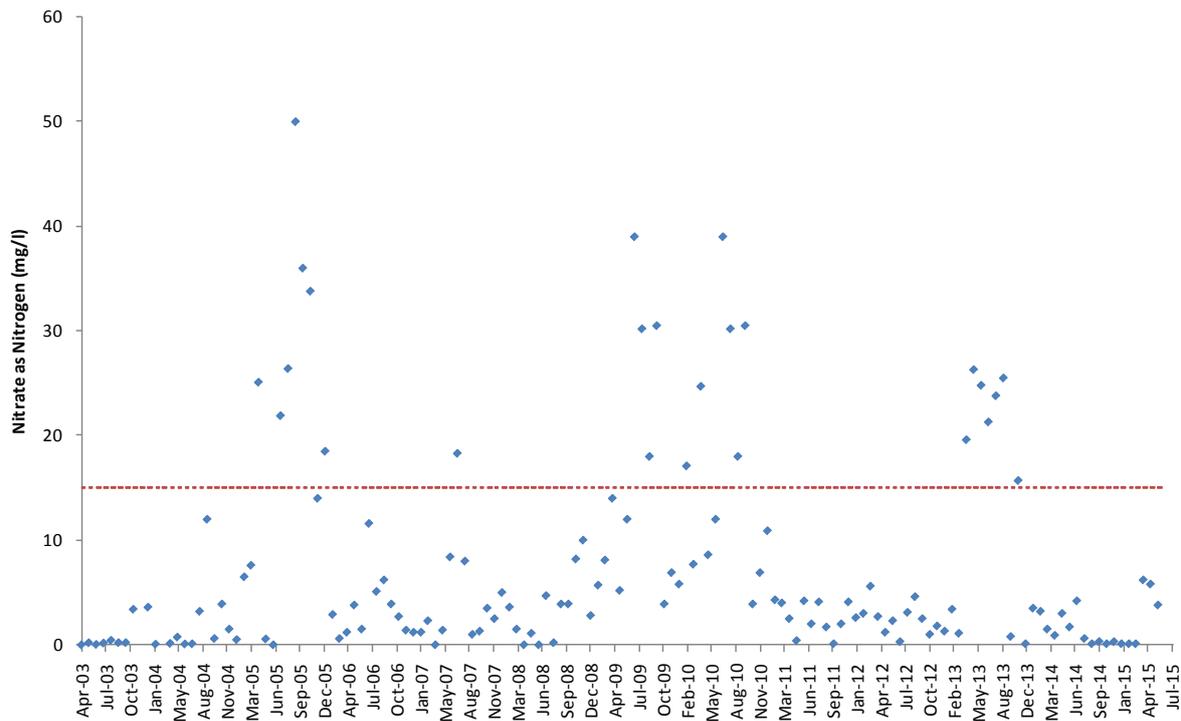


Figure 3.24 Monthly trends in Nitrate Nitrogen (mg/l as N) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2014. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

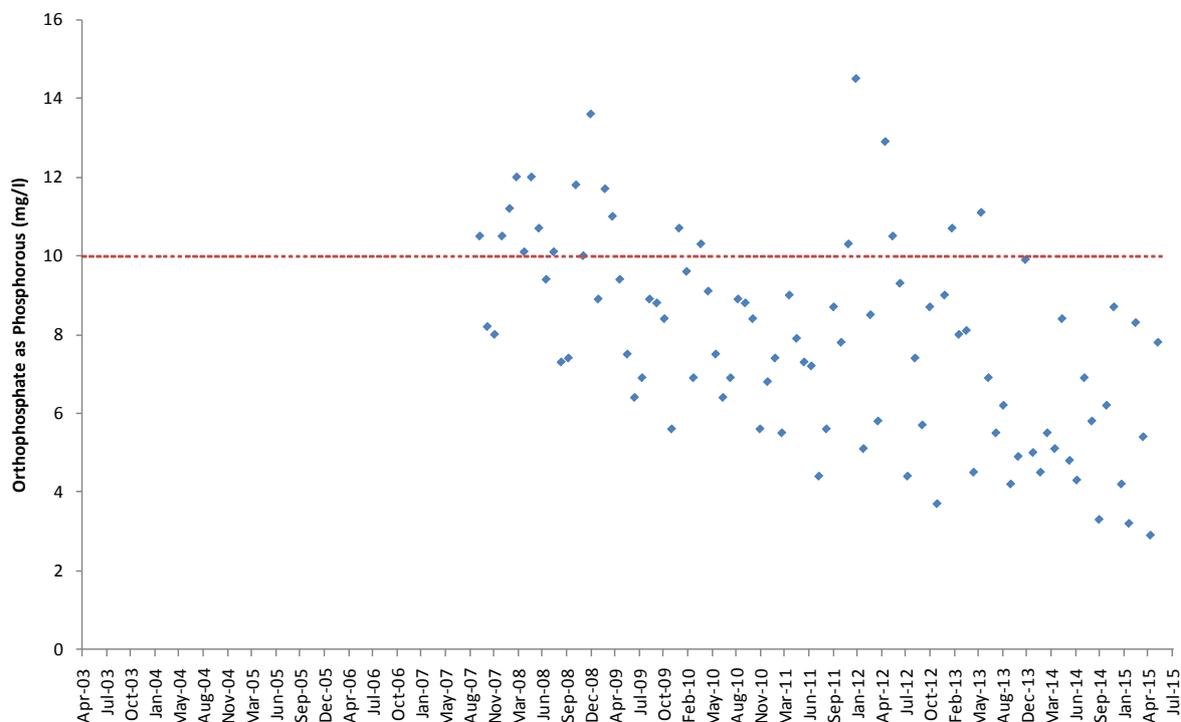


Figure 3.25 Monthly trends in Orthophosphate (mg/l as P) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

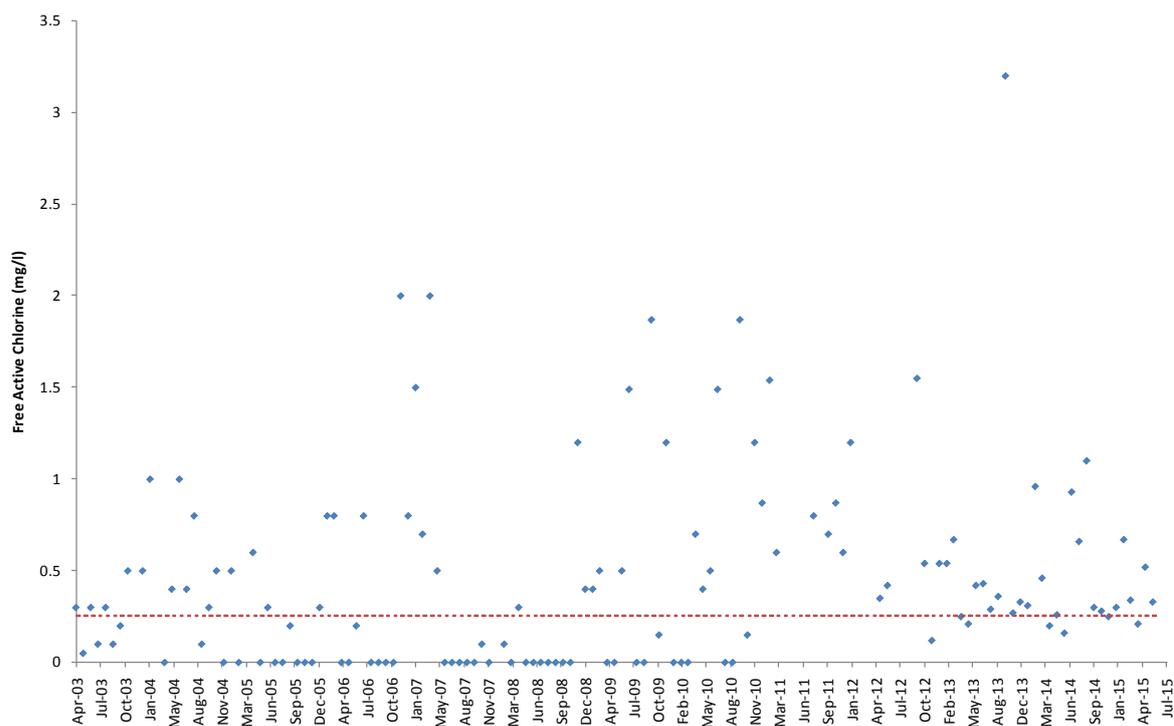


Figure 3.26 Monthly trends in Free Active Chlorine (mg/l) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line. An outlier of 12 mg/l measured for January 2008 was removed to show the trend more clearly.

3.4.3.4 Langebaan Wastewater Treatment Works

Until recently the Langebaan WWTW did not discharge any effluent into the water course as all of it was used to irrigate the local golf course. The Langebaan WWTW was issued an exemption under the NWA section 21(f) and (g), provided that the effluent volume did not exceed 588 000 m³ per year for the irrigation of the local golf course and that the water quality of the treated effluent is compliant with the General Discharge Limit of the revised General and Special Standard (Government Notice No. 36820 –6 September 2013) promulgated under the NWA (Table 3.5.).

However, increasing volumes of effluent received by this plant is yielding more water than is required for irrigation and increasing volumes have been discharged into the Langebaan Lagoon MPA. This is an illegal activity in terms of the National Environmental Management: Protected Areas Amendment (Act No 21 of 2014) (NEMPAAA) section 48A (d), which prohibits the discharging or depositing of waste or any other polluting matter into an MPA, unless a CWDP is granted by the Minister of Environmental Affairs in terms of the ICMA. A directive has been issued to the SBM to stop releasing effluent into the Langebaan Lagoon MPA. A consultant has been appointed to conduct a feasibility study to determine the best possible options for the re-use of treated effluent during the winter months to prevent future overflow of effluent into the MPA. In the meantime, over the weekend of the 8th August 2015, large build-up sludge in the channel was cleared from the final contact cleaning channel and lead to a greatly improved effluent (SBM, Gavin Williams, *pers. comm.* 2015). Finally, the SBM is currently in the process of appointing a consulting engineer for proposed R5 million upgrades to the plant over the next two years (SBM, Gavin Williams, *pers. comm.* 2015).

The SBM submitted an application for a General Authorisation in 2012, which was predicted to be finalised by the end of 2014 (SBM, Gavin Williams, *pers. comm.* 2014). However, more recently, the SBM was asked to resubmit their application for a water use license, as the discharge volumes now exceed the requirements of a General Authorisation (SBM, *pers. comm.* 2015).

The Langebaan WWTW treats sewage by means of activated sludge with BNR and drying ponds. Trends of water quality parameters in the effluent released into the Langebaan Lagoon MPA between 2009 and 2015 are shown in Figure 3.27. -Figure 3.30 and Figure 3.31 - Figure 3.34.

Water quality parameters associated with effluent from the Langebaan WWTW have only been measured since June 2009. The exemption permits the irrigation of the local golf course with 1611 m³ treated effluent per day, which is exceeded 91% of the time (Figure 3.27.). Although the average daily flow at Langebaan WWTW has decreased by approximately one third since the measurement of the highest levels in 2010, excess effluent has been illegally released into the Langebaan Lagoon MPA. Consequently, the magnitude of non-compliance for the water quality parameters described below is of great concern.

Concentrations of faecal coliforms in the effluent from the Langebaan WWTW exceeded the allowable limit of 1000 org/100ml on 19 occasions since June 2009 (26% of the time) (Figure 3.28). The frequency and magnitude of non-compliance events increased dramatically in 2013, where the allowable limit for faecal coliforms has been exceeded on 14 occasions since December 2012, reaching an all-time estimated high of 7257 org/100ml (maximum detectable limit 2419 org/100ml multiplied by 3). Furthermore, faecal coliform measurements below the allowable limit are generally higher. This is cause for concern, as it appears that Langebaan WWTW is unable to adequately process effluent volumes above the allowable limit.

TSS values exceeded the allowable limit of 25 mg/l on eight occasions since 2009 (11% of the time) (Figure 3.29). Overall, TSS levels were lowest in 2012 and have increased steadily since 2013 frequently exceeding the allowable limit reaching a maximum of 198 mg/l in March 2015. TSS levels roughly follow the trends observed in average daily flow volumes where TSS values are higher when flow is greater.

COD in filtered effluent exceeded the allowable limit of 75 mg/l 26% of the time since June 2009, reaching an all-time maximum of 130 mg/l in January 2015 (Figure 3.30). Compliance has generally worsened since reaching lowest levels in 2012, showing that the allowable limit was exceeded on nine occasions since January 2013.

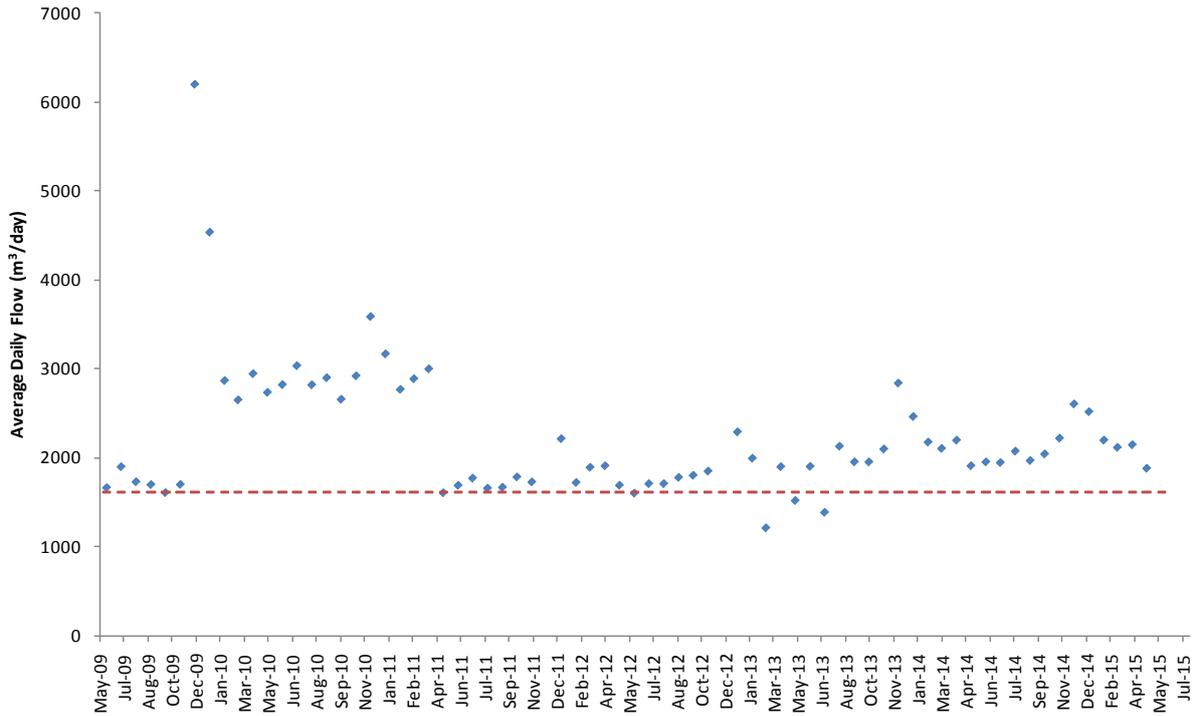


Figure 3.27. Trends in the volume of effluent (m³/month) released from the Langebaan Wastewater Treatment Works, June 2009 - June 2015. Allowable discharge limits in terms of the exemption issued by DWAF under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

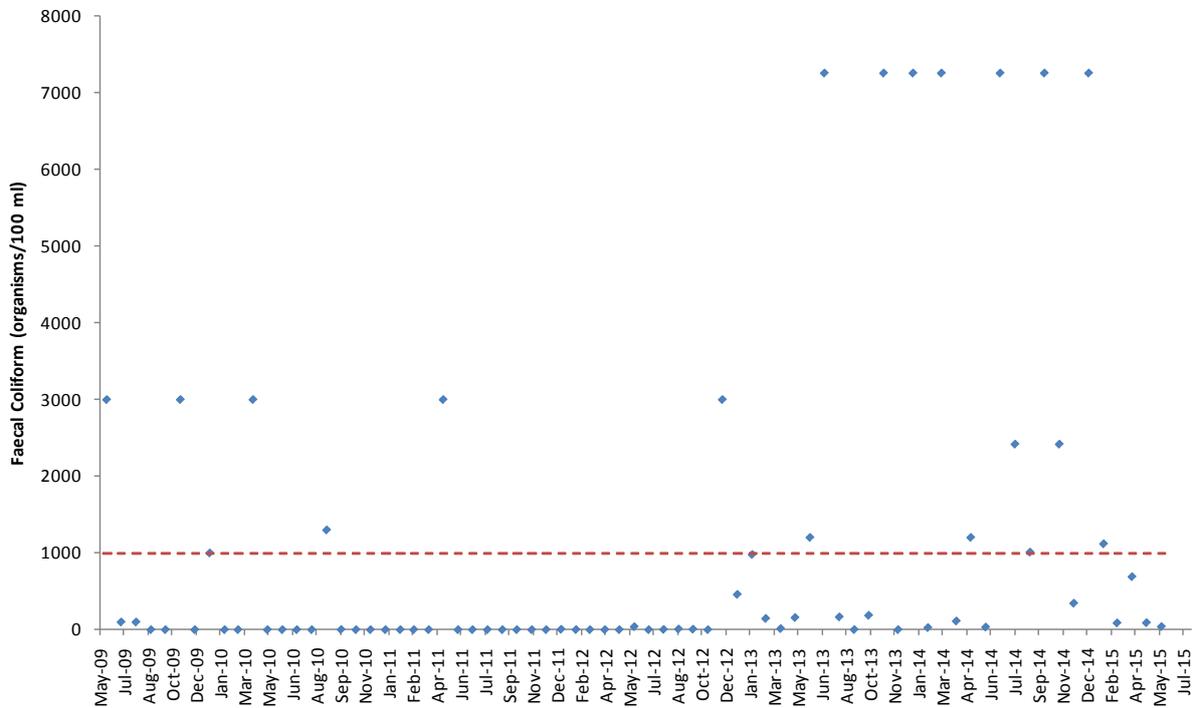


Figure 3.28 Monthly trends in Faecal Coliforms (org/100ml) in effluent released from the Langebaan Wastewater Treatment Works, June 2009 - June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

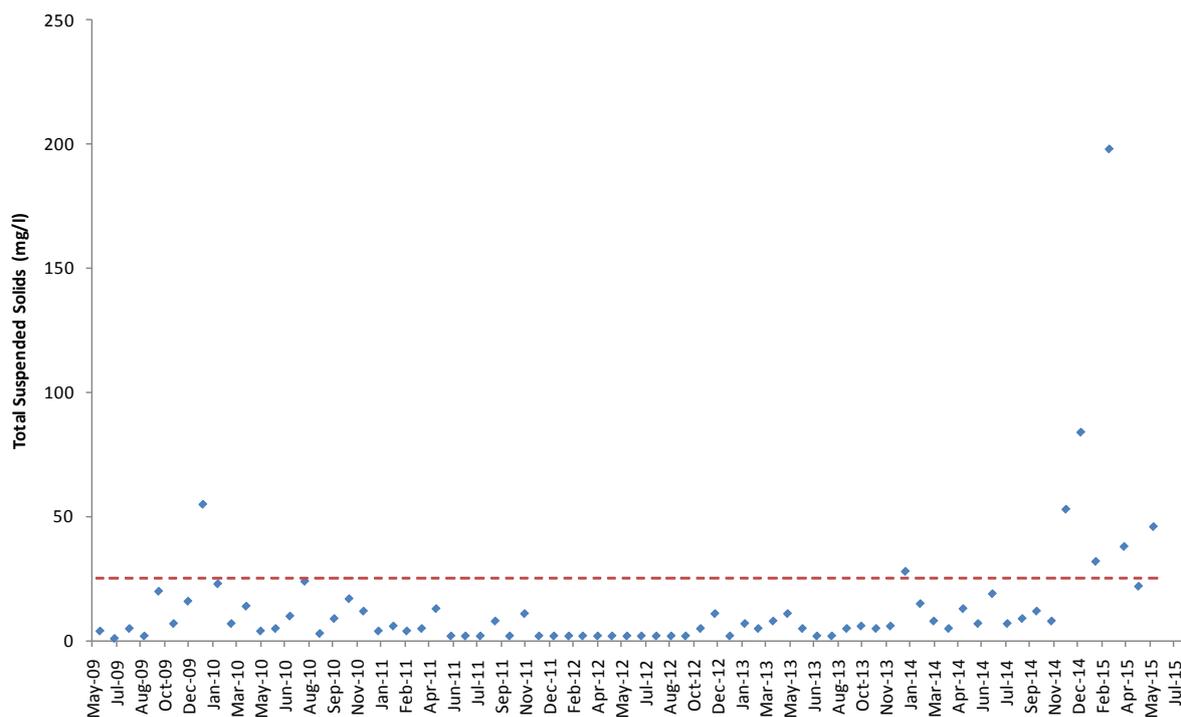


Figure 3.29 Monthly trends in total suspended solids (mg/l) in effluent released from the Langebaan Wastewater Treatment Works, June 2009 - June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

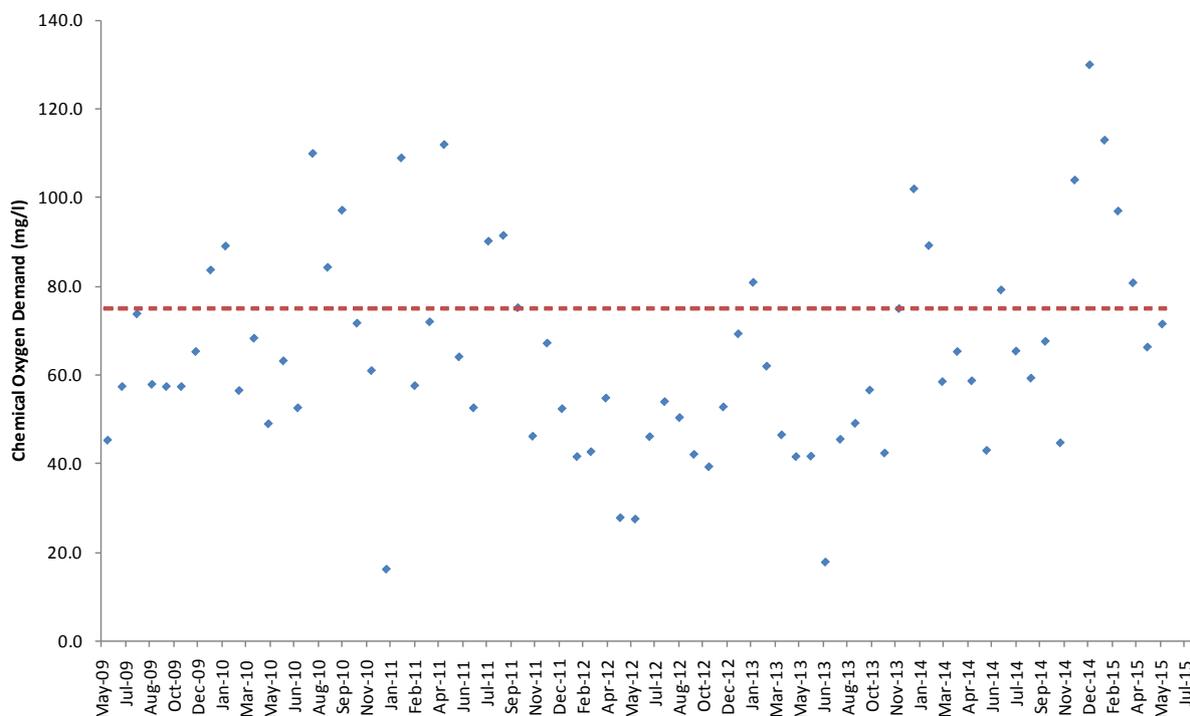


Figure 3.30 Monthly trends in chemical oxygen demand (mg/l filtered) in effluent released from the Langebaan Wastewater Treatment Works, June 2009 - June 2015. Allowable limits as specified in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

Ammonia Nitrogen levels discharged from the Langebaan WWTW have exceeded the allowable limit of 6 mg/l 79% of the time since June 2009 (Figure 3.31.). Although Ammonia Nitrogen levels decreased to below the allowable limit in October 2011, levels have been increasing steeply since October 2012, reaching the highest value of 99.6 mg/l in January 2014. However, measurements in the in 2015 have been lower but still are still not compliant with the legal limit. This trend follows closely the trend observed for faecal coliforms, which indicates that the Langebaan WWTW is unable to adequately process the effluent that it receives.

Nitrate Nitrogen levels have only exceeded allowable limits once since June 2009 (Figure 3.32). Nitrate Nitrogen levels increased steadily from June 2009 up to June 2012, peaking at 10.7 mg/l. Thereafter, levels decreased to nearly zero, with only high measurement recorded on January 2014 (19.3 mg/l as N), which coincided with the peak in Ammonia Nitrogen, COD and faecal coliform numbers. However, an increasing trend since November 2014 can be observed and should be monitored closely.

Orthophosphate concentrations fluctuate in a seasonal pattern similar to that seen at the Saldanha WWTW (Figure 3.33). Orthophosphate levels decreased from June 2009, reaching a minimum of 0.4 mg/l in April 2012 and have largely remained below the allowable limit of 10 mg/l since January 2013. High orthophosphate levels were recorded in February and November 2013 as well as June 2015, however, with values of 11.6 and 10.1 and 12.1 mg/l respectively.

Although the levels of free active chlorine have been steadily decreasing since a maximum of 6.6 mg/l was recorded in November 2012, allowable limits of 0.25 mg/l are still exceeded 70% of the time since monitoring commenced in 2009 (Figure 3.34). As observed at the Saldanha WWTW, free active chlorine levels above the allowable limit are always detected immediately after a rise in faecal coliforms.

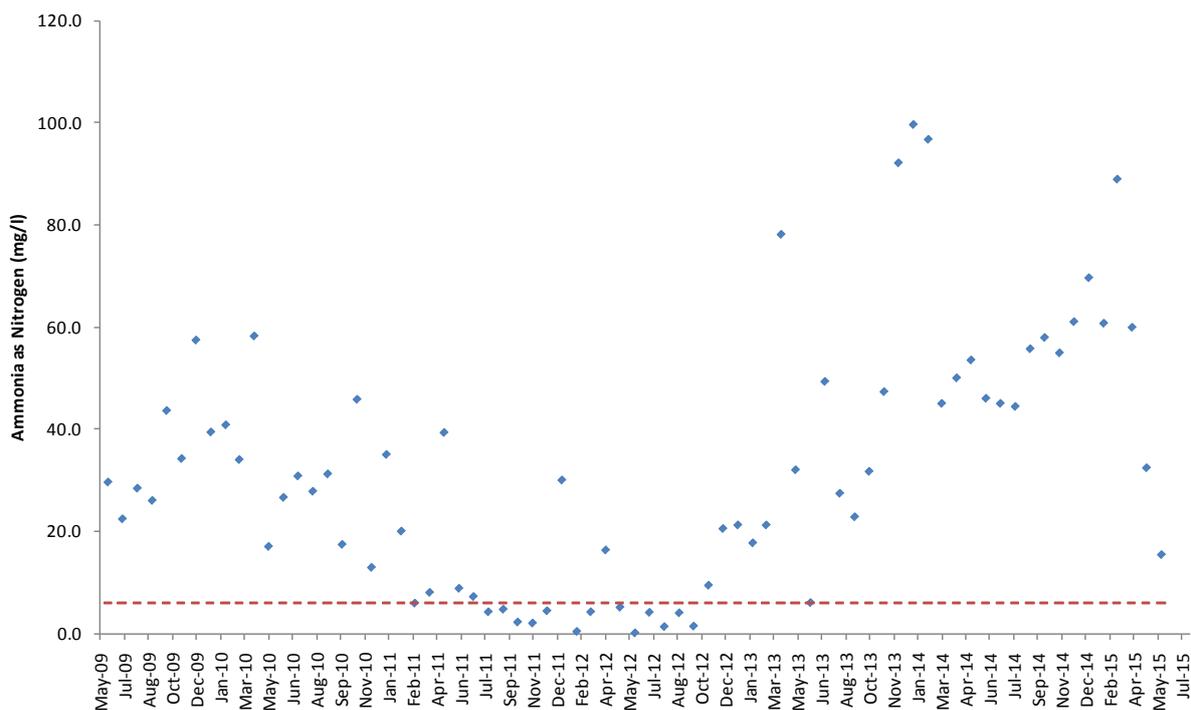


Figure 3.31. Monthly trends in Ammonia Nitrogen (mg/l as N) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

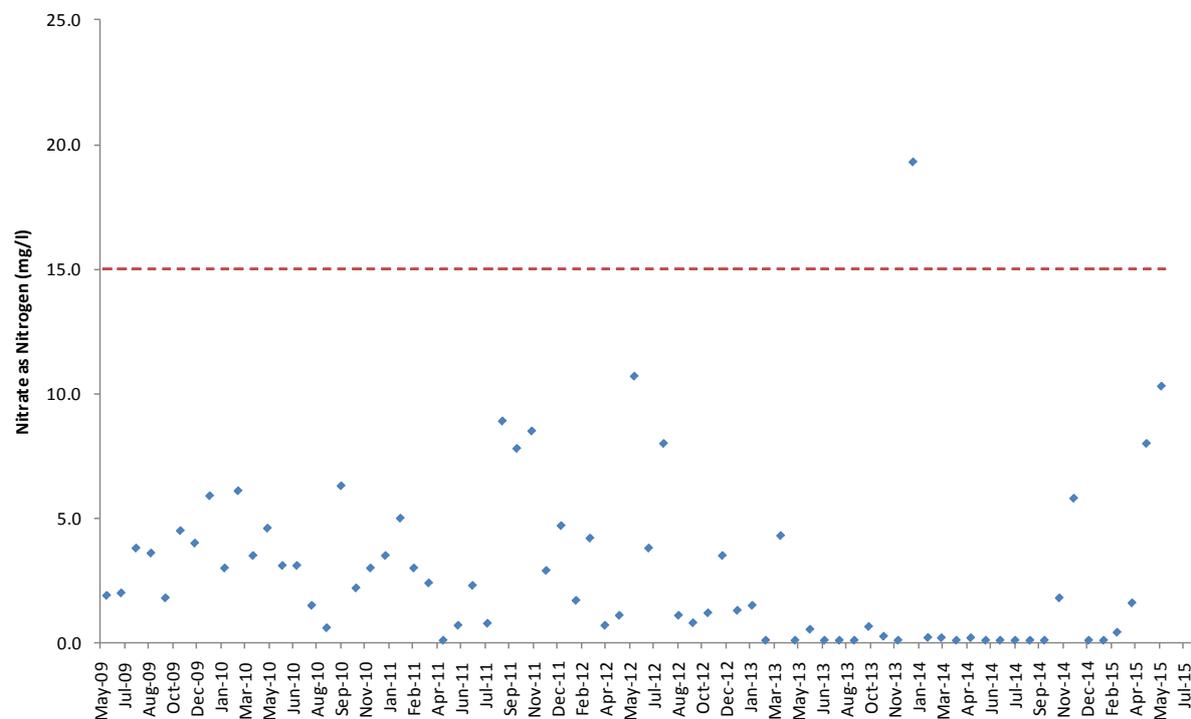


Figure 3.32 Monthly trends in Nitrate Nitrogen (mg/l as N) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

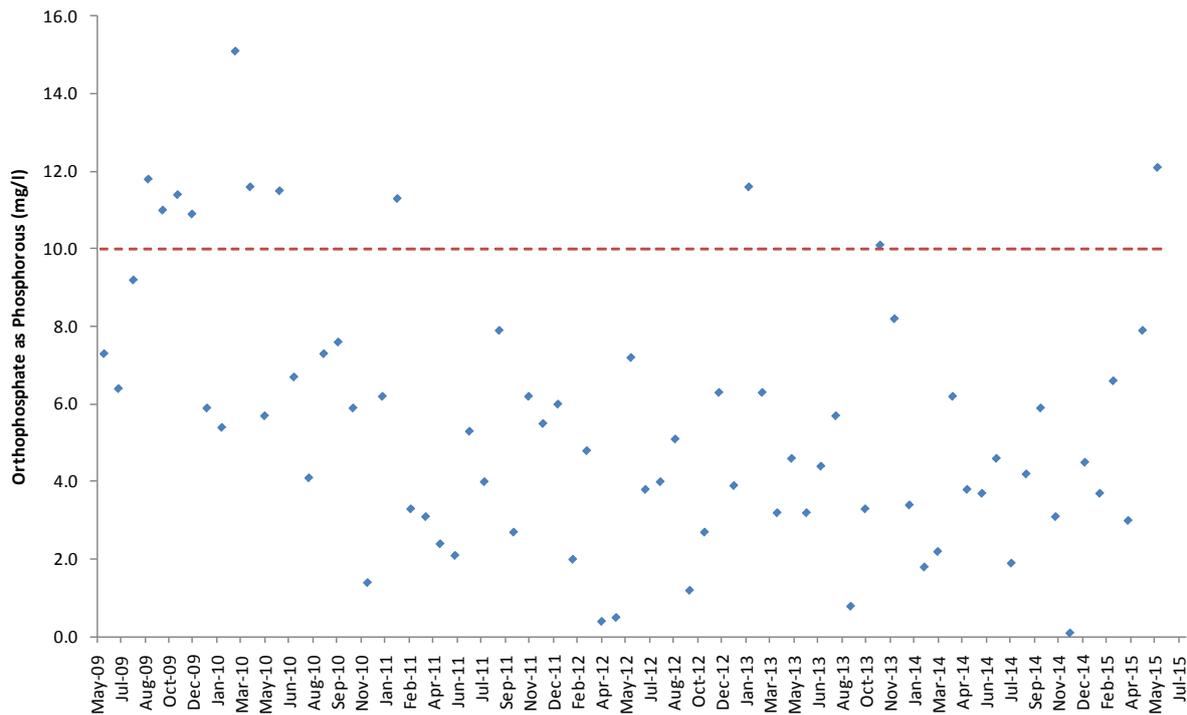


Figure 3.33 Monthly trends in Orthophosphate (mg/l as P) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

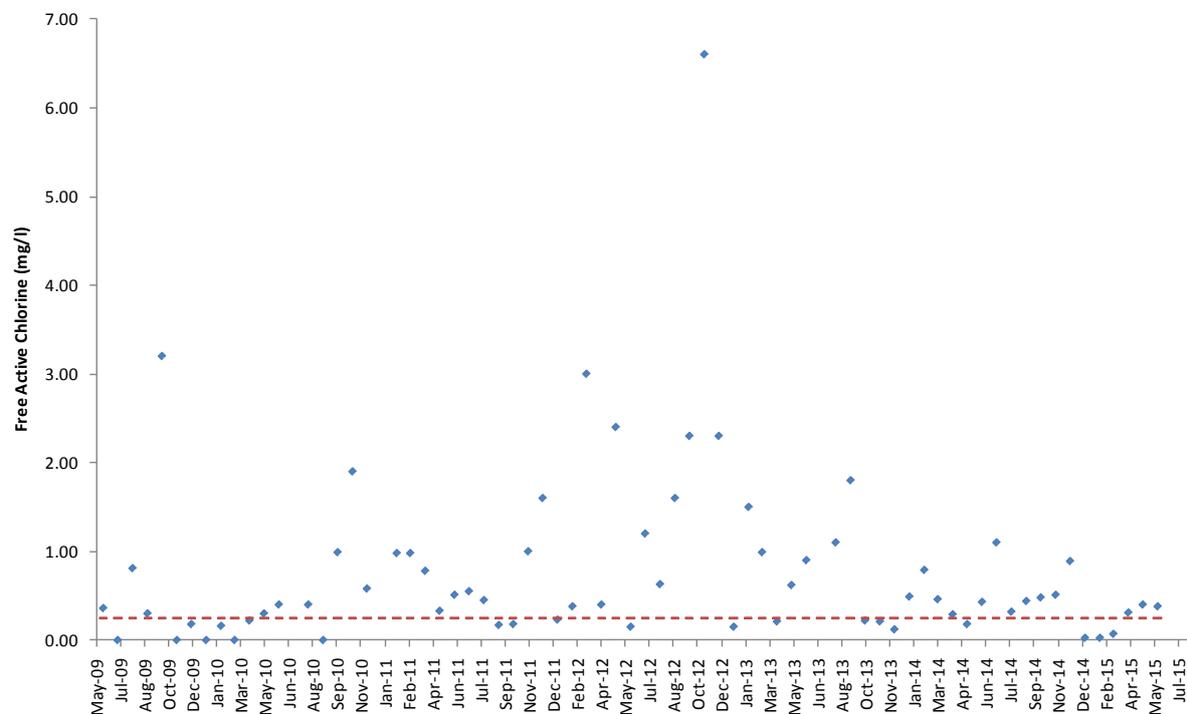


Figure 3.34 Monthly trends in Free Active Chlorine (mg/l) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2015. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line.

3.4.3.5 Summary

The data shows that the WWTW at Saldanha and Langebaan are experiencing difficulties in keeping effluent levels and water quality parameters within allowable limits and conditions as set out in the NWA (Government Gazette No.36820, 6 September 2013) (Table 3.5.). The data shows that both the Saldanha and Langebaan WWTW are receiving greater volumes of effluent for treatment than permitted and the consequences of this are clearly shown in their inability to process the effluent adequately. The frequency and magnitude of non-compliance with regard to faecal coliform counts have increased dramatically and as a result, require liberal application of chlorine gas to sterilise the effluent.

Excessive ammonia nitrogen levels at both WWTWs are also of great concern. Although ammonia nitrogen levels at Saldanha WWTW have dropped in recent years, a drastic improvement is required to ensure compliance. In contrast, the Langebaan WWTW shows a steep increase in ammonia nitrogen levels since October 2012 peaking at >30 fold the permissible level and only shows a slight decrease in ammonia nitrogen levels in the last year. Management interventions are urgently needed to reduce ammonia nitrogen in this effluent.

TSS, COD, nitrate nitrogen and orthophosphate levels have dropped at both WWTWs in recent years, however, both have yet to ensure compliance in terms of COD levels. Although TSS levels at both WWTWs were within the allowable limit, a steady increase since 2013 is evident and compliance with the required limit has not been achieved on a regular basis. Close monitoring of this water quality parameter is recommended.

3.4.4 Saldanha Regional Marine Outfall Project

Frontier Rare Earths is a mineral exploration and development company that is focused on rare earth elements. Frontier's flagship asset is the Zandkopsdrift rare earth deposit, located in the Northern Cape Province of South Africa. Ore from this deposit will be partially processed on site at Zandkopsdrift where after it will be transported to a separation plant in Saldanha in the Western Cape for further processing. Processing at the separation plant in Saldanha will generate brine effluent that will need to be disposed of. The preferred option for disposal is to sea through a deepwater marine discharge. Frontier Saldanha Utilities (Pty) Ltd. has proposed the Saldanha Regional Marine Outfall Project at Danger Bay in the Saldanha Bay region (Figure 3.35). This project has been proposed to discharge treated effluent of up to 8-9 mega litres per day into Danger Bay from three sources (CSIR 2013a):

- Rare Earth Element Separation plant proposed by Frontier Separation (Pty) Ltd.
- Chlor-Alkali Production Facility proposed by Chlor-Alkali Holdings (Pty) Ltd.
- Regional WWTW proposed by SBM.

The preferred alternative relies on the construction of the West Coast District Municipality desalination plant (refer to AEC 2014 for more detail on this development). In this scenario, the effluent will be disposed via the brine return disposal infrastructure of the desalination plant. However, alternatives have been considered in the event that the construction of the WCDM desalination plant is postponed. It must be noted that future development is required to undergo

separate feasibility studies and EIAs to consider the capacity of the receiving environment to assimilate additional effluent.

The effluent will largely be comprised of sodium chloride but will also contain biocides, co-pollutants and rare earth elements. Rare earth elements contain radioactive metals (thorium and uranium), which will be removed from the effluent prior to discharge. Nonetheless, accidental contamination is considered in the EIA. It is poorly understood how rare earth elements interact with organic compounds (i.e. whether or not they form bonds with organic compounds to become unavailable/nontoxic to organisms in the receiving environment). As a result it is unknown whether trace amounts of rare earth potentially elements can harm marine organisms. Furthermore, the discharged effluent is likely to have a higher temperature than the receiving environment and as a result dissolved oxygen levels are likely to be lower in the discharge plume.

It is envisioned that the proposed outfall structure will also be utilised by other, future developments in the Saldanha Bay area. The benefits of this project are twofold. Firstly, effluent from all three plants will be discharged through an open ocean outfall outside of Saldanha Bay where wave energy and the assimilative capacity of the environment is much higher than in the low energy environment in the Bay. Secondly, the outfall has been designed in such a way that it can accommodate effluent from other existing as well as a good number of new proposed developments. The potential thus exists for diverting some of the existing effluent streams that currently find their way into the Bay, outside of the Bay at a fraction of the cost that this may otherwise have required (note that the costs of constructing an open ocean or deep water outfall is the most commonly cited reason for needing to discharge effluent directly into the Bay). Frontier Saldanha Utilities (Pty) Ltd has also joined the Saldanha Bay Water Quality Forum Trust (SBWQFT) and have commissioned baseline marine monitoring in Danger Bay even through the intention is only to begin discharging effluent in 2018 at the earliest (Refer to the Sediment, Macrofauna, and Fish chapters for more details on this).

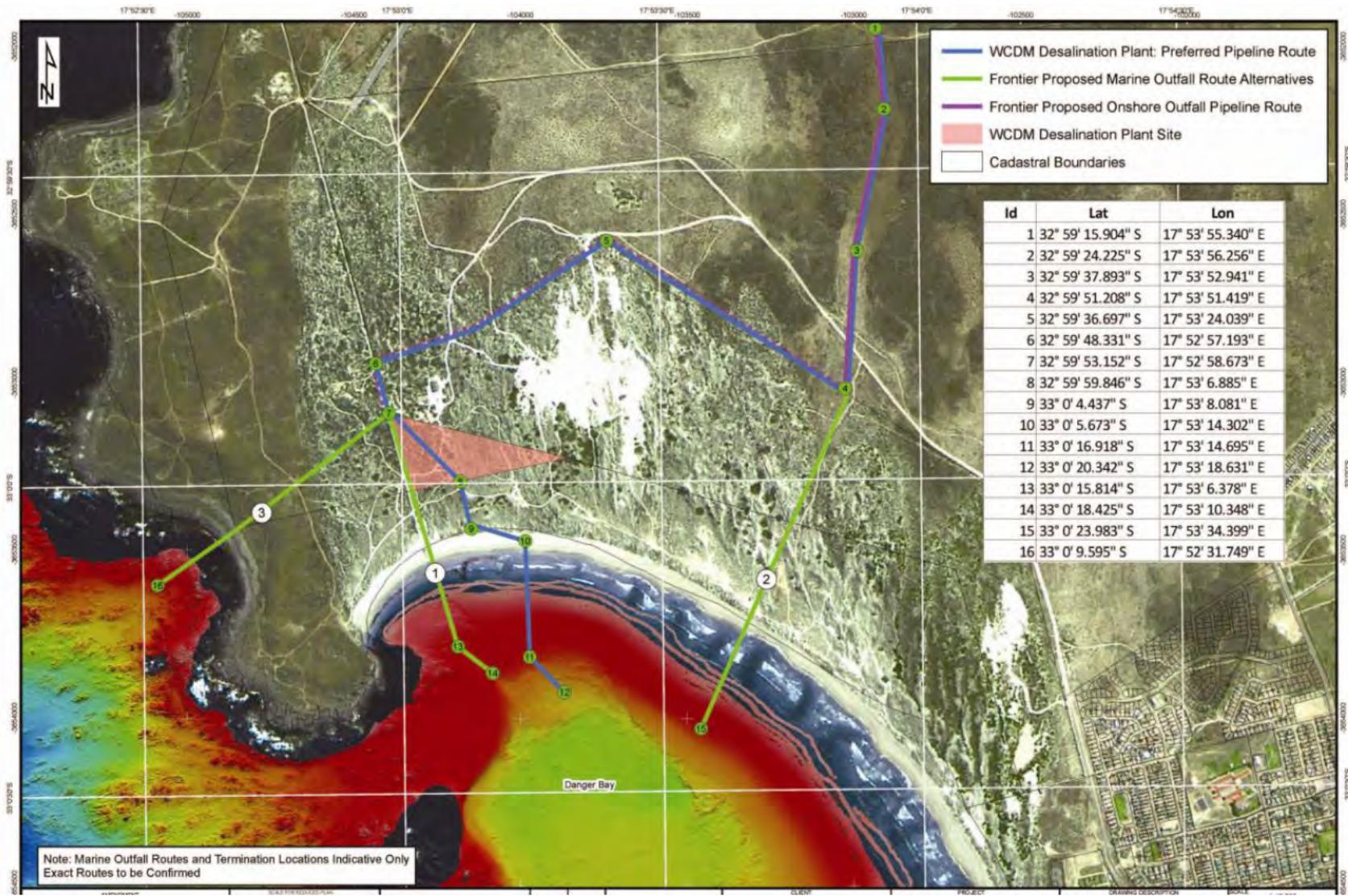


Figure 3.35 Alternative options for the routing of the Saldanha Regional Marine Outfall project pipelines and West Coast District Municipality Plant outfalls (Source CSIR 2013b).

3.4.5 Storm water

Storm water runoff, which occurs when rain flows over impervious surfaces into waterways, is one of the major non-point sources of pollution in Saldanha Bay (CSIR 2002). Sealed surfaces such as driveways, streets and pavements prevent rainwater from soaking into the ground and the runoff typically flows directly into rivers, estuaries or coastal waters. Storm water running over these surfaces accumulates debris and chemical contaminants, which then enters water bodies untreated and may eventually lead to environmental degradation. Contaminants that are commonly introduced into coastal areas via storm water runoff include metals (Lead and Zinc in particular), fertilizers, hydrocarbons (oil and petrol from motor vehicles), debris (especially plastics), bacteria and pathogens and hazardous household wastes such as insecticides, pesticides and solvents (EPA 2003).

It is very difficult to characterise and treat storm water runoff prior to discharge, and this is due to the varying composition of the discharge as well as the large number of discharge points. The best way of dealing with contaminants in storm water runoff is to target the source of the problem by finding ways that prevent contaminants from entering storm water systems. This involves public education as well as effort from town planning and municipalities to implement storm water management programmes.

The volume of storm water runoff entering waterways is directly related to the catchment characteristics and rainfall. The larger the urban footprint and the higher rainfall, the greater the runoff will be. At the beginning of a storm a “first flush effect” is observed, in which accumulated contaminants are washed from surfaces resulting in a peak in the concentrations of contaminants in the waterways (CSIR 2002). Several studies have shown degradation in aquatic environments in response to an increase in the volume of storm water runoff (Booth & Jackson 1997, Bay *et al.* 2003).

Storm water runoff that could potentially impact the marine environment in Saldanha and Langebaan originates from industrial areas (490 ha), the Saldanha Bay residential area (475 ha), industrial sites surrounding the Port of Saldanha (281 ha), and Langebaan to Club Mykonos (827 ha) (Figure 3.36.). All residential and industrial storm water outlets drain into the sea.

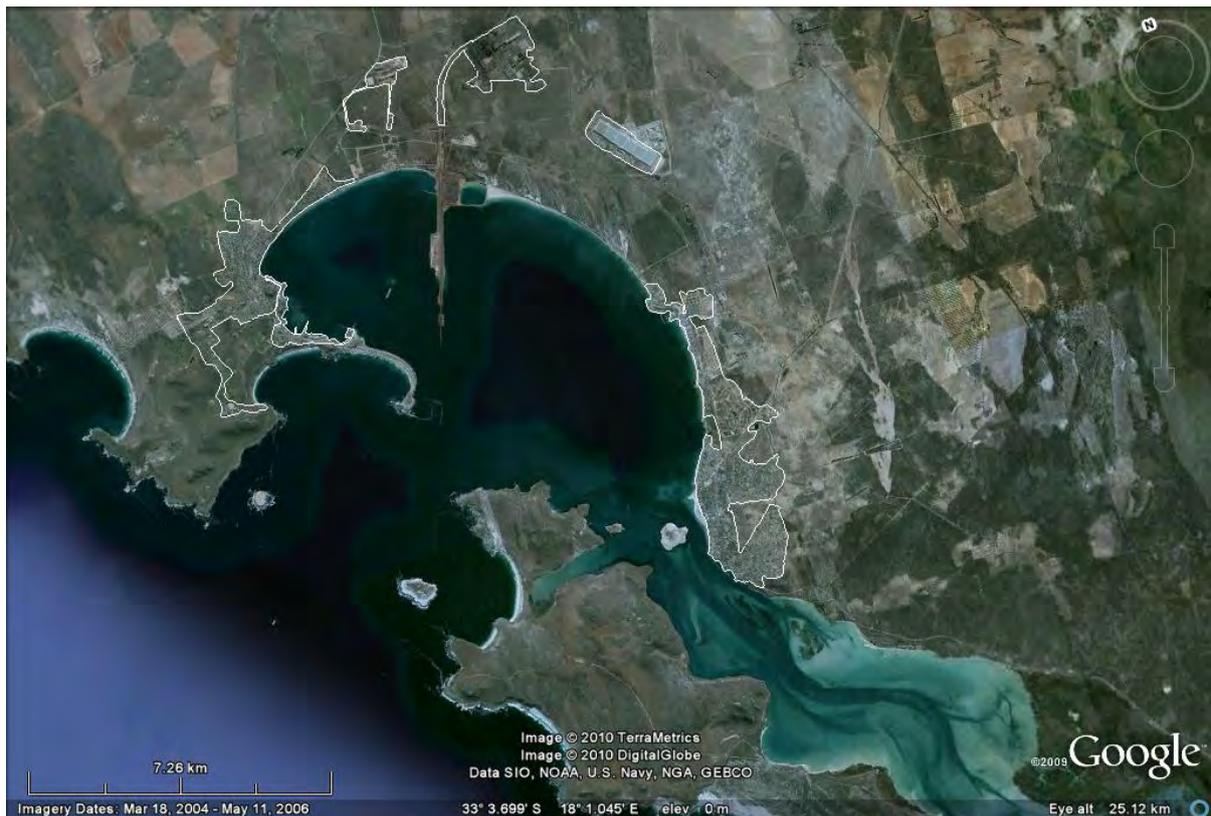


Figure 3.36. Spatial extent of residential and industrial areas surrounding Saldanha Bay and Langebaan Lagoon from which storm water runoff is likely to enter the sea (areas outlined in white). Note that runoff from the Port of Saldanha and ore terminal have been excluded as this is now reportedly all diverted to storm water evaporation ponds.

The CSIR (2002) estimated the monthly flow of storm water entering Saldanha Bay and Langebaan Lagoon using rainfall data and runoff coefficients for residential and industrial areas. In this report, these estimates have been updated by obtaining more recent area estimates of industrial and residential developments surrounding Saldanha Bay and Langebaan Lagoon using Google Earth and by acquiring longer term rainfall data (Figure 3.36. and Table 3.6.). Runoff coefficients used to calculate storm water runoff from rainfall data were 0.3 for residential areas and 0.45 for industrial areas (CSIR 2002). Note that runoff from the Port of Saldanha and ore terminal have been excluded from these calculations. Storm water runoff is highly seasonal and peaks in the wet months of May to August. Due to the rapid pace of holiday and retail development in the area, Langebaan residential area produces the greatest volumes of storm water runoff, followed by the industrial areas, with lower volumes arising from the Saldanha residential area. The actual load of pollutants entering the Bay and Lagoon via this storm water can only be accurately estimated when measurements of storm water contaminants in the storm water systems of these areas are made.

Table 3.6. Monthly rainfall data (mm) for Saldanha Bay over the period 1895-1999 (source Visser *et al.* 2007). MAP = mean annual precipitation.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
MAP	6	8	11	25	47	61	64	46	25	18	13	8	332
Ave. rain days	1.4	1.4	2.2	3.8	6.2	7.1	7.5	6.4	4.8	3.0	1.9	1.8	47.5
Ave./day	4.1	5.5	5.1	6.6	7.6	8.5	8.5	7.3	5.2	6.0	6.6	4.6	7.0

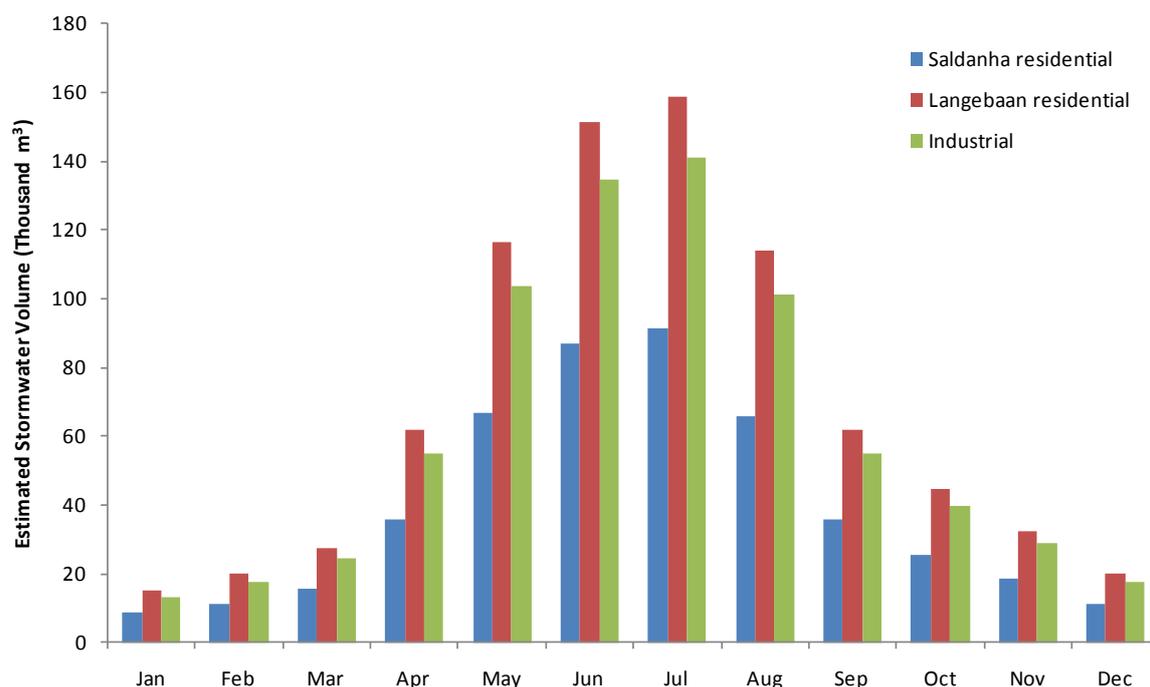


Figure 3.37. Monthly estimated storm water volume (m³) for Saldanha and Langebaan residential areas and industrial area. Note that runoff from the Port of Saldanha and ore terminal have been excluded as this is now reportedly all diverted to storm water evaporation ponds.

3.4.5.1 Stormwater management in Saldanha

There are approximately 15 outlets in the Saldanha Bay residential area. Historically, storm water from the Port of Saldanha and ore terminal was allowed to overflow into the Bay but most of this is now diverted to storm water evaporation ponds and any material settling in these ponds is trucked to a landfill site. The number of storm water outlets in Saldanha Bay industrial zone (along the western margin of Small Bay) is currently unknown.

Typical concentrations of various storm water constituents (metals, nutrients, bacteriological) for industrial and residential storm water from South Africa and elsewhere were extracted from the literature by the CSIR in 2002 (Table 3.7.). These values are rough estimates as site specific activities will have a strong influence on storm water composition and ideally more accurate data should be

acquired by monitoring of contaminants in the storm water systems of Saldanha and Langebaan. Storm water contaminant concentrations entering the sea from the Port of Saldanha were available from average monthly concentrations measured from residential and industrial sites in Saldanha over a four year period (1999-2002, Table 3.7.). It is clear that the estimated concentrations of many of the potentially toxic compounds are above the South African 1998 water quality guidelines for coastal and marine waters (values indicated in red). It is likely that introduction of contaminants via storm water runoff negatively impact the health of the marine environment, especially during the “first flush” period as winter rains arrive.

Table 3.7. Typical concentrations of water quality constituents in storm water runoff (residential and Industrial) (from CSIR 2002) and South Africa 1998 Water Quality Guidelines for the Natural Environment (*) and Recreational Use (). Values that exceed guideline limits are indicated in red.**

Parameter	Residential	Industrial	Water Quality Guidelines
Total suspended solids (mg/l)	500	600	-
Chemical oxygen demand (mg/l)	60	170	-
Nitrate-N (mg/l)	1.2	1.4	0.015*
Total Ammonia-N (mg/l)	0.3	0.4	0.6*
Orthophosphate-P (mg/l)	0.07	0.1	-
Cadmium (mg/l)	0.006	0.005	0.004*
Copper (mg/l)	0.05	0.05	0.005*
Lead (mg/l)	0.3	0.1	0.012*
Zinc (mg/l)	0.4	1.1	0.025*
Faecal coliform counts (counts/100 ml)	48 000	48 000	100**

Despite the efforts by the iron ore industry to reduce dust emission and to divert and store stormwater in evaporation ponds, Saldanha Bay experiences frequent and considerable pollution, especially when the terminals are washed down with hosepipes (Figure 3.38). Transnet currently holds a provisional AEL and it is unknown when a formal license will be issued by the competent authority. Several formal letters of complaint have been submitted by businesses and concerned citizens, of which one was submitted by FerroMarine Africa (Pty) Ltd in July 2015 to the West Coast District Municipality. FerroMarine claims that Transnet’s recent public statement to implement dust mitigation measures demonstrates non-compliance to their AEL, as compliance dates for the implementation of those very measures has already passed. FerroMarine also argues that the dust pollution damages important equipment of operational businesses, especially the oil and gas industry. The compliance letter also warns that new businesses have turned away and rig owners docking at repair quays have indicated that they would not return due to dust pollution issues.

Current emission control problems are predicted to worsen with the expansion of the iron ore export industry from 60 to 88 million tonnes per annum as proposed by Transnet (Section 3.2.4).

A report on the impacts of iron on the marine environment in Saldanha Bay was produced by Anchor Environmental Consultants in 2012 (Anchor Environmental Consultants 2012c). This report distinguished between the impacts of iron on the marine environment in its solid and hydrated state. Iron in the solid state affects organism by either smothering or through physical damage, thereby reducing the survival fitness of the affected organism. For example, high concentration of iron dust is known to inhibit photosynthesis in primary producers (Woolsey & Wilkinson 2007) and reduce fitness of intertidal organisms by changing the rate of heat absorption and reflective properties of their shells (Erasmus & De Villiers 1982). If iron is dissolved through chemical reactions with organic matter and oxygen, it becomes available to organisms in the marine environment. Dissolved iron is a micronutrient and shortage of this element can limit primary productivity in certain areas, while excess dissolved iron can result in unusual phytoplankton blooms. It has been shown that toxin levels in phytoplankton responsible for red tides also increase as a response to enhanced dissolved iron levels (He *et al.* 2009). Furthermore, accumulation of iron in tissue of bivalves can be harmful to humans when ingested and high levels of iron in tissue is recognised as an indicator for readily bioavailable iron (Rainbow 2002).



Figure 3.38 Pollution of Saldanha Bay by particulate iron carried by stormwater runoff (Source: Jaco Kotze, September 2014, Langebaan Rate Payers Association)

3.4.5.2 Stormwater management in Langebaan

Concerns and complaints have been publicly raised by the residents of Langebaan with regard to the poor stormwater management in Langebaan. Some parts of Langebaan are situated below the sea level and in the winter months, water becomes trapped on the roads in these areas. As a result, residents struggle to access their properties and to commute on flooded roads (Saldanha Bay Municipality 2014). Furthermore, the following concerns have been registered by the SBM:

- Deterioration/destructions of wetlands as well as canalisation of streams and rivers reduce the assimilative and dissipative capacity of the natural environment.
- Inadequate capacity of stormwater retention facilities east of Oostewal Street.

- Impact of stormwater effluent containing pollutants from roads, private properties and businesses discharging into the Langebaan Lagoon.
- Lack of maintenance of conveyance systems with large sediment deposits.
- Impact on tourism market due to deteriorating aesthetic value.

As a result of these concerns, a Stormwater Management Master Plan was drafted and is amended as new issues arise (living document) (Saldanha Bay Municipality 2014). A Stormwater Management Plan is a necessary precursor to an action plan for improving stormwater management in Saldanha. However, the importance of drafting and implementing a policy for the maintenance of existing and future stormwater management structures has also been recognised. Langebaan currently has approximately 30 existing ponds of various sizes for the collection of stormwater and three additional large ponds are proposed (Note that these numbers may change as the Stormwater Master Plan is amended). There are about 20 outlets for stormwater that drain directly into the Langebaan Lagoon. Three types of structural stormwater controls are proposed for Langebaan, namely stormwater wet extended detention ponds, enhanced swale and litter/silt traps. The former will control the volume and quality of stormwater to be released into the Lagoon. The enhanced swale will encourage groundwater recharge and litter/silt traps will enable separation of refuse and larger debris at the entrance to chosen stormwater structures.

3.4.6 Fish processing plants

Three fishing companies currently discharge land-derived wastewater into Saldanha Bay: SA Lobster Exporters (Marine Products), Live Fish Tanks (West Coast) – Lusitania (CSIR 2002) and Sea Harvest. The latter is dealt with in more detail in below. The locations of the fish factory intake and discharge points are shown in Figure 3.39. Premier Fishing is currently in the process of re-commissioning and upgrading their fish processing plant.

SA Lobster Exporters discharges seawater from their operations into Pepper Bay. The average monthly effluent volumes range from 40 to 60 000 m³, and this water cycles through tanks where live lobsters are kept prior to packing (CSIR 2002). It was not possible to obtain more updated information or data for effluent volume and quality. No CWDP application has been submitted (Source: DEA: OC) and it is unknown whether this organisation is compliant with the revised General Discharge Limit.

Live Fish Tanks (West Coast)-Lusitania take up and release wash water from Pepper Bay. Neither discharge volume or water quality is being monitored on a routine basis (CSIR 2002), but it is reported to be not markedly different from ambient seawater, as it basically cycles through tanks where live lobsters are kept prior to packaging (CSIR 2002). It is therefore unknown if this organisation is compliant with the revised General Discharge Limit and no CWDP application has been submitted (Source: DEA: OC). Furthermore, municipal water is released on a regular basis into the sea after cleaning of concrete slabs without cleaning agents (Live Fish Tanks, *pers. comm.* 2014). It must be determined how much freshwater is released into Small Bay by Live Fish Tanks (West Coast)-Lusitania in order to assess whether it significantly impacts the receiving environment.

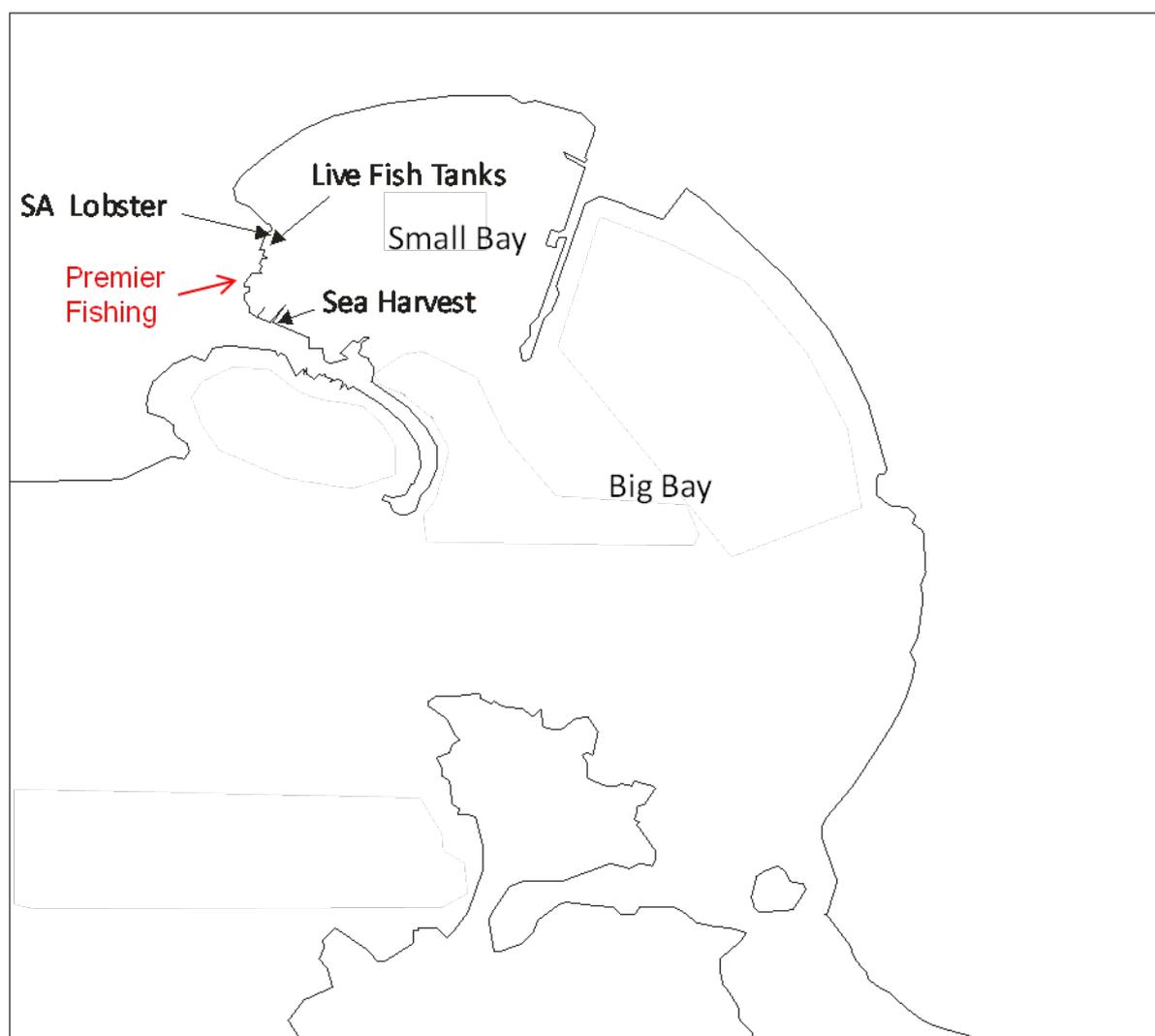


Figure 3.39. Location of seawater intakes and discharges for current and proposed seafood processing factories in Saldanha Bay. Current factories are indicated in black while the proposed Premier Fishing Fish Processing Plant is indicated in red.

3.4.6.1 Sea Harvest Fish Processing Plant

Sea Harvest is a predominantly demersal trawl fishing company which was established in 1964. The fish processing factory is situated near the base of the causeway to Marcus Island in Saldanha Bay and processes mostly hake (*Merluccius paradoxus* and *M. capensis*) into a variety of primary fish products including fillets, cutlets, steaks and loins. Previously, fish waste was processed into fish meal by an independent contractor, but EA was granted on 14 October 2013 for the establishment of a fish meal processing facility on the same premises and construction will commence during the course of 2015. Sea Harvest has been issued authorisation to increase the capacity of the fish processing plant from a 5-day to a 7-day work week. No final decision has, however, been made whether or when this proposal would be realised (Frank Hickley, Risk Control Manager, Sea Harvest, *pers. comm.* 2015).

Sea Harvest discharge large volumes of fresh fish processing (FFP) effluent into the sea daily. This includes seawater that has been used as wash-water as well as freshwater effluent originating from

the fish processing. The composition of the effluent from Sea Harvest was surveyed by the CSIR in 2001 and 2012 (Entech 1996 in CSIR 2002, Sea Harvest, F. Hickley, *pers. comm.*). The effluent is highly concentrated and contains suspended and combustible solids (flammable solids, fat, oil and grease, ammonia nitrogen, protein, phosphate and faecal coliforms, including *E.coli*) (Table 3.8.).

Table 3.8. Effluent constituents from Sea Harvest Fish Processing Plant (Data from CSIR 2002 and F. Hickley, Risk Control Manager for Sea Harvest) compared to the General Discharge Limit of the revised General and Special Standard (Government Notice No.20526 – 8 October 1999)

	Sea Harvest (2001)	Sea Harvest (2012)	General Standard
Effluent volume (m ³ /month)	69 595	-	-
Suspended solids(mg/l)	164	158	25
Combustible solids (mg/l)	144	-	-
Fat, Oil and grease(mg/l)	212	-	2.5
Ammonia-N (mg/l)	164	147	3
Kjeldahl Nitrogen-N (mg/l)	83	99	-
Phosphate-P (mg/l)	34	-	10
Faecal coliform (CFU/100 ml)	751	1347	1000
<i>E. coli</i> . (CFU/100ml)	5	789	-

Prior to 2014 the effluent plant consisted of a concrete sump into which two streams of effluent from the fresh fish processing facilities flowed. A sump pump controlled by level switches pumped the water from the sump across a rotating contrashear screen. The underflow of the screen flowed directly down the discharge channel into a concrete distribution box underneath the jetty and into the sea. The screen discharge was deposited into a container for transport to a fish meal producer.

The bulk of the major solids (fish frames, skins, etc.) went directly into a truck from the processing facility via a screw conveyor. Measurement of the flow was done in the discharge channel (flow restrictor with level measurement) to determine the flow rate and cumulative flow. This system never worked well due to foaming, aeration and turbulent flow, resulting in inaccurate volume readings. Furthermore, the solids handling capability of this system was very limited and pump blockages was a continuous problem. Most of the time, the sump overflowed into the discharge channel, with no treatment taking place.

In 2014, the plant was changed and improved to ensure continuous operation and better solids handling capabilities (Sea Harvest, Site Engineer Nico Van Houwelingen, *Pers comm* 2014). The two effluent streams are now directed through a screw conveyor sieve (mesh size 20 mm) to ensure that all solids larger than 20 mm are removed from the effluent stream before entering the distribution sump. Any particulate matter captured by the screw conveyor sieve is now transported off-site for disposal. The water containing solids <20 mm is then pumped into the contrashear screen for further screening (x Salsness SF2000 belt filters with 300 micron screens). The filtered water passes

through a flow meter before being discharged into the sea via the discharge channel and distribution box.

In order to limit the possibility of system faults, the following has been done:

- Two sump pumps have been installed to provide a back-up in case of failure;
- An alarm was installed to alert the plant operator should any part of the plant stop functioning; and
- The kontrashear screen, filters and sump are cleaned out every second weekend.

Daily checks on components of the plant are also conducted. Furthermore the plant is manned 24/7 by semiskilled staff to ensure quick reaction to deviations that occur mostly due to issues inside the processing area. This ensures that the effluent quality is constant. Currently, residual hygiene chemicals in the effluent are not removed or measured. The existing sanitizer is a quaternary ammonia compound which can result in high NH_4 levels in the effluent (clearly reflected in the water quality monitoring data (Figure 3.45)). This issue will be addressed through the use of a different sanitising process. The reduction of particulate matter in the effluent through the new effluent processing technology was expected to improve TSS significantly, which was, however, not realised and a component in the effluent discharge system has been reviewed and will be replaced (Frank Hickley, Risk Control Manager, Sea Harvest, *pers. comm.* 2015).

After the promulgation of the NWA, Sea Harvest Fish Processing Plant was granted an exemption, provided that the effluent was treated to comply with the General Discharge Limits of the revised General and Special Standard (Government Notice No. 36820 –6 September 2013) promulgated under the NWA (DEA 2014). In November 2002 Sea Harvest applied for the first water use license and is currently operating under a water use licence in terms of section 21(h) of the NWA, which was granted on 21 November 2011 (this license is from now on referred to as the ‘current license’). The current license authorises the disposal of industrial effluent into the Saldanha Bay harbour through an existing marine outfall. This water use license authorises Sea Harvest to dispose a maximum quantity of 758 847 m^3 per annum at a daily maximum of volume of 3546 m^3 . Unfortunately, the Saldanha Bay Municipal Water Treatment Works does not have the capacity to process the effluent volume generated by this operation and therefore the effluent is directly disposed into the sea.

Since the promulgation of the ICMA in 2008, Sea Harvest Fish Processing Plant was given 36 months to submit an application for a CWDP to the DEA. This application was submitted on 12 July 2012 (note that this application was submitted prior to the expiry date (November 2014) of the current water use license). The CWDP application did not, however, include dispersion modelling for the effluent to be discharged and additional information for this application, as well as a public participation process was requested by the DEA at the beginning of 2014. The application process is still ongoing.

Until such time that the CWDP has been issued, effluent quality at the pipe end is compared to the General Discharge Limits of the revised General and Special Standard (Government Notice No. 36820 –6 September 2013) promulgated under the NWA. The General Discharge Limit can be considered as the minimum requirement for compliance with the ICMA. It must be emphasised that in future, more conservative limits are likely to be required by the CWDP due to the nature of the effluent (volume, concentration and constituents), poor circulation at the outfall point and stringent targets

that should be achieved in the receiving environment (mariculture and biodiversity as the beneficiaries requiring most conservative targets).

Closer inspection of the current water use license reveals that the Department of Water Affairs issued a water use license applicable to a reverse osmosis plant rather than to a fish processing plant:

1. The word 'brine' is used throughout the document even though the fish processing plant is discharging brackish water (i.e. less saline than sea water).
2. The license requires reduction of non-oxidising Biocide (DBNPA) concentrations in the effluent. Biocides are used for the cleaning and disinfection of the membranes used during the de-salination process.
3. The monitoring conditions of the water use license are inadequate for the effluent generated by a fish processing plant (compare to effluent composition in Table 3.8) and include:
 - a. Dissolved oxygen
 - b. Salinity
 - c. Temperature
 - d. Total suspended solids

Sea Harvest realised towards the end of 2014 that the monitoring conditions of this current license differ from the variables that they have been monitoring since the issuing of the water use license in 2002 (i.e. including pH, TSS, conductivity, ammonia nitrogen, total Kjeldahl nitrogen, dissolved organic carbon, faecal coliforms and *E. coli*). Although the current licence is clearly not applicable to fish processing, Sea Harvest has adapted its monitoring programme to the requirements on the permit only. As a result, ammonia nitrogen, dissolved organic carbon, faecal coliforms and *E. coli* are no longer monitored in the effluent. While faecal coliform, *E.coli* and dissolved organic carbon are not of immediate concern, the lack of data on ammonia nitrogen is concerning. Ammonia nitrogen is toxic to aquatic organisms at very low concentrations and is the most important monitoring variable in effluent originating from a fish processing plant. Ammonia nitrogen levels in Sea Harvest's effluent were generally always in excess of the 6 mg/l limit specified in the General Discharge Limits of the revised General and Special Standard (Government Notice No. 36820 –6 September 2013). Data collected between March 2010 and December 2014 show average ammonia nitrogen levels of 99±86 mg/l with a maximum of 474 mg/l measured in September 2012 (Figure 3.45). It is recommended that Sea Harvest resume measurement of ammonia nitrogen and that the competent authorities take note of the omission in the licensing conditions.

It is also strongly recommended that COD is monitored in future to establish how much oxygen will be required to breakdown the organic waste in the effluent. Maintaining COD at acceptable levels will reduce risks of anoxic conditions developing in the receiving marine environment, especially in Small Bay which is considered a sheltered environment with limited mixing capacity.

It must also be noted that according to the water use license, the outfall should be situated in North Bay rather than Small Bay (Figure 3.40). Sea Harvest ensured however, that the DEA will be informed as soon as possible to ensure that that the CWDP application will reflect the correct position (Frank Hickley, Risk Control Manager, Sea Harvest, *pers. comm.* 2015). It is particularly important that the CWDP application contains the correct information, as dispersion modelling of

the effluent plume (and as an extension acceptable effluent limits) is likely to be very different in Small Bay compared to North Bay (also note proximity of the outfalls to the shore).

Monthly monitoring data of effluent volumes as well as effluent quality are available since 2007 and 2010, respectively. No data for ammonia nitrogen, total Kjeldahl nitrogen and faecal coliform are available since December 2014 due to changes in the monitoring programme implemented at the beginning of this year.



Figure 3.40 The locations of the actual effluent outfall point of the fish processing plant Sea Harvest and the outfall point as depicted in the water use license dated 22 November 2011.

Average daily fresh fish processing effluent volumes discharged into Small Bay by Sea Harvest is shown in Figure 3.41. No data is available for the period April 2007 to December 2012. Overall, measurements show that effluent volumes discharged into Small Bay have decreased substantially since 2004. During the period of August 2006 to November 2007, the volume of effluent disposed by Sea Harvest increased peaked at unusually high levels. It is not clear why this increase occurred, but data reporting and environmental monitoring at Sea Harvest have suffered irregularities due to high staff turnover (Sea Harvest, F. Hickley, *pers. comm.*). Average effluent discharged per day was 4350 m³ in 2004, increased to 6738 m³ in 2006 and dropped to a minimum of 703 m³ in 2013. A steady increase in effluent volume is evident since then. Correspondingly, the maximum daily limit of 3546 m³ as specified by the water use license has not been exceeded since 2013 (Figure 3.41). Prior to that non-compliance was very high with a maximum of 60 % in 2006.

A new flow meter has been purchased and was installed in September this year. This allows flow continuous flow rate measurements as of October 2015 and will be operated by security staff over weekends (Frank Hickley, Risk Control Manager, Sea Harvest, *pers. comm.* 2015). Prior to these

improvements, volume readings were taken irregularly due to a frequently broken flow meter and furthermore, the fish processing plant was often operational on weekends and measurements were not taken on these days (Sea Harvest, Environmental Officer, Fulufhedzani Ramashia, *pers. comm.* 2014). On average, 155 measures were taken per year, reporting on an average of 240 working days per year. Therefore annual effluent discharge was estimated from the average daily effluent volume⁵ and compared to the prescribed annual effluent limit of 758 847 m³ (Figure 3.42). It can be concluded with reasonable confidence that the annual effluent volume has not exceeded the prescribed limit since 2013.

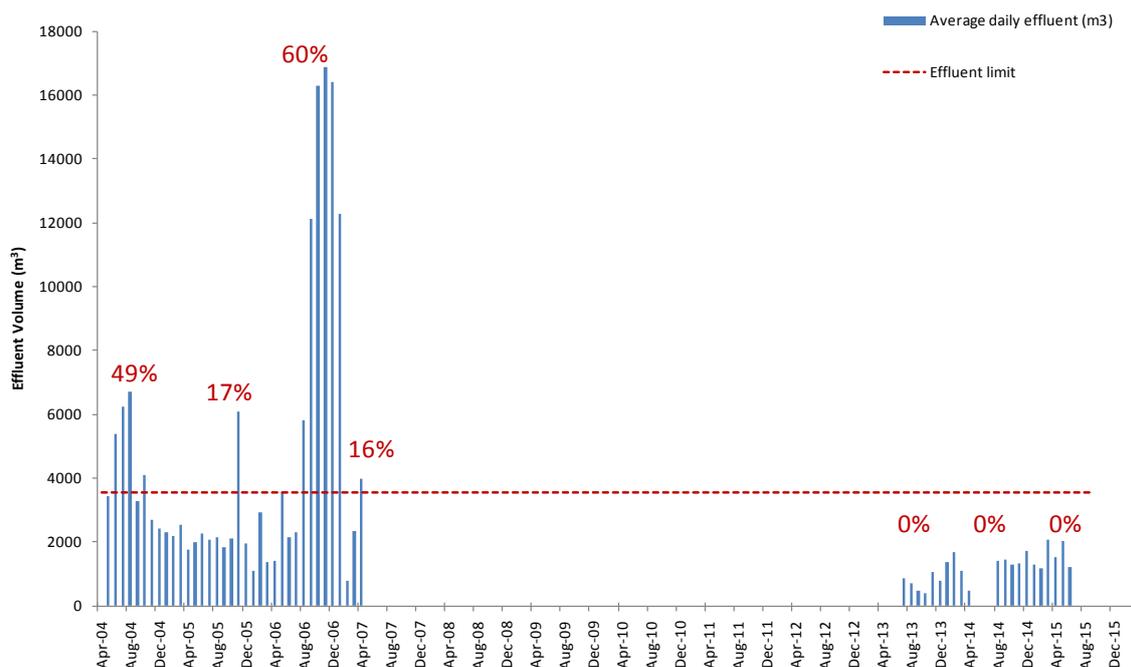


Figure 3.41. Average daily fresh fish processing effluent volume discharged into Small Bay by Sea Harvest from May 2004 - June 2015. Data was not available for the period May 2007 – August 2013. The red dotted line shows the maximum daily limit prescribed by the water use license. The red numbers show the proportion of non-compliance events per year (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).

⁵ Average daily effluent volume was calculated by dividing the measured annual volume by the number of measurements taken.

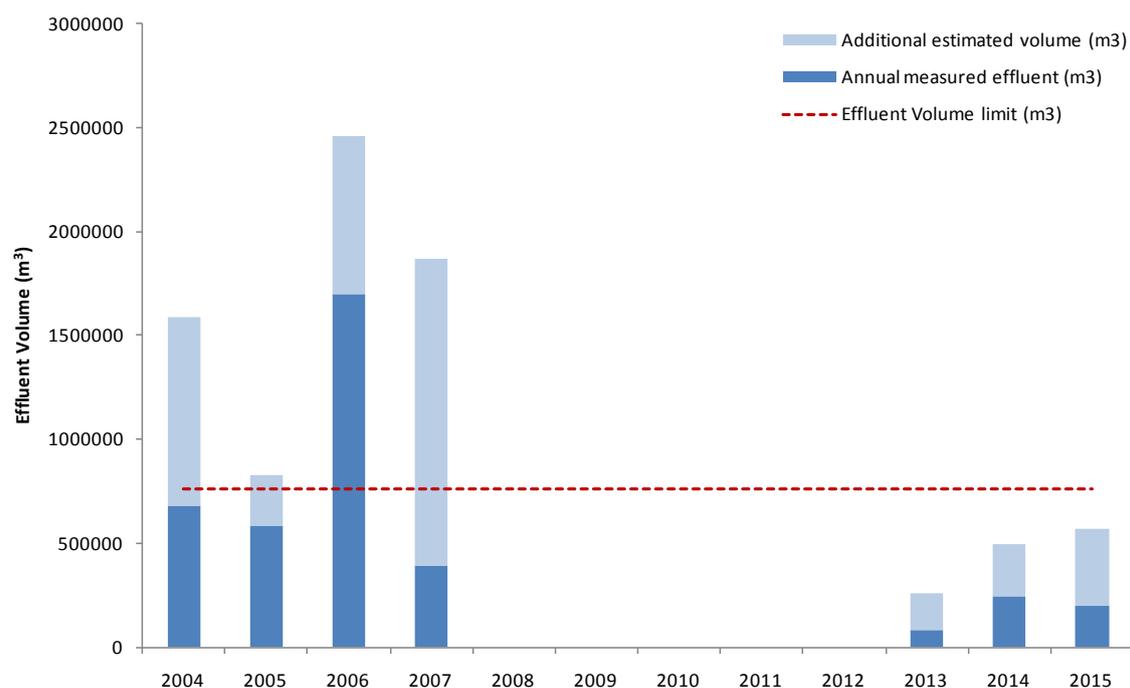


Figure 3.42 Estimated Fresh fish processing effluent volume discharged into Small Bay per year by Sea Harvest from May 2004 - June 2015. Data was not available for the period May 2007 – August 2013. The annual maximum limit of 758 847 m³ is indicated as the red dashed line. Additional estimated volume was calculated by multiplying the average daily discharge volume (per year) by 365 days (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).

As expected, faecal coliforms concentrations in the effluent are mostly compliant with the revised General Discharge Limit of 1000 Colony-forming units (CFU)/100 ml (Figure 3.43.). Until the beginning of 2013, concentrations were highest during the summer months, reaching a maximum of 3300 CFU/100 ml (>1100 detection limit multiplied by three). A decrease in frequency and magnitude of peaks in faecal coliform concentrations is evident since February 2013, with a maximum of 500 CFU/100ml in June 2014. The source of this contamination is not clear, as faecal coliforms are derived from the guts of warm blooded animals such as human and livestock rather than cold blooded animals such as fish.

Levels of TSS are extremely high and since measurements commenced in 2010, compliance with the revised General Discharge Limit of 25 mg/l could only be observed in October 2013 (14 mg/l) (Figure 3.44). Trends in TSS since 2010 suggest that concentrations peak in late summer to beginning of autumn each year (February-April). Overall concentrations have remained very high since 2010.

The revised General Discharge Limit for ammonia nitrogen is 6 mg/l, which is exceeded 96% of the time at very high concentrations. In 2010, ammonia nitrogen concentrations were lower, averaging 13.2 ±10 mg/l but have increased dramatically thereafter, reaching a maximum of 474 mg/l in September 2012. Overall, ammonia nitrogen has been decreasing since then, but peaking in June 2014 with 175 mg/l. Monitoring of ammonia nitrogen should be reinstated as soon as possible to ensure that technological upgrades implemented in 2014 as well as a change in sanitising protocols are indeed lowering ammonia nitrogen levels.

Total Kjeldahl Nitrogen (TKN) (mg/l) provides an indication of the protein content in the effluent. Protein content stayed constant between February 2010 and August 2012 with an average concentration of 76 ± 27 mg/l (Figure 3.46.). Concentrations peaked in May 2013 with 871.4 mg/l. Since then TKN concentrations have decreased to similar levels as observed prior to May 2013.

A conductivity limit at the end of the pipe is not specified in the revised General Discharge Limits. Fish processing involves the use of freshwater and sea water and therefore, conductivity (mS/m) is markedly lower than that of seawater (~ 5400 mS/m) (Figure 3.47). It is evident that conductivity has increased since May 2011, approaching levels expected in the receiving environment.

Since the revision of the effluent monitoring programme at Sea Harvest at the beginning of 2015, absolute salinity (g/kg), dissolved oxygen (mg/l), oil and grease (mg/l) and temperature ($^{\circ}\text{C}$) have been monitored on a monthly basis. Preliminary results indicate in comparison to sea water (35 g/kg) absolute salinity has an average of 17 ± 2.5 g/kg. Two measurements are available so far for dissolved oxygen with an average of 6.76 ± 0.2 mg/l. Oil and grease exceeds the General Discharge Authorisation with a very high average of 20.33 ± 5 mg/l. The three measurements taken between February and April indicate that levels may be decreasing, however, more measurements are needed to determine a long-term trend. Temperature readings in the effluent are acceptable with an average of 14.8 ± 1.3 $^{\circ}\text{C}$ and indicate no seasonally related pattern.

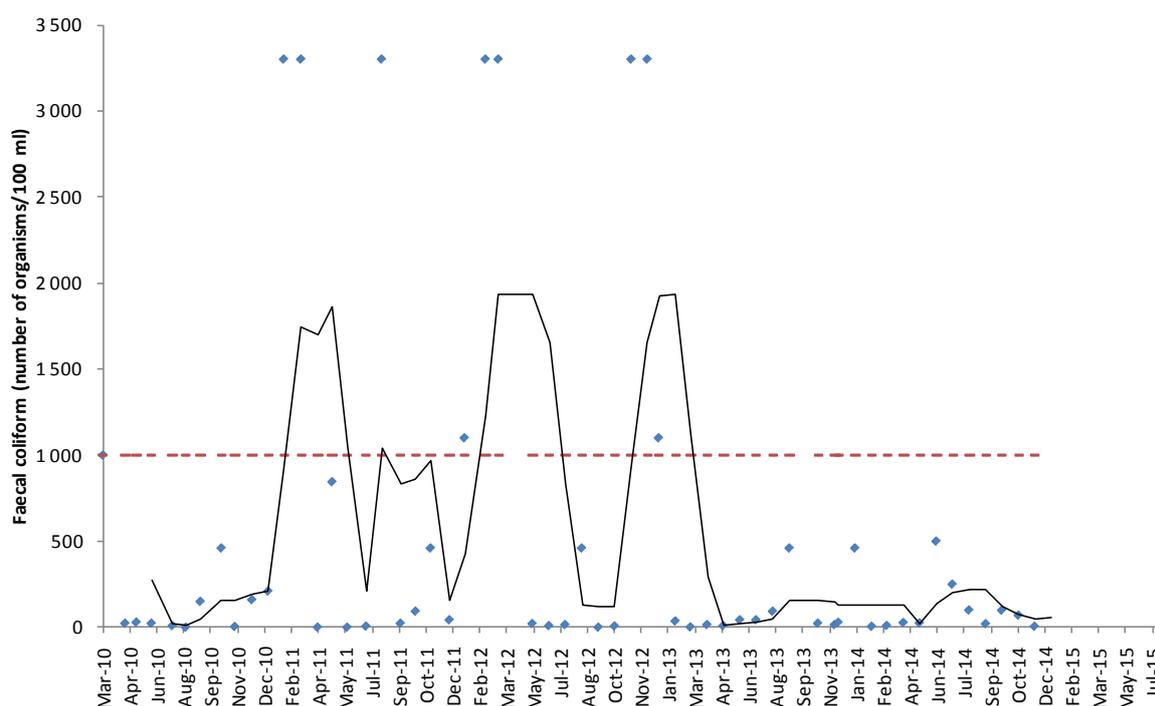


Figure 3.43. Monthly trends in the numbers of faecal coliforms (CFU/100 ml) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010 to December 2014. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (Government Notice No.36820 – 6 September 2013). The black line indicates the moving average across the time series using four data points.

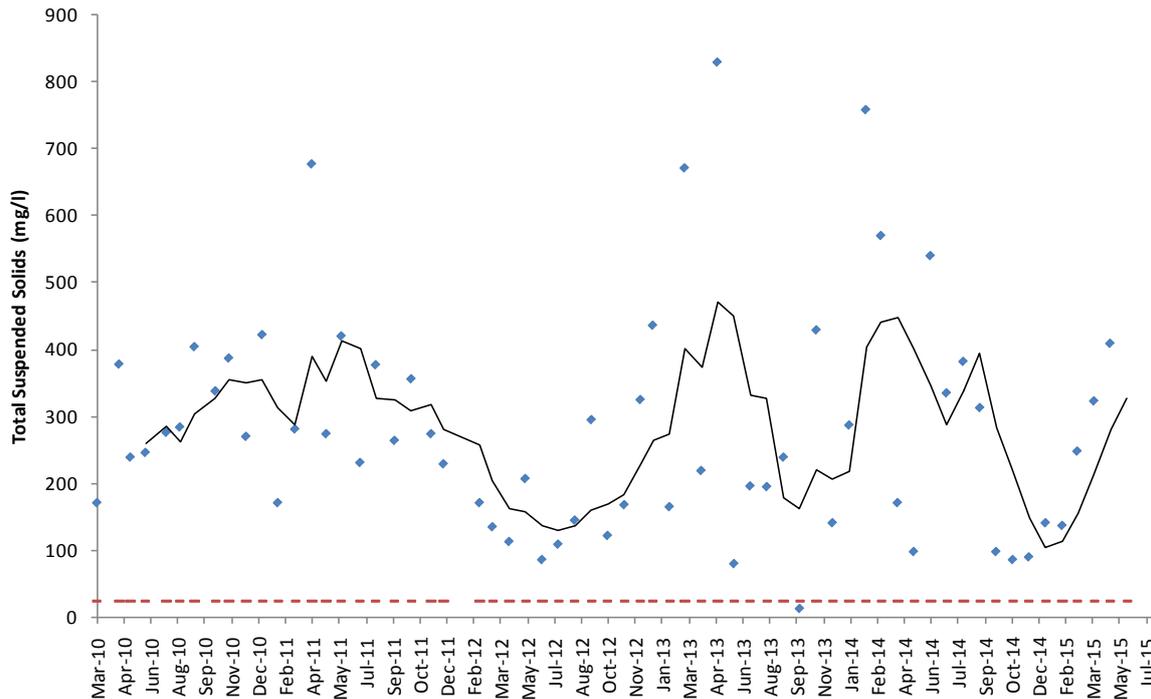


Figure 3.44 Monthly trends in total suspended solids (mg/l) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010 to December 2014. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (Government Notice No.36820 –6 September 2013). The black line indicates the moving average across the time series using four data points.

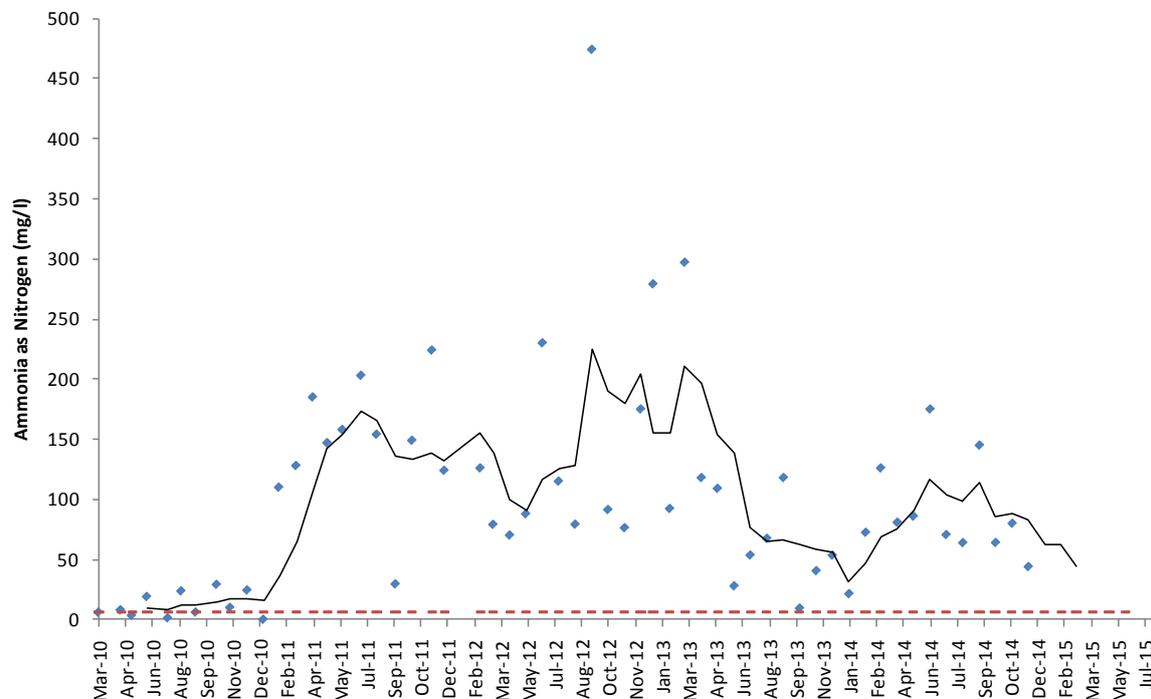


Figure 3.45 Monthly trends in ammonia nitrogen (mg/l) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010 to December 2014. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (Government Notice No.36820 –6 September 2013). The black line indicates the moving average across the time series using four data points.

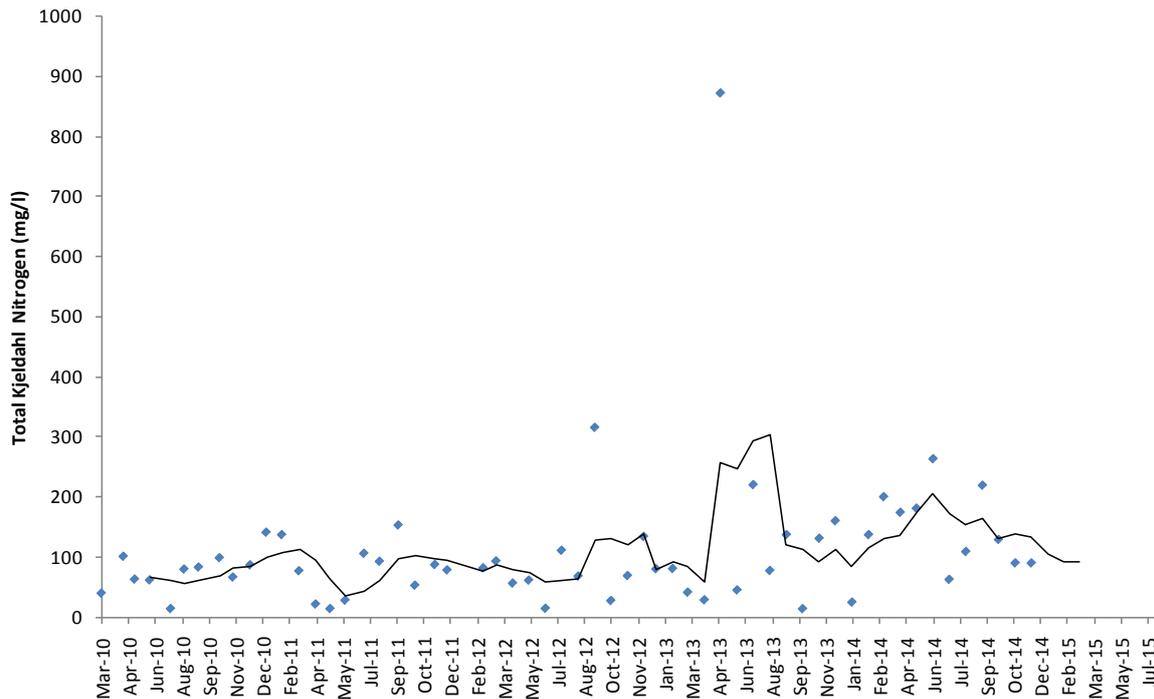


Figure 3.46. Monthly trends in Total Kjeldahl Nitrogen (mg/l) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010 to December 2014. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (Government Notice No.36820 –6 September 2013). The black line indicates the moving average across the time series using four data points.

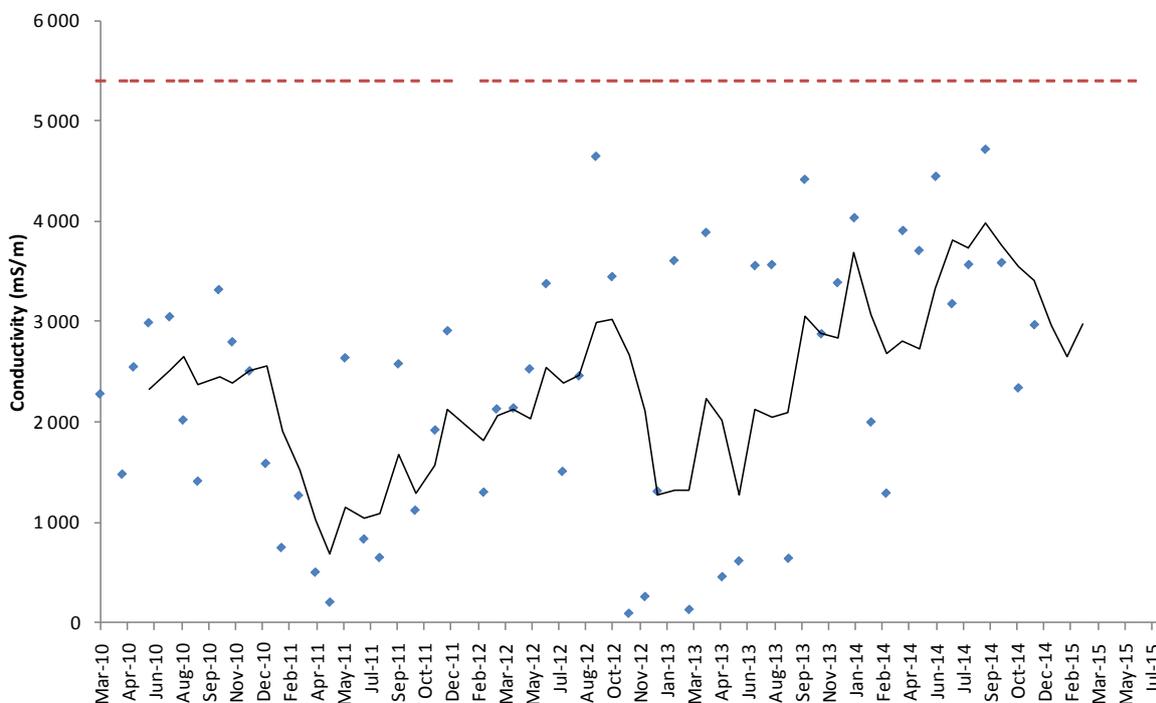


Figure 3.47 Monthly trends in Conductivity (mS/m) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010 to December 2014. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (Government Notice No.36820 –6 September 2013). The black line indicates the moving average across the time series using four data points.

In conclusion, it appears that despite a substantial decrease in effluent volumes since 2004, the effluent at the Sea Harvest Fish Processing Plant is not treated adequately to ensure minimum impact to the receiving environment. Data since 2010 shows that Sea Harvest fish Processing Plant has been non-compliant in terms of the revised General Discharge Limit for TSS and ammonia nitrogen, while faecal coliform limits have not been exceeded since the beginning of 2013. While faecal coliform levels are not of great concern at this point in time, TSS and ammonia nitrogen can have severe impacts on the ecology of the receiving environment by reducing light penetration for photosynthesis and toxicity to marine organisms respectively. No improvement can be detected for TSS since the installation of the enhanced mitigation methods in 2014. Ammonia nitrogen levels however, have shown a recent decrease but longer-term data would be necessary in determining if this is an anomaly. It is recommended that the monitoring of ammonia nitrogen be resumed to establish whether the new mitigation measures are indeed successful in reducing ammonia nitrogen levels. Finally, conductivity as an estimate of salinity is clearly lower than what is expected in the receiving environment and poses no risk and most recent absolute salinity values are congruent with these results. It is highly recommended that COD is measured in future, in addition to the above discussed variables.

3.4.6.2 Re-commissioning of the Premier Fishing fish processing plant

Southern Seas Fishing (now trading as Premier Fishing) previously discharged wastewater into the Bay but closed its factories in 2008 after being operational for 50 years. Premier Fishing is in the process of re-commissioning and upgrading the existing fishmeal and fish oil processing plant situated in Pepper Bay, the western side of Saldanha Bay. EA was granted in June 2013 and the Atmospheric Emission Licence was also approved in April 2014, but has been appealed. An application for a CWDP in terms of ICMA has been submitted to the Department of Environmental Affairs: Oceans and Coasts Branch (DEA:OC) for the discharge of cooling water containing condensate from the plant's scrubber to the sea. The permit application was provided for public review in Appendix H of the Revised Final EIA Report for the project (SRK Report 431676/10). On 24 April 2014 DEA:OC requested additional information for the CWDP application and that the application is subjected to another round of public participation. No license has since been issued and construction/operation has not commenced (SRK Consulting, Sue Reuther, *Pers comm* 2015).

3.5 Marine aquaculture

Saldanha Bay is the only natural sheltered embayment in South Africa and as a result it is regarded as the major area for mariculture (Stenton-Dozey *et al.* 2001). The Bay was zoned to cater for mariculture operations in 1997 and approximately 1 000 ha were demarcated for mariculture use (Stenton-Dozey *et al.* 2001). A total area of approximately 165 ha has been allocated to nine mariculture operators within Saldanha Bay (Table 3.8., Figure 3.48.). All operators except for Southern Atlantic Sea Farms hold rights to farm mussels (although only six of them currently exercise this) and six of the operators also farm oysters. Abalone, scallops, red bait and seaweed are not cultured on any of these farms, although some of the farms have the right to do so.

Blue Bay Aquafarm (Pty) Ltd. was the largest and oldest of the current farms and had rights to approximately 50 hectares of water at the entrance of Small Bay since 2002 for the farming of oysters and mussels. Blue Bay Aquafarm (Pty) Ltd was assimilated into Blue Ocean Mussel and now only farms mussels in Saldanha Bay. The other six operators have had rights to smaller areas in both Small Bay and Big Bay since 2010. West Coast Seaweeds is an oyster nursery operation and grown oysters are sold to Saldanha Bay Oyster Company, who applied for a CWDP in June 2014 to discharge aquaculture effluent into the surf zone (Source: DEA: OC 2015).

Table 3.9. Details of marine aquaculture rights issued in Saldanha Bay (BB and SB refer to Big Bay and Small Bay respectively (source: Personal communications with the respective farms). Black crosses indicate current products of the farms, while red crosses indicate the products for which rights exist but are not currently farmed.

Company	Products							Area (Location*)	Duration of right
	Mussels	Oysters	Abalone	Scallops	Red Bait	Seaweed	Finfish		
Blue Ocean Mussel (previously trading as Blue Bay Aquafarm (Pty) Ltd.	x							50.9 ha (SB)	2002-2016
Blue Sapphire Pearls CC	x	x	x			x		5 ha (SB)	2010-2024
Imbaza Mussels (Pty) Ltd (previously trading as Masiza Mussel Farm (Pty) Ltd)	x							30 ha (SB)	2010-2024
Saldanha Bay Oyster Company (previously trading as Striker Fishing CC)	x	x		x				25 (BB)	2010-2024
West Coast Aquaculture (Pty) Ltd	x	x			x			15 ha (SB)	2010-2024
West Coast Oyster Growers CC	x	x						15 ha (SB)	2010-2024
West Coast Seaweeds (Pty) Ltd	x	x						5 ha (SB) 5 ha (BB)	2010-2024
African Olive Trading 232 (Pty) Ltd	x							5 ha (SB) Port of Saldanha	2013-2028
Aqua Foods SA (Pty) Ltd	x	x						Port of Saldanha 10 ha (SB)	2014-2030

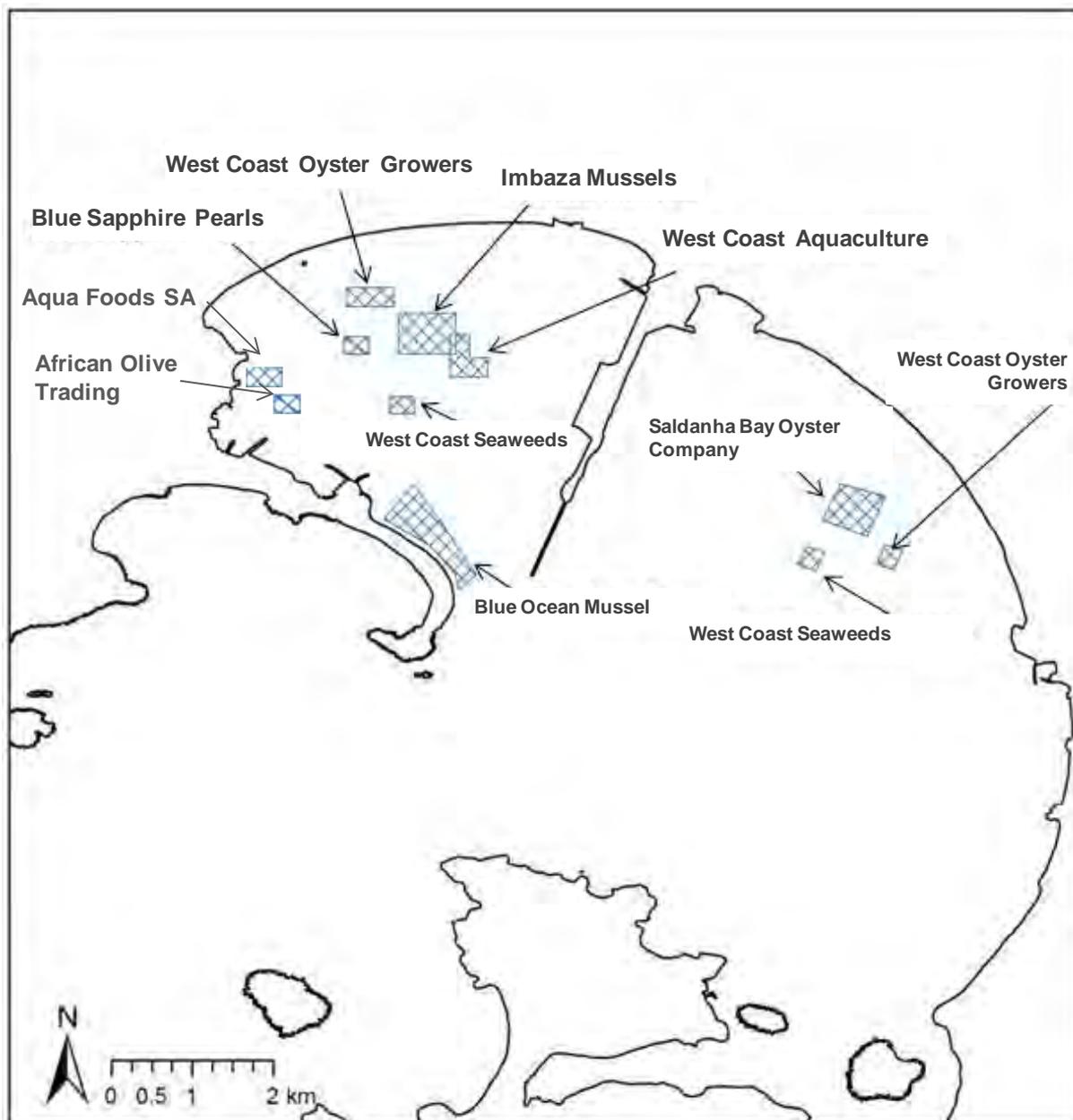


Figure 3.48. Allocated mariculture concession areas in Saldanha Bay 2015.

3.5.1 Shellfish, seaweed and redbait marine aquaculture

Raft culture of mussels has taken place in Saldanha Bay since 1985 (Stenton-Dozey *et al.* 2001). Larvae of the mussels *Mytilus galloprovincialis* and *Choromytilus meridionalis* attach themselves to ropes hanging from rafts and are harvested when mature. Mussels are graded, washed and harvested on board of a boat. Overall mussel productivity has been increasing steadily, peaking in 2013 at 1116 tons following a lull in productivity between 2005 and 2007 (Figure 3.49.). The sudden increase in production from 2012 to 2013 by 30% can be attributed to the establishment of a new mussel farm as well as another farm which terminated oyster farming to focus on mussel production (DAFF 2015). In 2013 the mussel sub-sector (based in Saldanha Bay) contributed 37% to the total

mariculture production and is currently the second highest contributor to the overall mariculture productivity for the country (DAFF 2015).

A study conducted between 1997 and 1998 found that the culture of mussels in Saldanha Bay created organic enrichment and anoxia in sediments under mussel rafts (Stenton-Dozey *et al.* 2001). The ratios of carbon to nitrogen indicated that the source of the contamination was mainly faeces, decaying mussels and fouling species. In addition, it was found that the biomass of macrofauna was reduced under the rafts and the community structure and composition had been altered (Stenton-Dozey *et al.* 2001).

On-going environmental impact monitoring surveys undertaken in Saldanha Bay by the Department of Agriculture, Forestry and Fisheries (DAFF) will provide an indication of the environmental impact of oyster culture (DAFF unpublished data). However, visual observations of the benthos underneath oyster rafts and preliminary data show minimal impact in this area when compared to other sites within the Bay.

A recent study by Olivier *et al.* (2013) investigated the ecological carrying capacity of Saldanha Bay with regards to bivalve (in particular mussels and oysters) farming. The findings indicate that the sector could increase 10 to 28 fold, potentially creating an additional 940 to 2500 jobs for the region without compromising the environment.

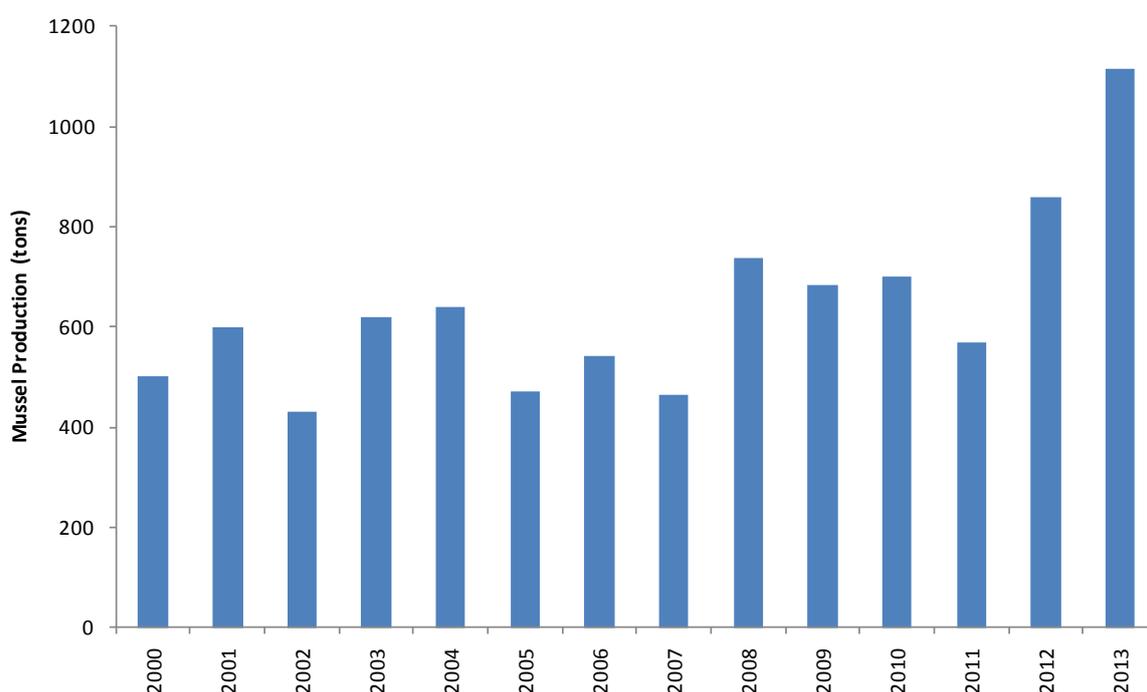


Figure 3.49. Annual mussel production (tonnes) in Saldanha Bay between 2000 and 2013 (source: Department of Agriculture, Forestry and Fisheries 2015).

3.5.2 Finfish cage farming

Offshore finfish cage culture is currently being pioneered in Saldanha Bay and is largely focused on the farming of salmonid species, including Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*). Both species are non-native to South Africa, however, *O. mykiss* is farmed in many parts of the country in land-based systems. Marine cage culture of Atlantic salmon was piloted in Gansbaai several years ago, however, this reportedly failed when the heavily fouled cages sank in strong seas. The biofouling accumulated on the cage mesh due to a lack of suitable cleaning equipment (specifically a suitable size work boat equipped with a crane) (Hutchings *et al.* 2011).

More recently, Southern Atlantic Sea Farms attempted to pioneer Atlantic salmon in Saldanha Bay. During the pilot phase of this project, however, it was found that Small Bay is not suitable for Atlantic salmon due to the susceptibility of this species to amoebic gill disease, which combined with frequent low dissolved oxygen events lead to high mortality rates. The project was therefore terminated this year (Southern Atlantic Seafarms, Director Gregory Stubbs, *Pers. comm.* 2015). Refer to AEC 2014 for more details on this development.

Amoebic gill disease (AGD) caused by *Paramoeba perurans* can cause high mortality, poor fish welfare and reduced growth if not treated early in the eruption phase. Atlantic salmon, rainbow trout, Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*Oncorhynchus kisutch*), Ayu (*Plecoglossus altivelis*), Ballan wrasse (*Labrus bergylta*), Corkwing wrasse (*Symphodus melos*) and Turbot (*Psetta maxima*) have been reported as common host species (VKM 2014). High temperature and high salinity are major risk factors and it has been shown that experimental cases of AGD are difficult to control at temperatures above 16 °C (Munday *et al.* 2001). Not much is known about the environmental sources of *P. perurans*, but it has frequently been detected in fouling organisms, sediments and the water column surrounding sea-based cages (VKM 2014). In the case of land-based and locally hatched and grown Atlantic salmon in South Africa, Hermanus, Mouton *et al.* (2014) found that *P. perurans* could not have only been introduced into the recirculation system through the intake water. It was suggested that *P. perurans* is a cosmopolitan species and occurs in South African waters. Notwithstanding, in the context of sea-based cage farming of finfish species highly susceptible to this disease, transmission of *P. perurans* from cultured fish to indigenous species in Saldanha Bay is a serious concern. The amoebae are shed from infected Atlantic salmon to the surrounding water and higher concentrations of *P. perurans* in the water near salmon farms have been identified as the main cause for the infection of native Atlantic salmon (Bridle *et al.*, 2010). In contrast, wild fish collected in or in the vicinity of Atlantic salmon farms in Tasmania were screened for *Paramoeba spp.* infections, but none of the 325 wild fish, representing 12 different species, were found infected (Douglas-Helders *et al.* 2002). More research is therefore urgently needed to establish whether transmission of *P. perurans* from sea-based cage farming practices could significantly impact on indigenous South African fish species.

Overall, operational phase environmental impacts of finfish cage culture have been well reported in international literature and include:

- Incubation and transmission of fish disease and parasites from captive to wild populations.
- Pollution of coastal waters due to the discharge of organic wastes.
- Escape of genetically distinct fish that compete and interbreed with wild stocks that are often already depleted.

- Chemical pollution of marine food chains (& potential risk to human health) due to the use of therapeutic chemicals in the treatment of cultured stock and antifouling treatment of infrastructure.
- Physical hazard to cetaceans and other marine species that may become entangled in ropes and nets.
- Piscivorous marine animals (including mammals, sharks, bony fish and birds) attempt to remove fish from the cages and may become tangled in nets, damage nets leading to escapes and stress or harm the cultured stock. Piscivorous marine animals may also be attracted to the cages that act as Fish Attractant Devices (FADs) and in so doing natural foraging behaviours and food webs may be altered. Farmers tend to kill problem predators or use acoustic deterrents.

The above impacts can largely be mitigated by the implementation of an EMPr (as required in the EIA regulations R982 of 2014). The aim of such a Programme would be to document and plan the management approach that will best achieve the avoidance and minimisation of potential environmental impacts in the construction, operation and decommissioning phase of a finfish cage culture operation.

New Alien and Invasive Species Regulations and Invasive Species Lists were promulgated on 1 August 2014 in terms of the National Environmental Management: Biodiversity Act (No. 10 of 2004) (NEMBA)⁶. These regulations and lists specify that any restricted activities related to an alien species legally introduced prior to the promulgation of these regulations are exempted from the requirement of a permit and risk assessment (NEMBA Section 65(1)). These new regulations raise concerns with regards to the introduction of alien species into new environments, as demonstrated in the case of pioneering sea-based finfish cage farming practices. Salmon and trout, previously only farmed on land (low risk) can now be introduced into the marine environment (higher/unknown risk) without a permit/risk assessment in terms of NEMBA.

3.5.2.1 Southern Cross Salmonid Farm

Southern Cross Salmon Farm (Pty) Ltd was one of the first companies to propose an offshore salmon and trout farm in Saldanha Bay. The first draft scoping report was submitted to the National DEA and the DEA&DP in June 2012, but many aspects were raised and extensive additional oceanographic modelling was performed since the project was first proposed. A new environmental

⁶ Note that revised Alien and Invasive Species lists are currently published for public comment (Draft Amendments to the Alien and Invasive Species Lists, 2015 – Notice 493 of 2015).

consultant was recently appointed to complete the EIA application process and the draft scoping report is going to be submitted by the end of September 2015 (A. Sempill, *pers. comm.* 2015) (refer to AEC 2014 for details on the project design, site selection and mitigation measures).

3.5.2.2 Viking Aquaculture

Viking Aquaculture, a subsidiary of Viking Fishing intends to farm salmonid species (including sea run rainbow trout) in offshore cages in Saldanha Bay (Viking Aquaculture, Baren Stander, *Pers. comm.* 2015). Viking Aquaculture is currently finalising the lease with Portnet, after which a Scientific Investigations and Practical Experiment Permit will be granted by DAFF. Two cages for the production of less than 50 000 kg per annum will be deployed at currently unknown locations. No EA will be required so long as annual production amounts to less than 50 000 kg per annum during the feasibility stage (NEMA, R.544 Listing Notice 1, Activity number 7 – EIA Regulations of 2014). An environmental monitoring plan has been drawn up in collaboration with DAFF and is currently being finalised. Viking Aquaculture purchased all the gear from Southern Atlantic Sea Farms (see above) and is claimed to be the best available hardware from Europe (Southern Atlantic Seafarms, Director Gregory Stubbs, *Pers. comm.* 2015).

In the light of the recent termination of the project of Southern Atlantic Seafarms, Viking Aquaculture is confident that sea-run rainbow trout (*O. mykiss*) will be more resilient to amoebic gill disease as compared to Atlantic salmon. Viking Aquaculture is also investigating suitability of other sites which are not subject to low oxygen events (dissolved oxygen < 2 mg/l).

3.6 Shoreline erosion in Saldanha Bay

Beach erosion in Saldanha Bay, particularly at Langebaan Beach, has been the subject of much controversy in recent years. On-going erosion for the past 30 years has been documented, with the loss of over 100 m of beach in some areas since 1960 and up to 40 m of shoreline lost in places in just the last 5 years (McClarty *et al.* 2006, Gericke 2008). This issue has been addressed in some detail in previous versions of the State of the Bay report (see for example Anchor Environmental Consultants 2010, 2011 and 2013b), as have the various ad hoc responses to these erosion problems (e.g. construction of groynes and rock revetments along Langebaan Beach, and gabion walls on Paradise Beach). Recently, two Environmental Management and Maintenance Plans (EMMP) were drafted by Common Ground Consulting and approved by the DEA&DP (Common Ground Consulting 2013a and b) (for more detail refer to Anchor Environmental 2013b). Updates with regards to the implementation of these management recommendations are provided below.

Although management and maintenance of structures to prevent further shoreline erosion in build-up areas of Langebaan are necessary, future impact of shoreline erosion due to storm events and climate change have to be anticipated in order to ensure sustainable development instead of ad hoc reactive management. Some innovative solutions in this respect are currently being trialled in the WCDM (which includes Saldanha Bay), which are summarised in Section 4.2.2.

3.6.1 Current status of Langebaan beach erosion management measures

Further maintenance is required to prevent further degradation of the groynes at Langebaan North beach and other erosion protection infrastructure in the Bay. While such interventions would normally require environmental authorisation (i.e. BA of Scoping and EIR), agreement was reached between the Saldanha Bay Municipality (SBM) and Department of Environmental Affairs & Development Planning (DEA&DP) that such works could be undertaken in terms of an EMMP. The EMMP was drafted and approved by DEA to provide the necessary management and reporting procedures for the contractor appointed to undertake the works. However, due to the lack of funding at the SBM no contractor has been assigned for the above repairs and maintenance and none of the recommended monitoring has been implemented to date (SBM, Environmental Officer, Nazema Duarte 2015, *pers. comm.*).

Upgrading, maintenance or managed retreat is also needed at the Leentjiesklip Caravan Park, the Alabama Street slipway and the terraced concrete walkway at the end of Uitsig Street/Melck Street and a separate EMMP was prepared for this purpose by Common Ground Consulting (Common Ground 2013b). Recommendations in the EMMP for the Leentjiesklip Caravan Park included various short term interventions not requiring engineering solutions of which some have so far been implemented. A low fence was erected to direct pedestrian traffic onto the wooden path accompanied by notices that prohibit people walking in the dunes. Unfortunately, neither dune rehabilitation nor the redirecting of stormwater was implemented due to the lack of funds. No awareness was created about the impacts of dumping of coals in the dunes (SBM, Environmental Officer, Nazema Duarte 2014, *pers. comm.*). This is despite the low financial cost associated with, for example, distributing flyers, emails or small signboards. Two different engineering solutions were proposed in the EMMP to stop further shoreline retreat in this area, both of which included the reshaping of the foredune, removal of the access road and construction of a submerged barrier. It was found that this project would require environmental authorisation and would be financially infeasible and the nature of such mitigation strategies would not be desirable within a National Park. It was therefore decided that managed retreat was the only feasible option for the Leentjiesklip Caravan Park. Unit 4A, which was identified as the highest risk area, was recently given notice regarding the termination of the lease agreement and tenants were asked to vacate the property. Other units in this area on municipal property have also been notified that managed retreat may be enforced in the near future should coastal erosion continue advancing at the current rate (SBM, Environmental Officer, Nazema Duarte, *pers. comm.* 2015).

Maintenance at the Alabama street slip way was not considered urgent and other sites have therefore been prioritised. In the case of the Melck Street/Uitsig Street Walkway it was recommended that the existing structure be demolished and rebuilt to ensure the repair of all hidden cavities. This project was considered urgent because of a sewer line that is situated near the deteriorating concrete steps. No leakage was detected then, but this collapsing concrete structure certainly had the capacity to cause damage to the sewer line. DEA&DP authorised the replacement of concrete steps based on the EMMP and consent from SANParks was also granted. Once construction had commenced, SANParks intervened and suspended construction in terms of the MLRA. It was argued that the original EMMP had not indicated the actual amount and depth of digging that would be required for the re-construction of the concrete steps. It became apparent that more sand than initially anticipated had to be excavated in order to remove the foundation.

Furthermore, an increased footprint was required to ensure the drying out of the area before the insertion of a new foundation. Although it was not possible to negotiate a smaller footprint, SBM and SANParks agreed on a depth of 300 mm instead of 600 mm for the new foundation. Construction has been completed but the contractor is still involved in the ongoing beach cleanup as construction material washes ashore (SBM, Environmental Officer, Nazema Duarte, *pers. comm.* 2015).



Figure 3.50. Groynes and rock revetment at Langebaan North beach. Source: Google Earth.

4 COASTAL AND ENVIRONMENTAL MANAGEMENT

Continuously accelerating urban and industrial development poses a significant threat in the form of fragmentation and loss of ecological integrity of remaining marine and coastal habitats in Saldanha Bay and Langebaan. While many of these developments are ostensibly “land-based”, a good number of them rely on ships to bring in or take away their raw material and/or processed products. While the increase in vessel traffic associated with each of these individual developments may be small in each case, they collectively contribute to the ever increasing number of vessels visiting the Bay each year and also to the ever increasing volumes of ballast water that are discharged into the Bay. Similarly, each of the individual developments also contributes to the increases in the volume of wastewater and stormwater that is produced (and ultimately discharged to the Bay) each year. The challenge of addressing these cumulative impacts in an area such as Saldanha is immense.

The current and future desired state of the greater Saldanha Bay area is polarised, where industrial development (Saldanha Bay IDZ and associated industrial development) and conservation areas (Ramsar Site, MPAs and National Parks) are immediately adjacent to one another. Furthermore, the Saldanha Bay environment supports conflicting uses including industry, fishery, mariculture, recreation and the natural environment itself. This situation necessitates sustainable development that is steered towards environmentally more resilient locations and away from sensitive areas (Thérivel *et al.*, 1994). Two recent and evolving management interventions have the potential to assist with this and are described in some detail below..

4.1 Saldanha Bay Environmental Management Framework

4.1.1 Introduction

Shortcomings that inhibit project-level EIA’s role as a tool for achieving sustainable development are widely documented. This can be attributed to the reactive and piecemeal focus at project level as opposed to an approach that is capable of anticipating and assessing changes to affected ecosystems beyond property boundaries. Project level EIAs are also not effective in addressing cumulative impacts from multiple developments or activities (Thérivel *et al.* 1994; Brown and Hill 1995; Glasson *et al.* 1999; Dalal-Clayton and Sadler, 2005). Inefficiencies arising from fragmented, activity-based EIA procedures can be countered by means of a strategic environmental management approach, which places a proposed activity within the environmental context of a particular geographical area. Accordingly, NEMA Section 24(3) provides that:

The Minister, or an MEC with the concurrence of the Minister, may compile information and maps that specify the attributes of the environment in particular geographical areas, including the sensitivity, extent, interrelationship and significance of such attributes which must be taken into account by every competent authority.

Environmental Management Frameworks (EMFs) are one of several prescribed environmental management instruments and give effect to NEMA Section 24(3) through the Environmental Management Framework Regulations of 2010. These regulations take cognisance of the fact that important natural resources must be retained to provide for the needs and ensure the health and well-being of citizens in a particular area in the long-term. The EMF Regulations of 2010 state that

an EMF should aim to promote sustainability, secure environmental protection and promote cooperative governance and may be adopted by the competent authority. If adopted by the competent authority, EMFs must be considered in all EIAs and must be taken into account by every competent authority during the decision-making process. The burden of proof to demonstrate that a proposed development is aligned to the EMF lies with the project proponent. The EMF provides applicants with a preliminary indication of the areas in which it would be potentially inappropriate to undertake an activity listed in terms of the NEMA EIA regulations by:

1. Specifying the sensitivity or conservation status of environmental attributes in a particular area;
2. Stating the environmental management priorities of the area; and
3. Indicating which activities would be compatible or incompatible with the specified area.

4.1.2 The Environmental Management Framework for the Greater Saldanha Bay Area

Chand Environmental Consultants was appointed in 2010 by the Western Cape Department of Environmental Affairs & Development Planning (DEADP) to draft an EMF for the Greater Saldanha Bay Area (from hereon referred to as 'the Saldanha Bay EMF'). The draft EMF was compiled and released to the public in 2013 and a final draft has been available since February 2015, but it is unclear whether the DEADP is intending to adopt the EMF in terms of NEMA.

The Saldanha Bay EMF covers the Saldanha Bay municipal area and a portion of the Berg River Municipality. To meet the requirements of the EMF Regulations of 2010, the report was structured to first describe the status quo of the environment, then provide a strategic assessment of the desired state of the environment and finally present a Strategic Environmental Management Plan (SEMP) for the study area. The Saldanha Bay EMF envisions protecting and managing natural and cultural resources so as to sustain livelihoods, economic activity as well as health and wellbeing of people. The SEMP identified three Environmental Management Zones (EMZs) with associated environmental attributes (Table 4.1). Suitable and unsuitable types of activities were identified for each EMZ. Finally, a management framework for each EMZ was developed by identifying management objectives, desired outcomes, limits of acceptable change, opportunity for benefit, as well as potential mitigation measures for each attribute. A brief summary of the Saldanha Bay EMF, focusing on attributes relevant to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay, is presented below. It is important to note that the summary of the Saldanha Bay EMF for this particular area only reflects attributes and management objectives relevant to the coastal and marine environment, and is insufficient to inform an EIA application.

Table 4.1 Environmental Management Zones (EMZs) and their environmental attributes as identified in the Environmental Management Framework (EMF) for the Greater Saldanha Bay Area (Adapted from DEADP 2015). Only attributes relevant to the marine and coastal environment in Saldanha Bay and Langebaan and Danger Bay areas are included.

Zone	Environmental attributes	
Zone 1: Keep assets intact	<ul style="list-style-type: none"> • Resources critical to sustaining ecological integrity • Resources important for food security, livelihoods, economic activity and job creation • Resources important for society, sense of place (heritage and scenic resources) 	<ul style="list-style-type: none"> • Marine Protected Areas • Critically endangered and endangered marine ecosystems • 100 m High Water Mark (HWM) – Coastal Protection Zone
Zone 2: Develop with care: valued resources	<ul style="list-style-type: none"> • Important resources but which are not as significant/or as threatened, vulnerable or at risk as those in EMZ 1. 	<ul style="list-style-type: none"> • Area targeted for national protected area and/or national park expansion • Listed Vulnerable ecosystems • Critical Ecological Support Areas (CESAs), Other Ecological Support Areas and Other Natural Areas of significance. • Rare plants • Sensitive lower vertebrate areas • Important bird flight paths • Important Bird Areas (IBAs) • Vulnerable marine ecosystems • Coastal Protection Zone (up to 1 km inland) • Surf/littoral zone • Biodiversity: Big Bay • Fisheries resources: Small Bay and Big Bay
Zone 3: Develop with care zone: restrictive conditions or risks	<ul style="list-style-type: none"> • Attributes inform possible restrictions on land use and development either due to environmental quality issues or due to potential natural environmental risks. 	<ul style="list-style-type: none"> • Water pollution “hot spots”(i.e. Small Bay) • Coastal management lines • Mobile dunefields/sand • Coastal protection zone (100 m from HWM)

4.1.2.1 EMZ 1: Keep assets intact

A large variety of environmental attributes were identified as being applicable to EMZ 1 in the Saldanha Bay, Langebaan and Danger Bay marine and coastal environments in the Saldanha Bay EMF (Figure 4.1). These included Wetland Clusters, Estuary Freshwater Ecosystem Priority Areas (FEPA), Terrestrial Critical Biodiversity Areas (CBAs) in the coastal environment, Dune Fields, Marine Protected Areas (MPAs), Ramsar Site (Langebaan Lagoon), the West Coast National Park, Endangered Terrestrial ecosystems in the coastal environment, as well as critically endangered and endangered marine ecosystems. Figure 4.2 shows the total extent of EMZ 1 based on the above attributes. A very large proportion of the Saldanha Bay, Langebaan and Danger Bay areas has been earmarked for keeping biodiversity assets intact, where the largest contribution to the extent of EMZ 1 is made by the Ramsar Site, the West Coast National Park, MPAs and Endangered marine ecosystems. Exceptions include urban areas, the Port of Saldanha Bay and associated IDZ, as well as property of the South African Navy.

Activities in EMZ 1 directly relevant to the marine or coastal environment that (a) should be avoided (b) should only be considered in exceptional cases and (c) that are unlikely to have a significant impact, are listed in Table 4.2. Finally, no negative changes to irreplaceable resources in EMZ 1 should occur and strategic management objectives for marine and coastal areas are presented in Table 4.3.

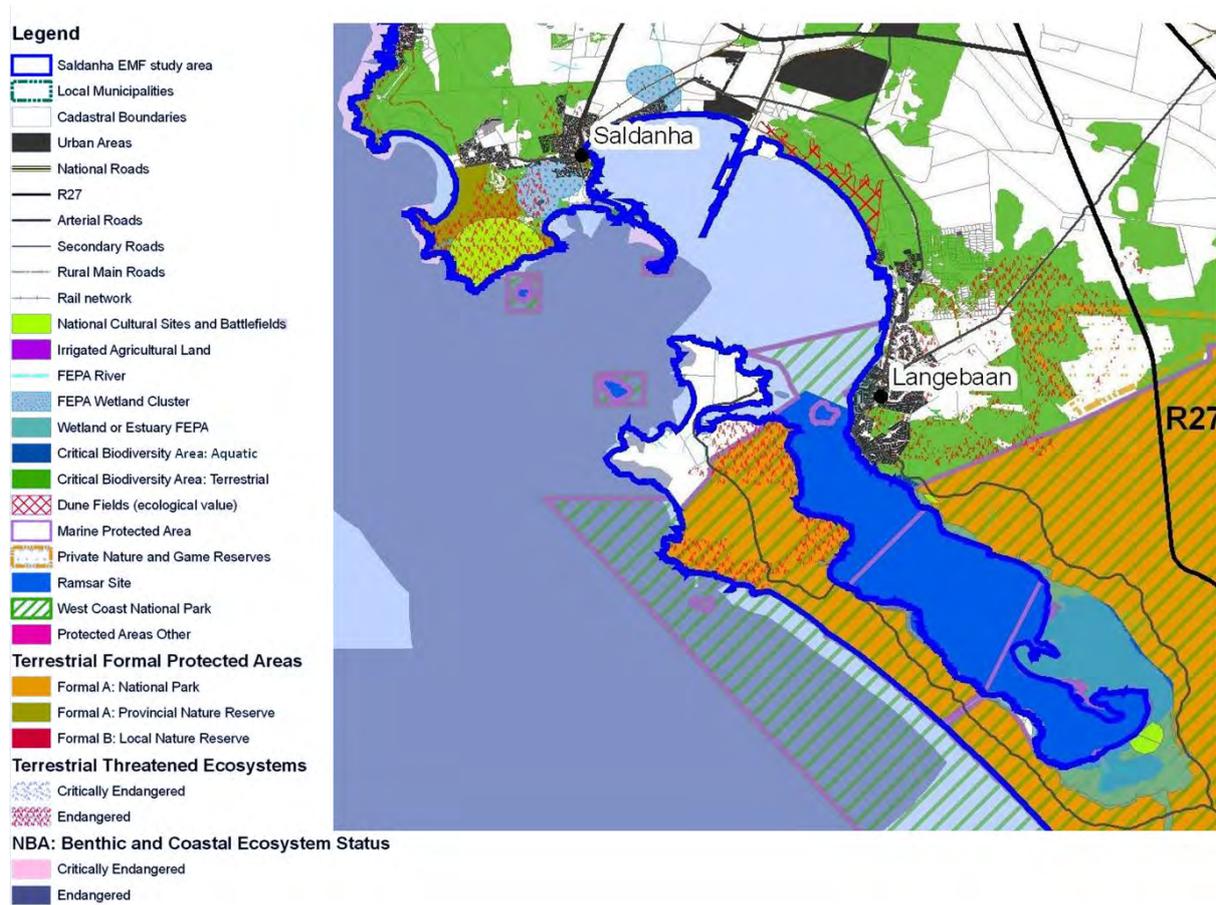


Figure 4.1 Environmental attributes applicable to Environmental Management Zone (EMZ) 1 (Keep Assets Intact zone) of Saldanha Bay, Langebaan Lagoon and Danger Bay area (Source: Environmental Management Framework for the Greater Saldanha Bay Area (Adapted from DEADP 2015)).



Figure 4.2 The total extent of Environmental Management Zone (EMZ) 1 (Keep Assets Intact zone) of Saldanha Bay, Langebaan Lagoon and Danger Bay area (Source: Environmental Management Framework for the Greater Saldanha Bay Area (Adapted from DEADP 2015))

Table 4.2 Risks and impact of identified developments or activities on the environmental attributes of Environmental Management Zone (EMZ) 1 –Keep Assets Intact, specifically applicable to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay (Adapted from DEADP 2015).

Activities that should be avoided	Activities that are likely to have a significant impact and can only be considered due to overriding public interest	Activities that are unlikely to have a significant negative impact
<ul style="list-style-type: none"> • Mining projects – including prospecting/exploration • Exploration, extraction or processing of oil or gas • Liquid waste storage facilities/waste lagoons • Sewage, wastewater or effluent treatment works • Bulk water, sewage or stormwater infrastructure • Extensive or large-scale recreational and tourism facilities • Reclamation of land from the sea/marine or aquatic environment • Jetties, slipways, marinas • Ports and harbours • Structures (fixed or temporary) in the coastal zone or on the seabed • Marine outfalls • Marine telecommunication facilities 	<ul style="list-style-type: none"> • Generation of renewable energy for public supply purposes, but only if no other option is available based on scientific reasons, not economic reasons. • Linear public infrastructure but only to be considered where essential for meeting basic needs, where no other option exists. This includes bulk public water supply infrastructure, sewage infrastructure and Stormwater infrastructure where flood risks are present. • Bulk stormwater outlets, canals or channels required to manage flood risk in low cost and informal settlements. 	<ul style="list-style-type: none"> • Non-consumptive nature and/or heritage tourism or recreational facilities, and associated infrastructure • Sustainable harvesting of natural products • Management (e.g. controlled burns, alien organism removal) for conservation purposes • Education • Research

Table 4.3 Management Framework for Environmental Management Zone (EMZ) 1 – Keep Assets Intact, specifically applicable to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay (Adapted from DEADP 2015).

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
Critically endangered (CR) and endangered species	<ul style="list-style-type: none"> To ensure the conservation status of species does not change to a more threatened category than the current designation. 	<ul style="list-style-type: none"> The conservation status of Critically Endangered (CR) and Endangered (E) species is at least the same but preferably improved. The localities and extent of CE, E and endemic plant or animal species are intact. 	<ul style="list-style-type: none"> Existing conservation status of CE and E species 	<ul style="list-style-type: none"> Restoration of degraded habitat will improve the viability of CE and E species. Promotion of community based natural resource projects 	<ul style="list-style-type: none"> Avoid. If unavoidable because of overriding reasons of public interest and the lack of alternative locations/ sites, then find alternative substitute areas as offsets to ensure conservation targets will still be met. A biodiversity offset would be required for any impacts on Endangered species provided that such impacts would not lead to the species becoming CR. Only in exceptional circumstances would impacts on CR or local endemic species be permitted and only if a biodiversity offset were shown to be feasible.
Protected and Conservation Areas (public and private)	<ul style="list-style-type: none"> To ensure protected natural areas are safeguarded in perpetuity. To make sure that there is no threat of degradation of these areas from activities on adjacent properties. To maintain the scenic value associated with protected areas. To prevent the loss or degradation of those parts of a protected area which provide a wilderness experience 	<ul style="list-style-type: none"> Protected natural areas are safeguarded in perpetuity and there is no threat of deproclamation. There is no evidence of biodiversity degradation due to adjacent activities. The viewshed protection zone for the WCNP is not eroded. The quality of areas that offer a wilderness experience within protected areas is retained. 	Existing mapped extent of Protected Areas (PAs), PA expansion areas.	<ul style="list-style-type: none"> Promotion of community based natural resource projects. Nature based tourism which has associated opportunities for small business development 	<ul style="list-style-type: none"> Avoid; limited development on already transformed areas within these areas only.
Freshwater	<ul style="list-style-type: none"> To avoid the loss or 	<ul style="list-style-type: none"> FEPAs are intact. 	<ul style="list-style-type: none"> Existing FEPAs. 	<ul style="list-style-type: none"> Restoration of degraded 	<ul style="list-style-type: none"> Avoid. If unavoidable because of

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
ecosystem priority areas (FEPAs)	<p>degradation of FEPAs.</p> <ul style="list-style-type: none"> To maintain resilience in wetland, riverine and estuarine ecosystems. To ensure the resilience of riverine, wetland and estuarine ecosystems is maintained so as to sustain delivery of ecosystem services. 	<ul style="list-style-type: none"> Buffer zones around FEPAs are maintained. Flow regimes in rivers make provision for ecological requirements in terms of volume and flooding patterns. 	<ul style="list-style-type: none"> Proposed buffer zones for different FEPAs. Published ecological reserve for rivers 	<p>habitat could improve ecosystem services.</p> <ul style="list-style-type: none"> Promotion of community based natural resource projects through habitat restoration 	<p>overriding reasons of public interest and the lack of alternative locations/ sites, then find alternative substitute areas as offsets to ensure conservation targets will still be met.</p> <ul style="list-style-type: none"> Avoid discharge of effluent, wastewater or stormwater from developed areas into these systems. Discharge could be considered provided that water quality and volume acceptable for ecological, or human us purposes will not be compromised. Avoid abstraction from these systems.
Marine Protected Areas	<ul style="list-style-type: none"> To ensure protected areas are safeguarded in perpetuity To avoid loss of irreplaceable biodiversity To prevent degradation of Langebaan Lagoon, a Ramsar Site 	<ul style="list-style-type: none"> Protected natural areas are safeguarded in perpetuity and there is no threat of de-proclamation. There is no evidence of biodiversity degradation due to adjacent activities 	<ul style="list-style-type: none"> The existing mapped extent of Marine Protected Areas 	<ul style="list-style-type: none"> Provide public access to coast Restoration of coastal area as buffer and ecological corridor 	<ul style="list-style-type: none"> Obtain specialist input/studies on effect of adding water to, and/or/ changing flow dynamics in the lagoon or Bay. Closed wastewater system; no effluent discharge.
Coastal Protection Zone (Land within 100m of the HWM and including coastal dune cordons)	<ul style="list-style-type: none"> To maintain coastal ecosystems and their resilience. To ensure public access to the coast. To prevent the loss of livelihoods dependent on coastal resources. To protect people and infrastructure from sea level rise, storm surges and coastal erosion risks. 	<ul style="list-style-type: none"> People continue to be able to access areas for livelihoods purposes that they currently use. Biophysical coastal / littoral processes are maintained. The aesthetic/ amenity value of the coastal/ littoral zone is protected. 	<ul style="list-style-type: none"> All existing undeveloped land within 100m from the HWM – the coastal protection zone, including coastal dune cordons. 	<ul style="list-style-type: none"> Provide public access to coast and allow sustainable use of the coastal/ littoral zone. Restoration of coastal/littoral area as buffer and ecological corridor. 	<ul style="list-style-type: none"> Determination of coastal setbacks in terms of the ICMA and the EIA Regulations. Compilation of coastal management plans (in terms of the ICMA). Management guidelines for landowners located in or adjacent to the coastal protection zone. Avoid discharge of pollutants / effluent. if this cannot be avoided, ensure treatment to a standard that meets ecological and recreational standards

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
Surf/ littoral zone (300m seaward from HWM)	<ul style="list-style-type: none"> To protect crucial nursery habitat for shoreline fish communities. To safeguard fisheries and ecosystem productivity in a unique coastal bay/ lagoon system. 	<ul style="list-style-type: none"> No evidence of deterioration in water quality in surf zone No loss, or alteration of dynamics, of existing surf zone through erection of structures or similar intervention. 	<ul style="list-style-type: none"> Existing surf zone in particularly sensitive and unique stretches of coast: Small Bay, Big Bay and St Helena. 	<ul style="list-style-type: none"> Improvement of water quality through reducing land-based pollution and effluent discharge into this zone. Removal of redundant structures and rehabilitation. Removal / harvesting of alien invasive species 	<ul style="list-style-type: none"> Closed wastewater system; no effluent to add to pollution load in this zone. Avoid erection of structures in this zone that would affect coastal / surf zone dynamics.

4.1.2.2 EMZ 2 - Develop with Care: Valued Resources

Development in EMZ 2 (Develop with Care: Valued Resources zone) focuses on avoiding “...change to valued resources that would jeopardize their long-term value and ability to sustain social and economic systems”. Figure 4.3 shows natural resources attribute types of the EMZ 2 relevant to the Saldanha Bay, Langebaan and Danger Bay marine and coastal environment. These include West Coast National Park: Potential Expansion area, proposed West Coast Protection Zone, Rare plants, Important Bird Corridors, Important Bird Areas (IBA), Big Bay and Vulnerable terrestrial (coastal) and marine ecosystems. Apart from very small isolated patches, the entire Saldanha Bay, Langebaan Lagoon and Danger Bay areas have been zoned as EMZ 2 (Figure 4.4).

Activities in EMZ 2 directly relevant to the marine or coastal environment that (a) should be avoided, (b) are likely to have significant negative impact in this zone and (c) could be considered for this zone, are listed in (Table 4.4). Finally, no negative changes to important biodiversity attributes in EMZ 2 should occur and corresponding strategic management objectives for marine and coastal areas are presented in Table 4.5.



Figure 4.3 Natural resource attributes applicable to Environmental Management Zone (EMZ) 2 (Develop with Care: Valued Resources) of Saldanha Bay, Langebaan Lagoon and Danger Bay area (Source: Environmental Management Framework for the Greater Saldanha Bay Area (Adapted from DEADP 2015)).



Figure 4.4 The total extent of Environmental Management Zone (EMZ) 2 (Develop with Care: Valued Resources) of Saldanha Bay, Langebaan Lagoon and Danger Bay area (Source: Environmental Management Framework for the Greater Saldanha Bay Area (Adapted from DEADP 2015)).

Table 4.4 Risks and impact of identified developments or activities on the natural resource attributes of Environmental Management Zone (EMZ) 2 – Develop with Care: Valued Resources, specifically applicable to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay (Adapted from DEADP 2015).

Activities that should be avoided	Activities that are likely to have a significant impact	Activities that could be considered for this zone
<ul style="list-style-type: none"> • Mining projects • Extraction or processing of oil or gas • Power generation projects (fossil fuels or nuclear) 	<ul style="list-style-type: none"> • Extensive large-scale recreational and tourism facilities • Intensive aquaculture and associated facilities • Bulk stormwater outlets, canals or channels • Infilling, excavation or depositing of material • Jetties, slipways, marinas • Ports and harbours • Structures (fixed or temporary) in the coastal zone or on the seabed • Marine outfalls • Marine telecommunication facilities 	<ul style="list-style-type: none"> • Non-consumptive nature and/or heritage tourism or recreational facilities, and associated infrastructure • Sustainable harvesting of natural products • Management (e.g. controlled burns, alien organism removal) for conservation purposes • Education • Research

Table 4.5 Management Framework for Environmental Management Zone (EMZ) 2 – Develop with Care: Valued Resources, specifically applicable to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay (Adapted from DEADP 2015).

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
Vulnerable (including listed) ecosystems	<ul style="list-style-type: none"> To avoid, or minimize, loss of Vulnerable ecosystems 	<ul style="list-style-type: none"> there is minimal loss of Vulnerable ecosystems Conservation status of Vulnerable ecosystems is at least maintained =, but preferably improved. 	<ul style="list-style-type: none"> Existing conservation status - Vulnerable 	<ul style="list-style-type: none"> Restoration protection and proper ongoing management of degraded habitat could improve the ecological condition, increase biodiversity and improve ecosystem services, and minimize fire hazard. Promotion of community-based projects to manage natural resources and support the green economy. 	<ul style="list-style-type: none"> A biodiversity offset would be required for any impacts on Vulnerable ecosystems.
Area targeted for national protected area and/ or national park expansion	<ul style="list-style-type: none"> To prevent development/use of land that could compromise expansion of national protected areas/West Coast National Park (e.g. through stewardship) 	<ul style="list-style-type: none"> Protected area / Park expansion is able to take place through stewardship or other means. Land suitable for protected area/ Park expansion maintains its conservation value. 	<ul style="list-style-type: none"> Current extent of CBAs adjacent to formal conservation areas 	<ul style="list-style-type: none"> Stewardship agreements with CapeNature or SANParks will secure important biodiversity 	<ul style="list-style-type: none"> Avoid.
Rare (i.e. all threatened) plants	<ul style="list-style-type: none"> Prevent negative change in threatened plant status 	<ul style="list-style-type: none"> Conservation status of threatened plants is maintained or improved 	<ul style="list-style-type: none"> No reduction in local populations of threatened species and/or local endemics; Existing conservation status of threatened plants. 	<ul style="list-style-type: none"> Positive contribution to improve habitats for threatened or local endemic species through restoring degraded habitats and, where applicable, locating offsets within earmarked ecological corridors or CBAs. 	<ul style="list-style-type: none"> Avoid where CE species are involved. For relatively less threatened species, where avoidance is not feasible, minimization, restoration of disturbed areas, and offsets to provide like habitat for threatened species.
Important Bird Corridors	<ul style="list-style-type: none"> To safeguard movement/ migration 	<ul style="list-style-type: none"> There are no bird mortalities or injuries that can be attributed to 	<ul style="list-style-type: none"> Existing natural rates of bird 		<ul style="list-style-type: none"> Obtain specialist input / study to assess potential impacts and

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
	<p>corridors of internationally and nationally important wildfowl.</p> <ul style="list-style-type: none"> To maintain flight paths free of obstruction or infrastructure that could lead to bird mortalities 	<p>the development of structures or infrastructure such as wind farms.</p>	<p>mortality</p>		<p>determine appropriate mitigation. Conduct baseline monitoring during impact assessment for wind farms (or any development that poses significant risks to birds) proposed in flight corridor between IBA (i.e. must be undertaken prior to decision)</p>
Vulnerable marine ecosystem	<ul style="list-style-type: none"> To avoid, or minimise, loss of Vulnerable ecosystems 	<ul style="list-style-type: none"> There is minimal loss of Vulnerable ecosystems Conservation status of Vulnerable ecosystems is at least maintained, but preferably improved. 	<ul style="list-style-type: none"> Existing conservation status - Vulnerable 	<ul style="list-style-type: none"> Restoration, protection and proper ongoing management of degraded habitat could improve the ecological condition, increase biodiversity and improve ecosystem services. Promotion of community-based projects to manage natural resources and support the green economy. 	<ul style="list-style-type: none"> A biodiversity offset would be required for any impacts on Vulnerable ecosystems
Big Bay	<ul style="list-style-type: none"> To maintain healthy ecosystem functioning 	<ul style="list-style-type: none"> Species diversity is unchanged or improved No further degradation in water quality, preferably improvement no beach erosion due to development in the Bay No unintended introduction of, or increase in, alien invasive organisms (i.e. excludes approved marine-based aquaculture) 	<ul style="list-style-type: none"> Current ecological status of Big Bay Current water quality Coastal set-back line 	<ul style="list-style-type: none"> Restoration of degraded habitat could improve the marine and coastal ecosystem and the potential for sustainable harvesting of resources and community based marine aquaculture opportunities. Promotion of community based natural resource projects through habitat restoration 	<ul style="list-style-type: none"> Avoid development that will alter the physical dynamics of Big Bay or that pose a pollution threat. Discharge of ballast water prohibited. Conduct specialist study on the implications on currents and flow dynamics in the Bay and the Lagoon. Where development cannot be avoided, a “closed system” design approach should be adopted (i.e. no releases into the Bay). Best practice dredging should be applied. The size of fixed structures that

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
					penetrate into the Bay should be minimized. Technologies to overcome negative impacts on flow dynamics should be investigated by specialists
Coastal Protection Zone (within 1 km of the coast)	<ul style="list-style-type: none"> To conserve landscape character of the coast To conserve the ecological functioning and resilience of coastal – and particularly dynamic - systems 	<ul style="list-style-type: none"> Biophysical coastal / littoral processes are maintained. The aesthetic/ amenity value of the coastal/ littoral zone is protected. 	<ul style="list-style-type: none"> Functioning littoral/coastal dune systems 	<ul style="list-style-type: none"> Provide public access to coast and allow sustainable use of the coastal/littoral zone Restoration of coastal areas as buffer and ecological corridor. 	<ul style="list-style-type: none"> Determination of coastal setbacks in terms of the ICMA and the EIA Regulations. Compilation of coastal management plans (in terms of the ICMA). Management guidelines for landowners located in or adjacent to the coastal protection zone.
Surf/littoral zone (300 m seaward of HWM)	<ul style="list-style-type: none"> To maintain the ecosystem dynamics and productivity of the surf/ littoral zone. To protect crucial nursery habitat for shoreline fish communities. To safeguard fisheries and ecosystem productivity in a unique coastal bay/ lagoon system. 	<ul style="list-style-type: none"> No loss or alteration of dynamics, of existing surf zone through erection of structures or similar intervention. Maintain water quality in surf zone within accepted standards for recreation purposes. No loss of important fish breeding areas. Re-establishment of indigenous species and habitats. State of the Bay monitoring shows improvement in the ecological conditions in Small Bay and no degradation of Big Bay and the Langebaan Lagoon (at least), preferably improvement. 	<ul style="list-style-type: none"> Applicable water quality standards. Current extent of intertidal indigenous species / communities. Current ecological state in particularly sensitive and unique stretches of coast: Small Bay, Big Bay and St Helena. 	<ul style="list-style-type: none"> Improvement of water quality through reducing land-based pollution and effluent discharge into this zone. Removal of redundant structures and rehabilitation. Removal / harvesting of alien invasive species 	<ul style="list-style-type: none"> No effluent discharge to add to pollution load in this zone. Compliance with applicable water quality standards. Avoid erection of structures in this zone that would have a major adverse effect on coastal / surf zone dynamics Conduct specialist study on the implications on surf zone and to determine mitigation measures to avoid adverse impacts.

4.1.2.3 EMZ 3 – Develop with Care: Restrictive Conditions or Constrains

Development or land use occurring in EMZ 3 (Develop with Care: Restrictive Conditions or Constraints zone) can be subject to restrictions due to environmental quality issues or due to potential natural environmental risks (e.g. flooding). The objective is “To avoid exacerbating existing restrictive conditions or risks, preferably to improve the current condition of resources and environmental quality wherever possible, and avoid placing people or development at risk”. Figure 4.5 shows environmental quality and risk attribute types relevant to the Saldanha Bay, Langebaan and Danger Bay marine and coastal environment. These include Small Bay, dune fields, Coastal Protection Zone and Coastal Management Lines (all risk levels, refer to Section 4.2.2 for more information). The total area identified as EMZ 3 is shown in Figure 4.6. It is important to note that the area allocated in Big Bay is mostly due to the risk of atmospheric iron pollution originating from the Port of Saldanha, which is not directly relevant to the marine environment.

Activities in EMZ 3 that are directly relevant to the marine or coastal environment that (a) should be avoided, (b) are likely to have significant negative impact in this zone and (c) could be considered for this zone only in existing transformed areas are listed in (Table 4.6). Finally, strategic management objectives for marine and coastal areas formulated to ensure that developments or activities in EMZ 3 will not exacerbate existing restrictive conditions or risks, are presented in Table 4.5.

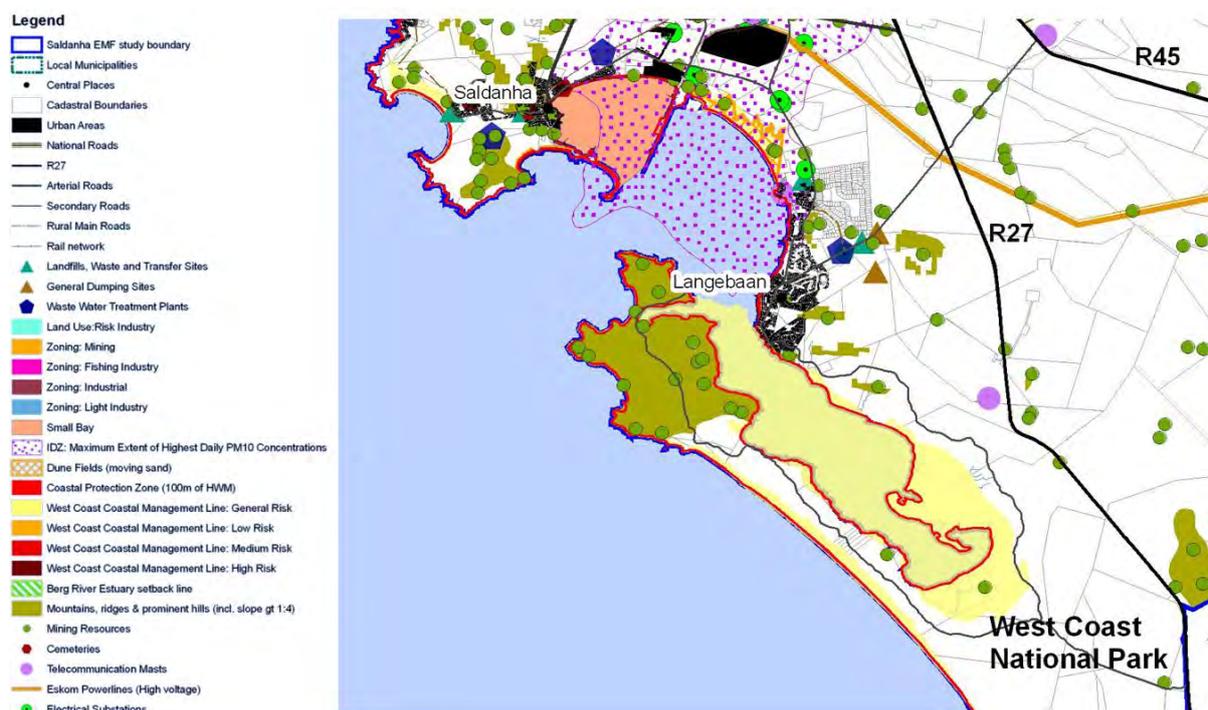


Figure 4.5 Environmental quality and risk attributes applicable to Environmental Management Zone (EMZ) 3 (Develop with Care: Restrictive Factors or Risks) of Saldanha Bay, Langebaan Lagoon and Danger Bay area (Source: Environmental Management Framework for the Greater Saldanha Bay Area (Adapted from DEADP 2015)).

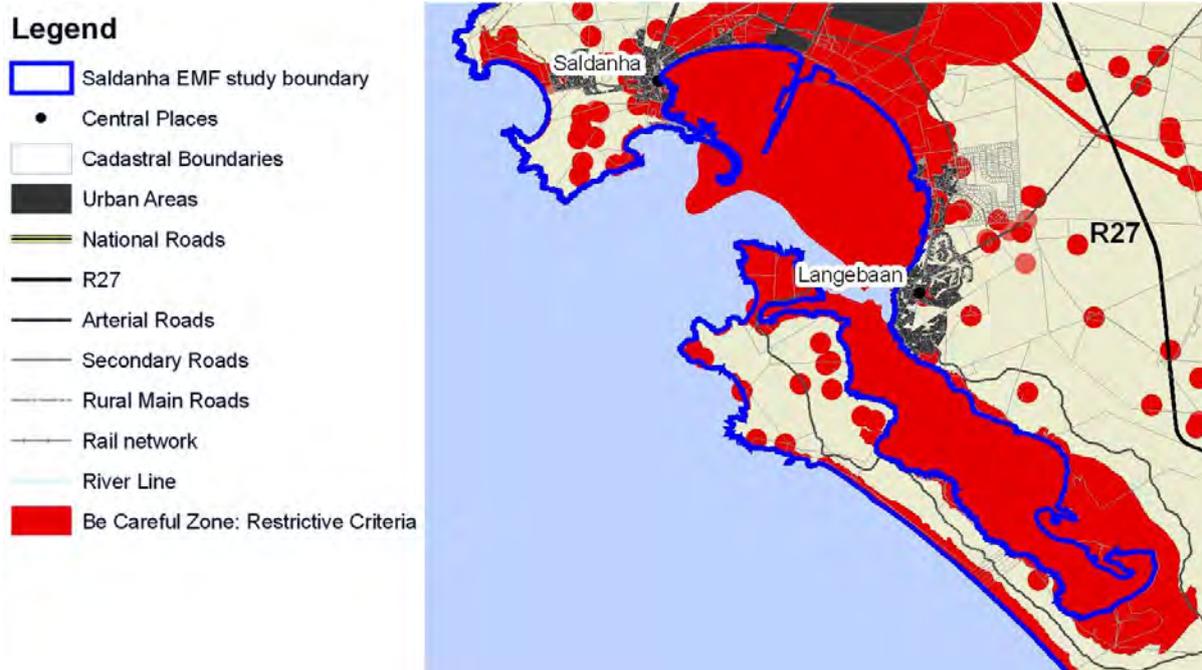


Figure 4.6 The total extent of Environmental Management Zone (EMZ) 3 (Develop with Care: Restrictive Factors or Risks) of Saldanha Bay, Langebaan Lagoon and Danger Bay area (Source: Environmental Management Framework for the Greater Saldanha Bay Area (Adapted from DEADP 2015)).

Table 4.6 Risks and impact of identified developments or activities on environmental quality and risk attributes of Environmental Management Zone (EMZ) 3 – Develop with Care: Restrictive Conditions or Constraints, specifically applicable to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay (Adapted from DEADP 2015).

Activities that should be avoided	Activities that are likely to have a significant impact	Activities that could be considered for this zone only in existing transformed areas
<ul style="list-style-type: none"> • Residential projects • Commercial or retail facilities • Recreational facilities • Tourism facilities 	<ul style="list-style-type: none"> • Mining • Extraction or processing of oil or gas • Power generation projects (fossil fuels or nuclear) • Sewage, wastewater or effluent treatment works • Jetties, slipways, marinas • Ports and harbours • Structures (fixed or temporary) in the coastal zone or on the seabed • Marine outfalls • Marine telecommunication facilities 	<ul style="list-style-type: none"> • Bulk water, sewage or stormwater infrastructure • Bulk stormwater outlets, canals or channels • Infilling, excavation of material • Aquaculture/mariculture facilities (depending on water quality)

Table 4.7 Management Framework for Environmental Management Zone (EMZ) 3 – Develop with Care: Restrictive Conditions or Constraints, specifically applicable to the marine and coastal environment of Saldanha Bay, Langebaan Lagoon and Danger Bay (Adapted from DEADP 2015).

Attribute	Management Objective	Desired Outcomes	Limit of Acceptable Change	Opportunity for Benefit	Mitigation/Management Approach
Marine water pollution “hot spots” specifically in Small Bay	<ul style="list-style-type: none"> To prevent further discharges of pollution into degraded water resources or marine environments 	<ul style="list-style-type: none"> No exceedance of applicable water quality standards occur. No water quality related human health impacts occur in the area 	<ul style="list-style-type: none"> Water quality standards applied in the State of the Bay project 	<ul style="list-style-type: none"> Improvement of quality of the affected marine environment 	<ul style="list-style-type: none"> Avoid discharge of effluent or Stormwater into Small Bay. Undertake a specialist study to determine design requirements to prevent effluent discharges and to store and recycle Stormwater. Treatment and re-use of effluent must be considered.
Coastal management lines	<ul style="list-style-type: none"> To ensure that development is not placed in high risk areas of the coastline 	<ul style="list-style-type: none"> No new residential, commercial or industrial development within the coastal management line No new bulk infrastructure or services within the coastal management lines 	<ul style="list-style-type: none"> Extent of current development within the coastal management line 	<ul style="list-style-type: none"> Rehabilitation of degraded coastal ecosystems 	<ul style="list-style-type: none"> Avoid any development that will hamper natural functioning of dune system. Obtain specialist input for placement of any structures (fences/boardwalks etc.) within the coastal management line.
Mobile dune field	<ul style="list-style-type: none"> To ensure that development in areas of mobile sand is avoided or planned and designed to take cognisance of risks 	<ul style="list-style-type: none"> No development in areas comprising mobile dunes No threat of loss or damage to property due to inappropriate development in mobile dune area 	<ul style="list-style-type: none"> Extent of current development on mobile dunes 	<ul style="list-style-type: none"> Rehabilitation of mobile dune systems (e.g. removal of alien invasive vegetation) 	<ul style="list-style-type: none"> Avoid any development that will hamper natural functioning of dune system. Obtain specialist input for placement of any structures (fences/boardwalks etc.) on mobile dunes.
Coastal Protection Zone	<ul style="list-style-type: none"> To ensure that development is placed outside of the coastal protection zone or if specified the coastal setback line 	<ul style="list-style-type: none"> No development of hard, immovable structures within the Coastal Protection Zone. No threat of loss or damage to property due to inappropriate development in mobile dune areas. 	<ul style="list-style-type: none"> Extent of current development within the coastal protection zone (100m of HWM) 	<ul style="list-style-type: none"> Rehabilitation of degraded coastal ecosystems. 	<ul style="list-style-type: none"> Avoid any development that will hamper natural functioning of dune system. Obtain specialist input for placement of any structures (fences/boardwalks etc.) on mobile dunes.

4.2 Integrated coastal management

The ICMA, which came into effect in December 2009, aims to ensure the integrated management of the coastline and the sustainable use of its resources. The ICMA obligates municipalities to prepare and adopt Coastal Management Programmes for the coastal zone, or specific parts of the coastal zone in areas under their jurisdiction, within four years of the Act coming into effect. These statutory programmes must incorporate a vision and management objectives for the coastal zone; priorities and strategies to achieve the objectives; and performance indicators to measure management effectiveness. The Coastal Management Programme must be consistent with other municipal plans, such as the IDP. Moreover Section 51 requires that an IDP be aligned with, contain the provisions of, and give effect to national and the applicable provincial coastal management programmes. The coastal zone, as defined by the ICMA includes the following areas and any aspect of the environment on, in, under and above these areas:

- **All coastal public property:** Comprises of coastal waters; land submerged by coastal waters; islands within coastal waters; the sea shore, excluding that which was lawfully alienated before this Act came into force; State owned land declared as coastal public property; and the natural resources on or in coastal public property, the exclusive economic zone (up to 200 nautical miles offshore) and any harbour, work or other installation in coastal public property);
- **The coastal protection zone:** Comprises of the land 1km inland from the high water mark zoned for agricultural or undetermined use and the wetlands, lakes, lagoons or dams situated on this land; any land within 100 m inland of the high water mark; seashore and admiralty reserves which are not coastal public property; and land inundated by 1:50 year floods or storm events;
- **All coastal access land:** Strips of land designated by municipal by-laws to secure public access to coastal public property;
- **Coastal protected areas:** those protected areas situated wholly or partially in the coastal zone and recognised under the National Environmental Management: Protected Areas Act (No. 57 of 2003). MPAs declared under the MLRA are recognised as protected areas;
- **The seashore:** the area between the low water mark and the high water mark;
- **Coastal waters:** territorial and internal waters of the Republic.

Future developments in and around Saldanha and Langebaan will have to be conducted in accordance with the provisions of the ICMA. The following aspects of the ICMA will affect future development activities in Saldanha and Langebaan:

- Section 15 of the ICMA prevents any person, owner or occupier of land adjacent to the seashore from requiring any organ of state or any other person to take measures to prevent the **erosion or accretion** of the seashore, or of land adjacent to coastal public property, unless the erosion is caused by an intentional act or omission of that organ of state or other person. Moreover it prohibits the construction, maintenance or extension of any structure, or the conduct of any other measures on coastal public property to prevent or promote erosion or accretion of the seashore except as provided for in the ICMA.
- Section 58 places a **duty of care** on every person who causes, has caused or may cause significant pollution or degradation of the environment, including an adverse effect to the

coastal environment, to take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, and to minimise and rectify such pollution or degradation of the coastal environment;

- Section 60 provides the Minister or MEC with the power to give notice to **repair or remove structures** in the coastal zone if the structures are likely to cause adverse effects to the coastal environment.
- **Coastal management lines**, determined by an MEC in accordance with section 25 of the Act, will demarcate an area within which development will be prohibited or controlled in order to achieve the objectives of the ICMA or coastal management objectives. Designated coastal set-back lines will help to protect biodiversity and heritage sites, ensure the safety of developments while minimizing maintenance issues.

4.2.1 Saldanha Bay as a Special Management Area

The SBWQFT is currently lobbying the relevant Provincial and National authorities to have Saldanha Bay declared a “Special Management Area” under the ICMA. In terms of section 23 (1) (a) of the Act, the Minister may publish a notice in the *Government Gazette* and thereby declare any area that is wholly or partially within the coastal zone to be a special management area. A special management area may be declared if environmental, cultural or socio-economic conditions require the introduction of measures which are necessary to more effectively conserve, protect or enhance coastal ecosystems and biodiversity in the area of question. The Minister also has the power to prohibit certain activities should these activities be consider contrary to the objectives of the special management area (ICMA Section 23 (4)).

4.2.2 Defining and adopting Coastal Management Lines

Historically, development in the coastal zone has been controlled largely through the EIA regulations published in terms of the NEMA, which require that an EIA be conducted for the development of any infrastructure within 100 m of the high-water mark. Recognising, however, that as well as being sensitive, vulnerable, and often stressed ecosystems, coastal areas are also highly dynamic in both space and time, and cannot be boxed within fixed boundaries, the approach to controlling development in coastal areas has changed dramatically in recent years. This is particularly pertinent in the light of climate change where rising sea-levels and potential increases in the frequency and intensity of storm events are upping the stakes even further. These changes are being implemented through the ICMA (as amended in 2014) which calls for coastal management lines to be determined for all coastal areas. Specifically, section 25 of the ICMA indicates the priority for coastal management lines to be established (or changed from existing locations), as follows:

1. (1) An MEC must by notice in the Gazette—
 - a. establish or change coastal management lines:
 - i. to protect coastal public property, private property and public safety;
 - ii. to protect the coastal protection zone;
 - iii. to preserve the aesthetic values of the coastal zone; or

iv. for any other reason consistent with the objectives of this Act; and

(1A) An MEC may, in regulations published in the Gazette, prohibit or restrict the building, erection, alteration or extension of structures that are wholly or partially seaward of a coastal management line.

(1B) When establishing coastal management lines in terms of subsection (1), the MEC must consider the location of immovable property and the ownership and zonation of vacant land.

The establishment of coastal management lines is to follow a participatory approach:

- (2) Before making or amending a notice referred to in subsection (1), or making the regulations referred to in subsection (1A), the MEC must—
- b. consult with any local municipality within whose area of jurisdiction the coastal management line is, or will be, situated; and
 - c. give interested and affected parties an opportunity to make representations in accordance with Part 5 of Chapter 6.

Coastal management lines are to be plotted on maps as part of zoning and made available to public, as indicated in the ICMA:

(3) A local municipality within whose area of jurisdiction a coastal management line has been established must delineate the coastal management line on a map or maps that form part of its zoning scheme in order to enable the public to determine the position of the coastal management line in relation to existing cadastral boundaries.

In response to the above motivation and legal requirements, the DEA&DP commissioned WSP Africa Coastal Engineers (Pty) Ltd to develop a methodology for defining and adopting coastal development management lines in the Western Cape and to test the methodology in the Cape Town Metropolitan area (Milnerton) and in the Saldanha Municipal area in consultation with the municipal authorities. WSP Africa Coastal Engineers issued a final report entitled Development of a Methodology for Defining and Adopting Coastal Development Setback Lines in May 2010 (WSP Africa Coastal Engineers 2010a).

In this report they included recommendations for two types of management line, one that demarcates “non-negotiable” areas for development and the other which is negotiable for limited or controlled development. These are as follows:

1. **A coastal processes (or no-development’) management line** which demarcates the set-back required for coastal erosion, wave penetration during storms (i.e. the limit of the wave hazard zone), and wind-blown sand transport. Development seawards of this line is non-negotiable as infrastructure in this area is likely to be at risk and/or can induce erosion on neighbouring shorelines. The only exception to be considered here are measures to protect the shoreline such as wooden walkways across sensitive dunes.
2. **A limited or controlled development management line** demarcating the set-back required for issues such as aesthetics, buffer zones, and for protection biodiversity and heritage resources (e.g. shipwrecks and shell middens). Limitations on development within

(seawards) of this line should be defined by the requirements of aesthetic or biodiversity protection. Different lines may be defined for different reasons (e.g. biodiversity, heritage or aesthetics).

The report also recommended that each management line have a time period associated with it, the recommended period being 100 years as this would take account of 1: 100 year storm erosion, sea level rise, and flood events. It was also recommended that the lines, once set, should only be revised in the face of (i) significant changes in global conditions, (ii) unforeseen changes in local or regional circumstances (e.g. significant change in river sand transport budget), (iii) after significant time has passed (e.g. 50 years for a 1:100 years management line), and (iv) changes in policy regarding an established management line. Furthermore, it was recommended that the management lines be scientifically determined regardless of existing development, that they apply equally to mining operations and development.

The process for determining coastal management lines included requirements for significant enabling studies including aerial topographic studies, wave modelling studies, water-level and storm surge analyses, and storm erosion modelling studies, as well as collection of significant additional data including: aerial photographs and/or maps, hydrographic charts, zoning scheme data, sediment grains size distributions, wind data, wave data, water-levels, beach topography data, biodiversity maps, heritage maps and socio-cultural information.

4.2.2.1 Coastal management lines of the West Coast District Municipality

Royal HaskoningDHV (previously SRK Consulting) was appointed by the DEA&DP to delineate coastal management lines for the WCDM. Using the provincial methodology, the approach by the City of Cape Town to manage development in the coastal urban space, as well as the recommendations produced in a pilot study in the Overberg Municipality, coastal management lines and overlay risk zones were produced for the WCDM. The coastal management lines were determined in the following way (van Weele *et al.* 2014):

1. Urban areas are comprised of existing development, existing development rights and/or land set aside for future municipal development. This was taken into account during the demarcation of the coastal management line.
2. Long-term risk projections (1:100 year risk zone) were used in rural areas and expanding into the littoral active zone. Existing development was taken into account where necessary to preserve development rights. The coastal management line was drawn around the developments to create 'development islands'.
3. Coastal management lines were determined for estuaries along a 5 m contour in undeveloped/rural areas. The lower (water side) boundary of properties was considered where development occurred along the banks of an estuary. Development islands were delineated around isolated existing developments and development rights.
4. Apart from taking into account existing development, development rights and areas set aside for future municipal development, environmental (biophysical sensitivities), heritage (areas of preservation), social (coastal access) and economic (activities which are reliant on

proximity to the sea) aspects were also considered in the delineation of coastal management lines.

The modelled physical process/hazard lines were used as overlay zones which reflect three risk scenarios (as recommended by the Overberg pilot study), namely low (20 years or 200 mm), medium (50 years or 500 mm) and high (100 years or 1000 mm). The modelling of these three scenarios is a five-step process, and relies on wave run-up modelling (van Weele & Breetzke 2013):

Step 1:	Offshore wave height	The 1:10 (current high water mark), 1:20 (short term), 1:50 (medium term) and 1:100 (long term) year storm wave heights and periods.
Step 2:	Wave run-up heights	Current wave run up (HWM), 1:20 (short term), 1:50 (medium term) and 1:100 (long term) wave run up
Step 3:	Future shoreline regression due to sea level rise	The amount of shoreline retreat for short, medium & long term sea level rise
Step 4:	Determine the short-term storm erosion risk along the coastline	Average short term shoreline retreat
Step 5:	Determine long-term beach retreat due to natural sand movement	Available historical aerial photography for sandy shorelines

Offshore wave height and period (including the 1:10 and 1:100 year storm wave height and period) was determined using available wave statistics. Wave run-up heights including the current (1:10 year, HWM), short term (1:20 year), medium term (1:50 year) and long term (1:100 year) for sandy and rocky shoreline were determined using the models of Mather *et al.* (2010) and the Eurotop manual (Pullen 2008) respectively. Movement of the shoreline inland is a function of increased inundation (due to sea level rise) as well as increased sediment losses from increased wave energy (also an effect of climate change) was assessed for three different scenarios termed low risk (sea level rise of 200 mm combined with a 1:20 year storm event), medium risk (sea level rise of 500 mm combined with a 1:50 year storm event) and high risk (1000 mm sea level rise combined with a 1:100 year storm event). On sandy shores, the amount of long term retreat was estimated in accordance with the Bruun's Rule (Bruun 1962), while in the case of rocky shorelines, where shoreline retreat is anticipated, the additional sea level rise was simply added to the wave run up positions. The authors correctly pointed out that the method used is not strictly correct as a 1:100 year storm event can occur at any time in the future (i.e. will not necessarily only be combined with a sea level rise of 1000 mm) but does simplify the outputs. No shoreline surveys were available for the study area and therefore, a short term storm erosion risk along the coastline was assessed as being 20 m on average for sandy shorelines. Due to poor and differing quality of aerial photographs, featureless beaches (difficult to detect common features), unclear position of the wet line and the lack of tidal information, no clear trend of long-term beach retreat due to natural sand movement could be detected. The final physical process line is then generated by joining the highest of the "stacked"

wave run-up lines derived from separate modelling studies undertaken for rocky and sandy sections of the shoreline.

These overlay zones must be superimposed onto the coastal management line, and together, these two management tools recognise existing development and development rights while directing development into the lower risk areas and informing how the development should be undertaken such that property, people and the integrity of the coast can be protected. Excerpts of the draft coastal management lines and overlay zones are shown in Figure 4.7., Figure 3.52, and Figure 3.53. Currently, this information is in preparation to be published in terms of ICMA (as amended) in the *Government Gazette* for public comment. It is important to note that this product is therefore subject to change if the outcomes of the formal public participation process should require such changes. Unlike the coastal management lines, the overlay zones have no legal standing under the ICMA and therefore the overlay zones are likely to be published in the *Government Gazette* in form of supporting documentation (DEA&DP, *pers. comm.*, 2014). Once the notices have been promulgated/adopted, the overlay zones could for example be given effect by incorporation into the municipal planning schemes under Municipal Systems Act (No. 32 of 2000). The coastal management lines and overlay zones were tabled before the MEC who is satisfied with the product, but requested that an implementation strategy, including a legal mechanism, be developed and published in the *Government Gazette* as part of the process. A website containing the above information has been developed and the DEA&DP is currently awaiting the final URL before it will be available to the public. In the interim, the coastal management lines and overlay zones have been used to inform decision making by local and district municipalities (including the Saldanha Bay Municipality) (DEA&DP, *pers. comm.* 2015).



Figure 4.7. The draft coastal management line and overlay zones for the area due south of the small craft harbour. The green line represents the coastal management line, the purple polygon outlines development islands within the 1:100 year risk zone. The green area shows the general risk zone in rural areas (1:100 year risk zone) and for estuaries. The red, orange and yellow areas represent the high (1:20), medium (1:50) and low (1:100 year) risk zones for the urban/developed areas respectively (Source: DEA&DP, Caren George).



Figure 3.52. The draft coastal management line and overlay zones for Paradise Beach in the Mykonos development. The green line represents the coastal management line; the green area shows the general risk zone in rural areas (1:100 year risk zone) and for estuaries. The red, orange and yellow areas represent the high (1:20), medium (1:50) and low (1:100 year) risk zones for the urban/developed areas respectively (Source: DEA&DP, Caren George).



Figure 3.53. The draft coastal management line and overlay zones for the Langebaan lagoon and town. The green line represents the coastal management line; the green area shows the general risk zone in rural areas (1:100 year risk zone) and for estuaries. The red, orange and yellow areas represent the high (1:20), medium (1:50) and low (1:100 year) risk zones for the urban/developed areas respectively (Source: DEA&DP, Caren George).

5 WATER QUALITY

5.1 Introduction

The temperature, salinity (salt content) and dissolved oxygen concentration occurring in marine waters are the variables most frequently measured by oceanographers in order to understand the physical and biological processes impacting on, or occurring within a body of seawater. Historical long-term data series exist for these three variables for Saldanha Bay spanning the period 1974-2000 and have recently been augmented by monitoring studies undertaken by the Council for Scientific and Industrial Research (CSIR) (van Ballegooyen *et al.* 2012) on behalf of Transnet for their newly constructed reverse osmosis desalination plant (data for the period 2010-2011). A thermister string comprising five underwater temperature meters (UTMs), used for continuous monitoring of water temperature in the Bay, was deployed at North Buoy in Small Bay in April 2014 by Anchor Environmental on behalf of the SBWQFT. The intention is to maintain this array in situ for as long as possible. These data are presented in this chapter together with a summary of the main natural driving forces influencing water quality in the Bay (currents and waves). Some recent data is also available on other physico-chemical parameters from the Bay including turbidity and bromide, as well as for faecal coliforms and trace metals (introduced to the Bay through wastewater discharges). These data are also presented in this chapter.

5.2 Circulation and current patterns

Circulation patterns and current strengths in Saldanha Bay prior to development (1974-75) were investigated using various different techniques (drogues, dye-tracing, drift cards and sea-bed drifters). Surface currents (within the upper five meters) are complex and appear to be dependent on wind strength and direction as well as the tidal state. Within Small Bay, currents were weak ($5-15 \text{ cm}\cdot\text{s}^{-1}$) and tended to be clockwise (towards the NE) irrespective of the tidal state or the wind (Figure 5.1). Greater current strengths were observed within Big Bay ($10-20 \text{ cm}\cdot\text{s}^{-1}$) and current direction within the main channels was dependent on the tidal state. The strongest tidal currents were recorded at the mouth of Langebaan Lagoon ($50-100 \text{ cm}\cdot\text{s}^{-1}$), these being either enhanced or retarded by the prevailing wind direction (Currents within the main channels in Langebaan Lagoon were also relatively strong ($20-25 \text{ cm}\cdot\text{s}^{-1}$). Outside of the main tidal channels, surface currents tended to flow in the approximate direction of the prevailing wind with velocities of 2-3% of the wind speed (Shannon & Stander 1977). Current strength and direction at 5 m depth was similar to that at the surface, but was less dependent on wind direction and velocity and appeared to be more influenced by the tidal state. Currents at 10 m depth at the mouth of the Bay were found to be tidal (up to $10 \text{ cm}\cdot\text{s}^{-1}$, either eastwards or westwards) and in the remainder of the Bay, a slow ($5 \text{ cm}\cdot\text{s}^{-1}$) southward or eastward movement, irrespective of the tidal state, was recorded.

The currents and circulation of Saldanha Bay subsequent to the construction of the Marcus Island causeway and the iron ore/oil Terminal were described by Weeks *et al.* (1991a). Historical data of drogue tracking collected by the Sea Fisheries Research Institute during 1976-1979 were analysed in this paper. This study confirmed that wind is the primary determinant of surface currents in both Small Bay and Big Bay; although tidal flows do influence currents below the thermocline and are the dominant forcing factor in the proximity of Langebaan Lagoon. Weeks *et al.* (1991a) noted that

because much of the drogue tracking was conducted under conditions of weak or moderate wind speeds, the surface current velocities measured ($5\text{-}20\text{cm}\cdot\text{s}^{-1}$), were probably underestimated. The authors concluded that the harbour construction had constrained water circulation within Small Bay, enhancing the general clockwise pattern and increasing current speeds along the boundaries, particularly the south-westward current flow along the iron ore/oil Terminal (Figure 5.1).

More recent data collected during strong NNE wind conditions in August 1990 revealed that greater wind velocities do indeed influence current strength and direction throughout the water column (Weeks *et al.* 1991b). These strong NNE winds were observed to enhance the surface flowing SSW currents along the ore terminal in Small Bay (out of the Bay), but resulted in a northward replacement flow (into the Bay) along the bottom, under both ebb and flood tides. The importance of wind as the dominant forcing factor of bottom, as well as surface, waters was further confirmed by Monteiro & Largier (1999) who described the density driven inflow-outflow of cold bottom water into Saldanha Bay during summer conditions when prevailing SSW winds cause regional scale upwelling.

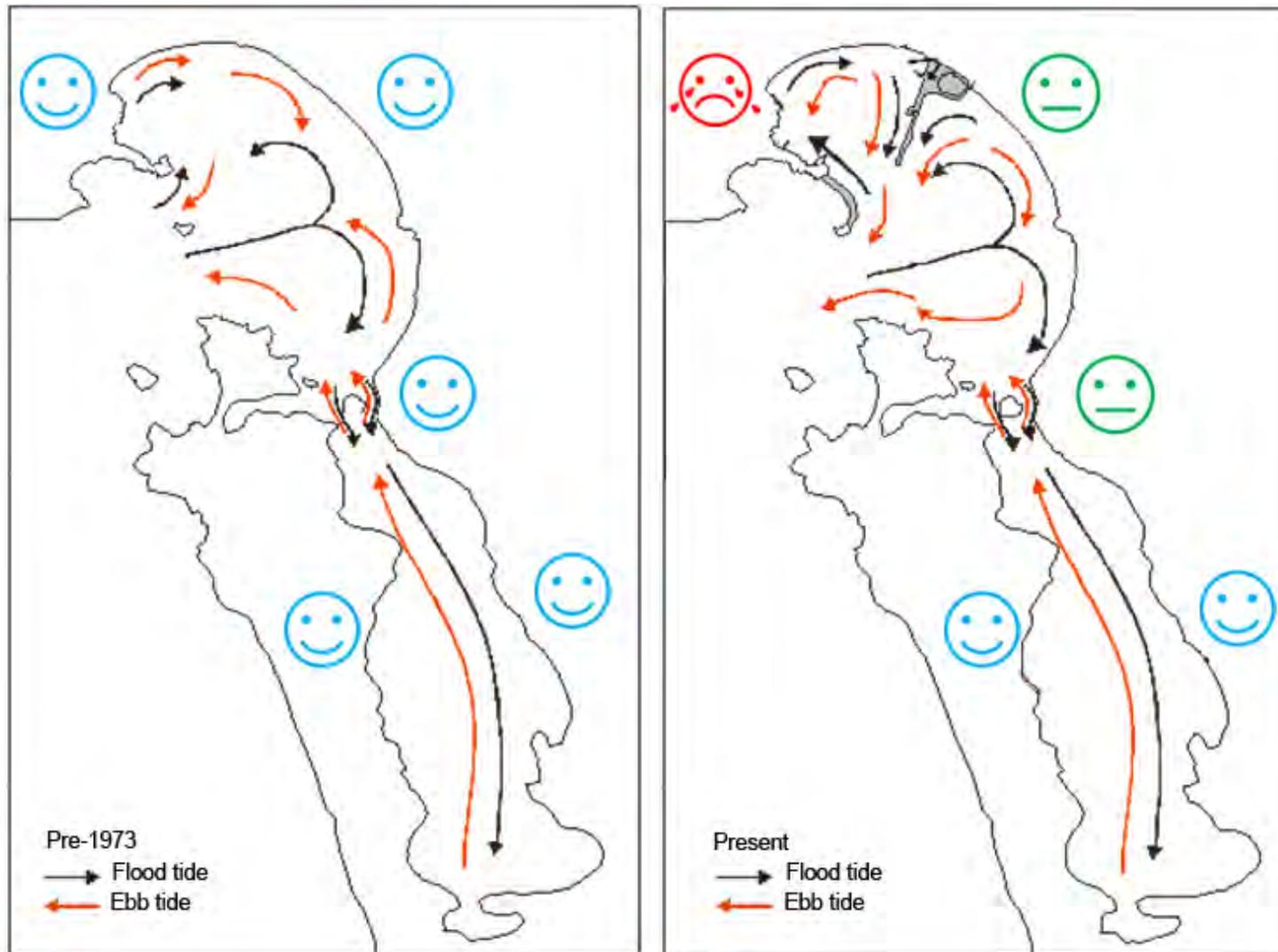


Figure 5.1 Schematic representation of the surface currents and circulation of Saldanha Bay prior to the harbour development (Pre-1973) and after construction of the causeway and iron-ore terminal (Present) (Adapted from: Shannon & Stander 1977 and Weeks *et al.* 1991a).

5.3 Wave action

Construction of the Iron Ore Jetty and the Marcus Island causeway had a major impact on the distribution of wave energy in Saldanha Bay, particularly in the area of Small Bay. Prior to port development in Saldanha Bay, Flemming (1977) distinguished four wave-energy zones in the Bay, defined as being a centrally exposed zone in the area directly opposite the entrance to the Bay, two adjacent semi-exposed zones on either side, and a sheltered zone in the far northern corner of the Bay (Figure 5.2). The iron ore terminal essentially divided the Bay into two parts, eliminating much, if not all, the semi-exposed area in Small Bay, greatly increasing the extent and degree of shelter in the north-western part of Small Bay, and subtly altering wave exposure patterns in Big Bay (Figure 5.3). Wave exposure in Big Bay was altered less dramatically, however, the extent of sheltered and semi-sheltered wave exposure areas increased after harbour development (Luger *et al.* 1999).

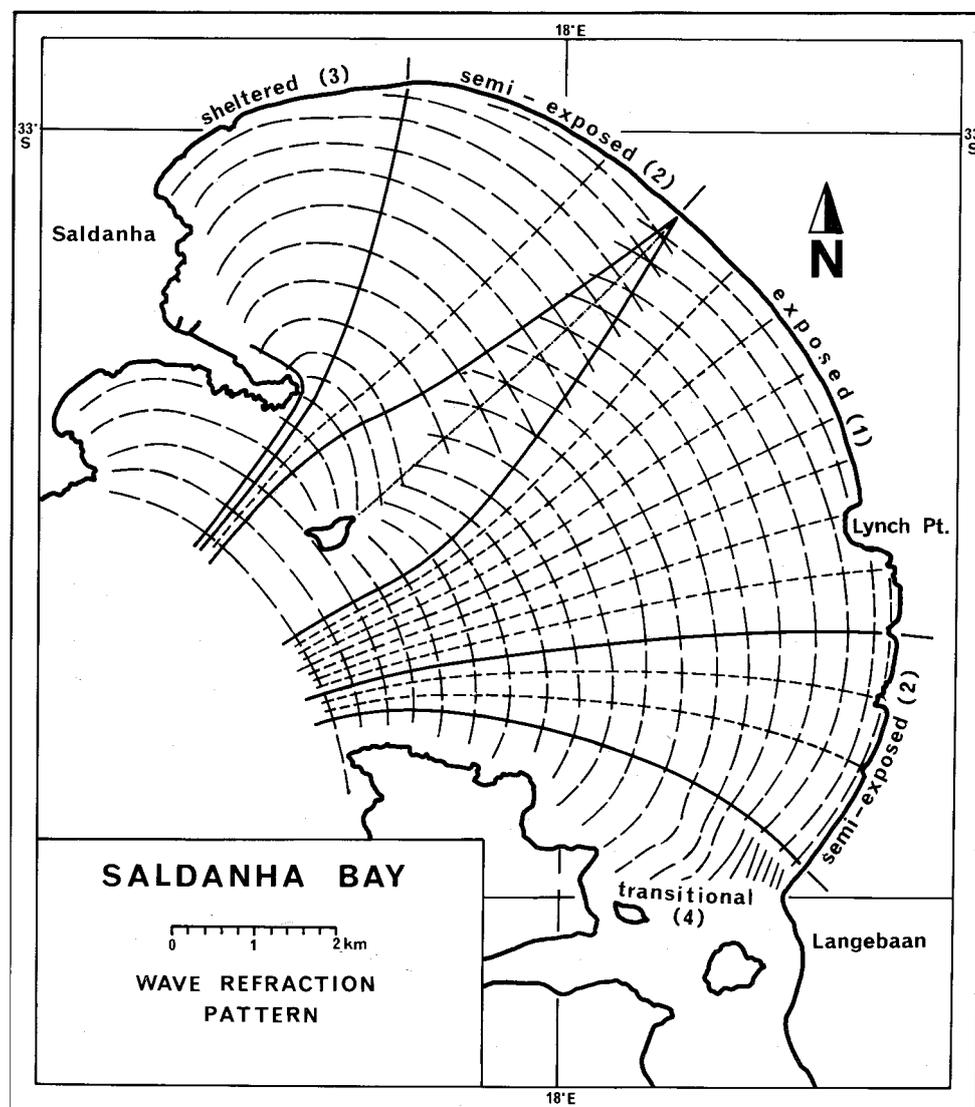


Figure 5.2 Predicted wave field in Saldanha Bay showing wave height and direction prior to harbour development (Source: Flemming 1977).

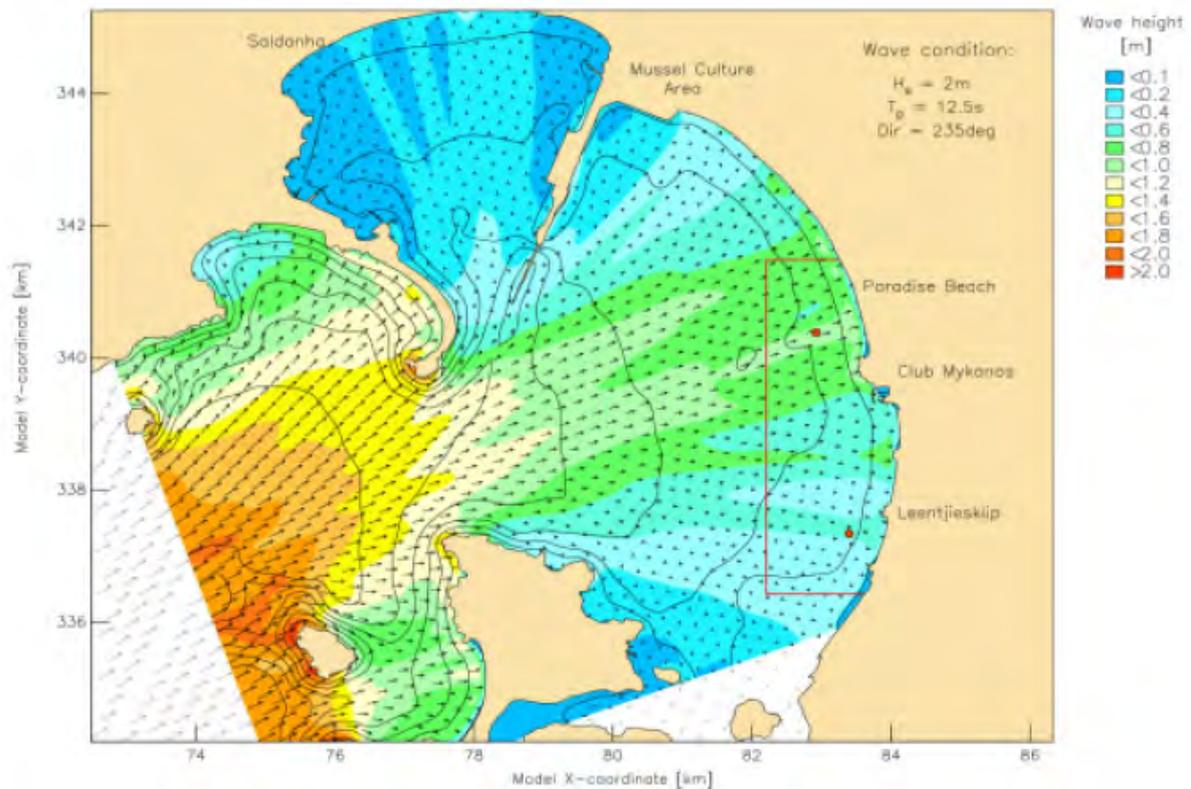


Figure 5.3 Predicted wave field in Saldanha Bay showing wave height and direction after the construction of the causeway and the iron-ore Terminal (Source: WSP Africa Coastal Engineers, 2010).

5.4 Water temperature

Water temperature records for Saldanha Bay and Langebaan Lagoon were first collected during 1974-75 as part of a detailed survey by the then Sea Fisheries Branch - Department of Industries (later renamed Marine and Coastal Management (MCM) - Department of Environmental Affairs and Tourism and now known as Oceans and Coasts – Department of Environmental Affairs). The survey was initiated to collect baseline data of the physical and chemical water characteristics prior to the development of the Bay as an industrial port. The findings of this survey were published in a paper by Shannon & Stander (1977). Surface water temperatures prior to the construction of the iron ore/oil Terminal and Marcus Island causeway varied from 16-18.5°C during summer (January 1975) and 14.5-16°C during winter (July 1975). During both periods, higher temperatures were measured in what is now the northern part of Small Bay and within Langebaan Lagoon, whilst cooler temperatures were measured at sampling stations in Outer Bay and Big Bay.

The water column was found to be fairly uniform in temperature during winter and spring (i.e. temperature did not change dramatically with depth) and the absence of a thermocline (a clear boundary layer separating warm and cool water) was interpreted as evidence of wind driven vertical mixing of the shallow waters in the Bay. A clear shallow thermocline was observed at about 5 m depth, during the summer and autumn months at some deeper stations and was thought to be the result of warm lagoon water flowing over cooler sea water. The absence of a thermocline at other shallow sampling stations was once again considered evidence of strong wind driven vertical mixing. Shannon & Stander (1977) suggested that there was little interchange between the relatively sun-

warmed Saldanha Bay water and the cooler coastal water through the mouth of the Bay, but rather a “slopping backwards and forwards tidal motion”.

The Sea Fisheries Research Institute continued regular monitoring (quarterly) of water temperature (and other variables) in Saldanha Bay until October 1982. These data were presented and discussed in papers by Monteiro *et al.* (1990) and Monteiro & Brundrit (1990). The temperature time series for Small Bay and Big Bay is shown in Figure 5.4. This expanded data series allowed for a better understanding of the oceanography of Saldanha Bay. The temperature of the surface waters was observed to fluctuate seasonally with surface sun warming in summer and cooling in winter, whilst the temperature of deeper (10 m depth) water shows a smaller magnitude, non-seasonal variation, with summer and winter temperatures being similar (Figure 5.4). In most years, a strong thermocline separating the sun warmed surface layer from the cooler deeper water was present during the summer months at between 5-10 m depth. During the winter months, the thermocline breaks down due to surface cooling and increased turbulent mixing, and the water column becomes nearly isothermal (surface and deeper water similar in temperature) (Figure 5.4). Unusually warm, deeper water was observed during December 1974 and December 1976 and was attributed to the unusual influx of warm oceanic water during these months (Figure 5.4).

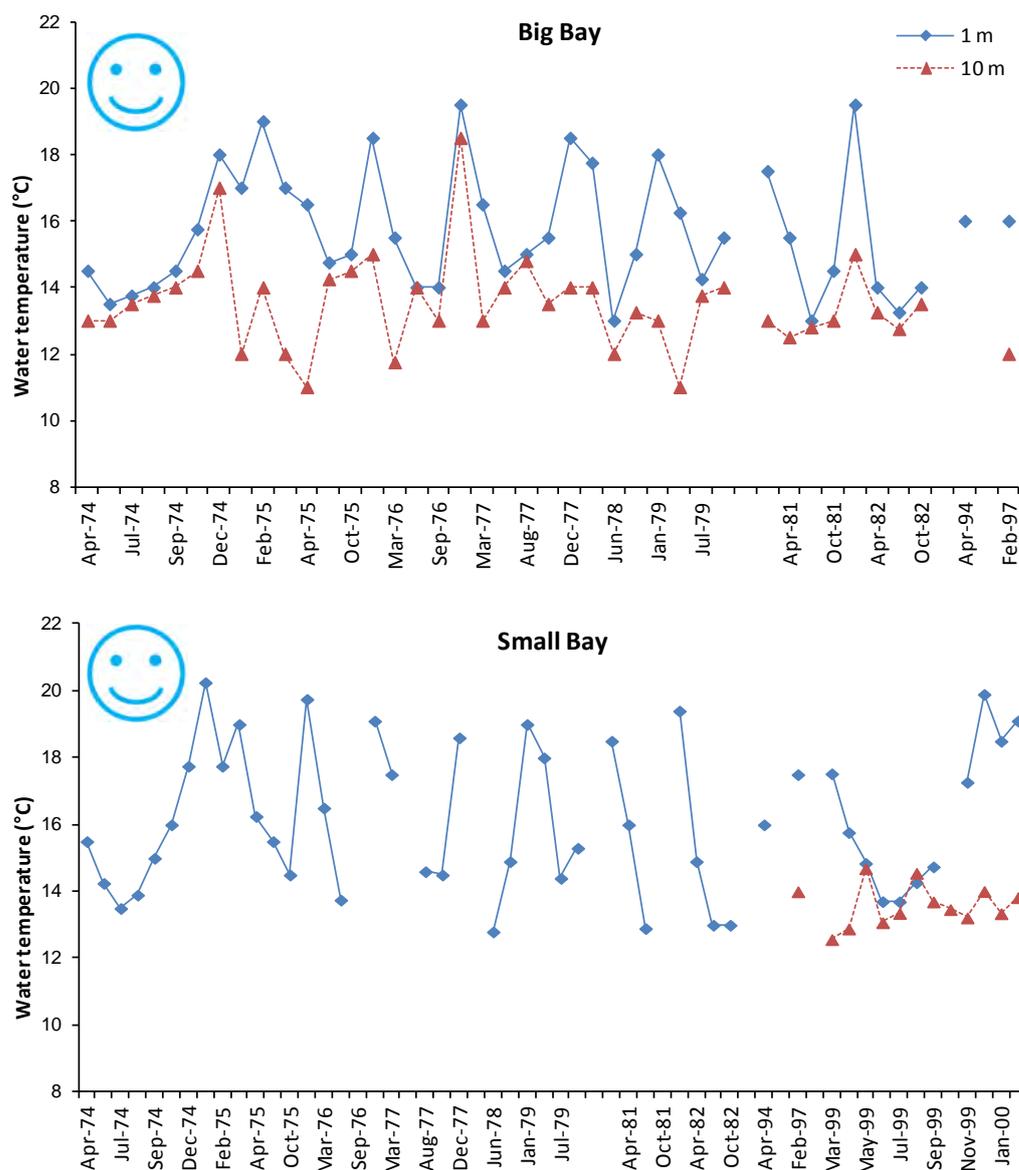


Figure 5.4 Water temperature time series at the surface and at 10m depth for Big Bay and Small Bay, Saldanha Bay (Data: Monteiro *et al.* 1990, Monteiro & Brundrit 1990. Monteiro *et al.* 2000 and Shannon & Stander 1977).

Warm oceanic water is typically more saline and nutrient-deficient than the cool upwelled water that usually occurs below the thermocline in Saldanha Bay. This was reflected in the high salinity (Figure 5.9), and low nitrate and chlorophyll concentration (a measure of phytoplankton production) measurements taken at the same time (Monteiro & Brundrit 1990). Monteiro *et al.* (1990) suggested that the construction of the Marcus Island causeway and the iron ore/oil Terminal in 1975 had physically impeded water movement into and out of Small Bay, thus increasing the residence time and leading to systematically increasing surface water temperatures when compared with Big Bay. There appears to be little support for this in the long-term temperature time series (Figure 5.4) and although the pre-construction data record is limited to only one year, Shannon & Stander (1977)

show Small Bay surface water being 2°C warmer than that in Big Bay during summer, prior to any harbour development. It is likely that the predominant southerly winds during summer concentrate sun warmed surface water in Small Bay, whilst much of the warm surface layer is driven out of Big Bay into Outer Bay.

More detailed continuous monitoring of temperature throughout the water column at various sites in Outer Bay, Small Bay and Big Bay during a two week period in February-March 1997, allowed better understanding of the mechanisms causing the observed differences in the temperature layering of the water column. The summer thermocline is not a long-term feature, but has a 6-8 day cycle. Cold water, being denser than warmer water, will flow into Saldanha Bay from the adjacent coast when wind driven upwelling brings this cold water close to the surface. The inflow of cold, upwelled water into the Bay results in a thermocline, which is then broken down when the cooler bottom water flows out the Bay again. This density driven exchange flow between Saldanha Bay and coastal waters is estimated to be capable of flushing the Bay within 6-8 days, substantially less than the approximately 20 day flushing time calculated based on tidal exchange alone by Shannon & Stander (1977). The influx of nutrient rich upwelled water into Saldanha Bay is critical in sustaining primary productivity within the Bay, with implications for human activities such as fishing and mariculture. The fact that the thermocline is seldom shallower than 5 m depth means that the shallower parts of Saldanha Bay, particularly Langebaan Lagoon, are not exposed to the nutrient (mainly nitrate) import from the Benguela upwelling system. As a result these shallow water areas do not support large plankton blooms and are usually clear.

Monitoring of water temperature in Saldanha Bay was conducted by the CSIR (Monteiro *et al.* 2000) over the period March 1999-February 2000. This was the most intensive long-term temperature record to date, with continuous measurements (every 30 minutes) taken at 1 m depth intervals over the 11 m depth range of the water column where the monitoring station was situated in Small Bay. The average monthly temperature at the surface (1 m) and bottom (10 m) for this period is shown in Figure 5.4. These data confirmed the pattern evident in earlier data, showing a stratified (layered) water column for spring-summer caused by wind driven upwelling, with the water column being more or less isothermal (of equal temperatures) during the winter (Figure 5.4). The continuous monitoring of temperature also identified a three week break in the usual upwelling cycle during December 1999, with a consequent gradual warming of the bottom water. Once again, this “warm water” event (although the water column remained stratified, indicating that the magnitude of this event was not as great as those observed during December 1974 and 1976 events) was associated with a decrease in phytoplankton production due to reduced import of nitrate, which in turn, impacted negatively on local mussel mariculture yields (Monteiro *et al.* 2000).

The CSIR undertook baseline monitoring in Saldanha Bay on behalf of Transnet before the implementation and operation of the Transnet reverse osmosis desalination plant in 2012 (van Ballegooyen *et al.* 2012). Monitoring of sea water temperature, salinity and dissolved oxygen included continuous monitoring over a period of 10 months (July 2010 to March 2011) at one site immediately adjacent to proposed outfall from the desalination plant (an underwater mooring) and also water column profiling undertaken at nine stations at discrete intervals during the course of the year. Locations of the sampling stations are listed in Table 5.1 and indicated on Figure 5.5. The combination of continuous monitoring and discrete profiling measurements was designed to address

the different scales of temporal variability in the Bay: seasonal, event (3 to 10 days) and diurnal scales.

Table 5.1 Location and details of sites sampled during the water column profiling surveys undertaken by the Council for Scientific and Industrial Research between July 2010 and March 2011.

Site	Latitude	Longitude	Depth (m)	Distance from discharge (m)	In/Out channel
North Buoy (NB)	33° 1.114'S	17°58.130'E	12.5	1 875	Out
Mussel Farm (MF)	33° 1.794'S	17° 58.247'E	16.0	1 400	Out
Intermediate Dredge site (IDS)	33° 1.889'S	17° 58.642'E	16.0	880	Out
WRO3	33° 1.935'S	17° 59.030'E	26.5	525	In
WRO4	33° 1.721'S	17° 59.127'E	28.5	105	In
WRO2	33° 1.651'S	17° 59.094'E	23.0	85	On slope
Brine Discharge Site (BDS)	33° 1.679'S	17° 59.147'E	17.3	30	On slope between the dredge channels berthing areas
WRO1	33° 1.688'S	17° 59.215'E	18.0	85	Out
East Buoy (Big Bay)	33° 3.188'S	18° 0.433'E	15.5	3450	Out

Sites were selected in an effort to address the following issues/aspects:

- Brine Discharge Site (BDS): to provide a measure of brine plume impacts in the immediate vicinity of the proposed brine discharge at caisson 3
- WRO3 and WRO4: to measure the brine plume extent along the dredged shipping channel. (Should a dense plume develop it is expected “drain” seawards along the axis of the shipping channel);
- WRO1 and WRO2: to monitor potential plume excursions out of the dredge channel and towards Small and Big Bay, respectively.
- Mussel Farm (MF) and Intermediate Dredge site (IDS): to couple WRO1 and WRO2 to data measured previously. The MR site was also considered to be a sensitive location, while the ID site lies roughly on a line between the proposed RO Plant discharge and the Mussel Raft site.
- North Buoy (NB): to create a baseline to complement both past and potential future long-term mooring at North buoy
- Big Bay (BB): to provide a baseline station in Big Bay even though the RO plant is not predicted to cause impacts at a site that is as remote from the discharge as is the Big Bay site.

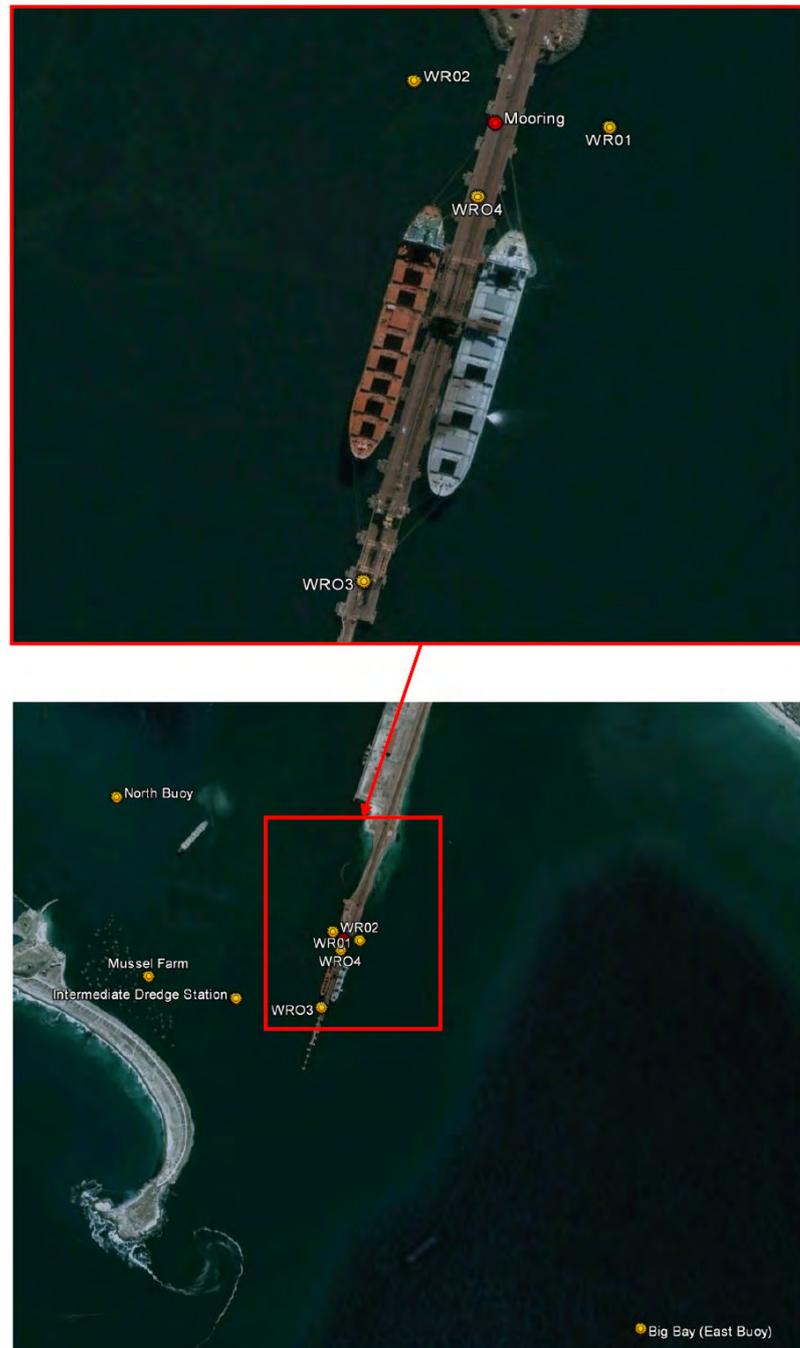


Figure 5.5 Water quality monitoring stations adopted for the RO plant baseline survey undertaken by the Council for Scientific and Industrial Research (Source: van Ballegooyen *et al.* 2012).

Examples of the temperature data from the water column profiling exercises undertaken at North Buoy are shown in Figure 5.6. In general the profiles at all sites indicated a well-mixed column in winter, becoming increasingly stratified in spring and early summer, and highly stratified in late summer/autumn. The temperature variability in the lower water column was very high during spring and early summer when strong wind events change the water column from being moderately to highly stratified to a well-mixed water column under strong wind conditions. This variability was much lower in Summer due to the presence of cold upwelled waters that help to stratify the water column and in so doing, increase the resistance of the water column to vertical mixing. Stratification

was less pronounced at East Buoy in Big Bay than at the more sheltered stations in and around Small Bay (van Ballegooyen *et al.* 2012). This was ascribed to the generally more turbulent conditions in Big Bay compared to Small Bay. A strong thermocline was also evident in the shipping channel which is more accessible to the cold bottom waters associated with upwelling that enters the Bay.

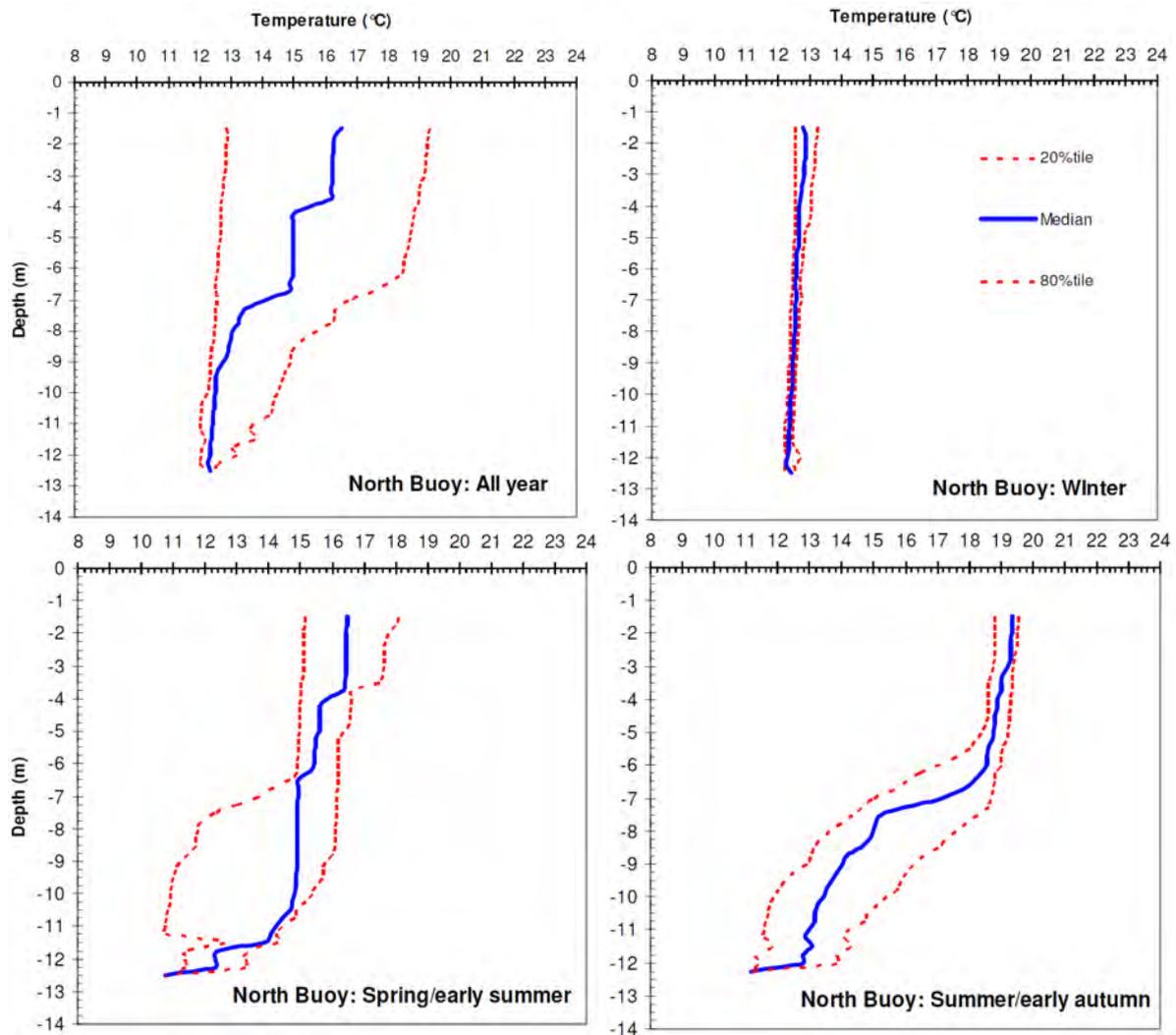


Figure 5.6 Seawater temperature median profiles at North Buoy for all seasons (winter, spring/early, summer and summer/early autumn). The 20 and 80 percentile limits of the profiles are indicated by the dotted red lines (Source: van Ballegooyen *et al.* 2012).

The in situ mooring installed by the CSIR in 2010/2011 as part of the baseline monitoring for the RO plant yielded temperature, salinity and dissolved oxygen times series for the period 09 July 2012 to 23 March 2012 at a temporal resolution of 10 minutes (van Ballegooyen *et al.* 2012). Observations highlighted by the CSIR (van Ballegooyen *et al.* 2012) from this data include the fact that the most obvious variability in the Bay is that which occurs over synoptic (weather) time scales, and was described as follows:

- south-easterly to southerly winds result in upwelling that advects cold, lower salinity and oxygen deficient waters into the Bay;
- If the winds continue to blow, then a degree of vertical mixing takes place, resulting in a slow increase in temperature, salinity and dissolved oxygen in the bottom waters;
- When the wind drops or reverses to NW, then the water column develops a high degree of stratification shortly followed by a relaxation of upwelling that leads to the colder, less saline and low oxygen bottom waters exiting the bay. This, coupled with vertical mixing results in the warmer, more oxygenated surface waters being mixed downwards, sometimes to the depth of the mooring.
- As summer progresses, the bottom waters are more and more insulated from the surface waters and the variability in temperature, salinity and dissolved oxygen of the bottom waters decreases compared to spring and early summer;
- The dissolved oxygen in the bottom waters decreases throughout summer to early autumn when the winter storms and vertical mixing of the water column alleviated these low oxygen conditions.

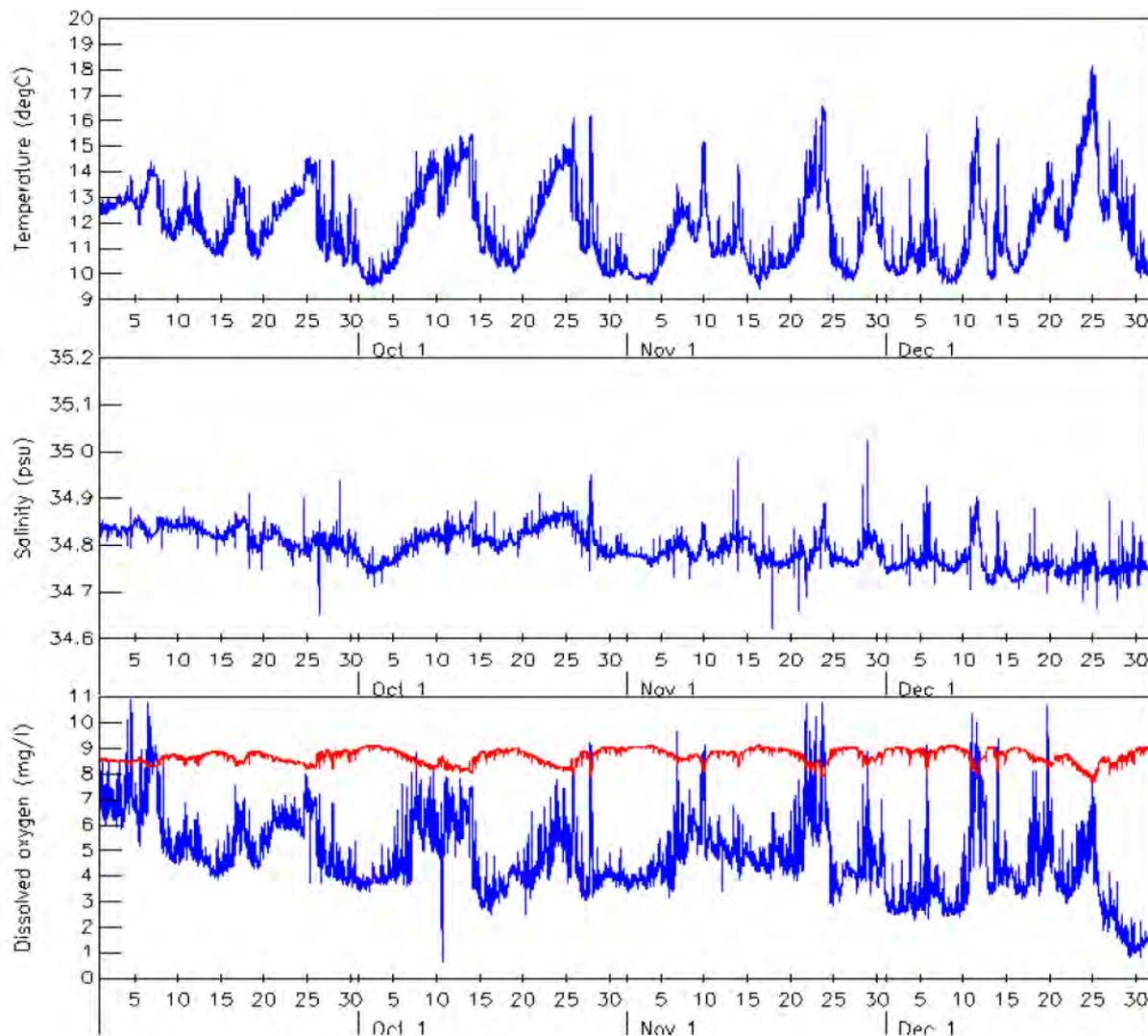


Figure 5.7. Time series of water temperature, salinity and dissolved oxygen concentration from the mooring site ($33^{\circ} 01.679'S$; $17^{\circ} 59.143'E$) for spring/early summer (Source: van Ballegooyen *et al.* 2012).

With a view to continuing the long term temperature data set at North Bouy, five Vemco mini-loggers, programmed to record temperature every six minute were deployed at 2 m, 4.5 m, 7 m, 9.5 m and 12 m depth on the 12 April 2014 and serviced on the 22 April 2015. These data reveal a similar pattern to historical data, with high variability and water column stratification evident from September to May (i.e. from Spring through to Autumn) and a well mixed, isothermal water column in the winter months. Variation in bottom water temperature is greater than in the surface waters and appears to happen over synoptic time scales as noted by van Ballegooyen *et al.* (2012). Relaxation of upwelling and the down mixing of warmer surface waters, or the intrusion of warm oceanic waters that results in warming of the bottom water is most frequently observed in Spring-early Summer and late Summer-early Autumn. The monthly average bottom (12-14°C) or surface (13-20°C) water temperatures are similar to those recorded in earlier monitoring (since 1974) (Figure 5.4). Establishment of continuous, high temporal resolution water temperature monitoring will, however, prove valuable in analysing long term trends. This is an economically viable way of

detecting changes in the frequency of anomalous conditions such as the intrusion of warm oceanic water events etc. which would have significant impacts on ecosystem productivity and health.

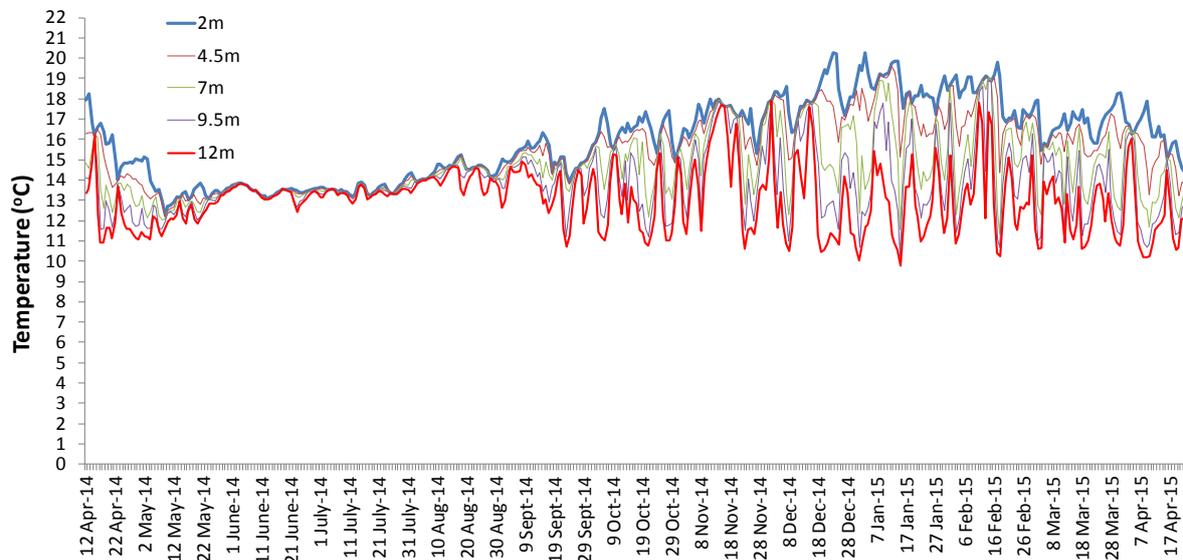


Figure 5.8 North buoy temperature time series for the period 12 April 2014 - 22 April 2015. The average daily temperature is shown (Vemco miniloggers moored at five different depths in the water column recorded temperature every six minutes).

5.5 Salinity

Salinities of the inshore waters along the west coast typically vary between 34.6-34.9 practical salinity units (PSU) (Shannon 1966), and the salinity values recorded for Saldanha Bay usually fall within this range. During summer months when wind driven coastal upwelling within the Benguela region brings cooler South Atlantic Central Water to the surface, salinities are usually lower than during the winter months when the upwelling front breaks down and South Atlantic surface waters move against the coast (warm surface waters are more saline due to evaporation).

The historic salinity data time series covers much of the same period as that for water temperature and salinity data were extracted from the studies of Shannon & Stander (1977), Monteiro & Brundrit 1990, Monteiro *et al.* (1990) and Monteiro *et al.* (2000) (Figure 5.9). There was little variation in the salinity with depth in the water column and the values recorded at 10 m depth are presented in Figure 5.9. Under summer conditions when the water column is stratified, surface salinities may be slightly elevated due to evaporation and therefore salinity measurements from the deeper water more accurately reflect those of the source water.

The salinity time series shows salinity peaks in December 1974 and 1976 which reflects the warm water inflows that occurred at this time (Figure 5.9). Higher than normal salinity values were also recorded in August 1977 and July 1979. Although this was not reflected in the temperature time series (probably due to rapid heat loss and mixing during winter), the salinity peaks do indicate periodic inflows of surface oceanic water into Saldanha Bay.

Oceanic surface waters tend to be low in nutrients and therefore limit primary production (phytoplankton growth). The oceanic water intrusions into Saldanha Bay, that were identified from the temperature and salinity measurements, corresponded to low levels of nitrate and chlorophyll concentrations measured at the same time as salinity and temperature peaks (Monteiro & Brundrit 1990) (Figure 5.10). This highlights the impacts of the changes in physical oceanography (water temperature and salinity) in the immediate area on the biological processes (nitrate and chlorophyll) occurring within Saldanha Bay (Monteiro & Brundrit 1990). Data concerning these parameters cover a short period only (1974-1979) and as such are little use in examining effects of human development on the Bay.

Examples of the salinity data from the water column profiling exercises undertaken at North Buoy by the CSIR in 2010/2011 are shown in Figure 5.11 (van Ballegooyen *et al.* 2012). In general, the profiles at all sites were found to be consistent with the notion that lower salinity bottom waters enter the bay during the upwelling season (summer), and higher salinity surface waters are present in late summer/autumn. The low salinity “spikes” observed in the profile data are reportedly spurious (instrument error) and can be ignored (van Ballegooyen *et al.* 2012).

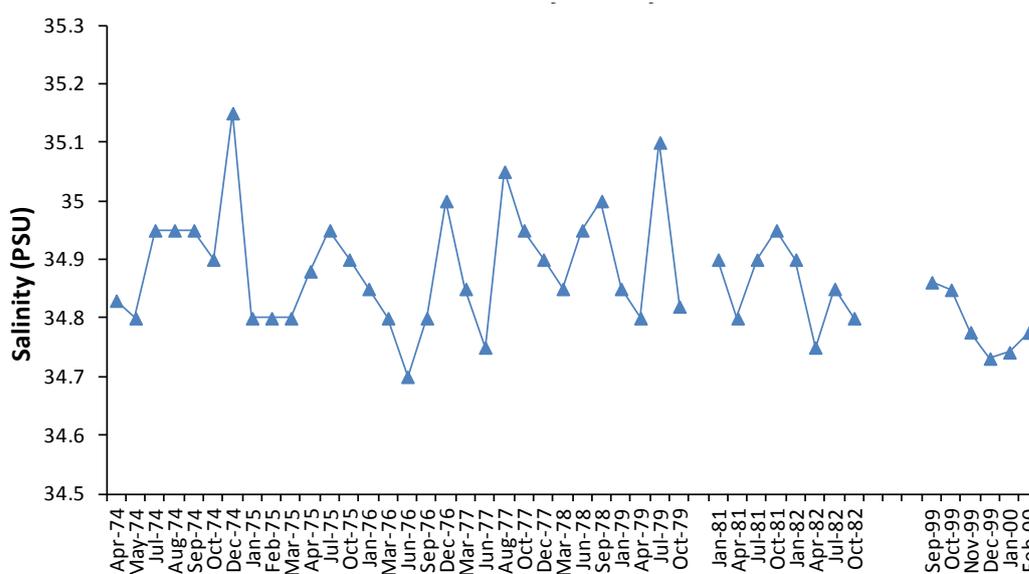


Figure 5.9 Time series of salinity records for Saldanha Bay (data sources: Shannon & Stander 1977, Monteiro & Brundrit 1990, Monteiro *et al.* 1990 and Monteiro *et al.* 2000).

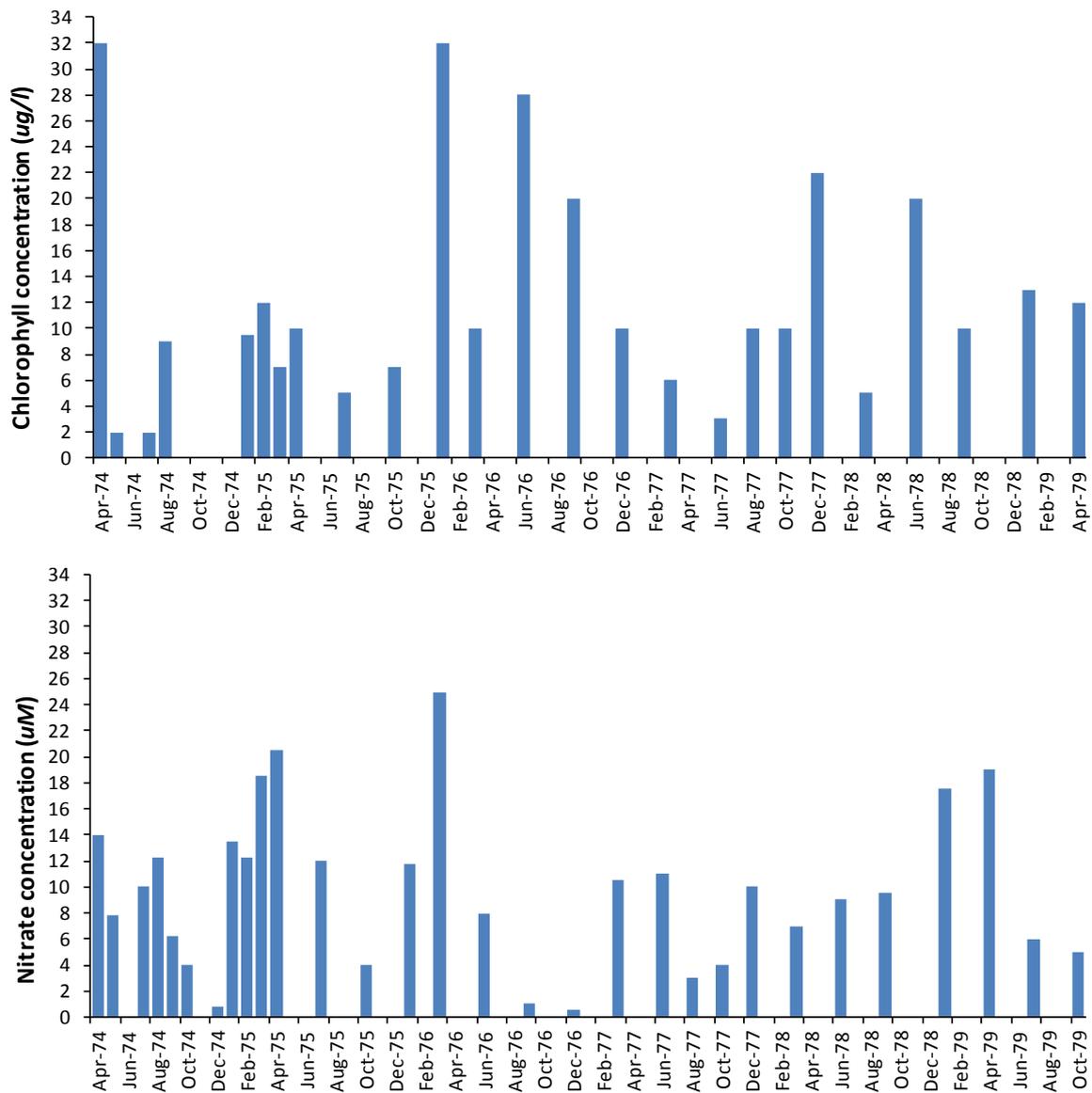


Figure 5.10 Time series of chlorophyll and nitrate concentration measurements for Saldanha Bay (Data source: Monteiro & Brundrit, 1990).

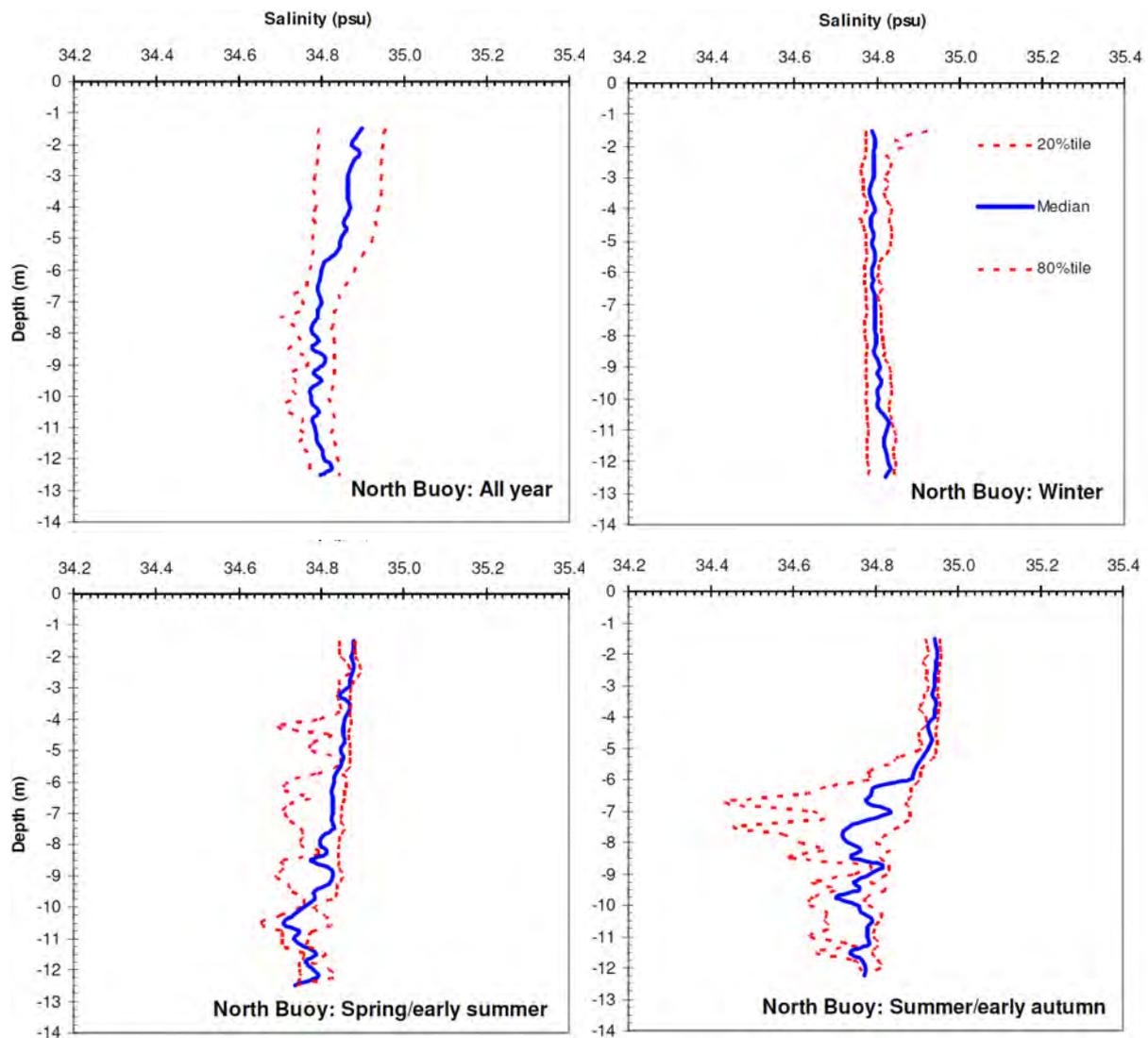


Figure 5.11 Salinity median profiles at North Buoy in Small Bay for all seasons (winter, spring/early, summer and summer/early autumn). The 20 and 80 percentile limits of the profiles are indicated by the dotted red lines (Source: van Ballegooyen *et al.* 2012).

5.6 Dissolved oxygen

Sufficient dissolved oxygen in sea water is essential for the survival of nearly all marine organisms. Low oxygen (or anoxic conditions) can be caused by excessive discharge of organic effluents (for example, from fish factory waste or municipal sewage) and microbial breakdown of this excessive organic matter depletes the oxygen in the water. The well-known “black tides” and associated mass mortality of numerous marine species, which occasionally occur along the west coast, result from the decay of large plankton blooms under calm conditions. Once all the oxygen in the water is depleted, anaerobic bacteria (not requiring oxygen) continue the decay process, causing the characteristic sulphurous smell.

Apparent oxygen utilization (AOU - a measure of the potential available oxygen in the water that has been used by biological processes) values for Small and Big Bay over the period April 1974 - October

1982 and July 1988 are given in Monteiro *et al.* (1990). AOU is defined as the difference between the saturated oxygen concentration (the highest oxygen concentration that could occur at a given water temperature e.g. 5 ml/l) and the measured value (e.g. 1 ml/l) – hence positive AOU (5 ml/l – 1 ml/l = 4 ml/l) values indicate an oxygen deficit (highlighted red in Figure 5.12). More recent data on oxygen concentration in Small Bay (covering the period September 1999-February 2000) were provided by Monteiro *et al.* (2000). During this study, oxygen concentration at 10 m depth was recorded hourly by an instrument moored in Small Bay. These values were converted to AOU and the monthly average plotted in Figure 5.10.

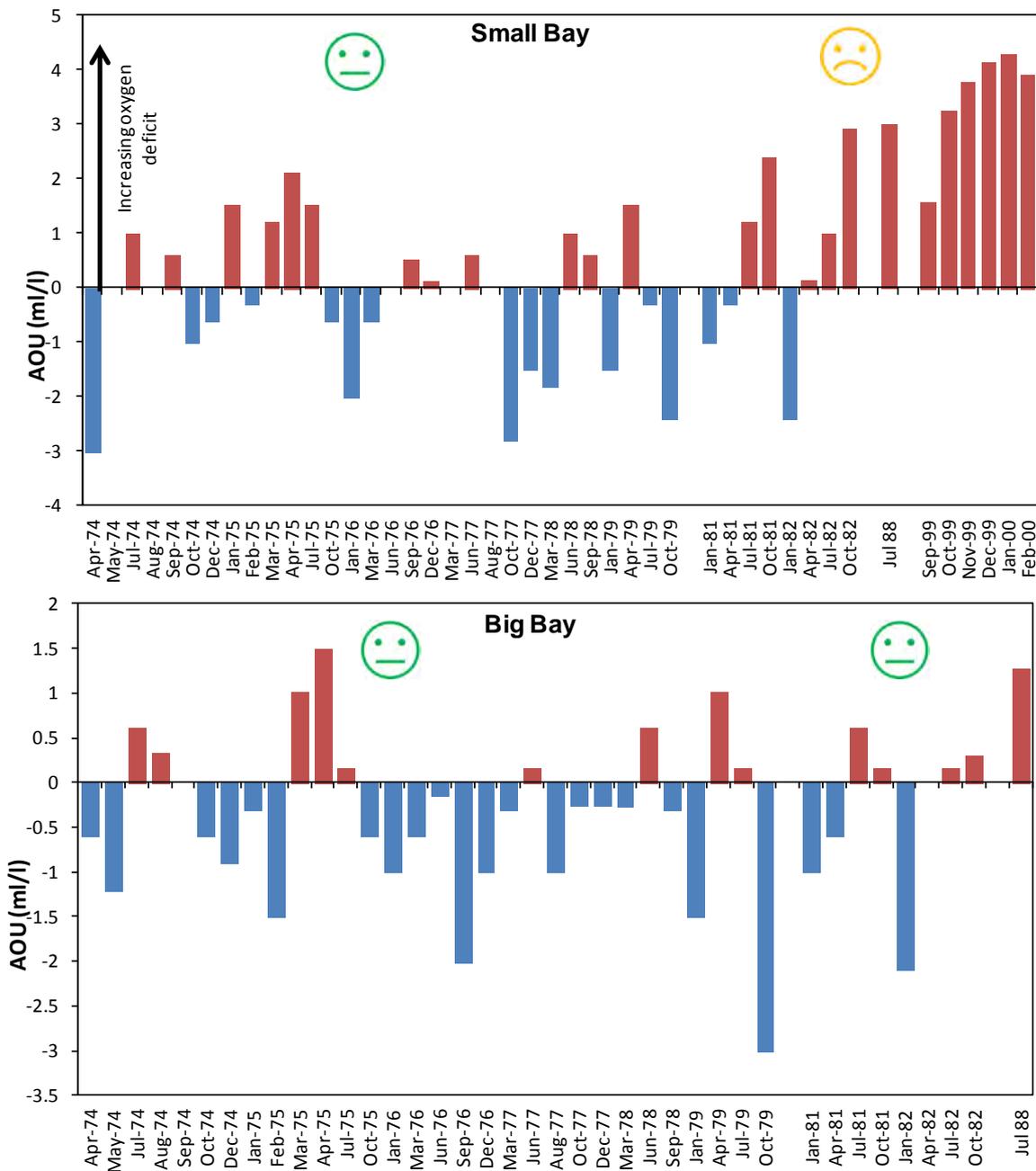


Figure 5.12 Apparent oxygen utilization time series for Small Bay and Big Bay in Saldanha Bay. Positive values in red indicate an oxygen deficit (Data sources: Monteiro *et al.* 1990 and 2000).

There is no clear trend evident in the AOU time series, low oxygen concentrations (high AOU values) occur during both winter and summer months (Figure 5.12). Small Bay does experience a fairly regular oxygen deficit during the winter months, whilst Big Bay experiences less frequent and lower magnitude oxygen deficits. Monteiro *et al.* (1990) attributed the oxygen deficit in Small Bay largely to anthropogenic causes, namely reduced flushing rates (due to the causeway and ore terminal construction) and discharges of organic rich effluents. The most recent data (September 1999-February 2000) indicate a persistent and increasing oxygen deficit as summer progresses (Figure 5.12). It is clear that oxygen levels within Small Bay are very low during the late summer months, likely as a result of naturally occurring conditions; however, the ecological functioning of the system could be further compromised by organic pollutants entering the Bay. There is evidence of anoxia in localised areas of Small Bay (e.g. under the mussel rafts and within the yacht basin) that is caused by excessive organic inputs. Monteiro *et al.* (1997) identified the effluent from a pelagic fish processing factory as the source of nitrogen that resulted in an *Ulva* seaweed bloom in Small Bay. Examples of the dissolved data from the water column profiling exercises undertaken by the CSIR at North Buoy in 2010/2011 are shown in Figure 5.13 (van Ballegooyen *et al.* 2012). The profiles indicated that dissolved oxygen concentrations are high in winter but very low in the bottom waters and near the seabed in summer, late summer and early autumn. These low oxygen concentrations in the near bottom waters are considerably lower than those reported by Shannon & Stander (1977) for the period prior to the development of the port, but those in the upper water column are similar. Shannon & Stander's results indicated dissolved oxygen concentrations at the surface of 8.60 ± 1.86 (std dev) mg/l, 7.96 ± 1.63 mg/l at -5m, 6.85 ± 1.54 mg/l at -10 m, and 5.13 ± 1.80 mg/l at -20m for period April 1974 to October 1975.

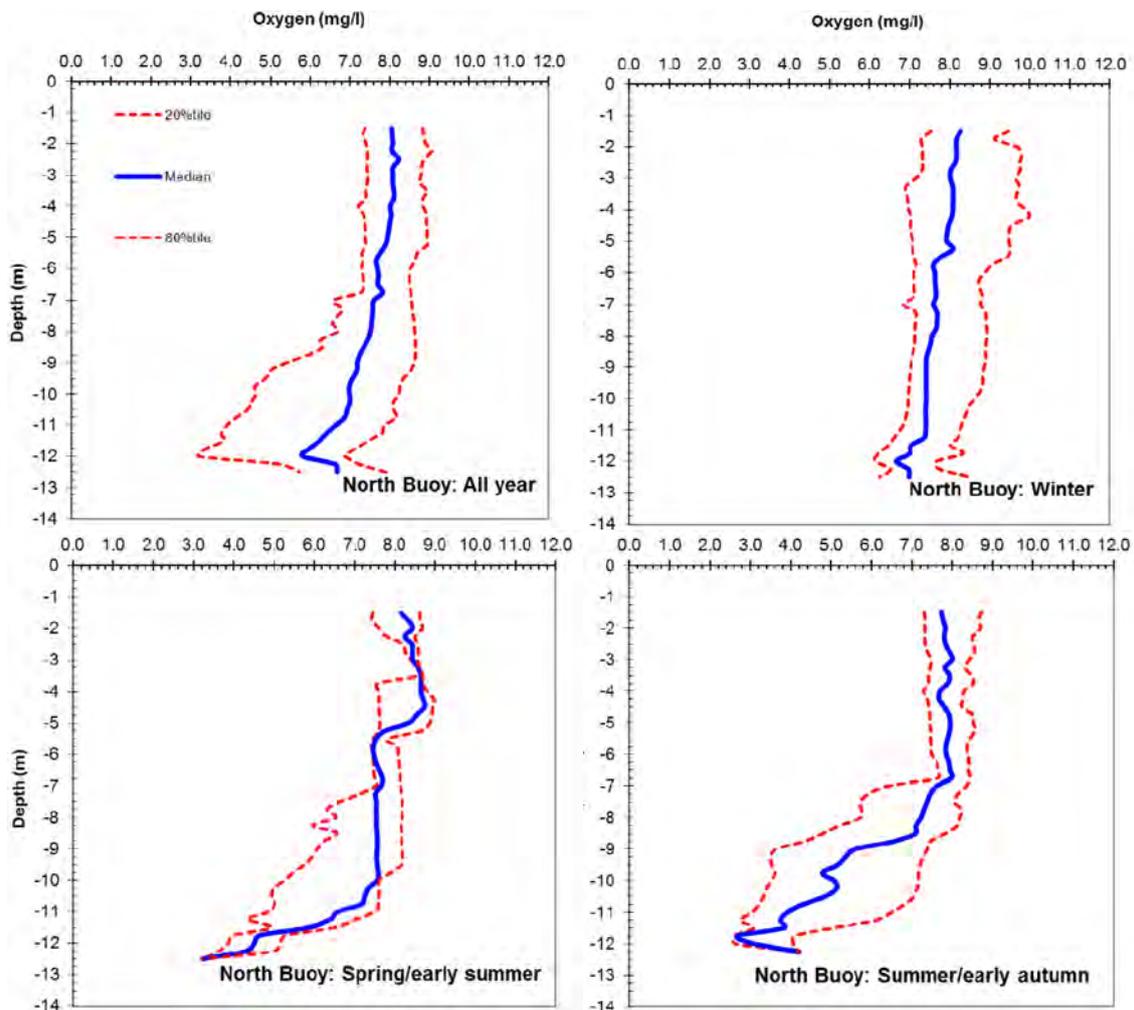


Figure 5.13 Dissolved oxygen concentration median profiles at North Buoy for all seasons (winter, spring/early, summer and summer/early autumn). The 20 and 80 percentile limits of the profiles are indicated by the dotted red lines (Source: van Ballegooyen *et al.* 2012).

5.7 Turbidity

The CSIR describe the water of Saldanha Bay as being “fairly turbid”, the turbidity comprising both organic and inorganic particulates that are suspended in the water column (van Ballegooyen *et al.* 2012). Turbidity in the Bay generally peaks under strong wind conditions (due to wind and wave action that suspend particulate matter in the water column, particularly Big Bay). Langebaan Lagoon, however, typically remains very clear even when the winds are very strong. Phytoplankton blooms and shipping movements have also been observed to cause significant increases in turbidity in the Bay. Historic measurements ($n = 90$) made by Carter and Coles (1998) indicate that average levels of total suspended solids (TSS) in the Bay are in the order of 4.08 mg/l (± 2.69 mg/l SD) and peak at around 15.33 mg/l. Higher values than this (162 mg/l), caused by shipping movements, have, however been recorded by the CSIR (1996). Variations in turbidity caused by these different driving forces are clearly demonstrated in Google Earth images presented by CSIR (van Ballegooyen *et al.* 2012).

Data on turbidity (a measure of light conditions in the water column) and TSS (a measure of the mass per unit volume of TSS in the water column) were collected at their water column profiling stations sampled for the RO plant baseline in 2010/2011 (van Ballegooyen *et al.* 2012). Turbidity data for the North Buoy site in Small Bay are shown here (Figure 5.15). In general the TSS concentrations are greatest near the seabed, particularly at the shallower sites in and around Small Bay. The TSS concentrations generally did not exceed approximately 10 mg/l, except for a few occasions where higher TSS of between 10 mg/l and 40 mg/l were observed (typically in the near bottom waters at the Mussel Farm site, at East Buoy in Big Bay and in the immediate vicinity of the berths along the iron-ore jetty). A few values above 100 mg/l were recorded in the vicinity of the iron ore jetty, and were reportedly related to shipping activities. The water column turbidity data reflected the same general trends as the TSS data, with turbidity in winter generally in the range of 5-12 NTU while in the other seasons the turbidity typically lay between 5 and 8 NTU (van Ballegooyen *et al.* 2012).



Figure 5.14 Turbidity generated under high wind conditions (top) and by propeller wash (bottom) in Saldanha Bay (Source: van Ballegooyen *et al.* 2012).

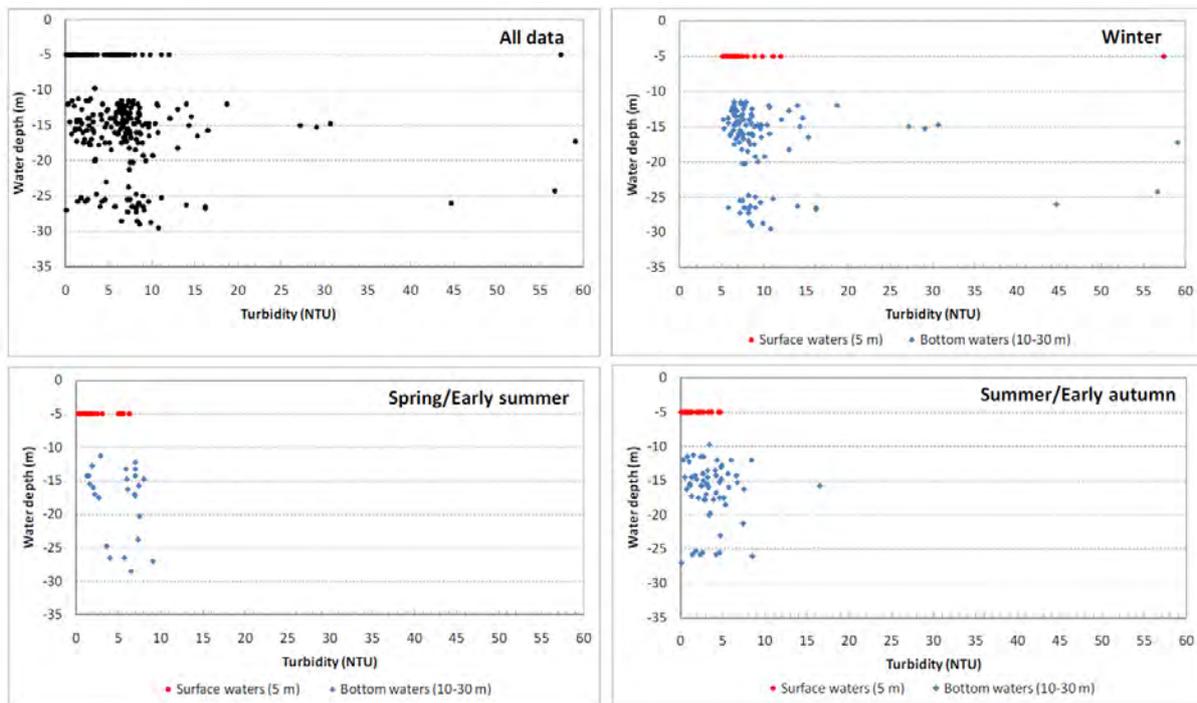


Figure 5.15 Turbidity (NTU) plotted as a function of depth and season (red –surface; blue – bottom) (Source: van Ballegooyen *et al.* 2012).

5.8 Bromide

Measurements of Bromide concentrations were collected at their water column profiling stations sampled for the RO plant baseline in 2010/2011 (van Ballegooyen *et al.* 2012). Measurements were taken at the surface and near the bottom at each station to provide a measure of its natural occurrence in the marine environment of Saldanha Bay. The purpose was to ensure that the biocide proposed to be used in the RO plant, 2,2-dibromo-3-nitropropionamide or its break-down products, do not change these natural distributions. Bromide concentrations in seawater are generally in the range of 65 mg/l to well over 80 mg/l in some confined sea areas. Data presented by the CSIR were consistent with these observations, variability being higher in summer than in winter (van Ballegooyen *et al.* 2012). Variability was particularly high in spring/early summer and it was suggested that this may be related to maintenance dredging that occurred close to the sample sites around the iron-ore jetty at the time.

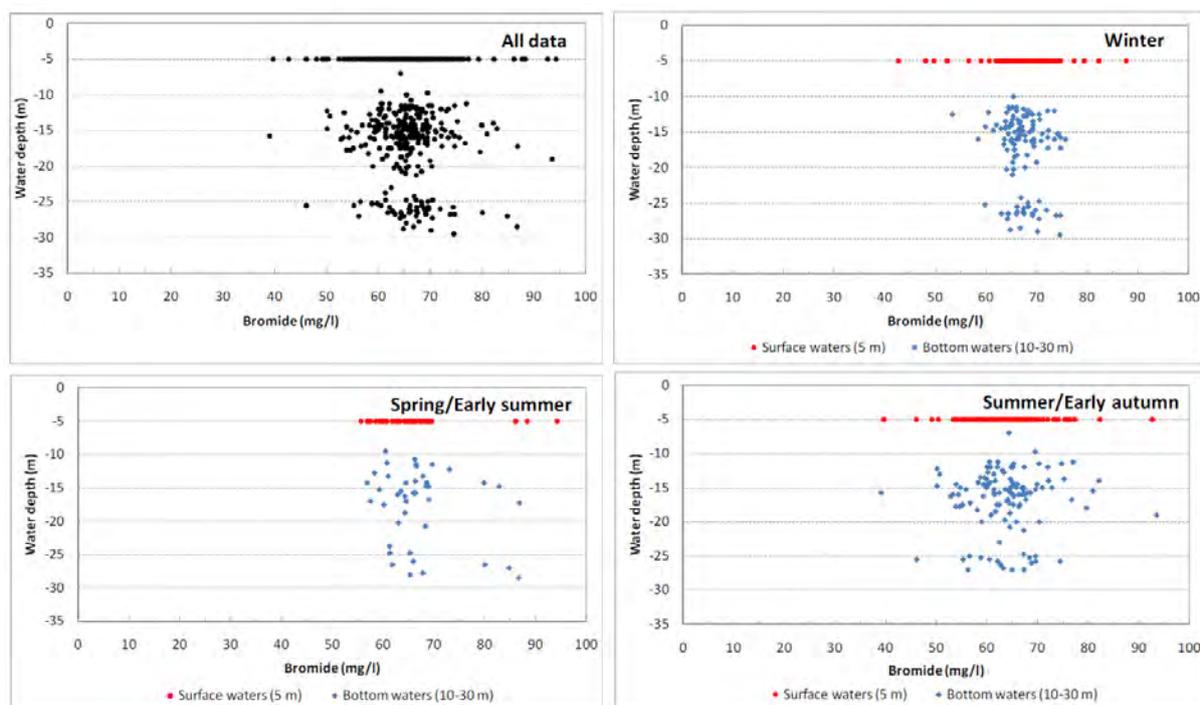


Figure 5.16 Bromide concentrations as measured at all stations in winter, spring/early summer and summer/early autumn (Source: van Ballegooyen *et al.* 2012).

5.9 Microbial indicators

Faecal pollution contained in, for example, untreated sewage or storm water runoff, may introduce disease-causing micro-organisms into coastal waters. These pathogenic micro-organisms constitute a threat to recreational water users and consumers of seafood. Bacterial indicators are used to detect the presence of faecal pollution. These bacterial indicators, however, only provide indirect evidence of the possible presence of water borne pathogens and may not accurately represent the risk to water users (Monteiro *et al.* 2000). Historically, the DWAF (1995a-d) guidelines for inland and coastal waters respectively, have been used to assess compliance in respect of human health criteria. In 2012, the Department of Environmental Affairs (DEA) published revised South African Water Quality Guidelines for Coastal Marine Waters Volume 2: Guidelines for Recreational Waters (DEA 2012). Sampling in Saldanha Bay and Langebaan Lagoon is still undertaken in accordance with the 1995 DWAF protocol but in this report, the evaluation of these data is done in accordance with revised guidelines for recreational use (DEA 2012) and the existing (DWAF 1995) guidelines for mariculture use.

5.9.1 Water quality guidelines

In 2012 the revised DWAF guidelines were published following an international review of guidelines for coastal waters, which highlighted several shortcomings in those developed by South Africa. The revised guidelines (DEA 2012) do not distinguish between different levels of contact recreation. Instead, aesthetics (which includes bad odours, discolouration of water and presence of objectionable matter), human health and safety (gastrointestinal problems, skin, eye, ear and

respiratory irritations, physical injuries and hypo-/hyperthermia), and mechanical interference are considered. Indicators used are the presence of objectionable matter, water temperature and pH and the levels of intestinal *Enterococci* (and *E. coli* where necessary).

Rather than using a measure of actual condition, a compliance index is used to determine deviation from a fixed limit. This method is increasingly used across Europe to determine the compliance in meeting stringent water quality targets within specified time frames (e.g. Carr & Rickwood 2008). Compliance data are usually grouped into broad categories, indicating the relative acceptability of different levels of compliance. For example, a low count of bacteria would be 'Excellent' while a 'Poor' rating would indicate high levels of bacteria. These methods are to be trialled in South Africa over the next few years to assess applicability and feasibility while determining target limits.

Guidelines state that samples should be collected 15-30 cm below the surface. In order to minimise contamination and reduce sediment content, samples should be collected on the seaward side of a recently broken wave (DEA 2012). Samples to be tested for *E. coli* counts should be analysed within 6-8 hours of collection, and those to be tested for intestinal *Enterococci*, within 24 hours. Analyses should be completed by an accredited laboratory, preferably one with ISO 17025 accreditation.

It is recommended that samples are analysed for intestinal *Enterococci* sp. rather than for *E. coli*. Several studies have shown thermotolerant coliforms and *E. coli* to be relatively poor indicators of health risks in marine waters. These organisms are also less resilient than *Enterococci* (and other pathogenic bacteria). Thus, if analysis is focused on coliforms, the risk could be underestimated due to mortality occurring in the time taken between collection and analysis.

In addition to this, an operational management process was recommended for South Africa, following *Enterococci* counts (Figure 5.17). A mode is assigned based on the levels of *Enterococci* in a single count (shaded green or amber) or on consecutive counts (shaded red). Each mode outlines a plan of action to be undertaken to deal with the problem.

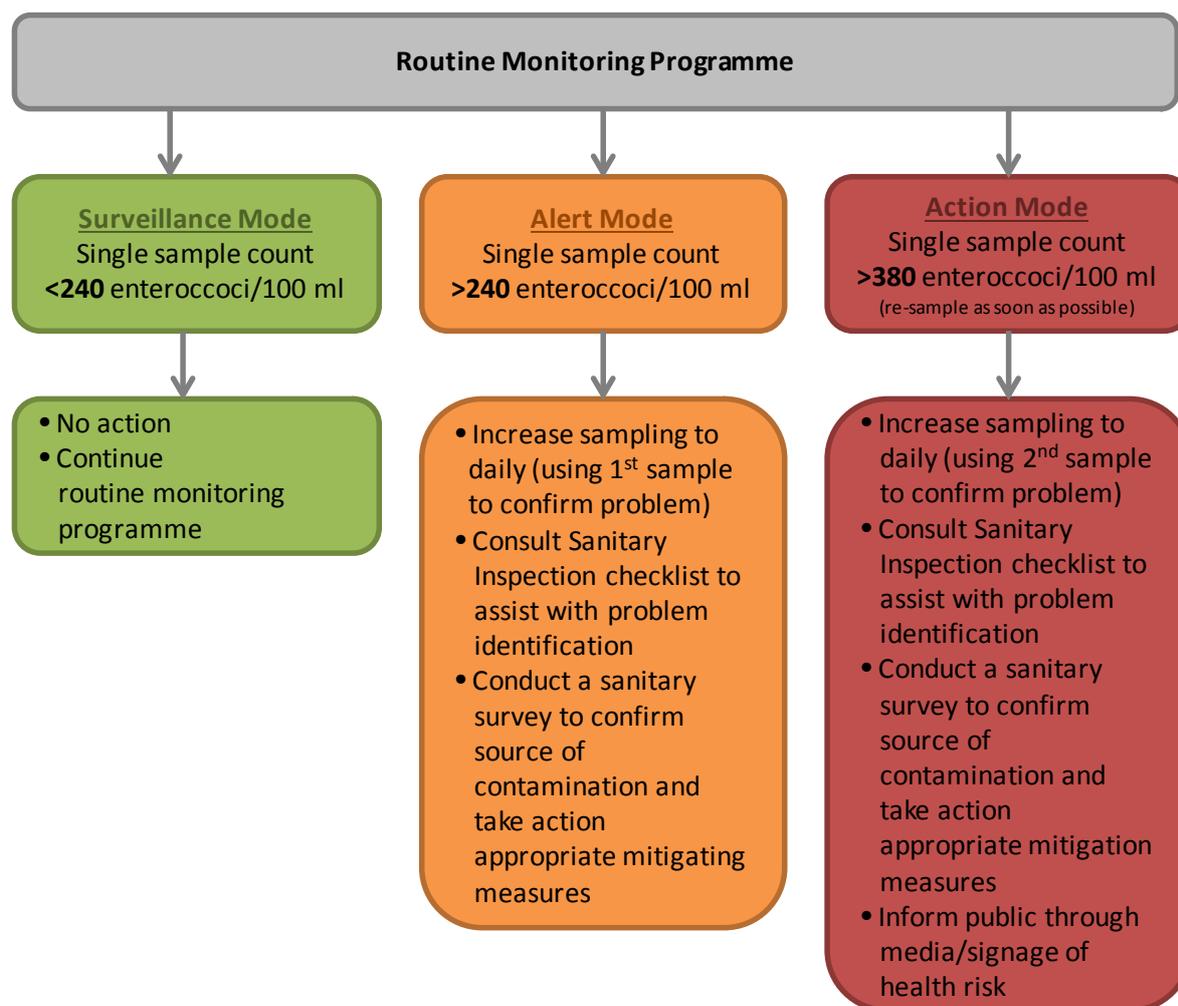


Figure 5.17 An illustration of the proposed routine monitoring programme to be trialled in South Africa. Source: South African Water Quality Guidelines for Coastal Marine Waters (DEA 2012).

The Hazen non-parametric statistical method is recommended for dealing with the microbiological data as these data do not typically fit a normal (bell shaped) distribution. The data are ranked into ascending order and then percentile values are calculated using a formula. Target limits, based on counts of intestinal *Enterococci* sp. and/or *E. coli*, for recreational water use are indicated below (Table 5.2). In order to calculate 95th percentiles, a minimum of 10 data points are required, while the calculation of the 90th percentile estimates require only five data points.

Table 5.2 Target limits for *Enterococci* sp. and *E. coli* based on revised final guidelines for recreational waters of South Africa's coastal marine environment (DEA 2012). The probability of contracting a gastrointestinal illness (GI) is also listed.

Category	Estimated risk per exposure	Enterococci (count/100 ml)	<i>E. coli</i> . (count/100ml)
Excellent	2.9% GI risk	≤ 100 (95 percentile)	≤ 250 (95 percentile)
Good	5% GI risk	≤ 200 (95 percentile)	≤ 500 (95 percentile)
Sufficient/Fair (min. requirement)	8.5% GI risk	≤ 185 (90 percentile)	≤ 500 (90 percentile)
Poor (unacceptable)	>8.5 % GI risk	>185 (90 percentile)	>500 (90 percentile)

The *Guidelines for Inland and Coastal Waters: Volume 4 Mariculture* (DWA 1995) provides target levels for faecal coliforms in water bodies used for mariculture as these filter feeding organisms such as shellfish can accumulate pathogenic organisms in their bodies and thereby infect people that consume them (Table 5.3).

Table 5.3 Maximum acceptable count of faecal coliforms (per 100 ml sample) for mariculture according to the DWA 1995 guidelines (DWA 1995).

Purpose/Use	Guideline value
Mariculture	20 faecal coliforms in 80% of samples 60 faecal coliforms in 95% of samples

5.9.2 Microbial monitoring in Saldanha Bay and Langebaan Lagoon

In 1998 the CSIR were contracted by the Saldanha Bay Water Quality Forum Trust (SBWQFT) to undertake fortnightly sampling of microbiological indicators at 15 stations within Saldanha Bay. The initial report by the CSIR, covering the period February 1999 to March 2000, revealed that within Small Bay, faecal coliform counts frequently exceeded the guidelines for both mariculture and contact recreation (the 1995 guidelines of 100 faecal coliforms occurring in 80% of samples analysed) at nine of the 10 sampling stations. These results indicated that there was indeed a health risk associated with the collection and consumption of filter feeding shellfish (mussels) and with contact recreation in Small Bay. Much lower faecal coliform counts were recorded at stations within Big Bay, with the exception of the 80th percentile guideline for mariculture being exceeded at one station (Paradise beach). All other stations ranged within the guidelines for mariculture and recreational use (Monteiro *et al.* 2000).

Regular monitoring of microbiological indicators within Saldanha Bay has continued to the present day and is now undertaken by the Saldanha Bay Municipality (SBM). The available data covers the period February 1999 to July 2015 for 20 stations (10 in Small Bay, 5 in Big Bay and 5 in Langebaan Lagoon). Data during this period has, for the most part, been collected on a monthly or bimonthly basis since 1999 at 14 stations within Small and Big Bay in Saldanha, with the exception of Station 11 (Seafarm – Transnet-NPA) where no data were collected during 2003, 2004, 2008, 2010 and 2011.

Regular data collection was initiated at some of the Langebaan sites in 2004. Samples were collected at Stations 19 and 20 (Kraalbaai North and South respectively) for the first time in 2012. Compliance with mariculture guidelines were assessed using faecal coliform counts and the DWAF 1995 guidelines, whilst recreational use compliance was assessed using *E. coli* count data and the DEA 2012 guidelines.

5.9.3 Water quality for recreational use

Recreational water quality rankings for all sampled sites throughout Saldanha Bay and Langebaan lagoon are shown in Table 5.4, whilst Figure 5.18 and Figure 5.19 graphically depict these data for Langebaan Lagoon. Compliance with mariculture guidelines that are more stringent than recreational guidelines are given in Section 5.9.4 and graphically depicted for Small Bay and Big Bay in Figure 5.20 - Figure 5.23.

Data from the microbial monitoring programme suggest that nearshore coastal waters in Saldanha Bay have improved considerably for recreational use since 2005 (Table 5.4). Based on the 2015 *E. coli* data, 18 of the 20 sampled stations are categorized as having excellent water quality. The Bok River Mouth site was ranked as having 'Good' water quality, which is the same ranking that was allocated to this site in 2014, and represents a sustained improvement on the 'Poor' ranking this site received in many earlier years (Table 5.4). In terms of recreational water use, the only area of concern highlighted in the 2015 data is the Hoedtjies Bay Hotel Beach site, where the water quality was classified as unacceptable (90th percentile value of > 500 *E.coli* per 100ml). This represents a deterioration in water quality from the 2013 ('Fair') and 2014 ('Good') situation (Table 5.4).

The 2012 State of the Bay report raised some concern over water quality in the Mykonos- Langebaan North area when 'Fair' or 'Poor' ratings were applicable at these sites (Table 5.4). The source of this microbiological pollution appears to have been addressed as a consistent improvement has been seen at these sites that are all ranked as having 'Excellent' water quality in 2015 (Table 5.4). Although *E.coli* counts in 2015 were low and water quality is rated 'Excellent', there is a trend of increasing values in the latter half of the time series at the Leentjiesklip and Langebaan Main Beach sites that reflects increased pollution inputs over time (Figure 5.18). Ongoing efforts to maintain the good water quality at these popular swimming and water sport sites must be encouraged. For recreational use, water quality at other Lagoon sites (Kraal Bay & Tooth Rock) remain 'Excellent' (Figure 5.19).

Table 5.4 Sampling site compliance for recreational use based on E. coli counts for 10 sites in Small Bay, 5 sites in Big Bay and 5 sites in Langebaan Lagoon. Ratings are calculated using Hazen percentiles with the 90th and 95th percentile results grouped together to give an overall rating per annum. 'ID' indicates that samples were collected that year, but there were insufficient data to allow calculation of Hazen percentiles. 'ND' indicates that no data were collected in that year and 'Ex.' indicates excellent water quality.

	Site	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	
Small Bay	1. Beach at Mussel Rafts	Fair	ID	Ex.															
	2. Small Craft Harbour	Ex.	ID	Good	Ex.	Ex.	Ex.	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Good	Ex.	Ex.	Ex.	
	3. Sea Harvest - Small Quay	Fair	ID	Ex.	Ex.	Fair	Ex.	Fair	Ex.	Ex.	Ex.	Good	Ex.	Fair	Ex.	Ex.	Ex.	Ex.	
	4. Saldanha Yacht Club	Poor	Poor	Poor	Fair	Poor	Poor	Poor	Ex.										
	5. Pepper Bay - Big Quay	Poor	ID	Poor	Fair	Fair	Fair	Fair	Poor	Ex.	Ex.	Fair	Ex.	Ex.	Good	Ex.	Ex.	Ex.	
	6. Pepper Bay - Small Quay	Poor	ID	Fair	Good	Ex.	Good	Ex.	Ex.	Good	Ex.	Good	Good	Ex.	Good	Fair	Fair	Ex.	
	7. Hoedjies Bay Hotel - Beach	Fair	ID	Poor	Fair	Good	Poor	Poor	Good	Fair	Ex.	Fair	Fair	Poor	Poor	Fair	Good	Poor	
	8. Beach at Caravan Park	Fair	ID	Fair	Poor	Ex.	Fair	Poor	Ex.	Good	Poor	Fair	Fair	Fair	Poor	Good	Fair	Ex.	
	9. Bok River Mouth - Beach	Poor	ID	Poor	Poor	Poor	Poor	Poor	Poor	Ex.	Fair	Poor	Poor	Good	Ex.	Poor	Fair	Good	Good
	10. General Cargo Quay - TNPA	Ex.	ID	Ex.	Ex.	Ex.	Ex.	Ex.	Good	Ex.									
Big Bay	11. Seafarm - TNPA	Ex.	ID	Ex.	Ex.	ND	ND	Ex.	Ex.	Ex.	ND	Ex.	ND	ND	Ex.	Ex.	Ex.	Ex.	
	12. Mykonos - Paradise Beach	Ex.	ID	Ex.															
	13. Mykonos - Harbour	Fair	ID	Ex.	Ex.	Fair	Ex.	Fair	Ex.	Ex.	Good	Ex.							
	14. Leentjiesklip	ND	ND	Good	Fair	Good	Ex.	Fair	Ex.	Good	Ex.								
Langebaan Lagoon	15. Langebaan North - Leentjiesklip	Ex.	ID	Good	Ex.	Poor	Good	Ex.	Ex.										
	16. Langebaan - Main Beach	ND	ND	Fair	Ex.	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.							
	17. Langebaan Yacht Club	ND	ND	ND	ND	ND	Poor	Ex.	Good	Ex.	Ex.								
	18. Tooth Rock	ND	ND	ND	ND	ND	ID	Ex.	Ex.	Ex.	Ex.	Fair	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	
	19. Kraalbaai North	ND	Ex.	Ex.	Good	Ex.													
	20. Kraalbaai South	ND	Ex.	Ex.	Ex.	Ex.													

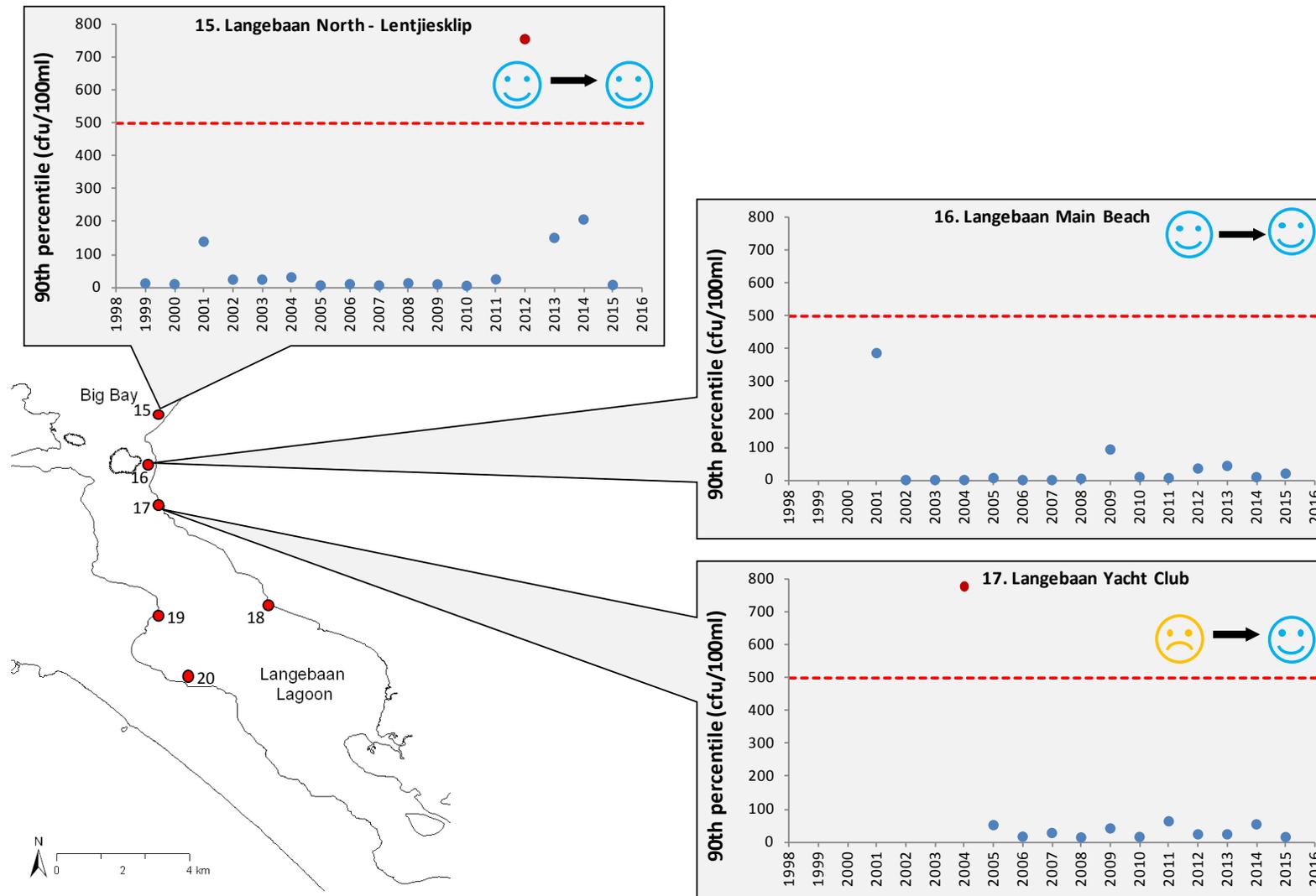


Figure 5.18 Hazen method 90th percentile values of *E.coli* counts at three of the 6 sampling stations within Langebaan Lagoon (Feb 1999 - July 2015). The red line indicates the Hazen method 90th percentile contact recreation limit of *E.coli* counts (500 cfu/100ml) above which water quality is ranked as 'Poor/Unacceptable'. Red data points indicate 90th percentile values exceeding the guideline, whilst blue data points fall within the recommended guideline. The smiley faces correspond to changes in *E.coli* counts over time. cfu: colony-forming units.

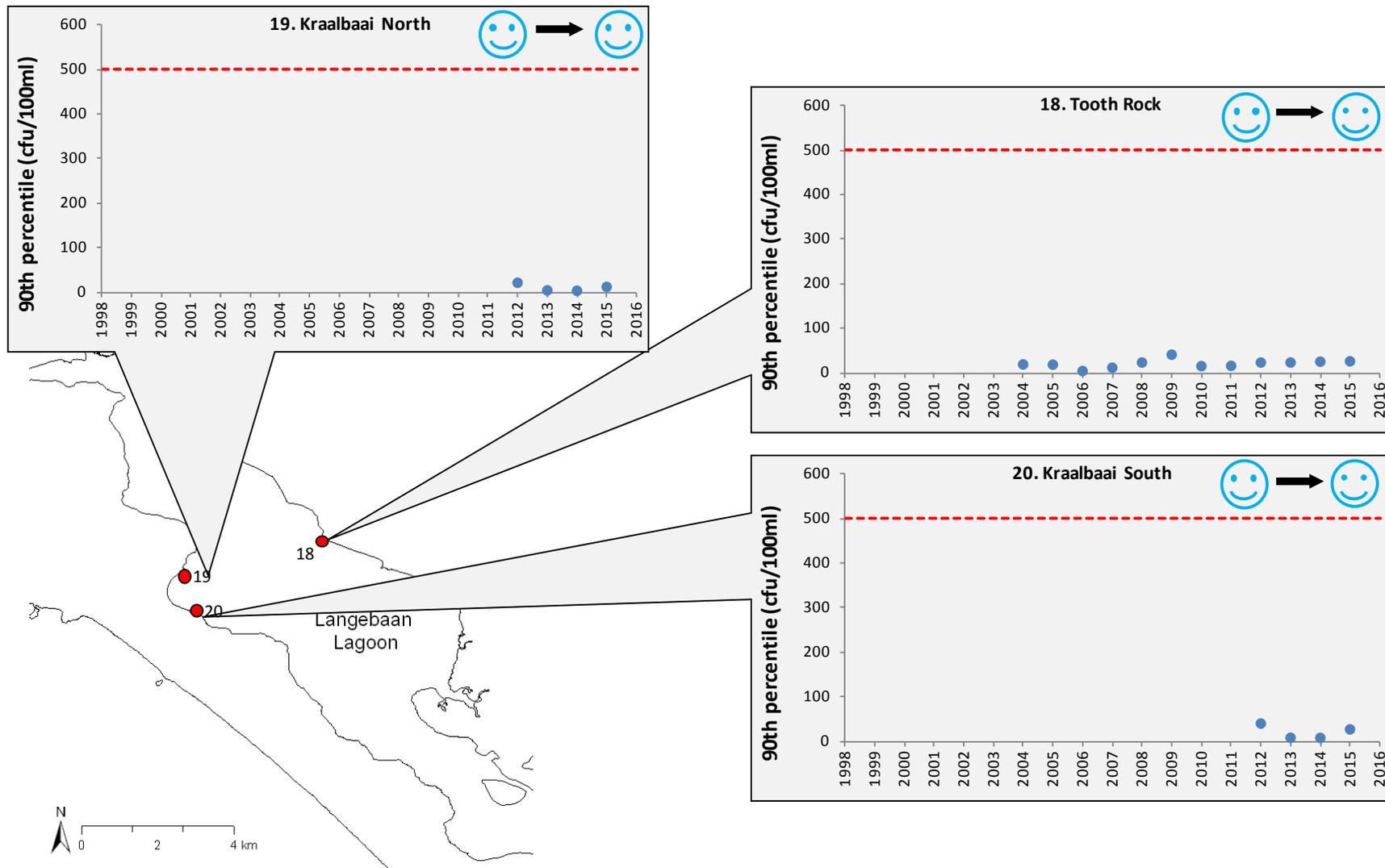


Figure 5.19 Hazen method 90th percentile values of *E.coli* counts at three of the 6 sampling stations within Langebaan Lagoon (Feb 1999 - July 2015). The red line indicates the Hazen method 90th percentile contact recreation limit of *E.coli* counts (500 cfu/100ml) above which water quality is ranked as 'Poor/Unacceptable'. Red data points indicate 90th percentile values exceeding the guideline, whilst blue data points fall within the recommended guideline. The smiley faces correspond to changes in *E.coli* counts over time. cfu: colony-forming units.

5.9.4 Water quality for mariculture

Guideline limits for mariculture are much stricter than the recreational guideline limits, thus levels of compliance for mariculture were predictably much lower. A total of six sites along the western and northern shore of Small Bay (Sites 4 - 9) were not compliant in respect of the 80th percentile limits for faecal coliforms (Figure 5.20, Figure 5.21 and Figure 5.22). Five of these six sites were also not compliant with the 95th percentile mariculture guideline limits in 2015 (the Saldanha Yacht club was compliant, whilst the Small Quay – Sea Harvest site exceeded the 95% guideline). These data indicate that there remains an issue of water quality with respect to mariculture operations within Small Bay. The areas of particular concern are the Hoedjies Bay, Caravan Park Beach and Bok River Mouth sites that are not showing any improvement towards meeting the guideline over the last 15 years, and continue to exceed the guidelines by a substantial margin (Figure 5.21 and Figure 5.22).

It must be stressed that these samples are collected from the shore and are much closer to sources of contamination (stormwater drains etc.). They are also in relatively shallow water, hence concentrations of microbiological contaminants are likely to be higher than those near the mariculture rafts that are located some distance offshore. Nonetheless the exceedance of mariculture water quality guidelines in near-shore waters remains a concern, particularly in light of the proposed mariculture growth in the area. Land-based mariculture facilities (potentially located in the IDZ) will have to extract water from Small Bay, and the prevailing poor water quality near-shore means that sea water extraction will have to take place further offshore at increased cost.

At the other sites within Small Bay, water quality has either remained well within the guidelines (Beach at Mussel Rafts, Small Craft harbour, General Cargo Quay) or a sustained improvement in levels of compliance with the guidelines for mariculture has occurred since the earlier 1999-2005 period (Figure 5.20, Figure 5.21). The most noticeable improvements have been at the Small Quay-Sea Harvest, the Saldanha Bay Yacht Club and the Pepper Bay sites (Figure 5.20 and Figure 5.21). Faecal coliform counts do remain above guideline levels at three of these four sites, but they have come down considerably and do not exceed the guidelines by a large margin in recent surveys (Figure 5.20 and Figure 5.21).

Faecal coliform counts at all four sites sampled within Big Bay in 2015 were well within both the 80th and 90th percentile limits for mariculture (Figure 5.23). There has been no discernible trend over time at these four sites with the exception of a dramatic decrease in faecal coliform counts after the first three (2001-2003) sampling events at Leentjiesklip. The water quality in Big Bay has met mariculture guidelines in nearly every year since 2004, with the exception of the Mykonos Harbour site when levels were marginally exceeded only in 2009 and 2011.

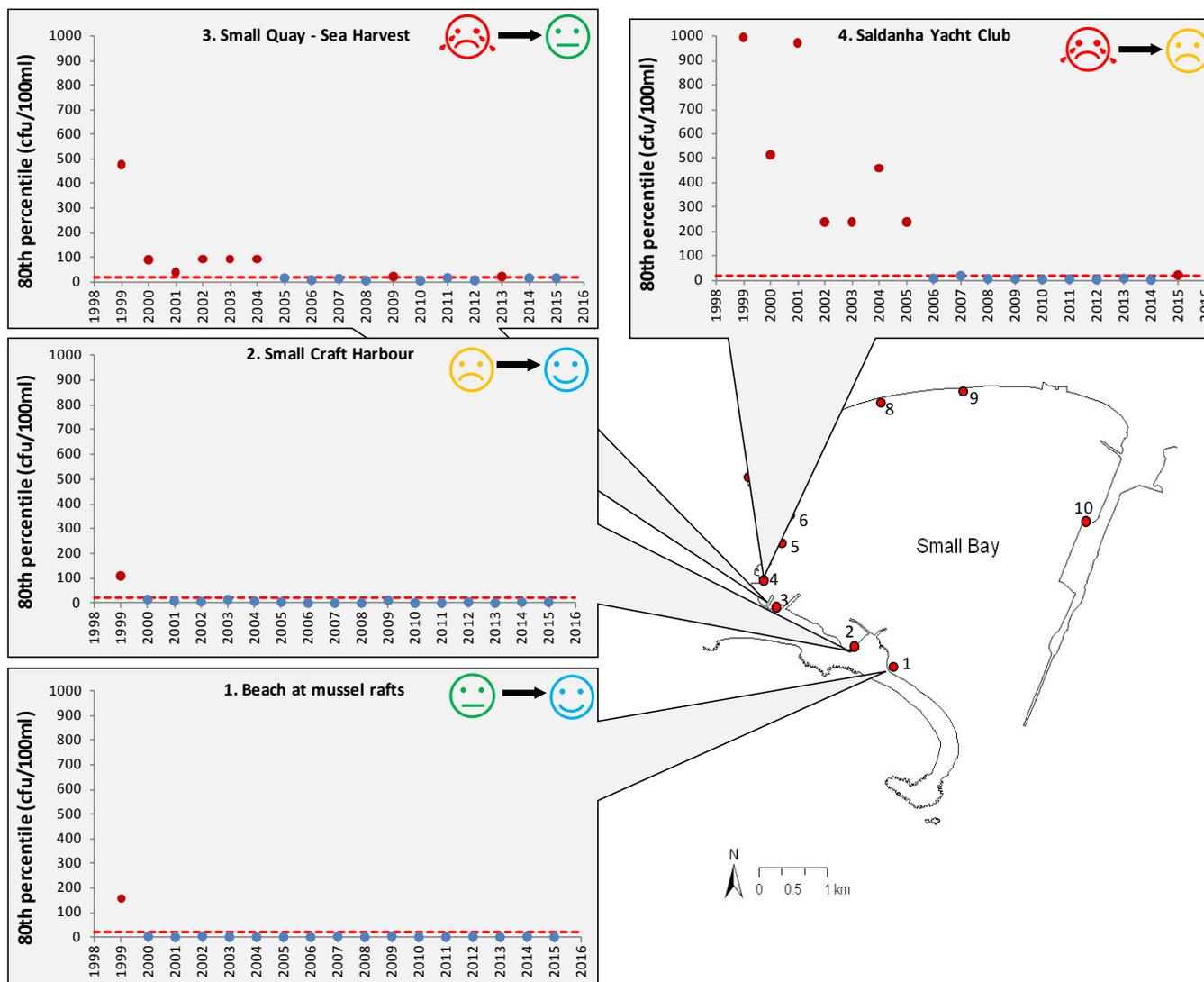


Figure 5.20 80th percentile values of faecal coliform counts at four of the 10 sampling stations within Small Bay (Feb 1999 - July 2015). The red line indicates the 80th percentile mariculture limit of faecal coliforms (20 cfu per100ml). Red data points indicate 80th percentile values exceeding the guideline, whilst blue data points fall within the recommended guideline. The smiley faces correspond to changes in faecal coliform counts over time. cfu: colony-forming units.

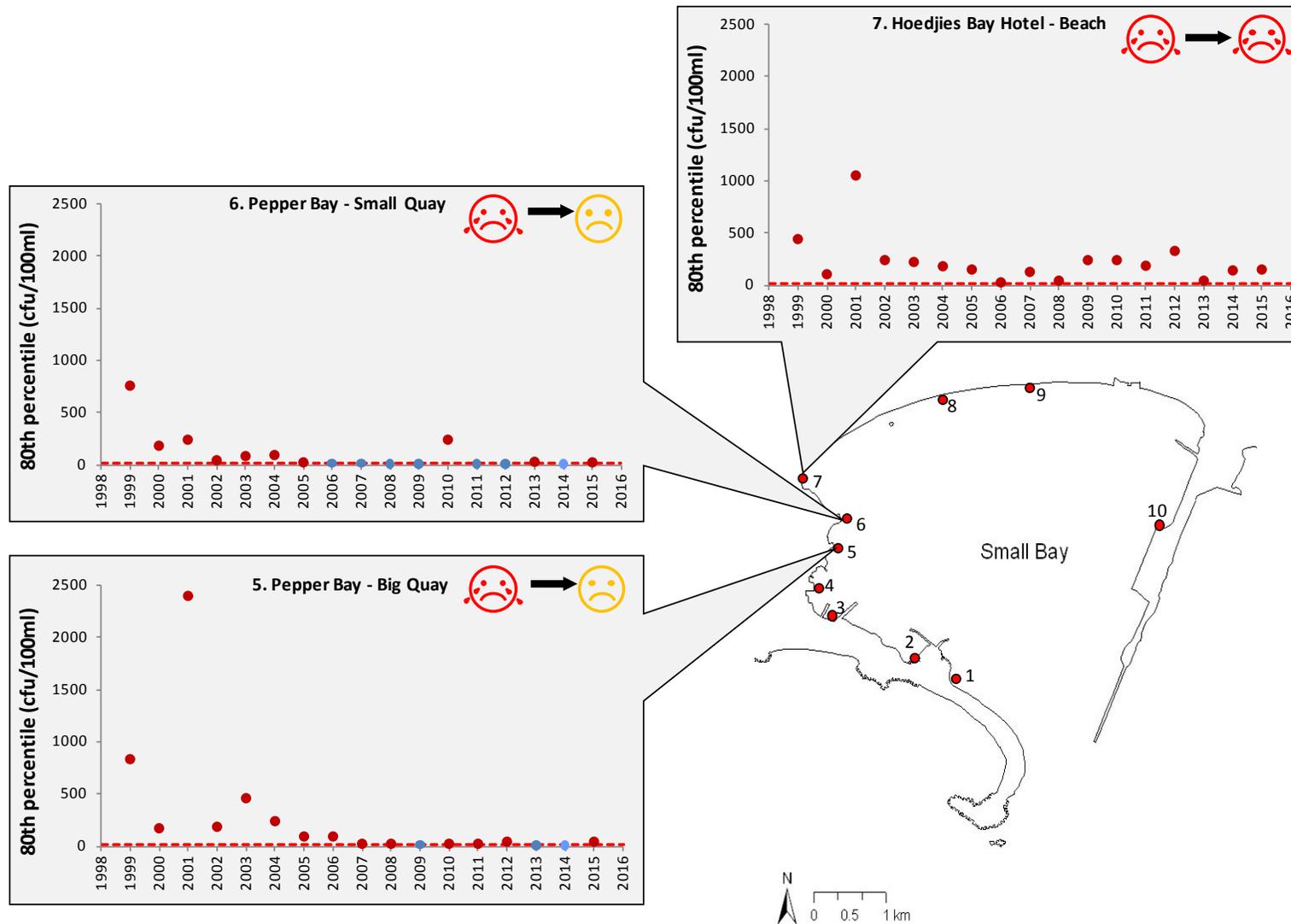


Figure 5.21 80th percentile values of faecal coliform counts at three of the 10 sampling stations within Small Bay (Feb 1999 - July 2015). The red line indicates the 80th percentile mariculture limit of faecal coliforms (20 cfu per 100ml). Red data points indicate 80th percentile values exceeding the guideline, whilst blue data points fall within the recommended guideline. The smiley faces correspond to changes in faecal coliform counts over time. cfu: colony-forming units.

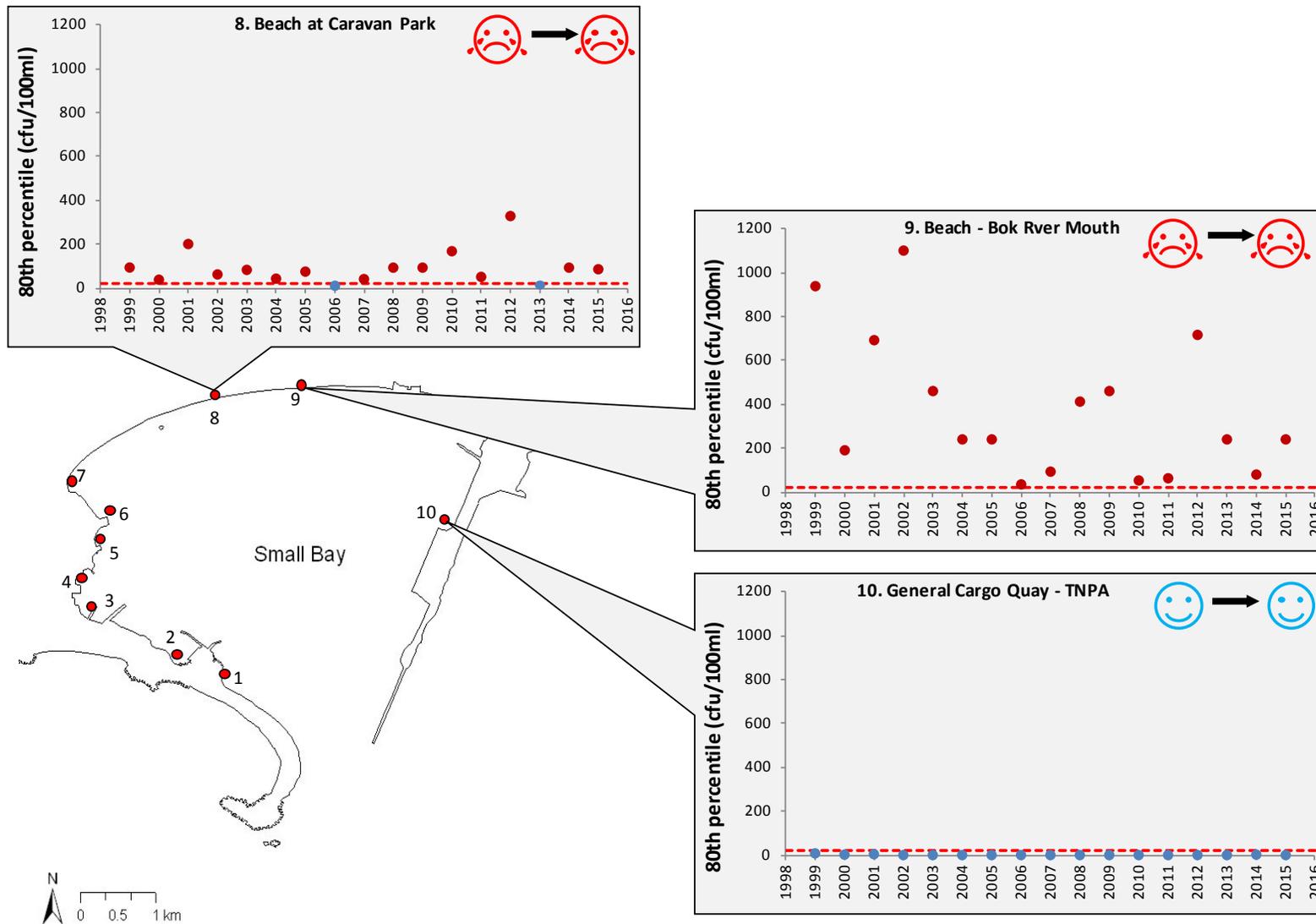


Figure 5.22 80th percentile values of Faecal coliform counts at three of the 10 sampling stations within Small Bay (Feb 1999 - July 2015). The red line indicates the 80th percentile mariculture limit of faecal coliforms (20 cfu per100ml). Red data points indicate 80th percentile values exceeding the guideline, whilst blue data points fall within the recommended guideline. The smiley faces correspond to changes in faecal coliform counts over time. cfu: colony-forming units.

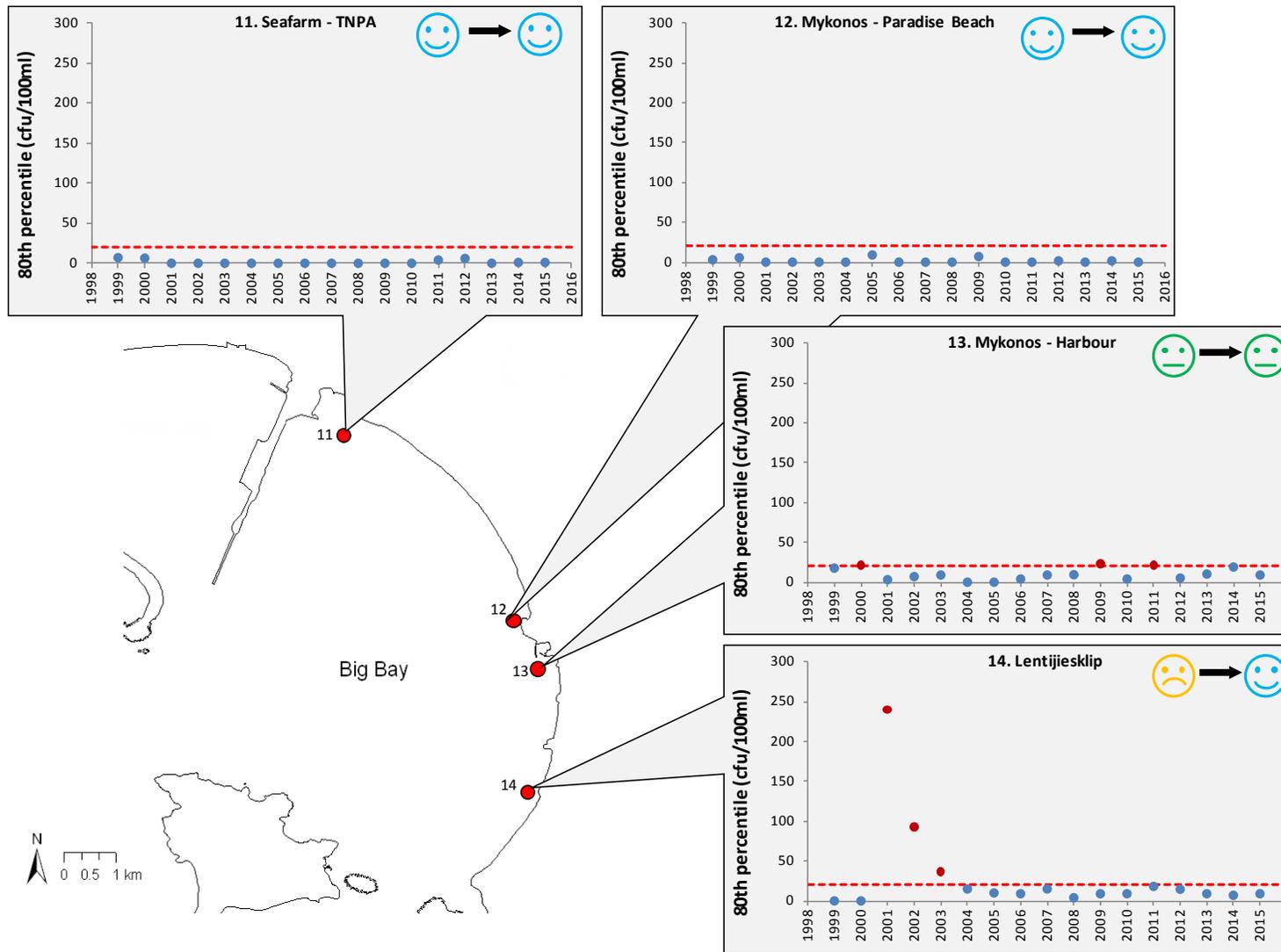


Figure 5.23 80th percentile values of Faecal coliform counts at the four sampling stations within Big Bay (Feb 1999 - July 2015). The red line indicates the 80th percentile mariculture limit of faecal coliforms (20 cfu per 100ml). Red data points indicate 80th percentile values exceeding the guideline, whilst blue data points fall within the recommended guideline. The smiley faces correspond to changes in faecal coliform counts over time. cfu: colony-forming units.

5.10 Trace metal contaminants in the water column

There is an increasing global trend emerging in countries like Canada, Australia, New Zealand and South Africa to monitor the long-term effects of water quality by assessing impacts on specific marine species or species assemblages. Mussels and oysters (i.e. filter feeding organisms) are considered to be good indicator species for the purpose of monitoring water quality as they tend to accumulate trace metals, hydrocarbons and pesticides in their flesh. Mussels are sessile organisms (anchored in one place for their entire life) and will be affected by both short-term and long-term trends in water quality. Monitoring the contaminant levels in mussels can therefore provide an early warning of poor water quality and dramatic changes in contaminant levels in the water column.

Trace/heavy metals are often regarded as pollutants of aquatic ecosystems. However, they are naturally occurring elements, some of which (e.g. copper & zinc) are required by organisms in considerable quantities (Phillips 1980). Aquatic organisms accumulate essential trace metals that occur naturally in water as a result of, for example, geological weathering. All of these metals, however, have the potential to be toxic to living organisms at elevated concentrations (Rainbow 1995). Human activities greatly increase the rates of mobilization of trace metals from the earth's crusts and this can lead to increases in their bioavailability in coastal waters via natural runoff and pipeline discharges (Phillips 1995). Dissolved metal concentrations in water are typically low (presenting analytical problems), have high temporal and spatial variability (e.g. with tides, rainfall events etc.) and most importantly reflect the total metal concentration rather than the portion that is available for uptake by aquatic organisms (Rainbow 1995). Measuring metal concentrations in sediments resolves some of the analytical and temporal variability problems as metals accumulate in sediments over time and typically occur at higher concentrations than dissolved levels, but this still does not reflect their bioavailability. Measuring metal concentrations in the tissues of aquatic organisms appears to be the most suitable method for assessing ecotoxicity as the metals are frequently accumulated to high (easily measurable) concentrations and reflect a time-integrated measure of bioavailable metal levels (Rainbow 1995).

Filter feeding organisms such as mussels of the genus *Mytilus* have been successfully used as bio-indicator organisms in environmental monitoring programs throughout the world (Kljaković-Gašpić *et al.* 2010). These mussels are abundant, have a wide spatial distribution, are sessile, are able to tolerate changes in salinity, are resistant to stress, and have the ability to accumulate a wide range of contaminants (Phillips & Rainbow 1993, Desideri *et al.* 2009, Kljaković-Gašpić *et al.* 2010).

Elevated levels of cadmium reduce the ability of bivalves to efficiently filter water and extract nutrients, thereby impeding successful metabolism of food. Cadmium can also lead to injury of the gills of bivalves further reducing the effectiveness of nutrient extraction. Similarly, elevated levels of lead result in damage to mussel gills, increased growth deficiencies and possibly mortality. Elevated levels of zinc are known to suppress growth of bivalves at levels between 470 to 860 mg/l and can result in mortality of the mussels (DEA 1995d).

In 1985 the MCM initiated a "Mussel Watch" Programme whereby mussels (either brown mussels *Perna perna* or Mediterranean mussels *Mytilus galloprovincialis*) were collected every six months (Apr/May and October) from 26 coastal sites. Mussels were collected periodically from five stations in Saldanha Bay. According to DEA, challenges in processing the mussel samples have resulted in data from the Saldanha Bay Mussel Watch programme only being available between 1997-2001 and

2005-2007. No new data have been received since 2007 despite the fact that the programme was due to resume in late 2014. In the interim, Anchor Environmental Consultants collected mussel samples from the same five sites during the field surveys in April 2014 and April 2015. The mussel samples were analysed for the metals lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn).

Data from the mussel watch programme and from the April 2014 and April 2015 collections by Anchor Environmental Consultants are represented in Figure 5.24 to Figure 5.30 below. The maximum legal limits prescribed for each contaminant in shellfish for human consumption in South Africa, as stipulated by the Regulation R.500 (2004) published under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act 54 of 1972), are indicated in red text. Where limits have not been specified in national legislation, those adopted by other countries have been used (Table 5.5).

Data showed that concentrations of lead in mussels at the Portnet site were consistently above the regulatory limit for foodstuffs, with values averaging more than 135 ppm (Figure 5.24). Values spiked to very high levels at this site in May 1999 (252.5 ppm) and October 2001 (714.6 ppm). This site is situated at the base of the iron ore terminal on the Small Bay side. The high levels of lead are almost certainly linked to the export of lead ore from the multipurpose quay, which is situated in close proximity to the Portnet site. The concentration of lead was generally below 10 ppm at the other sites, although values spiked to 250 ppm at the Mussel Raft in October 2000. Compared to the limit of 0.5 ppm, these levels were extremely high. Although concentrations dropped to an average of 1.3 ppm over all the sites in 2014, they increased again at all sites in 2015, resulting in an average of 7.6 ppm in 2015. While the situation is greatly improved, especially at the Port Net site, the levels of lead in mussels on average remain ~15 times value deemed as being safe for human consumption.

Concentrations of cadmium frequently exceeded the regulatory limit of 3 ppm at all sites (Figure 5.25). Levels of cadmium in mussels from Saldanha Bay fluctuated less than those of lead and ranged between 1-10 ppm, but occasionally exceeded this level with a maximum reading of 49.3 ppm in April 2007 at the Mussel Rafts. The concentration of cadmium in mussels tissue collected at all sites in 2015 averaged 7 ppm, which is high relative to the limits (more than double) and remains a human health concern.

Zinc concentrations in mussel tissue collected in 2015 were higher than the 150 ppm regulatory limit listed by the Canadian Authorities (Table 5.5) at Portnet, Fish Factory and Saldanha Bay North; while those at the Mussel Raft and the Iron Ore Jetty were below this value (Figure 5.26). The values observed in 2015 were well within the historical range indicating little change over time. In contrast with lead, cadmium and zinc, concentrations of copper remain well below the specified level of 70 ppm at all sites in 2015. The maximum value recorded for copper was 18.1 ppm at Mussel Raft 27/28 in 2014. No regulatory limits exist for manganese, which reached a maximum of 11.3 ppm at Saldanha Bay North in May 1999. All values measured in 2015 were below 6 ppm and well within the observed historical range (Figure 5.28).

Iron poisoning is usually only associated with the over consumption of iron supplements with toxic effects evident with ingestion of 10–20 mg/kg body weight of elemental iron (<http://www.webmd.com/a-to-z-guides/iron-poisoning>). As there are no official guideline limits for the safe concentration of iron present in foodstuffs, it is not possible to comment on the suitability of these mussels for consumption based on this trace metal. Average values were highest at

Saldanha Bay North and fish factory sites and lowest at the Mussel Raft. In 2015 iron concentration in mussel tissue had decreased from 2014 values at all sites except for the Fish Factory site where it was the highest recorded to date (Figure 5.29). There is no record of acute toxicity of iron ingested by humans in regular foodstuffs and excess iron is not stored by the body. Iron ore is processed in Saldanha Bay on a large scale and iron ore residue is apparent on all structures in vicinity of Saldanha Steel processing plant. Thus, it is recommended that the concentration of this substance in the flesh of bivalves continue to be monitored to flag any sharp increases over time. Overall, no clear trends of trace metal contamination in the flesh of bivalves in Saldanha Bay were evident over time.

Table 5.5 Regulations relating to maximum levels for metals in molluscs in different countries.

Country	Cu (ppm)	Pb (ppm)	Zn (ppm)	As (ppm)	Cd (ppm)	Hg (ppm)
South Africa ¹		0.5		3.0	3.0	0.5
Canada ²	70.0	2.5	150.0	1.0	2.0	
Australia & NZ ³		2.0			2.0	0.5
European Union ⁴		1.5			1.0	0.5
Japan ⁵		10.0			2.0	0.2
Switzerland ²		1.0			0.6	0.5
Russia ⁶		10.0			2.0	
South Korea ²		0.3				
USA ^{7,8}		1.7			4.0	
China ⁹					2.0	
Brazil ¹⁰						0.5
Israel ¹⁰						1.0

1. Regulation R.500 (2004) published under the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act 54 of 1972)
2. Fish Products Standard Method Manual, Fisheries & Oceans, Canada (1995).
3. Food Standard Australia and New Zealand (website)
4. Commission Regulation (EC) No. 221/2002
5. Specifications and Standards for Foods. Food Additives, etc. Under the Food Sanitation Law JETRO (Dec 1999)
6. Food Journal of Thailand. National Food Institute (2002)
7. FDA Guidance Documents
8. Compliance Policy Guide 540.600
9. Food and Agricultural Import Regulations and Standards.
10. Fish Products Inspection Manual, Fisheries and Oceans, Canada, Chapter 10, Amend. No. 5 BR-1, 1995.

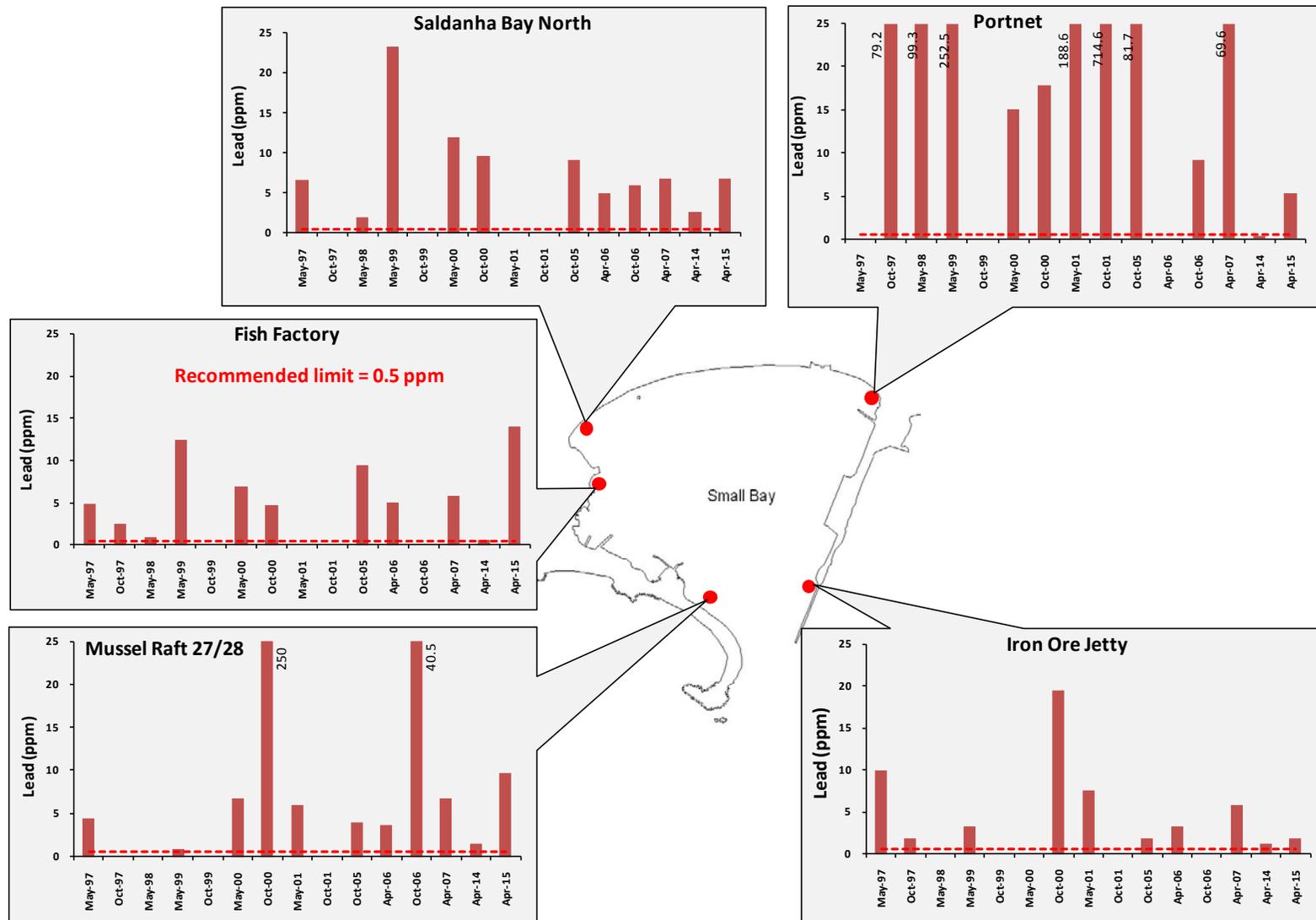


Figure 5.24 Lead concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor in 2014 and 2015. Recommended maximum limits for trace metals in seafood are shown as a dotted red line. Values exceeding 25 ppm are indicated by text alongside the data bars.

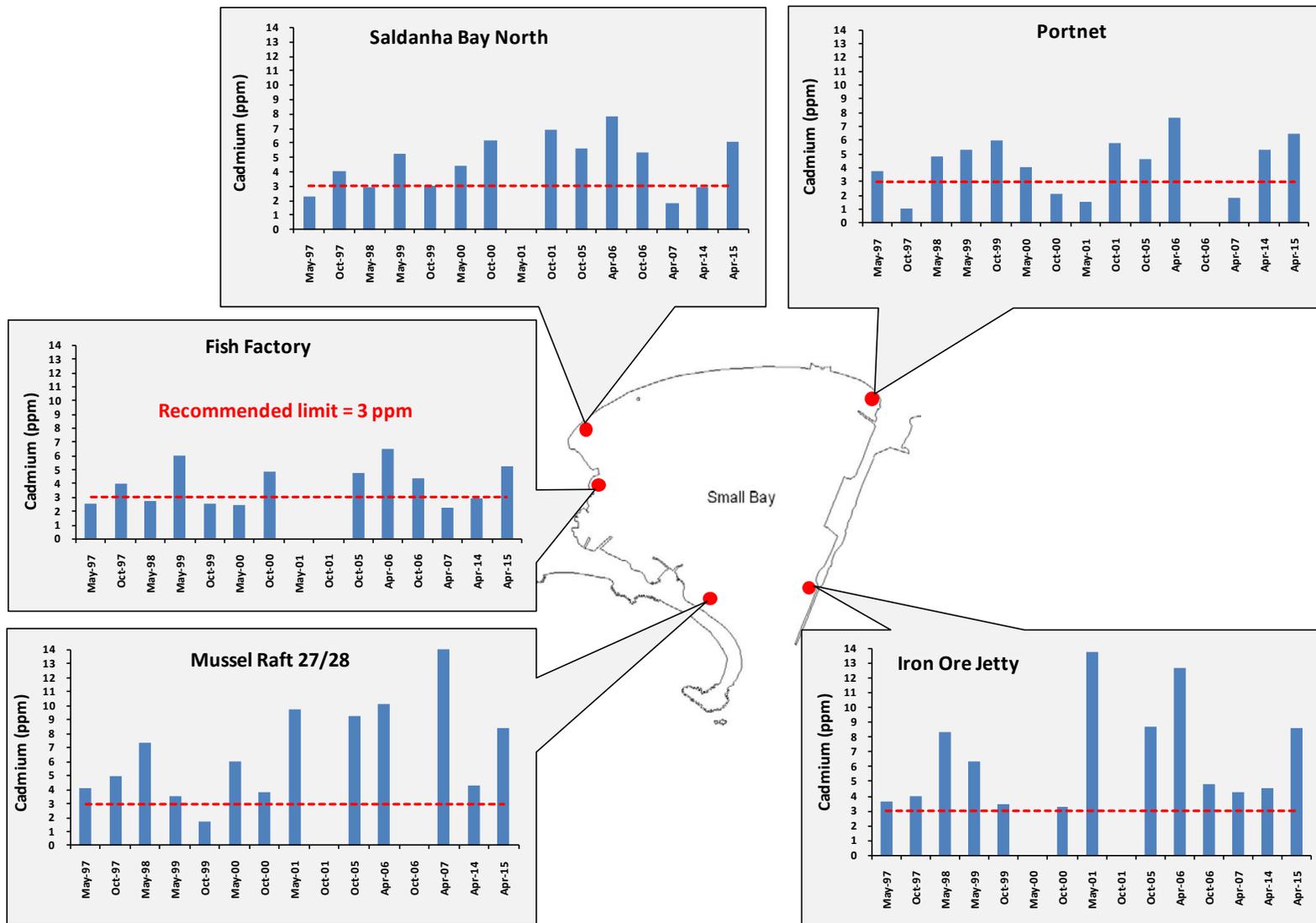


Figure 5.25 Cadmium concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor in 2014 and 2015. Recommended maximum limits for trace metals in seafood are shown as a dotted red line.

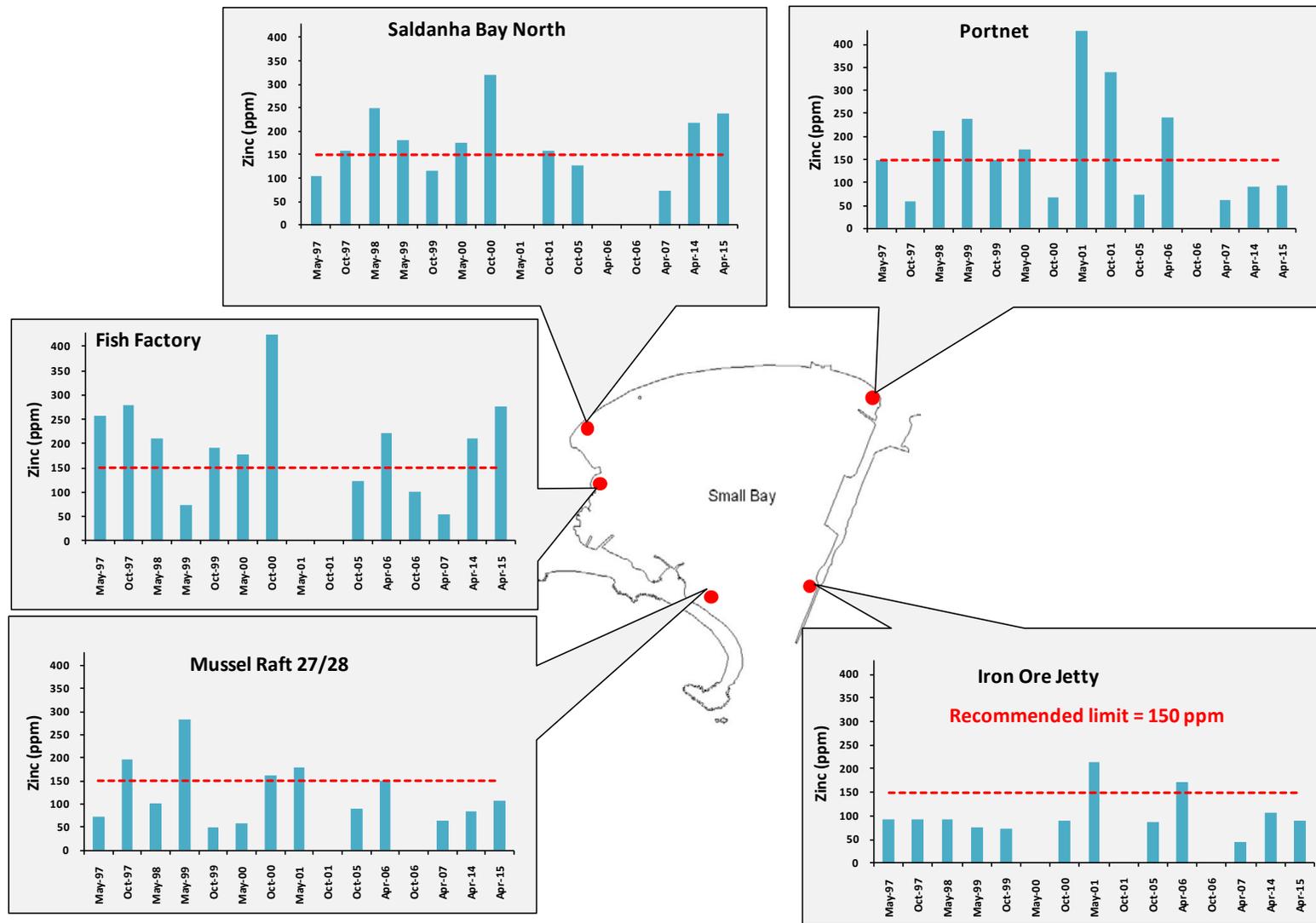


Figure 5.26 Zinc concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (source: G. Kiviets, Department of Environmental Affairs) and by Anchor in 2014 and 2015. Recommended maximum limits for trace metals in seafood are shown as a dotted red line. Values exceeding 400 ppm are indicated by text alongside the data bars.

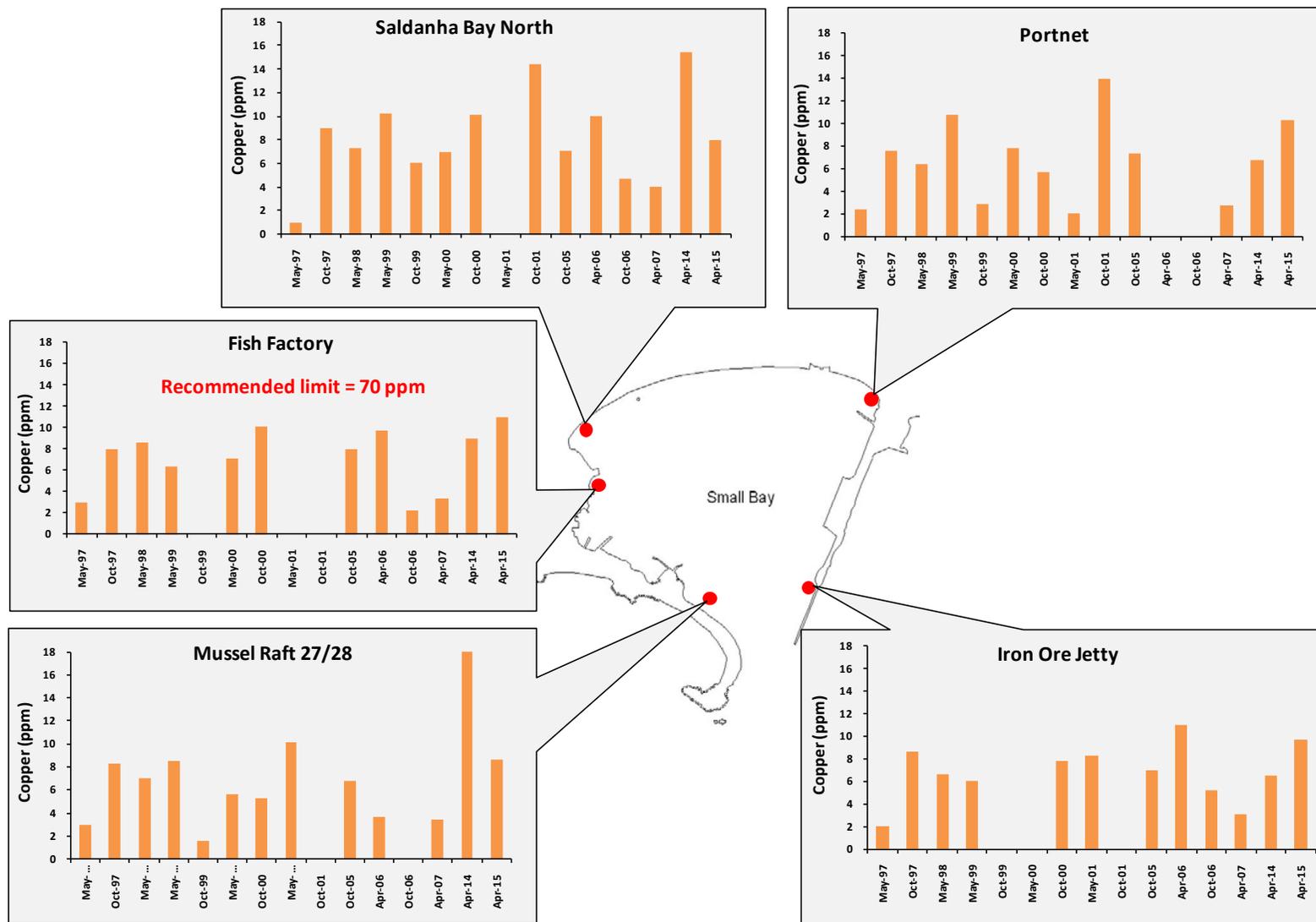


Figure 5.27 Copper concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor in 2014 and 2015.

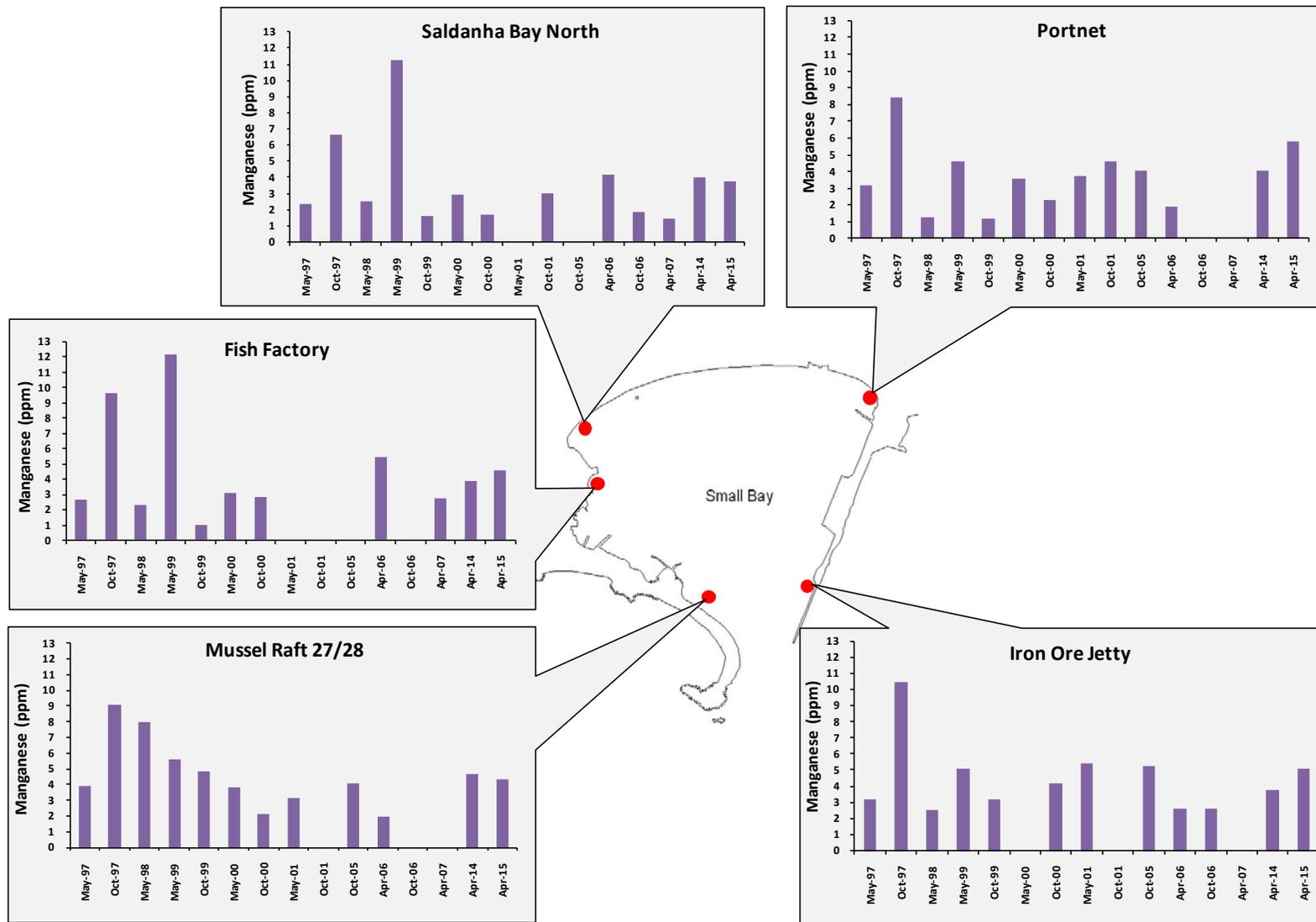


Figure 5.28 Manganese concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor in 2014 and 2015.

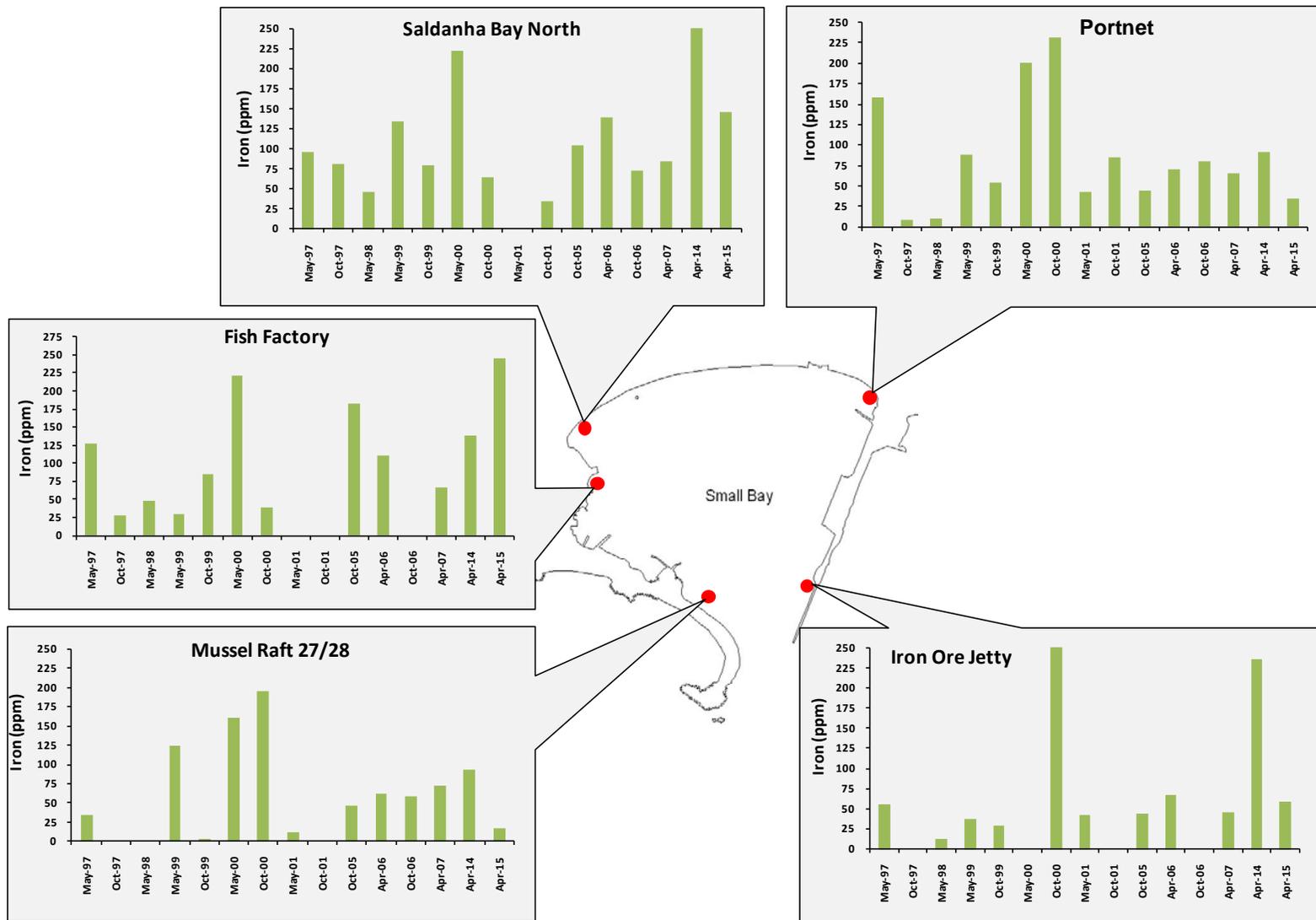


Figure 5.29 Iron concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor in 2014 and 2015.

Rights holders engaged in bivalve culture of mussels and oysters in South Africa are required to report on concentrations in harvested organisms on an annual basis. Data were obtained for four trace metal indicators (lead, cadmium, mercury and arsenic) for ten aquaculture farms in Saldanha Bay (Figure 5.30).

Concentrations of lead were generally above the regulatory limit in the period prior to 2000, with especially high levels recorded in 1988 of 5.3 ppm, 14.1 ppm and 3.9 ppm at Blue Bay Aquafarm, West Coast Oyster Growers and Striker Fishing respectively. Although these values were high, they were still much lower than those measured in nearshore mussel samples (Figure 5.24). From 2000 onwards, lead concentrations were mostly within the regulatory limit (i.e. less than 0.5 ppm); although bivalves from West Coast Aquaculture and West Coast Oyster Growers exceeded this limit on numerous occasions. Exceedance was observed at West Coast Aquaculture in 2010, 2011, 2014 and 2015 with a maximum value of 1.25 ppm over this period as well as at West Coast Oyster Growers in 2007, 2014 and 2015 with a maximum value of 1.78 ppm.

Until 2014, concentrations of cadmium had not exceeded the regulatory limit of 3 ppm, with the maximum level recorded measuring 2.90 ppm at West Coast Oyster Growers in 2011. Subsequently, the highest concentration of cadmium recorded was recorded as 3.39 ppm from oysters farmed at West Coast Oyster Growers in 2014 (Figure 5.30). This company exceeded the limit again in 2015 with a concentration of 3.14 ppm. It is advised that West Coast Oyster Growers investigate possible causes resulting in the elevated cadmium levels with a view of lowering this value below that of the regulatory limit.

Mercury concentrations have largely been within the regulatory limit of less than 0.5 ppm, apart from one or two spikes above this level. These readings were recorded at Blue Bay Aquafarm in 1994 and 2011 (1.7 and 1.0 ppm respectively), Striker Fishing in 2007 (1.1 ppm), and West Coast Aquaculture in 2009 (1.0 ppm). Since 2011, no exceedance has been recorded and all samples collected contained less than 0.04 ppm of mercury (Figure 5.30).

Samples were analysed for arsenic for the first time in 2012. Data exist for 2012 and 2013 for most farms; however, arsenic was dropped from the suite of aquaculture farm measurements in 2014 in Saldanha Bay and there are no data for the past two years. Four of the nine aquaculture farms assessed met the regulatory requirements (< 3 ppm) between 2012 and 2013. Blue Bay Aquafarm, Saldanha Bay Mussel Farmers, Saldanha Bay Oyster Company, Striker Fishing and West Coast Oyster Growers all exceeded the regulatory limit over this period (Figure 5.30), with Saldanha Bay Mussel Farmers exceeding the limit by 7 ppm. Due to the frequency of exceedance, it is recommended that the annual analysis of arsenic in the tissue of bivalves at all aquaculture farms within Saldanha Bay is reinstated.

Overall, data from these farms suggest that the situation in the deeper parts of Saldanha Bay, where the aquaculture farms are located, is less of a problem than in the nearshore coastal waters, where the Mussel Watch Programme samples are collected. Mussels are filter feeders which extract particulate matter out of the water column for food, thus, it is expected that organisms filtering clean water washing into the Bay from offshore will accumulate fewer toxins than mussels filtering contaminated water close to shore based industry. The reasons for the lower concentrations of trace metals in farmed mussels compared with those on the shore may also be linked to higher

growth rates experienced by the farmed mussels due to the availability of phytoplankton washing into the Bay, resulting in less time for the accumulation of toxins within the mussel tissue.

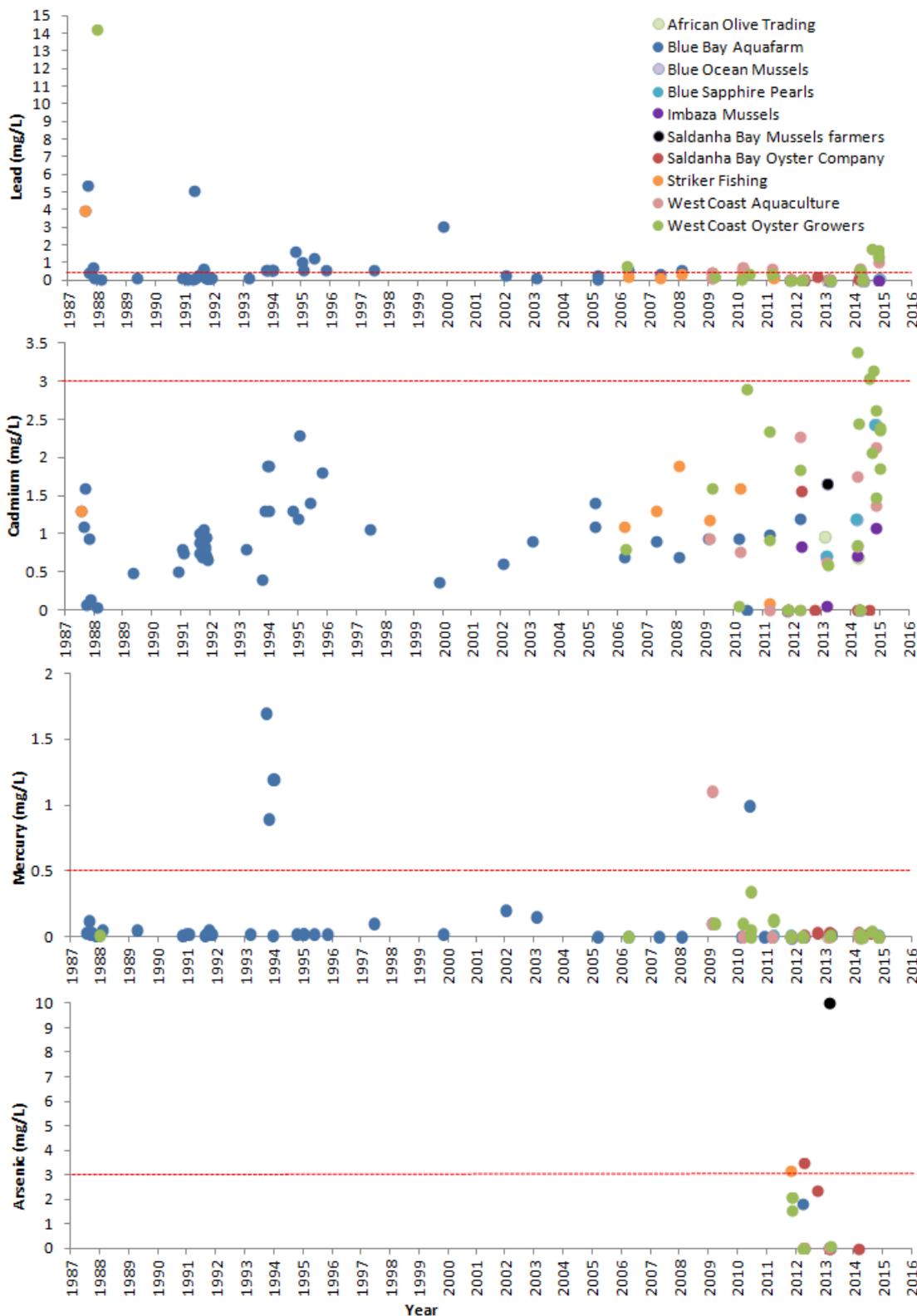


Figure 5.30 Concentrations of Lead, Cadmium, Mercury and Arsenic in bivalves from six bivalve culture operations in Saldanha Bay from 1988 to 2015. Recommended maximum limits for trace metals in seafood as stipulated in South African legislation are indicated by a dotted red line.

5.11 Summary of water quality in Saldanha Bay and Langebaan Lagoon

There are no long term trends evident in the water temperature, salinity and dissolved oxygen data series that solely indicate anthropogenic causes. In the absence of actual discharge of industrially heated sea water into Saldanha Bay, water temperature is unlikely to show any change that is discernible from that imposed by natural variability. Admittedly there is limited pre-development data (pre 1975). Although it is conceivable that construction of the causeway and ore/oil jetty has impeded water flow, increased residence time, increased water temperature, decreased salinity and decreased oxygen concentration (particularly in Small Bay); there is little data to support this. Given that cold, nutrient rich water influx during summer is density driven; dredging shipping channels could have facilitated this process which would be evident as a decrease in water temperature and salinity and an increase in nitrate and chlorophyll concentrations. Once again there is little evidence of this in the available data series. Natural, regional oceanographic processes (wind driven upwelling or down welling and extensive coast to bay exchange), rather than internal, anthropogenic causes, appear to remain the major factors affecting physical water characteristics in Saldanha Bay. The construction of physical barriers (the iron ore/oil jetty and the Marcus Island causeway) do appear to have changed current strengths and circulation within Small Bay, resulting in increased residence time (decreased flushing rate), enhanced clockwise circulation and enhanced boundary flows. There has also been an increase in sheltered and semi-sheltered wave exposure zones in both Small and Big Bay subsequent to harbour development.

The microbial monitoring program provides evidence that while chronic problems with faecal coliform pollution were present in the early parts of the record, conditions have improved considerably since this time. Currently, 18 of the 20 monitoring stations in the Bay are rated as having 'Excellent' water quality, one site (the Bok River Mouth) is rated as 'Good, while Hoedjiesbaai is rated as 'Poor/Unacceptable'. Both of these sites are located in Small Bay. There is also a concerning trend of increasing faecal coliform levels at two popular recreational sites in Big Bay (Leentjiesklip and Langebaan Main Beach) and the authorities are advised to remain vigilant.

Guideline limits for mariculture are much stricter than the recreational guideline limits, thus levels of compliance for mariculture were predictably much lower. Data for 2015 did, however, indicate substantial improvements relative to previous years. Six sites of the ten sites in Small Bay (Sites 4 - 9) were not compliant in respect of the 80th percentile limits for mariculture, and five of these were also not compliant with the 95th percentile limits. Noticeable improvements were evident at the Small Quay-Sea Harvest, the Saldanha Bay Yacht Club and the Pepper Bay sites. Faecal coliform counts at all four sites in Big Bay were well within both the 80th and 90th percentile limits for mariculture in 2015.

Given the current importance and likely future growth of both the mariculture and tourism industries within Saldanha Bay, it is imperative that whatever efforts have been taken in recent years (e.g. upgrading of sewage and storm water facilities to keep pace with development and population growth) to combat pollution by harmful microbes, such as *E. coli* and faecal coliforms, in Small Bay should be increased and applied more widely. Continued monitoring of bacterial indicators (intestinal *Enterococci* in particular), to assess the effectiveness of adopted measures, is also required and should be undertaken at all sites on a bimonthly basis.

Data supplied by the Mussel Watch Programme (DEA) and data collected as part of the State of the Bay monitoring programme suggest that concentrations of trace metals are high along the shore (particularly for lead at the Portnet site) and are frequently or even consistently (in the case of lead) above published guidelines for foodstuffs. In comparison, data collected by mariculture operators in Saldanha Bay clearly show that concentrations offshore are much lower and are less of a concern. The high concentrations of trace metals along the shore points to the need for management interventions to address this issue, as metal contamination poses a very serious risk to the health of people harvesting mussels from the shore.

6 SEDIMENTS

6.1 Sediment quality

6.1.1 Changes in sediment particle size composition in the Bay

The particle size composition of the sediments occurring Saldanha Bay and Langebaan Lagoon are strongly influenced by the wave energy and current circulation patterns in the Bay. Coarser or heavier sand and gravel particles are typically found in areas with high wave energy and strong currents as the movement of water in these areas suspends fine particles (mud and silt) and flushes these out of the area. Disturbances to the wave action and current patterns, which reduce the movement of water, can result in the deposition of mud in areas where sediments previously much coarser. Since 1975, industrial developments in Saldanha Bay (Marcus Island causeway, iron ore terminal, multi-purpose terminal and establishment of a yacht harbour) have resulted in some level of obstruction to the natural patterns of wave action and current circulation prevailing in the Bay. The extent to which changes in wave exposure and current patterns has impacted on sediment deposition and consequently on benthic macrofauna (animals living in the sediments), has been an issue of concern for many years. The quantity and distribution of different sediment grain particle sizes (gravel, sand and mud) through Saldanha Bay influences the status of biological communities and the extent of contaminant loading that may occur in Saldanha Bay.

Contaminants such as metals and organic toxic pollutants, are predominantly associated with fine sediment particles (mud or cohesive sediments). This is due to the fact that fine grained particles have a relatively larger surface area for the adsorption and binding of pollutants. Higher proportions of mud, relative to sand or gravel, can thus lead to high organic loading and trace metal contamination. It follows then that with a disturbance to natural wave action and current patterns, an increase in the proportion of mud in the sediments of Saldanha Bay, could result in higher organic loading and dangerous levels of metals retention (assuming that these pollutants continue to be introduced to the system). Furthermore, disturbance to the sediment (e.g. dredging) can lead to re-suspension of the mud component from underlying sediments, along with the associated organic pollutants and metals. It may take several months or years following a dredging event before the mud component that has settled on surface layers is scoured out of the Bay by prevailing wave and tidal action. Changes in sediment particle size in Saldanha Bay is therefore of particular interest and are summarised in this section.

6.1.1.1 Historical data

The earliest studies reporting on the sediments of Saldanha Bay and Langebaan Lagoon were conducted by Flemming (1977) prior to large scale development of the area. Flemming (1977), however, did not report specifically on the distribution of the mud component of the sediments in Saldanha Bay and Langebaan Lagoon as, at that time, they were considered to have an “overall low content”. The mud component in Saldanha Bay prior to development (1977) was thus considered to be negligible and sediments were assumed to be comprised predominantly of sand particles (size range from 2 mm to 63 μm).

Due to concern about deteriorating water quality in Saldanha Bay, sediment samples were collected again in 1989 and 1990 (Jackson & McGibbon 1991). At the time of the Jackson & McGibbon study, the iron ore terminal had been built dividing the Bay into Small Bay and Big Bay, the multi-purpose quay had been added to the ore terminal, various holiday complexes had been established on the periphery of the Bay and the mariculture industry had begun farming mussels in the sheltered waters of Small Bay. The 1989 and 1990 studies revealed that sediments occurring in both Small Bay and Big Bay were still primarily comprised of sand particles but that mud now made up a noticeable, albeit small, component at most sites in the Bay (Figure 6.3). The Jackson & McGibbon (1991) study concluded that an increase in organic loading in the Bay had indeed occurred although this was not strongly reflected in the sediment analysis conducted at the time.

The next study on sediment particle size in Saldanha Bay occurred nearly a decade later, in 1999. However, immediately preceding this (in 1997/98) an extensive area adjacent to the ore terminal was dredged (indicated by arrows in Figure 6.3), resulting in a massive disturbance to the sediments of the Bay. The 1999 study clearly shows a substantial increase in the percentage of mud particles making up the sediment composition, specifically at the Multi-purpose Quay, Channel end of the ore terminal, the Yacht Club Basin and the Mussel Farm area (Figure 6.3). Two sites least affected by the dredging event were the North Channel site in Small Bay and the site adjacent to the Ore Jetty in Big Bay. The North Channel site is located in shallow water where the influence of strong wave action and current velocities are expected to have facilitated in flushing out the fine sediment particles (mud) that are likely to have arisen from dredging activities. Big Bay remained largely unaffected by the dredging event that occurred in Small Bay and fine sediments appear to be removed to some extent by the scouring action of oceanic waves in this area.

Subsequent studies conducted in 2000 and 2001 indicated that the mud content of the sediment remained high but that there was an unexplained influx of coarse sediment (gravel) in 2000 followed by what appears to be some recovery over the 1999 situation. The 2000 results are somewhat anomalous and may be related to an unidentified processing error that arose when the samples were analysed. Sampling conducted in 2004 shows almost complete recovery of sediments over the 1999 situation to a majority percentage of sand in five of the six sites examined for this report (Figure 6.3). The only site where a substantial mud component remained was at the Multi-purpose Quay. The shipping channel adjacent to the Quay is the deepest section of Small Bay (artificially maintained to allow passage of vessels) and is expected to concentrate the denser (heavier) mud component of sediment occurring in the Bay.

The survey conducted in 2008 revealed that there had been an increase in the percentage of mud at all sites, most notably in the Yacht Club Basin and at the Multi-purpose Quay. This was probably due the maintenance dredging that took place at the Mossgas and Multi-purpose quays at the end of 2007/beginning of 2008. The Yacht Club basin and the Small Bay side of the Multi-purpose quay are sheltered sites with reduced wave energy and are subject to long term deposition of fine grained particles. The benthic macrofauna surveys conducted between 2008 and 2011 revealed that benthic health at both the Yacht Club basin and adjacent to the Multi-purpose Quay was severely compromised, with benthic organisms being virtually absent from the former.

Smaller dredging programmes were also undertaken in the Bay 2009/10, when 7 300 m³ of material was removed from an area of approximately 3 000 m² between Caisson 3 and 4 near the base of the

Iron ore terminal on the Saldanha side, and a 275 m² area in Salamander Bay was dredged to accommodate an expanded SANDF Boat park. The former programme seems to have had a minimal impact of the Bay while the latter appears to have had a more significant impact and is discussed in detail below.

The percentage mud in sediments declined at most sites in Small Bay over the period 2008 to 2011. This bay-wide progressive reduction in mud content suggested a shift in the balance between the rate at which fine sediments are suspended and deposited and the rate at which currents and wave activities flushed fine sediments from the Bay.

Unfortunately no early historical data is available for grain size distribution in Langebaan Lagoon, and only the recent results from the 2004, 2008, 2009- 2015 surveys are presented in this report. During these surveys, the sediments in Langebaan Lagoon were principally composed of medium to fine grained sands with a very small percentage of mud. This is most likely due to the strong tidal currents experienced in the Lagoon.

In summary, the natural, pre-development state of sediment in Saldanha Bay comprised predominantly sand particles; however, developments and activities in the bay (causeway, ore terminal, Yacht Club Harbour and mussel rafts) reduced the overall wave energy and altered the current circulation patterns. This compromised the capacity of the system to flush the bay of fine particles and led to the progressive accumulation of mud (cohesive sediment) in surface sediments in the Bay, followed in more recent times by a reduction in the mud fraction. Dredge events, which re-suspended large amounts of mud from the deeper lying sediments, seem to be a dominant contributor to the elevated mud content in the Bay and results of surveys have shown a general pattern of an increase in mud content following dredge events followed by a recovery in subsequent years. Any future dredging or other such large-scale disturbance to the sediment in Saldanha Bay are likely to result in similar increases in the mud proportion as was evident in 1999, with accompanying increase in metal content.

6.1.1.2 Sediment particle size results for 2015

Sediment samples were collected and analysed for particle size composition, Total organic carbon (TOC), Total organic nitrogen (TON) and trace metals. During April 2015 sediment samples were collected from a total of 43 sites, 11 in Small Bay, nine in Big Bay, 14 in Danger Bay and nine in Langebaan Lagoon (Table 6.1).

Samples collected comprised predominantly sand (particle size ranging between 63 µm and 2000 µm). Sites located in Small Bay had on average the highest proportion of mud (5.15%), followed by Big Bay (2.67%), Langebaan Lagoon (0.55%) and Danger Bay with the lowest average proportion of mud (0.14%) (Table 6.1). Overall, very low proportions of gravel (particles exceeding 2000 µm) were found across all samples sites. Sites with the highest gravel content include BB20, located near the entrance to Big Bay (10.45%) and LL38, located near Schaapen Island (8.64%)

Table 6.1. Particle size composition and percentage organic carbon and nitrogen in surface sediments collected from Small Bay, Big Bay, Langebaan Lagoon and Danger Bay in 2015 (Particle size analysed by Scientific Services, and total organic carbon (TOC) and total organic nitrogen (TON) analysed by the Council for Scientific and Industrial Research).

	Sample	Gravel (%)	Sand (%)	Mud (%)	TOC (%)	TON (%)	C:N	
Small Bay	Average	0.72	94.12	5.15	1.19	0.17	7.59	
	SB1	1.04	86.02	12.94	5.25	0.64	9.50	
	SB2	0.07	91.67	8.26	0.28	0.05	7.00	
	SB3	0.31	98.54	1.15	0.21	0.03	7.12	
	SB5	0.00	99.74	0.26	0.22	0.04	7.24	
	SB8	0.05	98.40	1.55	0.42	0.07	7.11	
	SB9	0.39	93.52	6.09	0.98	0.16	7.33	
	SB10	1.38	97.97	0.65	0.24	0.04	6.48	
	SB14	0.17	90.14	9.69	2.47	0.36	7.93	
	SB15	1.62	86.66	11.71	1.49	0.19	8.98	
	SB16	0.98	96.68	2.34	0.91	0.15	7.10	
	Sea Harvest	1.92	96.02	2.06	0.59	0.09	7.75	
	Big Bay	Average	1.71	95.62	2.67	0.67	0.12	7.01
		BB20	10.45	88.11	1.44	1.28	0.29	5.22
BB21		1.78	95.19	3.03	0.53	0.09	7.21	
BB22		2.48	93.01	4.51	0.68	0.10	7.64	
BB24		0.31	98.99	0.70	0.77	0.13	7.09	
BB25		0.16	99.30	0.53	0.33	0.05	7.09	
BB26		0.04	95.27	4.69	0.63	0.10	7.29	
BB29		0.08	97.52	2.40	0.42	0.06	7.69	
BB30		0.01	99.78	0.21	0.18	0.03	7.40	
LPG		0.07	93.40	6.53	1.22	0.22	6.43	
Danger Bay	Average	0.16	99.71	0.14	0.28	0.04	7.80	
	DB1	0.00	100.00	0.00	0.11	0.03	4.91	
	DB2	0.72	99.06	0.22	0.07	0.03	2.94	
	DB3	0.00	99.81	0.19	0.19	0.02	9.13	
	DB4	0.00	99.69	0.31	0.25	0.06	4.98	
	DB5	0.04	99.90	0.05	0.48	0.06	9.51	
	DB 6	0.49	99.46	0.06	0.45	0.06	8.46	
	DB7	0.00	99.88	0.12	0.32	0.03	11.27	
	DB8	0.36	99.61	0.03	0.25	0.03	11.19	
	DB9	0.01	99.72	0.27	0.11	0.02	6.58	
	DB10	0.01	99.91	0.08	0.25	0.03	8.93	
	DB11	0.00	99.83	0.17	0.23	0.02	12.31	
	DB12	0.00	99.94	0.06	0.20	0.02	10.79	
DB13	0.00	99.72	0.28	0.01	0.02	0.40		

	Sample	Gravel (%)	Sand (%)	Mud (%)	TOC (%)	TON (%)	C:N
	DB14	0.56	99.39	0.05	1.01	0.15	7.84
Langebaan Lagoon	Average	1.24	98.21	0.55	0.19	0.03	8.49
	LL31	0.02	99.63	0.34	0.17	0.02	9.09
	LL32	0.34	99.62	0.04	0.13	0.02	9.66
	LL33	0.00	99.45	0.55	0.12	0.02	7.77
	LL34	1.09	98.27	0.64	0.25	0.04	7.85
	LL37	0.60	98.98	0.42	0.15	0.02	7.97
	LL38	8.64	90.01	1.35	0.31	0.05	6.88
	LL39	0.38	99.46	0.15	0.13	0.02	7.11
	LL40	0.06	99.86	0.08	0.16	0.02	10.75
	LL41	0.00	98.61	1.39	0.26	0.03	9.33

Mud is the most important particle size component to monitor given that fine grained particles provide a larger surface area to which contaminants bind. The sites beneath the mussel farm, and in the shipping channels adjacent to the Ore Jetty, are the deepest and are expected to yield sediments with a higher mud fraction than elsewhere in the Bay. Long term sampling confirms these expectations, with the highest proportion of mud recorded in sediments in the vicinity of the Ore Jetty, multipurpose quay, the mussel farms and the Yacht Club Basin (Figure 6.2). The remainder of sites in Big Bay had a relatively moderate to low mud content and Langebaan Lagoon had very low mud content in all recent surveys.

Mud content at sites for which historical data exists (1977- 2015) in Small Bay showed a declining trend from 1999-2010, where after it has remained relatively constant and at a much lower level than during the 1999-2009 period (Figure 6.3). Mud content in sediments sampled from sites SB14 and SB15, located adjacent the Ore Jetty, remained elevated (>9%) in 2015 (Table 6.1).

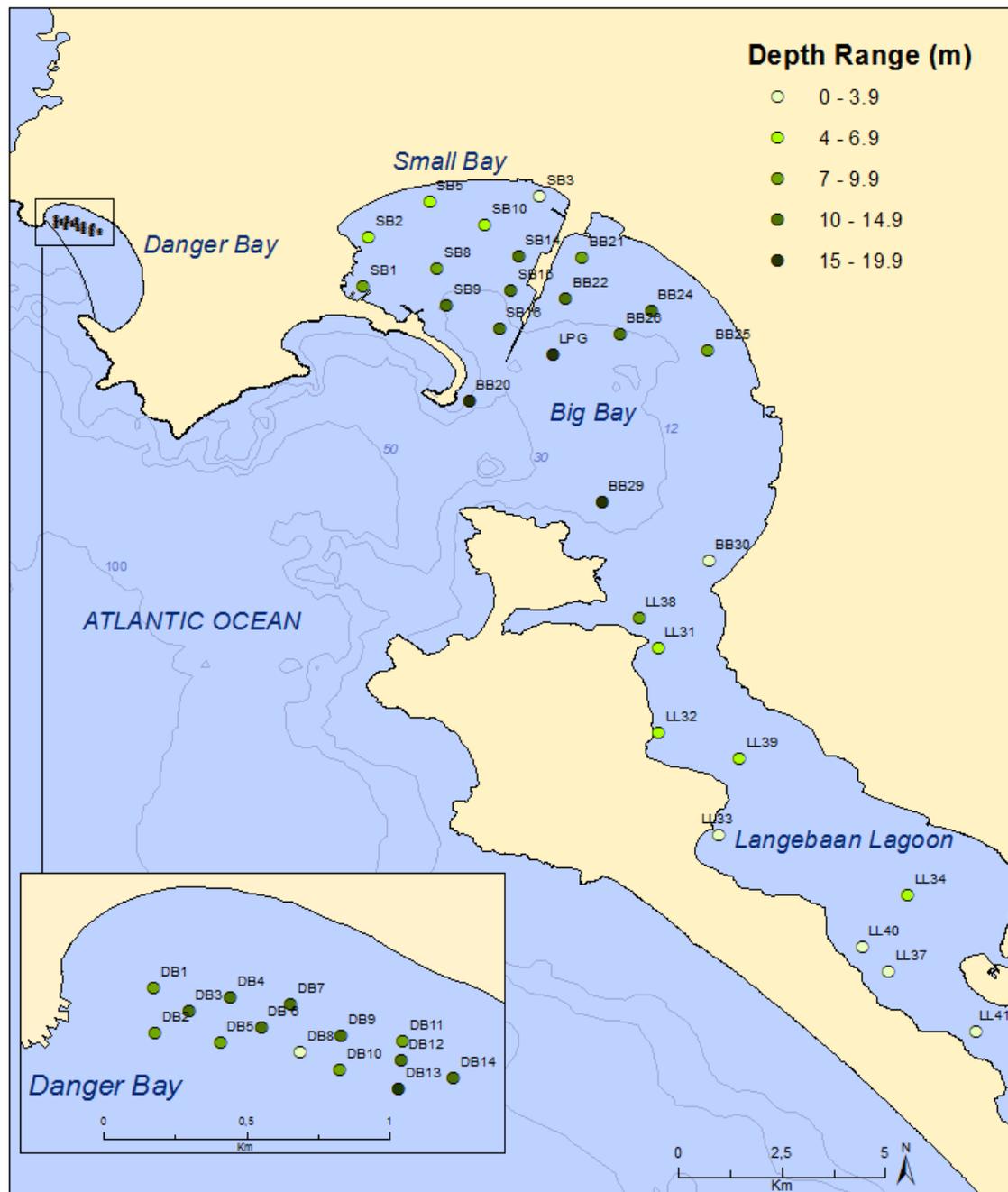


Figure 6.1 Sediment sampling sites in Saldanha Bay, Danger Bay and Langebaan Lagoon for 2015. Sites sampled from pre-1980 to 2015 are marked and labelled in red.

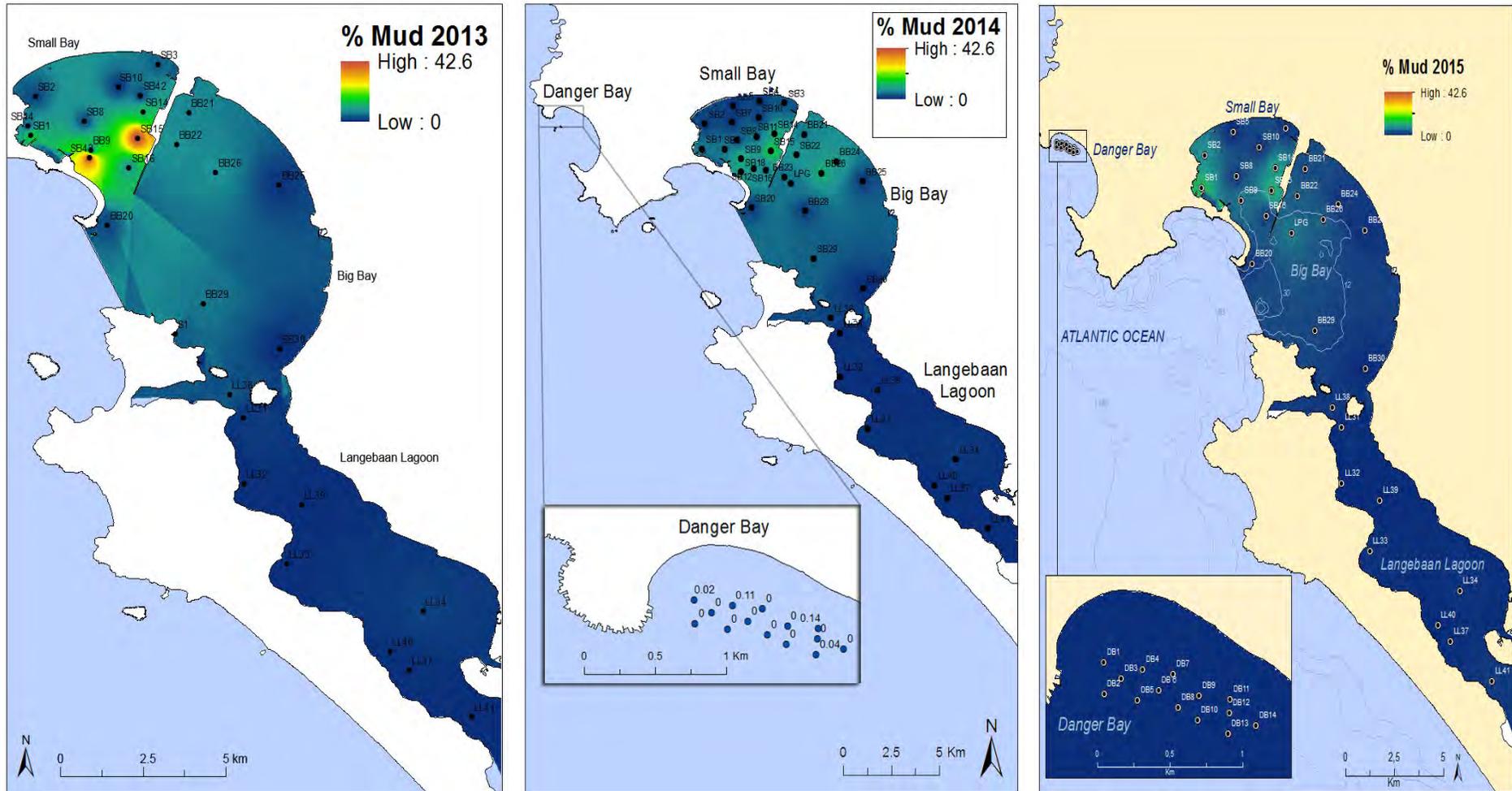


Figure 6.2 Variation in the percentage mud in sediments in Saldanha Bay, Danger Bay and Langebaan Lagoon as indicated by the 2013 (left), 2014 (centre) and 2015 survey results.

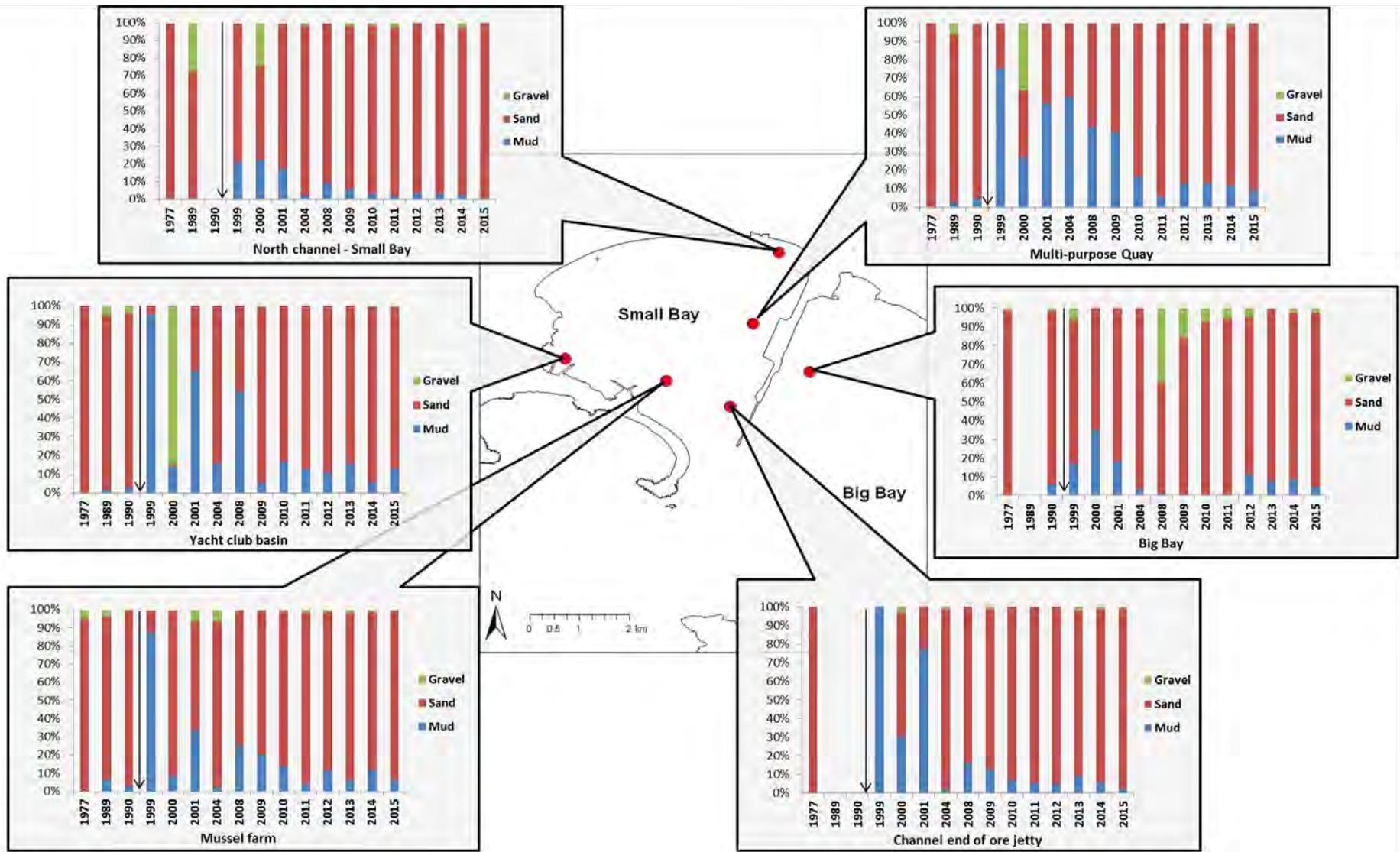


Figure 6.3 Particle size composition (percentage gravel, sand and mud) of sediments at six localities in the small bay area of Saldanha Bay between 1977 and 2015.

6.1.2 Total organic carbon (TOC) and nitrogen (TON) in sediment in the Bay

Total organic carbon (TOC) and total organic nitrogen (TON) accumulates in the same areas as mud as most organic particulate matter is of a similar particle size range and density to that of mud particles (size <60 µm) and settle out of the water column together with the mud. Hence TOC and TON are most likely to accumulate in sheltered areas with low current strengths, where there is limited wave action and hence limited dispersal of organic matter. The accumulation of organic matter in the sediments doesn't necessarily directly impact the environment, but the bacterial breakdown of the organic matter can (and often does) lead to hypoxic (low oxygen) or even anoxic (no oxygen) conditions. Under such conditions, anaerobic decomposition prevails, which results in the formation of sulphides such as hydrogen sulphide (H₂S). Sediments high in H₂S concentrations are characteristically black, foul smelling and toxic for most living organisms.

The most likely sources of organic matter in Saldanha Bay are from phytoplankton production at sea and the associated detritus that forms from the decay thereof, fish factory waste discharged into the Bay, faecal waste concentrated beneath the mussel and oyster rafts in the Bay, treated sewage effluent discharged into the Bay from the wastewater treatment works (Saldanha & Langebaan), and the leaking of sewage from septic tanks and conservancy tanks. The molar ratios of carbon to nitrogen (C:N ratio) can be useful in determining the sources of organic contamination. Organic matter originating from marine algae typically has a C:N ratio ranging between 6 and 8, whereas matter originating from terrestrial plant sources exceeds this. Fish factory waste is nitrogen-rich and thus extremely low C:N ratios would be expected in the vicinity of a fish waste effluent outfall. However; nitrogen is typically the limiting nutrient for primary productivity in most upwelling systems including the Benguela, and the discharge of nitrogen-rich waste from fish factories has been linked to algal blooms using stable isotope studies (Monteiro *et al.* 1997). The excess nitrogen in the system is taken up by algae thereby allowing for bloom development. By consuming the nitrogen the bloom effectively increases the C:N ratio. In addition phytoplankton production and decomposition will then add to the levels of organic matter within the system.

6.1.2.1 Spatial trends in TOC and TON

TOC levels in Saldanha Bay were mostly very low (between 0.2 and 0.5%) throughout the Bay prior to any major development (pre-1974). The next available TOC data was collected in 1989 after the construction of the iron ore terminal and the establishment of the mussel farms in Small Bay. At this stage all sites monitored had considerably elevated levels of TOC with the greatest increase occurring in the vicinity of the Mussel Farm. TOC levels peaked at 17% at this site in 1990. The reason for this extremely high TOC percentage is uncertain. Through all subsequent years of TOC monitoring (1990, 1999-2001, 2004, 2008-2015), levels have remained higher than those reported prior to development.

Spatial variation in the amount of TOC and TON recorded in the sediments in Saldanha Bay and Langebaan Lagoon in 2015 are presented in Figure 6.4 and Figure 6.5. The spatial trends in TOC and TON recorded in 2015 correspond with previous 2013 and 2014 results. Concentrations were generally highest in Small Bay at the Yacht Club Basin and along the Ore Jetty. This pattern mirrors the distribution of muddy sediments in the bay. In addition, both TOC and TON levels were elevated

in the vicinity of the Liquid Petroleum Gas (LPG) site and across the entrance of Big Bay in the 2015 samples.

The Danger Bay sediments collected in 2015 mostly had low TOC and TON concentrations similar to those measured in Langebaan Lagoon and Big Bay (Figure 6.4, Figure 6.5 & Table 6.1). This is expected given the exposed nature of Danger Bay and the coarse sandy sediments with very low mud content found there. From recent surveys TOC and TON sediment concentrations recorded from Danger Bay gave no indication of organic carbon and nitrogen enrichment.

6.1.2.2 Spatial trends in the C:N ratio

The C:N ratio results from 2013–2015 were highly variable. In 2013 all sites bar the yacht club basin had values below that expected from marine production, i.e. reflecting nitrogen enrichment (Figure 6.6A). In 2014, however, most sites within Langebaan Lagoon and four out of the nine Big Bay sites had C:N ratios above that expected from marine production, reflecting terrestrial nitrogen sources or (and more plausibly) nitrogen depletion in these areas, whilst most Small Bay sites had values expected from marine production. There were some exceptions in Small Bay in 2014, with below expected C:N ratios recorded in the vicinity of the Bok River, which is known to be enriched with processed sewage (Figure 6.6B). The majority of sites in 2015 were within the expected range of marine production, only two sites in Small Bay, Yacht Club Basin and Ore Jetty, and four sites in Langebaan Lagoon were above the expected range (Figure 6.6C). Eight of the fourteen sites in Danger Bay were above the expected range for marine productivity, this is, however, due to low nitrogen levels recorded in Danger Bay rather than terrestrial sourced nitrogen enrichment.

There are two possible reasons for elevated C:N ratios; the first being that the organic matter found in these areas originated from terrestrial sources. The alternate explanation is that natural decomposition processes reduced the amount of nitrogen present thereby elevating the C:N ratio. This process is known as denitrification and it occurs in environments where oxygen levels have been depleted (anoxic or hypoxic) and nitrates are present. Under these conditions, denitrifying bacteria are likely to dominate as they are able to substitute oxygen, normally required for organic matter degradation, through nitrate reduction (Knowles 1982, Tyrrell & Lucas 2002). In areas where photosynthetic rates are very high, such as in upwelling systems, or where there is a high degree of organic input, a high biological oxygen demand deeper in the water column and sediments can lead to complete oxygen utilisation.

Denitrification may be responsible for the elevated C:N ratios in the deeper areas where a high TOC content was recorded and stratification is possible. It is, however, highly unlikely that this process is responsible for the elevated C:N ratios at Langebaan sites in 2014 and 2015, given that many of the sites with high C:N ratios are in highly exposed, shallow areas with low organic content. It thus seems likely the organic matter in many areas of the system originates from a terrestrial source. An alternative hypothesis is that enhanced productivity with selectively greater recycling of nitrogen-rich relative to carbon-rich organic matter can lead to elevated C:N ratios (Twichell *et al* 2002).

The observed temporal variability of C:N ratios in Saldanha Bay may well reflect upwelling events and associated water column and benthic productivity over the summer period that precedes the annual surveys in April. Given the high inter-annual variability in the C: N ratios, interpretation that

focuses on the outliers in any given year (e.g. Yacht Club Basin sites in 2013 and 2015, Bok River sites in 2014) is probably more informative than a temporal analysis.

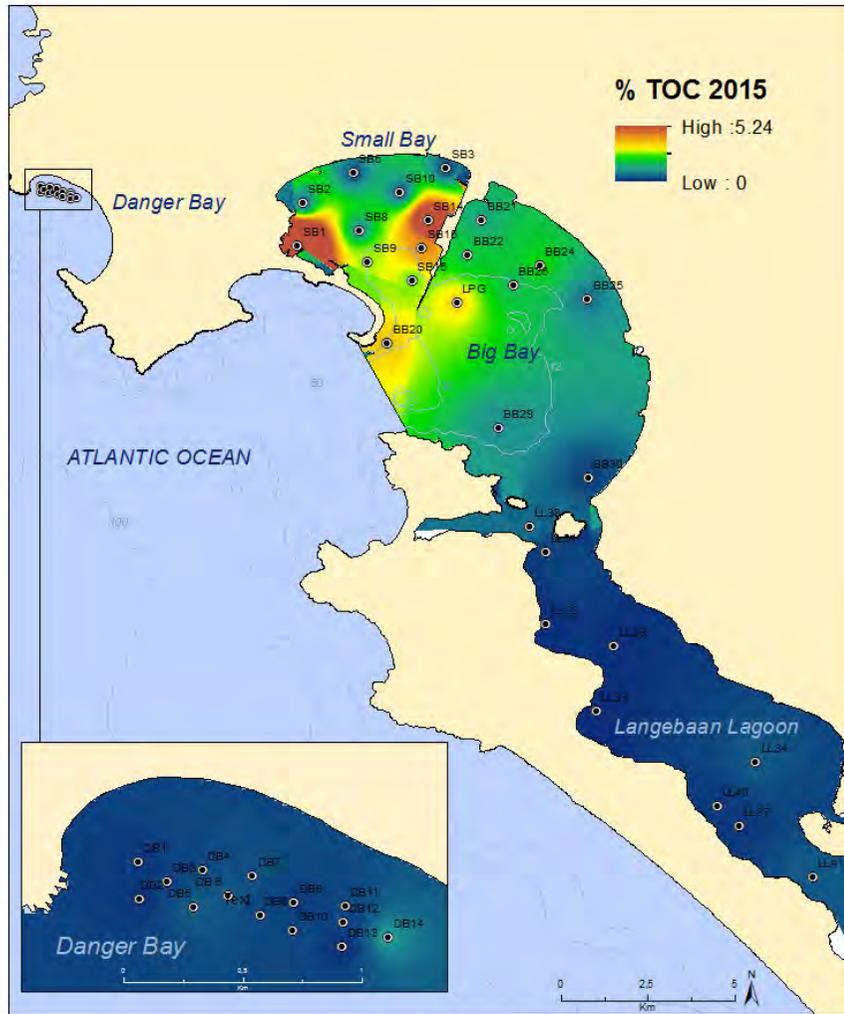


Figure 6.4 Total organic carbon in Saldanha Bay, Danger Bay and Langebaan Lagoon as indicated by the 2015 survey results.

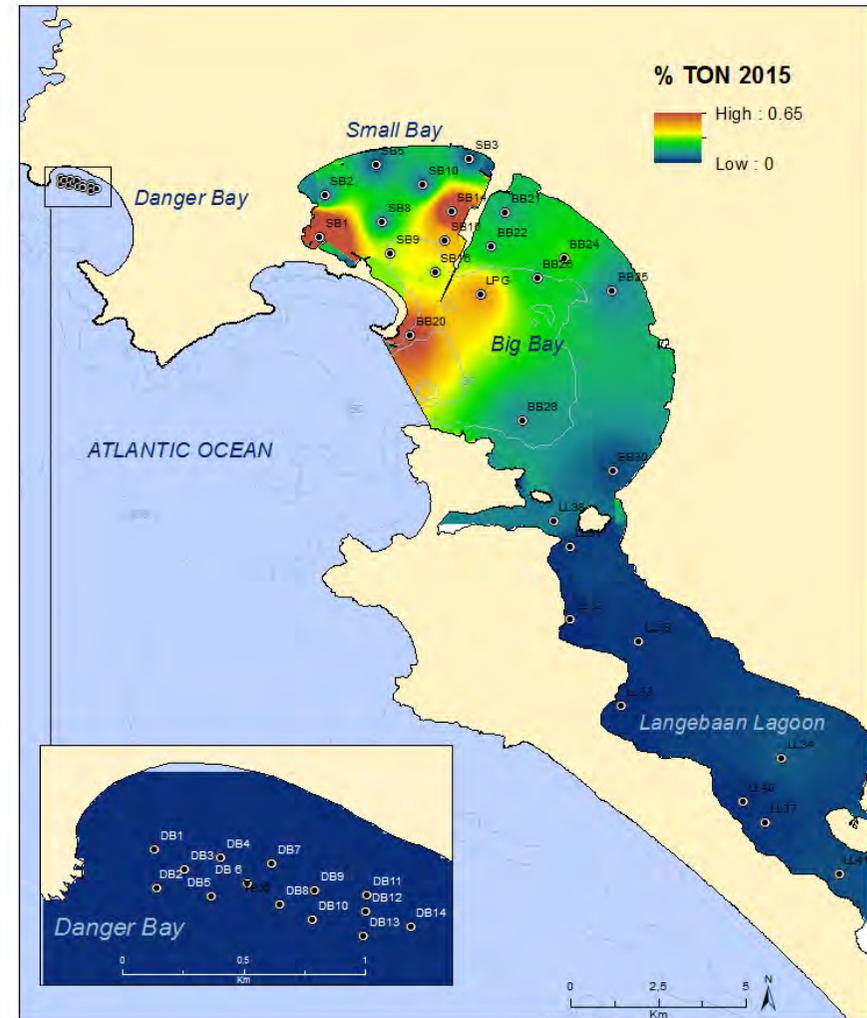


Figure 6.5 Total organic nitrogen in Saldanha Bay, Danger Bay and Langebaan Lagoon as indicated by the 2015 survey results.

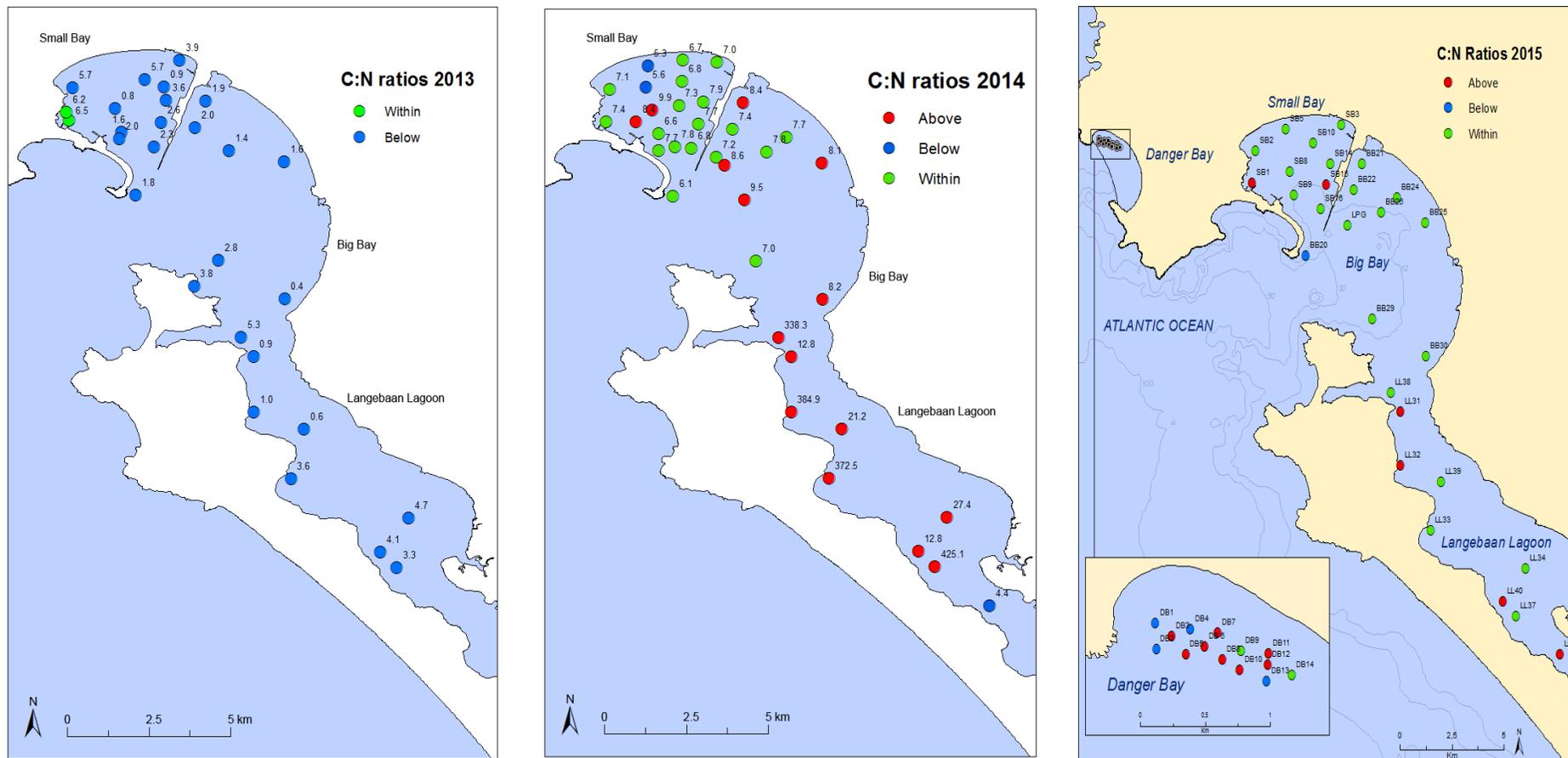


Figure 6.6 C:N ratios at different sites surveyed in Saldanha Bay and Langebaan Lagoon in 2013, 2014 & 2015 (red = exceeds the range expected for marine production, green = within the range expected for marine production and blue = below range expected for marine production).

6.1.2.3 Temporal trends

Total organic carbon

A total of six sites have been sampled and TOC compared at various stages between 1974 and 2015 (Figure 6.7). The sediments from the Yacht Club Basin (SB1) and Multi-purpose Quay (SB14) consistently had the highest TOC content of the six sites sampled since 1989. The Mussel Farm site (SB9) historically had elevated TOC, but since 2008 levels have been mostly low. The TOC at all six sites had increased in 2012, but decreased substantially in the subsequent years, particularly in 2014 at the Yacht Club Basin where the lowest % TOC was recorded since pre-1974. Excluding the North Channel site, TOC levels in 2015 increased at all sites. At the Yacht Club Basin TOC levels increased in 2015 to similar levels prior to the low levels recorded in 2014.

Historically, elevated organic carbon levels in sediments at the Yacht Club Basin has been (and still are) attributed to a combination of organic matter input from dredge events and the fish factories and high retention rates due to the sheltered nature of the area. Elevated levels of organic carbon at the mussel farm site were attributed to the deposition of faecal pellets and biogenic waste. Elevated organic carbon levels at the Multi-purpose Quay is also most likely attributable to the historical dredging that took place at the site and a relatively higher retention rate of organic matter and fine sediments, given the depth and the sheltered nature of the site.

The historical data have shown that that level of organic matter typically increases immediately following a dredging event and declines in subsequent years. This suggests the re-suspension of organic matter from deeper sediments and the subsequent settling of this matter is a primary contributor to organic matter in surface sediments in the Bay. The only exception to this trend was that of the mussel farm site. This suggests that the mussel farm activities had a stronger local influence at that particular site than that of the dredging activities.

Total organic nitrogen

Sources of organic nitrogen in Small Bay include fish factory wastes, biogenic waste from mussel and oyster culture, sewage effluent from the wastewater treatment works and leaking of sewage from septic tanks. TON was not measured in early (historic) studies of the Bay, and data is only available from 1999 onwards (Figure 6.8). Historically the TON concentrations have been greatest at the Yacht Club Basin, Multi-purpose Quay and near the Mussel rafts. This was considered to be linked to the discharge of waste from the fish processing plants in this area, faecal waste accumulating beneath the mussel rafts and dredging operations at the Multi-purpose Terminal. The 2013 data indicate an increase in the TON at all six sites except the North End of Small Bay. This increase was particularly great at the Yacht Club Basin, Mussel farm and Multi-Purpose Quay sites. However, in 2014 all six sites indicated a substantial decrease in TON, with the Yacht Club Basin, Mussel Farm and Big Bay sites indicating some of the lower recordings of TON since 1999. In 2015 TON levels increased substantially at the Yacht Club Basin to levels similar to those recorded prior to 2014. Slight increases were also observed at the Mussel farm, Multi-purpose Quay and Big Bay.

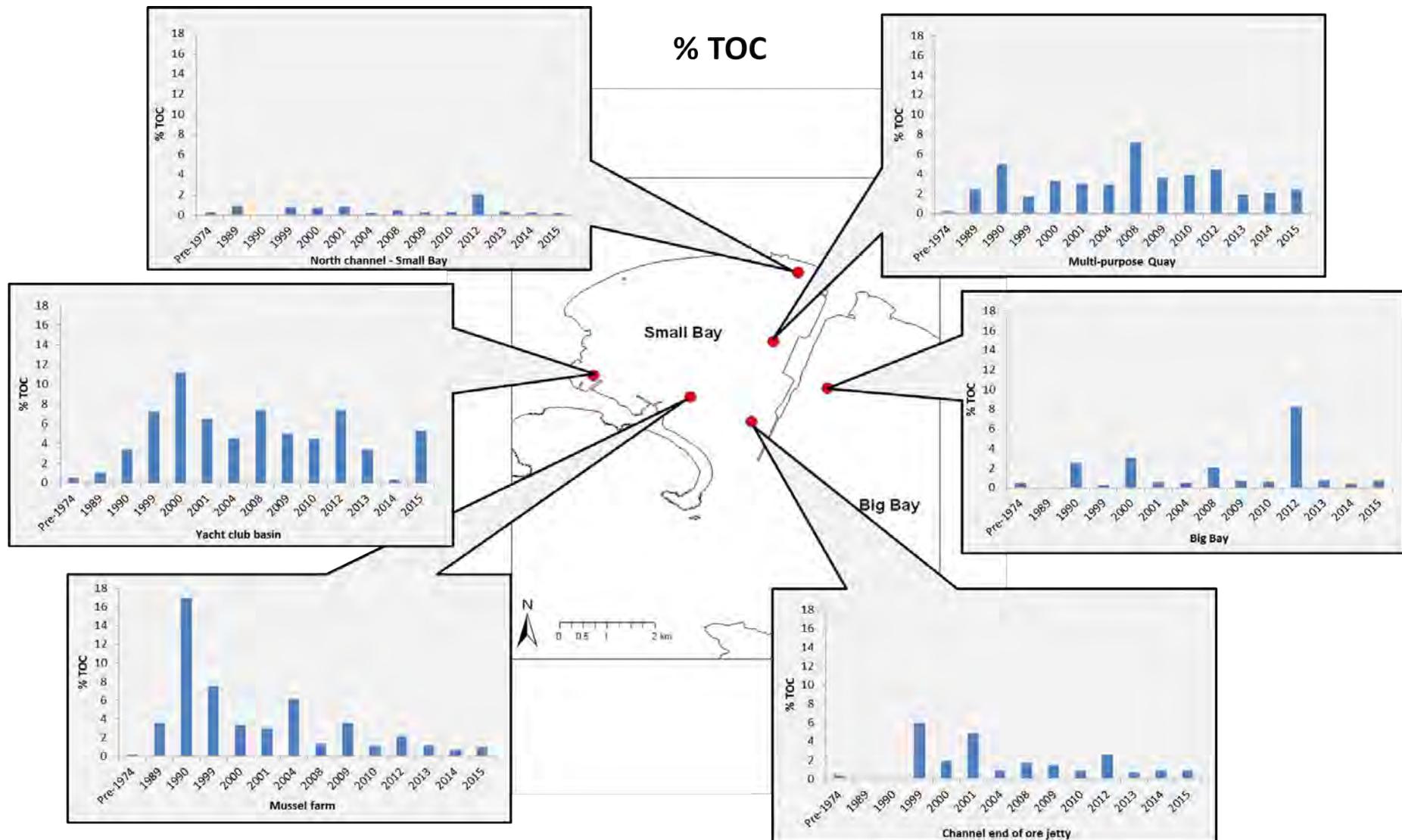


Figure 6.7 Total organic carbon percentage occurring in sediments of Saldanha Bay at six locations between pre-1974 and 2015.

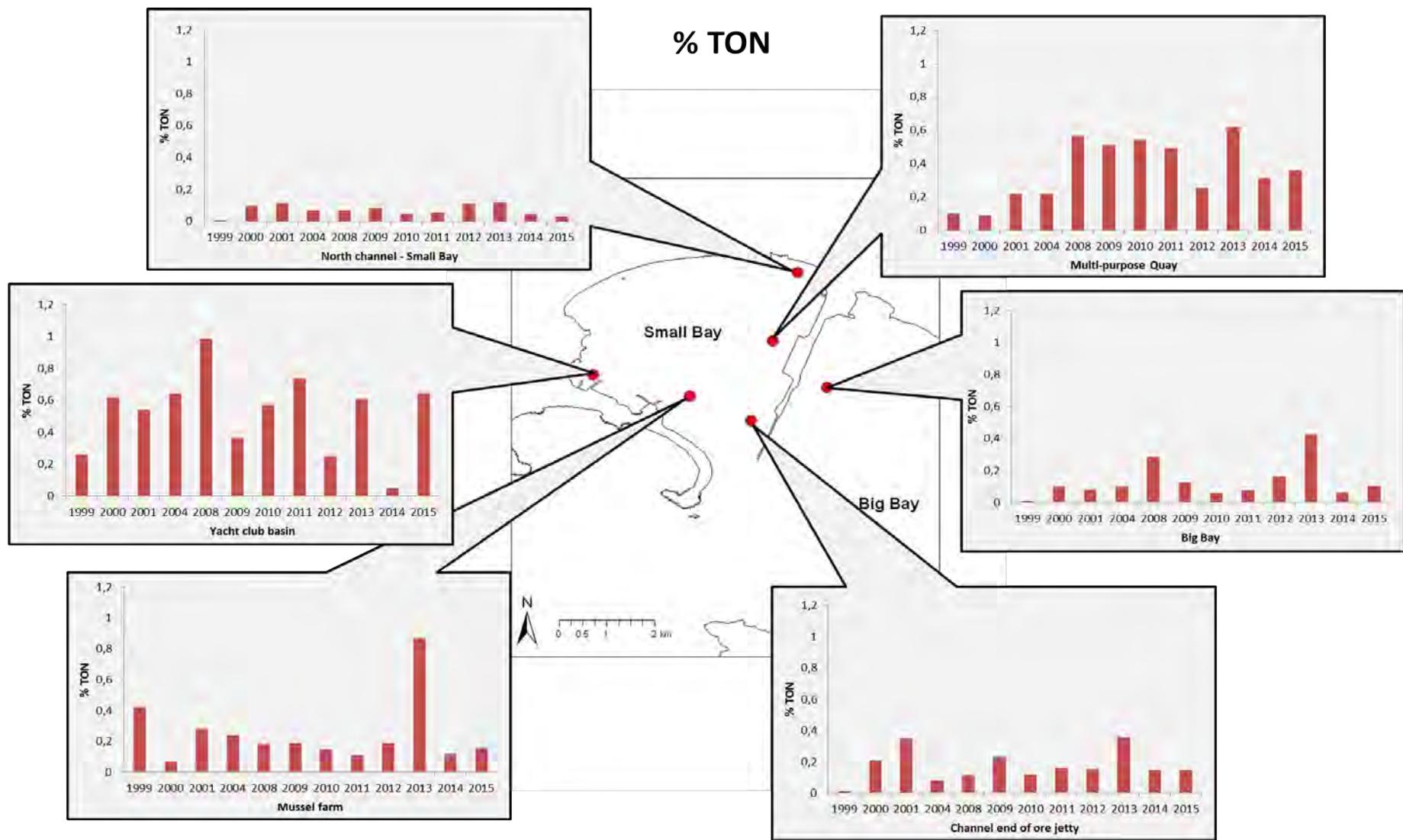


Figure 6.8 Total organic nitrogen percentage occurring in sediments of Saldanha Bay at six locations between 1999 and 2015.

6.1.3 Trace metals

Trace metals occur naturally in the marine environment, and some are important in fulfilling key physiological roles. Disturbance to the natural environment by either anthropogenic or natural factors can lead to an increase in metal concentrations occurring in the environment, particularly sediments. An increase in metal concentrations above natural levels, or at least above established safety thresholds, can result in negative impacts on marine organisms, especially filter feeders like mussels that tend to accumulate metals in their flesh. High concentrations of metals can also render these species unsuitable for human consumption. Metals are strongly associated with the cohesive fraction of sediment (i.e. the mud component) and with TOC. Metals occurring in sediments are generally inert (non-threatening) when buried in the sediment but can become toxic to the environment when they are converted to the more soluble form of metal sulphides. Metal sulphides are known to form as a result of natural re-suspension of the sediment (strong wave action resulting from storms) and from anthropogenic induced disturbance events like dredging activities.

The Benguela Current Large Marine Ecosystem (BCLME) program reviewed international sediment quality guidelines in order to develop a common set of sediment quality guidelines for the coastal zone of the BCLME (Angola, Namibia and west coast of South Africa) (Table 6.2). The BCLME guidelines cover a broad concentration range and still need to be refined to meet the specific requirements of each country within the BCLME region (CSIR 2006). There are thus no official sediment quality guidelines that have been published for the South African marine environment as yet, and it is necessary to adopt international guidelines when screening sediment metal concentrations. The National Oceanic and Atmospheric Administration (NOAA) have published a series of sediment screening values, which cover a broad spectrum of concentrations from toxic to non-toxic levels as shown in Table 6.2

The Effects Range Low (ERL) represents the concentration at which toxicity may begin to be observed in sensitive species. The ERL is calculated as lower 10th percentile of sediment concentrations reported in literature that co-occur with any biological effect. The Effects Range Median (ERM) is the median concentration of available toxicity data. It is calculated as lower 50th percentile of sediment concentrations reported in literature that co-occur with a biological effect (Buchman 1999). The ERL values represent the most conservative screening concentrations for sediment toxicity proposed by the NOAA, and ERL values have been used to screen the Saldanha Bay sediments.

Table 6.2 Summary of Benguela Current Large Marine Ecosystem and National Oceanic and Atmospheric Administration metal concentrations in sediment quality guidelines

Metal (mg/kg dry wt.)	BCLME region (South Africa, Namibia, Angola)		NOAA2	
	Special care	Prohibited	ERL	ERM
Cd	1.5 – 10	> 10	1.2	9.6
Cu	50 – 500	>500	34.0	270.0
Pb	100 – 500	> 500	46.7	218.0
Ni	50 – 500	> 500	20.9	51.6
Zn	150 – 750	> 750	150.0	410.0

1(CSIR 2006), 2 (Long *et al.* 1995, Buchman 1999)

6.1.3.1 Historic data

Dramatic increases in trace metal concentrations, especially those of cadmium and lead after the start of the iron ore export from Saldanha Bay, raised concern for the safety and health of marine organisms, specifically those being farmed for human consumption (mussels and oysters). Of particular concern were the concentrations of cadmium which exceeded the lower toxic effect level published by the NOAA. Both lead and copper concentrates are exported from Saldanha Bay and it was hypothesised that the overall increase of metal concentrations was directly associated with the export of these metals. The concentrations of twelve different metals have been evaluated on various occasions in Saldanha Bay; however, the overall fluctuations in concentrations are similarly reflected by several key metals throughout the time period. For the purposes of this report, four metals that have the greatest potential impact on the environment were selected from the group. These are cadmium (Cd), lead (Pb), copper (Cu) and nickel (Ni).

The earliest data on metal concentrations in Saldanha Bay were collected in 1980, prior to the time at which iron ore concentrate was first exported from the ore terminal. The sites sampled were 2 km north of the Multi-purpose Quay (Small Bay) and 3 km south of the Multi-purpose Quay (Big Bay) and metals reported on included lead (Pb), cadmium (Cd) and copper (Cu). Concentrations of these metals in 1980 were very low, well below the sediment toxicity thresholds. Subsequent sampling of metals in Saldanha Bay (for which data is available) only took place nearly 20 years later in 1999. During the period between these sampling events, a considerable volume of ore had been exported from the Bay, extensive dredging had been undertaken in the Bay (1997/98), and the Mussel Farm and the small craft harbour (Yacht Club Basin) had been established (1984). As a result of these activities, the concentrations of metals in 1999 were very much higher (up to 60 fold higher) at all stations monitored. This reflects the accumulation of metals in the intervening 20 years, much of which had recently been re-suspended during the dredging event and had settled in the surficial (surface) sediments in the Bay. Concentrations of most metals in Saldanha Bay were considerably lower in the period 2000-2010, although nowhere near levels measured in 1980. This closely mirrors changes in the proportion of mud in the sediments, and most likely reflects the removal of fine sediments together with the trace metal contaminants from the Bay, by wave and tidal action. Monitoring surveys between 2001 and 2014 indicates that with a few exceptions, metal

concentrations had continued to decrease in Saldanha Bay and were much reduced from the exceptionally high concentrations recorded in 1999 and 2000.

6.1.3.2 Analysis and results for 2015

Sediments were analysed for concentrations of aluminium (Al), iron (Fe), copper (Cu), cadmium (Cd), nickel (Ni), lead (Pb), manganese (Mn) and zinc (Zn). For the purpose of this report only the data for Cd, Cu, Pb, Ni and Fe are presented as these are the metals deemed to pose the greatest threat to the health of the marine environment. Metals in the sediments were analysed by Scientific Services using a Nitric Acid (HNO₃) / Perchloric Acid (HClO₃)/ Hydrogen Peroxide (H₂O₂)/ Microwave digestion and JY Ultima Inductively Coupled Plasma Optical Emission Spectrometer. Trace metal concentrations recorded in the sediments of Saldanha Bay, Danger Bay and Langebaan Lagoon are shown in Table 6.3 and Figure 6.9 to Figure 6.12.

Table 6.3 Concentrations (mg/kg) of metals in sediments collected from Saldanha Bay in 2015. Values that exceed sediment quality guidelines are highlighted in red font.

	Sample #	Al	Fe	Cd	Cu	Ni	Pb	Mn
*ERL Guideline (mg/kg)		-	-	1.2	34	20.9	46.7	56.50
Small Bay	SB1	23632	14927	3.13	45.34	13.44	34.24	31.96
	SB2	9243	6330	1.10	5.74	4.24	10.47	30.98
	SB3	3468	3796	0.42	6.20	2.66	12.80	24.79
	SB5	2600	2854	0.37	4.24	4.60	8.19	23.48
	SB8	4843	4264	0.59	2.82	2.01	4.82	28.58
	SB9	7022	6787	0.81	4.53	5.82	12.52	42.66
	SB10	3618	5585	0.61	6.79	5.38	14.95	38.15
	SB14	11255	10621	1.40	17.40	8.20	45.80	30.98
	SB15	11648	8921	1.22	5.60	6.41	19.25	26.91
	SB16	5346	5815	0.75	6.20	4.24	13.86	144.0
	Sea Harvest	7502	5991	1.05	10.95	5.69	16.76	54.88
Big Bay	BB20	3542	3019	0.61	16.07	1.29	1.58	28.12
	BB21	5880	5881	0.73	1.33	5.15	8.32	18.69
	BB22	6958	6893	0.65	3.36	2.97	4.10	69.87
	BB24	5523	6372	0.66	4.41	6.21	10.92	73.85
	BB25	2613	2873	0.50	2.57	2.87	8.10	39.14
	BB26	5853	5539	0.77	6.72	5.13	10.49	24.57
	BB29	4180	4159	0.63	1.86	3.65	4.21	94.21
	BB30	1956	2574	0.37	3.64	2.35	4.16	32.20
	LPG	7256	6626	0.77	2.50	3.59	1.04	19.01
Danger Bay	DB1	833	1002	0.38	ND	0.70	5.61	24.78
	DB2 (new)	603	826	0.34	ND	0.23	ND	24.13

	Sample #	Al	Fe	Cd	Cu	Ni	Pb	Mn
	DB3	793	1065	0.22	1.33	0.07	4.85	25.80
	DB4	857	909	0.34	0.96	0.11	3.81	68.09
	DB5 (new)	629	967	0.29	ND	ND	2.70	18.03
	DB 6 (new)	769	1010	ND	2.70	0.50	1.61	30.87
	DB7	855	1016	0.37	1.74	1.21	6.58	30.81
	DB8	885	1245	0.11	ND	0.31	7.01	40.97
	DB9	824	1080	0.38	0.68	1.48	5.48	8.41
	DB10	827	998	0.32	1.18	1.19	7.64	7.711
	Db11	650	929	0.34	0.44	0.88	6.72	10.34
	DB12	790	1009	0.30	1.13	2.11	9.02	8.55
	DB13	962	1042	0.33	0.75	1.29	3.44	8.23
	DB14	704	985	0.29	ND	0.17	2.50	10.50
Langebaan Lagoon	LL31	5726	4958	0.07	0.49	2.65	4.90	9.31
	LL32	3185	4408	0.06	0.08	1.20	0.55	11.87
	LL33	2724	3642	ND	0.28	1.78	0.96	9.05
	LL34	4897	3902	0.07	ND	2.11	1.75	9.88
	LL37	2975	3764	ND	0.15	1.79	1.47	8.50
	LL38	10169	8908	0.30	0.15	6.02	7.01	10.23
	LL39	2413	2845	ND	ND	1.00	2.06	9.85
	LL40	1511	3117	ND	ND	1.25	ND	9.10
	LL41	6667	5053	0.07	ND	2.66	3.60	56.50

In 2015, Cd concentrations were highest and exceeded ERL guidelines in the vicinity of the Yacht Club Basin and adjacent to the Ore Jetty (Figure 6.9; Table 6.3). The highest Cu concentrations were recorded at the Yacht Club Basin, near the Ore Jetty and near the entrance to Big Bay (Figure 6.10). The ERL guideline level for Cu, however, was only exceeded at the Yacht Club Basin (Table 6.3). Nickel concentrations increased marginally in the vicinity of the Yacht Club Basin and Ore Jetty but did not exceed ERL guideline levels (Figure 6.11). Although Pb levels also did not exceed ERL guidelines, concentrations were considerably higher at the Yacht Club Basin and adjacent to the multi-purpose terminal (Figure 6.12). The concentrations of Cd, Cu, Ni and Pb were below the ERL guideline at all other sites within the Bay and Lagoon. Concentrations of trace metals in the sandy Danger Bay sediment samples were very low relative to sites with anthropogenic impacts and muddy sediments collected within Saldanha Bay. Comparing these results to the ERL guidelines provides a useful indication of areas in the Bay that may be toxic to living organisms. However, this comparison does not provide an indication of whether the build-up of a trace metal is due directly to anthropogenic contamination of the environment with that particular metal or whether it is an indirect result of other environmental perturbations, for example a high concentration of mud.

The concentrations of metals in sediments are affected by grain size, total organic content and mineralogy. Since these factors vary in the environment, one cannot simply use high absolute concentrations of metals as an indicator for anthropogenic metal contamination. Metal concentrations are therefore commonly normalized to a grain-size parameter or a suitable substitute for grain size, and only then can the correct interpretation of sediment metal concentrations be made (Summers *et al.* 1996a). A variety of sediment parameters can be used to **normalize metal concentrations**, and these include Al, Fe and total organic carbon. Aluminium or iron are commonly used as normalisers for trace metal content as they ubiquitously coat all sediments and occur in proportion to the surface area of the sediment (Gibbs 1994); they are abundant in the earth's crust and are not likely to have a significant anthropogenic source (Gibbs 1994, Summers *et al.* 1996a); and ratios of metal concentrations to Al or Fe concentrations are relatively constant in the earth's crust (Summers *et al.* 1996a). Normalized metal/aluminium ratios can be used to estimate the extent of metal contamination within the marine environment, and to assess whether there has been enrichment of metals from anthropogenic activities. Due to the known anthropogenic input of iron from the iron ore quay and industrial activity in Saldanha Bay, metal concentrations were normalized against (divided by) aluminium and not iron.

Another means of evaluating the extent of contamination of sediments by metals is to calculate the extent to which the sediments have been enriched by such metals since development started. **Metal enrichment factors** were calculated for Cd, Pb and Cu relative to the 1980 sediments (Table 6.4). Unfortunately historic enrichment factors could not be calculated for Ni and Mn as no data was available for this element in 1980. Enrichment factors equal to (or less than) 1 indicate no elevation relative to pre-development conditions, while enrichment factors greater than 1 indicate a degree of metal enrichment within the sediments over time. Enrichment factors were not calculated for Langebaan Lagoon since all concentrations were below detection limits. The extent of contamination for Cd, Cu, Ni and Pb is discussed below using both metal concentrations and the metal enrichment factors.

Cadmium

Sediments from sites located alongside the Ore Jetty and in the vicinity of the yacht club within Small Bay displayed elevated Cd concentrations (Figure 6.9 & Table 6.3). Cd is a trace metal used in electroplating, in pigment for paints, in dyes and in photographic process. The likely sources of Cd to the marine environment are in emissions from industrial combustion process, from metallurgical industries, from road transport and waste streams (OSPAR 2010). A likely point source for Cd contamination in the marine environment is that of storm water drains. Cd is toxic and liable to bioaccumulation, and is thus a concern for both the marine environment and human consumption (OSPAR 2010). Given the spatial pattern it is unlikely that the contamination of Cd in the Bay is a result of storm water drainage, but rather that the Cd contamination is resulting from shipping and boating. The areas where this is particularly concerning include site SB1 (near the Yacht Club Basin) and site SB14 and SB15 (near the Multi-Purpose Quay) as the level of contamination at these sites exceeds the ERL limits. Furthermore the enrichment values for these three sites since 1980 are very high, indicating significant contamination of these areas with Cd since 1980 (Table 6.4).

Copper

Cu concentrations were highest near the entrance to the Bay, along the Ore Jetty and near the yacht club within Small Bay (Figure 6.10 & Table 6.3). This suggests that there may be a source of copper pollution affecting most of the Small Bay region. Copper (Cu) is used as a biocide in antifouling products as it is very effective for killing marine organisms that attach themselves to the surfaces of boats and ships. Anti-fouling paints release Cu into the sea and can make a significant contribution to Cu concentrations in the marine environment (Clark 1986). The areas with elevated normalized Cu values also correspond with those with high levels of boat traffic. It is thus likely that anti-fouling paints used on boats may have been contributing Cu to the system. It must be noted that no sites are situated in close proximity to Mykonos and the yacht club in Langebaan Lagoon. It is possible that both these areas have also been contaminated by Cu. The Cu concentration at the Yacht Club Basin in Saldanha Bay exceeded the ERL guideline, the normalized value indicates the pollution source was anthropogenic and the enrichment factor was also alarmingly high in 2015 (Table 6.4).

Nickel

Ni values measured in 2015 were slightly elevated at the yacht club and alongside the Ore Jetty within Small Bay, near the base of the jetty in Big Bay and on the western side of Schaapen Island at the entrance to Langebaan Lagoon (Figure 6.11 & Table 6.3). Nickel is introduced to the environment by both natural and anthropogenic means. Natural means of contamination include windblown dust derived from the weathering of rocks and soils, fires and vegetation (Cempel & Nickel 2006). Common anthropogenic sources include the combustion of fossil fuels and the incineration of waste and sewerage (Cempel & Nickel 2006). Contamination of the Bay by Nickel is not of great concern though, as Nickel concentrations are well below the ERL guideline limits.

Lead

Elevated Pb concentrations were recorded in Small Bay, particularly in the vicinity of the multi-purpose quay and the yacht club, whilst Big Bay and Langebaan Lagoon sediments had low concentrations of Pb (Figure 6.12 & Table 6.3). Lead pollution is a worldwide problem and is generally associated with mining, smelting and the industrial use of Pb (OSPAR 2010). Pb is a persistent compound which is toxic to aquatic organisms and mammals, and thus the contamination is of concern for the marine environment and human consumption (OSPAR 2010). The area adjacent to the multi-purpose terminal had the highest Pb values indicating that this area is subject to high levels of lead pollution. The enrichment factor for the site nearest to the multi-purpose terminal was very high (57.2) and the concentration of lead was marginally below recommended ERL toxicity limits (Table 6.4).

Normalized metal/aluminium ratios revealed that metal contamination was high at numerous sites in Small Bay (Table 6.5). Areas of concern corresponded with sites where high metal concentrations and metal enrichment were indicated. The high normalised values indicated in Danger Bay however, is not an indication of anthropogenic metal contamination but rather a result of the naturally low background aluminium levels.

Manganese

Mn concentrations were highest near the entrance to the Bay, near LPG and along the Ore Jetty within Big Bay (Figure 1.13 & Table 1.3). This suggests that there may be a source of manganese pollution affecting most of the Big Bay region. Mn is naturally ubiquitous in the marine environment, however, can become potentially harmful through its tendency to accumulate in certain organisms, such as shellfish. The higher concentrations of Mn recorded in Big Bay is possibly associated with the recent start of Mn exports (Section 3.2.2).

Table 6.4 Enrichment factors for Cadmium, Copper and Lead in sediments collected from Saldanha Bay in 2015 relative to sediments from 1980.

	Sample	Cd	Cu	Pb
	1980 average	0.075	0.41	0.8
Small Bay	SB1	41.7	110.6	42.8
	SB2	14.7	14.0	13.1
	SB3	5.6	15.1	16.0
	SB5	4.9	10.3	10.2
	SB8	7.8	6.9	6.0
	SB9	10.8	11.0	15.7
	SB10	8.2	16.6	18.7
	SB14	18.6	42.4	57.2
	SB15	16.3	13.7	24.1
	SB16	10.0	15.1	17.3
	Sea Harvest	14.0	26.7	20.9
Big Bay	BB20	8.2	39.2	2.0
	BB21	9.7	3.2	10.4
	BB22	8.7	8.2	5.1
	BB24	8.8	10.7	13.6
	BB25	6.6	6.3	10.1
	BB26	10.3	16.4	13.1
	BB29	8.3	4.5	5.3
	BB30	5.0	8.9	5.2
	LPG	10.3	6.1	1.3

Table 6.5 Normalized values for Cadmium, Copper, Nickel, Lead and Manganese in sediments collected from Saldanha Bay in 2015.

	Sample #	Cd:Al	Cu:Al	Ni:Al	Pb:Al	Mn: Al	
Small Bay	SB1	1.32	19.18	5.69	14.49	23.91	
	SB2	1.19	6.21	4.59	11.33	34.59	
	SB3	1.22	17.88	7.67	36.89	89.33	
	SB5	1.41	16.29	17.69	3148	95.37	
	SB8	1.21	5.83	4.16	9.96	48.50	
	SB9	1.15	6.45	8.29	17.83	40.70	
	SB10	1.69	18.77	14.88	41.31	117.93	
	SB14	1.24	15.46	7.28	40.69	33.90	
	SB15	1.05	4.81	5.50	16.53	26.60	
	SB16	1.41	11.59	7.94	25.92	50.34	
	Sea Harvest	1.40	14.59	7.59	22.34	406.77	
	Big Bay	BB20	1.73	45.38	3.63	4.46	78.88
		BB21	1.24	2.27	8.75	14.15	67.27
BB22		0.94	4.83	4.26	5.9	95.56	
BB24		1.19	7.98	11.25	19.76	118.82	
BB25		1.90	9.84	10.97	30.99	133.72	
BB26		1.31	11.48	8.76	17.92	94.07	
BB29		1.50	4.44	8.74	10.07	66.89	
BB30		1.91	18.61	12.01	21.27	129.84	
LPG		1.06	3.45	4.94	1.43	56.23	
Danger Bay		DB1	4.52	ND	8.4	67.35	59.70
	DB2	5.59	ND	3.78	ND	90.97	
	DB3	2.76	16.76	0.84	61.11	49.28	
	DB4	4.00	11.24	1.32	44.41	86.75	
	DB5	4.66	ND	ND	42.91	66.96	
	DB 6	ND	35.12	6.54	20.88	74.76	
	DB7	4.37	20.36	14.14	76.92	204.38	
	DB8	1.23	ND	3.48	79.18	46.21	
	DB9	4.59	8.29	17.94	66.50	54.62	
	DB10	3.82	14.25	14.36	92.39	100.93	
	Db11	5.16	6.82	13.50	103.48	127.95	
	DB12	3.80	14.26	26.67	114.23	130.48	
	DB13	3.38	7.81	13.39	35.73	99.79	
	DB14	4.16	ND	2.37	35.44	131.01	
Langebaan Lagoon	LL31	0.11	0.86	4.62	8.55	136.64	
	LL32	0.19	0.25	3.78	1.74	108.86	

	Sample #	Cd:Al	Cu:Al	Ni:Al	Pb:Al	Mn: Al
	LL33	ND	1.02	6.54	3.52	134.18
	LL34	0.15	ND	4.30	3.58	109.97
	LL37	ND	0.51	6.00	4.94	119.45
	LL38	0.29	0.15	5.92	6.9	130.87
	LL39	ND	ND	4.15	8.52	129.64
	LL40	ND	ND	8.28	ND	102.44
	LL41	0.10	ND	3.98	5.41	129.22
	Sample #	Cd:Al	Cu:Al	Ni:Al	Pb:Al	Mn: Al

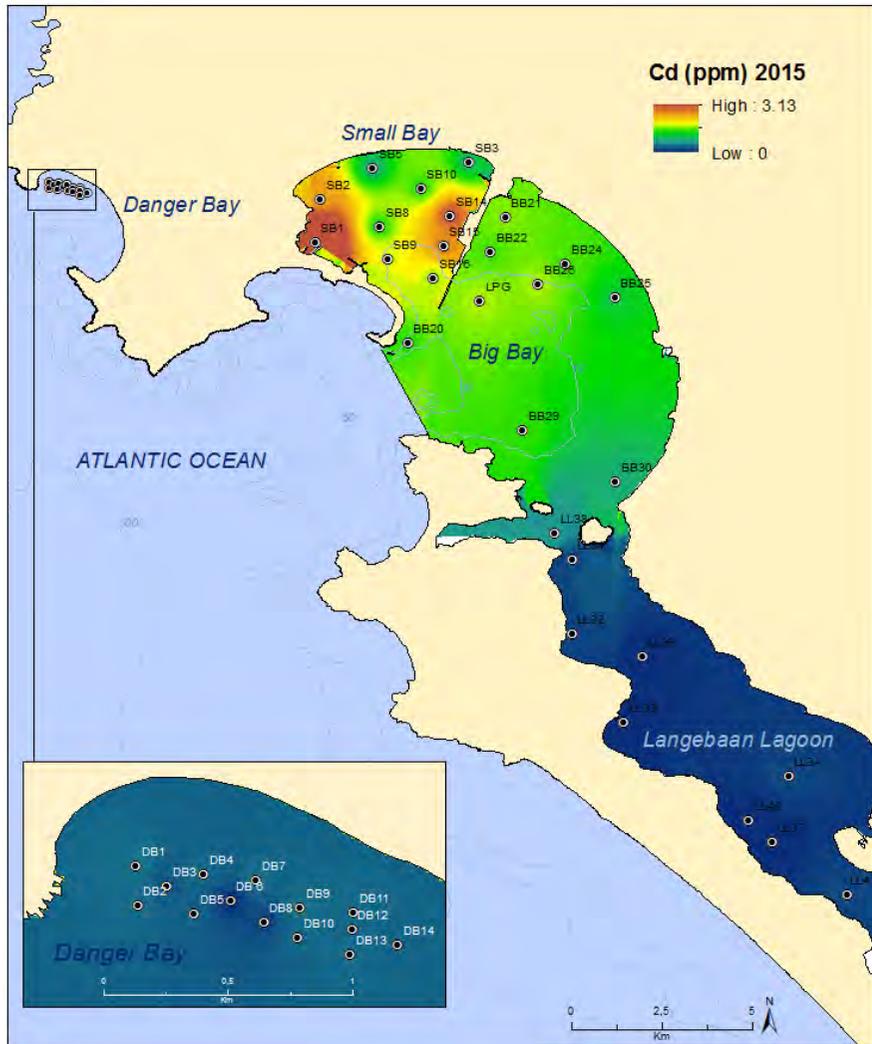


Figure 6.9 Spatial interpolation of cadmium values based on values measured in Saldanha Bay and Langebaan Lagoon in 2015.

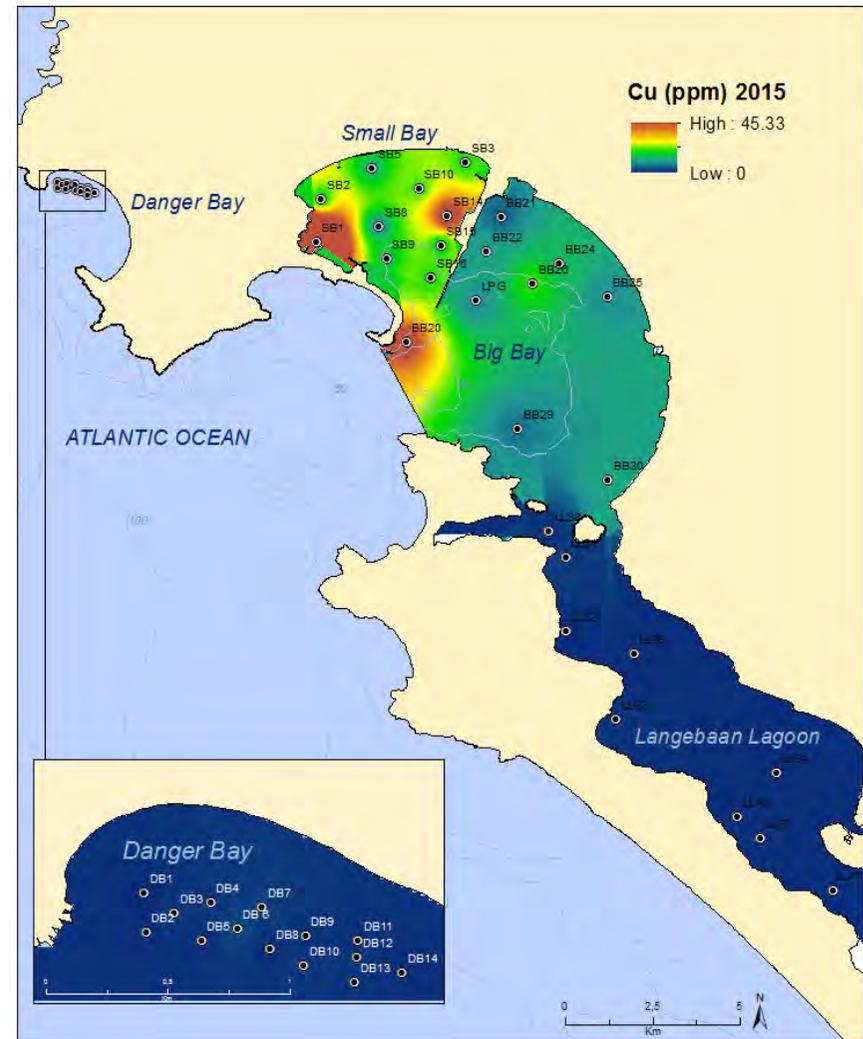


Figure 6.10 Spatial interpolation of copper values based on values measured in Saldanha Bay and Langebaan Lagoon in 2015.

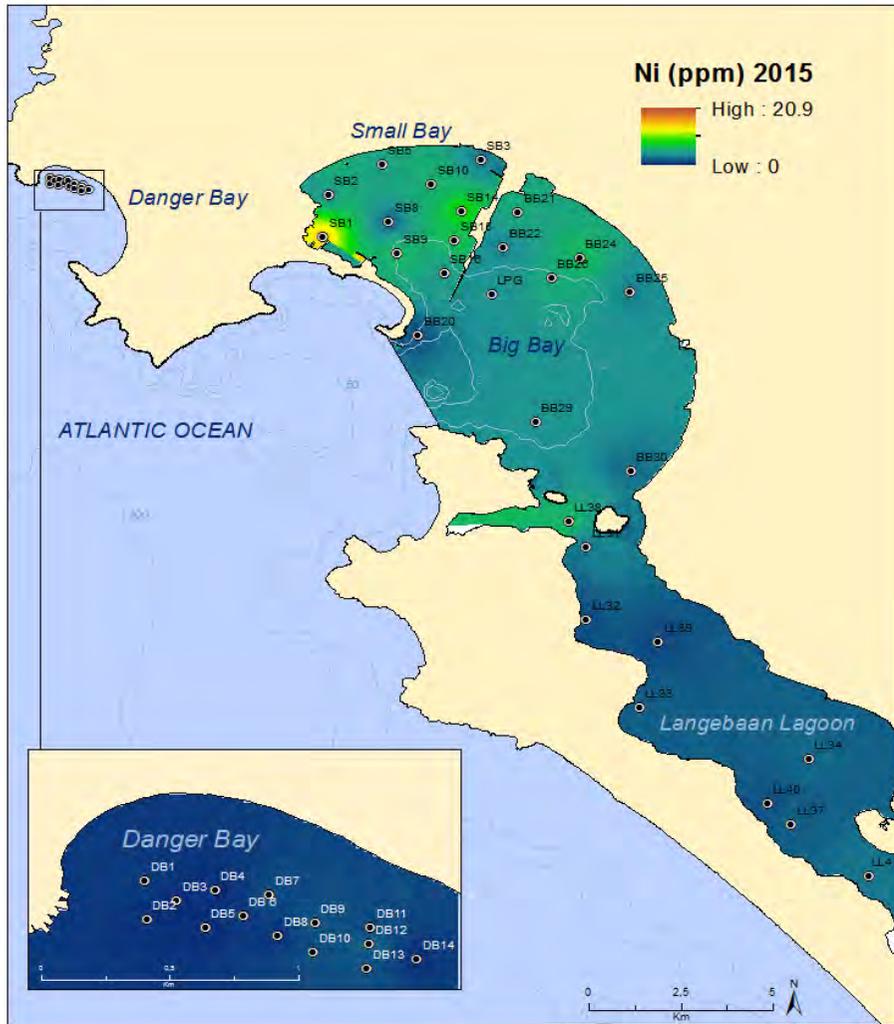


Figure 6.11 Spatial interpolation of nickel values based on values measured in Saldanha Bay and Langebaan Lagoon in 2015.

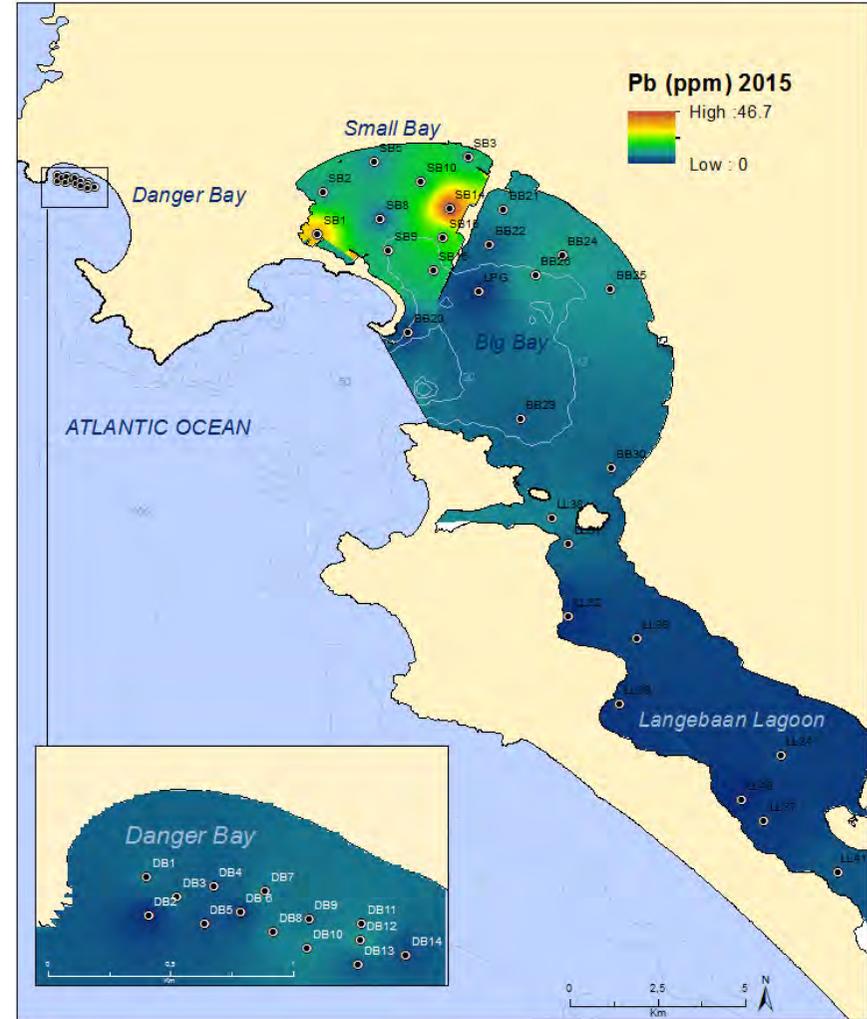


Figure 6.12 Spatial interpolation of lead values based on values measured in Saldanha Bay and Langebaan Lagoon in 2015.

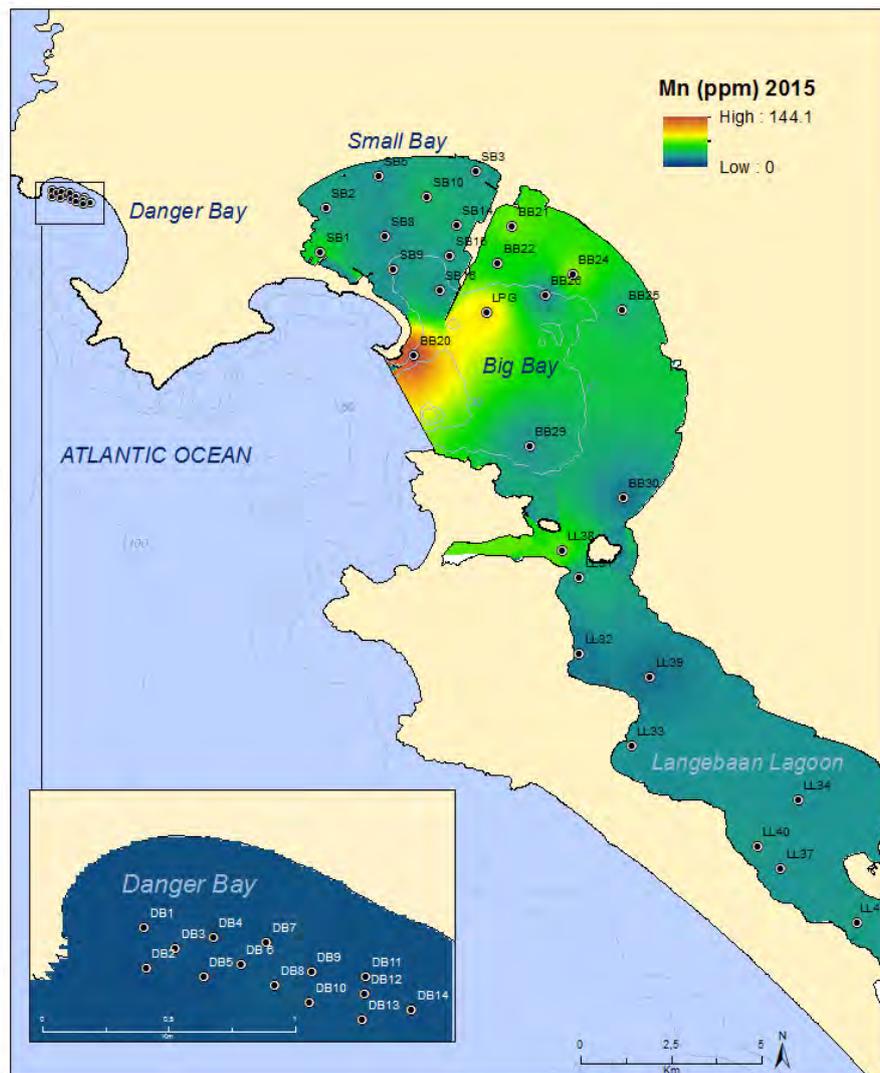


Figure 6.13 Spatial interpolation of manganese values based on values measured in Saldanha Bay and Langebaan Lagoon in 2015.

6.1.3.3 Temporal variation

The temporal variation in the concentration of trace metals in the most heavily contaminated areas (Small Bay and along the ore jetty in Big Bay) relative to the ERL guideline is discussed below.

Cadmium

There was a considerable increase in the concentration of Cadmium detected in the sediments of Saldanha Bay between 1980 and 1999. In 1999, the levels of cadmium recorded at the Mussel Farm, the Yacht Club Basin and the Channel End of the Ore Terminal exceeded the ERL toxicity threshold of 1.2 mg/kg established by NOAA (Figure 6.14). Cadmium concentrations have shown a progressive and dramatic decrease in the period 1999-2010, however, the results between 2010 and 2013 indicated a steady increase again in the cadmium concentrations in the Yacht Club Basin. At the time of the 2014 survey, Cadmium concentrations had decreased to below the ERL toxicity threshold within the Yacht Club Basin but increased in 2015 to levels similar to that of 2013. All other sites

have displayed a decrease in cadmium concentrations in 2015 compared to 2014, however, the Multi-purpose Quay still exceeded the ERL toxicity limit.

Copper

The total concentration of copper in the sediments of the sites assessed temporally has remained below the ERL threshold consistently since 1980, with the exception of the Yacht Club Basin which exceeded the ERL in 1999, 2008, 2010 to 2013 and 2015 (Figure 6.15). Copper concentration observed during 2014 decreased at all sites from the 2013, however, in 2015 all sites increased.

Nickel

The concentration of nickel was the highest at the yacht club basin and the mussel farm sites in 1999 where it exceeded the ERL threshold (Figure 6.16). Since 1999, nickel concentrations have declined markedly at both sites, never again exceeding the ERL threshold. Peak nickel concentration at the remaining four sites was observed in 2000, though concentrations did not exceed the ERL threshold. Since 2000, levels of nickel have declined at all four of these sites. In 2012 there was a slight increase in the concentration of nickel at all six sites, though it remains well below the ERL threshold value. The 2013 results displayed mostly similar concentrations to 2012, while the 2014 results indicated a decrease in nickel concentrations at all six sites. 2015 levels remained below the ERL toxicity threshold. Slight increases in nickel concentration were indicated across the six sites with the most substantial increase at the Yacht Club Basin.

Lead

The concentration of lead peaked and exceeded the ERL threshold at the Yacht Club Basin and Mussel farm site in 1999 (Figure 6.17). The concentration of lead at these sites has not exceeded the ERL level since this time. The concentrations of lead at either end of the ore jetty and at the site in Big Bay have fluctuated over the last 15 years with no apparent pattern and have remained relatively low and well below the ERL threshold. The concentration of lead at sites adjacent to the multi-purpose terminal has frequently exceeded the ERL threshold over the last 15 years, with concentrations exceeding the threshold in 2008, 2009, 2011, 2012 and 2013 and being just below the threshold in 2014 and 2015. Fluctuations in the concentration of lead at this site do not follow any clear pattern though. This result suggests that industrial and shipping activities taking place at the multi-purpose terminal continue to contaminate the adjacent marine environment with lead.

Manganese

The temporal variation in manganese concentrations in sediments around the ore terminal in Saldanha Bay is shown in Figure 6.18. Manganese concentrations at sites located along the ore terminal with in Small Bay have fluctuated over recent years. High concentrations of manganese were recorded at the Small Bay sites in 2014 but were found to have decreased in 2015. The two sites located along the ore terminal with in Big Bay however, have shown consistent increases since 2013. This may have been due to the start in manganese exports in Saldanha Bay and simply reflects the accumulation of manganese in the sediments.

Iron

The temporal variation in the concentration of iron in sediments around the ore terminal in Saldanha Bay is shown in Figure 6.19. The concentration of iron increased between 1999 and 2004 at sites 14 and 15 which are in closest proximity to and on the downwind side (of the predominant southerly winds) of the multi-purpose quay. This may have been due to increases in volumes of ore handled or increases in losses into the sea over this period, or simply reflects accumulation of iron in the sediments over time. There was a reduction in the concentration of iron in the sediments at most sites on the Small Bay side of the ore terminal between 2004 and 2010. Dredging took place at the multi-purpose quay in 2007 and the removal of iron rich sediment at Site 15 is probably the reason for the dramatic decrease in iron concentration recorded at this station between 2008 and 2009 sampling. Sediment iron concentration at this site did increase in 2009, but decreased again in 2010 samples. The 2011 survey revealed that iron concentrations had increased at most sites around the ore terminal despite reductions in the mud contents at all sites. This suggests that fluctuations in iron content are a result of iron inputs rather than the flushing experienced at the sites.

Transnet has implemented a number of new dust suppression measures in recent years (SRK 2009, Viljoen *et al.* 2010). Dust suppression mitigation measures implemented since mid-2007 include conveyer covers, a moisture management system, chemical dust suppression, surfacing of roads and improved housekeeping (road sweeper, conveyor belt cleaning, vacuum system, dust dispersal modelling and monitoring) amongst others. The volume of ore handled at the bulk quay has increased from around 4.5 million tons per month during 2007-2008 to around 6.5 million tons during 2009-2010 (~50% increase), yet the concentration of iron in the sediments at sites adjacent to the ore terminal remained fairly stable or decreased between 2009 and 2010. Relatively small fluctuations in the concentration of iron were seen at five of the six sites between 2010 and 2015. This does suggest that the improved dust control methods implemented since 2007 have been successful in reducing the input to the marine environment. However the concentration of iron at SB15 increased very dramatically in 2012, but decreased equally dramatically in 2013. In 2014 the concentration at SB15 increased again but not as high as in 2012. The reason for the increase at this site but not at any of the other sites is unclear. However, concentrations recorded in 2015 increased at all sites, excluding SB15. The two sites located on the Big Bay side of the ore terminal and the site at the end of the terminal on the Small Bay side all had the highest recorded iron concentrations since 2004. On-going monitoring of sediment iron concentration will reveal whether the increases observed at these sites will continue with the anticipated higher volumes of ore handling or if concentrations will continue to fluctuate.

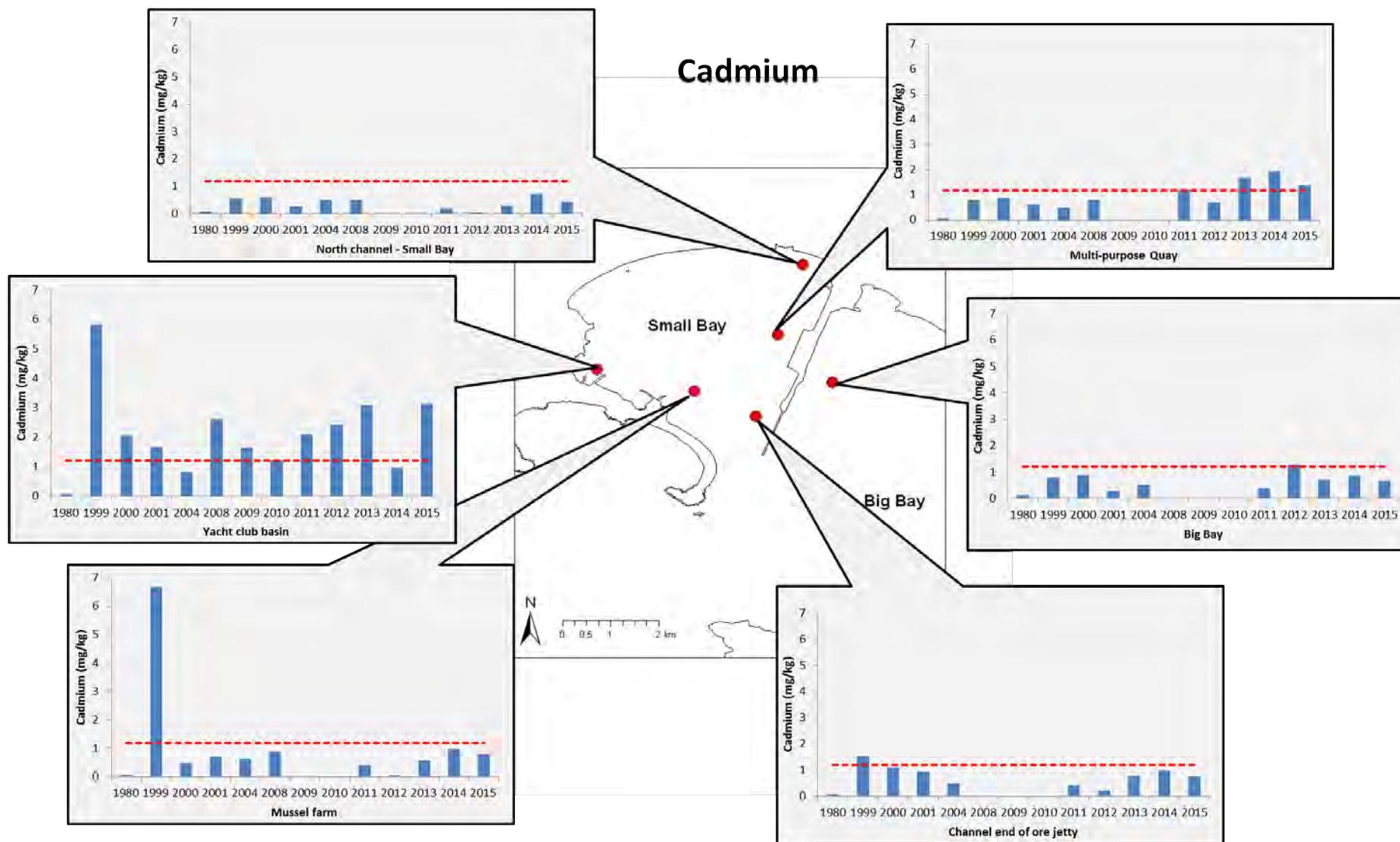


Figure 6.14 Concentrations of Cadmium (Cd) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2015. Dotted lines indicate Effects Range Low values for sediments.

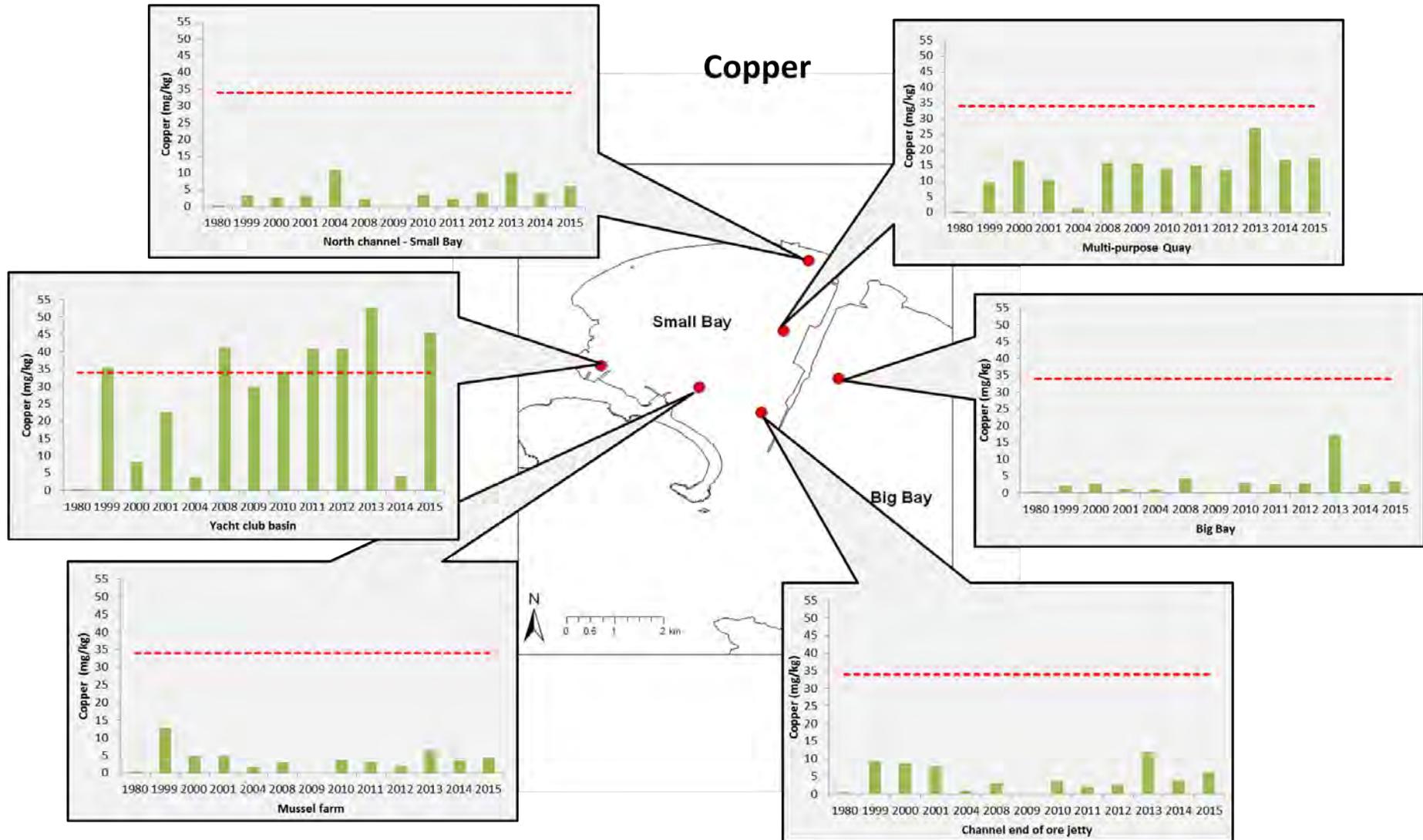


Figure 6.15 Concentrations of Copper (Cu) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2015. Dotted lines indicate Effects Range Low values for sediments.

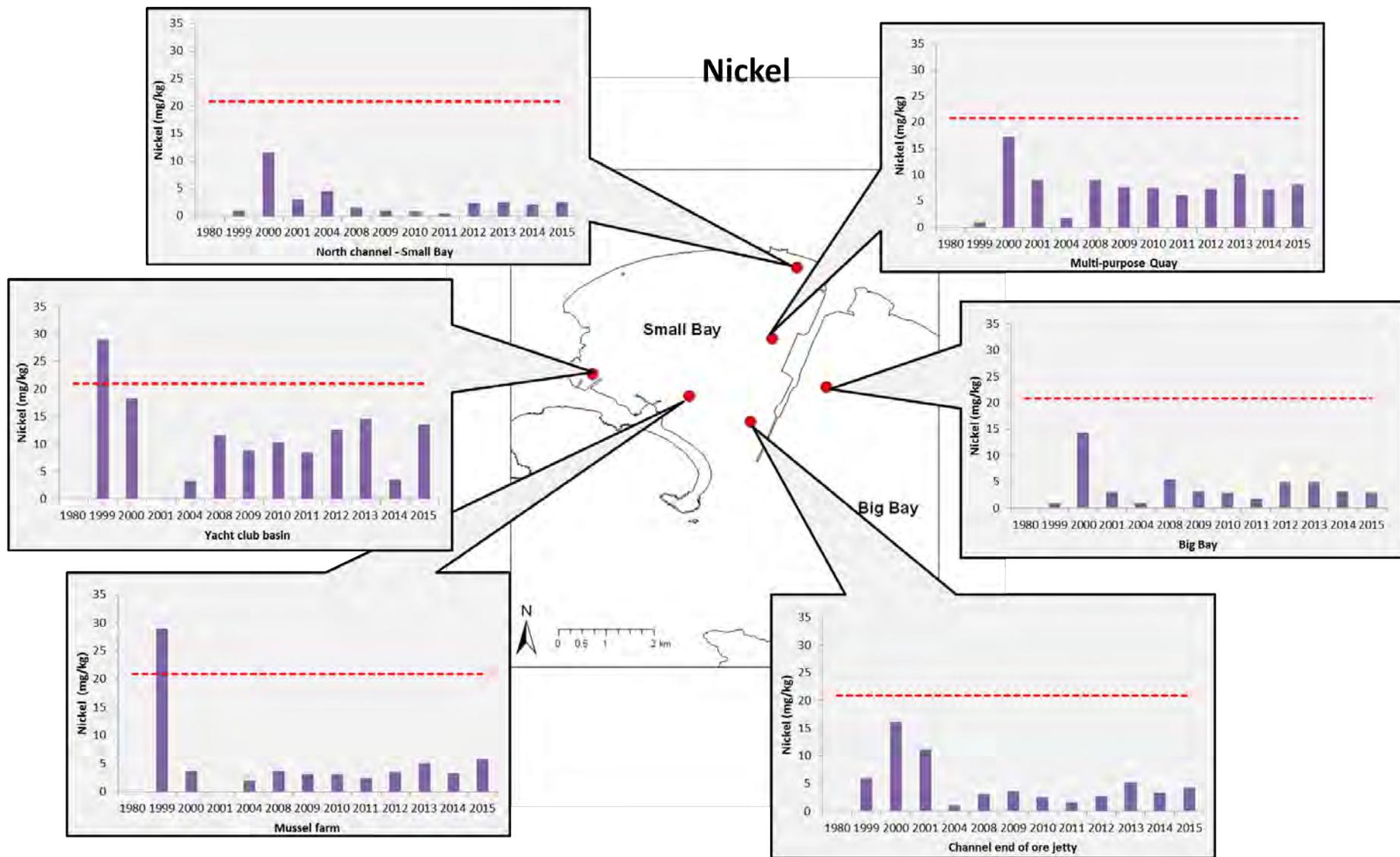


Figure 6.16 Concentrations of Nickel (Ni) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2015. Dotted lines indicate Effects Range Low values for sediments.

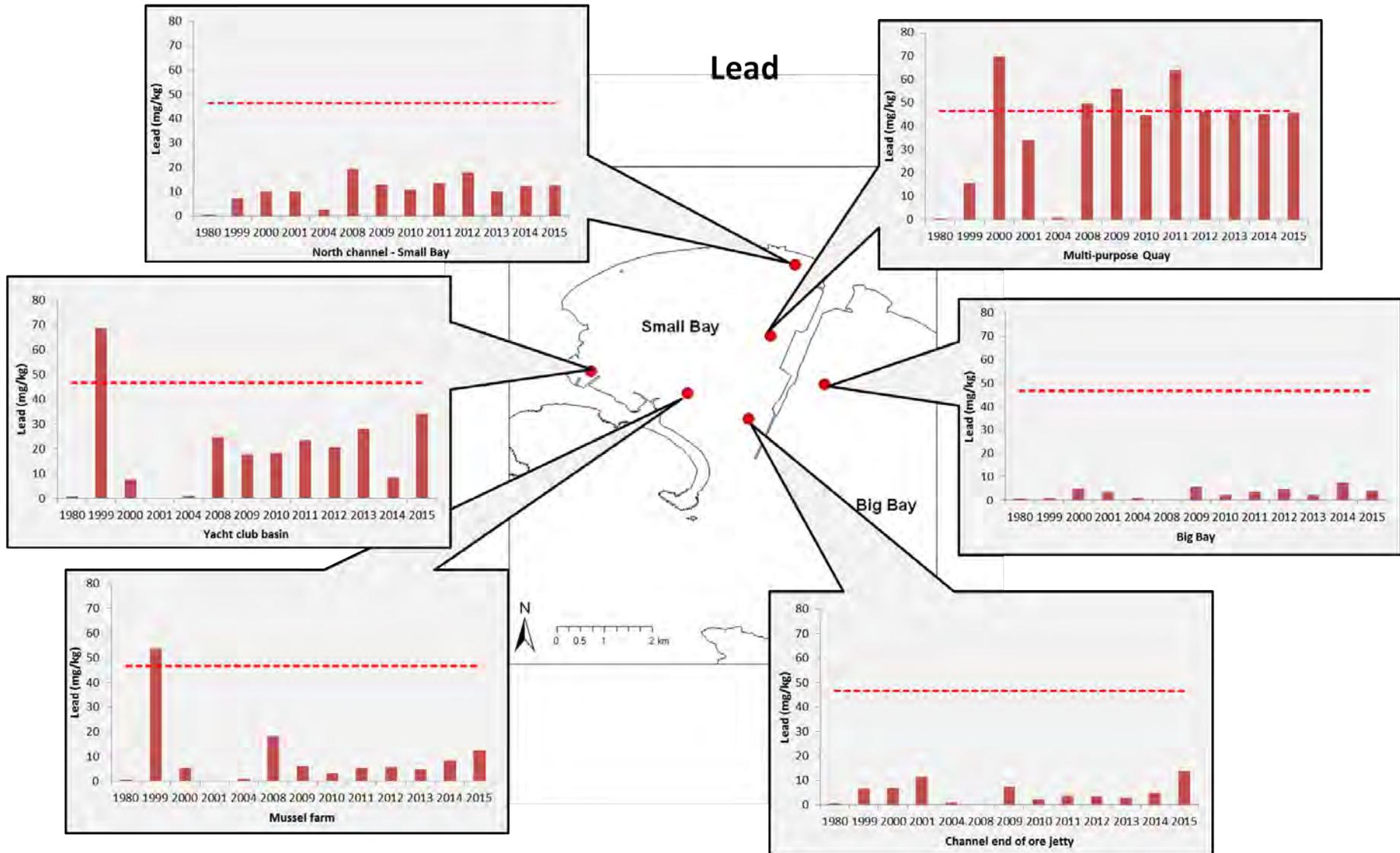


Figure 6.17 Concentrations of Lead (Pb) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2015. Dotted lines indicate Effects Range Low values for sediments.

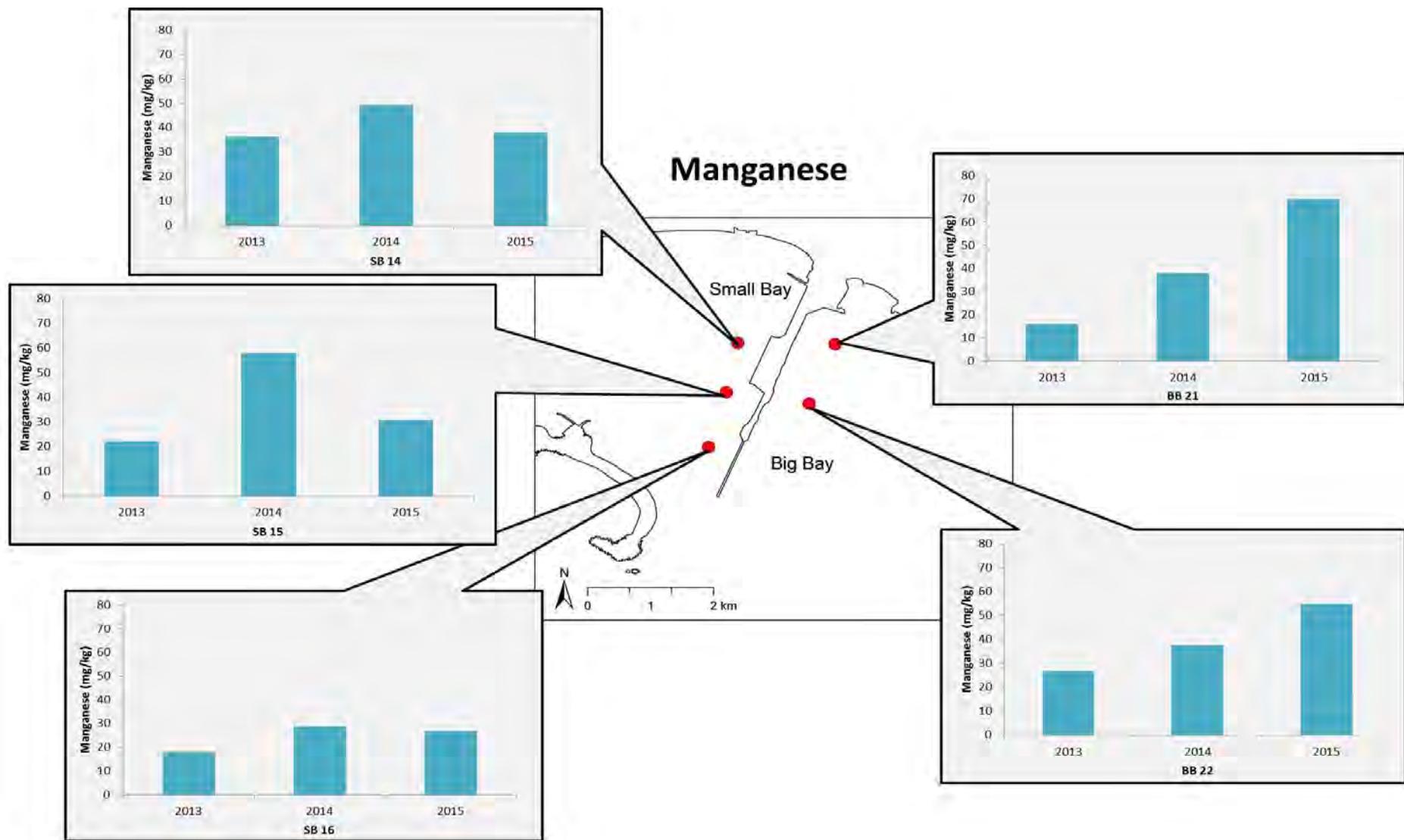


Figure 6.18 Concentration of manganese (Mn) in mg/kg recorded at five sites in Saldanha Bay between 2013 and 2015.

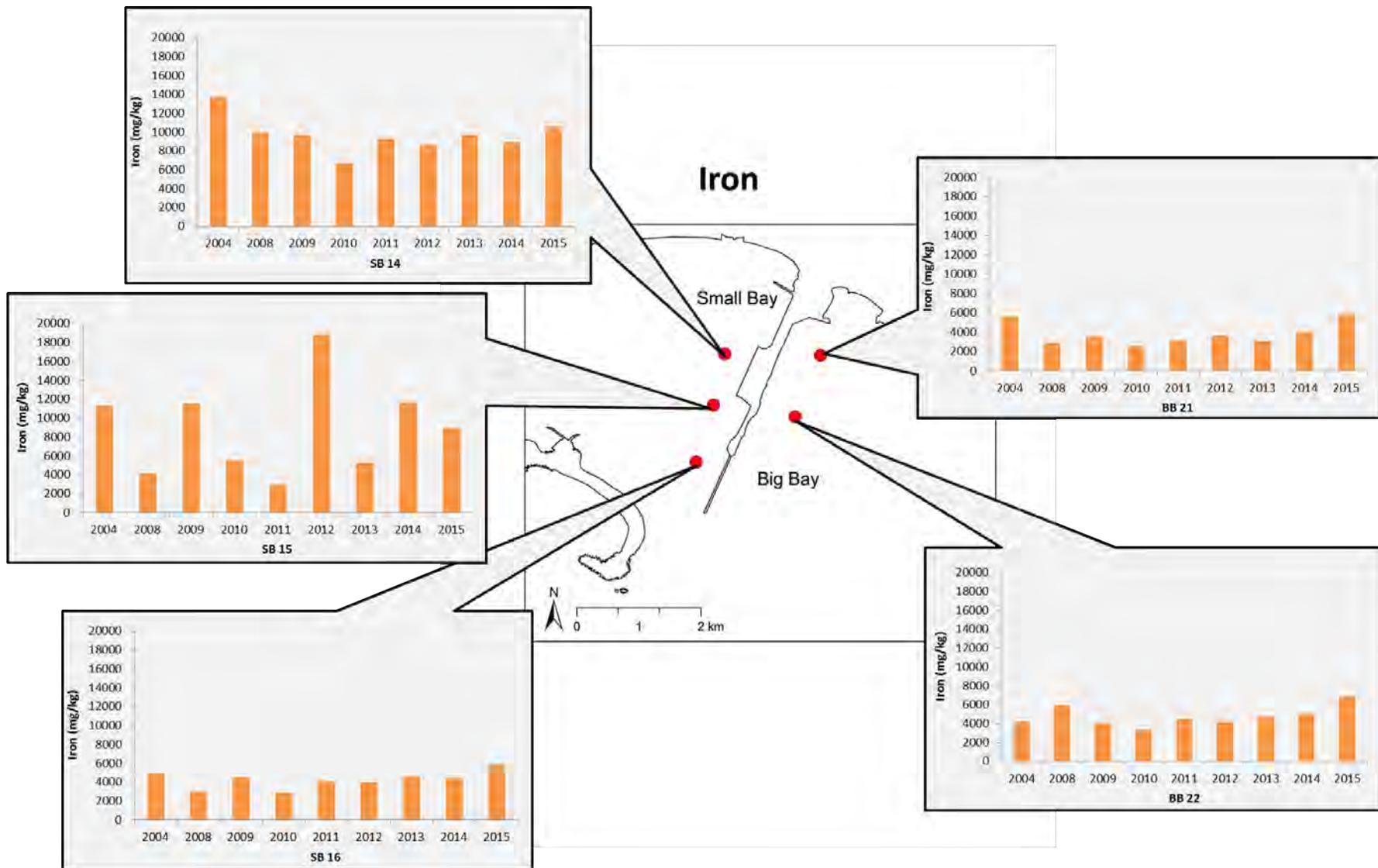


Figure 6.19 Concentrations of Iron (Fe) in mg/kg recorded at five sites in Saldanha Bay between 2004 and 2015.

6.1.4 Hydrocarbons

Poly-aromatic hydrocarbons (PAH) (also known as polynuclear or polycyclic-aromatic hydrocarbons) are present in significant amounts in fossil fuels (natural crude oil and coal deposits), tar and various edible oils. They are also formed through the incomplete combustion of carbon-containing fuels such as wood, fat and fossil fuels. PAHs are one of the most wide-spread organic pollutants and they are of particular concern as some of the compounds have been identified as carcinogenic for humans (Nikolaou *et al.* 2009). PAHs are introduced to the marine environment by anthropogenic (combustion of fuels) and natural means (oil welling up or products of biosynthesis) (Nikolaou *et al.* 2009). PAHs in the environment are found primarily in soil, sediment and oily substances, as opposed to in water or air, as they are lipophilic (mix more easily with oil than water) and the larger particles are less prone to evaporation. The highest values of PAHs recorded in the marine environment have been in estuaries and coastal areas, and in areas with intense vessel traffic and oil treatment (Nikolaou *et al.* 2009).

Marine sediment samples from Saldanha Bay were analysed for the presence of hydrocarbons in 1999. No PAHs were detectable in the samples, but low levels of contamination by aliphatic (straight chain) molecules, which pose the lowest ecological risk, were detected. This suggested that the main source of contamination is the spilling and combustion of lighter fuels from fishing boats and recreational craft (Monteiro *et al.* 1999). Sediment samples from five sites in the vicinity of the oil terminal in Saldanha Bay were tested for PAH contamination in April 2010. PAH concentrations at all five sites were well below ERL values stipulated by NOAA. From 2011 to 2014 PAH levels were not tested due to the continual low levels, however, analysis of total petroleum hydrocarbon (TPH) concentrations was continued.

Table 6.6 Total petroleum hydrocarbons (mg/kg) in sediment samples collected over the period 2011-2014 from five stations in Saldanha Bay. Values in red indicate exceptionally high total petroleum hydrocarbon levels.

	2011	2012	2013	2014	2015
SB14	<20	34	130	19	<38
SB15	<20	35	NO DATA	53	<38
SB16	<20	24	28	14649	<38
BB21	<20	20	32	20	<38
BB22	<20	17	27	<0.2	<38

Unfortunately, NOAA guideline standards for total PAH levels were incorrectly applied to TPH values in previous years where it was stated that TPH exceeded guideline standards. This error was identified by Newman (2015) who correctly pointed out that there are no guidelines for TPH, only for PAHs. PAH levels have been well below the guideline limits and despite there being no guideline limits to determine the toxicological significance of TPH contamination there have been considerable fluctuations in contamination levels since 2011. TPH levels recorded in 2011 were below the detection limit of 20 mg/kg (Table 6.6). Slight increases in TPH levels were indicated at all sites in 2012 and 2013. TPH levels at site SB14 decreased from 130 mg/kg to 19 mg/kg in 2014, however,

there was the extreme increase at site SB16 from 28 mg/kg to 14 649 mg/kg. This is of major concern as such levels are considered to be toxic (Nikolaou *et al.* 2009). The high TPH concentrations recorded at SB16 indicated heavily polluted conditions compared to highly oil-contaminated sediments in other parts of the world such as, oil-contaminated sediments in Bahrain (779 ug/g) (Tolosa *et al.* 2005) and the coastline of Saudi Arabia after the Gulf war (11–6 900 mg/kg) (Readman *et al.* 1996). Analysis of the carbon ranges in 2014 showed that the majority (14 283 mg/kg) of the contamination was that of weathered diesel fuel. Site SB16 is situated alongside the iron ore jetty and is in close proximity to bulk-shipping berths and associated mooring activities. The most likely explanation for the high TPH levels is that a pollution incident associated with these shipping activities took place. Alternatively, a pollution incident or routine operational activities on the jetty itself could be the root of this contamination. TPH levels in 2015 have decreased since 2014 and were below the detection limit of 38 mg/kg.

Table 6.7 Sediment Quality guidelines and Poly-aromatic hydrocarbons concentrations measured in sediment samples collected from Saldanha Bay and Langebaan Lagoon in April 2015.

Hydrocarbon (mg/kg)	ERL*	ERM**	SB1	SB2	SB3	SB10	SB14	SB15	SB16	BB21	SB22
Acenaphthene	0.016	0.5	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Acenaphthylene	0.044	0.64	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Anthracene	0.0853	1.1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(a) anthracene	0.261	1.6	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(a) pyrene	0.43	1.6	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(b) flouranthene	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(g,h,i) perylene	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Benzo(k) flouranthene	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Chrysene	0.384	2.8	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dibenzo(a,h) anthracene	0.0634	0.26	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Flouranthene	0.6	5.1	0.0029	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Flourene	0.019	0.54	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Indeno(1.2.3-c.d) pyrene	-	-	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Naphthalene	0.16	2.1	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Phenanthrene	0.24	1.5	0.0025	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Pyrene	0.665	2.6	0.0031	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Total PAH	4	44.7	0.0085	-	-	-	-	-	-	-	0

*Effects Range Low guideline stipulated by NOAA below which toxic effects rarely occur in sensitive marine species.

**Effects Range Median guideline stipulated by NOAA above which toxic effects frequently occur in sensitive marine species.

Sediment samples collected in 2015 had undetectable PAH levels at all sites with the exception of the Yacht Club Basin site (Table 6.7). At this site, PAH's Flouranthene, Phenanthrene and Pyrene were detectable, but were well below ERL guideline standards. The elevated PAH concentration near the Yacht Club is in agreement with the CSIR findings, however the total PAH concentration recorded here ($0.0085\text{mg}\cdot\text{kg}^{-1}$) is substantially lower than the peak of $1.075\text{mg}\cdot\text{kg}^{-1}$ recorded in this area by Newman (2015). Analysis of the ratio of specific PAH compounds can allow for the identification of potential sources of contamination (Tiganus *et al.* 2013). The ratio of Flouranthene / (Flouranthene + Pyrene) fell within the 0.4 – 0.5 range, characteristic of combustion products of liquid oil and fuel, emissions which are typically found in areas with high small craft activity. Analysis of the carbon ranges of the TPH from the Yacht Club basin further supported this (Table 6.8). While the TPH and PAH finding present no major concern, it is recommended that TPH monitoring within the vicinity of the ore terminal is continued annually so as to identify the frequency of occurrence of pollution incidents, like that recorded in 2014, and assess the ecological implications to the Bay.

Table 6.8 Total petroleum hydrocarbon (TPH) sampling effort for 2015 in Saldanha Bay (SB = Small Bay, BB = Big Bay). Data presented are for the amount (mg/kg) of petroleum-based hydrocarbons within each of the two carbon ranges for which samples were analysed, C₁₀-C₂₈ (diesel fuels), C₂₈-C₄₀ (lubricants, motor oil and grease) and the total amount of TPH.

Site	C10-C28 (mg/kg)	C28-C40 (mg/kg)	Total (mg/kg)
SB1	62	73	140
SB2	<38	<38	<38
SB3	<38	<38	<38
SB10	<38	<38	<38
SB14	<38	<38	<38
SB15	<38	<38	<38
SB16	<38	<38	<38
BB21	<38	<38	<38
BB22	<38	<38	<38

7 AQUATIC MACROPHYTES IN LANGEBAAN LAGOON

Three distinct intertidal habitats exist within Langebaan Lagoon: seagrass beds, such as those of the eelgrass *Zostera capensis*; salt marsh dominated by cordgrass *Spartina maritime* and *Sarcocornia perennis*; and unvegetated sandflats dominated by the sand prawn, *Callinassa kraussii* and the mudprawn *Upogebia capensis* (Siebert & Branch 2005). Sand and mud prawns are considered ecosystem engineers as their feeding and burrowing activities modify the local environmental conditions, which in turn modify the composition of the faunal communities (Rhoads & Young 1970, Woodin 1976, Wynberg & Branch 1991, Siebert & Branch 2006). Seagrass beds and salt marshes perform an opposite and antagonistic engineering role to that of the sand and mud prawns as the root-rhizome networks of the seagrass and saltmarsh plants stabilize the sediments (Siebert & Branch 2005). In addition, the three dimensional leaf canopies of the seagrass and saltmarsh plants reduce the local current velocities thereby trapping nutrients and increasing sediment accretion (Kikuchi & Perez 1977, Whitfield *et al.* 1989, Hemmingra & Duarte 2000). The importance of seagrass and saltmarsh beds as ecosystem engineers has been widely recognized. The increased food abundance, sediment stability, protection from predation and habitat complexity offered by seagrass and saltmarsh beds provide nursery areas for many species of fish and invertebrates and support, in many cases, a higher species richness, diversity, abundance and biomass of invertebrate fauna compared to unvegetated areas (Kikuchi & Peres 1977, Whitfield *et al.* 1989, Hemmingra & Duarte 2000, Heck *et al.* 2003, Orth *et al.* 2006, Siebert & Branch 2007). It is therefore surprising that recent research in the Langebaan Lagoon (Pillay *et al.* 2011) showed that the opposite was true when comparing sediment penetrability and species richness between habitats dominated by the sandprawn *Callinassa kraussi* and cordgrass *Spartina maritime*. Bioturbation by the sandprawn loosened the sediment, resulting in less anoxic conditions, enhanced organic content and colonisation of burrowing species. It is speculated that the sandprawn may aid in increasing food availability to higher trophic levels. Seagrass and saltmarsh beds are also important for waterbirds some of which feed directly on the shoots and rhizomes, forage amongst the leaves or use them as roosting areas at high tide (Baldwin & Lovvorn 1994, Ganter 2000, Orth *et al.* 2006).



Figure 7.1. Seagrass (black) and saltmarsh (green) near Bottelary in Langebaan Lagoon. Source: Google Earth.

7.1 Long term changes in seagrass in Langebaan Lagoon

Seagrass beds are particularly sensitive to disturbance and are declining around the world at rates comparable to the loss of tropical rainforests, placing them amongst the most threatened ecosystems on the planet (Waycott *et al.* 2009). The loss of seagrass beds is attributed primarily to anthropogenic impacts such as deterioration of water quality including coastal eutrophication, alterations to food webs caused by the overexploitation of predatory fish, modified sediment dynamics associated with coastal and harbour development (Waycott *et al.* 2009) and direct physical damage through bait collection (Pillay *et al.* 2010). Most recently, research has shown that warmer temperatures and longer exposure to air resulted in significantly lower biomass of seagrass in the Langebaan Lagoon (University of Cape Town, Cloverly Lawrence, *pers. comm.* 2014).

The loss of seagrass meadows has been shown to have profound implications for the biodiversity associated with them, including loss of invertebrate diversity, fish populations, that use the sheltered habitat as nurseries, and waterbirds, that use the seagrass meadows as foraging grounds during their non-breeding period (Hughes *et al.* 2002). Loss of seagrass is also associated with increased fragmentation of large seagrass beds, which leads to the reduced species diversity. For example, Källén *et al.* (2012) demonstrated that large seagrass beds were home to significantly greater epifaunal richness and abundance of *Assiminea globules*. *A. globules* is a gastropod which favours seagrass bed edges. Species composition was found to differ between the edges and the interior of seagrass beds and interestingly, it was shown that species composition converged in more fragmented seagrass beds (Källén *et al.* 2012).

Long-term changes in seagrass beds in Langebaan Lagoon have been investigated by Angel *et al.* 2006 and Pillay *et al.* (2010). Angel *et al.* (2006) focused on long term trends at Klein Oesterwal and Bottelary, and was able to show that the width of the *Z. capensis* bed changed substantially between 1972 and 2004, with three major declines evident in this period (Figure 7.2.). The first occurred in

the late 1970s, and was followed by a slow recovery in the early 1980's, the second occurred between 1988 and 1993 and the third between 2002 and 2004 (Angel *et al.* 2006). Mirroring this decline were the striking fluctuations of the small endemic limpet *Siphonaria compressa*, which lives on the leaves of *Z. capensis* and is completely dependent on the seagrass for its survival. The densities of *S. compressa* collapsed twice in this period to the point of local extinction, corresponding with periods of reduced seagrass abundance (Figure 7.2.). At Bottelary, the width of the seagrass bed and densities of *S. compressa* followed the same pattern as at Klein Oesterwal, with a dramatic collapse of the population between 2002 and 2004, followed by a rapid recovery in 2005 (Angel *et al.* 2006). The first decline in seagrass cover coincided with blasting and dredging operations in the adjacent Saldanha Bay, but there is no obvious explanation for the second decline (Angel *et al.* 2006).

Pillay *et al.* (2010) documents changes in seagrass *Zostera capensis* abundance at four sites in the Lagoon – Klein Oesterwal, Oesterwal, Bottelary and the Centre banks using a series of aerial photographs covering the period 1960 to 2007. During this time the total loss of *Z. capensis* amounted to 38% or a total of 0.22 km² across all sites. The declines were most dramatic at Klein Oesterwal where close to 99% of the seagrass beds were lost during this period, but were equally concerning at Oesterwal (82% loss), Bottelary (45% loss) and Centre Bank (18% loss) (Pillay *et al.* 2010). Corresponding changes were also observed in densities of benthic macrofauna at these sites, with species that were commonly associated with *Zostera* beds such as the starfish *Parvulastra exigua* and the limpets *Siphonaria compressa* and *Fisurella mutabilis* and general surface dwellers such as the gastropods *Assiminea globules*, *Littorina saxatilis*, and *Hydrobia* sp. declining in abundance, while those species that burrowed predominantly in unvegetated sand, such as amphipods *Urothoe grimaldi* and the polychaetes *Scoloplos johnstonei* and *Orbinia angrapequensis* increased in density. Pillay *et al.* (2010) was also able to show that the abundance of at least one species of wading bird Terek sandpiper which feeds exclusively in *Zostera* beds was linked to changes in the size of these beds, with population crashes in this species coinciding with periods of lowest seagrass abundance at Klein Oesterwal. By contrast, they were able to show that populations of wader species that do not feed in seagrass beds were more stable over time.

While the precise reasons for the loss of *Z. capensis* beds remain speculative, the impact of human disturbance cannot be discounted, particularly at Klein Oesterwal where bait collection is common (Pillay *et al.* 2010). Most recent research in the Langebaan Lagoon shows that seagrass morphometric growth patterns are mainly controlled by temperature, followed closely by turbidity as a proxy for light levels. It was found that cooler temperatures and less tidal exposure time favoured higher seagrass biomass than warmer more exposed areas. This result could be linked to distribution patterns in the lagoon based on aerial photography (University of Cape Town, Cloverly Lawrence, *pers. comm.* 2014).

By 2007 the intertidal habitat at Klein Oesterwal had been transformed from a seagrass bed community to unvegetated sand flat which was colonized by the burrowing sandprawn *Callinassa kraussi* and other sandflat species that cannot live in the stabilized sediments promoted by the seagrass (Pillay *et al.* 2010). The burrowing sandprawn turns over massive quantities of sediment and once established effectively prevents the re-colonization of seagrass and the species associated with it (Siebert & Branch 2005, Angel *et al.* 2006). The long-term effects of the loss of seagrass at Klein Oesterwal, and to lesser degree at Bottelary and the Central banks, are not yet fully understood. However, studies suggest that the reduced seagrass bed coverage and the associated

changes to macro-invertebrates may have cascading effects on higher trophic levels (Whitfield *et al.* 1989, Orth *et al.* 2006). Alterations to fish species diversity and abundance, and changes in the numbers of water birds that forage or are closely linked to seagrass beds may be seen in Langebaan Lagoon as a result of the loss of seagrass beds (Whitfield *et al.* 1989, Orth *et al.* 2006).

The loss of seagrass beds from Langebaan Lagoon is a strong indicator that the ecosystem is undergoing a shift, most likely due to anthropogenic disturbances. It is critical that this habitat and the communities associated with it be monitored in future as further reductions are certain to have long term implications, not only for the invertebrate fauna but also for species of higher trophic levels.

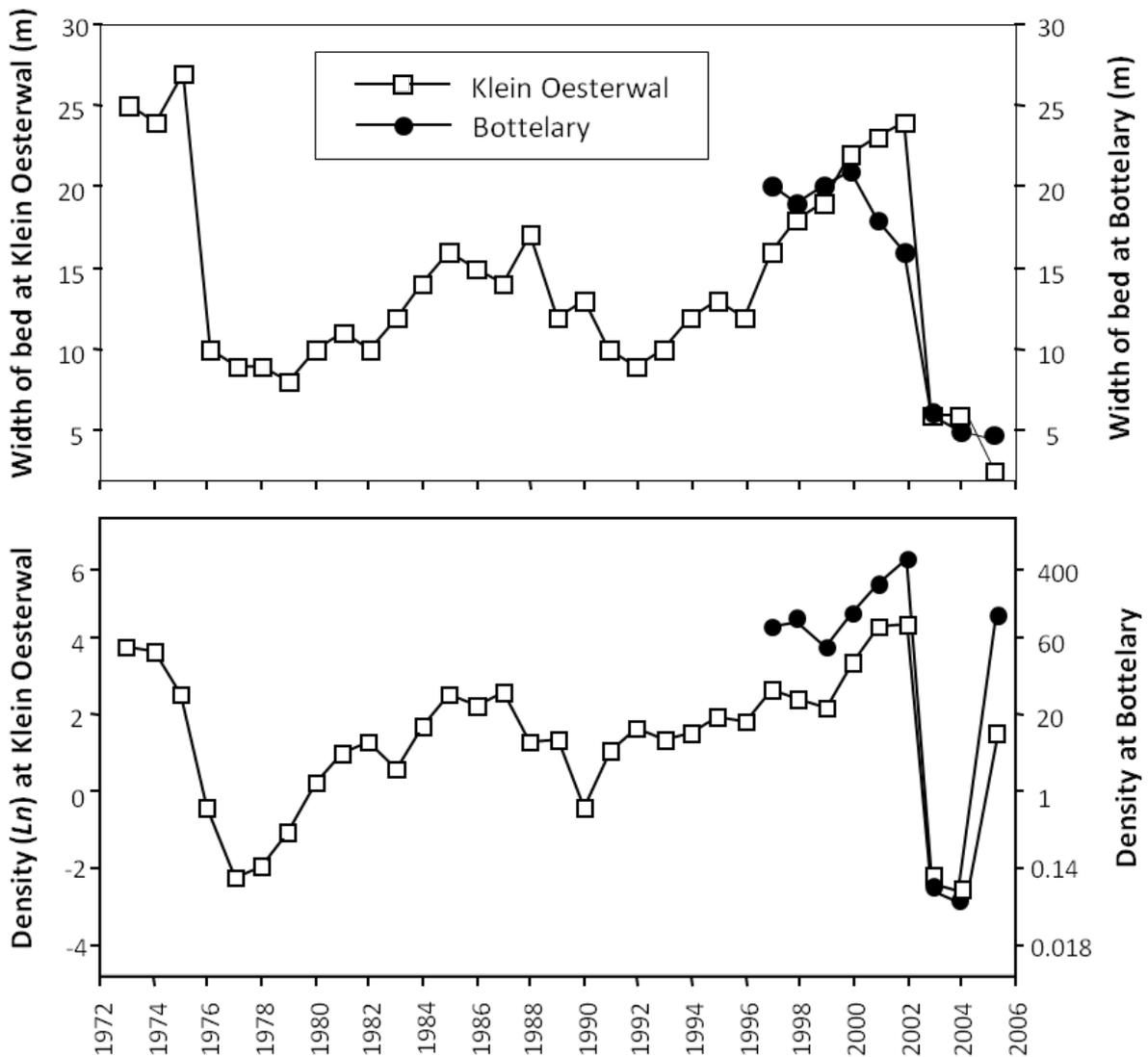


Figure 7.2. Width of the *Zostera* beds and density of *Siphonia* at Klein Oesterwal and Bottelary in Langebaan Lagoon, 1972-2006.

7.2 Long term changes in saltmarshes in Langebaan Lagoon

Saltmarshes in Langebaan are reportedly an important habitat and breeding ground for a range of fish, bird and invertebrate species (Christie 1981, Day 1981, Gericke 2008). Langebaan Lagoon incorporates the second largest salt marsh area in South Africa, accounting for approximately 30% of this habitat type in the country, being second only to that in the Knysna estuary (Adams *et al.* 1999).

Long term changes in salt marshes in Langebaan Lagoon were investigated by Gericke (2008) using aerial photographs taken in 1960, 1968, 1977, 1988 and 2000. He found that overall saltmarsh area had shrunk by only a small amount between 1960 and 2000, losing on average 8 000 m² per annum. Total loss during this period was estimated at 325 000 m², or 8% of the total (Figure 7.3.). Most of this loss has been from the smaller patches of salt marsh that existed on the seaward edge of the main marsh. This is clearly evident from the change in the number of saltmarsh patches in the lagoon over time, which has declined from between 20 and 30 in the 1960s and 70s to less than 10 at present. Gericke (2008) attributed the observed change over time to increases in sea level that would have drown the seaward edges of the marshes or possibly reduced sediment inputs from the terrestrial edge (i.e. reduced input of windblown sand due to stabilization by alien vegetation and development).



Figure 7.3. Change in saltmarsh area over time in Langebaan Lagoon. (Data from Gericke 2008)

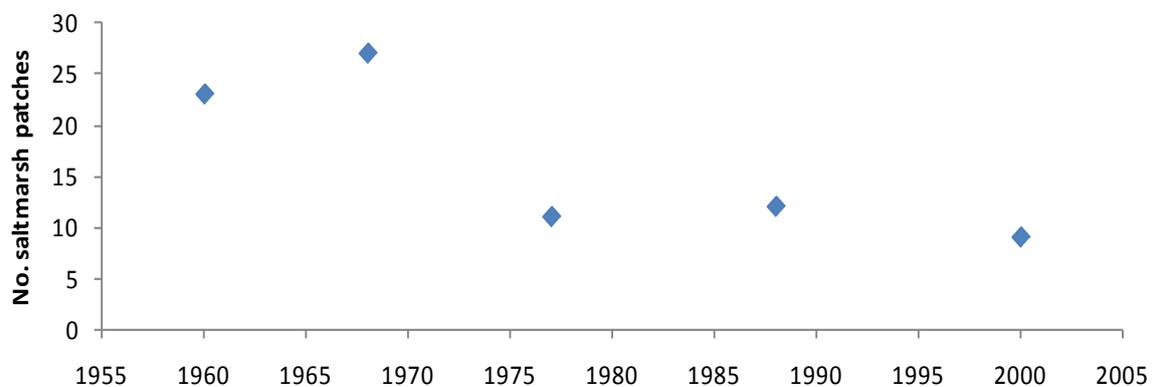


Figure 7.4. Change in the number of discrete saltmarsh patches over time in Langebaan Lagoon. (Data from Gericke 2008).

8 BENTHIC MACROFAUNA

8.1 Background

It is important to monitor biological components of the ecosystem in addition to physico-chemical and eco-toxicological variables, as biological indicators provide a direct measure of the state of the ecosystem in space and time. Benthic macrofauna are the biotic component most frequently monitored to detect changes in the health of the marine environment. This is largely because these species are short lived and, as a consequence, their community composition responds rapidly to environmental changes (Warwick 1993). Given that they are also relatively non-mobile (as compared with fish and birds) they tend to be directly affected by pollution and they are easy to sample quantitatively (Warwick 1993). Furthermore they are scientifically well-studied, compared with other sediment-dwelling components (e.g. meiofauna and microfauna) and taxonomic keys are available for most groups. In addition, benthic community responses to a number of anthropogenic influences have been well documented.

Organic matter is one of the most universal pollutants affecting marine life and it can lead to significant changes in community composition and abundance, particularly in semi-enclosed or closed bays where water circulation is restricted, such as Saldanha Bay. High organic loading typically leads to eutrophication, which may bring about a number of community responses amongst the benthic macrofauna. These include increased growth rates, disappearance of species due to anoxia, changes in community composition and reduction in the number of species following repeat hypoxia and even complete disappearance of benthic organisms in severely eutrophic and anoxic sediments (Warwick 1993). The community composition of benthic macrofauna is also likely to be impacted by increased levels of other contaminants such as trace metals and hydrocarbons found in the sediments. Furthermore, areas that are frequently disturbed by mechanical means (e.g. through dredging) are likely to be inhabited by a greater proportion of opportunistic pioneer species.

The main aim of monitoring the health of an area is to detect the effects of stress, as well as to monitor recovery after an environmental perturbation. There are numerous indices, based on benthic invertebrate fauna information, which can be used to reveal conditions and trends in the state of ecosystems. These indices include those based on community composition, diversity and species abundance and biomass. Given the complexity inherent in environmental assessment it is recommended that several indices be used (Salas *et al.* 2006).

The community composition, diversity, and species abundance and biomass of soft bottom benthic macrofauna samples, collected in Saldanha Bay and Langebaan Lagoon from 1999 to 2015, are considered in this report.

8.2 Historic data on benthic macrofauna communities in Saldanha Bay

The oldest records of benthic macrofauna species occurring in Saldanha Bay date back to the 1940s, prior to the construction of the iron-ore terminal and Marcus Island causeway. Due to differences in sampling methodology, data from these past studies are not directly comparable with subsequent studies and as such cannot be used for establishing conditions in the environment prior to any of the major developments that occurred in the Bay. Moldan (1978) conducted a study in 1975 where the effects of dredging in Saldanha Bay on the benthic macrofauna were evaluated. Unfortunately, this study only provided benthic macrofauna data after the majority of Saldanha Bay (Small Bay and Big Bay) had been dredged. A similar study conducted by Christie and Moldan (1977) in 1975 examined the benthic macrofauna in Langebaan Lagoon, using a diver-operated suction hose, and the results thereof provide a useful description of baseline conditions present in the Lagoon from this time.

Studies, conducted in the period 1975-1990, examined the benthic macrofauna communities of Saldanha Bay and/or Langebaan Lagoon, but are also, regrettably not comparable with any of the earlier or even the more recent studies. Recent studies conducted by the Council for Scientific and Industrial Research (CSIR) in 1999 (Bickerton 1999) and Anchor Environmental Consultants in 2004 and 2008-2014 do, however, provide benthic macrofauna data from Saldanha Bay and Langebaan Lagoon that are comparable with those collected in 2015. Direct comparisons to earlier studies are complicated owing to the fact that different equipment was used in the earlier surveys than those undertaken from 1999 to present. The 1975 study, for example, made use of a modified van Veen grab weighted to 20 kg which sampled an area of 0.2 m² from the surface fraction of sediment. Subsequent surveys, from 1999 to present, made use of a diver-operated suction sampler with a sampling area of 0.24 m² to a depth of 30 cm. The former sampling technique (van Veen grab) would be expected to sample a smaller proportion of benthic macrofauna due to its limited ability to penetrate the sediment beyond the surface layers. The suction sampler is effective in penetrating to a depth of 30 cm, which is within range of larger species such as prawns and crabs. The study conducted in 1975 in Langebaan Lagoon (Christie and Moldan 1977), and those conducted by Anchor Environmental Consultants, both made use of a diver-operated suction sampler which sampled an area of 0.24m². However, in 1975 a depth of 60 cm was sampled while in surveys since 2004 a depth of only 30 cm was sampled. Thus, considering the differences in sampling techniques employed, it is likely that the changes reflected by the data between the 1975 and 1999-2008 in Saldanha Bay and Langebaan Lagoon are a function both of real changes that occurred in the Bay and an artefact of differences in sampling methodology. The location of sites sampled during 1975 and 1999-2015 studies also differed (refer to previous versions of this report), however, the broad distribution of sites throughout the sampling area ensures that the data collected are representative of Small Bay, Big Bay and Langebaan Lagoon and as such, can be compared with one another.

8.3 Approach and methods used in monitoring benthic macrofauna in 2015

8.3.1 Sampling

A total of 42 sites were sampled for benthic macrofauna in 2015, 11 of which were in Small Bay, nine in Big Bay, nine in Langebaan Lagoon and 13 in Danger Bay. The localities and water depth ranges of these sites are illustrated in Chapter 6– the shallowest sites being those in Langebaan Lagoon. Samples were collected using a diver-operated suction sampler, which sampled an area of 0.08 m² to a depth of 30 cm and retained benthic macrofauna (>1 mm in size) in a 1 mm mesh sieve bag. Three samples were taken at each site and pooled, resulting in a total sampling surface area of 0.24 m² per site. Three hand-core samples were taken at sites less than 2 m deep, totalling a sampling surface area of 0.08 m². All macrofauna abundance and biomass data were ultimately standardised per unit area (m²). These methods correspond exactly with those employed in 1999, 2004 and 2008-2014 and thus facilitate comparisons between these sets of data. Samples were stored in plastic bottles and preserved with 5% formalin.

In the laboratory, samples were rinsed of formalin and stained with Rose Bengal to aid sorting of biological from non-biological matter. All fauna were removed and preserved in 1% phenoxetol (Ethyleneglycolmonophenylether) solution. The macrofauna were then identified to species level where possible, but at least to family level in all instances. The validity of each species was then checked on The World Register of Marine Species (WoRMS, www.marinespecies.org). The biomass (blotted wet mass to four decimal places) and abundance of each species was recorded for each sample.

8.3.2 Statistical analysis

The data collected from this survey were used for two purposes 1) to assess spatial variability in the benthic macrofauna community structure and composition between sites in 2015 and 2) to assess changes in benthic community structure over time (i.e. in relation to past surveys). Both the spatial and temporal assessments are necessary to provide a good indication of the current state of health of the Bay.

8.3.2.1 Community structure and composition

Changes in benthic species composition can be the first indicator of disturbance, as certain species are more sensitive (i.e. likely to decrease in abundance in response to stress) while others are more tolerant of adverse conditions (and may increase in abundance in response to stress, taking up space or resources vacated by the more sensitive species). Monitoring the temporal variation in community composition also provides an indication of the rate of recovery of the ecosystem following disturbances in different areas of the system. This allows one to more accurately predict the impacts of proposed activities. “Recovery” following environmental disturbance is generally defined as the establishment of a successional community of species which progresses towards a community that is similar in species composition, density and biomass to that previously present (C-CORE 1996 and Newell 1998). The rate of recovery is dependent on environmental conditions and

the communities supported by such conditions. Given the spatial variation in environmental conditions (largely influenced by depth and exposure) and anthropogenic disturbance throughout Saldanha Bay and Langebaan Lagoon, it is expected that recovery will vary throughout system.

It has been shown that species with a high fecundity, rapid growth rate and short life-cycle are able to rapidly invade and colonise disturbed areas (Newell 1998). These species are known as “r-strategists”, pioneer or opportunistic species and their presence generally indicates unpredictable short-term variations in environmental conditions as a result of either natural factors or anthropogenic activities. In stable environments the community composition is controlled predominantly by biological interactions rather than by fluctuations in environmental conditions. Species found in these conditions are known as “K-strategists” and are selected for their competitive ability. K-strategists are characterised by long life-spans, larger body sizes, delayed reproduction and low mortality rates. Intermediate communities with different relative proportions of opportunistic species and K-strategists are likely to exist between the extremes of stable and unstable environments.

The statistical program, PRIMER 6 (Clarke and Warwick 1993), was used to analyse benthic macrofauna abundance data. Data were root-root (fourth root) transformed and converted to a similarity matrix using the Bray-Curtis similarity coefficient. Multidimensional Scaling (MDS) plots were constructed in order to find ‘natural groupings’ between sites for the spatial assessment and between years for the temporal assessment. SIMPER analysis was used to identify species principally responsible for the clustering of samples. These results were used to characterise different regions of the system based on the communities present at the sites. It is important to remember that the community composition is a reflection of not only the physico-chemical health of the environment but also the ability of communities to recover from disturbance.

8.3.2.2 Diversity indices

Diversity indices provide a measure of diversity, i.e. the way in which the total number of individuals is divided up among different species. Understanding changes in benthic diversity is important because increasing levels of environmental stress generally decreases diversity. Two different aspects of community structure contribute to community diversity, namely species richness and equability (evenness). Species richness refers to the total number of species present while equability or evenness expresses how evenly the individuals are distributed among different species. A sample with greater evenness is considered to be more diverse. It is important to note when interpreting diversity values that predation, competition and disturbance all play a role in shaping a

community. For this reason it is important to consider physical parameters as well as other biotic indices when drawing a conclusion from a diversity index.

The *Shannon-Weiner diversity index* (H') was calculated for each sampling location using PRIMER V 6:

$$H' = - \sum p_i(\log p_i) \quad ^7$$

The diversity (H') value for each site was plotted geographically and this was used to interpolate values for the entire system using ArcGIS in order to reveal any spatial patterns. Alpha diversity (total number of species) was also then calculated for the three pre-designated locations for past surveys from 1999 to present: Small Bay, Big Bay and Langebaan Lagoon.

8.4 Benthic macrofauna 2015 survey results

8.4.1 Species diversity

Variations in species diversity (represented by the Shannon Weiner Index, H') for Saldanha Bay, and Langebaan Lagoon in 2015 (including Danger Bay) are presented in Figure 8.1. Diversity was highest in Langebaan Lagoon, intermediate in Big Bay and Danger Bay, and lowest around the ore terminal and in Small Bay. This is most likely attributable to the higher levels of disturbance (mainly dredging) and a high proportion of fines (mud) in the sediment, which contains elevated levels of contaminants (trace metals, organic material, etc.) in the latter two areas. It is well known that high levels of disturbance associated with pollution can allow a small number of opportunistic, short-lived or r-selected species to colonize the affected area and prevent a more diverse community comprising longer living k-strategist species from becoming established. The intermediate diversity recorded in Danger Bay was expected, given that Danger Bay is more exposed to wave action in comparison to Saldanha Bay and Langebaan Lagoon. This exposure results in dynamic and coarse sandy sediments and a near complete absence of mud, creating a highly disturbed habitat, which is unsuitable for benthic species that require more consolidated sediments (e.g. for burrow construction).

⁷ Where p_i is the proportion of the total count arising from the i th species. This is the most commonly used diversity measure and it incorporates both species richness and equability.

8.4.2 Community structure

Ordination plots prepared from the 2015 macrofauna abundance data, are presented in Figure 8.2. These data show a very similar pattern as for the diversity data, with the Langebaan Lagoon and Danger Bay sites standing out as being clearly different to those in Big Bay and Small Bay. The sampling sites in Big Bay and Small Bay are also distinct from one another, but to a lesser extent than those in the lagoon. These differences are a function of differences in community structure (i.e. the abundance or presence/absence of different species at each site) and not just the total number of species present at a particular site. “Sensitive” species that cannot tolerate high levels of disturbance are present in abundance in the Lagoon and in moderate numbers at some of the Big Bay sites but are largely absent from sites in Small Bay and those surrounding the ore terminal. The community structure of benthic macrofauna present at Danger Bay is also clearly different to that recorded at Small Bay, Big Bay and Langebaan Lagoon. This is attributable to the difference in the physical and environmental parameters present in Danger Bay (increased wave action and exposure on a sandy subtidal habitat) which in turn influence the community structure of the benthic macrofauna present.

The “hardier” filter feeders such as *Upogebia capensis* are, for example, abundant in both Big Bay and Small Bay samples, but the “more sensitive” filter feeders such as the amphipods *Ampelisca spinimana* and *A. anomala*, the mollusc *Macoma odinaria* and the polychaete *Sabellides luderitzi* were notably more abundant in Big Bay than Small Bay. Similarly, the sea pen *Virgularia schultzei*, widely regarded as a “sensitive species” was found only in Big Bay.

Species that contributed significantly to the dissimilarity between the Saldanha Bay and Langebaan Lagoon samples include the filter feeding amphipods *Ampelisca* sp. and the predatory whelks *Nassarius* sp. that were relatively abundant in Small Bay and Big Bay, but either rare or absent from lagoon samples. Other species such as the sand prawn *Callichirus kraussi*, the isopod *Natatolana hirtipes*, and the crown crab *Hymenosoma orbiculare* (detritivores, scavengers or predators) were more abundant in the lagoon samples.

The community structure of benthic macrofauna in Danger Bay was dominated by small crustaceans (mostly amphipods), polychaetes and gastropods. The absence of large crustaceans such as the mud prawn *Upogebia capensis* and associated commensal species (e.g. *Spiroplax spiralis*) and the crown crab, *Hymenosoma orbiculare*, and the abundance of the small sand-dwelling amphipods *Urothoe coxalis* and *U. pinnata* found only in Danger Bay, were the main causes of dissimilarity in community structure between Danger Bay and the Saldanha Bay and Langebaan Lagoon samples.

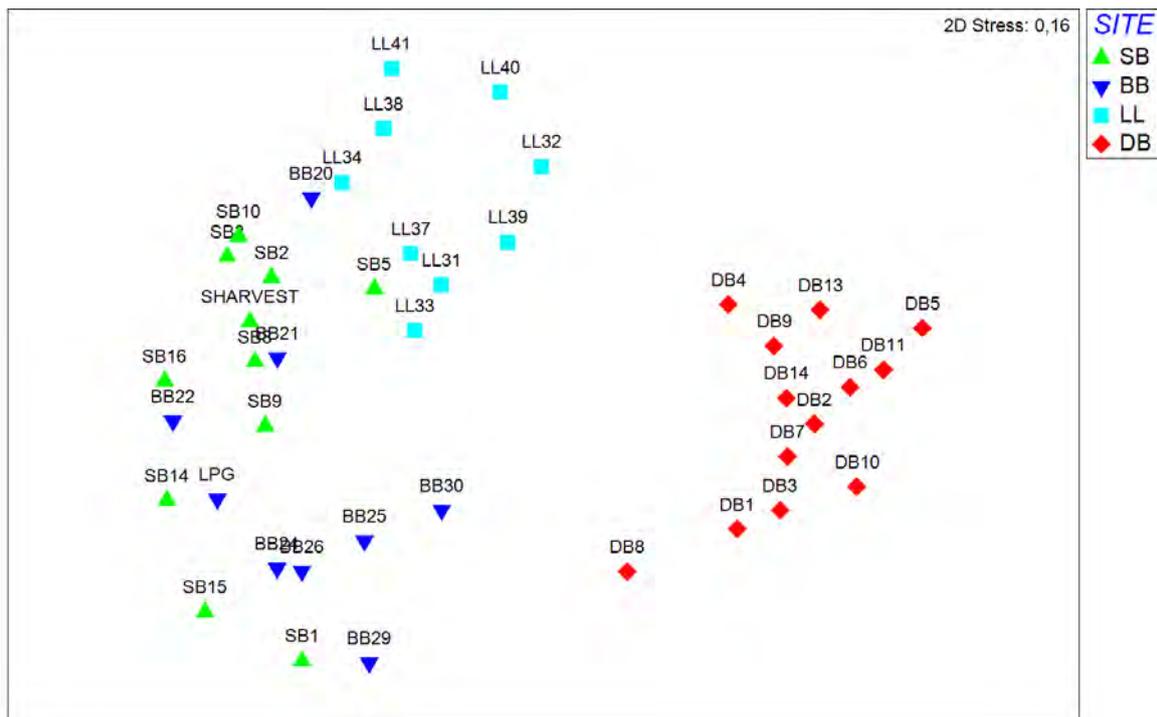


Figure 8.2 Ordination plots showing similarity amongst sites based on benthic macrofauna abundance in 2015. Symbols on the ordination plots are as follows: Small Bay (SB), Big Bay (BB), Langebaan Lagoon (LL) and Danger Bay (DB).

These differences in species composition between areas can sometimes be more easily understood at higher taxonomic or functional group (essentially feeding mode) levels (Figure 7.3). Crustaceans (this diverse group includes prawns, shrimps, mysids, crabs, amphipods and isopods) were the dominant taxonomic group in all areas. The next most abundant taxonomic group were polychaetes, and a relatively greater abundance of these worms were found in Langebaan Lagoon than in Small Bay and Big Bay (Figure 8.3). Filter feeders were by far the dominant functional group in Small bay and Big bay with a greater average abundance in the latter area (Figure 8.3). Detritivores were numerically the most abundant group in Langebaan Lagoon and Danger Bay (Figure 8.3). Average biomass of benthic macrofauna at Danger Bay sites was an order of magnitude lower than that in Saldanha Bay and Langebaan Lagoon during 2015. This indicates that the fauna recorded in Danger Bay, despite their abundance, are mostly small, short-lived r-selected species, the total biomass of which is much lower than for the larger k-selected species in Saldanha Bay and Langebaan Lagoon.

These differences are attributable to physical habitat differences between the benthic environments found in the different areas which in turn are linked to past and present anthropogenic activities – e.g. port construction, dredging, organic pollution. In contrast to sediments within Saldanha Bay, Danger Bay sediments comprised almost entirely of sand (>99%) with an extremely low mud fraction (on average 0.14%). Consequently organic matter concentrations (total organic carbon and total organic nitrogen) in these sediments were also very low. These differences are attributed to the much higher wave exposure of Danger Bay, compared to sites within Saldanha Bay, and also higher inputs of organic matter in particularly in Small Bay.

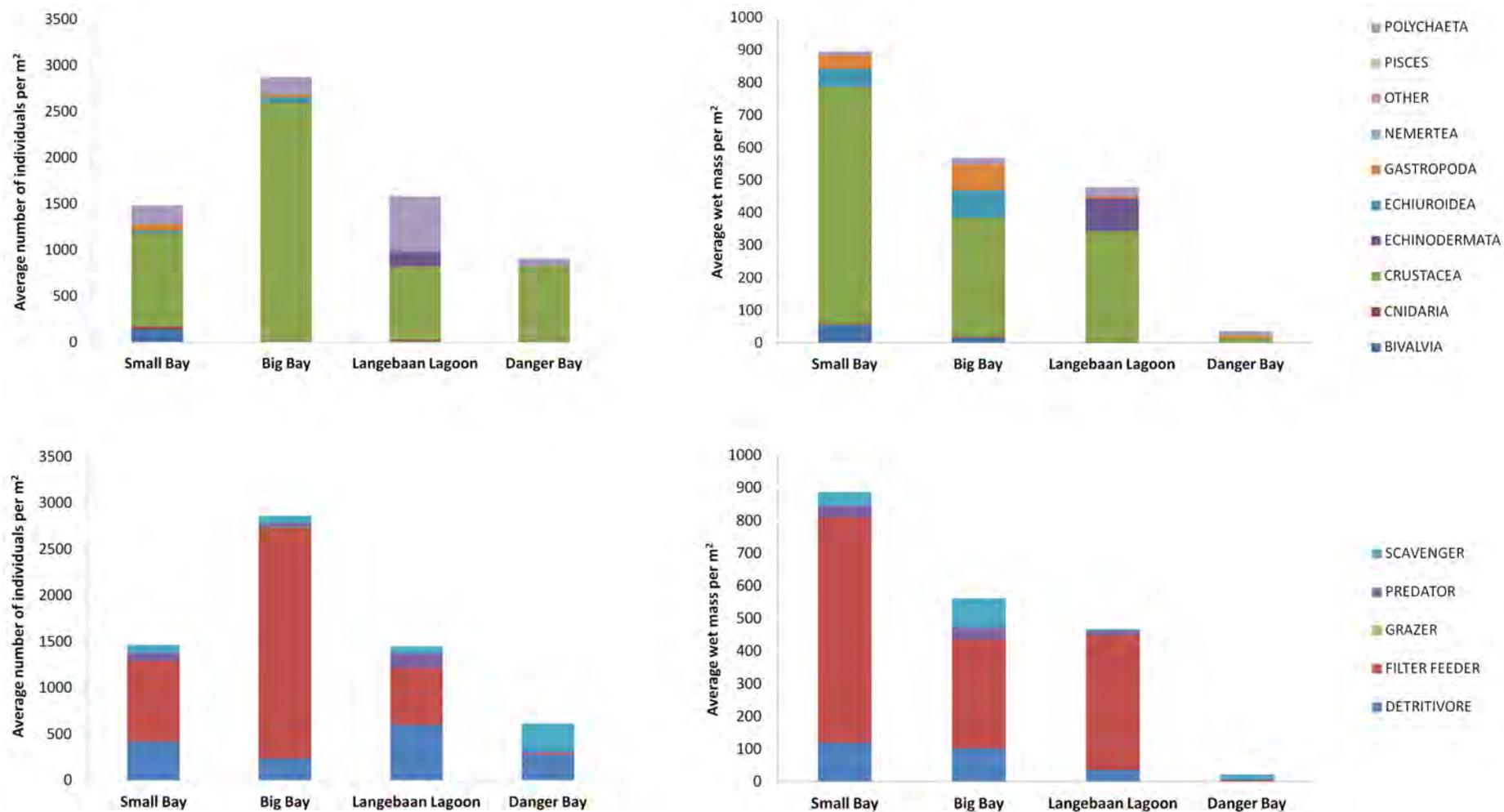


Figure 8.3 Average abundance and biomass (g/m²) of benthic macrofauna by functional and taxonomic group in Big Bay, Small Bay, Langebaan Lagoon and Danger Bay in 2015.

8.5 Changes in abundance, biomass and community structure over time

8.5.1 Species richness

Variation in the total number of macrofauna species recorded in Small Bay, Big Bay, Langebaan Lagoon and Danger Bay during each annual survey from 1999 to 2015 is shown in Figure 8.4. While there appears to be a slight increase in the numbers of species recorded over time, this is more than likely related to improvements in taxonomic resolution rather than a real increase with time. In Small Bay and Big Bay species richness was lowest in 1999, 2008 and 2012, while in Langebaan Lagoon the lowest richness was recorded in 2004, 2008 and 2012 (note that no samples were collected from the Lagoon in 1999). If one considers these dates in the light of recent developments in the Bay, it is immediately clear that these changes may be linked to major dredging events in the Bay. Following the original construction of the original port in 1973, the most significant dredging events were implemented in 1996/7 (when 2 million m³ of material was removed from the Small Bay side of the ore terminal for the construction of the Multipurpose Terminal), the second in 2007/2008 (when approximately 50 000 m³ of seabed material was removed from the area of the Moss gas quay and the Multi-Purpose Terminal) and the third in 2009/2010, (when 7 300 m³ of material was removed from the Saldanha side of the ore terminal). Species richness tends to drop (or starts off very low) immediately following these events (1999, 2008 and 2012) but tends to be higher (or even increase with time) in the intervening periods (2004, 2009-2011, 2013-2015).

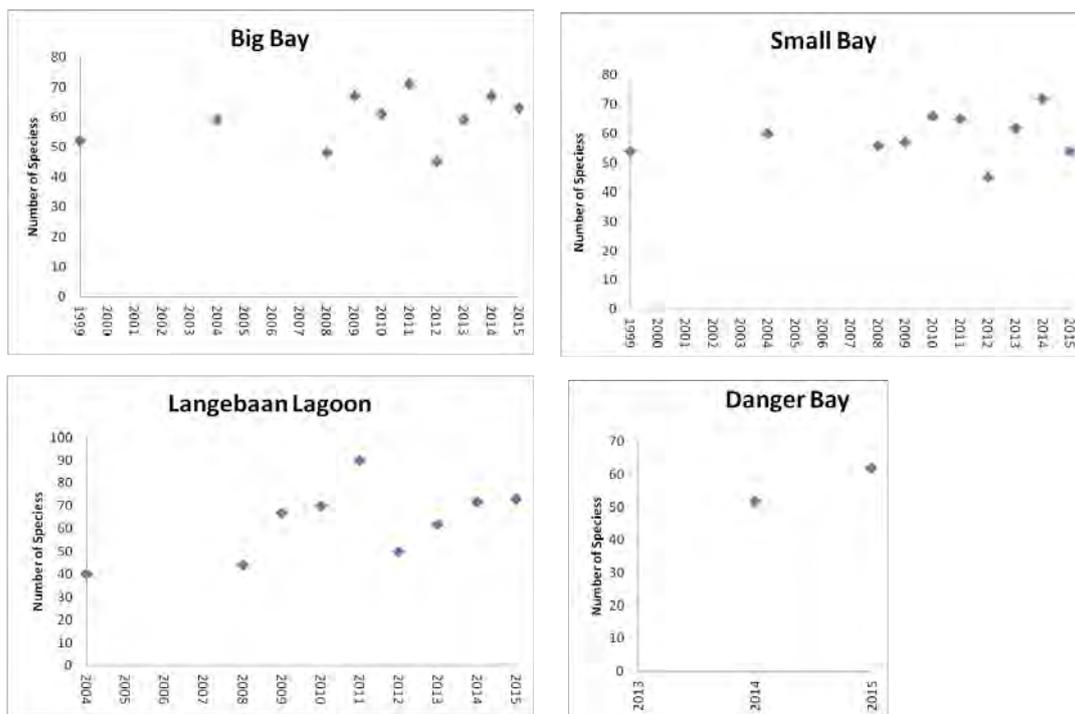


Figure 8.4 Variation in the number of species recorded at Small Bay, Big Bay, Langebaan Lagoon and Danger Bay in the time period 1999-2015.

The low species richness in Langebaan Lagoon recorded during the 2004 sampling event may be related to an entirely different phenomenon. During the mid-1990s the alien invasive mussel *M. galloprovincialis* began establishing dense intertidal beds on two intertidal sand flats close to the mouth of Langebaan Lagoon (Hanekom and Nel 2002). The mussel beds reached an estimated biomass of close to eight tons in 1999 raising concerns that the invasion could spread to the rest of the lagoon and other sandy substrata (Hanekom and Nel 2002). In early 2001, however, the mussels had started to die off and by mid-2001 only dead shells and anoxic sands remained. In an effort to prevent the re-settlement of the mussel, South African National Parks began to remove dead mussel shells in late 2001 (Robinson *et al.* 2007b). The precise causes of the die off have not been established but siltation and lowered food availability are suggested as possible reasons behind the declines (Hanekom and Nel 2002). There is a high probability that the reduced macrofauna species richness in the 2004 State of the Bay samples may have been linked to a residual impact of the mussel invasion.

8.6 Abundance, biomass and community composition

Changes in the abundance and biomass of benthic macrofauna in Small Bay, Big Bay and Langebaan Lagoon are presented in Figure 8.5. - Figure 8.7. The relative importance of different feeding groups (i.e. trophic functioning which reflects changes in food availability) and taxonomic groups (i.e. different species which differ in size, growth rates and other characteristics) in each year are also shown on the same graphs. In all three areas (Small Bay, Big Bay and Langebaan Lagoon), there is a suggestion that both abundance and biomass of benthic macrofauna has been increasing over time up until 2014 (top panels on all three figures), aside from a number of major perturbations (troughs) that are evident at the start of the monitoring period (1999, Small and Big Bay only), and 2008/2009 (all three areas) and 2012 (all three areas). However, in 2015 both abundance and biomass decreased slightly in all areas apart from the lagoon where biomass remained more or less constant. There are some clear changes in the relative contribution of major taxonomic groups (Bivalvia, Crustacea, Gastropoda, etc.) in the periods of reduced abundance/biomass but the changes in the relative contributions by the different feeding groups is much more pronounced. The relative contribution by the group known as filter feeders (i.e. those that feed by filtering particulate matter out of the water column) dropped dramatically during these perturbations in all three areas of the Bay while the contribution by the group known as detritivores (those that feed on particulate organic matter in or on the surface of the sediment) tended to increase. Filter feeders tend to be more sensitive to levels of suspended sediment than the other feeding groups, and this certainly lends weight to the argument that these period of reduced abundance and/biomass may be linked to major dredging events that have taken place in the Bay. Filter feeders in the Bay consist mostly of the mud prawn (*Upogebia capensis*) and smaller amphipod species belonging to the genus *Ampelisca*. The Sea pen, *Virgularia schultzei*, is another important filter feeding species in the Bay. This species was reportedly “very abundant” in the period prior to port development, and was present throughout Big Bay and Small Bay. It is now completely absent from Small Bay but still present in Big Bay albeit in small numbers only. Detritivores, the second most important group of benthic macrofauna in Small Bay, comprise mostly of tongue worms (*Ochaetostoma capense*) and polychaetes belonging to the genera *Polydora* and *Euclymene*. These species are less sensitive to

water quality and changes in wave movement patterns and hence tend to increase in abundance or even dominate when conditions deteriorate.

8.7 Community structure

In this and previous reports, multivariate analysis has revealed clear differences in the macrofaunal communities inhabiting Small Bay, Big Bay and Langebaan Lagoon that are largely driven by physical habitat characteristics of each area. Investigation of any changes in macrofaunal communities over time, however, is useful as an ecosystem health monitoring tool as community scale perturbations outside of natural variability can indicate anthropogenic impacts on habitat quality. In order to do this without the confounding effects of the documented spatial structure, multivariate analysis of macrofaunal samples collected in all years since 2004 was undertaken separately for Small Bay, Big Bay and Langebaan Lagoon.

8.8 Small Bay

The Small Bay ordination plot (a technique that groups samples with similar macrobenthic communities close together and separates dissimilar samples), shows clear separation of all samples collected during 2008 from samples collected in all other years (Figure 8.8.). Overall abundance in Small Bay was not notably low in 2008, but the macrobenthic community was different in that there were a high abundance of detritivores such as the shrimp *Betaeus jucundus*, the polychaetes *Mediomastus capensis* and *Maldanidae* sp., and crustaceans of the Family Cumacea that were not common in samples collected during other years. Conversely, detritivorous crustaceans such *Spiroplax spiralis*, polychaetes *Polydora* sp. and *Orbinia angrapequensis*, the sea cucumber *Ochetostoma capense*, predatory whelks of the genus *Nassarius* and filter feeding amphipods *Ampelisca* sp. and the mud prawn *Upogebia capensis*, were common in samples collected in other years, but were rare or absent in 2008 samples.

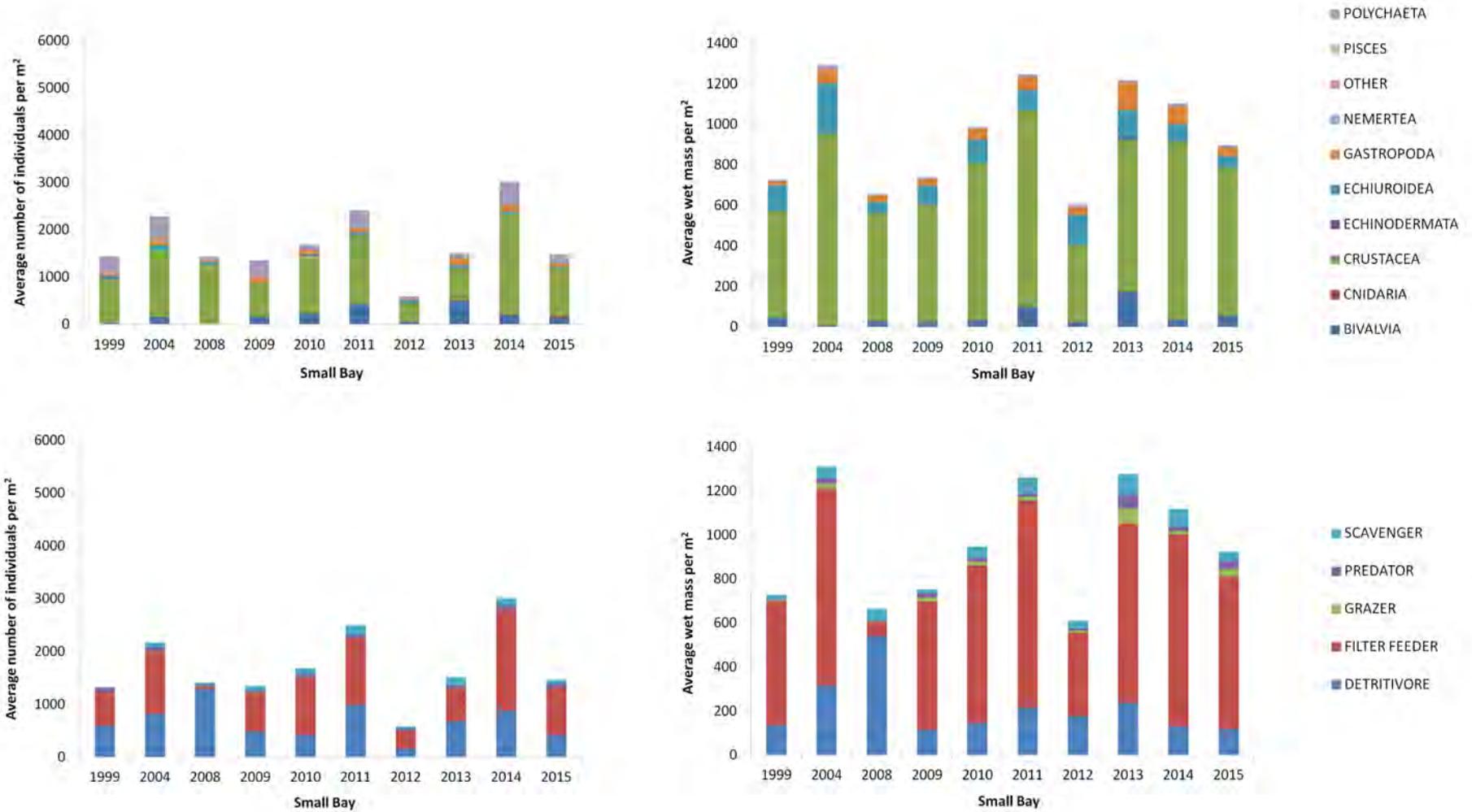


Figure 8.5. Overall trends in the abundance and biomass (g/m²) of benthic macrofauna in Small Bay as shown by taxonomic and functional groups.

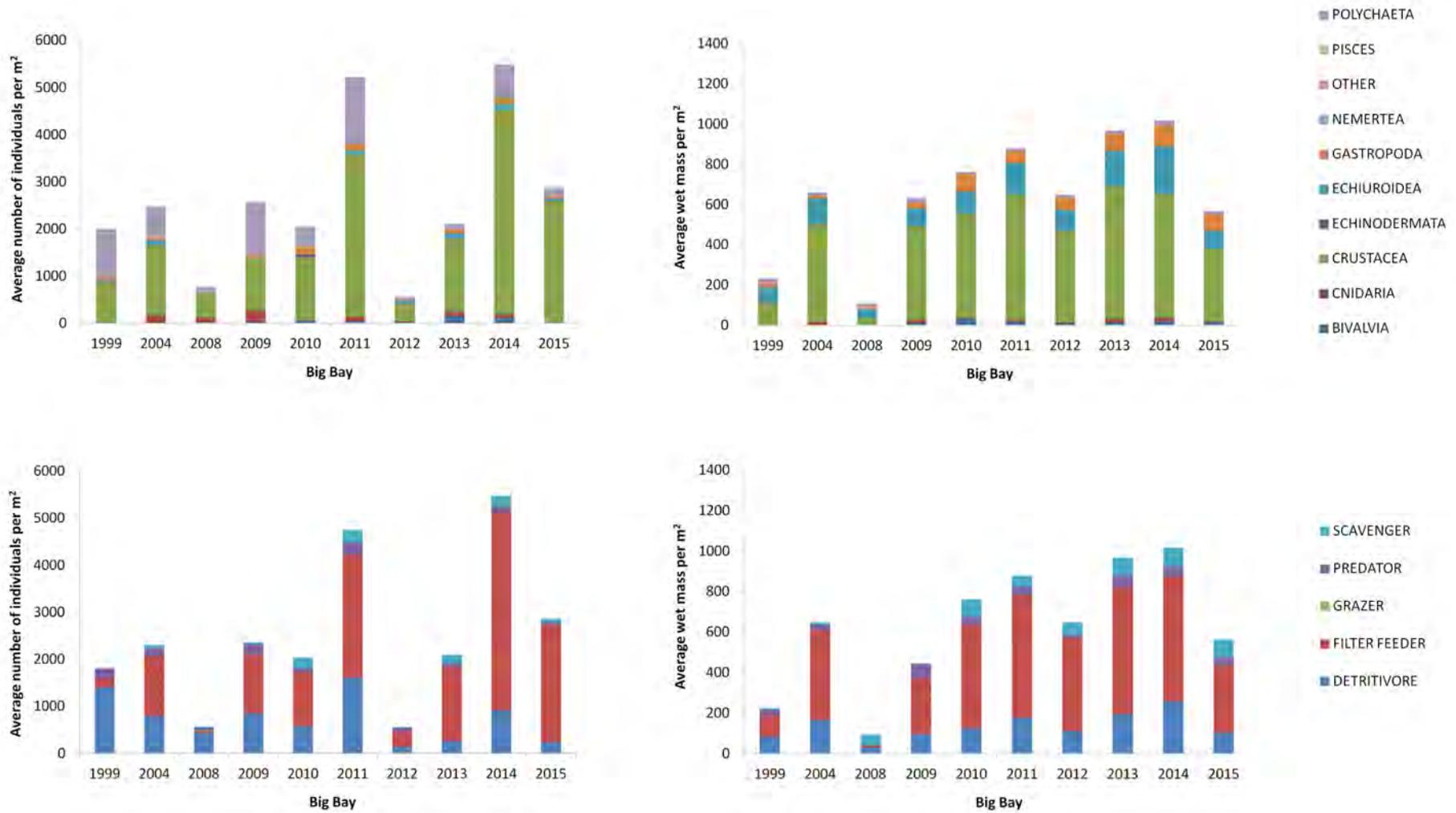


Figure 8.6. Overall trends in the biomass and abundance (g/m^2) of benthic macrofauna in Big Bay as shown by taxonomic and functional groups.

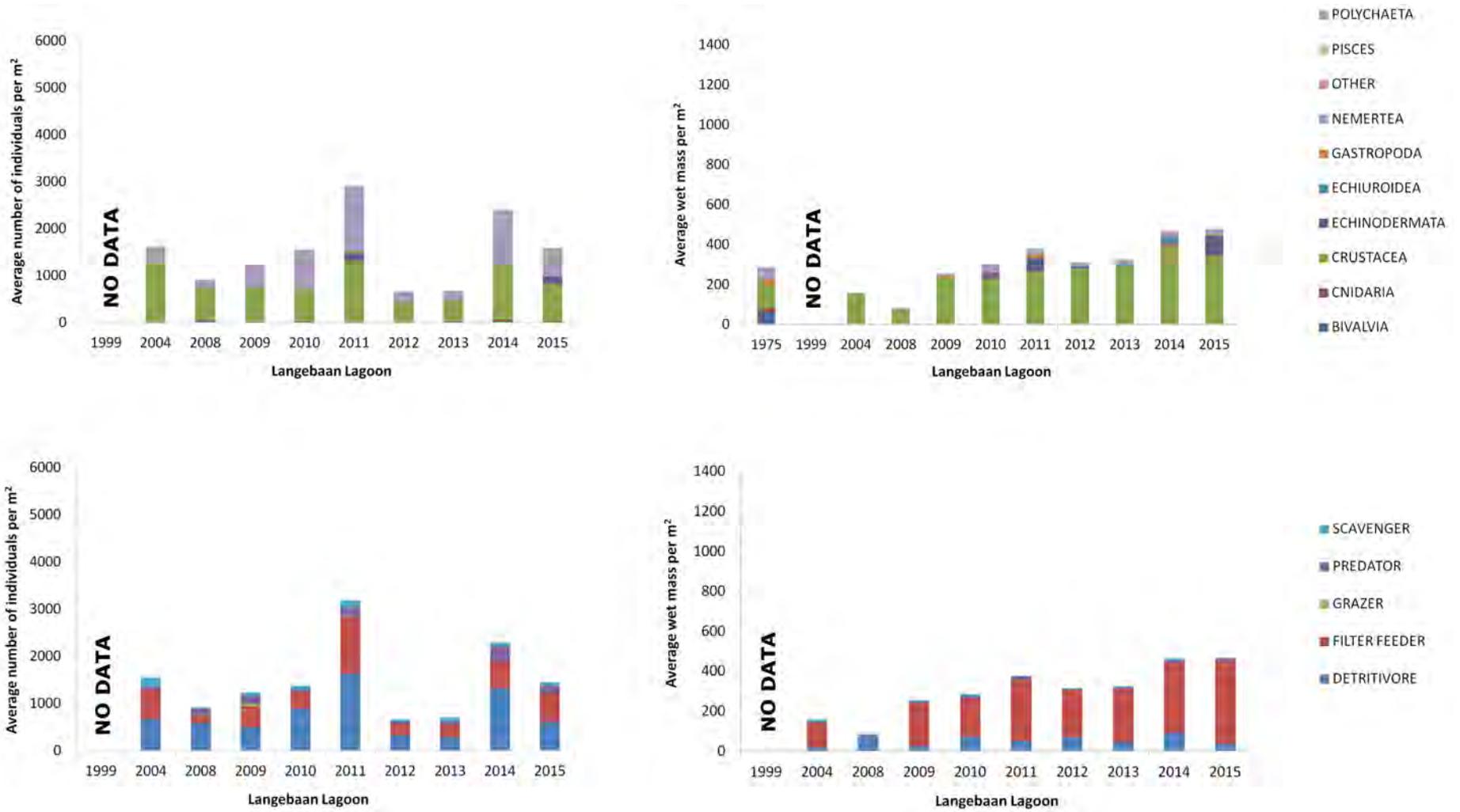


Figure 8.7. Overall trends in the biomass (g/m^2) and abundance of benthic macrofauna in Langebaan Lagoon as shown by taxonomic and functional groups.

8.9 Big Bay

The 2008 Big Bay macrobenthos samples also clustered separately from all other years on the ordination plot indicating that they were dissimilar to the others in some way (Figure 8.8.). Species primarily responsible for the dissimilarity of 2008 samples from all other years include very low abundance or absence of detritivores, *Orbinia angrapequensis* and *Ochetostoma capense*, filter feeders such as *Upogebia capensis*, *Ampelisca* sp. and *Virgularia schultzei* and predators such as *Nassarius* sp. whelks in 2008 samples. The same resilient species that were abundant in Small Bay 2008 samples also dominated the macrofauna in Big Bay, e.g. *Betaeus jucundus*, *Mediomastus capensis* and *Platynereis australis*.

8.10 Langebaan Lagoon

The 2008 samples were also outliers in the Langebaan Lagoon ordination plot (Figure 8.8.). Low abundance or absence of filter feeding mud prawns *Upogebia capensis*, the polychaete *Notomastus latericeus* and the isopod *Natanolana hirtipes*; and high abundance of *Betaeus jucundus* and the polychaetes *Marphysa sanguine* and *Eteone foliosa* in 2008 samples were the species consistently responsible for the dissimilarity of 2008 Lagoon samples from those collected in other years

As mentioned above, these changes in macrobenthic community structure are thought to be related to the extensive dredging activities undertaken during 2007 and early 2008 that appeared to have had Bay-wide impacts, resulting a temporary loss of less tolerant species and a shift in community composition to one dominated by more tolerant species. Multivariate analysis of the macrobenthic samples collected over the period 2009-2015 suggests that the smaller 2009 dredging event had a limited impact with little change in macrobenthic community structure over the last six years.

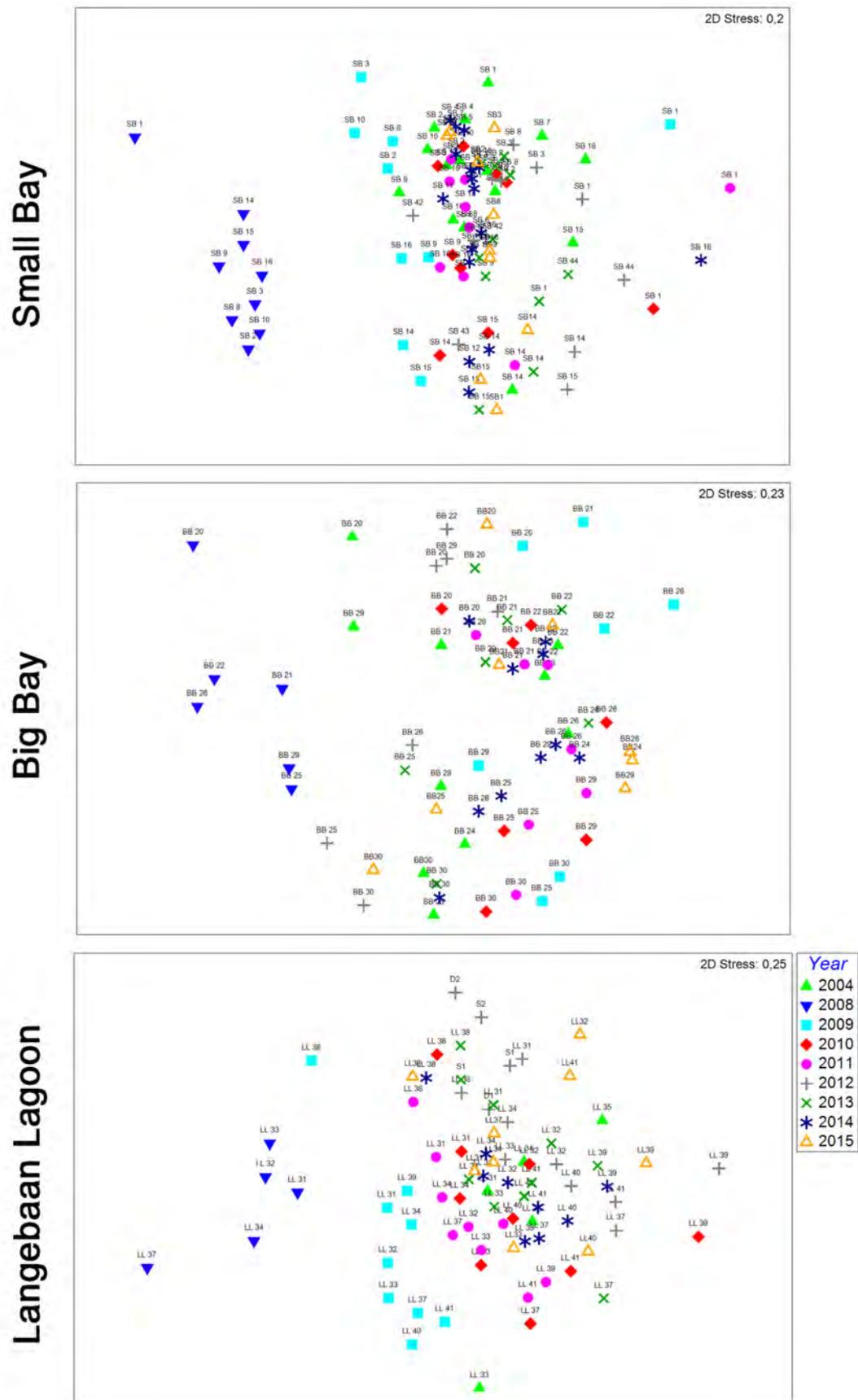


Figure 8.8. MDS plots showing differences in community structure amongst benthic macrofauna assemblages in Small Bay (top), Big Bay (middle) and Langebaan Lagoon (bottom) in the period 2004-2015.

8.11 Summary of benthic macrofauna findings

Macrobenthic community structure within Saldanha Bay has been the subject of several studies in the past, most of which focus on anthropogenic impacts to benthic health. These earlier studies showed very clearly that there was a substantial change in benthic communities before and after harbour development in the early 1970s. At this time, approximately 25 million cubic meters of sediment were dredged from the Bay, and the dredge spill was used to construct the new harbour wall (Moldan 1978). Severe declines in a number of species were reported, along with a change in the relative abundance of different trophic (feeding) groups, with a reduction in the number of suspension feeders in particular and an increase in the numbers of opportunistic scavengers and predators (Moldan 1978, Kruger *et al.* 2005). Within Saldanha Bay, many species disappeared completely after dredging (most notably the sea-pen, *Virgularia schultzei*) and were replaced by opportunistic species such as crabs and polychaetes (Moldan 1978). Dredging reportedly directly impacts benthic community structure in a variety of ways: many organisms are either directly removed or buried, there is an increase in turbidity and suspended solids, organic matter and toxic pollutants are released and anoxia occurs from the decomposition of organic matter (Moldan 1978). Harbours are known to be some of the most highly altered coastal areas that characteristically suffer poor water circulation, low oxygen concentrations and high concentrations of pollutants in the sediment (Guerra-Garcia and Garcia-Gomez 2004). Beckley (1981) found that the marine benthos near the iron-ore loading terminal in Saldanha Bay was dominated by pollution-tolerant, hardy polychaetes. This is not surprising since sediments below the ore terminal were found to be anoxic and high in hydrogen sulphide (characteristically foul-smelling black sludge).

Methods for collecting macrofauna samples for the State of the Bay surveys, which commenced in 1999, are unfortunately very different to those that were employed for the earlier surveys, and thus data from these studies cannot be compared directly. Analysis of the data from these studies as reported in this chapter is thus focussed on changes that have occurred in this latter period only. Variations in species richness, abundance biomass, and community composition and community structure all show very similar patterns over this period. Starting off at modest levels in 1999, both abundance and biomass rose to fairly high levels in Small Bay and Big Bay in 2004 before dropping down to low levels again in 2008 (regrettably no data are available to show what happened in the intervening years between 1999 and 2004 and between 2004 and 2008). Thereafter both overall abundance and biomass in all three parts of the Bay (Langebaan Lagoon included) increased steadily year-on-year until 2011, before dropping dramatically again in 2012, rising again in 2013 and 2014 and then finally decreasing slightly in 2015 (the latest survey). These changes in abundance and biomass were, to a large extent, driven by the loss of filter feeding species during period of low abundance (1999, 2008 and 2012). Filter feeding species are thought to be highly sensitive to changes in water quality (more so than detritivores or scavengers) and it is thought that reductions in abundance and biomass of these species may also be linked to a sequence of dredging events that have occurred in recent years (1996/, 2007/2008 and 2009/2010).

Other more localised factors are also clearly important in structuring benthic macrofauna communities in the Bay and the Lagoon (see previous versions of the State of the Bay Report – Anchor Environmental 2010, 2011, 2012) for more details on this. For example, reduced water circulation patterns in parts of Small Bay (e.g. near the Small Craft Harbour) and localised discharges of effluent from fish processing establishment in this area, contribute to the accumulation of fine

sediment, organic material and trace metals, and results in macrofauna communities in this area being highly impoverished. Similarly, the impacts of dredging required for the expansion and refurbishment of the Salamander Bay boatyard at the entrance of the lagoon in 2010 had a very clear impact on macrofaunal communities in this area (Anchor Environmental 2012, 2013). Invasion of Langebaan Lagoon by the European mussel *Mytilus galloprovincialis* also had a major impact on the fauna in the affected areas of the Lagoon (Hanekom and Nel 2002, Robinson and Griffiths 2002, Robinson *et al.* 2007b) and presumably on the results of the earliest 2004 State of the Bay survey as well.

Overall, increases in abundance, biomass and diversity of macrofauna across all parts of the Bay (Small Bay, Big Bay and Langebaan Lagoon) in 2013 and 2014 is a very positive sign and points to an overall increase in the health of the Bay. The slight decrease observed in the 2015 data is not of major concern as overall community structure remains largely unchanged – abundance, biomass and diversity levels remain well above those recorded in 2012 and can be considered to have stabilised since the marked increases observed in 2014. The benthic macrofauna samples were collected for the first time in Danger Bay during 2014 as the start of a baseline monitoring programme and then repeated in 2015. Now in its second year, cumulative effort expended for sampling in Danger Bay has thus doubled, therefore explaining the detection of additional species in the 2015 survey (Figure 8.4). Detection of additional species is expected to continue with subsequent surveys (albeit at a decreasing rate) until a point is reached where adequate cumulative sampling effort has resulted in the detection of most species present. Results from the 2014 and 2015 surveys revealed a distinct community at Danger Bay – attributable to physical habitat differences between this open coast bay and the more sheltered Saldanha Bay and Langebaan Lagoon habitats. The Danger Bay macrofaunal community is dominated by crustaceans that are largely free living forms (as opposed to burrow forming animals) adapted to the dynamic, coarse sediments present at this site. The physical habitat and associated macrobenthic biota are indicative of an exposed, dynamic environment (suggesting high flushing rates), however, discharge of organically and chemically enriched effluent from the proposed regional marine outfall is still expected to have a discernable impact on macrobenthic communities within a zone of impact. Ongoing collection of comprehensive baseline data on macrobenthic communities in Danger Bay to capture the natural variability is essential for objective and quantitative assessment of expected impacts.

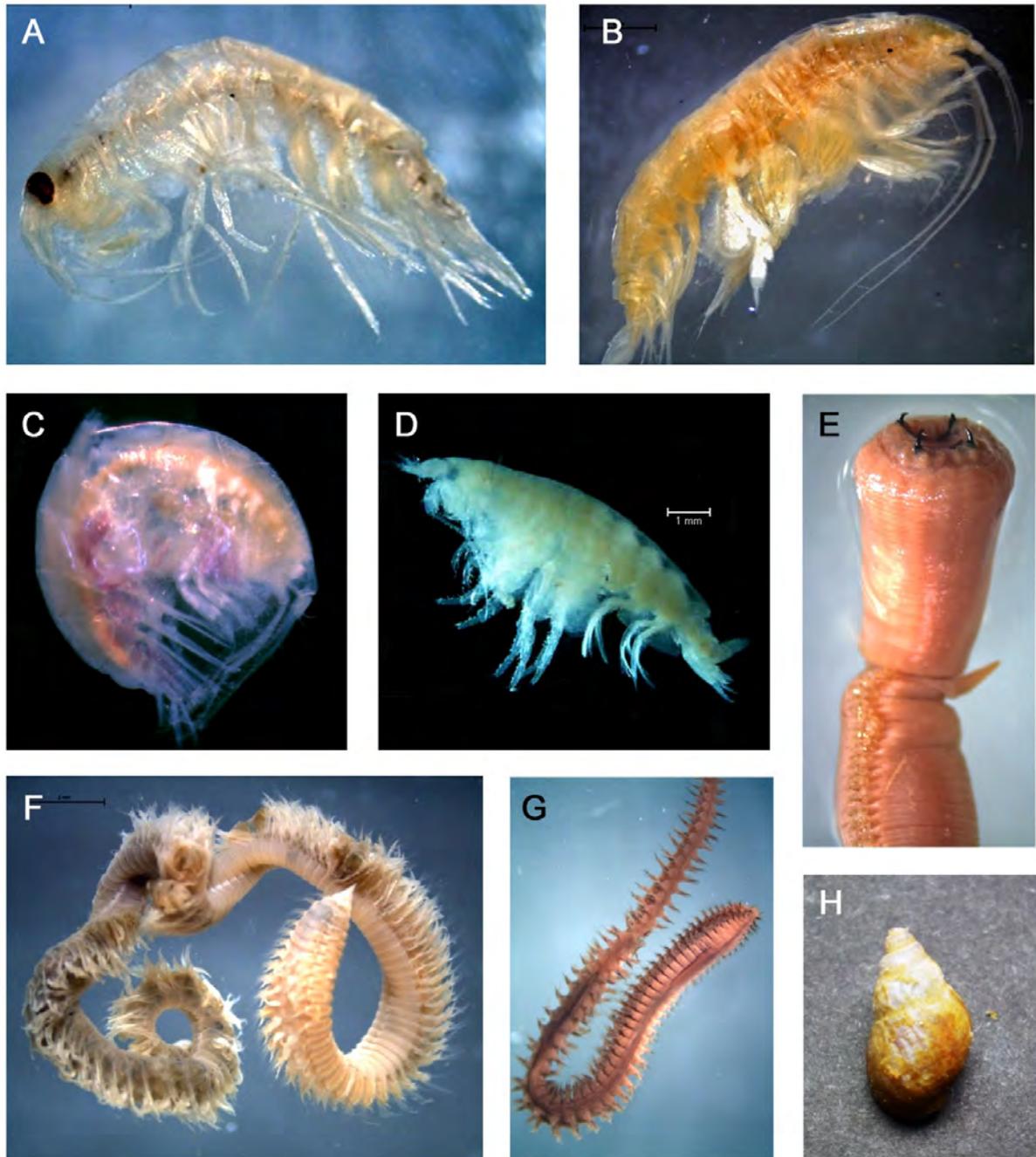


Figure 8.9. Benthic macrofauna species frequently found to occur in Saldanha Bay and Langebaan Lagoon, photographs by: Nina Steffani and Aiden Biccard. A – *Paramoera capensis*, B – *Ampelisca brevicornis*, C – *Ampelisca palmata*, D – *Hippomedon normalis*, E – *Glycera tridactyla*, F – *Orbina angrapequensis*, G – *Nephtys hombergii*, H – *Nassarius vincetus*.

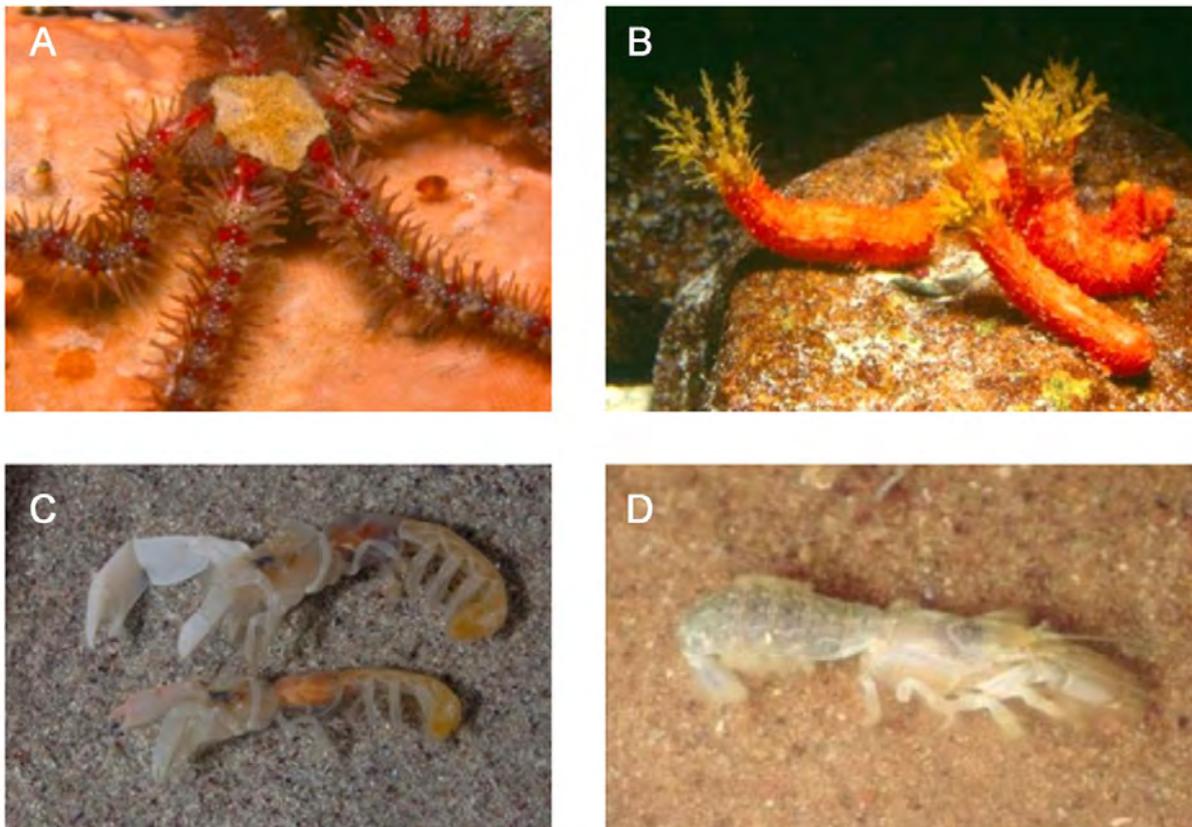


Figure 8.10. Benthic macrofauna species frequently found to occur in Saldanha Bay and Langebaan Lagoon, photographs by: Charles Griffiths. A – *Ophiuroidea*, B - *Pseudonella insolens*, C - *Callichirus kraussi* , D – *Upogebia capensis*.

9 ROCKY INTERTIDAL INVERTEBRATES

9.1 Background

Limited historical data exists on the state of the rocky-shore habitats within the Saldanha Bay system. Species presence/absence data was collected by undergraduate students of the University of Cape Town at Lynch Point and Schaapen Island between 1965 and 1974 (University of Cape Town, Prof. C. Griffith, *pers. comm.*); however, the accuracy and reliability of these data is questionable and it is of limited value for monitoring changes in the health of the Saldanha Bay ecosystem. Historical studies by Simons (1977) and Schils *et al.* (2001) reported on the algal species assemblages, while Robinson *et al.* (2007b) examined the species composition of rocky intertidal communities on Marcus Island between 1980 and 2001, focusing on the impact of the alien invasive Mediterranean mussel, *Mytilus galloprovincialis*.

Monitoring of rocky intertidal communities in Saldanha Bay was initiated as part of the State of the Bay Monitoring Programme in 2005 an effort to fill the gap in knowledge relating to rocky intertidal communities in Saldanha Bay and Langebaan Lagoon. The first rocky shore survey for this programme was conducted in 2005, the results of which are presented in the first 'State of the Bay' report (Anchor Environmental Consultants 2006). Eight rocky shores spanning a wave exposure gradient from very sheltered to exposed, were sampled in Small Bay, Big Bay and Outer Bay as part of this baseline. These surveys have been repeated annually since 2008 (Anchor Environmental Consultants 2009, 2010, 2011, 2012b, 2013b, 2014).

The baseline survey report concluded that wave exposure is the primary physical driver shaping the intertidal rocky shore communities across the study area. More sheltered shores were dominated by seaweeds, while sites exposed to higher wave energy were dominated by filter-feeders. It was suggested that the construction of the Marcus Island causeway and the Iron Ore Terminal had reduced the wave energy reaching rocky shores in Small Bay, and led to a change in community structure. The lack of historical data from these shores precludes confirmation of this hypothesis, however.

The results further indicated that the topography and substratum type of the shore influences community structure as, for example, sites consisting of rocky boulders had different biotic cover to shores with a flatter profile. Geographic location was also considered to be important, for example, sampling stations on the bird breeding island Schaapen Island are situated in a transitional zone between the Saldanha Bay and the Langebaan Lagoon system. These same sites are also affected by high nutrient input from seabird guano that favours algal growth. Generally, the Saldanha Bay communities were healthy but the presence of four alien invasive species, the Mediterranean mussel *Mytilus galloprovincialis*, and the three barnacles *Balanus glandula*, *Menesiniella regalis* and *Amphibalanus amphitrite amphitrite* were noted.

This chapter presents results from the ninth annual monitoring survey conducted in April 2015.

9.2 Approach and methodology

9.2.1 Study sites

The location of the eight rocky shore sampling sites is shown in Figure 9.1. The Dive School and Jetty sites are situated along the northern shore in Small Bay. The Marcus Island, Iron Ore Jetty and Lynch Point sites are in Big Bay, while the Schaapen Island East and West sites are located at the entrance to Langebaan Lagoon. The North Bay site is situated in Outer Bay at the outlet of Saldanha Bay.



Figure 9.1 Location of the eight rocky shore study sites in Saldanha Bay indicated by red dots.

The sampling sites were specifically chosen to cover the different rocky shore habitats found in the Saldanha Bay system incorporating the full range of wave exposure and topographical heterogeneity (type of rock surface and slope). Dive School (DS) and Jetty (J) are very sheltered sites with gentle slopes, consisting of boulders and rubble interspersed with sandy gravel (Figure 9.2). Schaapen Island East (SE) is situated in a little baylet and is relatively sheltered and mostly flattish with some ragged rock sections. Schaapen Island West (SW) is a little less sheltered and mostly flat with some elevated topography.

The site at the Iron Ore Jetty (IO) is semi-exposed with a very steep slope resulting in a very narrow total shore width (distance from low-water to high-water mark). The rock surface at this site comprises medium-sized broken boulders that are piled up to support a side arm of the iron ore jetty, which encircles a small area that was previously used for aquaculture purposes. The semi-exposed site Lynch Point (L) has a relatively smooth surface with occasional deep crevices. North Bay (NB) is exposed with a relatively flat high and mid shore. The low shore consists of large unmovable square boulders separated by channels. The rocky intertidal site on Marcus Island (M) is flat and openly exposed to the prevailing south-westerly swell.



Dive School - very sheltered



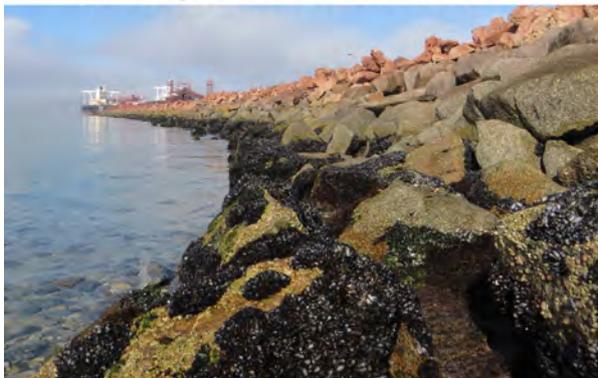
Jetty - very sheltered



Schaapen East - sheltered



Schaapen West - sheltered



Iron Ore Jetty - semi-exposed



Lynch Point - semi-exposed



North Bay - exposed



Marcus Island - exposed

Figure 9.2 Rocky shore study sites in Saldanha Bay. Dive School and Jetty are situated in Small Bay, Schaapen Island East and West are in Langebaan Lagoon, Iron ore Jetty and Lynch Point are in Big Bay, and North Bay and Marcus Island are in Outer Bay.

9.2.2 Methods

At each study site, the rocky intertidal was divided into three shore height zones: the high, mid and low shore. In each of these zones, six 100x50 cm quadrats were randomly placed on the shore and the percentage cover of all visible species recorded as primary (occurring on the rock) and secondary (occurring on other benthic fauna or flora) cover. Individual mobile organisms were counted to calculate densities within the quadrat area (0.5m²). The quadrat was subdivided into 171 smaller squares to aid in the estimation of the percentage cover. Finally, the primary and secondary cover data for both mobile and sessile organisms were combined and down-scaled to 100%. Percentage cover refers to the space that organisms occupy on the rock surface, while abundance refers to the number of organisms present. The survey protocol has remained consistent for all surveys.

Sampling was non-destructive, *i.e.* the biota was not removed from the shore, and smaller infaunal species (e.g. polychaetes, amphipods, isopods) that live in the complex matrix of mussel beds or dense stands of algae were not recorded by this survey protocol. Some algae and invertebrates cannot be easily identified to generic or species level in the field and are thus recorded under a general heading only (e.g. crustose and articulate corallines, red turfs, sponge, colonial ascidian). For further analysis, intertidal species were categorized into seven functional groups: grazers (mostly limpet species), filter-feeders (including sessile suspension feeders such as mussels and barnacles), predators and scavengers (such as carnivorous whelks and anemones), encrusting algae (crustose and articulated coralline algae), corticated algae, ephemeral foliose algae and kelps.

9.2.3 Data analysis

The rocky shore biota from the eight study sites were analysed with multivariate statistical techniques employing the software package PRIMER 6. These methods are useful for a graphical presentation of the results obtained from the typically large data sets collected during ecological sampling. The principle aim of these techniques is to discern the most conspicuous patterns in the community data. Comparisons between intertidal communities are based on the extent to which they share particular species at similar levels of occurrence. Patterns in the data are represented graphically through hierarchical clustering (dendrogram) and multi-dimensional scaling (MDS) ordination techniques. The former produces a dendrogram in which samples with the greatest similarity are fused into groups, and these are successively grouped into clusters as the similarity criteria defining the groups are gradually reduced. MDS techniques compliment hierarchical clustering methods by more accurately 'mapping' the sample groupings two-dimensionally in such a way that the distances between samples represent their relative similarities or dissimilarities. All percentage cover data were 4th-root transformed and a Bray-Curtis resemblance matrix was used.

Statistical comparisons of *a priori* defined groups of samples (e.g. sites, treatments, years) were analysed by means of PERMANOVA. PERMANOVA is a routine for testing the simultaneous response of one or more variables to one or more factors in an analysis of variance (ANOVA) experimental design on the basis of any resemblance measure, using permutation methods (Anderson *et al.* 2008). In essence, the routine performs a partitioning of the total sum of squares according to the specified experimental design, including appropriate treatment of factors that are fixed or random, crossed or nested, and all interaction terms. A distance-based pseudo-*F* statistic is calculated in a fashion that

is analogue to the construction of the F statistic for multi-factorial ANOVA models. P-values are subsequently obtained using an appropriate permutation procedure for each term. Following the main overall test, pair-wise comparisons are conducted. Significance level for the PERMANOVA routine is $p < 0.05$ (i.e. a 95% probability that the finding is not due to chance).

The contributions of each species to the average dissimilarity between two sites, and to the average similarity within a site, were assessed using a SIMPER (Similarity Percentages) analysis. The taxa principally responsible for differences detected in community structure between sites or groups were identified.

A variety of diversity indices were determined that are used as measures of some attribute of community structure. Diversity indices include:

- *Species number (S)* - total number of species present.
- *Percentage/biotic cover* - the percentage of intertidal rocky surface that is covered by biota (fauna and flora).
- *Evenness (J')* - expresses how evenly the individuals are distributed among the different species, in other words, whether a shore is dominated by individuals of one or few species (low evenness) or whether all species contribute evenly to the abundance on the shore (high evenness). The index is constrained between 0 and 1 where the index increases towards 1 with less variation in communities.
- *Shannon-Wiener diversity index (H' [loge] or d)* - a measurement of biodiversity taking into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness.

9.3 Results and discussion

9.3.1 Spatial variation in community composition

In 2015, a total of 116 taxa were recorded from all rocky shore sites, of which 68 taxa were invertebrates (58.6%) and 48 (41.4%) algae. The faunal component was represented by 23 filter feeding taxa, 28 grazers, and 17 predators/scavengers. The algal component comprised 35 corticated (foliose) seaweeds, six ephemerals, five encrusting algae, and two kelp species. This is likely a gross underestimation of coralline taxa as most species are not identifiable in the field and are thus lumped into larger groups. The total number of taxa recorded at the study sites has remained relatively constant over the years (Anchor Environmental Consultants 2009, 2010, 2011, 2012b, 2013b, 2014). Most of the species have already been recorded during one or more of the previous monitoring years, and many are listed by other studies conducted in the Saldanha Bay area (e.g. Simons 1977, Schils *et al.* 2001, Robinson *et al.* 2007b). The species are generally common to the South African West Coast (e.g. Day 1974, Branch *et al.* 2010).



Figure 9.3 Photographs of a typical high, mid and low rocky shore site in Saldanha Bay (from left to right).

Intertidal rocky shores are alternately submerged underwater and exposed to air by tidal action. This creates a steep vertical environmental gradient for the biota that inhabit these shores resulting in biota lower on the shore being mostly submerged and biota higher on the shore mostly exposed. Rocky shores can thus be partitioned into different zones according to shore height level, whereby each zone is distinguishable by their different biological communities (Menge & Branch 2001). An ANOSIM confirmed that there was a significant difference between shore heights in 2015 ($R=0.58$, $p=0.01$), while a SIMPER analysis between the species found at different shore heights affirmed that high, mid and low shores in Saldanha Bay were relatively dissimilar among the sites (Figure 9.4).

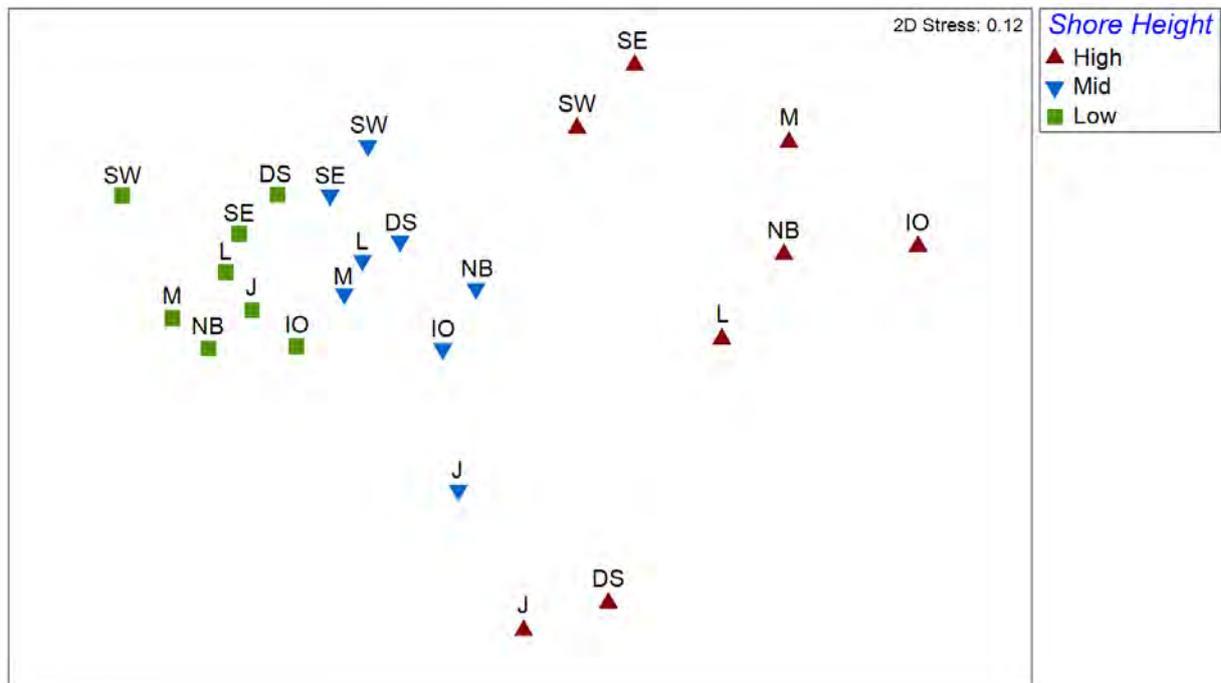


Figure 9.4 MDS plot showing differences in shore height amongst rocky shore assemblages in Saldanha Bay in 2015.

9.3.1.1 High shore

The composition and distribution of the rocky intertidal biota is strongly influenced by the prevailing wave exposure at a shore, as well as substratum topography (McQuaid & Branch 1984). Within a site, shore height is the critical factor as a result of the increasing exposure to air from low to high shore, whereby the existence of distinct patterns of zonation of flora and fauna has been well described (Stephenson & Stephenson 1972). The effects of wave action are generally attenuated up-shore and superseded by the uniformly severe desiccation stress experienced high on the shore.

In agreement with the above, previous State of the Bay reports showed that very few mobile species occurred on the high shore at all Saldanha Bay sites (Anchor Environmental Consultants 2014). It was also found that at the very sheltered boulder shores (Dive School and Jetty), considerable amounts of sand and gravel accumulated amongst the boulders (Anchor Environmental 2014). A typical species found at the high shore sheltered sites was the winkle *Oxystele variegata*, while at the exposed sites the anemone *Bunodactis reynaudi* and, in larger numbers, the tiny periwinkle *Afrolittorina knysnaensis* dominated this zone (Anchor Environmental 2014). The latter typically accumulated in moist cracks and crevices at Lynch Point, Marcus Island and North Bay (Anchor Environmental 2014).

Field data collected in 2015 showed that Jetty and Dive School were less similar to the other high shore sites due to the presence of the barnacle *Notomegabalanus algicola* (Figure 9.4). Similar to previous findings, most quadrats were largely barren with 75% of the similarity collectively attributed to the periwinkle *A. knysnaensis*, the quick growing ephemeral algae *Porphyra capensis* and the periwinkle *O. variegata*. Ephemerals are opportunistic algae that have short life cycles and are usually the first settlers on a rocky shore after a disturbance event (Maneveldt *et al.* 2009). The alien barnacle *Balanus glandula* occurred in the high shore zone at Lynch Point, Marcus Island and North bay but with low coverage (<3%). Barren rock accounted for >80% at most high shores, while algal cover was extremely sparse, except at Marcus Island which had >3% cover of *P. capensis*.

9.3.1.2 Mid shore

Following the trend on the high shore, the mid shore at the sheltered sites was also relatively barren; while the exposed sites had higher biotic cover (Anchor Environmental Consultants 2014). The dwarf cushion starfish *Parvulastra exigua* was typically found in moist rock-depressions and small pools, while the whelk *Burnupena* spp. and the periwinkle *Oxystele variegata* were frequently observed sheltering in depressions created by mussel carpets. In previous years, a tube-building polychaete living deeply cemented in a compact matrix of sand was common at sheltered sites (Anchor Environmental Consultants 2011), but in 2012 the worm had declined at the mid shore and was only recorded from lower down the shore albeit with low cover.

Field data collected in 2015 showed that the whelk *Burnupena* spp., the periwinkle *Oxystele variegata*, the introduced mussel *Mytilus galloprovincialis*, the cushion starfish *Parvulastra exigua*, the limpet *Cymbula granatina* the brown algae *Ralfsia verrucosa*, the ephemeral algae *Ulva* spp. and the red algae *Nothogenia erinacea* together accounted for 50% of the similarity between mid shore sites. Algal presence was generally low in the mid shore with some ephemeral cover.

With increasing wave force across sites, the mid shores were dominated by filter feeders, particularly two alien invasive species; the mussel *M. galloprovincialis* and the barnacle *Balanus glandula*. Both were particularly abundant at the semi-exposed site Iron Ore Jetty in 2015 with an average cover of 37% and 17% respectively. In contrast, neither of these species was present on the mid shore at the Dive School and at both Schaapen Island sites. The tiny periwinkle *A. knysnaensis* was found nestling in amongst the barnacles at sites inundated with *B. glandula*. This snail is normally abundant primarily in the upper intertidal where it congregates in crevices to escape the heat of the day, emerging at night or on moist days to feed (Branch *et al.* 2010). At Lynch Point and North Bay the tiny snail reached high abundances in the mid shore with a maximum of >117 individuals/0.5m² in 2012 and increased to a maximum of 178 individuals/0.5m² in 2015. It seems that in the high shore where wave stress is minimal, *A. knysnaensis* is naturally abundant but in the mid-shore, where wave stress is greater, the periwinkle normally declines in abundance without shelter (Laird & Griffiths 2008, Griffiths *et al.* 2011).

9.3.1.3 Low shore

At the very sheltered sites (Dive School and Jetty) average faunal cover was only 10% in comparison with the exposed sites (North Bay and Marcus Island), which had 36% cover. Algal cover at sheltered sites was much lower than that at exposed sites (13% compared to 44% respectively), and consisted primarily of the brown alga, *Ralfsia verrucosa*, the foliose seaweed *Gigartina bracteata*, and various species of encrusting coralline. At the sheltered Schaapen Island sites, the ground cover was dominated by a diverse array of up to 31 different algae species, a variety of corallines being the most common.

The following invertebrates together accounted for 20% of the similarity attributed between low shore sites: the mussels *M. Galloprovincialis* and *Aulacomya atra*, the whelk *Burnupena* spp., and the limpet *Cymbula granatina*. The sea urchin *Parechinus angulosus* was exclusively found in crevices hidden under pieces of shell or gravel in the low shore, although not in high abundance. The pear-shaped limpet *Scutellastra cochlear* (always surrounded by narrow gardens of fast-growing, fine red algae) is found exclusively in the low shore zone and was present at Lynch Point, Marcus Island and North Bay. *Scutellastra cochlear* was clearly restricted to wave swept shores where it lived in patches of dense aggregations.

Aulacomya atra can be found living deep down in *Mytilus* beds, taking advantage of the moisture within the overlying dense mussel matrix. In 2011, the indigenous ribbed mussel *Aulacomya atra* was fairly prominent at the low shore at Marcus Island and could locally supersede the alien mussel (Anchor Environmental Consultants 2012b) but during the 2015 survey, the ribbed mussel contributed <3% to the cover. As *A. atra* populations cannot be seen without destructive sampling, it is likely that the changes in *A. atra* cover that were recorded between survey years are at least partly due to the overlying *Mytilus* layers being ripped off from the rocks by waves, exposing the indigenous mussel beneath.

Reflecting known zonation patterns, total biotic cover generally increased from high to low shore. As an example, total cover on the high shore at Lynch Point was only 2% compared to 76% at the low

shore. Differences in community structure are thus most pronounced at the low shore where the wave energy is greatest.

9.3.2 Temporal analysis

9.3.2.1 Temporal analysis of diversity indices

Diversity indices provide insight into the way in which the total number of individuals in a community is divided up among different species. Understanding changes in benthic diversity is important because increasing levels of environmental stress generally decreases diversity. Two different aspects of community structure contribute to community diversity, namely species richness (calculated using the Shannon-Weiner diversity index) and equability (evenness). Species richness refers to the total number of species present, while evenness expresses how uniformly the individuals are distributed among different species. A sample with greater evenness is considered to be more diverse. It is important to note when interpreting diversity values that predation, competition and disturbance all play a role in shaping a community. For this reason it is important to consider physical parameters as well as other biotic indices when drawing a conclusion from a diversity index.

As previous reports showed no clear trend in diversity indices over time (Anchor Environmental 2014), temporal biotic cover data were averaged across years from 2005 to 2015 at each site (Figure 9.5). Sites were sorted from left to right according to increase in wave force and the indices are calculated for the whole shore across all zones. Marcus Island had the highest average number of species over this period, while Jetty had the lowest; although there was no clear trend across the wave exposure gradient. In contrast, average biotic cover increased among the shores with intensifying wave force from 12% cover at Jetty to 60% cover at Marcus Island. This trend was not evident for evenness and Shannon-Wiener diversity, although the site at the Iron Ore Jetty had the lowest values for both these indices. This indicated low overall diversity and but high variation in communities over the years, which may be an indication of disturbance.

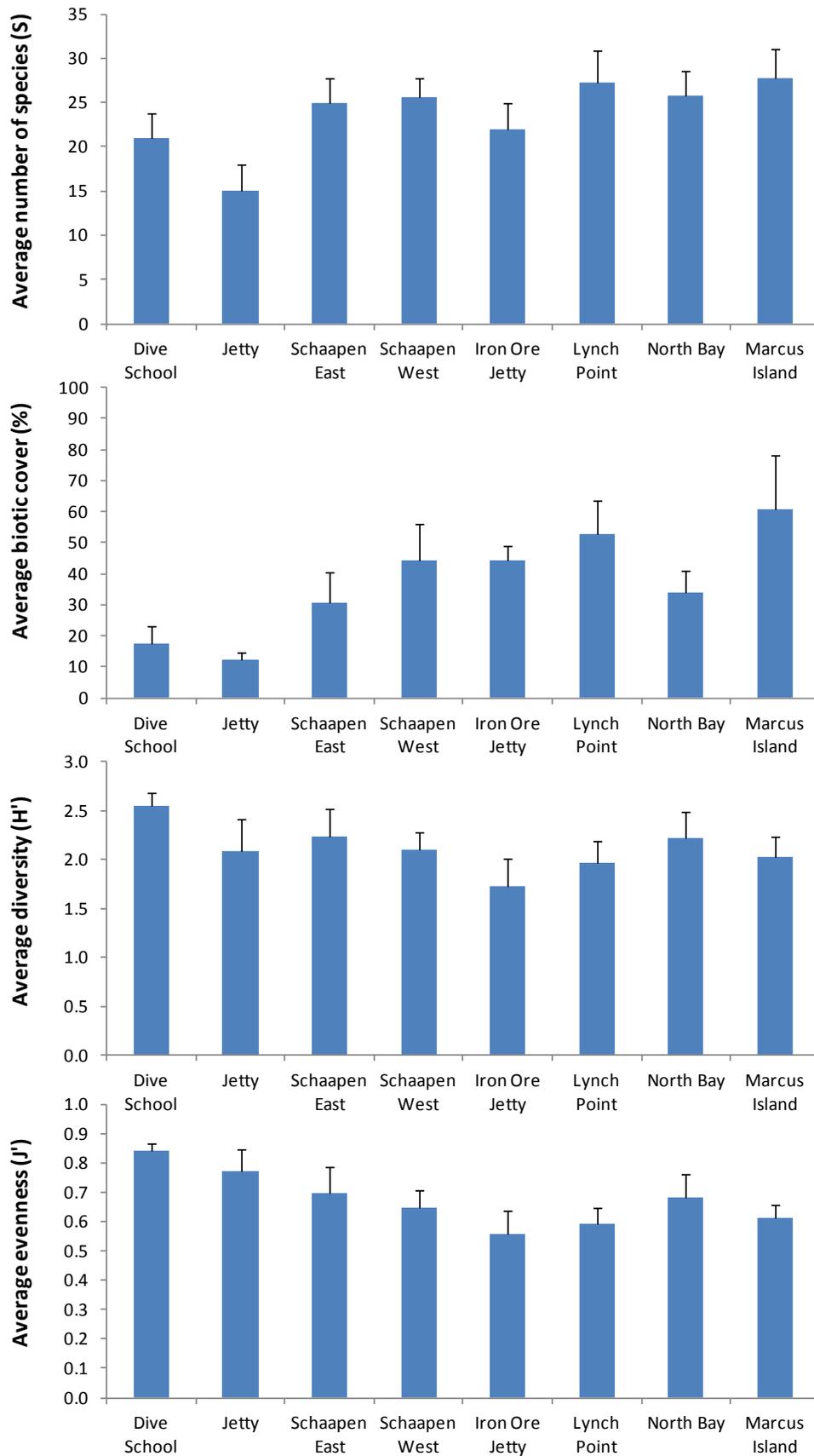


Figure 9.5 Temporal biotic cover data from 2005 – 2015 averaged across years and displayed as biotic indices of 'species number' (S), 'biotic cover' (N), 'diversity' (d) and 'evenness' (J'). Error bars indicate standard error.

9.3.2.2 *Temporal trends in rocky shore community patterns*

PERMANOVA tests conducted for each site confirmed significant differences among the years ($p = 0.0001$ for all tests). Pair-wise tests further reveal that for every site-by-year combination tested, inter-annual changes in community composition were significant. When data were analysed according to year, every year was significantly different from every other year with average similarity between years ranging between 35.4 and 47.1%.

Temporal trends in rocky shore community patterns are illustrated in the MDS plot (Figure 9.6). Consistent for all years is the grouping according to wave exposure, with the cluster on the left of the MDS plot grouping all samples from the more exposed sites (Iron Ore Jetty, Lynch Point, North Bay, and Marcus Island), a cluster in the centre grouping the semi-exposed sites (Schaapen Island East and West), and a cluster on the right grouping samples from the sheltered sites (Dive School and Jetty). Within the exposed cluster, a separation of Iron Ore Jetty from the other three exposed sites is apparent.

Inter-annual variability within each site is also evident, but this is more pronounced for some of the sites than for others. At Dive School, for example, samples from 2013 tend to be on the right of the cluster, while those from 2005 are on the left (Figure 9.6). The greatest within-site variability (or patchiness) occurs at the boulder site Jetty where the replicates per year often disperse widely. Due to the high stress level of 0.21, the MDS plot needs to be interpreted with caution, but there is good agreement with the pattern observed between years, suggesting that the representation is fairly reasonable.

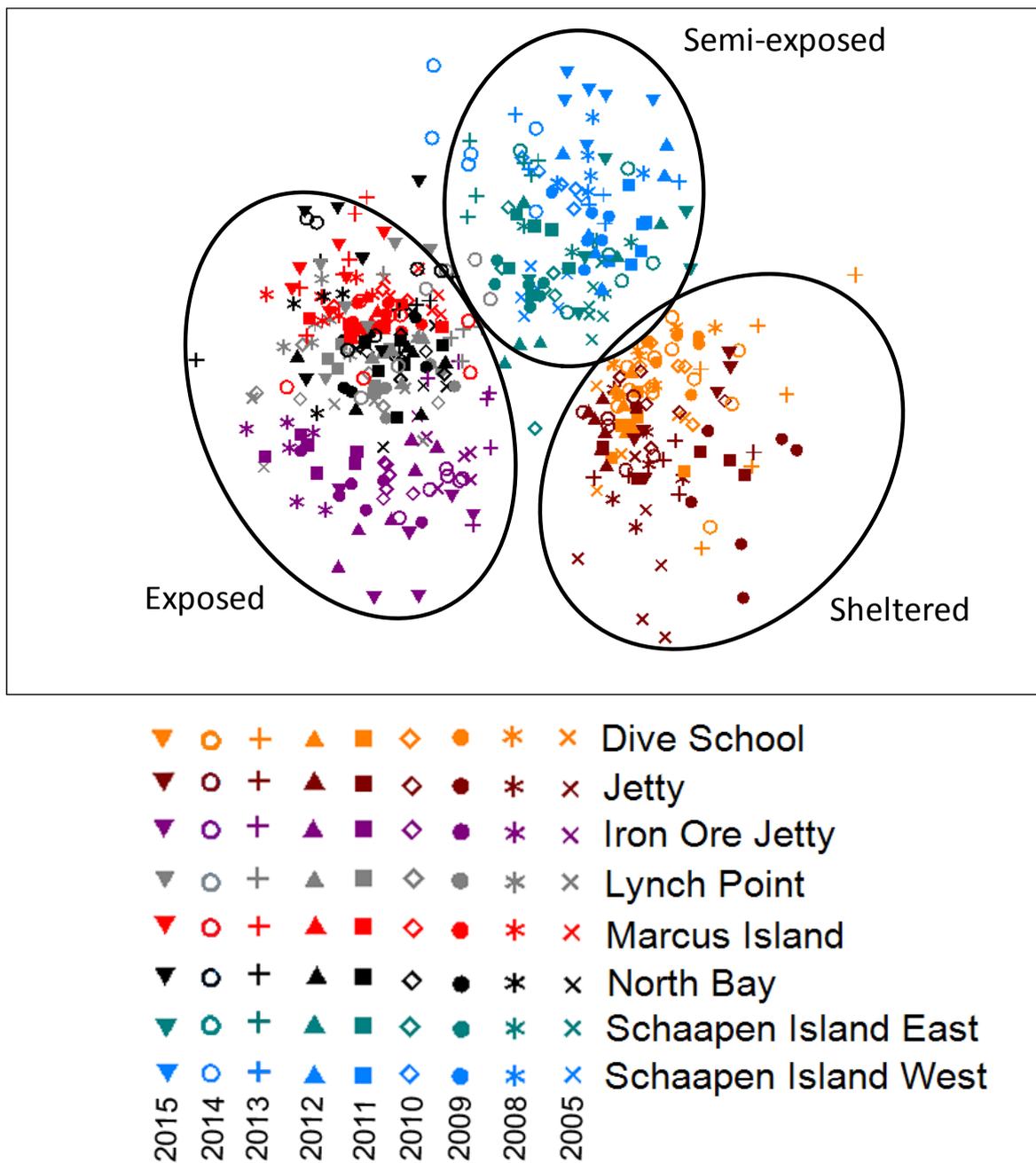


Figure 9.6 Multi-dimensional scaling (MDS) plot of the rocky shore communities at the eight study sites from 2005 to 2015. The circles delineate a 40% similarity level and the plot has with a 2D stress of 0.2.

9.3.2.3 Species responsible for temporal trends

The species that are primarily responsible for the observed differences in community structure among the years are identified by the SIMPER routine. For brevity, only species contributing >4% to the dissimilarity at any specific site and only comparisons between 2014 and the current dataset from 2015 are presented (Table 9.1). At most of the sites only two or three species contributed largely (>4%) to the differences in community structure between 2014 and 2015, except for Jetty where six species contributed and the exposed sites (Lynch Point and Marcus Island) where no single species contributed >4% (Table 9.1). For the latter sites, the species contributing the most to the dissimilarity was listed.

Algae were common contributors to differences between years and 77% of the species listed in Table 9.1 were seaweeds (Table 9.1). Of the 11 algal species listed, one was ephemeral algae, seven were corticated algae, and three were encrusting algae. The only animals listed were two filter-feeding species, the white dwarf barnacle *Notomegabalanus algicola* and the introduced barnacle *Balanus glandula*. The alien barnacle declined from 2014 to 2015 across sites and completely disappeared from the Jetty site.

The presence of diatoms contributed largely to differences between the years at six of the eight rocky shore sites. Diatoms often cover high shore rocks together with other microscopic algae (e.g. spores of macroalgae), but their presence is typically temporary as they are eventually replaced by macroalgae (Robles 1982, Cubit 1984, Maneveldt *et al.* 2009). This succession is seen in Saldanha Bay with visible increases in the percentage of macroalgal species on the shore at all sites except at Dive School. Guano run-off from Schaapen Island is likely to be responsible for enhanced intertidal algal growth in that area (Bosman *et al.* 1986, Bosman & Hockey 1986 & 1988).

A reduction in cover of *Gigartina polycarpa* contributed largely to the difference between the years at Dive School and Jetty, although this is likely to be an artefact of misidentification as this species is easily mistaken as the very similar *G. bracteata*. An increase in *N. algicola* cover was partly responsible for changes at Jetty. At Marcus Island and Iron Ore Jetty, crustose coralline was the main species responsible for the differences between the years. Average dissimilarities between the years at both of the sheltered sites were low (Table 9.1), indicating that temporal differences in rocky shore communities were small.

Table 9.1 SIMPER results listing the species that contribute >4% to the dissimilarity between 2014 and 2015 at each site. The percentage cover data presented are averages across the six replicates per site and are on the fourth-root transformed scale.

Site	Species	2014 %cover	2015 %cover	% Contribution	Ave. dissimilarity
Dive School	<i>Gigartina polycarpa</i>	1.06	0	6.56	44.23
	Diatoms	1.07	0.19	5.66	
Jetty	<i>Balanus glandula</i>	1.04	0	7.16	46.58
	<i>Gigartina polycarpa</i>	1.13	0.12	6.90	
	<i>Gigartina bracteata</i>	0	0.90	6.15	
	<i>Notomegabalanus algicola</i>	0.2	0.99	5.48	
	<i>Leathesia marina</i>	0.68	0	4.72	
	<i>Cladophora spp.</i>	0	0.62	4.28	
Schaapen East	Diatoms	1.15	0	5.56	50.48
	<i>Hildenbrandia lecanellieri</i>	0.92	0	4.61	
	<i>Sarcothalia scutellata</i>	0	0.87	4.32	
Schaapen West	Diatoms	0.88	1.85	4.32	60.92
Iron Ore Jetty	Coralline (crustose)	0.93	0	4.77	55.54
	<i>Balanus glandula</i>	1.65	1.13	4.11	
Lynch Point*	<i>Plocamium spp.</i>	0	0.95	3.75	47.81
	Diatoms	0.87	0	3.37	
	Cochlear Garden	0	0.80	3.12	
	<i>Balanus glandula</i>	0.78	0.63	3.02	
North Bay	Diatoms	0.25	1.58	5.01	55.96
Marcus Island*	<i>Sarcothalia stiriata</i>	0.19	1.00	3.69	51.43
	Coralline (crustose)	0.73	1.50	3.25	
	<i>Balanus glandula</i>	0.87	0.41	3.11	

* Note that at sites marked with an asterisk none of the species contributed >4% to the dissimilarity. The species with the highest contribution is thus listed.

9.3.2.4 Temporal variations in abundance of functional groups

Many studies have been conducted worldwide focusing on the effect of wave action on the distribution of organisms on rocky shores (Lewis 1964, McQuaid & Branch 1984, Raffaelli & Hawkins 1996, Bustamante *et al.* 1997, Menge & Branch 2001, Denny & Gaines 2007). Increasing exposure reduces siltation and increases the supply of dissolved oxygen and particulate food, favouring certain sessile, filter-feeding species and leading to an elevation of overall biomass (McQuaid & Branch 1985, Bustamante & Branch 1996, Bustamante *et al.* 1995, Steffani & Branch 2003a). Although increasing exposure carries an increased risk of dislodgement and physical damage thus limiting the range of susceptible and physically fragile species, Pfaff *et al.* (2011) showed that wave exposure has

an overall positive effect on the recruitment of mussels and barnacles on the southern African west coast. In contrast, sheltered shores are typically dominated by algae (McQuaid & Branch 1985) as species richness of most algal groups decrease with increasing exposure. The effect of wave exposure, however, varies with phyla and functional form group as some forms can better withstand hydrodynamic forces than others (Denny & Gaylord 2002, Nishihara & Terada 2010).

Despite adaptations evolved as a result of different wave exposures, hydrodynamic forces can at times cause massive damage to rocky shore communities, fundamentally altering the structure and function of exposed rocky habitats and creating changes that may persist for many years. The magnitude and frequency of physical disturbance is not as severe on protected shores as on exposed shores, thus the structure of protected communities is often more stable than that of exposed assemblages. The rocky shores at Saldanha Bay are separated with regard to wave force and range from very sheltered to exposed.

While wave force is clearly the main factor for differences among the shores, shore topography is also of importance. The roughness of the substratum or generally termed habitat structure can be a crucial factor driving species richness, abundance and even body size (Kostylev *et al.* 2005). According to McCoy and Bell (1991), habitat structure is generally thought to have two independent components: complexity (the physical architecture of a habitat) and heterogeneity (the relative abundance of different structural features such as boulders or crevices within a habitat). Several studies have shown that many mobile animals exhibit preferential movement from smooth surfaces into habitats with more structural complexity (e.g. crevices) where they are more protected from hydrodynamic forces (McGuinness & Underwood 1986, Kostylev *et al.* 2005, O'Donnell & Denny 2008). This does not apply only to physical complexity, but also microhabitats offered by biota (e.g. the barnacle *Balanus glandula*). Mobile invertebrates can respond to environmental extremes by moving between microhabitats to ameliorate thermal and desiccation stress (Meager *et al.* 2011).

The distribution of sessile species is largely driven by the longer-term processes of settlement, growth and mortality; whereby substratum availability, microtopography and surface smoothness can be limiting factors at local scales (Guarnieri *et al.* 2009). Topographic complexity influences the settlement of benthic organisms as planktonic larvae are more likely to be retained on rough surfaces, while water movement may wash them off smooth surfaces (Eckman 1990, Archambault & Bourget 1996, Skinner & Coutinho 2005, Guarnieri *et al.* 2009).

Boulder shores also have greater microhabitat diversity compared to more level shores. One of the reasons for this is because the tops of larger boulders stay exposed for a significantly longer period than smaller boulders (or flat platforms), with each boulder essentially having its own shore height zonation. During low tide, the top of the boulder provides the lower section with shade, thus maintaining lower temperatures and higher moisture content (Takada 1999). This arrangement increases the surface area for the attachment of organisms but may reduce water movement, which may cause detritus to accumulate, possibly resulting in low oxygen conditions. Large boulders can considerably reduce the water flow velocity, thus invertebrate biomass is expected to decrease significantly downstream of boulders. Smaller boulders may be unstable and often have a more impoverished community than larger rocks (McGuinness 1987, Guichard & Bourget 1998, Londoño-Cruz & Tokeshi 2007, McClintock *et al.* 2007). All these factors result in boulder fields supporting different species assemblages in comparison to those of flatter shores (Sousa 1979a, McGuinness

1984, McQuaid *et al.* 1985, McGuinness & Underwood 1986, Takada 1999, Cruz-Motta *et al.* 2003, Davidson *et al.* 2004, Hir & Hily 2005).

Shore topography is a likely reason for differences in community structure between the rocky shores on Schaapen Island and the other two sheltered sites, although it may also be related to the fact that Schaapen Island lies in the transition zone between Saldanha Bay and Langebaan Lagoon. The water in the Lagoon has slight differences in water quality (e.g. temperature) compared to the water in the Bay, which in turn leads to differences in their biological communities (Day 1959, Robinson *et al.* 2007b). For example, Schils *et al.* (2001) report a distinct separation in algal composition between the Bay and the Lagoon as the Lagoon contains a significant number of South Coast species due to its warmer waters. Perlemoen Punt, located less than 1 km from Schaapen Island at the entrance to Langebaan Lagoon, is described as the transition area between the Bay and the Lagoon, but with a marked Lagoon affinity in its overall algal composition. Clear differences in community composition between the Bay and the Lagoon are also described for zooplankton and sandy substrate assemblages (Grindley 1977, Anchor Environmental Consultants 2012b).

The biotic cover of the various functional groups across the shores with regard to exposure is depicted in Figure 9.7 with sites arranged from very sheltered to exposed. Very sheltered shores had generally low biotic cover consisting primarily of grazers, corticated algae and encrusting algae, with the exception of Schaapen Island East and West that had high biotic cover and were clearly dominated by algae. With an increase in wave force, the dominance of sessile filter feeders (e.g. barnacles) was evident.

At the two sheltered sites (Dive School and Jetty), filter feeders and ephemeral algae slightly decreased over time, while corticated algae, encrusting algae and grazers increased slightly. At both Schaapen Island sites, the abundance of ephemerals and encrusting algae varied considerably over the years but without a consistent trend. In 2010 and 2011, filter feeders at the Schaapen Island sites had increased in cover to >10% averaged across the whole shore, but declined again from 2012 onwards. Iron Ore Jetty and Lynch Point remained relatively constant over time, with only minor variations in encrusting algae and ephemeral cover. At North Bay, filter feeders increased steadily over time with only a slight drop in cover in 2012. Ephemerals again showed slight temporal fluctuations, with encrusting algae increasing noticeably in 2014 but decreasing again in 2015. At Marcus Island, ephemeral algae had greatly increased from 2008 to 2009, while at the same time corticated algae, encrusting algae and filter feeders declined. This substantial increase in ephemeral cover resulted in an overall greater biotic cover in 2009. In 2010, ephemerals had somewhat reduced but returned again 2011. There was no noteworthy change in functional groups in 2012 but encrusting algae and kelp increased substantially in 2013, decreasing again in 2014. Ephemeral algae decreased substantially at Schaapen Island West and encrusting algae decreased at North Bay in 2015.

Overall, none of the sites indicated a temporal change in their rocky shore communities that would suggest a dramatic alteration such as the arrival or loss of a key species. Instead, the intertidal communities show temporal fluctuations that reflect mostly the dominance of ephemerals over one or more years, often with a concomitant decline in filter feeders (e.g. Schaapen West in 2008). Ephemeral algae are usually the first to colonize rock space denuded of biota due to physical (e.g. wave action) or biological (e.g. grazing) disturbance. In the ecological succession that follows,

ephemerals are then replaced by longer-lived late successional species (Sousa 1979b, 1984). As low percentages of ephemerals were recorded in 2015, it is unlikely that any disturbance or pollution events occurred close to the study sites and the small fluctuations of functional groups over the years are likely to be a natural seasonal and inter-annual phenomenon.

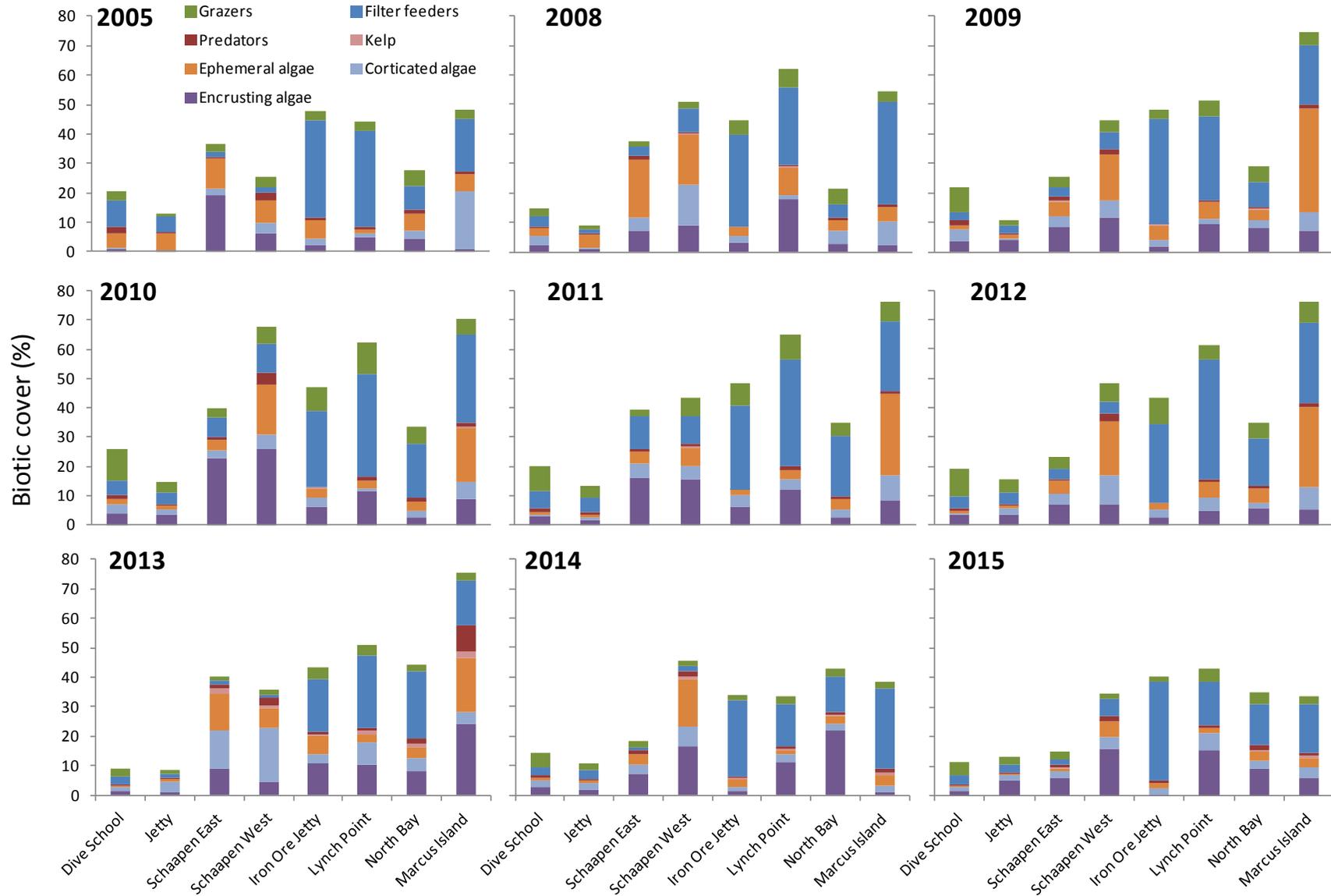


Figure 9.7 Total percentage cover (averaged across the whole shore) of the seven functional groups at the eight study sites from 2005 to 2015.

9.3.3 Summary of findings

In 2015, a total of 116 taxa were recorded from the eight study sites, most of which had been found in previous survey years. The faunal component was represented by 23 species of filter-feeders, 28 species of grazers, and 17 species of predators and scavengers combined. The algal component comprised 35 corticated (foliose) seaweeds, six ephemerals, five species of encrusting algae, and two species of kelp. The species recorded in Saldanha Bay are generally common to the South African West Coast and many are listed by other studies conducted in the Saldanha Bay area including the two alien invasive species, the Mediterranean mussel *Mytilus galloprovincialis*, the North American acorn barnacle *Balanus glandula*, and the two alien barnacle species *Amphibalanus amphitrite amphitrite* and *Menesiniella regalis*.

Within a site, the vertical emersion gradient of increasing exposure to air resulted in a clear zonation of flora and fauna from low shore to high shore. Differences among the rocky shores, however, were strongly influenced by the prevailing wave exposure at a shore as well as substratum topography. Very sheltered shores had generally low biotic cover consisting primarily of grazers, with minor cover of sessile filter feeders and algae. Sheltered shores were dominated by seaweeds and encrusting corallines. With increasing wave exposure filter feeders were clearly the most important group. The two very sheltered sites in Small Bay separate out from the flat Schaapen Island sites. This result may be related to geographic location as Schaapen Island lies in a transitional zone between the Bay and the Lagoon. In addition, nutrient input in the form of seabird guano favours algal growth on Schaapen Island. The steep boulder beach Iron Ore Jetty also separates from the more flattish semi-exposed to exposed sites.

From the temporal variation evident in the rocky shore communities, it appears that there is no directional change in community composition that would indicate a persistent change, such as the arrival or loss of a species. Instead the communities demonstrate temporal fluctuations, reflecting the temporary dominance of short-lived ephemeral species and/or inter-annual variation in larval supply or recruitment success. In general, rocky shore communities were relatively stable with only minor changes over the years.

The two most important filter feeders were the aliens *M. galloprovincialis* and *B. glandula*. These were the characteristic species at most shores and zones. The latter is most abundant in the mid shore zone of semi-exposed sites, but rarer at exposed sites and low shores. *Mytilus galloprovincialis*, on the other hand, is most abundant at wave-exposed sites and lower down the shore. One of the greatest threats to rocky shore communities in Saldanha Bay is the introduction of alien species via shipping, and their potential to become invasive (see Chapter 12 for detailed information on invasive species).

10 FISH COMMUNITY COMPOSITION AND ABUNDANCE

10.1 Introduction

The waters of Saldanha Bay and Langebaan Lagoon support an abundant and diverse fish fauna. Commercial exploitation of the fish within the Bay and lagoon began in the 1600s by which time the Dutch colonists had established beach-seine fishing operations in the region (Poggenpoel 1996). These fishers' targeted harders *Liza richardsonii* and other shoaling species such as white steenbras *Lithognathus lithognathus* and white stumpnose *Rhabdosargus globiceps*, with much of the catch dried and salted for supply to the Dutch East India Company boats, troops and slaves at the Castle in Cape Town (Griffiths *et al.* 2004). Commercial netfishing continues in the area today, and although beach-seines are no longer used, gill-net permits holders targeting harders landed an estimated 590 tons valued at approximately R1.8 million during 1998-1999 (Hutchings & Lamberth 2002a). Species such as white stumpnose, white steenbras, silver kob *Argyrosomus inodorus*, elf *Pomatomus saltatrix*, steentjie *Spodilyosoma emarginatum*, yellowtail *Seriola lalandi* and smoothhound shark *Mustelus mustelus* support large shore angling, recreational and commercial boat line-fisheries which contribute significantly to the tourism appeal and regional economy of Saldanha Bay and Langebaan. In addition to the importance of the area for commercial and recreational fisheries, the sheltered, nutrient rich and sun warmed waters of the Bay provide a refuge from the cold, rough seas of the adjacent coast and constitute an important nursery area for the juveniles of many fish species that are integral to ecosystem functioning.

The importance and long history of fisheries in the Bay and Lagoon, has led to an increasing number of scientific studies being conducted on the fish resources and fisheries in the area. Early studies, mostly by students and staff of the University of Cape Town investigated fish remains in archaeological middens surrounding Langebaan Lagoon (Poggenpoel 1996), whilst many UCT Zoology Department field camps sampled fish within the lagoon (mostly unpublished though). Gill net sampling with the aim of quantifying bycatch in the commercial and illegal gill net fishery was undertaken during 1998-99 (Hutchings & Lamberth 2002b). A once of survey for small cryptic species utilizing rotenone, a fish specific, biodegradable toxin that prevents the uptake oxygen by small fish, was conducted by Anchor Environmental Consultants during April 2001 (Awad *et al.* 2003). The data from the earlier gill netting and rotenone sampling survey was presented in the "State of the Bay 2006" report (Anchor Environmental Consultants 2006). Seine-net sampling of near-shore, sandy beach fish assemblages was conducted over short periods during 1986-1987 (UCT Zoology Department, unpublished data), in 1994 (Clark 1997), and 2007 (Anchor Environmental Consultants, UCT Zoology Department). Monthly seine-net hauls at a number of sites throughout Saldanha Bay-Langebaan over the period November 2007-November 2008 were also conducted by UCT M.Sc. student Clement Arendse who was investigating white stumpnose recruitment. These data were reported on in the "State of the Bay 2008" report (Anchor Environmental Consultants 2009).

Other recent research on the fish fauna of the area includes acoustic tracking and research on the biology of white stumpnose, hound sharks and elf within Langebaan lagoon and Saldanha Bay; monitoring of recreational shore and boat angler catches and research on the taxonomy and life history of steentjies and sand sharks and (Næsje *et al.* 2008, Kerwath *et al.* 2009, Tunley *et al.* 2009, Attwood *et al.* 2010, Hedger *et al.* 2010, da Silva *et al.* 2013). Key findings from these studies include

evidence that the Langebaan lagoon Marine Protected Area (MPA) provides a certain level of protection for white stumpnose stocks in the Bay, particularly during the summer months which coincide with both peak spawning and peak recreational fishing effort (Kerwath *et al.* 2009). Elf and smooth hound sharks were also shown to derive protection from the MPA with tagged individuals of both species spending the majority of the study period (up to 2 years) within the MPA boundaries, and indeed a high degree of residency within Saldanha Bay as a whole (Hedger *et al.* 2010, da Silva *et al.* 2013). Tagged elf did show a long term movement out of the lagoon into the Bay and one individual was recaptured in Durban confirming that long distance migration does take place (Hedger *et al.* 2010). However, the fact that nearly all fish within the Bay were resident for the one - two years after tagging and the presence of young of the year juveniles in the surf zone suggests that elf within Saldanha Bay exhibit a mixed evolutionary strategy with migratory and resident spawning components (Hedger *et al.* 2010). Out of the 24 hound sharks acoustically tagged within Langebaan lagoon, 15 were monitored for more than 12 months and two of these did not leave the MPA at all. Six of these tagged hound sharks left the Saldanha embayment for the open coast, during spring and winter for periods of between two to 156 days, but all returned during the study period. These acoustic telemetry studies have clearly demonstrated that these three priority fish species all derive protection from the Langebaan MPA.

White stumpnose within the Saldanha-Langebaan system grow more rapidly and mature earlier than populations elsewhere on the South African coast (Attwood *et al.* 2010). Male white stumpnose in Saldanha Bay reach maturity in their second year at around 19 cm fork length (FL) and females in their third year at around 22 cm FL (Attwood *et al.* 2010). Similar differences in growth rate and the onset of maturity for steentjies between Saldanha Bay and south coast populations were reported by Tunley *et al.* (2009). These life history strategies (relatively rapid growth and early maturity) in combination with the protection afforded by the MPA are probably part of the reason that stocks of these fish species in Saldanha and Langebaan have to date, been resilient to rapidly increasing recreational fishing pressure (but see paragraph below on stock status). Results from angler surveys indicate that approximately 92 tons of white stumpnose is landed by anglers each year (Næsje *et al.* 2008). Further details of the results of these studies were reported on in the State of the Bay 2008 report (Anchor Environmental Consultants 2009). The research on sand sharks suggests that the common sand shark species in Bay and Lagoon is actually *Rhinobatos blockii*, not *R. annulatus* as previously thought (Dunn & Schultz UCT Zoology Department personal communication). New information on the life history of this species has been collected and will be published in the near future.

The most recent data on the stock status of white stumpnose, the most important angling species within Saldanha-Langebaan, however, shows that the stock is fully exploited or overexploited, suggesting that the Langebaan MPA alone may not be enough to prevent stock collapse with the increases in fishing pressure (Arendse 2011). This author used catch-at-age data from the boat fishery and per-recruit modelling to estimate that spawner biomass at the time (2006-2008) was less than 25% of pristine. The target reference point for optimally exploited stocks is 40-50% of pristine biomass, and Arendse (2011) calculated that a 20% reduction in fishing mortality was required to achieve this target. It was recommended by Arendse (2011) that a reduction in bag limit from 10 to 5 fish per person per day, or an increase in size limit to 29 cm Total Length (TL) be implemented. These management measures were modelled to rebuild spawner biomass to the 40-50% target, but unfortunately, have not been implemented to date.

The Saldanha Bay Water Quality Forum Trust (SBWQFT) commissioned Anchor Environmental to undertake experimental seine-net sampling of near shore fish assemblages at a number of sites throughout the Saldanha-Langebaan system during 2005, and annually over the period 2008-2015 as part of the monitoring of ecosystem health “State of the Bay” programme. In the 2006 report it was noted that the existing seine-net survey data was the most suitable for comparative analyses over time and it was recommended that future seine-net surveys were conducted during late summer - early autumn, as this was the timing of peak recruitment of juveniles to the near-shore environment, as well as the timing of most of the earlier surveys. Since 2008, seine-net surveys have therefore been conducted during March-April of each year. These studies have made a valuable contribution to the understanding of the fish and fisheries of the region. In the 2012 report, data on the commercial catch and effort of harders (the principal target of the net fisheries in the Bay) were presented and compared to the results of the experimental seine net surveys. A similar comparison of commercial and recreational white stumpnose catches to fishery independent, experimental seine net survey data was presented in the 2011 State of the Bay report.

This report presents and summarizes the data for the 2015 seine-net survey and investigates trends in the fish communities by comparing this with data from previous seine-net surveys (1986/87, 1994, 2005, 2008-2014) in the Saldanha- Langebaan system. White stumpnose catch and effort data for the commercial line fishery is presented and the trends interpreted in conjunction with the juvenile abundance data obtained from the seine net surveys.

10.2 Methods

10.2.1 Field sampling

Experimental seine netting for all surveys covered in this report was conducted using a beach-seine net, 30 m long, 2 m deep, with a stretched mesh size of 12 mm. Replicate hauls (3-5) were conducted approximately 50 m apart at each site during daylight hours. The net was usually deployed from a small rowing dinghy 30-50 m from the shore. Areas swept by the net were calculated as the distance offshore multiplied by the mean width of the haul. Sampling during 1986-87 was only conducted within the lagoon where 30 hauls were made, whilst 39 and 33 replicate hauls were made at 8 and 11 different sites during 1994 and 2005 surveys respectively in the Bay and Lagoon. During 2007, 21 hauls were made at seven sites in the Bay and Lagoon and over the period 2008-2012, 2-3 hauls have been made at each of 15 sites every April. Since the 2013 survey, a sixteenth site was added in the lagoon at Rietvlei (Figure 10.1). A new site (Danger Bay) on the open coast to the north of Saldanha Bay was sampled for the first time in 2014 and again in 2015. As this site lies outside of the Saldanha Bay- Langebaan lagoon system, data from this site are presented separately and are not included in the summary graphs or statistical comparisons. Large hauls were sub-sampled on site, the size of the sub-sample estimated visually and the remainder of the catch released alive.

10.2.1.1 Data analysis

Numbers of fish caught were corrected for any sub-sampling that took place in the field prior to data analysis. All fish captured were identified to species level (where possible, larval fish to Family level) and abundance calculated as the number of fish per square meter. The resulting fish abundance data were used for analysis of spatial and temporal patterns.

The number of species caught and average abundance of fish (all species combined) during each survey were calculated and graphed. The average abundance of the most common fish species caught in the three main areas of the system, namely Small Bay, Big Bay and Langebaan lagoon during each survey, were similarly calculated and presented graphically. The average abundance of the four-five most ubiquitous species in the system over all survey years was calculated and plotted for each sampling site.

In order to investigate changes in the entire fish community composition in Small Bay, Big Bay and Langebaan lagoon between years, multivariate statistical analysis were conducted using the PRIMER software. Fish density data were fourth-root transformed and the Bay-Curtis similarity index was used to create similarity matrices. Relationships between years were represented using multidimensional scaling and these were statistically tested using two way mixed model PERMANOVA tests with years as a fixed effect and sites as a random effect (this takes into account the variability between sampled sites when comparing samples between years). The principal species contributing to dissimilarities between years were identified using the SIMPER routine. Trends in the abundance of key species that are of importance in local fisheries over time were analysed using a one way ANOVA and post-hoc unequal N HSD tests in STATISTICA 12. Abundance data for all sites throughout the Bay were $\log(x + 1)$ transformed to account for heteroscedacity prior to analysis.

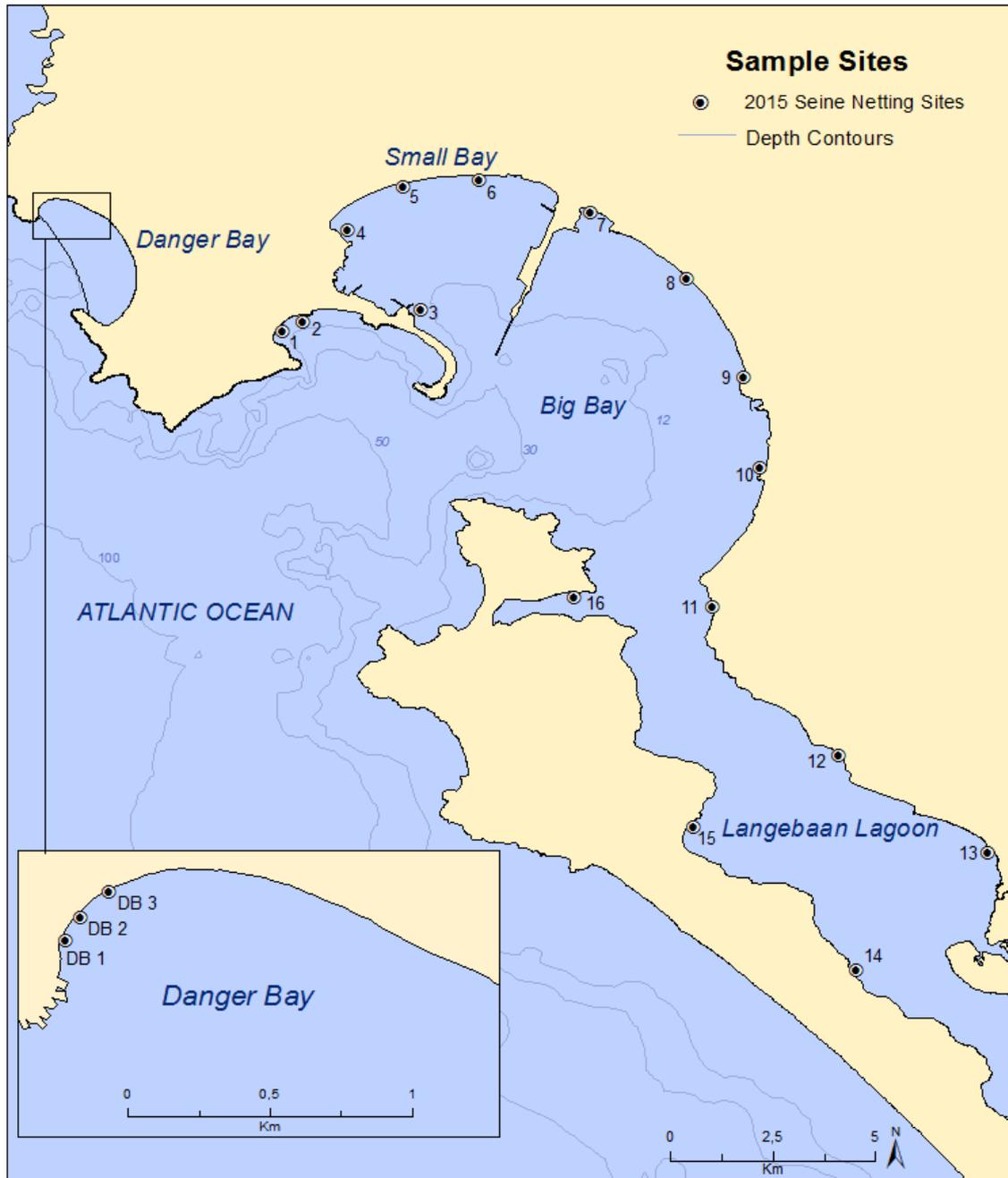


Figure 10.1. Sampling sites within Saldanha Bay and Langebaan lagoon where seine net hauls were conducted during the 2005 and 2007-2015 annual sampling events. 1: North Bay west, 2: North Bay east, 3: Small craft harbour, 4: Hoedjiesbaai, 5: Caravan site, 6: Blue water Bay, 7: Sea farm dam, 8: Spreeuwalle, 9: Lynch point, 10: Strandloper, 11: Schaapen Island, 12: Klein Oesterwal, 13: Bottelary, 14: Churchaven, 15: Kraalbaai, 16: Rietbaai.

10.3 Results

10.3.1 Description of inter annual trends in fish species diversity

The tongue fish *Cynoglossus capensis* was recorded in the seine net surveys for the first time in 2015 with a single specimen caught at Leentjies Klip and another at the Small Craft Harbour site. This species has a reported distribution from the Cunene River in Northern Namibia to Natal (Smith & Heemstra 1986). The total species count in all surveys to date now stands at 48 species taking into account the three different species of goby of the genus *Caffrogobius*, namely: *C. nudiceps*, *C. gilchristi* and *C. caffer* that have been identified in samples from the Bay. Due to the uncertainty surrounding identification of these species in earlier surveys, they have been grouped at the generic level for data presented reports since 2008. The species list and abundance of each species caught in Small Bay, Big Bay and the Lagoon during each of the different surveys are shown in Table 10.1., Figure 10.2 & Table 10.3., respectively. Considering data from all surveys conducted to date, a greater diversity of species have been captured in Big Bay (35) and Small Bay (33), than the Lagoon (24) (Table 10.1., Figure 10.2 & Table 10.3.). Species richness is typically similar in Small Bay and Big Bay, although the number of species sampled has been less variable over time in Small Bay (Figure 10.2.). Slightly more variation in the number of species caught over the period of sampling is apparent for Langebaan lagoon and Big Bay, with the most diverse samples collected from Big Bay during 2012 (Figure 10.2.). Overall there is no indication of a trend in species richness over time in any of the three parts of the Bay.

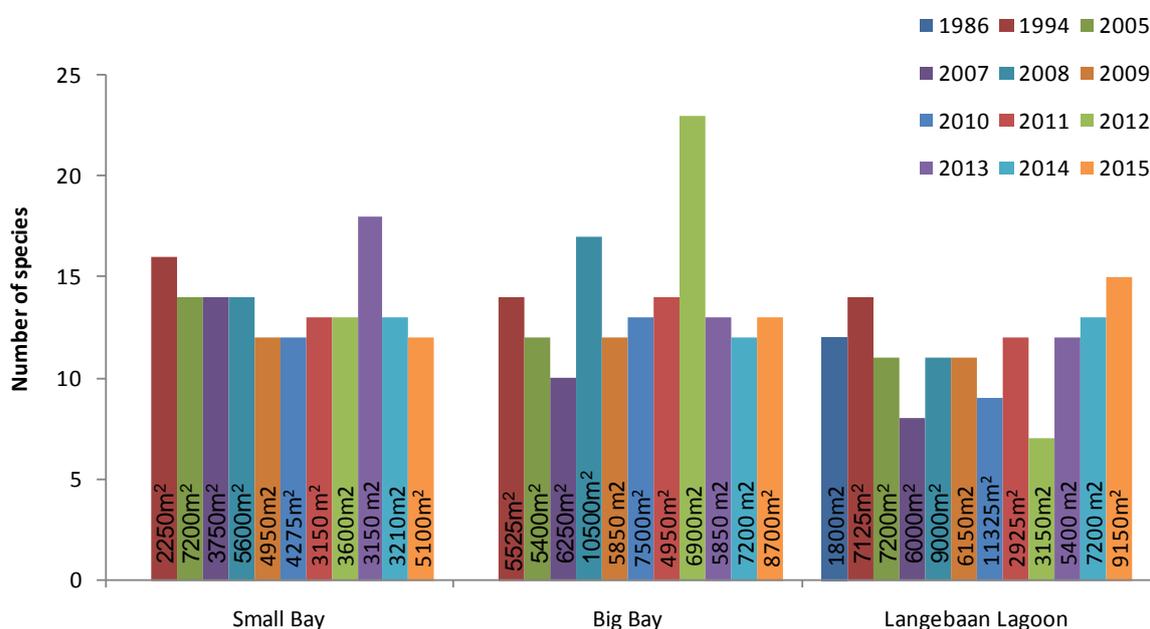


Figure 10.2. Fish species richness in 12 seine-net surveys in Saldanha Bay and Langebaan lagoon conducted over the period 1986-2015. The total area netted in each area and survey is shown. Note: The low species richness for Langebaan lagoon during 2012 is an artefact due to low sampling effort.

The actual species composition in the different areas between the surveys does change substantially between years, but the same ubiquitous species occur in nearly all surveys in the three areas (Table

10.1., Figure 10.2 & Table 10.3.). Within Small Bay, eight species occurred in all earlier surveys, with blacktail being absent for the first time in 2015 and pipefish absent from the 2005 and 2015 samples. Gurnard was captured in all of the first six surveys, but not over the period 2011-2014, but was again sampled at three sites in Small Bay in 2015. Four of the 35 species recorded in Big Bay occurred in all surveys (gurnard, Cape sole, harders and white stumpnose). Four more species - silversides, False Bay klipvis, elf and sand sharks - were only absent in one survey each (2007, 1994, 2009 and 2014 respectively). Similarly, six of the 24 species found in the lagoon occurred in all surveys. It appears that Small Bay has the highest proportion of “resident” species that occur there consistently, whilst a larger proportion of the Big Bay and Langebaan Lagoon ichthyofauna occur sporadically in these areas. Short term fluctuations in diversity and abundance of near shore sandy beach fish communities with changes in oceanographic conditions are the norm rather than the exception (see for e.g. Clark 1994). Over the past 11 sampling events average species richness has been similar in Small Bay and Big Bay (14 species) and on average, slightly lower in the lagoon (11 species) (Figure 10.2.).

10.3.2 Description of inter-annual trends in fish abundance and current status of fish communities in Small Bay, Big Bay and Langebaan lagoon

The overall fish abundance (all species combined) shows high inter annual variability in all three areas of the Bay (Figure 10.4.). Harders and to a lesser extent silversides, numerically dominated the catches for all surveys and large variation in the catches of these abundant shoaling species is the main cause of the observed variability between years. Overall, catches made during 2012 were the lowest on record for all three areas. Within Small Bay, estimated fish density was substantially lower than recorded for any earlier survey. Overall abundance in 2013 remained lower than any of the earlier surveys in both Small Bay and Big Bay, but was higher than average in Langebaan Lagoon. In 2014 the overall abundance compared favourably with earlier surveys, however as stated above this is largely a result of good catches of harders and/or silversides. Overall fish abundance in 2015, in all three areas was less than that recorded during 2014 (significantly so in Small Bay), but was comparable with earlier sampling events when low abundance was recorded in Small Bay and Big Bay (e.g. 2005,2009,2010, 2012,2013) and similar to above average abundance estimates for Langebaan lagoon (Figure 10.4.).

Estimated white stumpnose, nude goby and blacktail abundance, that was above average in Small Bay during the 2007 and 2008 surveys, has remained below these maxima in this region since 2009 (Figure 10.5). It may be that the peak densities attained by these species during 2007-2008 were the exception, and the lower densities recorded before and after this period represent the more typical situation. However, there is concerning trend that white stumpnose and blacktail abundance during the last three years are amongst the lowest yet recorded for Small Bay. Blacktail in fact disappeared entirely from catches for the first time in 11 years of sampling in 2015. This recruitment failure (to the nursery habitat) could be the result of unfavourable conditions during the spring-summer spawning season or it may reflect a more concerning loss of spawner biomass from the system. Hopefully it is the former scenario, and as blacktail are relatively long-lived sparids attaining 20 years of age, the adult population within Saldanha Bay should persist to spawn in future years (Mann & Dunlop 2013). Certainly a large aggregation of adult blacktail was caught (and

released) by UCT Zoology Department researchers in Small Bay during 2013, suggesting that a reasonable spawner biomass was at that time present in the Bay (Figure 10.3). Indeed this is confirmed by the consistent presence of juveniles in Small Bay samples for 10 consecutive years. Blacktail appear scarce along the SA west coast outside of Saldanha Bay. Mann & Dunlop (2013) report blacktail distribution as two disjunct populations, one found east of Cape Point and the other from Namibia to southern Angola, whilst genetic studies suggest that these two stocks are actually two different species. It is highly likely that the Saldanha-Langebaan blacktail population is a semi-isolated stock of the South African species, and may be vulnerable to local extirpation.



Figure 10.3 Large haul of adult blacktail made in Small Bay during winter 2013. (The fish were released alive).

Within Big Bay too, average harder density observed during the 2013-2015 sampling was comparable to earlier surveys, but the abundance of white stumpnose, elf and cape sole remain low (Figure 10.5). White stumpnose abundance within Big Bay had recovered from the very low 2013 and 2014 estimates, but remained well below the long term average (Figure 10.5). The 2009 survey estimates of all the more common fish species in Small and Big Bay were lower than the preceding two years and in some cases the lowest recorded during sampling thus far. The 2012-2015 surveys saw a similar situation (with the exception of harders and silverside), and it appears that the unfavourable environmental conditions or anthropogenic impacts that reduced the spawning success of adults and/or caused high mortality rates of eggs, larval and juveniles of several species during the 2008-2009 periods, returned during 2011-2014 summers. The situation appears worst in Small Bay where only shoaling species (harders and silversides) were recorded at densities similar to the 2013, 2014 and 2015 surveys. In contrast, the estimated abundance of the more common species in Langebaan lagoon during 2013-2015 compared favourably with earlier surveys (Figure 10.5). The exception was again white stumpnose, and estimated abundance in Langebaan lagoon remained at the lowest levels since 2005 for the third year running.

Year/species	Common name	Apr-94	Oct-05	Apr-07	Apr-08	Apr-09	Apr-10	Apr-11	Apr-12	Apr-13	Apr 14	Apr 15
<i>Myliobatis aquila</i>	Eagle ray	0.0013	0.0004	0.0079				0.0004				
<i>Parablennius cornutus</i>	Blenny									0.0014		
<i>Pomatomus saltatrix</i>	Elf	0.0009		0.0013	0.0003			0.0007			0.0030	0.0008
<i>Poroderma africana</i>	Striped catshark	0.0009										
<i>Psammogobius knysnaensis</i>	Knysna sand gobi						0.0028		0.0037	0.0011	0.0071	0.0088
<i>Raja clavata</i>	Thornback skate			0.0011								
<i>Rhabdosargus globiceps</i>	White stumpnose	0.0618	0.0079	5.0564	0.4191	0.0562	0.0822	0.0244	0.0640	0.0019	0.0318	0.0074
<i>Rhinobatos blockii</i>	Bluntnose guitar fish	0.0009	0.0013	0.0153	0.0007	0.0010	0.0008	0.0006	0.0012	0.0014	0.0072	0.0013
<i>SpondylIOSoma emarginatum</i>	Steentjie	0.0013	0.0092		0.0003			0.0237			0.0002	
<i>Syngnathus temminckii</i>	Pipe fish	0.0022		0.0037	0.0257	0.0004	0.0035	0.0033	0.0148	0.0069	0.0011	
<i>Trachurus trachurus</i>	Horse mackerel				0.0094							
Total		2.11	0.81	9.37	3.46	0.70	1.64	39.25	0.31	0.37	3.40	0.70
Number of species	33	16	14	14	15	12	12	13	13	18	13	12
Number of hauls	115	5	12	6	12	12	12	12	9	12	11	12
Total area sampled (m²)	46 235	2250	7200	3750	5600	4950	4275	3150	3600	3150	3210	5100

Table 10.2. Average abundance of fish species (number per m-2) recorded during annual beach seine-net surveys in Big Bay, Saldanha. Species sampled for the first time in an area are highlighted in bold font.

Year/species	Common name	Apr-94	Oct-05	Apr-07	Apr-08	Apr-09	Apr-10	Apr-11	Apr-12	Apr-13	Apr-14	Apr-15
<i>Argyrozona argyrozona</i>	Silverfish											0.0001
<i>Atherina breviceps</i>	Silverside	0.0003	0.0025		0.1257	0.094599	0.02889	0.1679	0.0059	0.0061	0.183	0.0037
<i>Blennophis sp</i>	Blenny sp.		0.0001		0.0001							
<i>Brama brama</i>	Angelfish								0.0001			
<i>Caffrogobius sp.</i>	Goby				0.0002	0.003086		0.0005	0.0001		0.0001	
<i>Callorhinchus capensis</i>	St joseph	0.0017							0.0002			
<i>Cancelloxus longior</i>	Snake eel		0.0001				0.0003	0.0004	0.0008	0.0001	0.0001	0.0001
<i>Cheilidonichthys capensis</i>	Gurnard	0.0021	0.0079	0.0005	0.0054	0.00216	0.0001	0.0063	0.0001	0.0007	0.0014	0.0014
<i>Cheilidonichthys kumu</i>	Bluefin gurnard								0.0002			
<i>Chorisochismus sp</i>	Suckerfish sp.				0.0001							
<i>Clinus latipennis</i>	False Bay klipvis		0.0017	0.0003	0.0007	0.000679	0.0002	0.0002	0.0009	0.0006	0.0032	0.0011
<i>Clinus sp. larvae</i>	Klipvis larvae				0.0027					0.0002	0.0019	
<i>Clinus superciliosus</i>	Super klipvis	0.0037			0.0017	0.000556	0.0002		0.0011	0.0012		0.0001
<i>Cynoglossus capensis</i>	Tongue fish											0.0002
<i>Dasyatis chrysonota</i>	Blue stingray					0.00037	7.4E-05					
<i>Diplodus capensis</i>	Blacktail			0.0004	0.0009							
<i>Engraulis japonicus</i>	Anchovy						0.0002					
<i>Galeichthys feliceps</i>	Barbell								0.0001			
<i>Gonorhynchus gonorhynchus</i>	Beaked sand eel	0.0005								0.0004		
<i>Haploblepherus pictus</i>	Dark shy shark					0.000185						
<i>Heteromycteris capensis</i>	Cape sole	0.0725	0.0014	0.0897	0.0433	0.014074	0.01067	0.0086	0.0058	0.0043	0.0054	0.0027
<i>Liza richardsonii</i>	Harder	0.3877	0.2098	1.4077	0.1805	0.120123	0.2153	0.9968	0.0951	0.2099	0.3185	0.2319
<i>Mustelus mustelus</i>	Smoothhound shark	0.0013	0.0001						0.0004			

Year/species	Common name	Apr-94	Oct-05	Apr-07	Apr-08	Apr-09	Apr-10	Apr-11	Apr-12	Apr-13	Apr-14	Apr-15
<i>Myliobatis aquila</i>	Eagle ray	0.0049		0.0003								
<i>Parablennius cornutus</i>	Blenny							0.0002				
<i>Pomatomus saltatrix</i>	Elf	0.0005	0.0001	0.0159	0.0430		0.0068	0.0217	0.0101	0.0026	0.0008	0.0005
<i>Psammogobius knysnaensis</i>	Knysna sand gobi			0.0006				0.0006				0.0001
<i>Rhabdosargus globiceps</i>	White stumpnose	0.003	0.0207	0.3358	0.2012	0.050062	0.05096	0.1341	0.0722	0.007	0.0006	0.0436
<i>Rhabdosargus holubi</i>	Cape stumpnose							0.0007	0.0046			
<i>Rhinobatos blockii</i>	Bluntnose guitar fish	0.0066	0.0022	0.0029	0.0019	0.000123	0.0009	0.0009	0.0013	0.0002		0.0001
<i>Sardinops sagax</i>	Sardine								0.0007			
<i>Sarpa salpa</i>	Streepie								0.0002			
<i>SpondylIOSoma emarginatum</i>	Steentjie	0.0004	0.0004		0.0003				0.0002			
<i>Syngnathus temminckii</i>	Pipe fish	0.0002			0.0004	0.000185	0.0002	0.0002	0.0007	0.0002	0.0004	
<i>Trachurus trachurus</i>	Horse mackerel				0.0001				0.0002		0.0003	
<i>Zeus faber</i>	John dory								0.0002			
Total		0.48	0.25	1.85	0.61	0.29	0.31	1.34	0.17	0.23	0.52	0.29
Number of species	35	14	12	10	17	12	13	14	23	13	12	13
Number of hauls	174	14	12	6	18	18	18	18	16	18	18	18
Total area sampled (m ²)	74 625	5525	5400	6250	10500	5850	7500	4950	6900	5850	7200	8700

Table 10.3. Average abundance of fish species (number.m⁻²) recorded during annual beach seine-net surveys in Langebaan Lagoon.

Year/species	Common name	1986-87	Apr-94	Oct-05	Apr-07	Apr-08	Apr-09	Apr-10	Apr-11	Apr-12	Apr-13	Apr-14	Apr-15
<i>Atherina breviceps</i>	Silverside	1.1916	1.1865	0.0524	0.0786	0.1416	0.0654	0.1206	0.2857	0.2280	3.5085	1.03841	0.6246
<i>Blennophis sp.</i>	Blenny sp.			0.0001									
<i>Caffrogobius sp.</i>	Goby	0.0888	0.0608	0.1776	0.3072	0.0626	0.0748	0.0973	0.3764	0.0003	0.2022	0.17628	0.0819
<i>Cheilidonichthys capensis</i>	Gurnard		0.002	0.0038		0.0001					0.0004	0.00030	0.0006
<i>Clinus latipennis</i>	False Bay klipvis			0.0163		0.0001	0.0002					0.00022	0.0004
<i>Clinus sp. larvae</i>	Clinid larvae												0.0001
<i>Clinus superciliosus</i>	Super klipvis	0.0698	0.0063	0.0006			0.0031					0.02802	
<i>Clinus heterodon</i>	West coast klipvis										0.0339		0.0136
<i>Diplodus capensis</i>	Blacktail	0.0120					0.0003						
<i>Heteromycteris capensis</i>	Cape sole		0.0009	0.0014	0.0027	0.0331	0.0145	0.0148	0.0032	0.0003	0.0024	0.00925	0.0357
<i>Lichia amia</i>	Leervis		0.0002										
<i>Liza richardsonii</i>	Harder	0.2452	0.7182	0.3452	3.8468	0.1548	0.3750	9.5032	1.572	0.2239	0.3548	0.3895	0.2621
<i>Parablennius cornutus</i>	Blenny						0.0002					0.0001	0.0006
<i>Pomatomus saltatrix</i>	Elf		0.0001					0.0002	0.0013		0.0024		0.0002
<i>Poroderma africana</i>	Striped catshark								0.001				
<i>Psammogobius knysnaensis</i>	Knysna sand gobi	0.0958	0.4916	0.1411	0.6768	0.2237	0.2736	0.1691	0.1176	0.1722	0.2317	0.27579	
<i>Rhabdosargus globiceps</i>	White stumpnose	0.0009	0.0055	0.0001	0.2016	0.0354	0.0263	0.2445	0.0959	0.0146	0.0035	0.0006	0.1694
<i>Rhabdosargus holubi</i>	Cape stumpnose								0.0114				0.0039
<i>Rhinobatos blockii</i>	Bluntnose guitar fish		0.0176		0.0011	0.0008	0.0065		0.0005	0.0003		0.0002	
<i>Sarpa salpa</i>	Strepie										0.0204		0.0001
<i>Solea turbynei</i>	Blackhand sole		0.0006		0.0004	0.0003		0.0001	0.0003				
<i>Spondyliosoma emarginatum</i>	Streepie	0.0001				0.0009		0.0001	0.0006			0.0001	0.0001
<i>Syngnathus temminckii</i>	Pipefish	0.0063	0.0007								0.0015	0.0003	

Year/species	Common name	1986-87	Apr-94	Oct-05	Apr-07	Apr-08	Apr-09	Apr-10	Apr-11	Apr-12	Apr-13	Apr-14	Apr-15
<i>Trachurus trachurus</i>	Horse mackerel		0.0001								0.0013		0.0001
Total		1.71	2.49	0.69	5.12	0.65	0.84	10.2	2.47	0.274	4.36	1.92	1.19
Number of species	24	9	14	11	8	11	11	9	12	7	12	13	15
Number of hauls	188	30	20	12	9	15	13	15	14	6	18	18	18
Total area sampled (m²)	93 825	18000	7125	7200	6000	9000	6150	11325	2925	3150	5400	7200	9150

Naturally high variability in recruitment strength is frequently observed for marine fish species and it is likely that natural environmental fluctuations rather than anthropogenic factors caused the poor recruitment in 2009 and 2012, as abundance was low throughout the system. The lower than average recruitment into the surf zones suggests that these were “poor” years for egg, larval and juvenile survival within the Bay as a whole. Either the environmental conditions were not suitable for the survival of eggs and larvae, or it was not good for the survival of young juveniles. The decline in abundance for most species (except for harders and silversides) at Small Bay sites does, however, appear more severe and sustained (was low since 2009 in Small Bay), than in Big Bay and Langebaan Lagoon and remains a cause for concern. The 2015 data supports the conclusion of a possible decline in juvenile fish habitat quality in Small Bay and the concerning trend in the status of the white stumpnose stock throughout the Bay-Lagoon that was highlighted in the 2014 report.

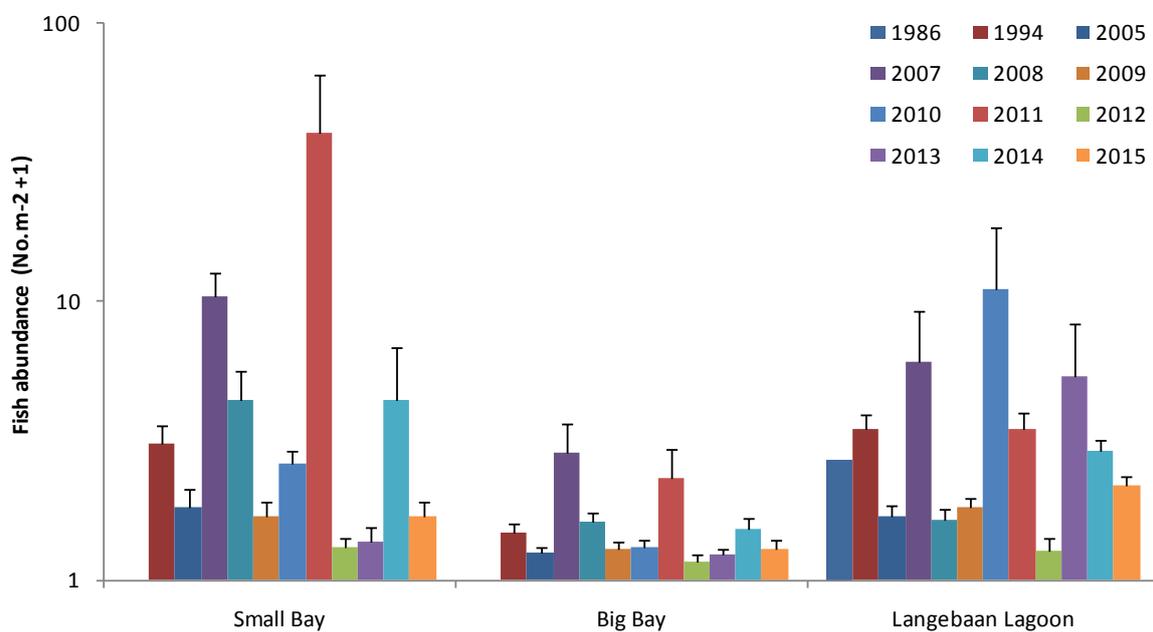


Figure 10.4. Average fish abundance (all species combined) during twelve annual seine-net surveys conducted in Saldanha Bay and Langebaan lagoon (Error bars show one Standard Error of the mean). The data are transformed (x + 1) and displayed on a logarithmic axis.

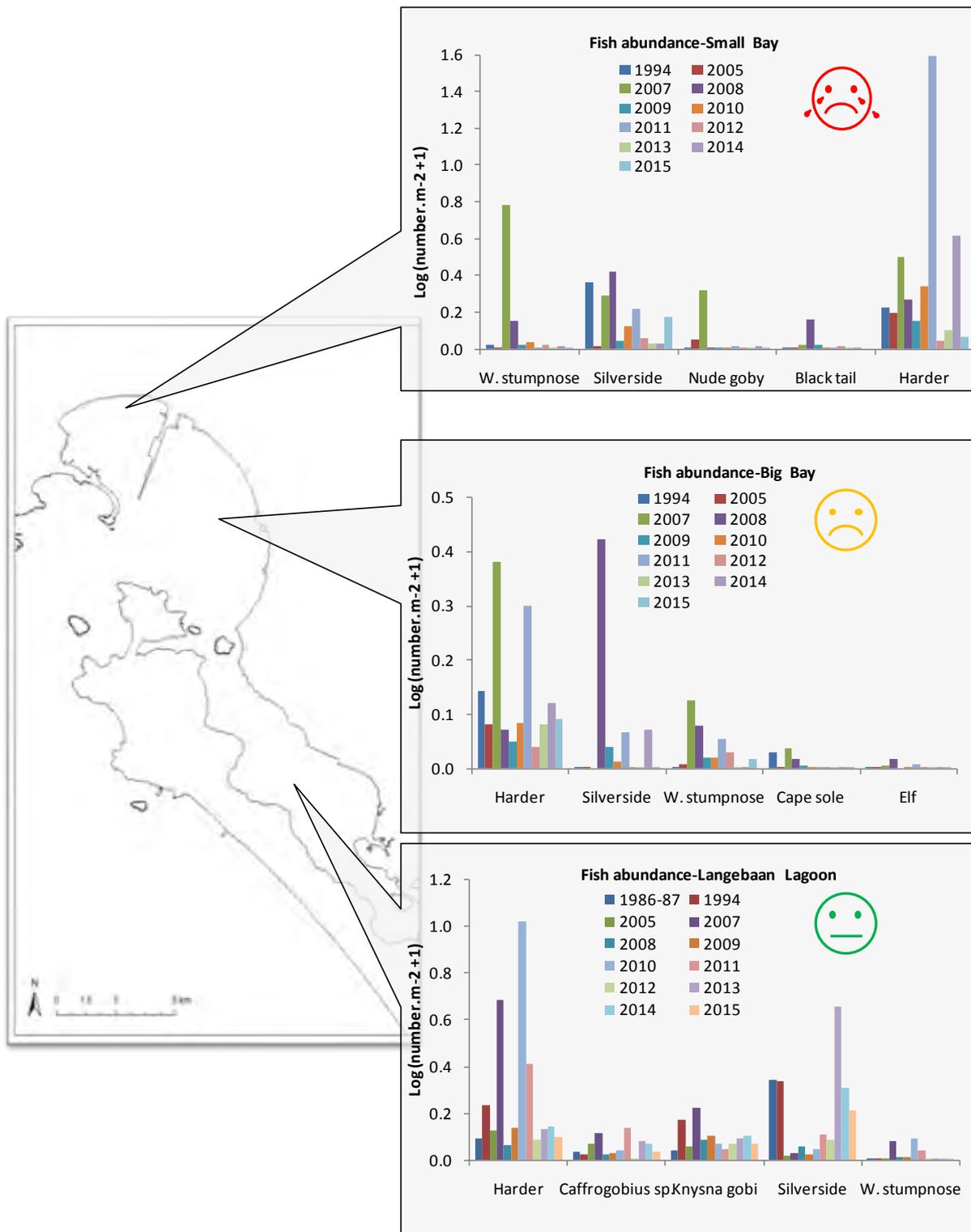


Figure 10.5. Abundance of the most common fish species recorded in annual seine-net surveys within Saldanha Bay and Langebaan Lagoon (1986/87, 1994, 2005 & 2007-2015).

10.3.3 Status of fish populations at individual sites sampled in 2013/2014

The average abundance of the four most common species in catches made during all earlier surveys and the most recent 2013, 2014 & 2015 surveys at each of the sites sampled is shown in Figure 10.6., Figure 10.7. and Figure 10.8.). These common fish species include two commercially important species (white stumpnose and harders), benthic gobies of the genus *Caffrogobius*, and the ubiquitous shoaling silverside (an important forage fish species). The average abundance of harders and silversides at Small Bay sites in the 2015 surveys were comparable to those recorded in earlier surveys (Figure 10.6.).

The average abundance of white stumpnose and gobies at all sites is, however, significantly lower than the average recorded over the previous ten surveys. At all the Big Bay sites, catches of harders during 2015 were similar to or greater than those made in the past, whilst silverside catches were lower than the historical average (Figure 10.7). White stumpnose catches at three of the Big Bay sites are significantly lower than the long-term average, lower (but not significantly so) at the Seafarm dam site, and higher (but not significantly) at the Lynch Point sites (Figure 10.7.). Catches of silversides, harders and gobies at lagoon sites during 2015 were similar to the long term average, whilst white stumpnose density was significantly lower (Figure 10.8).

Within each of the three main areas, there are also differences in the fish communities between sites, with sites on the northern shore of Small Bay historically having consistently higher densities of these four species than the Small Craft Harbour site on the western shore of Small Bay or the exposed Spreeuwalle and Lynch Point sites within Big Bay (Figure 10.6. & Figure 10.7). Since the 2012 survey this has not been the case, with exceptionally low catches made at the Hoedjiesbaai and the Caravan Park sites, whilst catches at the other two Small Bay sites were very similar to those made at the three sites along the eastern shore of Big Bay. The presence of large quantities of drifting weed at the Hoedjiesbaai and the Caravan Park site during these years did adversely affect sampling efficacy, but this is the norm at these sites and good catches were made in the past, despite the presence of weed. Although the average densities of these more common species are highly variable between years, it is clear that the average abundance of most species within Small Bay had decreased substantially (with the exception of harders), but within Big Bay and Langebaan Lagoon, they were of a similar magnitude to the historical average with the exception of white stumpnose (Figure 10.6., Figure 10.7. & Figure 10.8).

This is a concerning trend, possibly indicating a decrease in habitat quality for juvenile fish within Small Bay. The on-going trend of decreasing abundance of juvenile white stumpnose at nearly all sampled sites is extremely concerning and may indicate recruitment overfishing of this species within Saldanha Bay.

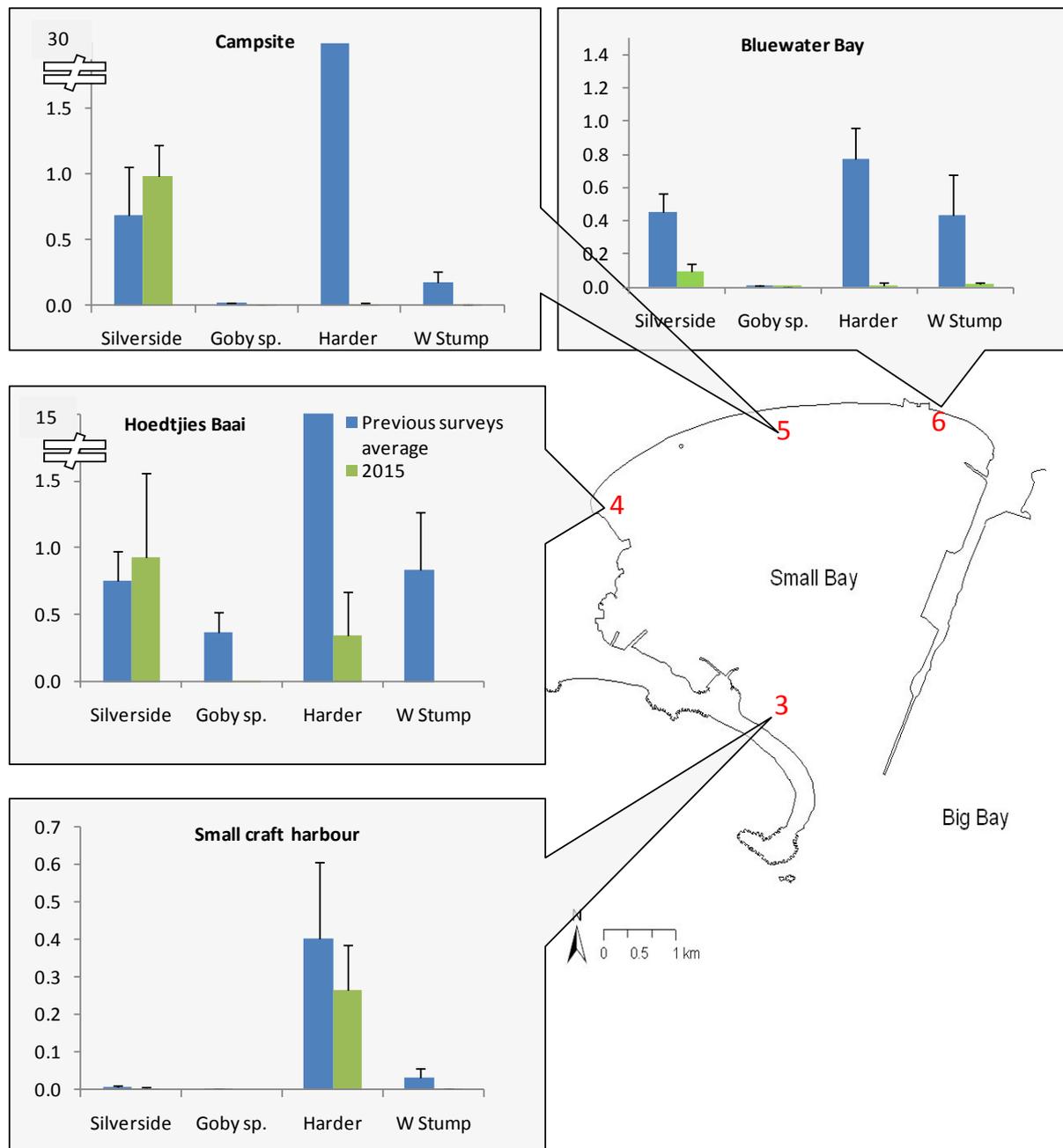


Figure 10.6. Average abundance (No.fish.m⁻²) of the four most common fish species at each of the sites sampled within Small Bay during the earlier surveys (1994, 2005, 2007-2014) and during the 2015 survey. Error bars show plus 1 Standard error.

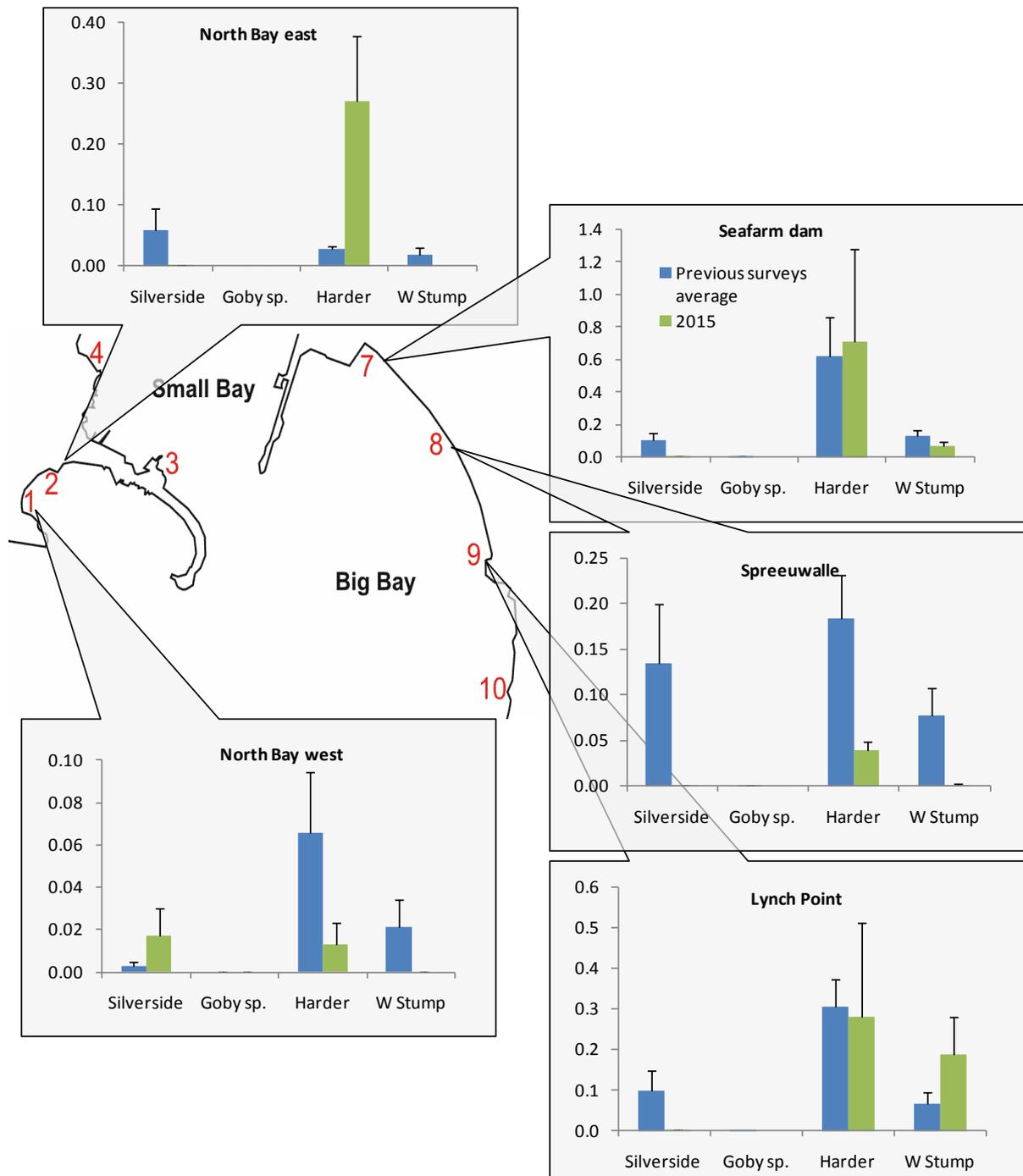


Figure 10.7. Average abundance (#fish.m⁻²) of the four most common fish species at each of the sites sampled within Big Bay during the earlier surveys (1994, 2005, 2007-2014) and during the 2015 survey. Errors bars show plus 1 Standard error.

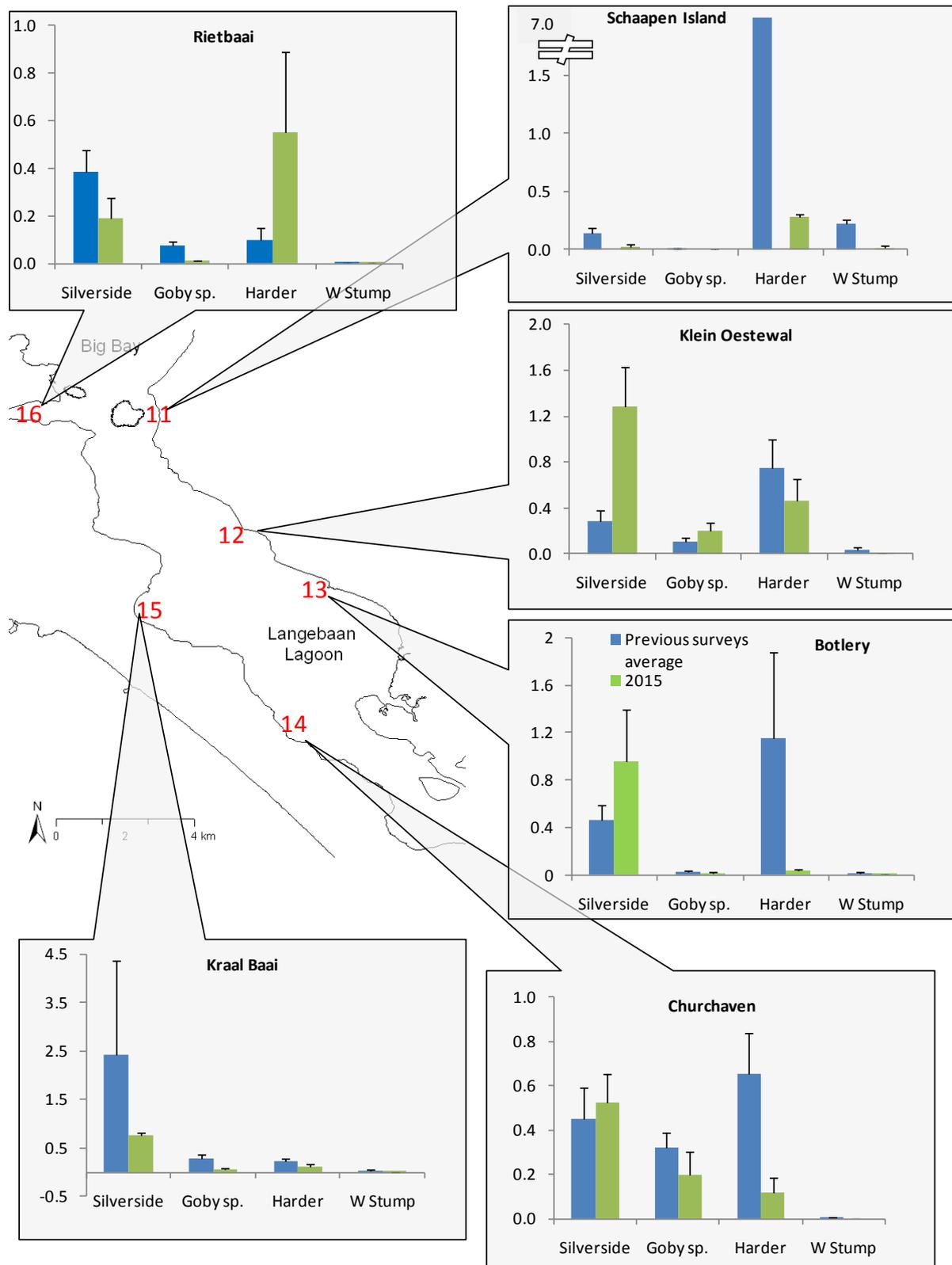


Figure 10.8. Average abundance (#fish.m⁻²) of the four most common fish species at sites sampled within Langebaan lagoon during the earlier surveys (1994, 2005, 2007-2014) and during the 2015 survey. Errors bars show plus 1 standard error.

Despite increased sampling effort from six to nine hauls at Danger Bay in 2015, only one more species, the sand snake eel *Cancellotus longior*, which is fairly regularly caught at other Big Bay sites, was added to the species count. Diversity was low compared with catches made at most sites within the Saldanha Bay and reflects the less sheltered, cooler and cleaner water found on the more exposed coast. These conditions are less suitable as a nursery area for many fish species in that they do not offer the increased turbidity, temperature and food availability found within the Bay. Once again most of the species caught were adults (sand sharks, klipvis and snake eel), whilst the average size harder caught at Danger Bay was 13 cm total length, nearly double the average size harder (6.7 cm TL) sampled within Saldanha Bay-Langebaan in 2015. Catches of klipvis were lower, whilst harders were more abundant in 2015 compared to the 2014 sampling at Danger Bay (Figure 10.9).

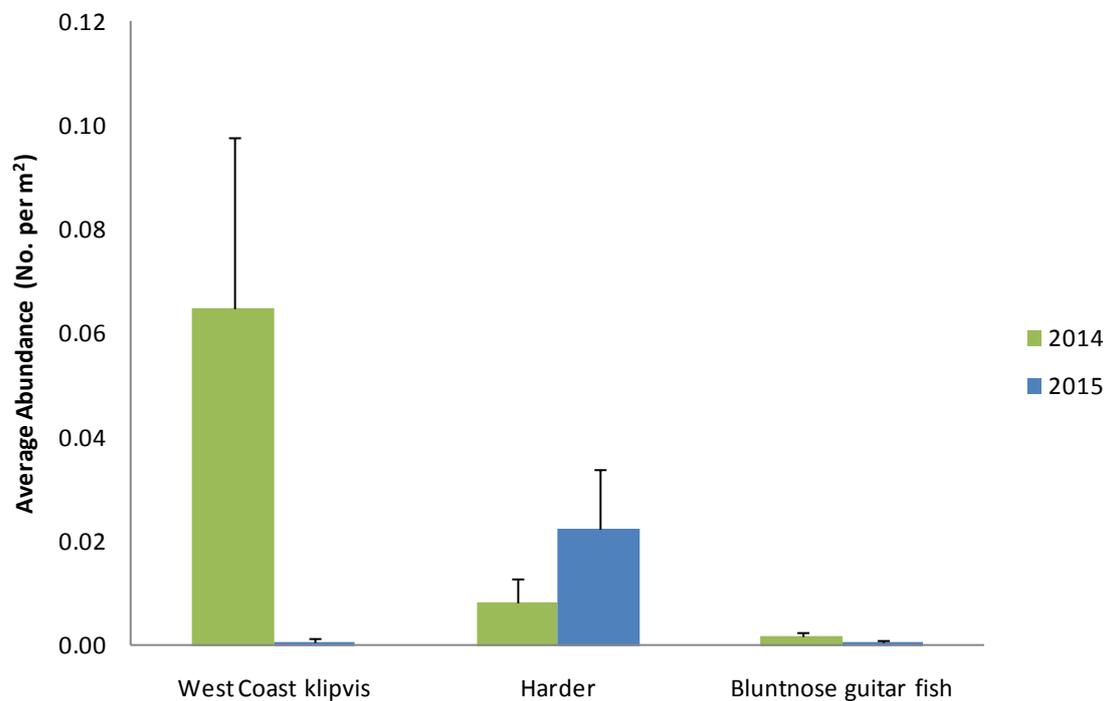


Figure 10.9. Average abundance of three species sampled at Danger Bay sites during 2014 and 2015 sampling.

10.3.4 Multivariate analysis of spatial and temporal trends in fish communities

The use of multivariate statistical techniques allows for the analysis of patterns in the complete fish community, taking account of both the species composition of the assemblages as a whole, and the abundance of individual species. In the 2009 State of the Bay report, multivariate analyses showed that on average, the fish communities from each of the three areas (Small Bay, Big Bay and Langebaan Lagoon) were significantly different from each other. This was related to environmental differences between the three areas. It was concluded that although the whole Saldanha Bay-Langebaan Lagoon system is connected, the near-shore environment in one area (i.e. Small Bay, Big Bay or the Lagoon) on average, appears more suitable for the juveniles of particular species than the other areas.

The statistically significant differences in the fish communities found in the three main areas (Small Bay, Big Bay and Langebaan Lagoon), as well as the similarities between sites within each of these areas, supported the analysis of temporal trends (which provide information on changes in the health of the marine environment) on an area specific basis. The 2010 State of the Bay report also reported on the separation of the different sites within each area, based on dissimilarities in the fish community between sites. This separation is similar to the overall trend in fish communities throughout the Bay and Lagoon, a pattern relating to the degree of exposure of each site was evident, from the most exposed sites through to the most sheltered samples. In subsequent reports, analysis focused on detecting any differences between years, taking account of the established inter-site variability by using a two factor (sites and years as factors) PERMANOVA design. Temporal changes in fish community from year to year are indicative of both natural variability in spawning and survival as well as possible changes in the environmental health of the habitat.

10.3.4.1 Small Bay

The MDS plot for Small Bay shows that samples from most years grouped centrally (Figure 10.10.). However, there does appear to be a pattern with a disproportionate number of samples collected in recent years (2011, 2013 and 2014) located to the lower left hand side of the MDS plot indicating that they are dissimilar to samples collected in the earlier years. This suggests that there has been some change in the fish community over time, although this is not consistent with 2012 and 2015 samples located mostly within the centre cluster. Outliers around the central cluster in all years are mostly Small Boat harbour sites, reflecting the inter-site rather than temporal variation (this site typically has cooler, cleaner water than others and is a more reflective beach than the other Small Bay sites). In 2013 and 2014 however, Hoedtjies Bay and Campsite samples were also situated to the left or below the centre cluster indicating that these were somewhat different from samples collected at these sites in earlier surveys.

A two way PERMANOVA indicated significant differences in the fish community between sample years (Pseudo F = 2.6, P < 0.001) and between sites (Pseudo F = 12.9, P < 0.001) and a significant interaction effect (Pseudo F = 2.9, P < 0.001). Pair wise tests indicate that there were significant differences between all years sampled and at least one of the other annual sampling events (Table 10.4.). This is indicative of the high natural variability in the surf zone fish community inhabiting Small Bay. We suspect, given the orientation of Small Bay facing into the prevailing southerly wind, that short term meteorological changes (such as a wind change to a northerly or westerly) that are common during April and strongly influence the nature of the surf zone, are the primary drivers of this variability. The only way to account for this natural variability is to sample more intensively, by replicating the survey within years, sampling the same sites on different days within each survey and repeating it over several weeks. This is unfortunately not logistically possible, but trends in the ecological health of the Bay (for fish at least) can still be inferred from any long term consistent trends over time. Pair wise tests identified the 1994 and 2008 samples as being significantly different from the 2015 (Table 10.4.).

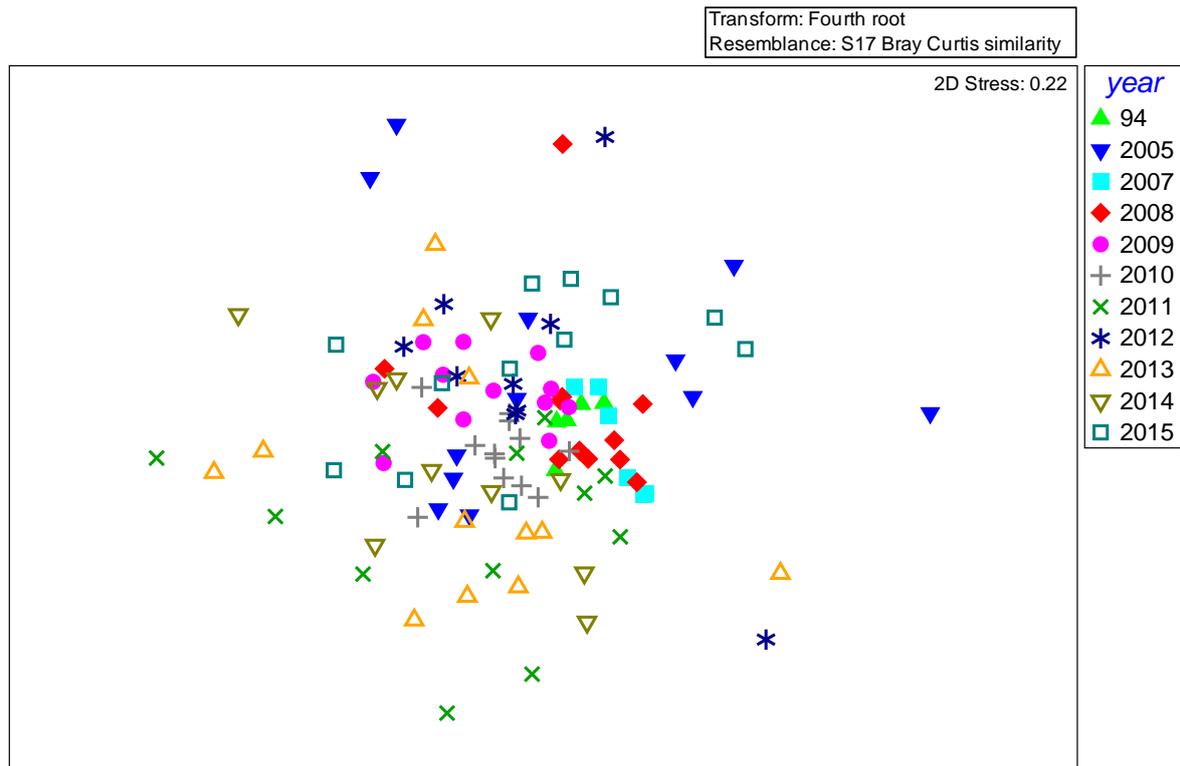


Figure 10.10. Multidimensional scaling plots showing similarities between the fish communities sampled at four sites within Small Bay during 1994, 2005, 2007-2015 sampling events. The block arrow indicates a possible change in fish community over time.

SIMPER analyses identified decreased average abundance of harders, silversides, white stumpnose, klipvis, gobies, gurnards, and sand sharks and the absence of pipefish, stingrays and blacktail in the 2015 samples as the dominant causes of dissimilarity between the 2015 samples and the 1994 samples. A decrease in abundance of these species was also major contributors to the significant dissimilarity between 2015 and 2008 samples. Several of these species have disappeared from catches or have been found at greatly reduced abundance in Small Bay during the 2015 survey. This was identified in the SIMPER analysis as a major cause of dissimilarity between this year's samples and earlier samples. This is concerning, particular in the case of important fishery species and a univariate analysis for selected fishery species is presented in Section 10.4.

Table 10.4. Results of the multivariate PERMANOVA pair wise tests between Small Bay fish samples collected in different years. NS: not significant, *: P < 0.05, **: P < 0.01.

	1994	2005	2007	2008	2009	2010	2011	2012	2013	2014
1994										
2005	**									
2007	**	NS								
2008	NS	*	NS							
2009	**	NS	NS	*						
2010	NS	*	NS	*	*					
2011	*	NS	*	NS	*	NS				
2012	**	NS	NS	NS	NS	NS	NS			
2013	*	NS	*	*	NS	NS	NS	NS		
2014	**	NS								
2015	*	NS	NS	*	NS	NS	NS	NS	NS	NS

10.3.4.2 Big Bay

Within Big Bay, little grouping of sampling years in the MDS plot is evident with the 2007, 2008, 2012 and 2013 outliers representing more exposed sites including North Bay, Plankiesbaai and one Lynch Point 2012 sample (Figure 10.11.). Generally the 2015 samples are distributed well within the range of samples collected in earlier years, suggesting no substantial changes in the Big Bay fish communities overall. The mixed model PERMANOVA test did, however, indicate significant differences between sites (Pseudo F = 8.2, P < 0.001), between sampling events (Pseudo F = 2.1, P < 0.001) and a significant interaction effect (Pseudo F = 2.7, P < 0.001). Pair wise testing, however, showed that the 2015 sample was not significantly different from those collected during any of the earlier surveys. SIMPER did identify lower abundance of harders, Cape sole and white stumpnose in the 2015 sample as contributing towards the dissimilarity between 2015 samples and 2007 and 2008 samples, but not for other years (e.g. 1994,2005) when these species were less abundant in catches.

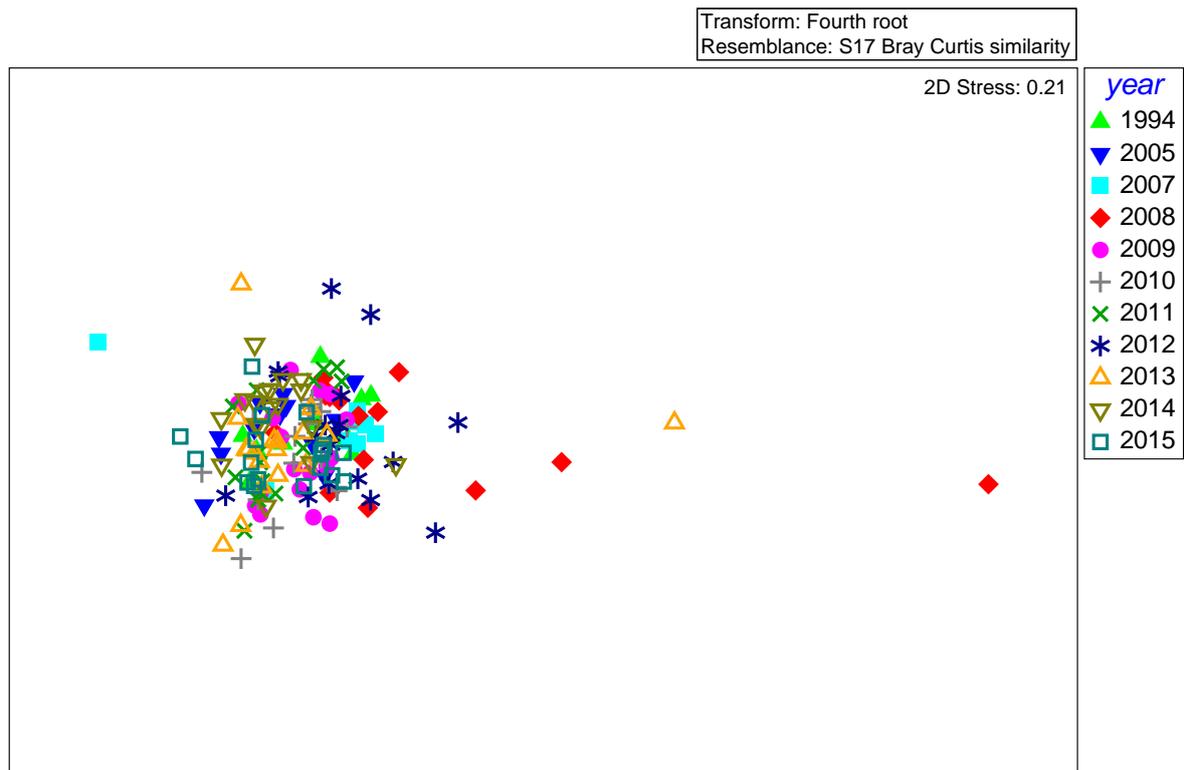


Figure 10.11. Multidimensional scaling plot showing similarities between the fish communities sampled at seven Big Bay sites during 1994, 2005, 2007-2015 annual sampling events.

10.3.4.3 Langebaan Lagoon

An MDS plot of Langebaan Lagoon fish samples shows some evidence of separation between sampling years; with the 2013 outliers on the right hand side of the plot representing Kraalbaai, Klein Oestewal and Rietbaai sites where relatively large catches of silversides or a zero catch of harders were made. The spread of sites on the left of the plot represent exclusively Schaapen Island hauls where depending on the tidal phase at the time of sampling, strong currents influence catches (Figure 10.12.). The 2015 samples grouped together with samples from most of the earlier surveys, indicating little change in the Langebaan lagoon fish community overall. A PERMANOVA test showed significant differences between sites (Pseudo $F = 20.2$, $P < 0.001$), between sampling events (Pseudo $F = 3.7$, $P < 0.001$) and a significant interaction effect (Pseudo $F = 2.83$, $P < 0.001$). Pair wise testing showed that fish catches in all years were different to samples collected in at least one other year (2007) and as many as six or seven other years (2008 & 2011) (Table 10.5.). Lagoon fish samples collected during the most recent 2015 surveys were significantly different from those collected during 2011 and 2013 surveys. SIMPER identified greater catches of Knysna sand gobies and Cape soles in the 2015 surveys as the principal contributing species to the dissimilarity between the most recent survey and the earlier 2011 and 2013 surveys. Lower catches of white stumpnose in the 2015 sample compared to the 2011 sample was also a contributing factor to between group dissimilarity, but this was not the case in the comparison with the 2013 sample, when white stumpnose abundance was even lower than in 2015.

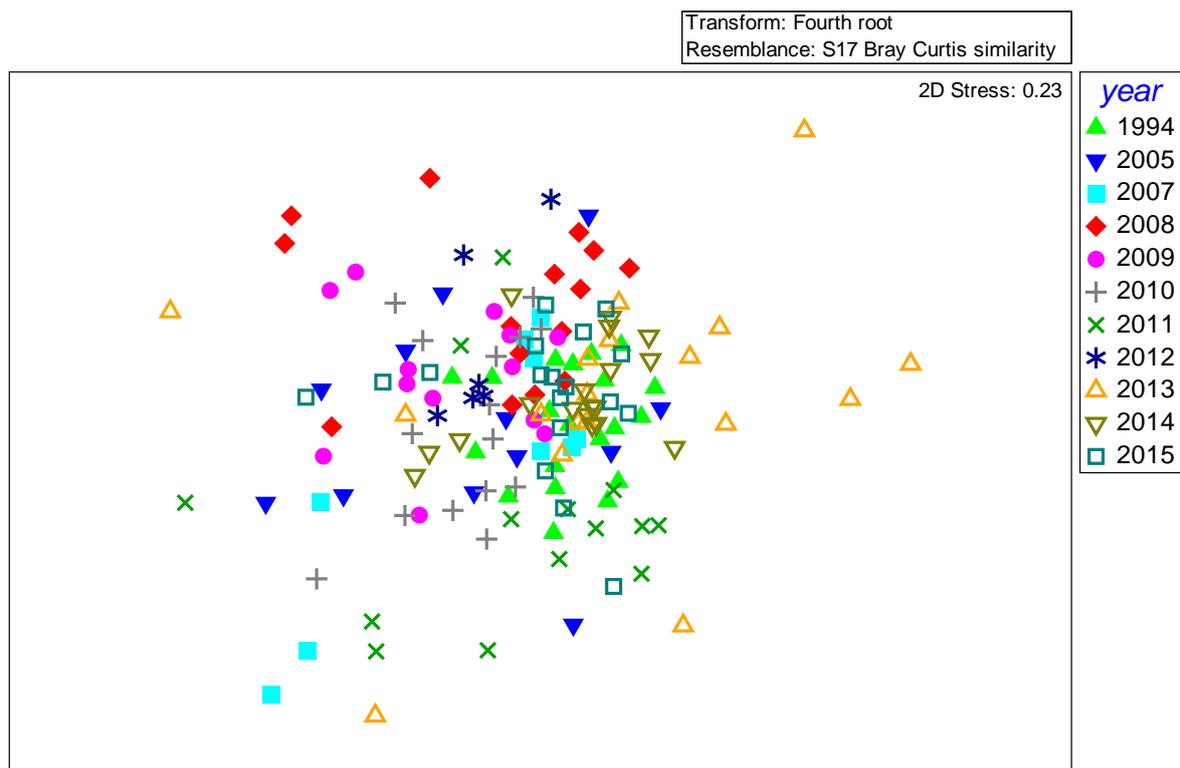


Figure 10.12. Multidimensional scaling plots showing similarities between the fish communities sampled at six Lagoon sites during 1994, 2005, 2007-2015 sampling events.

Table 10.5. Results of the multivariate PERMANOVA pair wise tests between Langebaan fish samples collected in different years. NS: not significant, *: P < 0.05, **: P < 0.01

	1994	2005	2007	2008	2009	2010	2011	2012	2013	2014
1994										
2005	*									
2007	NS	NS								
2008	NS	NS	*							
2009	NS	NS	NS	*						
2010	*	NS	NS	*	NS					
2011	*	*	NS	**	*	NS				
2012	no test	no test	no test	no test	NS	NS	NS			
2013	NS	NS	NS	**	*	NS	*	NS		
2014	NS	NS	NS	*	*	NS	*	NS	NS	
2015	NS	NS	NS	NS	NS	NS	*	NS	*	NS

10.4 Univariate analysis of key fishery species trends

The spatially separate analysis of fish survey data by site or embayment (Big Bay, Small Bay and Langebaan Lagoon) is a valid approach for the purposes of ecosystem health monitoring whereby sites or areas of concern need to be identified. The analyses presented above have identified a concerning decrease in abundance of some of the dominant species in Small Bay in recent surveys (2009 onwards) and a notable decrease in white stumpnose abundance throughout the system. The inter-annual variation in recruitment of white stumpnose could be due to natural variability in spawning success and survival (poor and good year classes are normal), but given the sustained declines throughout the system, and the findings of Arendse (2011), it appears that recruitment overfishing could be the cause. Recruitment overfishing can be defined as overfishing of the adult population so that the number and size of mature fish (spawning biomass) is reduced to the point that it did not have the reproductive capacity to replenish itself. To further investigate temporal variation in recruitment of species important in the Bay's fisheries (harders, blacktail, elf and white stumpnose) univariate statistical analysis (ANOVA) was used to test for significant differences between survey years. To deal with the observed spatial variability in survey catches and to account for the fact that Saldanha Bay- Langebaan Lagoon is a single system and different sites may be more utilized by juvenile fish in different years depending on prevailing weather and oceanography, abundance data for all sites was combined for this analysis.

These analyses revealed statistically significant inter-annual variation in the abundance of blacktail, harders and white stumpnose, but not in the average density of elf and steentjies (Figure 10.13, Figure 10.14 & Figure 10.15). The density of blacktail juveniles in sampled habitats was significantly higher in 2008 than in all other years except 2007 (Figure 10.13). Inter annual variation in the abundance of harders was greatest, with estimated abundance in 2007, 2010 and 2011 significantly greater than most other sampling events (Figure 10.13). Estimated white stumpnose abundance in 2007 was significantly greater than all other years, whilst the estimated abundance during the three most recent surveys (2013-2015) was less than during nearly all other years (2015 abundance was similar to that recorded during 1994 and 2005) and significantly less than that recorded during the 2007 and 2008 surveys. Recorded steentjie and elf abundance also showed inter-annual variation with relatively high average abundance of steentjie juveniles recorded in 2005 and 2011 and relatively high average abundance of elf juveniles in 2007, 2008, 2011 and 2012. The intra-annual (within year) variability in abundance of these two species, a result of a zero catch at many sites, however, means that these differences are not statistically significant.

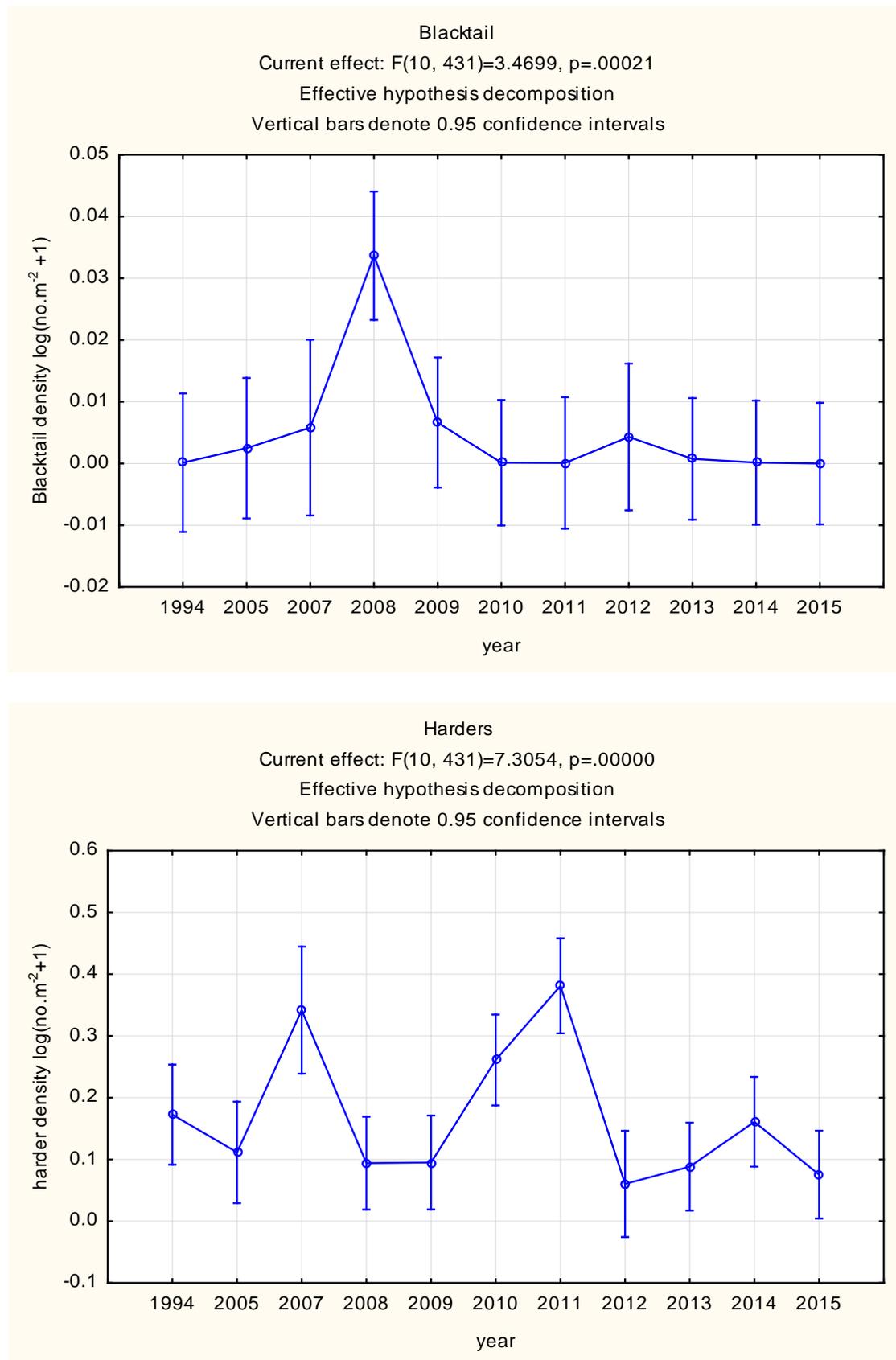


Figure 10.13. ANOVA results comparing the average annual density of blacktail and harders at all sites sampled in all surveys.

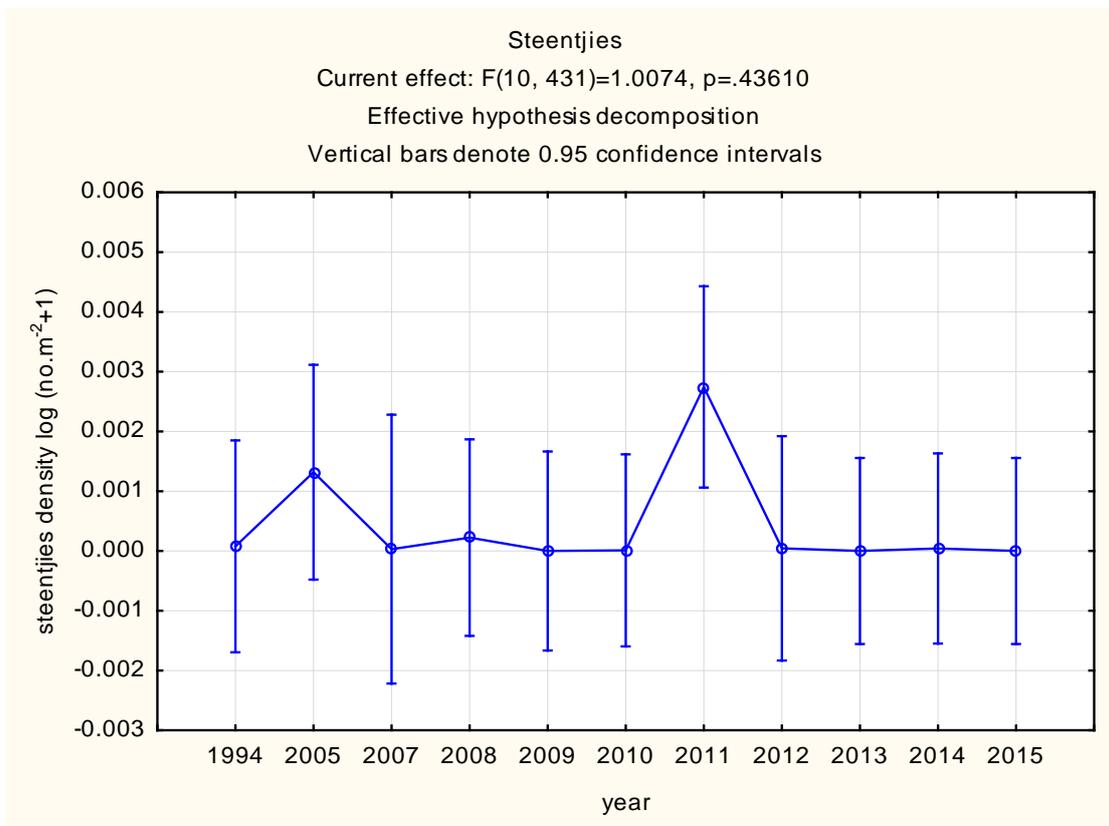
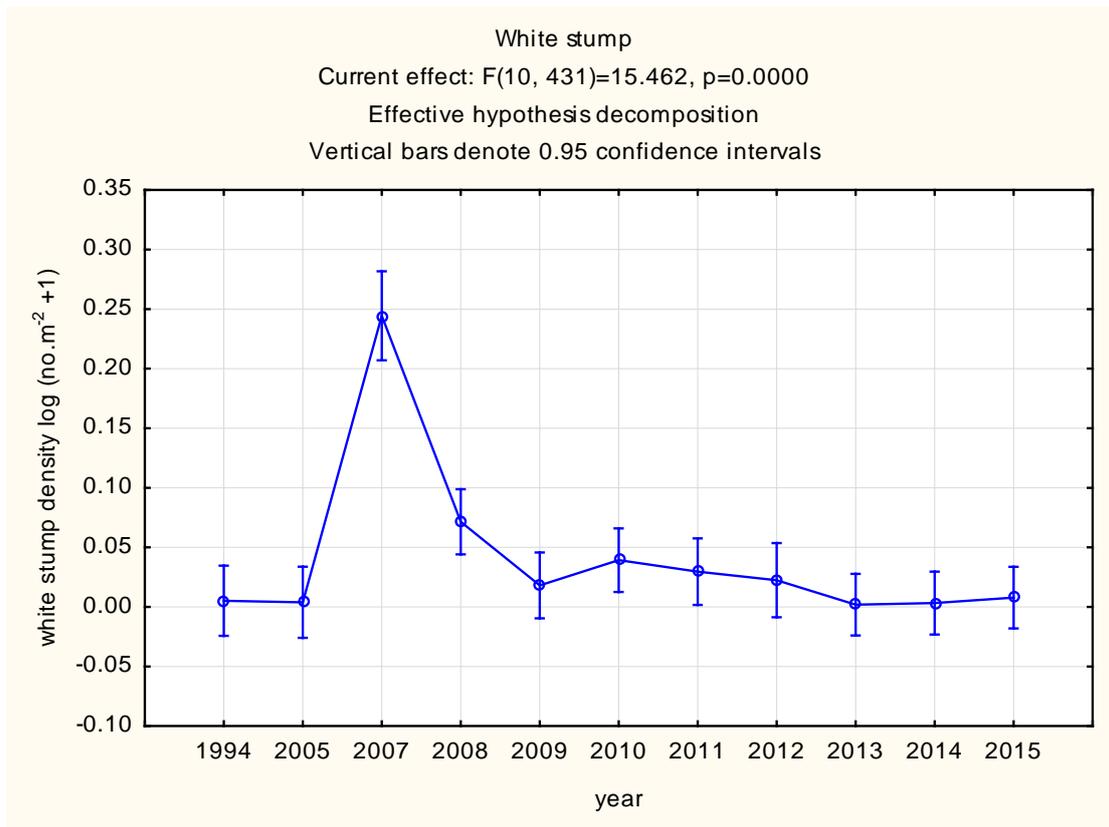


Figure 10.14. ANOVA results comparing the average annual density of white stumpnose and steentjies at all sites sampled in all surveys.

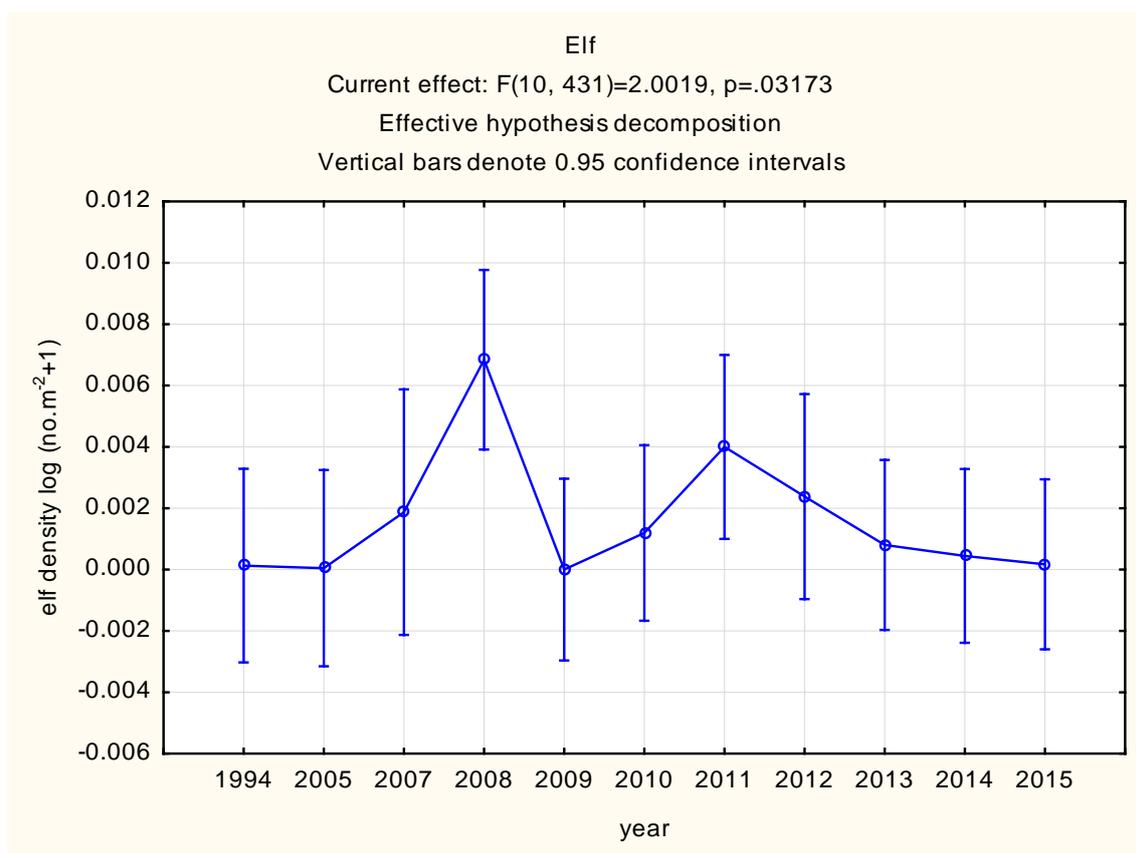


Figure 10.15. ANOVA results comparing the average annual density of elf at all sites sampled in all surveys.

10.5 Stock status of white stumpnose – commercial catch trends

The 2013-2015 seine net surveys have provided evidence of comparatively poor white stumpnose recruitment to the near shore juvenile nursery areas throughout the Bay and Lagoon. This was highlighted in the 2014 State of the Bay Report as concerning in that it might indicate overexploitation of the stock (recruitment overfishing). It was suggested that the implementation of the harvest control measures recommended by Arendse (2011); namely a reduction in bag limit from 10 to 5 fish per person per day and an increase in size limit from 25 cm TL to 30 cm TL be considered. This recommendation was opposed by local recreational anglers and the validity of the juvenile seine net survey data as an early warning system was questioned. Data on the status of the adult white stumpnose stock were therefore sought to elucidate if the decline in recruitment was simply a result of natural, interannual variation in spawning success and survival of eggs and larvae, or if there was evidence of declines in adult biomass. Data on the recreational white stumpnose fishery from the access point and roving creel surveys undertaken by SANParks were requested, but we were refused access to these data on the grounds that they constitute data to be used in a post graduate thesis (Mbulelo Dopolo SANParks personal communication). Data on commercial white stumpnose catch and effort, as reported by traditional line fish rights holders were, however, obtained from the Department of Agriculture, Forestry and Fisheries for the period January 2003 until December 2013 (i.e. post medium term rights allocations).

Data are plotted to show a summer fishing season, rather than a calendar year, for example, 2003_4 season is data from 1 July 2003 to 30 June 2004. These data show that commercial line fish effort on the Saldanha white stumpnose stock has increased substantially over this 10 year period (Figure 10.16). The increase in fishing effort has not been smooth, and probably reflects the availability of other species, particularly snoek to the commercial line fish fleet. Nonetheless, the most recent available data show reported commercial effort levels of around 14 000 fisher hours per year for the 2011-2013 period, substantially up from the ~4 000 fisher hours reported for the 2003-2004 seasons (Figure 10.16).

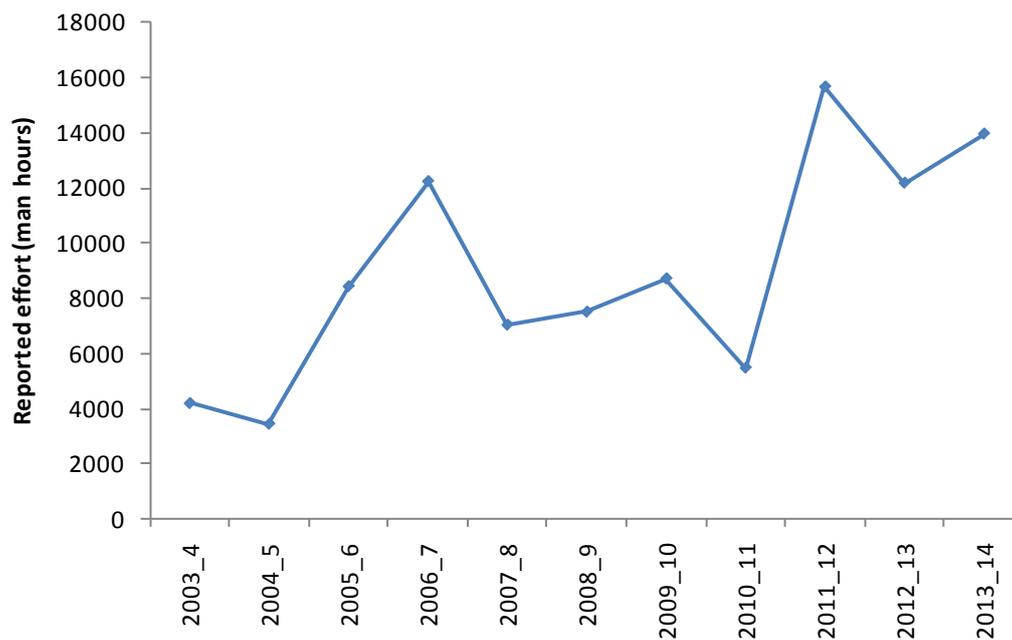


Figure 10.16. Reported commercial line fish effort in the Saldanha- Langebaan area over the summer fishing seasons (from July till June) over the period 2003-2013. The total man hours fished when catches of white stumpnose were reported are shown. Note that the 2013_14 season only represents reported data up until the 31 December 2013 (i.e. half a season)

Reported catch has largely followed the trend in fishing effort, with peaks in the 2006_7 season and the more recently over the 2011-2014 period, when annual white stumpnose catches of 35-40 tons were reported. The 2013_14 reported catch of ~35 tons shown here is also only that caught between the 1 July 2013 and 31 December 2013 i.e. half a fishing season. It is noteworthy that Næsje *et al.* (2008) estimated the annual commercial white stumpnose catch at 41 tons for the 2006-7 period based on access point survey data. This suggests that the commercial catch return data are within 10% of the actual catches made by the rights holders. Næsje *et al.* (2008) calculated that the annual recreational white stumpnose catch (shore and boat based) at this time was around 51 tons (i.e. 55% of the total catch), and it is reasonable to assume that white stumpnose catch and effort has also increased in the recreational sector over the last 8 years. Total annual white stumpnose catches from Saldanha – Langebaan have therefore probably exceeded 100 tons per year for the 2011_12 to the 2013_13 fishing seasons.

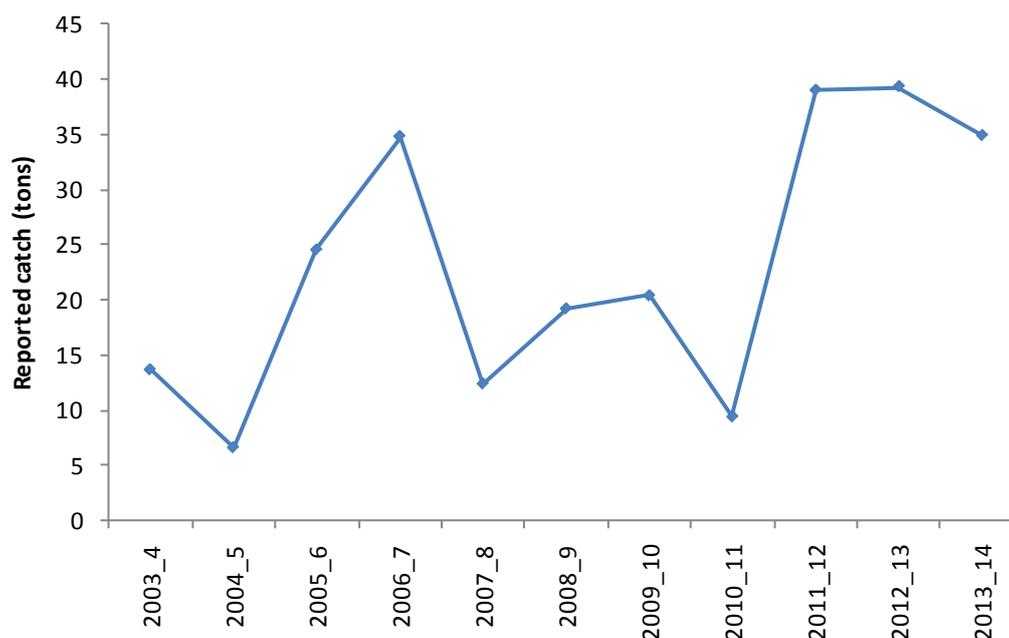


Figure 10.17. Total reported white stumpnose catch by commercial line fish rights holders from the Saldanha-Langebaan area 2003-2013. Note that the 2013_14 season only represents reported data up until the 31 December 2013 (i.e. half a season)

The catch-per-unit-effort (CPUE), reported here as kg per fisher per hour, can be used as an index of fish abundance. The rationale is that the more abundant the fish are, the higher the catch rate, i.e. CPUE and abundance are positively related. Assumptions inherent in the use of CPUE as an index of abundance are that availability of the fish to the gear (e.g. they do exhibit changes in movement of other behaviours that make them more or less vulnerable to capture) and fishing efficiency remain constant over time (usually fishers get better at catching fish over time due to technological advancements in gear and expertise = effort creep). The white stumpnose stock within Saldanha-Langebaan is largely resident and for demographic purposes isolated from the rest of the South African stock. It is unlikely that the Saldanha-Langebaan white stumpnose have altered behaviour patterns nor have there been any major technological advances over the ten year period under consideration (braided line, echo sounders, prawn pumps, GPS were all widely used in 2003). Commercial white stumpnose CPUE is therefore considered a reasonable approximation of adult abundance in the Bay. The commercial white stumpnose fishery CPUE showed a significant decrease from an average of 3.7 kg.fisher.hour⁻¹ during the 2003-2006 seasons to an average 2.2 kg.kg.fisher.hour⁻¹ thereafter (Figure 10.18). This suggests that the increased catch and effort has reduced the abundance of white stumpnose over this period. Following this 40% decline in CPUE (i.e. since 2006-7), catch rates have, however, remained relatively constant, or even increased slightly in the 2012_13 season (significantly different values are indicated by non-overlapping confidence intervals in Figure 10.18).

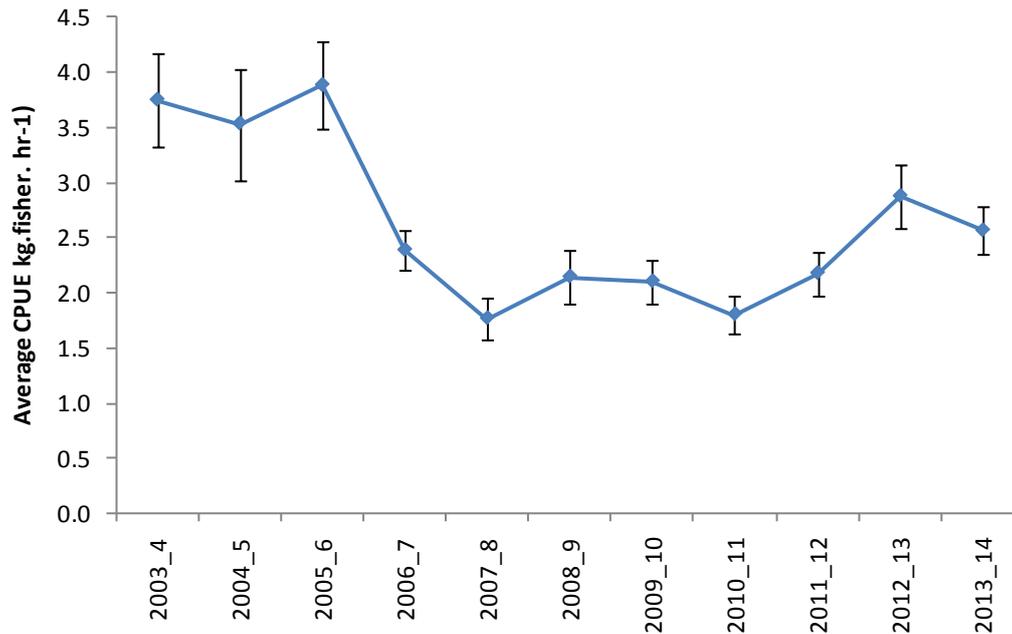


Figure 10.18. Catch-Per-Unit-Effort of white stumpnose by commercial line fish boats operating in the Saldanha-Langebaan area over the period 2003-2014. Error bars show approximate 95% Confidence intervals (1.96 standard errors of the mean). Note that the 2013_14 season only represents reported data up until the 31 December 2013 (i.e. half a season).

CPUE is however, a retrospective measure of fish abundance and a dramatic decline in abundance can only be detected after it has occurred (and catch rates have dropped). We do not yet have catch data for the 2014_15 season, but we do have research seine net survey data from the nursery habitats throughout the Bay and Lagoon that provide abundance estimates of juvenile white stumpnose (Figure 10.19). These seine net surveys can serve as an early warning system, and in the light of three consecutive years of very low juvenile density estimates, and evidence of increased fishing effort and catches of adult white stumpnose, we are again advising reductions in adult white stumpnose catches through the implementation of more stringent harvest control measures.

The fishery catches numerous year classes of 2+ year old fish and a collapse in recruitment will take some time to influence catches. Indeed, a clear stock-recruitment relationship is not even expected in this situation, given that good recruitment can result from a relatively low spawner biomass under conditions that are favourable for spawning, egg and larval survival, and vice versa under unfavourable conditions. Nonetheless, the juvenile abundance estimates from the seine net survey did decrease substantially following the initial drop in CPUE with a year's delay. Replenishment of adult biomass is now a serious concern and the three consecutive years of very low juvenile abundance estimates suggest this will be a problem in the near future. The precautionary approach would be to take steps now to reduce fishing mortality, rather than wait for a further drop in adult biomass and more severe recruitment failure.

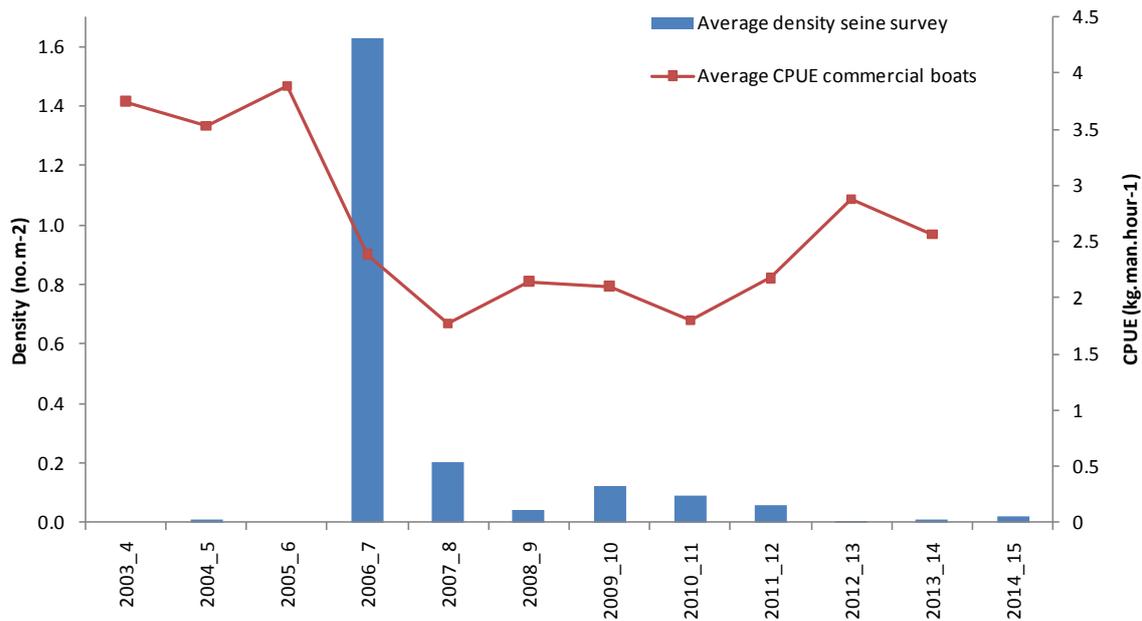


Figure 10.19. Time series of juvenile white stumpnose abundance from the annual seine net surveys and commercial line fish catch rate. Note that only 33 hauls were conducted in 2005 (cf. 45-50 in latter surveys) and no seine net surveys were conducted in 2004 and 2006.

10.6 Conclusion

With the exception of white stumpnose, the current status of juvenile fish communities within Big Bay and Langebaan lagoon appears satisfactory. The persistent declines in the abundance of common species (except shoaling species such as harders and silversides) within Small Bay are concerning, however. Long term monitoring by means of experimental seine-netting has revealed statistically significant differences in fish community structure between different sampling sites within years and between sampling years. A consistent long-term negative trend, since fish sampling began in 1986-87 has not been detected for the principal species found in Big Bay and Langebaan Lagoon. In fact, fish abundance at sites within or in close proximity to the Langebaan MPA appears to be stable within the observed inter-annual variability. This reflects natural and human induced impacts on the adult population size, recruitment success and use of the near shore habitat by fish species; but may also be a result of the benefits of protection from exploitation and reduced disturbance at some sites due to the presence of the Langebaan MPA. Certainly, the studies by Kerwath *et al.* (2009), Hedger *et al.* (2010) and da Silva *et al.* (2013) demonstrated the benefits of the MPA for white stumpnose, elf and smooth hound sharks; and the protection of harders from net fishing in the MPA undoubtedly benefits this stock in the larger Bay area.

The significant declines in juvenile white stumpnose abundance at all sites throughout the system in recent years, however, suggest that the protection afforded by the Langebaan MPA may not be enough to sustain the fishery at the current high effort levels. Commercial fishing effort and catch data for white stumpnose has increased dramatically over the period 2003-2013, particularly over the more recent period. It is likely that recreational fishing effort for white stumpnose has also increased. The low juvenile white stumpnose abundance in recent years may simply be a result of

natural variability in recruitment strength (possibly at decadal time scales greater than the monitoring record). However, given the findings of Arendse (2011) who found the adult stock to be overexploited using data collected during 2006-08 already, this could indicate that recruitment overfishing is occurring and a precautionary approach is warranted. The annual seine net surveys can act as an early warning system that detects poor recruitment and allows for timeous adjustments in fishing regulations to reduce fishing mortality on weak cohorts and preserve sufficient spawner biomass for the future. The consistent declining trend in juvenile white stumpnose abundance in the nursery surf-zone habitats since 2007, with the three lowest abundance estimates emanating from the last three annual surveys, strongly supports the implementation of the harvest control measures recommended by Arendse (2011); namely a reduction in bag limit from 10 to 5 fish per person per day and an increase in size limit from 25 cm TL to 30 cm TL. This is the second time we are making this recommendation in the State of the Bay Report, despite it previously receiving vocal opposition from local anglers after the 2013/14 report was published. Anchor Environmental have no vested interests in the white stumpnose resource or the fishery and are making this recommendation based on our scientific interpretation of the catch and survey data.

The 2013-2015 sampling events recorded average recruitment of common species such as harders, gobies and silversides within Big Bay and Langebaan Lagoon sites that are comparable with data from earlier surveys. In Small Bay, however, with the exception of harders and silversides, estimated abundance of key species was well below average, with very low white stumpnose density and a complete absence of black tail for the first time in the 11 year sampling record. This follows the trend observed since 2010/11 and it is somewhat concerning that the estimated abundance of some key species is decreasing in the areas of maximum anthropogenic disturbance within Small Bay, whilst they are stable or increasing in other less disturbed areas of Big Bay and Langebaan Lagoon.

In the data set collected to date, the average density of commercially important fish, such as white stumpnose and harders, was much higher at Small Bay sites compared to Big Bay and Lagoon sites. Since 2011, however, estimated densities of these species were similar and low in both Big Bay and Small Bay. Over the period 2005-2010, the average white stumpnose density calculated from all seine net surveys was 1.2 fish.m⁻² in Small Bay, over the period 2011-2015 this dropped to 0.03 fish.m⁻² compared with the long term average of 0.09 fish.m⁻² in Big Bay and 0.05 fish.m⁻² in Langebaan lagoon. The juveniles of other species were historically also more abundant in Small Bay. This gives an indication of the importance of Small Bay as a nursery habitat for the fish species that support the large and growing fisheries throughout the Bay. Small Bay is often viewed as the more developed or industrialized portion of the Bay and is considered by many as a 'lost cause'. These data provide a strong argument to stamp out such negative thinking and to continue lobbying strongly for enhanced protection of this portion of the Bay. The concerning trend in decreasing white stumpnose recruitment throughout the Bay makes it even more critical that the quality of what is demonstrably the most important white stumpnose nursery habitat is improved.

The monetary value of the recreational fishery in Saldanha-Langebaan should not be regarded as regionally insignificant as a lot of the expenditure associated with recreational angling is taking place within Langebaan and Saldanha itself. Furthermore the popular white stumpnose fishery is undoubtedly a major draw card to the area and has probably contributed significantly to the residential property market growth the region has experienced. Despite the decreased density

estimates for the last three years surveys, the value of Small Bay as a fish nursery and the economic value of the resultant fisheries should not be disregarded when considering the environmental impacts of the proposed future industrial developments within Small Bay.

The monitoring record from the annual seine net surveys will prove increasingly valuable in assessing and mitigating the impacts of future developments on the regions ichthyofauna. Extending the seine net monitoring record would also facilitate analysis of the relationship between recruitment to the near shore nursery habitat and future catches in the commercial and recreational fisheries in the Bay. A preliminary investigation of this relationship was undertaken for white stumpnose and harders in the 2011 and 2012 reports, respectively and investigated again in this report for the commercial line white stumpnose fishery. Should this relationship prove robust and quantifiable as more years of data become available, this will allow for adaptive management of the fisheries in the future as fishing effort continues to increase and at some point fishing mortality will need to be contained, if the fisheries are to remain sustainable. We think that point has arrived for the Saldanha-Langebaan white stumpnose fishery and recommend that resource users lobby the authorities to implement the recommended harvest control measures as a precautionary approach. Regional species specific fishery management has been implemented elsewhere in South Africa (e.g. Breede River night fishing ban to protect dusky kob). White stumpnose in Saldanha appear to be an isolated stock and there is good on site management presence in the form of SANParks and DAFF, and we think this approach would work well in Saldanha-Langebaan. We are not advocating permanently implementing more stringent harvest control measures, rather a temporary intervention and an adaptive management approach guided by fishery dependent (catch data, creel & access point surveys) and independent (seine net survey) data. Should future surveys reveal improved juvenile white stumpnose abundance in the nursery habitat and if catches are sustained, daily bag limits could again be increased.

11 BIRDS

11.1 Introduction

Together with the five islands within the Bay and Vondeling Island slightly to the South, Saldanha Bay and Langebaan Lagoon provide extensive and varied habitat for waterbirds. This includes sheltered deepwater marine habitats associated with Saldanha Bay itself, sheltered beaches in the Bay, islands that serve as breeding refuges for seabirds, rocky shoreline surrounding the islands and at the mouth of the Bay, and the extensive intertidal salt marshes, mud- and sandflats of the sheltered Langebaan Lagoon. Langebaan Lagoon has 1 750 ha of intertidal mud- and sandflats and 600 ha of salt marshes (Summers 1977). Sea grass *Zostera capensis* beds are more extensive at the southern end of the lagoon. Beds of the red seaweed *Gracilaria verrucosa* are mainly found at the mouth and patchily distributed over the sandflats. There are also small salt pans and drainage channels which add habitat diversity around the lagoon. Most of the plant communities bordering the lagoon belong to the West Coast Strandveld, a vegetation type which is seriously threatened by agricultural activities and urban development. Twelve percent of this vegetation type is conserved within the park (Boucher & Jarman 1977, Jarman 1986). Although there is no river flowing into the Lagoon, it has some estuarine characteristics due to the input of fresh groundwater in the southern portion of the lagoon.

Saldanha Bay and Langebaan Lagoon are not only extensive in area but provide much of the sheltered habitat along the otherwise very exposed West Coast of South Africa. There are only four other large estuarine systems which provide sheltered habitat comparable to Langebaan Lagoon for birds along the West Coast – the Orange, Olifants and Berg and Rietvlei/Diep. There are no comparable sheltered bays and relatively few offshore islands. Indeed, these habitats are even of significance at a national scale. While South Africa's coastline has numerous estuaries (about 290), it has few very large sheltered coastal habitats such as bays, lagoons or estuaries. The Langebaan-Saldanha area is comparable in its conservation value to systems such as Kosi, St Lucia and the Knysna estuary.

Saldanha Bay, and particularly Langebaan Lagoon, are of tremendous importance in terms of the diversity and abundance of waterbird populations supported. A total of 283 species of birds have been recorded within the boundaries of the West Coast National Park, of which 11 are seabirds, known to breed on the islands within the Bay (Birdlife International 2011).

11.2 Birds of Saldanha Bay and the islands

11.2.1 National importance of Saldanha Bay and the islands for birds

Saldanha Bay and the islands are important not so much for the diversity of birds they support, but for the sheer numbers of birds of a few species in particular. The islands of, Vondeling (21 ha), Schaapen (29 ha), Malgas (18 ha) and Jutten (43 ha), Meeuw (7 ha), Caspian (25 ha) and Marcus (17 ha), support important seabird breeding colonies and forms one of only a few such breeding areas along the West Coast of South Africa. They support nationally-important breeding populations of African Penguin (recently up-listed to Endangered under IUCN's red data list criteria), Cape Gannet (Vulnerable), Cape Cormorant (recently up-listed to Endangered under IUCN's red data list

criteria), White-breasted Cormorant, Crowned Cormorant (Near Threatened), and Bank Cormorant (Endangered), Kelp and Hartlaub's gulls and Swift Tern.

In addition to seabird breeding colonies, the islands also support important populations of the rare and endemic African Black Oystercatcher (Near-threatened). These birds are resident on the islands, but are thought to form a source population for mainland coastal populations through dispersal of young birds.

11.2.1.1 Ecology and status of the principle bird species



The African Penguin *Spheniscus demersus* is endemic to southern Africa, and breeds in three regions: central to southern Namibia, Western Cape and Eastern Cape in South Africa (Whittington *et al.* 2005a). The species has recently been up-listed to Endangered, under IUCN's 'red data list' due to recent data revealing rapid population declines as a result of competition with commercial fisheries for food and shifts in prey populations (Pichegru *et al.* 2009, Birdlife International 2011, Crawford *et al.* 2011). The Namibian population collapsed in tandem with the collapse of its main prey species, the sardine (*Sardinops sagax*; Ludynia *et al.* 2010). In South Africa the penguins breed mainly on offshore islands in the

Western and Eastern Cape with strongly downward trends at all major colonies (Whittington *et al.* 2005b).

The changes in population sizes at islands in Saldanha is believed to be partially linked to patterns of immigration and emigration by young birds recruiting to colonies other than where they fledged, with birds tending to move to Robben and Dassen Islands in recent years (Whittington *et al.* 2005b). However, once they start breeding at an island, they will not breed anywhere else. Penguin survival and breeding success is closely tied to the availability of pelagic sardines *S. sagax* and anchovies *Engraulis encrasicolus* within 20-30 km of their breeding sites (Pichegru *et al.* 2009). Diet samples taken from penguins at Marcus and Jutten Islands showed that the diet of African penguins in the Southern Benguela from 1984 to 1993 was dominated by anchovy (Laugksch & Adams 1993). During periods when anchovy are dominant, food is more consistently available to penguins on the western Agulhas Bank than at other times (older anchovy remain there throughout the year and sardines are available in the region in the early part of the year). Penguin colonies closest to the Agulhas Bank would benefit during periods of anchovy dominance while those colonies between Lüderitz and Table Bay (including Saldanha Bay) would be faced with a diminished food supply as the anchovy population contracts to the north off Namibia and the south off South Africa (Whittington *et al.* 2005b). The reduced abundance of anchovy may explain the decrease in the African penguin population evident from 1987 to 1993 clearly reflected in Saldanha (Figure 11.1.). Furthermore, both prey species are exploited by purse-seine fisheries which together with the eastward displacement of the pelagic fish off the South African coast between 1997 and 2005, further reduced food availability for the penguins.

The number of African penguins breeding in the Western Cape decreased from some 92 000 pairs in 1956, to 18 000 pairs in 1996, there was a slight recovery to a maximum of 38 000 pairs in 2004, before another dramatic collapse to 11 000 pairs in 2009, equating to a total decline of 60.5% in 28 years (Crawford *et al.* 2008a, b, R. Crawford unpubl. data). In Saldanha Bay the population initially grew from 552 breeding pairs in 1987 to a peak of 2 156 breeding pairs in 2001 and then underwent a severe decline to just 314 breeding pairs in 2014 (Figure 11.1.). This reduction in numbers is consistent with the overall downward trend evident since 2002 and strongly reinforces the argument that immediate conservation action is required to prevent further losses of these birds.

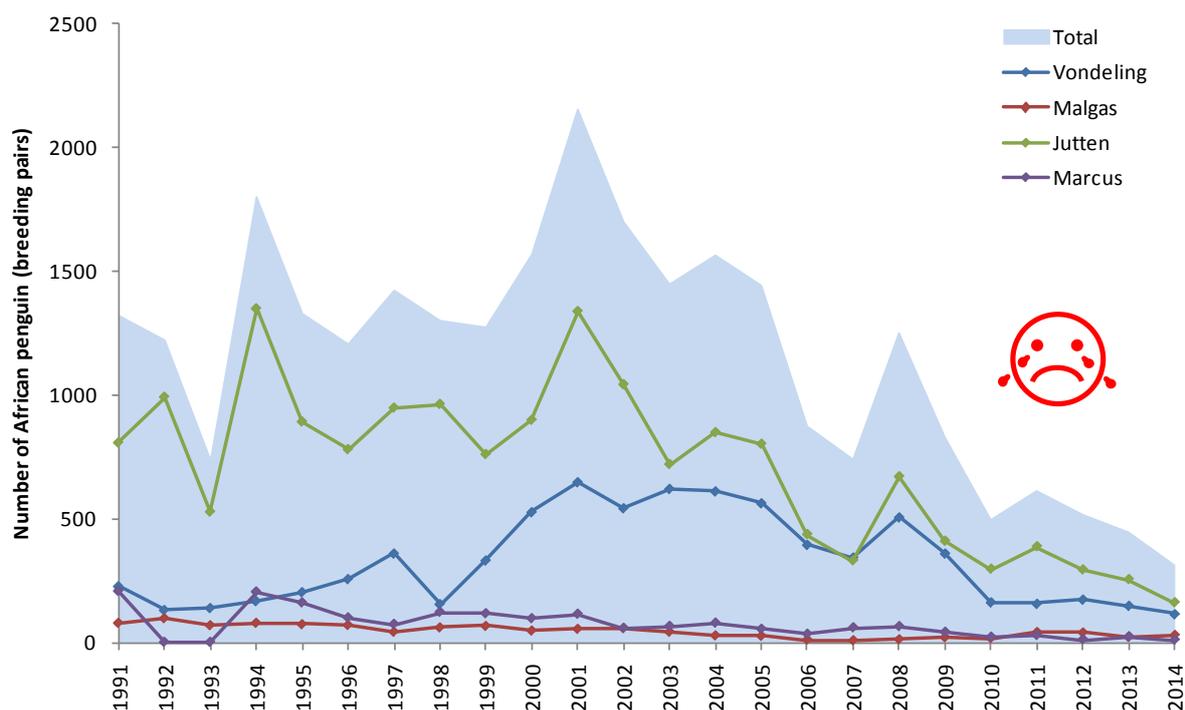


Figure 11.1. Trends in African Penguin populations at Malgas, Marcus, Jutten and Vondeling islands in Saldanha Bay (Data source: Makhado *et al.* 2015, Department of Environmental Affairs: Oceans & Coasts).

There is considerable uncertainty around the cause of the decreases, however. One of the measures currently being employed to curb these declines is the use of no-take zones for purse-seine fishing. This strategy, recently tested at St Croix Island in the Eastern Cape, was effective in decreasing breeding penguins' foraging efforts by 30% within three months of closing a 20 km zone to purse-seine fisheries (Pichegru *et al.* 2010). In this case the use of small no-take zones has represented immediate benefits for the African penguin population dependent on pelagic prey, with minimum cost to the fishing industry, while protecting ecosystems within these habitats and important species. However, experimental fishing closures at Dassen and Robben Islands have not delivered such positive results, resulting in published rebuttals labelling the findings of Pichegru *et al.* (2010) premature.

The reduction in colony sizes at most of the islands in Saldanha Bay will have had severe negative consequences for penguins. When Penguins breed in large colonies, packed close to one another,

they are better able to defend themselves against egg and chick predation by Kelp gulls. Also, these losses are trivial at the colony level. However, the fragmented colonies and the rise in gull numbers associated with the rapidly expanding human settlements in the area during the 1980s, meant that gull predation became problematic. Kelp gull numbers in Saldanha Bay have decreased dramatically in recent years (see below), but the population remains at more than 3 000 pairs and gull predation on penguin eggs probably remains problematic. Research has indicated that the provision of correctly designed artificial nest sites that provide protection both from gull predation and extreme temperatures (half concrete pipes were found to be superior to fibreglass artificial burrows) can be effective in enhancing fledging success (Pichegru 2012). Similarly, predation by seals (on land and around colonies) is having an increasingly negative impact on these dwindling colonies (Makhado *et al.* 2009). Additional stress, such as turbidity and increased vessel traffic, will not only impact penguins directly, but is likely to influence the location of schooling fish that the penguins are targeting and their ability to locate these schools. There are also concerns that toxin loads influence individual birds' health, reducing their breeding success and/or longevity (Game *et al.* 2009).

In summary, the initial collapse of the penguin colonies in the area is probably related to food availability around breeding islands and in areas where birds not engaged in breeding are foraging. However, now that colonies have shrunk so dramatically, the net effect of local conditions at Saldanha Bay are believed to be an increasingly important factor in the continued demise of African penguin colonies at the islands.

The Kelp Gull *Larus dominicanus* breeds primarily on offshore islands, as well as a small number of mainland sites. The Islands in Saldanha Bay support a significant proportion of South Africa's breeding population. Within this area, the majority breed on Schaapen, Meeuw and Jutten Islands, with additional small but consistent breeding populations on Vondeling and Malgas islands. Small numbers of breeding kelp gulls were recorded on Marcus Island in 1978, 1985 and 1990-92, but breeding has since ceased, probably due to the causeway connecting the island



to the mainland allowing access to mammal predators (Hockey *et al.* 2005). Overall, the number of Kelp gulls on the islands increased until 2000 (Figure 11.2.), probably due to the increase in availability of food as a result of the introduction and spread of the invasive alien mussel species *Mytilus galloprovincialis*. This was not particularly good news, however, as Kelp Gulls are known to eat the eggs of several other bird species (e.g. African penguins, Cape Cormorants and Hartlaub's Gulls). Since 2000, the populations on the islands have been steadily decreasing following large-scale predation by Great White Pelicans *Pelecanus onocrotalus* that was first observed in the mid-1990s (Crawford *et al.* 1997). During 2005 and 2006 pelicans caused total breeding failure of Kelp Gulls at Jutten and Schaapen Islands (de Ponte Machado 2007) the effects of which are still apparent (Figure 11.2.). Recent counts suggest that numbers are now well below (less than half) those at the start of the comprehensive counting period.

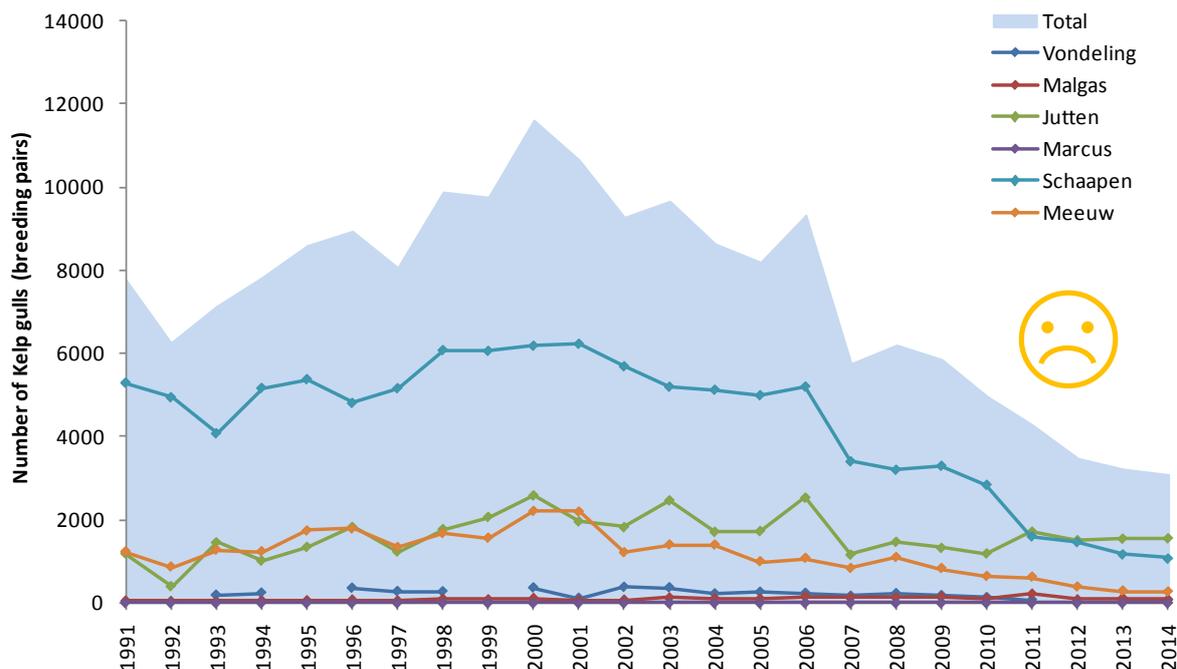


Figure 11.2. Trends in breeding population of Kelp gulls at Vondeling, Malgas, Jutten, Marcus, Schaapen, and Meeuw Islands in Saldanha Bay (Data source: Makhado *et al* 2015, Department of Environmental Affairs: Oceans & Coasts).



Hartlaub's Gull, *Larus hartlaubii*, is about the 10th rarest of the world's roughly 50 gull species. It is endemic to southern Africa, occurring along the West Coast from Swakopmund to Cape Agulhas. It breeds mainly on protected islands but has also been found to breed in sheltered inland waters. Hartlaub's Gulls are relatively nomadic, and can alter breeding localities from one year to the next (Crawford *et al.* 2003).

The numbers breeding on the different islands are highly erratic, as are the total numbers in the Bay. The highest and most consistent numbers of breeding birds are found on Malgas, Jutten and Schaapen islands, with a few birds breeding Vondeling Island between 1991 and 1999 and again in 2014 when 86 pairs were recorded. They have also been recorded breeding on Meeuw Island in 1996, from 2002 to 2004 and again for the last three years (2012-2014). There are substantial inter-annual fluctuations in numbers of birds breeding, suggesting that in some years an appreciable proportion of the adults do not breed (Crawford *et al.* 2003). Natural predators of this gull are the Kelp Gull, African Sacred Ibis and Cattle Egret, which eat eggs, chicks and occasionally adults (Williams *et al.* 1990). In Saldanha Bay there is no discernable upward or downward trend over time. Concern was recently expressed over the fact that breeding appeared to have ceased at Schaapen Island during the period 2008-2011. The number of pairs breeding on Schaapen Island did, however, recover dramatically with 925 pairs recorded in 2012, but then decreased again to just 20 pairs in 2014 (Figure 11.3.).

Approximately 200 pairs were counted on both Malgas and Meeuw in 2014 and around 100 pairs on Jutten and Vondeling in 2014. The total number of breeding pairs recorded in 2014 (622) is close to the midpoint of the substantial inter-annual variation observed in the Hartlaub’s gull breeding numbers (Figure 11.3.).

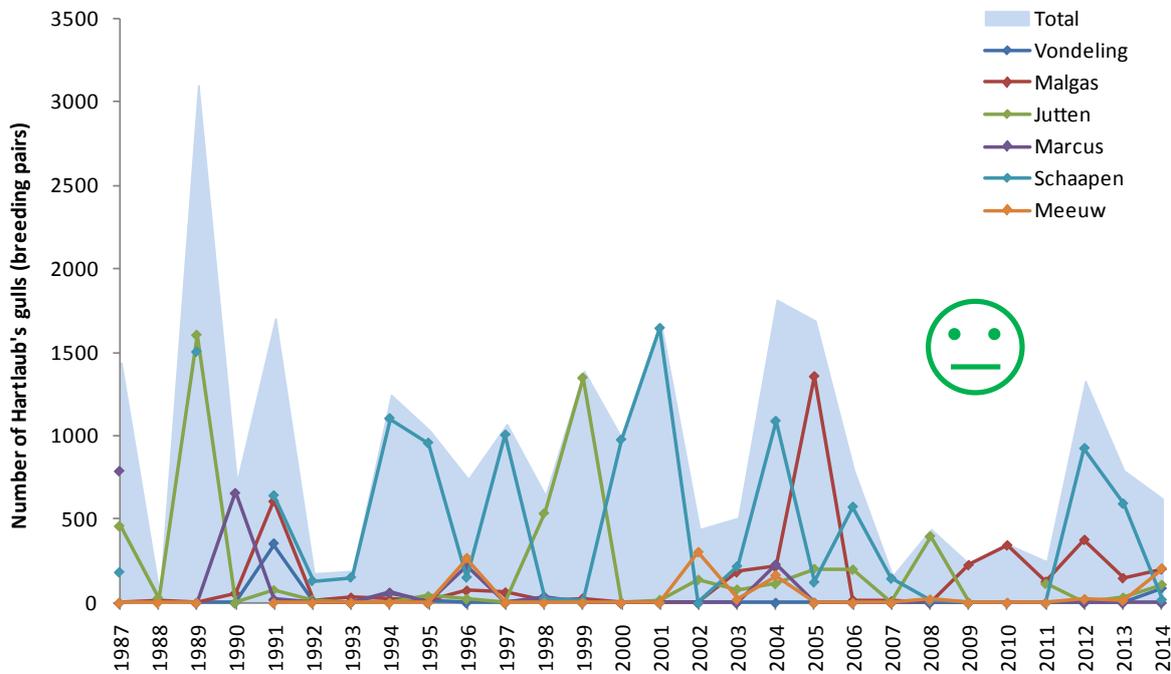


Figure 11.3. Trends in breeding population of Hartlaub’s Gulls at Malgas, Marcus, Jutten, Schaapen and Vondeling Islands in Saldanha Bay (Data source: Makhado *et al* 2015, Department of Environmental Affairs: Oceans & Coasts).

The Swift Tern, *Sterna bergii*, is a widespread species that occurs as a common resident in southern Africa. Swift Terns breed synchronously in colonies, usually on protected islands, and often in association with Hartlaub’s Gulls. Sensitive to human disturbance, their nests easily fall prey to Kelp Gulls, Hartlaub’s Gulls and Sacred Ibis (Le Roux 2002). During the breeding season, fish form 86% of all prey items taken, particularly pelagic shoaling fish, of which the Cape Anchovy (*Engraulis encrasicolus*) is the most important prey species. Since 2001 there has been an increase in the Swift Tern population number in South Africa. This increase coincided with a greater abundance of two of their main prey species, sardines and anchovies. However, since 2005, the population in the Western Cape has shifted south and eastward, coinciding with a similar shift of their prey species (Crawford 2009). In southern Africa, Swift Terns show low fidelity to breeding localities, unlike the African Penguin, Cape Gannet



and Cape Cormorant, which enables them to rapidly adjust to changes in prey availability (Crawford 2009).

In Saldanha Bay, Jutten Island has been the most important island for breeding Swift Terns over the past 30 or more years, but breeding numbers are erratic at all the islands. The breeding population shifted to Schaapen Island in 2007, but no swift terns were reported breeding on islands in the Bay for the four years following this, the longest such period on record. It is encouraging therefore that the birds returned again in 2012-2014, with 543 breeding pairs recorded on Malgas, Jutten and Schaapen Islands in 2014 (Figure 11.4.).

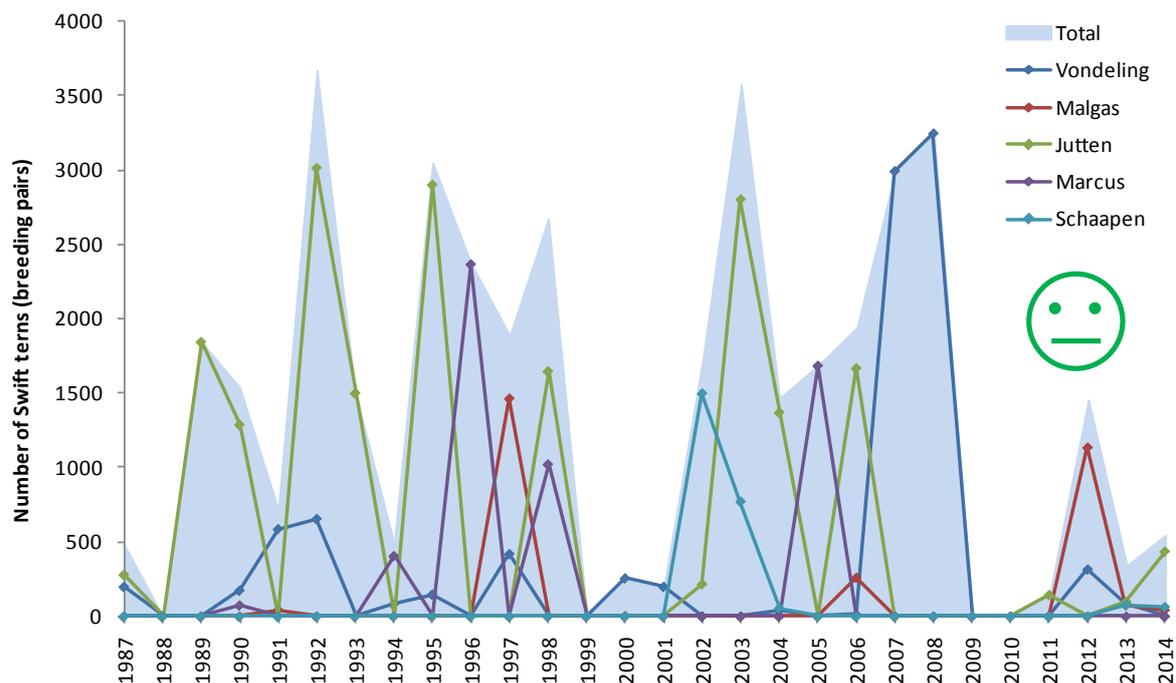


Figure 11.4. Trends in breeding population of Swift Terns at Vondelig, Malgas, Jutten, Marcus, and Schaapen Islands in Saldanha Bay (Data source: Makhado *et al* 2015, Department of Environmental Affairs: Oceans & Coasts).



Cape Gannets *Morus capensis* are restricted to the coast of Africa, from the Western Sahara, around Cape Agulhas to the Kenyan coast. In southern Africa they breed on six offshore islands, three off the Namibian coast, and two off the west coast of South Africa (Bird Island in Lambert's Bay and Malgas Island in Saldanha Bay), and one (Bird Island) at Port Elizabeth. The Cape Gannet is listed as Vulnerable on the IUCN's global Red Data List, due to its restricted range and population declines (Birdlife International 2011).

Cape Gannets breed on islands which afford them protection from predators. They feed out at sea and will often forage more than a hundred kilometres away from their nesting sites (Adams & Navarro 2005). This means that only a small proportion of foraging takes place within Saldanha Bay. The quality of water in Saldanha Bay should therefore not have a significant effect on the Cape Gannet population.

The bird colony at Malgas Island has shown population fluctuation since the early 1990's and a steady decline since 1996 (Figure 11.5.). The 2012 and 2013 data reveal that the breeding population on Malgas Island has fallen to record low levels. The decline in numbers at Malgas Island contrasts with population figures for Bird Island, off Port Elizabeth, where numbers have increased. The total South African gannet population appears to respond to the population dynamics of small pelagic fish (particularly sardines), with the number of breeding pairs peaking around the turn of the century and declining to around 100 thousand pairs in 2013 (Data provided by Makhado *et al* 2014). A study suggested that Cape Gannet population trends are driven by food availability during their breeding season (Lewis *et al.* 2006). Pichegru *et al.* (2007) showed that Cape Gannets on the west coast have been declining since the start of the eastward shift of the pelagic fish in the late 1990s. This has resulted in west coast gannets having to increase their foraging efforts, during the breeding season, forage in areas with very low abundance of their preferred prey, and feed primarily on low-energy fishery discards (93% of total prey intake; Crawford *et al.* 2006, Pichegru *et al.* 2007). A bioenergetics model showed that enhanced availability of low-energy fishery discards does not seem to compensate for the absence of natural prey (Pichegru *et al.* 2007). In addition to the above, and of more concern at a local level, is the recent increase in predation by Cape fur seals *Arctocephalus pusillus pusillus* and the Great White Pelican *Pelecanus onocrotalus* (Makhado *et al.* 2006, Pichegru *et al.* 2007). Predation by seals caused a 25% reduction in the size of the colony at Malgas Island between 2001 and 2006 (Makhado *et al.* 2006). These added threats weigh heavily on an already vulnerable species.

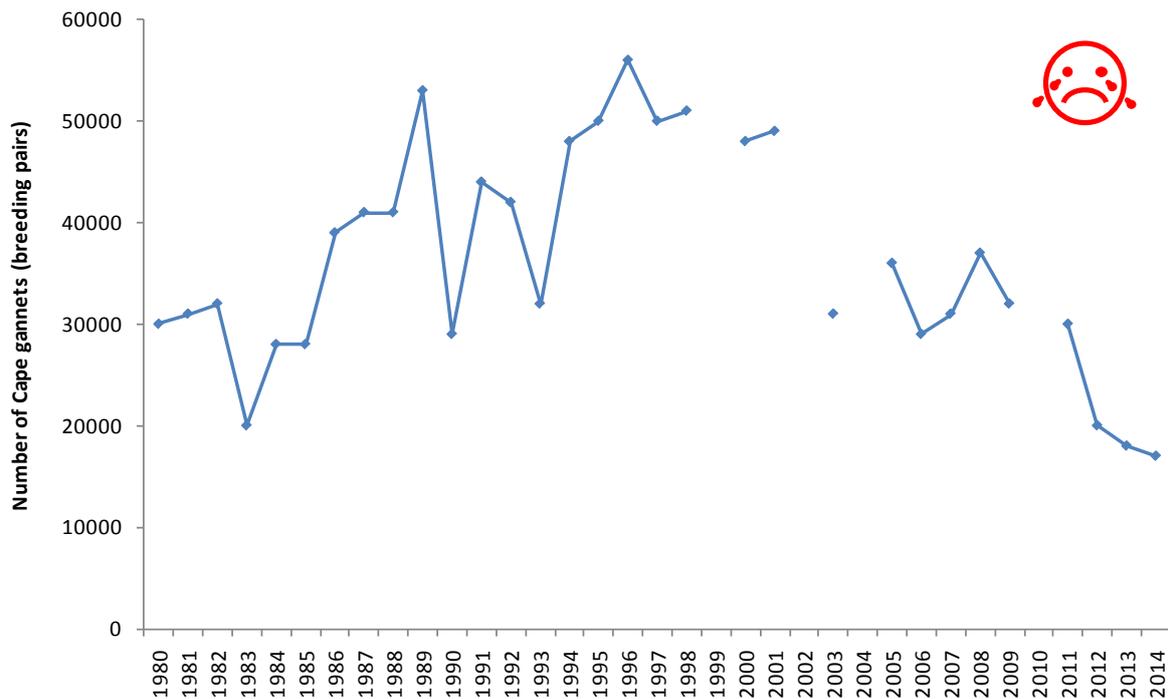


Figure 11.5. Trends in breeding population of Cape Gannets at Malgas Island, Saldanha Bay (Data source: Makhado *et al* 201, Department of Environmental Affairs: Oceans & Coasts).

These recent findings have changed the overall health of the Gannet population on Malgas Island from Good to Fair based on the increase in predation by fur seals and recently observed predation by the Great White Pelican (Pichegru *et al.* 2007). Management measures were implemented between 1993 and 2001 and 153 fur seals seen to kill Gannets, were shot (Makhado *et al.* 2006). This practice has continued in an effort to improve breeding success (Makhado *et al.* 2009). The effects of this may be manifest in the slight recovery in Gannet numbers between 2006 and 2009, but numbers have declined further since then.

Cape Cormorants *Phalacrocorax capensis* are endemic to southern Africa, where they are abundant on the west coast but less common on the east coast, occurring as far as Seal Island in Algoa Bay.



They breed between Ilha dos Tigres, Angola, and Seal Island in Algoa Bay, South Africa. They generally feed within 10-15 km of the shore, preying on pelagic goby *Sufflogobius bibarbatius*, Cape anchovy *Engraulis capensis*, pilchard *Sardinops sagax* and Cape horse mackerel *Trachurus trachurus* (du Toit 2004).

Key colonies of the Cape Cormorant in South Africa and Namibia have undergone very rapid population declines over the past three generations and the Cape Cormorant has therefore been uplisted to Endangered (BirdLife International 2015). Declines are primarily believed to have been driven by collapsing pelagic fish stocks, but the species is also susceptible to oiling and avian cholera outbreaks (BirdLife International 2015). This trend currently shows no sign of

reversing, and immediate conservation action is required to prevent further declines (Crawford *et al.* 2013).

In South Africa, numbers decreased during the early 1990s following an outbreak of avian cholera, predation by Cape fur seals and White Pelicans as well as the eastward displacement of sardines off South Africa (Crawford *et al.* 2007). As a result there are large inter-annual fluctuations in breeding numbers due to breeding failure, nest desertion and mass mortality related to the abundance of prey, for which they compete with commercial fisheries. This makes it difficult to accurately determine population trends. In addition, during outbreaks of avian cholera, tens of thousands of birds die. Cape Cormorants are also vulnerable to oiling, and are difficult to catch and clean. Discarded fishing gear and marine debris also entangles and kills many birds. Kelp Gulls prey on Cape Cormorant eggs and chicks and this is exacerbated by human disturbance, especially during the early stages of breeding, as well as the increase in gull numbers (du Toit, 2004).

The Saldanha Bay population has been quite variable since the start of monitoring in 1988, with the bulk of the population residing on Jutten Island in recent years (Figure 11.6.). Overall, the number of breeding pairs has declined substantially since the 1990s. In 2013, a total of only 1268 breeding pairs were recorded, representing the lowest level recorded to date (when counts were conducted on all five islands) (Figure 11.6.). Although numbers of breeding pairs recovered in 2014 to a total of 8609 (Jutten Island contributing 74%), it remains to be seen if populations will continue to decline over time. .

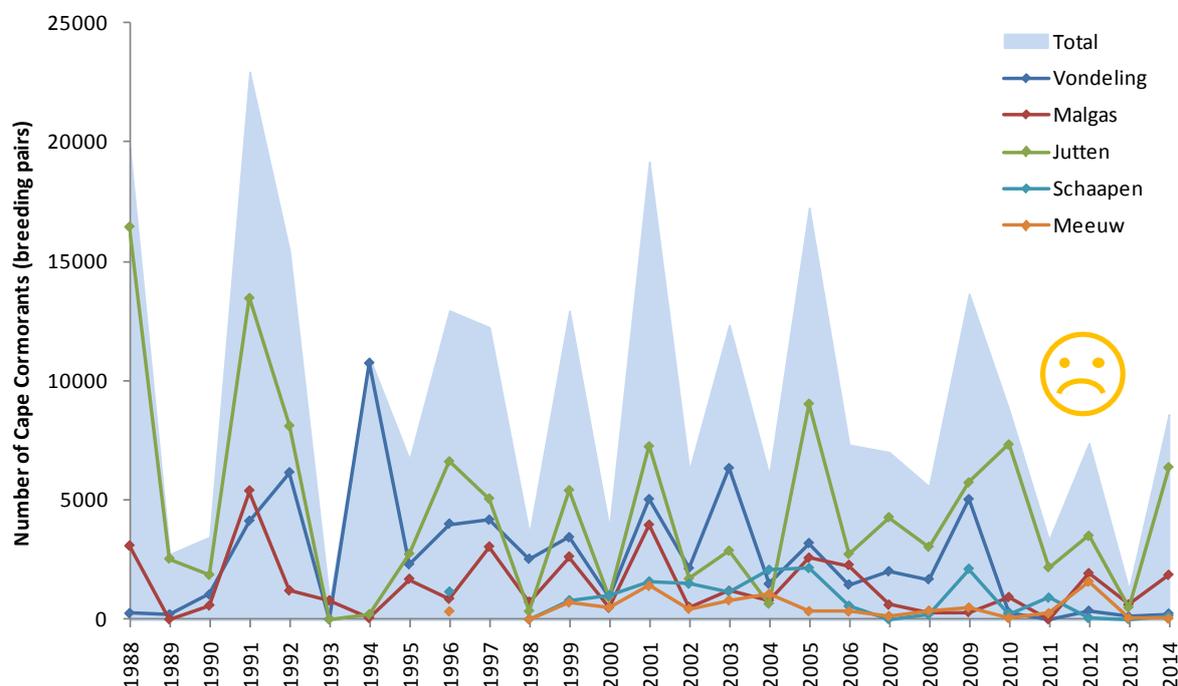


Figure 11.6. Trends in breeding population of Cape Cormorants at Vondeling, Malgas, Jutten, Schaapen, and Meeuw islands in Saldanha Bay (Data source: Makhado *et al* 2015, Oceans & Coasts, Department of Environmental Affairs).

Bank Cormorants *Phalacrocorax neglectus* are endemic to the Benguela upwelling region of southern Africa, breeding from Hollamsbird Island, Namibia, to Quoin Rock, South Africa. They seldom range farther than 10 km offshore. Their distribution roughly matches that of kelp *Ecklonia maxima* beds. They prey on various fish, crustaceans and cephalopods, feeding mainly amongst kelp where they catch West Coast rock lobster, *Jasus lalandii* and pelagic goby *Sufflogobius bibarbatus* (du Toit 2004). The total population decreased from about 9000 breeding pairs in 1975 to less than 5000 pairs in 1991-1997 to 2800 by 2006 (Kemper *et al.* 2007). One of the main contributing factors to the decrease in the North and Western Cape colonies was a major shift in the availability of the West Coast rock lobster from the West Coast to the more southern regions, observed between the late 1980s and early 1990s to the turn of the century (Cockcroft *et al.* 2008). The abundance of lobsters was further severely affected by an increase in the number and severity of mass lobster strandings (walkouts) during the 1990s and increases in illegal fishing, with the national stock rock lobster status now estimated at just 3% of pristine biomass (Cockcroft *et al.* 2008, DAFF 2013). Ongoing population declines led to the Bank Cormorant's status being changed from Vulnerable to Endangered (Birdlife International 2011).



Count data from the Saldanha Bay area shows the dramatic decrease in the population at Malgas Island, which was previously the most important island for this species. The number of breeding pairs on Jutten, Marcus and Vondeling remained relatively constant at this time, but declined steadily since 2003 on all the islands (except Marcus where the number of breeding pairs remained stable until 2012 when only 2 pairs were recorded). The population in Saldanha Bay has declined drastically approximately by approximately 80% since 1990 (Figure 11.7.).

In Saldanha Bay the declines are mainly attributed to scarcity of their main prey, the rock lobster which in turn has reduced recruitment to the colonies (Crawford 2007, Crawford *et al.* 2008c). Bank Cormorants are also very susceptible to human disturbance and eggs and chicks are taken by Kelp Gulls and Great White Pelicans. Increased predation has been attributed to the loss of four colonies in other parts of South Africa and Namibia (Hockey *et al.* 2005). Smaller breeding colonies are more vulnerable to predation which would further accelerate their decline. Birds are also known to occasionally drown in rock-lobster traps, and nests are often lost to rough seas.

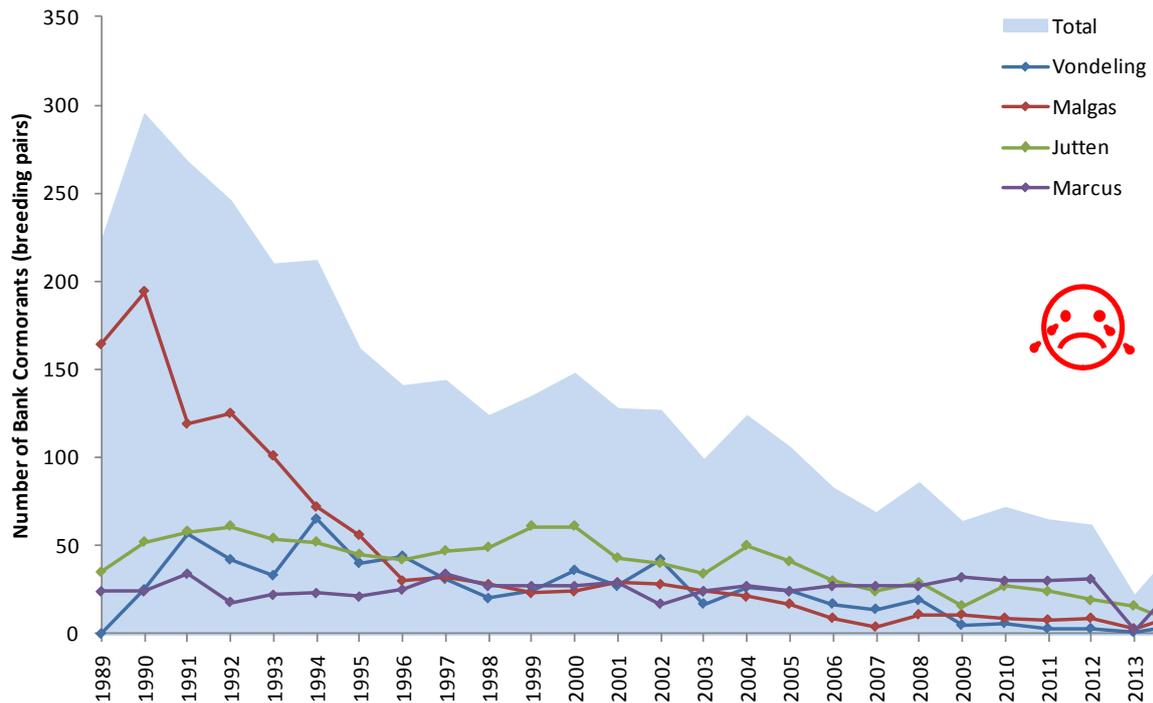
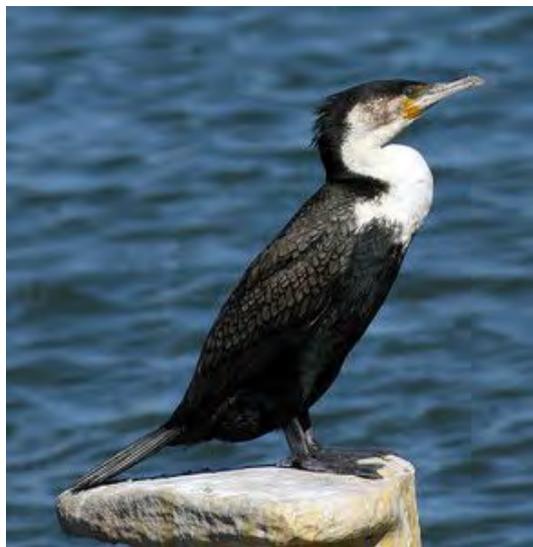


Figure 11.7. Trends in breeding population of Bank Cormorants at Vondeling, Malgas, Jutten, and Marcus, islands in Saldanha Bay (Data source: Makhado *et al* 2015, Oceans & Coasts, Department of Environmental Affairs).



The **White-breasted Cormorant** *Phalacrocorax carbo lucidus*, also known as Great Cormorant, occurs along the entire southern African coastline, and is common in the eastern and southern interior, but occurs only along major river systems and wetlands in the arid western interior. The coastal population breeds from Ilha dos Tigres in southern Angola, to Morgan Bay in the Eastern Cape. Along the coast, White-breasted Cormorants forage offshore, mainly within 10 km of the coast, and often near reefs. White-breasted Cormorants that forage in the marine environment feed on bottom-living, mid-water and surface-dwelling prey, such as sparid and mugillid fishes e.g. Steentjies, White stumpnose and harders (du Toit

2004). This species forages in Saldanha Bay and Langebaan Lagoon, making it susceptible to local water quality (Hockey *et al.* 2005).

Within Saldanha Bay, breeding effort has occasionally shifted between islands. White-breasted Cormorant bred on Malgas Island in the 1920's, and low numbers of breeding pairs were counted on Marcus and Jutten Islands intermittently between 1973 and 1987 when they stopped breeding there and colonized Schaapen, Meeuw and Vondeling islands (Crawford *et al.* 1994). Most of the breeding population was on Meeuw in the early 1990s, but shifted to Schaapen in about 1995. By 2000, the breeding numbers at Schaapen had started to decline and the breeding population had shifted

entirely back to Meeuw by 2004, where it has remained since (Figure 11.8.). Overall numbers have been more or less stable in recent years, and there is no long term declining trend.

Human disturbance poses a threat at breeding sites. These cormorants are more susceptible to disturbance than the other marine cormorants, and leave their nests for extended periods if disturbed, exposing eggs and chicks to Kelp Gull predation. Other mortality factors include Avian Cholera, oil pollution, discarded fishing line and hunting inland (du Toit 2004). Due to Schaapen Islands' close proximity to the town of Langebaan, the high boating, kite-boarding and other recreational use of the area may pose a threat to these birds. The substantial growth in participation in recreational water sports (particularly kite boarding) over the last decade may have been a contributing factor to the shift in breeding location from Schaapen to Meeuw Island in 2004, but this appears unlikely given that the opposite shift happened ten years previously. Furthermore the total population estimate, although variable, has not shown a decreasing trend, which suggests that recreational water sport activities are not negatively impacting this species.

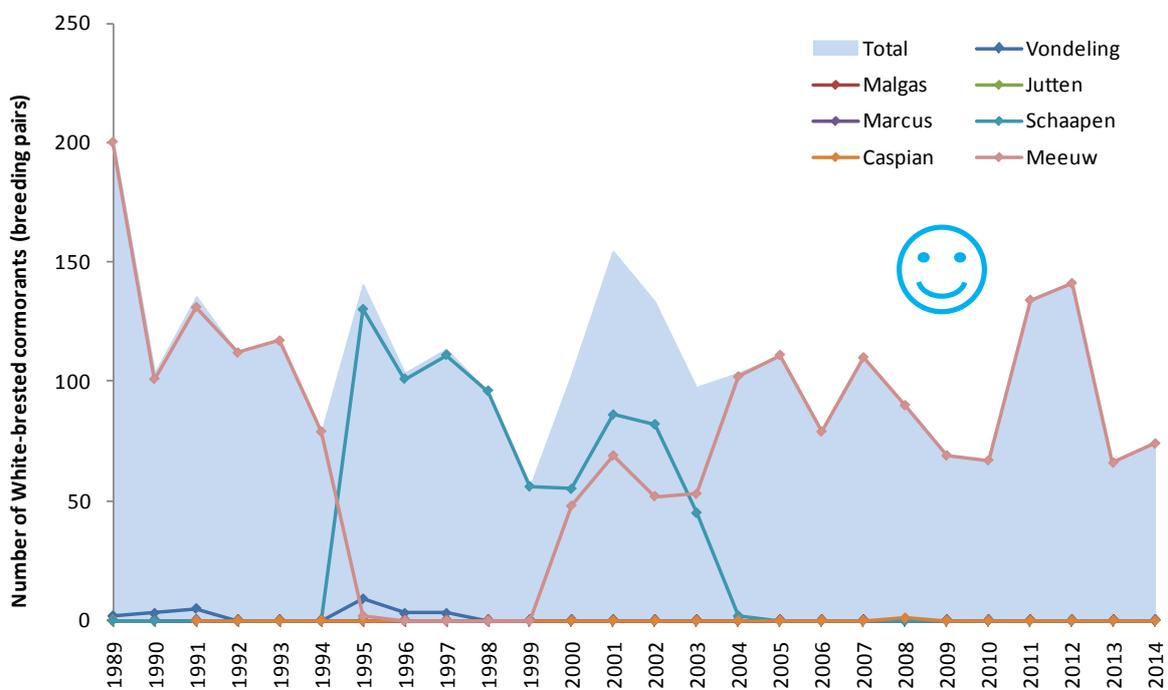


Figure 11.8. Trends in breeding population of White-breasted Cormorants at Malgas, Jutten, Marcus, Schaapen, Caspian and Meeuw islands in Saldanha Bay (Data source: Makhado *et al* 2015, Department of Environmental Affairs: Oceans & Coasts).

The **Crowned Cormorant** *Phalacrocorax coronatus* is endemic to Namibia and South Africa, occurring between the Bird Rock Guano Platform in southern Namibia and Quoin Rock, South Africa. It is listed as Near Threatened on the IUCN’s Red Data List due to its small and range restricted population, making it very vulnerable to threats at their breeding colonies (Birdlife International 2011). This species is highly susceptible to human disturbance and predation by fur seals, particularly of fledglings. Crowned Cormorants generally occur within 10 km from the coastline and occasionally in estuaries and sewage works up to 500 m from the sea. They feed on slow-moving benthic fish and invertebrates, which they forage for in shallow coastal waters and among kelp beds (du Toit 2004).



Populations of this species have been comprehensively counted since 1991 (Figure 11.9.). Since then, numbers have shown considerable interannual variations with an overall slow but decreasing trend (Figure 11.9.).

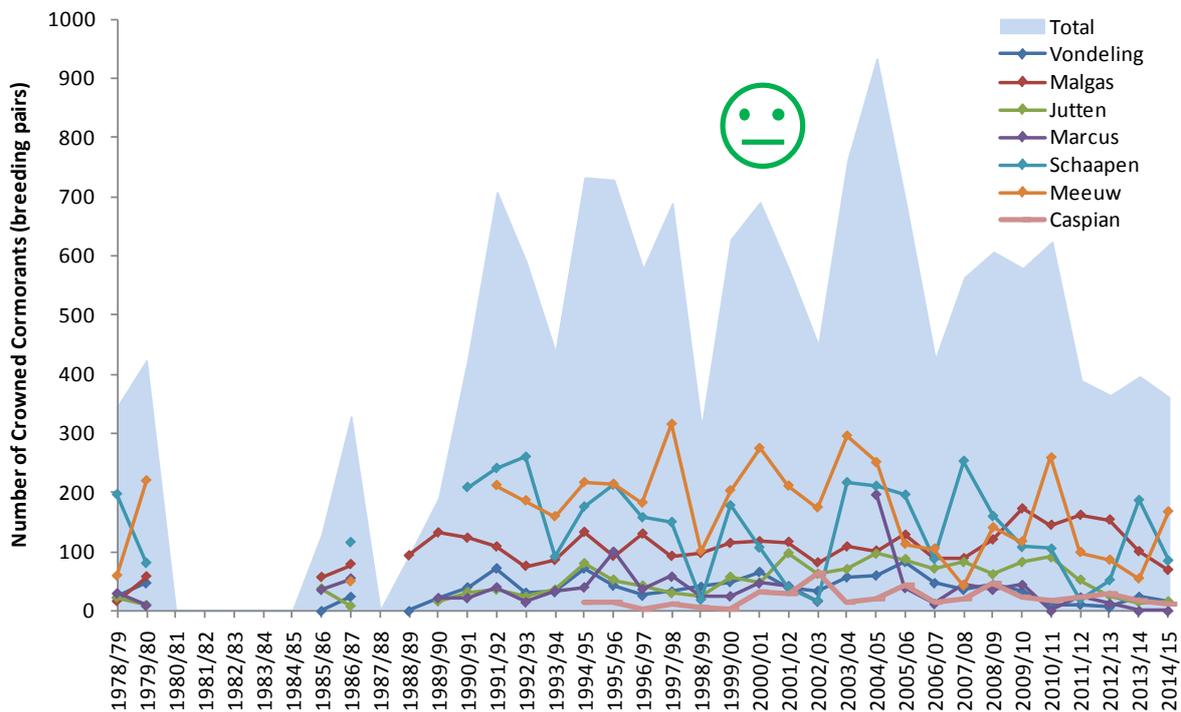


Figure 11.9. Trends in breeding population of Crowned Cormorants at the Vondeling, Malgas, Jutten, Marcus, Schaapen, Meeuw and Caspian islands in Saldanha Bay (Data source: Makhado *et al* 2015, Department of Environmental Affairs: Oceans & Coasts).



The **African Black Oystercatcher** *Haematopus moquini* is endemic to southern Africa. It is listed as Near Threatened in the IUCN's Red Data List, owing to its small population and limited range (Birdlife International 2011). It breeds in rocky intertidal and sandy beach areas from Namibia to the southern KwaZulu-Natal coast. Their numbers have increased dramatically over the past 25 years. The islands in Saldanha Bay support an important number of these birds, where highest numbers are encountered at

Marcus, Malgas and Jutten Islands. In the last 35 years (since 1980) the population has grown by 100 breeding pairs on the three main breeding islands in Saldanha Bay (Figure 11.10.). This steady increase in Oystercatcher numbers over the past two decades is due primarily to the introduction and proliferation of the alien mussel *Mytilus galloprovincialis*, as well as due to the enhanced protection of the Oystercatcher throughout much of its range.

African Black Oystercatchers are resident on the islands, feeding in the rocky intertidal. While the invasive alien mussels proliferated and became important in the diet between the late 1980s and the early 1990s, the effects on population only began to show much later because of the age at first breeding and slow breeding rate of these birds (Hockey 1983). The population stabilised in the early 2000s and appears to remain stable, suggesting that carrying capacity of the islands has been reached (Loewenthal *pers. comm.*). Oystercatchers are unlikely to be affected by water quality in Saldanha Bay except in as much as it affects intertidal invertebrate abundance. Like most of the birds described above, they are, however, vulnerable to catastrophic events such as oil spills. Due to the sad passing of the two champions of the Oystercatcher Conservation Project (Prof. Phil Hockey and Dr Douglas Loewenthal) the regular censuses of oystercatchers in Saldanha Bay have unfortunately stopped. SANParks could possibly be encouraged to take on this task as part of their routine ecological monitoring and maintain this valuable long-term data series.

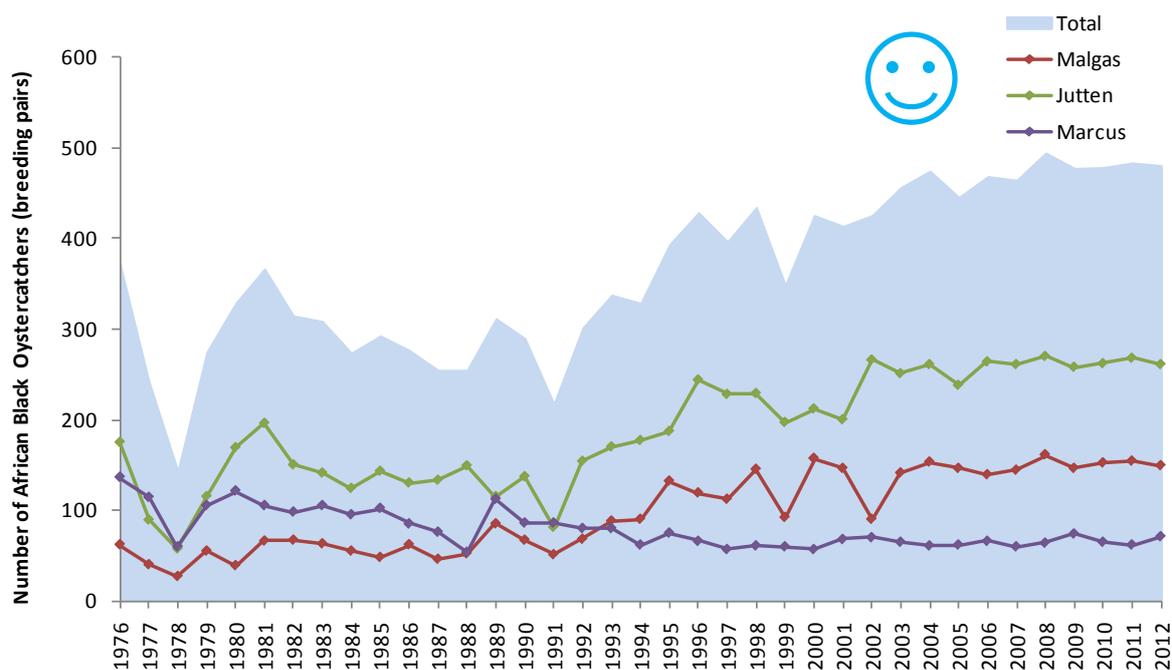


Figure 11.10. Trend in breeding population of African Black Oystercatchers older than 1 year, on Malgas, Jutten and Marcus Islands. (Data source: Douglas Loewenthal, Oystercatcher Conservation Programme).

11.3 Birds of Langebaan Lagoon

11.3.1 National importance of Langebaan Lagoon for birds

Langebaan Lagoon supports an average of about 50 000 waterbirds during summer and about 18 000 during winter. Approximately Fifty-five non-passerine species of waterbirds are regularly recorded at Langebaan Lagoon. About two thirds of the waterbird species are waders, of which 20 species are regular migrants from the Palearctic region of Eurasia; these make up 83% of the summer wader population by numbers. Important non-waders which utilise the system are Kelp and Hartlaub's Gulls, Greater Flamingo, Sacred Ibis and Common Tern. Resident waterbird species which utilise the rocky and sandy coastlines include the African Black Oystercatcher and the White-fronted Plover, both of which breed in the area.

The thousands of migratory waders visit Langebaan Lagoon during the austral summer making it the most important 'wintering' area for these birds in South Africa (Underhill 1987). Since Langebaan Lagoon regularly supports over 20 000 waders it is recognised as an internationally important site under the Ramsar Convention on Wetlands of International Importance, to which South Africa is a signatory. With regard to density and biomass of waders, Langebaan Lagoon compares favourably to other internationally important coastal wetlands in West Africa and Europe.

The true importance of Langebaan Lagoon for waders cannot be assessed without recourse to a comparison with wader populations at other wetlands in southern Africa. During the summer of 1976 to 1977, wader populations at all coastal wetlands in the south-western Cape were counted (Siegfried 1977). The total population was estimated at 119 000 birds of which 37 000 occurred at Langebaan. Only one other coastal wetland, the Berg River estuary, contained more than 10 000

waders. Thus, Langebaan Lagoon held approximately one third of all the waders in the south-western Cape (Siegfried 1977). Studies were extended to Namibia (then South West Africa) in the summer of 1976-77. Walvis Bay Lagoon contained up to 29 000 waders and Sandvis had approximately 12 000 waders. Therefore, it was determined that Langebaan Lagoon was the most important wetland for waders on the west coast of southern Africa (Siegfried, 1977). Taking species rarity and abundance into account, Langebaan Lagoon has been ranked fourth of all South African coastal lagoons and estuaries in terms of its conservation importance for waterbirds (Turpie 1995).

In 1985, Langebaan Lagoon was declared a National Park (West Coast National Park), and recreational activities such as boating, angling and swimming have since been controlled within the Lagoon through zonation. Nevertheless, some important feeding areas lie within the zones that are highly utilised for recreation.

11.3.2 The main groups of birds and their use of habitats and food

The waterbirds of Langebaan Lagoon can be divided into nine different taxonomic orders (Table 11.1.), the most species-rich being the Charadriiformes, which include the waders, gulls and terns. Table 11.1. also shows the more commonly used groupings of waterbirds, each of which is described in more detail below. Their relative contribution to the bird numbers on the estuary differs substantially in summer and winter, due to the prevalence of migratory birds in summer (Figure 11.11.). Waders account for about 83% of the birds on Langebaan Lagoon during summer, nearly all of these being migratory. In winter, resident wader numbers increase slightly, and numbers of flamingos increase substantially.

Table 11.1. Taxonomic composition of waterbirds in Langebaan Lagoon (excluding rare or vagrant species).

Common groupings	Order	No. of SA resident species	No. of migrant species
Waterfowl	Podicipediformes (Grebes)	2	
	Anseriformes (Ducks, geese)	10	
	Gruiformes (Rails, crakes, gallinules, coots)	7	
Cormorants, darters, pelicans	Pelecaniformes (Cormorants, darters, pelicans)	7	
Wading birds	Ciconiiformes (Hérons, egrets, ibises, spoonbill, etc.)	14	
	Phoenicopteriformes (Flamingos)	2	
Birds of prey	Falconiformes (Birds of prey)	3	1
Waders	Charadriiformes: Waders	12	20
Gulls	Gulls	3	1
Terns	Terns	3	6
Kingfishers	Alcediniformes (Kingfishers)	3	
Total		66	28

Waders are the most important group of birds on Langebaan Lagoon in terms of numbers. The influx of waders into the area during summer accounts for most of the seasonal change in community composition. Most of the Palearctic migrants depart quite synchronously around early April, but the immature birds of many of these species remain behind and do not don the breeding plumage of the rest of the flock. The resident species take advantage of relief in competition for resources and use this period to breed. The migrants return more gradually in spring, with birds beginning to trickle in from August, and numbers rising rapidly during September to November.

Waders feed on invertebrates that mainly live in intertidal areas, at low tide, both by day and night (Turpie & Hockey 1993). They feed on a whole range of crustaceans, polychaete worms and gastropods, and adapting their foraging techniques to suit the type of prey available. Among the waders, plovers stand apart from the rest in that they have insensitive, robust bills and rely on their large eyes for locating prey visually. Oystercatchers have similar characteristics, using their strong bills to prise open shellfish. Most other waders have soft, highly sensitive bills and can locate prey by touch as well as visually. Those feeding by sight tend to defend feeding territories, whereas tactile foragers often forage in dense flocks.

Waders require undisturbed sandflats in order to feed at low tide and undisturbed roosting sites at high tide. In the 1970's it was determined that the most important sandflats, in terms of the density of waders they support, were in Rietbaai, in the upper section of Langebaan Lagoon, and at the mouth, near Oesterwal. The important roosting sites were the salt marshes, particularly between Bottelary and Geelbek (Summers 1977).

Gulls and terns are common throughout the area. Although their diversity is relatively low, they make up for this in overall biomass, and form an important group. Both Kelp Gulls and Hartlaub's Gulls occur commonly in the lagoon.

Cormorants, darters and pelicans are common as a group, but are dominated by the marine cormorants which breed on the Saldanha Bay islands. Great White Pelicans visit the bay and lagoon to feed, but they breed beyond the area at Dassen Island. African Darters *Anhinga rufa* are uncommon, and are more typical of lower salinities and habitats with emergent vegetation which is relatively uncommon in the study area.

Waterfowl occur in fairly large numbers because of the sheer size of the study area, but they are not as dense as they might be in freshwater wetland habitats or nearby areas such as the Berg River floodplain.

Other birds that commonly occur on the lagoon include birds of prey such as African Fish-Eagle *Haliaeetus vocifer*, Osprey *Pandion haliaetus* and African Marsh-Harrier *Circus ranivorus*, and species such as Pied Kingfisher *Ceryle rudis* and Cape Wagtail *Motacilla capensis*.

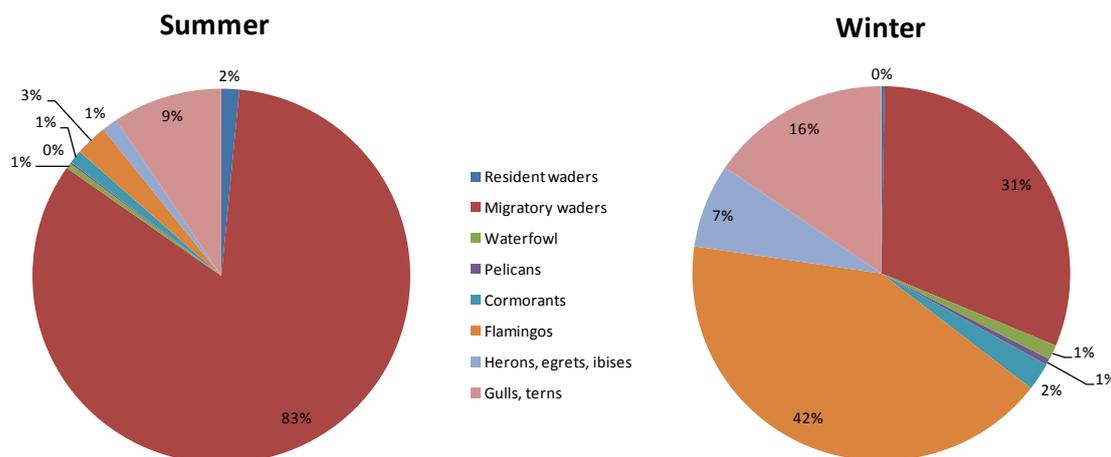


Figure 11.11. Average numerical composition of the birds on Langebaan Lagoon during summer (1985-2015) and winter (1985-2013) (Data source: CWAC data, Animal Demography Unit at the University of Cape Town).

11.3.3 Inter-annual variability in bird numbers

Irregular waterbird surveys were conducted at Langebaan Lagoon from 1934, but, due to the large size of the lagoon, these early counts were confined to small areas. It was not until 1975 that annual summer (January or February) and winter (June or July) surveys of the total population of waders at high tide, when waders congregate to roost on saltmarshes and sand spits, were conducted by members of the Western Cape Water Study Group (WCWSG) (Underhill, 1987). An analysis of the numbers of waders over the period 1975 to 1980 showed stable summer populations, but large year to year variations in the number of Palearctic migrants that over-wintered (Robertson 1981). The WCWSG monitored Langebaan continuously up to 1991, and since 1992, the Lagoon has been monitored bi-annually by the Co-ordinated Waterbird Counts (CWAC), organised by the Avian Demography Unity at the University of Cape Town.

The above data sets provide the opportunity to examine the long term trends in bird numbers at Langebaan Lagoon up to the present day. This reveals a downward trend in the numbers of Palearctic waders at the Lagoon since 1989, especially in the last five years (Figure 11.12.). Very low numbers of Curlew Sandpiper were recorded on the lagoon during 2011-2012. It is important to note that no CWAC data was collected at the Kraalbaai and Geelbek West sites in summer 2015. Together, migratory wader numbers at these sites account for approximately 32% of the total migratory waders counted each year (average calculated from data available for 2012-2014). Therefore, extrapolation of bird counts provide an estimate of 10 894 birds as supposed to 7408 as shown in Figure 11.12. It remains to be seen if migrant waders indeed stabilise, but in the meantime the total estimate of 10894 birds is approximately 74% down from the pre 1990 average of ~34 000 birds.

The reasons for these declines are diverse and poorly understood, but seem to be a combination of loss and degradation of their breeding sites as well as of their over-wintering grounds during their non-breeding period (Dias *et al.* 2006). The downward trend in migrant wader numbers may echo global trends in certain wader populations. Indeed, Ryan (2012) reports on similar declines in

migrant waders throughout the Western Cape over the last three decades, irrespective of the protection status of the areas where counts were undertaken. This suggested that factors outside of the Western Cape were at least partially responsible for the observed trends and probably reflected global population declines (Ryan 2012). What is of more concern is that the trend appeared to be echoed by resident waders over the period 1990-2004 (Figure 11.13.). In recent years (2005-2015) winter resident wader numbers appear to have stabilized although resident wader estimates do still remain at ~50% of the pre 1990 average (Figure 11.13.). As for the migratory waders, resident wader numbers are likely to be underestimated this year due to the missing data from Kraalbaai and Gelbek Wes sites. Missing data represent approximately 30% of the total numbers counted each year and winter resident wader numbers were therefore extrapolated, providing an estimated 234 birds for the summer of 2015.

Whatever the case, it does suggest that conditions at Langebaan Lagoon were at least partially to blame for the decline in waders numbers (migrant and resident species) during the 1990-2004 period. The most likely problems are that of siltation of the system reducing the area of suitable (e.g. muddy) intertidal foraging habitat, loss of seagrass beds with their associated invertebrate fauna (Pillay *et al.* 2010 see Chapter 7) and human disturbance, which has been shown to have a dramatic impact on bird numbers in other estuaries (Turpie & Love 2000).

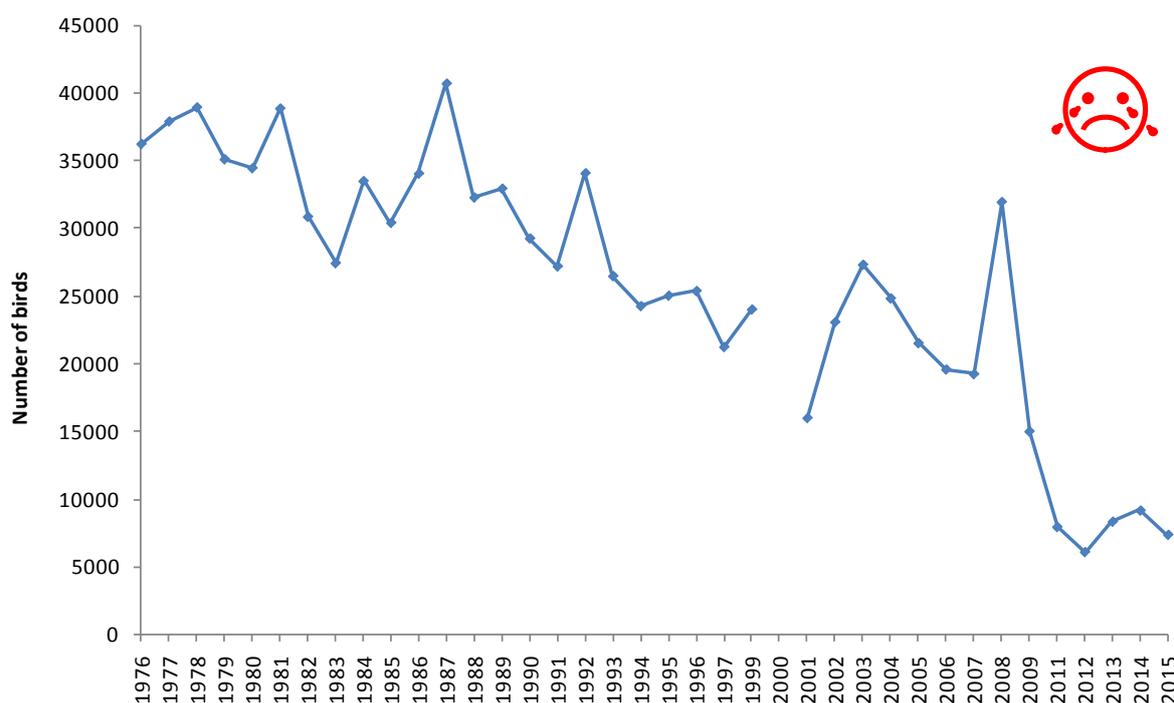


Figure 11.12. Long term trends in the numbers of summer migratory waders on Langebaan Lagoon (Data source: CWAC data, Animal Demography Unit at the University of Cape Town).

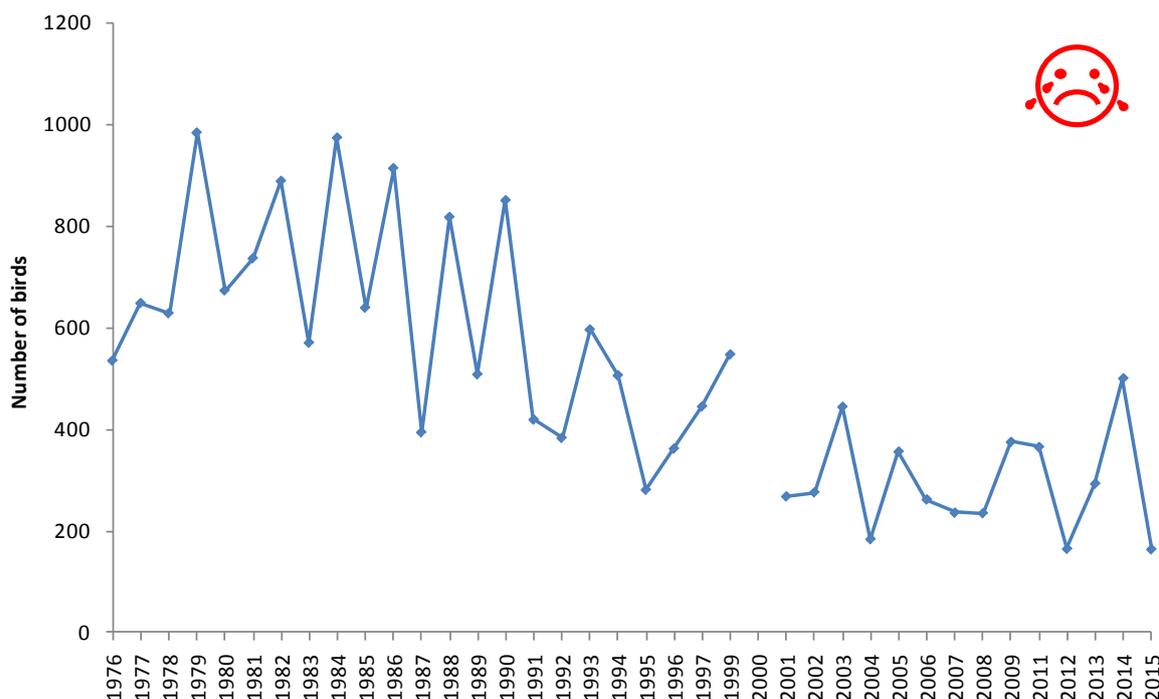


Figure 11.13. Long term trends in the numbers of winter resident waders on Langebaan Lagoon (Data source: CWAC data, Animal Demography Unit at the University of Cape Town).

11.4 Overall status of birds in Saldanha Bay and Langebaan Lagoon

Populations of two cormorant species, namely Bank Cormorants and Cape Cormorants, that utilise islands within the Saldanha Bay region for shelter and breeding, have decreased since early to mid-1990. In the past this has been attributed to the construction of the causeway linking Marcus Island to the mainland, and to increased human disturbance. However, given that the populations of several other seabirds that breed on these islands have not decreased over this period, it appears that declines in local availability of their principal prey species, (rock lobster and sardines), as well as egg and chick predation by pelicans and gulls may be the principal drivers. The Cape Gannet population on Malgas Island has also undergone severe decline due mainly to predation by Cape fur seals and more recently by Great White Pelicans. Predation by the seals was responsible for a 25% reduction in the size of the colony at Malgas Island, between 2001 and 2006. Management measures have been put in place, through selective culling of seals, which has improved conditions for the gannets at Malgas Island. The African Penguin populations are also under considerable pressure, partially due to causes unrelated to conditions on the island such as the eastward shift of the sardines, one of their main prey species. However, because populations are so depressed, conditions at the islands in Saldanha have now become an additional factor in driving current population decreases. Direct amelioration actions to decrease these impacts at the islands are difficult to find, however, support for conservation activities that improve penguin conservation, as a means to offset these impacts, should be considered. Most other species of seabirds investigated in this study in the Saldanha Bay region appear to have healthy populations with either stable or increasing numbers.

Decreasing numbers of migrant waders utilising Langebaan Lagoon reflects a global trend of this nature, largely due to increasing disturbance to breeding grounds of many species. Decreasing populations of resident waterbirds in Langebaan Lagoon over the period 1990-2012, a concern in itself, suggested that local conditions may be partly to blame for the decrease in migratory birds over the same period. This long-term trend is most likely due to unfavourable conditions persisting in Langebaan Lagoon as a result of anthropogenic impacts. Although wader numbers have not dropped below the lowest numbers as observed in 2012, it remains to be seen if winter resident wader populations remain stable, and if perhaps migratory waders are also stabilising at current levels. It is highly recommended that the status of key species continue to be monitored in future and that these data be made available and used as an indication of environmental conditions in the area.

12 ALIEN INVASIVE SPECIES IN SALDANHA BAY-AND LANGEBAAN LAGOON

To date 92 marine alien species have been recorded from South African waters (Zsilavec 2007, Mead *et al.* 2011a, Anchor Environmental Consultants 2011, Peters *et al.* 2014, *Pers. obs.* Prof. George Branch and Prof. Charles Griffiths, 2015). Seventy of these species are thought to occur along the west coast of South Africa, although only 30 have been confirmed from Saldanha Bay and/or Langebaan Lagoon to date (Table 12.1.). One of these species, the European porcelain crab *Porcellana platycheles* found in 2012 on Schaapen Island (*Pers. obs. Prof. George Branch*), has now been confirmed to occur in the study area (See Section 12.1). A small number of confirmed alien species in the study area are considered invasive, including the Mediterranean mussel *Mytilus galloprovincialis*, the European green crab *Carcinus maenas* (Griffiths *et al.* 1992, Robinson *et al.* 2005), the barnacle *Balanus glandula* (Laird & Griffiths 2008), and the Pacific South American mussel *Semimytilus algosus* (de Greef *et al.* 2013).

An additional 39 species are currently regarded as cryptogenic (of unknown origin and potentially introduced) but very likely introduced to South Africa. Of these, 20 are likely to be found in Saldanha Bay and/or Langebaan Lagoon and six have already been identified from the Bay. Comprehensive genetic analyses are urgently required to determine the definite status of these cryptogenic species (Griffiths *et al.* 2008).

Most of the introduced species in South Africa have been found in sheltered areas such as harbours, and are believed to have been introduced through shipping activities, for example ballast water discharge or hull fouling. As ballast water tends to be loaded in sheltered harbours, the species that are transported originate from these habitats and therefore have trouble adapting to South Africa's exposed coast. This might explain the low number of introduced species that have established along the coast (Griffiths *et al.* 2008) and the high number found in sheltered bays such as Saldanha.

Future surveys in Saldanha Bay will be used to confirm the presence of listed species and to ascertain if any additional or newly arrived introduced species are present. Current information on several key alien species in Saldanha Bay, some of which were identified through the State of the Bay monitoring programme, are presented below (Table 12.1.). Species occurrence in Saldanha Bay and/or Langebaan Lagoon is listed as either confirmed or likely (not confirmed from Saldanha Bay but inferred from the regional distribution of the species).

Table 12.1. List of introduced and cryptogenic species from Saldanha Bay and Langebaan Lagoon. Region of origin and likely vector for introduction (SB = ship boring, SF = ship fouling, BW = ballast water, BS = solid ballast, OR = oil rigs, M = mariculture, F = Fisheries activities, I = intentional release) are listed. Data extracted from Mead et al. (2011a & b) unless otherwise stated.

Taxon	Occurrence in Saldanha/Langebaan	Introduced/cryptogenic	Origin	Vector
<u>PROTOCTISTA</u>				
<i>Mirofolliculina limnoriae</i>	Likely	Introduced	Unknown	SB
<i>Zoothamnium</i> sp.	Likely	Cryptogenic	Unknown	SF
<u>DINOFLAGELLATA</u>				
<i>Alexandrium tamarense-complex</i>	Likely	Introduced	N Atlantic/N Pacific	BW
<i>Alexandrium minutum</i>	Likely	Introduced	Europe	BW
<i>Dinophysis acuminata</i>	Likely	Introduced	Europe	BW
<u>PORIFERA</u>				
<i>Suberites ficus</i>	Likely	Introduced	Europe	SF
<u>CNIDARIA</u>				
ANTHOZOA				
<i>Sagartia ornata</i>	Confirmed	Introduced	Europe	SF/BW
<i>Metridium senile</i>	Likely	Introduced	N Atlantic/N Pacific	SF/OR
<u>HYDROZOA</u>				
<i>Pachycordyle navis</i>	Likely	Introduced	Europe	SF/BW
<i>Coryne eximia</i>	Confirmed	Introduced	N Atlantic/N Pacific	SF/BW
<i>Pinauay larynx</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Pinauay ralphii</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Laomedea calceolifera</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Gonothyrea loveni</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Obelia bidentata</i>	Likely	Introduced	Unknown	SF/BW
<i>Obelia dichotoma</i>	Likely	Introduced	Unknown	SF/BW
<i>Obelia geniculata</i>	Likely	Introduced	Unknown	SF/BW
<u>ANNELIDA</u>				
POLYCHAETA				
<i>Boccardia proboscidea</i>	Confirmed	Introduced	Eastern Pacific	M
<i>Capitella</i> sp.	Likely	Cryptogenic	Unknown	SF/BW
<i>Polydora hoplura</i>	Confirmed	Introduced	Europe	SF/BW
<i>Dodecaceria fewkesi</i>	Likely	Introduced	North American Pacific	SF/BW
<i>Ficopomatus enigmaticus</i>	Likely	Introduced	Australia	SF
<i>Hydroides elegans</i>	Likely	Introduced	Indo-Pacific	SF/BW
<i>Neodexiospira brasiliensis</i>	Confirmed	Introduced	Indo-Pacific	SF/BW
<i>Janua pagenstecheri</i>	Likely	Introduced	Europe	SF/BW
<i>Simplicaria pseudomilitaris</i>	Likely	Cryptogenic	Unknown	SF/BW

Taxon	Occurrence in Saldanha/Langebaan	Introduced/cryptogenic	Origin	Vector
<u>CRUSTACEA</u>				
CIRRIPEDIA				
<i>Amphibalanus amphitrite amphitrite</i>	Confirmed (AEC 2014)	Introduced	Unknown	SF/BW
<i>Balanus glandula</i>	Confirmed	Introduced	North American Pacific	SF/BW
<i>Menesiniella regalis</i>	Confirmed (AEC 2014)	Introduced	North American Pacific	SF/BW
ISOPODA				
<i>Dynamene bidentata</i>	Likely	Introduced	Europe	SF/BW
<i>Paracerceis sculpta</i>	Likely	Introduced	Northeast Pacific	SF/BW
<i>Synidotea hirtipes</i>	Confirmed	Cryptogenic	Indian Ocean	SF/BW
<i>Synidotea variegata</i>	Confirmed	Cryptogenic	Indo-Pacific	SF/BW
<i>Ligia exotica</i>	Likely	Cryptogenic	Unknown	SB
<i>Limnoria quadripunctata</i>	Likely	Introduced	Unknown	SB
<i>Limnoria tripunctata</i>	Likely	Introduced	Unknown	SB
AMPHIPODA				
<i>Chelura terebrans</i>	Confirmed	Introduced	Pacific Ocean	SF/SB
<i>Ischyrocerus anguipes</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Erichthonius brasiliensis</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Erichthonius difformis</i>	Likely (Peters <i>et al.</i> 2014)	Introduced	Unknown, northern hemisphere	SF
<i>Cymadusa filosa</i>	Likely	Cryptogenic	Unknown	BS
<i>Caprella equilibra</i>	Likely	Cryptogenic	Unknown	SF/BW
<i>Caprella penantis</i>	Likely	Cryptogenic	Unknown	SF/BW
<i>Paracaprella pusilla</i>	Likely	Cryptogenic	Unknown	SF/BW
<i>Jassa marmorata</i>	Likely	Introduced	North Atlantic	SF/BW
<i>Jassa slatteryi</i>	Confirmed	Introduced	North Pacific	SF/BW
<i>Orchestia gammarella</i>	Confirmed	Introduced	Europe	BS
<i>Cerapus tubularis</i>	Confirmed	Introduced	North American Atlantic	BS
DECAPODA				
<i>Carcinus maenas</i>	Confirmed (G. Branch <i>pers. comm.</i>)	Introduced	Europe	SF/BW/OR
<i>Pinnixa occidentalis</i>	Confirmed (Anchor 2011)	Introduced	North American Pacific	BW
<i>Porcellana platycheles</i>	Confirmed (Branch and Griffiths <i>pers. comm.</i> 2015)	Introduced	Mediterranean	BW
<i>Xantho incicus</i>	Likely	Introduced	France	M
<u>INSECTA</u>				
<i>Cafius xantholoma</i>	Likely	Introduced	Europe	BS
<u>MOLLUSCA</u>				

Taxon	Occurrence in Saldanha/Langebaan	Introduced/cryptogenic	Origin	Vector
GASTROPODA				
<i>Littorina saxatilis</i>	Confirmed	Introduced	Europe	BS
<i>Castriona columbiana</i>	Likely	Introduced	North Pacific	SF/BW
<i>Tritonia nilsodhneri</i>	Likely (Zsilavec 2007)	Introduced	Europe	SF/BW
<i>Kaloplocamus ramosus</i>	Likely (Zsilavec 2007)	Introduced	Unknown	SF/BW
<i>Thecacera pennigera</i>	Likely	Cryptogenic	Unknown	SF/BW
<i>Anteaeolidiella indica</i>	Confirmed	Cryptogenic	Unknown	SF/BW
BIVALVIA				
<i>Mytilus galloprovincialis</i>	Confirmed	Introduced	Europe	SF/BW
<i>Ostrea edulis</i>	Likely	Introduced	Europe	M
<i>Crassostera gigas</i>	Confirmed (Haupt <i>et al.</i> 2010)	Introduced	Japan	M
<i>Semimytilus algosus</i>	Confirmed (de Greef <i>et al.</i> 2013)	Introduced	South Pacific	SF/BW
<i>Teredo navalis</i>	Likely	Introduced	Europe	SB
<i>Lyrodus pedicellatus</i>	Likely	Introduced	Unknown	SB
<i>Bankia carinata</i>	Likely	Cryptogenic	Unknown	SB
<i>Bankia martensi</i>	Likely	Cryptogenic	Unknown	SB
<i>Dicyathifer manni</i>	Likely	Cryptogenic	Unknown	SB
<i>Teredo somersi</i>	Likely	Cryptogenic	Unknown	SB
BRACHIOPODA				
<i>Discinisca tenuis</i>	Confirmed (Peters <i>et al.</i> 2014)	Introduced	Namibia	M
BRYOZOA				
<i>Watersipora subtorquata</i>	Confirmed	Introduced	Caribbean	SF
<i>Bugula neritina</i>	Likely	Introduced	Unknown	SF
<i>Bugula flabellata</i>	Likely	Introduced	Unknown	SF
<i>Conopeum seurati</i>	Confirmed	Introduced	Europe	SF
<i>Cryptosula pallasiana</i>	Confirmed	Introduced	Europe	SF
CHORDATA				
ASCIDIACEA				
<i>Ascidia sydneiensis</i>	Likely	Introduced	Pacific Ocean	SF
<i>Asciidiella aspersa</i>	Likely	Introduced	Europe	SF
<i>Botryllus schlosseri</i>	Likely	Introduced	Unknown	SF
<i>Ciona intestinalis</i>	Confirmed (Picker & Griffiths 2011)	Introduced	Unknown	SF
<i>Clavelina lepadiformis</i>	Confirmed (Picker & Griffiths 2011)	Introduced	Europe	SF

Taxon	Occurrence in Saldanha/Langebaan	Introduced/cryptogenic	Origin	Vector
<i>Cnemidocarpa humilis</i>	Likely	Introduced	Unknown	SF
<i>Corella eumyota</i>	Confirmed	Cryptogenic	Unknown	SF
<i>Diplosoma listerianum</i>	Confirmed	Introduced	Europe	SF
<i>Microcosmus squamiger</i>	Likely	Introduced	Australia	SF
<i>Trididemnum cerebriforme</i>	Confirmed	Cryptogenic	Unknown	SF
PISCES				
<i>Cyprinus carpio</i>	Likely	Introduced	Central Asia to Europe	I
<u>RHODOPHYTA</u>				
<i>Schimmelmannia elegans</i>	Likely	Introduced	Tristan da Cunha	BW
<i>Antithamnionella ternifolia</i>	Likely	Cryptogenic	Australia	SF/BW
<i>Antithamnionella spirographidis</i>	Confirmed	Introduced	North Pacific	SF/BW
<u>CHLOROPHYTA</u>				
<i>Codium fragile fragile</i>	Confirmed	Introduced	Japan	SF/BW
<u>VASCULAR PLANTS</u>				
<i>Ammophila arenaria</i>	Confirmed	Introduced	Europe	I
<i>Spartina maritima</i>	Confirmed	Cryptogenic	Europe	BS

12.1 The occurrence and spread of marine alien species in Saldanha Bay

12.1.1 European mussel *Mytilus galloprovincialis*

Mytilus galloprovincialis was first detected in South Africa (in Saldanha Bay) in 1979 (Mead *et al.* 2011b) but was only confirmed in 1984 (Grant *et al.* 1984, Grant & Cherry 1985). At this stage the population was already widespread in the country, being the most abundant mussel species on rocky shores between Cape Point and Lüderitz. This species has subsequently extended its distribution range as far as East London (Robinson *et al.* 2005). It is suspected that *Mytilus* was most likely first introduced to the country between the late 1970s and early 1980s (Griffiths *et al.* 1992) and the reason for the late detection is due to the fact that it is easily confused with the indigenous black mussel, *Choromytilus meridionalis*. *Mytilus* is, however, easily distinguished by the trained eye, being fatter, and having a pitted residual ridge. The preferred habitat of the two species also differs with *Mytilus* occurring higher on the shore and away from sand-inundated sites (Figure 12.1). The alien mussel is commercially cultured in Saldanha Bay and elsewhere, and is widely exploited by recreational and subsistence fishers (Robinson *et al.* 2005 & 2007a).

In Europe, *M. galloprovincialis* is known to form dense subtidal beds directly on sandy bottoms (Ceccherelli & Rossi 1984), while it is typically found on exposed rocky shores in southern Africa. *Mytilus* began establishing dense intertidal beds on the sandy centre banks of Langebaan Lagoon in the mid-1990s (Hockey & van Erkom Schurink 1992, Hanekom & Nel 2002, Robinson & Griffiths 2002, Robinson *et al.* 2007a), with biomass peaking at an estimated 8 tonnes in 1998 (Robinson & Griffiths 2002). The population subsequently crashed, decreasing in size by 88% by early 2001 (Hanekom & Nel 2002) and had died off completely by mid-2001, leaving only empty shells and anoxic sand (Robinson *et al.* 2007a). The reason for the die off is still not clear, and impacts on the macrobenthic infauna on the banks was evident for at least six months after most of the dead mussel shells had been removed by SANParks in late 2001.



Figure 12.1 European mussel *Mytilus galloprovincialis*. (Photo: Prof. C.L. Griffiths.)

Data from the State of the Bay surveys suggest that *Mytilus* occurs mainly on exposed rocky shores in Saldanha Bay (i.e. North Bay, Iron Ore Jetty, Marcus Island and Lynch Point) and is present in low numbers at the more sheltered sites (Dive School, Jetty and Schaapen Island East and West). Populations grew fairly rapidly in the period 2005 until 2012/2013 at most exposed sites, after which populations declined or stabilized. The average percentage of the shore covered by this species across all sites increased from 5.4% in 2005 to 11.1% in 2012, and has since stabilized at approximately 7%. The Iron Ore Terminal site was slightly different in that populations initially contracted (2005-2011) but have been expanding steadily since then. *M. galloprovincialis* is still by

far the most dominant faunal species on the rocky shore, and covers 100% of the available space across substantial portions of the shore at some sites. It reaches its highest densities low down on the shore, in areas exposed to high wave action.

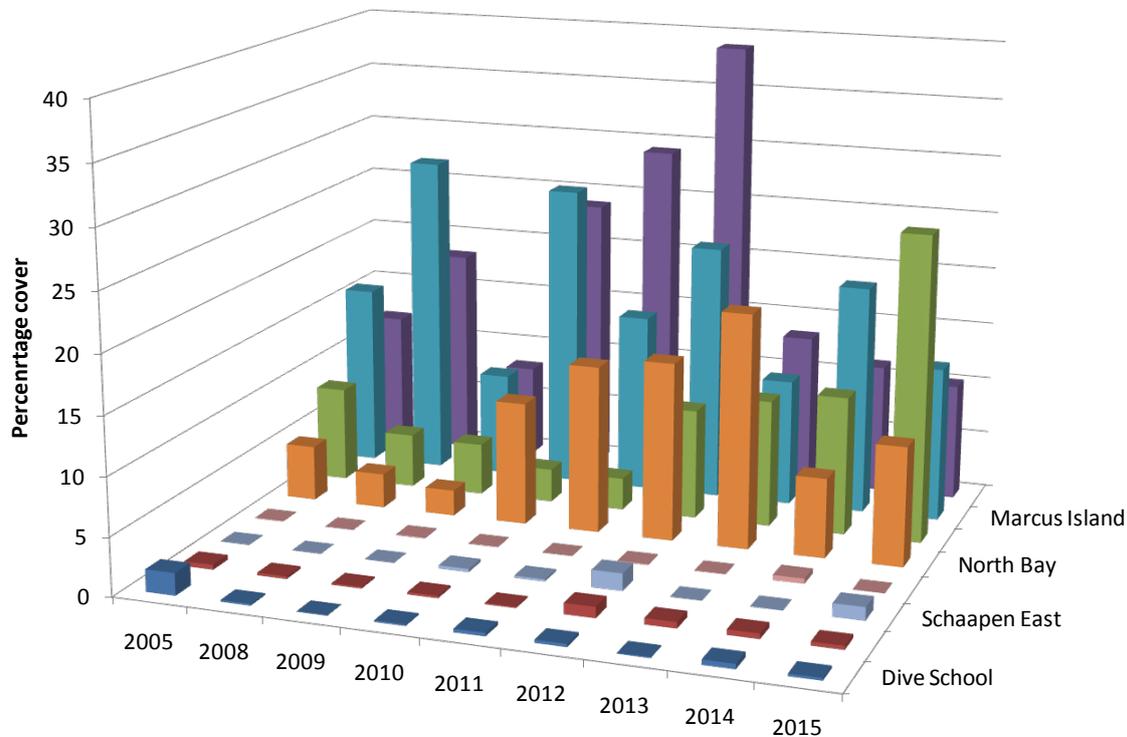


Figure 12.2. Changes in the abundance (% cover) of the Mediterranean mussel *Mytilus galloprovincialis* at eight rocky intertidal sites in Saldanha Bay over the period 2005-2015. Information of the locations of these sampling stations is provided in Chapter 8.

12.1.2 European shore crab *Carcinus maenas*

Carcinus maenas is a native European crab species that has been introduced on both the Atlantic and Pacific coasts of North America, in Australia, Argentina, Japan and South Africa (Carlton & Cohen 2003) (Figure 12.3). It is typically restricted to sheltered, coastal sites and appears thus far to have been unable to establish on the open wave-swept coastline in South Africa (Hampton & Griffiths 2007). In South Africa, it was first collected from Table Bay Docks in 1983 and later in Hout Bay Harbour. It has established dense populations in both harbours where it has reportedly decimated shellfish populations (Robinson *et al.* 2005). Surveys in Saldanha Bay have not turned up any live



Figure 12.3 European shore crab *Carcinus maenas*. (Photo: Prof. C.L. Griffiths).

specimens of this species to date, but a single dead specimen was picked up by Robinson *et al.* (2004) in Small Bay at the Small Craft Harbour. Due to a lack of specimens, it is unlikely that there is an extant population in Saldanha Bay at present.

12.1.3 Shell worm *Boccardia proboscidea*

Boccardia proboscidea is a small (20 mm long) tube-dwelling worm found in shallow sand-lined burrows on the surfaces of oysters, abalone and other shellfish. It occurs naturally on the Pacific coast of North America and Japan (Simon *et al.* 2009, Picker & Griffiths 2011). In South Africa it is known to occur on a number of oyster and abalone farms and has also recently been recorded in Saldanha Bay outside aquaculture facilities (Haupt *et al.* 2010).

12.1.4 Pacific South American mussel *Semimytilus algosus*

The Pacific South American mussel *Semimytilus algosus* is a small (up to 50 mm) elongated, relatively flat and smooth brown mussel, with a green tinged shell. This species has been long known from Namibia (since the 1930s, Kensley & Penrith 1970) but was only recently (2010) found in South Africa. It reportedly occurs in huge densities of thousands of individuals per square metre low on the shore, along most of the West Coast of South Africa. It is likely that it was transported southwards from Namibia either by shipping as a



Figure 12.4 Pacific South American mussel *Semimytilus algosus* (Photo: Prof. C.L. Griffiths)

new invasion or through range expansion from the Namibian population (University of Cape Town, C.L. Griffiths, *pers. comm.*). This species shows a strong preference for wave exposed shores (University of Cape Town, C.L. Griffiths, *pers. comm.*) and thus is unlikely to reach high densities in Saldanha Bay. It has, however, been observed on the ropes of mussel farms in Saldanha Bay.

12.1.5 Acorn barnacle *Balanus glandula*

The presence of *B. glandula*, which originates from the Pacific coast of North America, was first recognized in 2008 (Laird & Griffiths 2008, Simon-Blecher *et al.* 2008). It seems, however, that this species has been in South Africa since at least the early 1990s. It is now the most abundant intertidal barnacle in Saldanha Bay and indeed along much of the southern west coast (Laird & Griffiths 2008). *B. glandula* looks very similar to the indigenous species, *Chthamalus dentatus*, which may account for the fact that it went undetected for so long (Figure 12.5). *B. glandula* has reportedly displaced populations of the indigenous and formerly abundant *C. dentatus* species which is now very rare on South African west coast shores (Laird & Griffiths 2008). *B. glandula* was first

correctly identified in the State of the Bay surveys in Saldanha Bay in 2010 but it is very likely, however, that it had been present during the baseline surveys in 2005 and 2008-2009 but was identified as the indigenous barnacle species. Abundance of this species was very high when it was first detected in 2010 (three sites had > 5% cover and one site >20 % cover but has been declining steadily since then at most sites and now only occupies more than 5% of the shore at the Iron Ore Jetty site (Figure 12.6).



Figure 12.5 Acorn barnacle *Balanus glandula* (Photo: Prof. C.L. Griffiths)

The State of the Bay surveys (Anchor Environmental Consultants 2012) and studies conducted elsewhere suggest that this species competes directly with other alien species for space on the shore. For example, expanding populations of the Mediterranean mussel *Mytilus galloprovincialis* may be displacing this species. Nevertheless, it remains one of the most abundant species on the shore in Saldanha Bay and is still of significant concern.

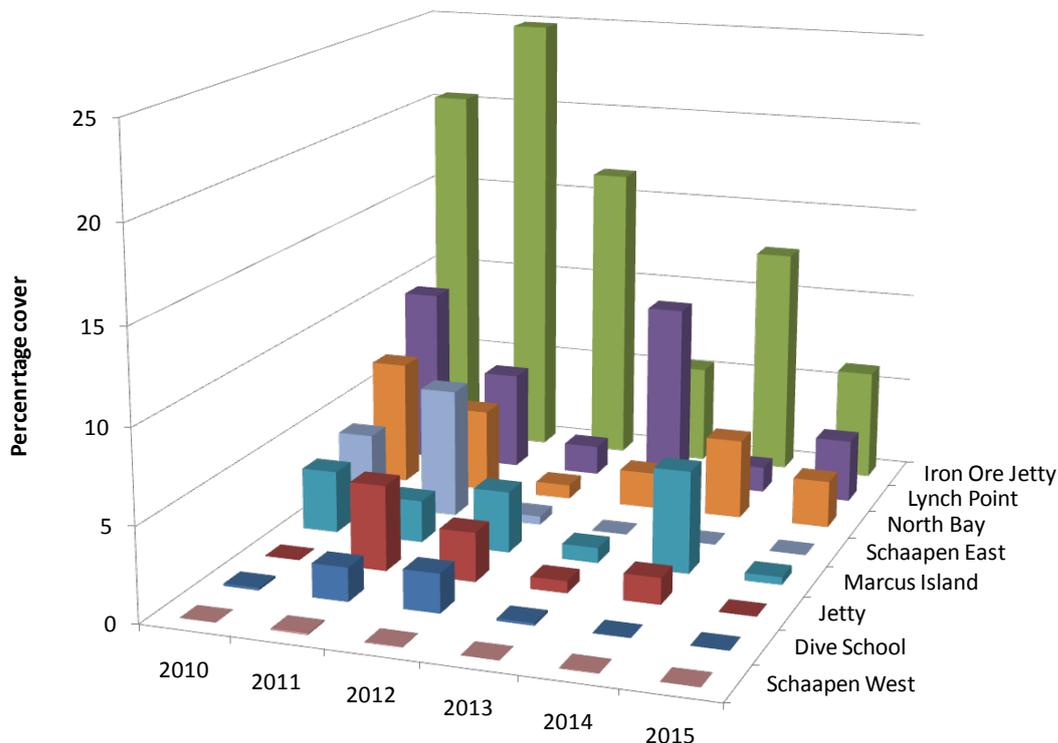


Figure 12.6. Changes in the abundance (% cover) of the acorn barnacle *Balanus glandula* at eight rocky intertidal sites in Saldanha Bay over the period 2010-2015. Information of the locations of these sampling stations is provided in Chapter 8.

12.1.6 Alien barnacle *Menesiniella regalis*

This species is known only by its scientific name *Menesiniella regalis* and as yet has not been assigned a common name. The presence of *M. regalis* in Saldanha Bay was first recognised in 2011 and was picked up as “an unfamiliar barnacle” at the Dive School in Saldanha Bay as part of the intertidal rocky shore survey in that year. It constitutes the first known record of this barnacle species in South Africa. This species is included in the Sub-family, *Concavinae* (Pitombo 2004) – animals an extended sheath and longitudinal abutment present on the inner surface of the radii and a bifid sutural edge present on the alga. Characters of the terga; a pronounced beak, closed spur-furrow and absence of longitudinal striations (Newman 1982, Zullo 1992) confirm the identification to species level (Figure 12.7).

This species originates from the Pacific coast of North America, with live material recorded intertidally from Baja California, Mexico (Pilsbry 1916). It is difficult to tell when exactly it was reduced to Saldanha Bay in South Africa as, to the untrained eye based on external appearance, it can be easily confused with the local volcano barnacle, *Tetraclita serrata*. However, past reports from the annual State of the Bay monitoring programme have shown that *Tetraclita serrata* has never been recorded at the dive school in Saldanha Bay and that *Menesiniella regalis* appeared for the first time in April 2011. It is likely that the introduction of this species occurred via shipping given the high amount of shipping traffic in Saldanha Bay much like the alien acorn barnacle, *Balanus glandula*, which was also introduced from the Pacific coast of North America (Laird & Griffiths 2008).



Figure 12.7 *Menesiniella regalis* (Pilsbry, 1916) (Photograph: Dr. Nina Steffani)

12.1.7 Amphibalanus amphitrite amphitrite

This alien barnacle species was recorded from Saldanha Bay in the baseline survey in 2005. Only in 2012 this species was recognised to be *Amphibalanus amphitrite amphitrite*, an alien barnacle which is a prolific fouling species worldwide. This species has longitudinal striations on the exterior shell, which is marked with thick, sparse, purple longitudinal stripes (Figure 12.8). *A. amphitrite amphitrite* is easily confused with another ‘purple-pink striped’ species which has not yet been identified (Biccard 2012).



Figure 12.8 *Amphibalanus amphitrite amphitrite* (Photo: Prof. C.L. Griffiths)

12.1.8 Disc lamp shell *Discinisca tenuis*

The disc lamp shell *Discinisca tenuis* is a small (20 mm diameter) disc shaped brachiopod with a semi-transparent, hairy, fringed shell (Figure 12.9). It was first recorded clinging on oysters grown in suspended culture in Saldanha Bay in 2008 (Haupt *et al.* 2010). More recently, it has been reported as living freely outside of the oyster culture operation on Schaapen Island (Peters *et al.* 2014). This species is endemic to Namibia and is thought to have been introduced to South Africa with cultured oyster imports from this country (Haupt *et al.* 2010). This species reportedly reaches very high densities in its home range and could become a significant fouling species in Saldanha Bay in the foreseeable future, although no previous history of invasion exists for this brachiopod.



Figure 12.9 Disc lamp shell *Discinisca tenuis* (Photo: Prof. C.L. Griffiths)

12.1.9 Brooding anemone *Sagartia ornata*

The only known records of the brooding anemone *Sagartia ornata* in South Africa are from Langebaan Lagoon (West Coast National Park), where it occurs intertidally in seagrass beds, attached to rocks covered by sand, and in loose rocks resting on fossilized oyster beds (Acuña *et al.* 2004, Robinson *et al.* 2004, Picker & Griffiths 2011, Robinson & Swart 2015). *S. ornata* was first detected in 2001 (Acuña *et al.* 2004) and was probably introduced unintentionally through shipping via the Saldanha Bay harbour (Robinson *et al.* 2004). Its home range extends throughout Western Europe, Great Britain and the Mediterranean (Manuel 1981), where it occurs in crevices on rocky shores and on kelp holdfasts (Gibson *et al.* 2001). Invading species commonly exploit novel habitats, which may reflect the adaptive ability of *S. ornata*.

Robinson & Swart (2015) recently established the current status and distribution of this alien anemone, which represents the first comparison to the baseline data collected in 2001 (Robinson *et al.* 2004). The distribution of *S. ornata* has changed within the lagoon and the species is now found in *Nanozostera capensis* (Cape eelgrass) instead of in *Spartina maritima* (spiky cord grass) beds. No apparent reason explains the increase in *S. ornata* abundance compared to 2001 (increasing from 426 ± 81 to 508 ± 218 individuals per m^2). Invaded sandy-shore areas support a higher invertebrate abundance, biomass and diversity, as well as altered community structures and appear to be impacted by *S. ornata*, less



Figure 12.10 Brooding anemone *Sagartia ornata* (Photo: Prof. C.L. Griffiths)

so through its role as a predator, but rather as a result of impacts on the habitat structure and associated indirect impacts on native biota (Robinson & Swart 2015). *S. ornata* consolidates sand and traps coarse sediment (Robinson *pers. obs.*), which has the potential to significantly change the soft sediment system by altering abiotic factors (e.g. water movement, sediment characteristics) (Ruiz *et al.* 1997, Berkman *et al.* 2000, McKinnon *et al.* 2009).

The habitat types currently preferred by *S. ornata* in South Africa are geographically restricted and limit the potential of this alien species to significantly affect indigenous biota within the WCNP. However, it has the potential to spread more widely into Saldanha Bay and along the South African west coast, where conditions and habitats are similar to that in its home range (Robinson & Swart 2015).

12.1.10 Lagoon snail *Littorina saxatilis*

Littorina saxatilis was first recorded in South Africa in 1974 (Day 1974), and the only known populations are those in Langebaan and Knysna lagoons (Hughes 1979, Robinson *et al.* 2004, Picker & Griffiths 2011). In its home range in the North Atlantic this species occurs in crevices on rocky shores (Gibson *et al.* 2001), but in South Africa it is restricted to sheltered salt marshes and lagoons, where it occurs on the stems of the cord grass *Spartina maritima* (Hughes 1979). It occurs only in the upper reaches of Langebaan Lagoon, between Bottelary and Churchhaven, and has not spread further afield than this in at least 20 years (Robinson *et al.* 2004). It is not considered to be a major threat to the Lagoon or Bay ecosystems.



Figure 12.11 Lagoon snail *Littorina saxatilis* (Photo: Prof. C.L. Griffiths)

12.1.11 Hitchhiker amphipod *Jassa slatteri*

Jassa slatteri is a small (9 mm) inconspicuous amphipod that constructs tubes of soft mud or crawls around on seaweeds, hydroids and other marine growth (Colan 1990, Picker & Griffiths 2011). It is common on piers, buoys and other structures in Saldanha Bay. It is suspected that it was introduced directly via ship fouling or ballast water transfer from its native habitat in Pacific North America or another infected temperate harbour where they are common. It is small and occurs in high densities and is probably a valuable food source for fish and other predators.



Figure 12.12 Hitchhiker amphipod *Jassa slatteri* (Photo: Prof. C.L. Griffiths)

12.1.12 Dentate moss animal *Bugula dentata*

Bugula dentata is a bryzoan (lace animal) that forms colonies up to 50 mm tall and looks superficially like seaweed. It attaches to hard surfaces such as ship hulls, wharfs and rocks, hanging vertically in the water. It was introduced to South Africa from the Indo-Pacific region, very early on in our history (first report in 1852). It is common and a minor nuisance as a fouling species and occurs along much of the South African coast (Florence *et al.* 2007, Picker & Griffiths 2011).



Figure 12.13 Dentate moss animal *Bugula dentata* (Photo: Prof. C.L. Griffiths)

12.1.13 Vase tunicate *Ciona intestinalis*

Ciona intestinalis is a tall (15 cm), cylindrical yellowish solitary ascidian with a soft floppy, transparent test. It forms large aggregations on submerged structures in harbours and lagoon from Saldanha Bay to Durban (Figure 12.14). It was originally introduced from North Atlantic prior to 1955. It is an economically important pest as it rapidly fouls hard marine surfaces. It is known to smother and kill mussels on aquaculture facilities, especially mussel ropes.



Figure 12.14 A typical aggregation of *Ciona intestinalis* (Photo: National Museums Northern Ireland).

12.1.14 Jelly crust tunicate *Diplosoma listerianum*

Diplosoma listerianum is a colonial sea squirt that forms thin, fragile, yellow to dark grey jelly-like sheets up to 50 cm in diameter that grow over all types of substrata on sheltered shores between Alexander Bay and Durban (Monniot *et al.* 2001, Picker & Griffiths 2011). It is believed to have been accidentally introduced from Europe prior to the 1949, probably as a fouling organism.



Figure 12.15 Jelly crust tunicate *Diplosoma listerianum* (Photo: Prof. C.L. Griffiths).

12.1.15 Dirty sea squirt *Ascidella aspersa*

Ascidella aspersa is a medium sized (10 cm), solitary sea squirt that occurs on the west coast between Saldanha Bay and Table Bay (Monniot *et al.* 2001, Picker & Griffiths 2011) (Figure 12.16). It was introduced from Europe and is normally found attached to ropes and floating pontoons in harbours. This species can form aggregations with others of the same species or other fouling species.



Figure 12.16 *Ascidella aspersa* is often found covered in epibionts (Photograph: Arjan Gittenberger).

12.1.16 European porcelain crab *Porcellana platycheles*

The European porcelain crab *Porcellana platycheles* commonly occurs on boulder beaches in the lower mid-shore level (Smaldon 1972) in the Mediterranean Sea and east Atlantic (WoRMS 2015). In 2012, *P. platycheles* was found in some numbers for the first time in South Africa on Schaapen Island, Langebaan Lagoon (*Pers. obs.* Prof. George Branch, 2012). *P. platycheles* is euryhaline and can therefore adapt to a wide range of salinities (Davenport 1972). Not much else is known about its potential to adapt to novel environments and so far, no invasions of *P. platycheles* have been recorded outside its native range. *P. platycheles* occurs intertidally under boulders in the colder east Atlantic and the warm Mediterranean Sea and this species may therefore have the potential to establish and spread in similar habitats along the coastline of South Africa (Figure 12.17). Professor Charles Griffiths (Department of Zoology at the University of Cape Town) is intending to follow up on this discovery and establish its current distribution in Saldanha Bay and Langebaan Lagoon.

12.1.17 Western pea crab *Pinnixa occidentalis*

The Western Pea crab *Pinnixa occidentalis* (Figure 12.18) was originally described from California by MJ Rathbun in 1893, but is presently reported to occur along the whole west coast of North America from Alaska to Mexico (Ocean Biogeographic Information System 2011). The depth range distribution for this species is reported to range from 11-319 m. This species was identified in the collections from the Saldanha Bay State of the Bay surveys in 2010 (Anchor Environmental Consultants 2011), although it was previously listed as unidentified. It appears to have established itself in the Bay in the period between 1999 (at which time no specimens were recorded in a comprehensive set of samples from Saldanha Bay) and 2004 when it was recorded at four of the 25 sampling sites in Saldanha Bay. The average abundance of this species at the time was 36.5 individuals per m².

Since then, the number of sites where this species has been detected has increased over time, reaching a peak of eight sites in 2013 and 2014 and a peak density of 44 individuals per m² in 2013. It put in a brief appearance at one site in Langebaan Lagoon in 2009 and again in 2014, but abundance at these sites was very low in comparison to Saldanha Bay (Figure 12.19). This suggests that the lagoon habitat may not be entirely suited to the species, which favours deeper water (>10 m) in its native range (Ocean Biogeographic Information System 2011). This year, *P. occidentalis* was found for the first

time in Danger Bay, occurring at one of 13 sites sampled, albeit in low numbers (average of 0.71 organisms per m²). These data suggest that *P. occidentalis* is now well established in Small Bay and Big Bay and may be in the process of expanding into more exposed and deeper habitats outside of the Bay, including Danger Bay.



Figure 12.17 European porcelain crab *Porcellana platycheles* (Photo: Prof. C.L. Griffiths).



Figure 12.18 Western pea-crab *Pinnixa occidentalis* (Photograph: Anchor Environmental Consultants).

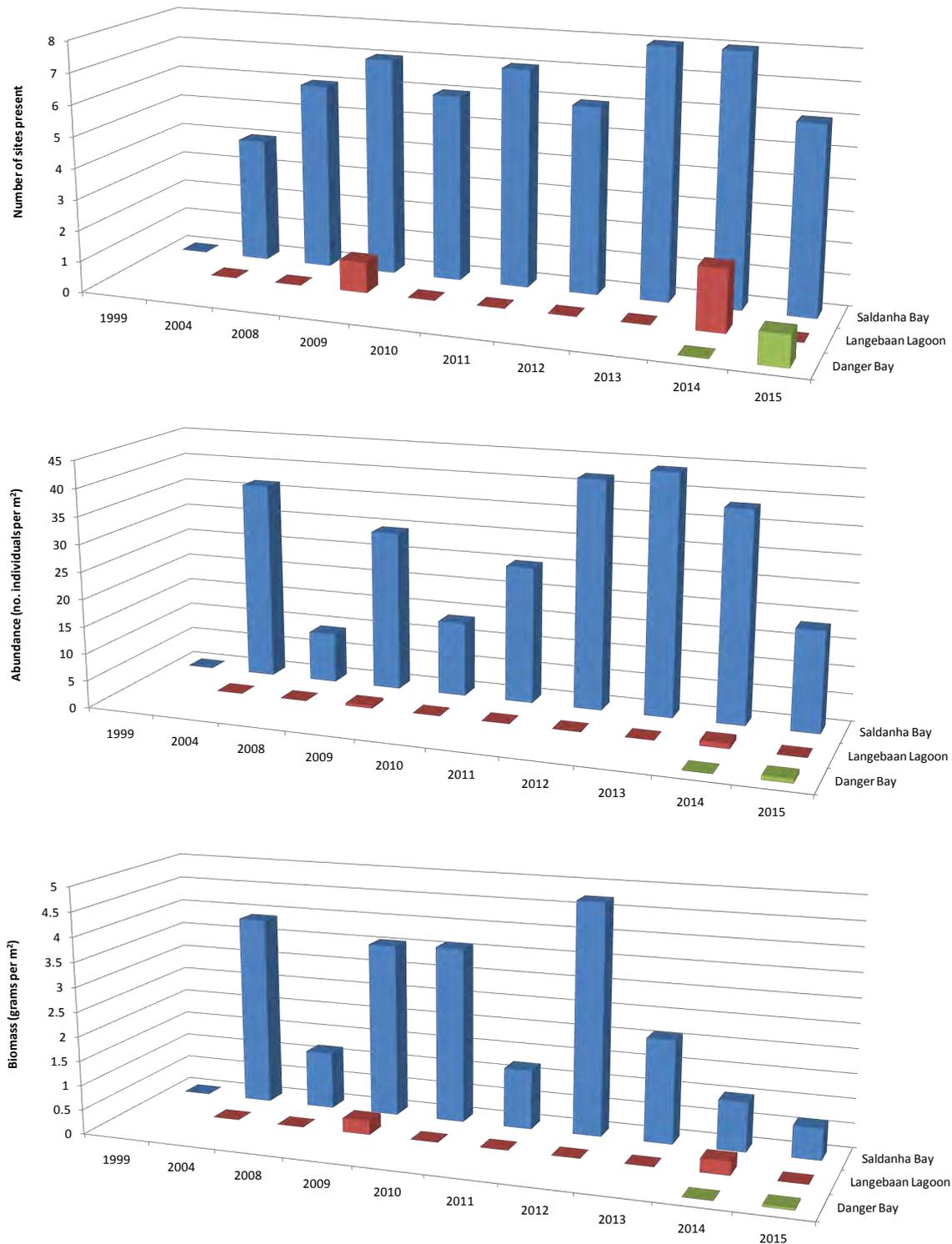


Figure 12.19 The number of sites (top) at which the Western Pea crab *Pinnixa occidentalis* has been recorded in Saldanha Bay, Langebaan Lagoon and Danger Bay in the period 1999-2015, the abundance of the crab (middle) and the biomass (bottom) of the crab over time per square metre. Note that Langebaan Lagoon and Danger Bay were first sampled in 2004 and 2014 respectively.

13 MANAGEMENT AND MONITORING RECOMMENDATIONS

Monitoring of aquatic health and activities and discharges potentially affecting health of Saldanha Bay and Langebaan Lagoon has escalated considerably in recent years owing to concerns over declining health in the Bay. This section provides a summary of the state of health of Saldanha Bay and Langebaan Lagoon as reflected by the various environmental parameters reported on in this study. It also briefly describes current monitoring efforts and provides recommendations as to management actions that need to be implemented in order to mitigate some of the threats that have been detected. It also provides recommendations on how existing monitoring activities may need to be modified in the future to accommodate changes in the state of the Bay.

13.1 Activities and discharges affecting the health of the Bay

Continuously accelerating urban and industrial development is an important driver of habitat fragmentation and loss of ecological integrity of remaining marine and coastal habitats in Saldanha Bay and Langebaan. The current and future desired state of the greater Saldanha Bay area is polarised, where industrial development (Saldanha Bay IDZ and associate industrial development) and conservation areas (Ramsar Site, MPAs and National Parks) are immediately adjacent to one another. Furthermore, the Saldanha Bay environment supports conflicting uses including industry, fishery, mariculture, recreation and the natural environment itself. This situation necessitates sustainable development that is steered towards environmentally more resilient locations and away from sensitive areas.

Shortcomings that inhibit project-level EIAs role as a tool for achieving sustainable development are widely documented. This can be attributed to the reactive and piecemeal focus at project level as opposed to an approach that is capable of anticipating and assessing changes to affected ecosystems beyond property boundaries. Inefficiencies arising from fragmented, activity-based EIA procedures can be countered by means of a strategic environmental management approach, which places a proposed activity within the environmental context of a particular geographical area. Accordingly a draft Environmental Management Framework (EMF) for the Greater Saldanha Bay Area (DEADP 2015) has been available since February 2015 and it is strongly recommended that the EMF is adopted by the DEADP in terms of NEMA.

The SBWQFT is currently lobbying the relevant Provincial and National authorities to have Saldanha Bay declared a “Special Management Area” in terms of the ICMA to aid in more effective conservation of natural resources in Saldanha Bay and Langebaan Lagoon. In terms of section 23 (1) (a) of the Act, the Minister to publish a notice in the *Government Gazette* to declare an area that is wholly or partially within the coastal zone to be a special management area. The Minister also has the power to prohibit certain activities should these activities be considered contrary to the objectives of the special management area. Considering the great conflict between the various uses of the Saldanha Bay and Langebaan Lagoon marine environment, it is strongly recommended that this management intervention be adopted by the Minister.

13.1.1 Human settlements and storm water

Human settlements surrounding Saldanha Bay and Langebaan Lagoon have expanded tremendously in recent years. This is brought home very strongly by population growth rates of 9.24% per annum in Langebaan and nearly 2.66% in Saldanha over the period 2001 to 2011 (Statistics South Africa 2014). Numbers of tourists visiting the area every year have also increased by 13% per annum since 2005. This rapid rate in development translates to proportional increase in the amounts of waste and wastewater that is produced and has to be treated. Expansion and upgrades of treatment facilities have for the most part not been able to cope with such a rapid rate of expansion, with the result that much of the effluent produced is discharged to the environment without adequate treatment. The amount of hardened (as opposed to naturally vegetated) surfaces surround the Bay and Lagoon have also expanded at break-neck speed in recent years, with concomitant increases in volumes of contaminated storm water running off into the Bay. The contaminant loads in wastewater is not adequately monitored (e.g. there is no monitoring of storm water quality or run off from Saldanha or Langebaan, trace metals in ballast water have not been assessed since 1996, trace metals in bivalves assessed through the mussel watch programme was last available in 2007), nor is it adequately controlled at present (e.g. the Saldanha and Langebaan wastewater treatments works still operate off an exemption issued under the National Water Act (No. 36 of 1998) in spite of the fact that the ICMA with attendant water quality guidelines was enacted in 2009 and came into force in 2011). The contribution to trace metal and organic loading in the Bay from these sources is thus largely unknown, but is of concern.

Historically, insufficient provision was made for buffers zones around the Lagoon and Bay with the result that development encroaches right up to the waters' edge and is now widely threatened by coastal erosion. An Environmental Management Programme (EMPr) to upgrade and maintain mitigation measures for the prevention of erosion was accepted by the Western Cape Department of Environmental Affairs & Development Planning (DEA&DP) and implementation for some of these have been successful to date. Furthermore, coastal management lines were produced for the West Coast District Municipality (WCDM) and are currently in preparation to be published in the *Government Gazette* for public comment. Although not yet promulgated, these coastal management lines have already been used to inform planning and development decisions in Saldanha Bay, taking into account short, medium and long-term risks alongside the consideration of the time frame and value of the proposed development.

Disturbance from increasing numbers of people recreating in the Bay and lagoon of is taking its toll of sensitive habitats and species, especially seagrass, water birds and fish in Langebaan Lagoon. Small Bay in particular is becoming increasingly industrialised and this is now threatening the vitally important nursery function of this area for important commercial and recreational fish species.

Urgent management intervention is required to limit further degradation of the environment from these pressures, and should focus on the following issues in particular:

- Ensuring that all discharges to the Bay are properly licensed and adequately monitored (both volume and water quality) and that the quality of the effluent at the edge of the mixing zone is compliant with existing South African Water Quality Guidelines for the Coast Zone and any other legislative requirements;

- Implementation of the coastal management lines around the perimeter of the Bay and Lagoon and allow for adequate protection of the environment and infrastructure arising from current and future (i.e. climate change) pressures; and
- Sensitive habitats and fauna and flora in the Bay are assigned levels of protection that ensure minimal disturbance to these areas/populations.

13.1.2 Dredging

Dredging interventions in the Bay in the past, particularly those associated with the Iron Ore Terminal have been shown to have devastating impacts on the ecology of the Bay. Effects of the most recent major dredging event are still discernable in the sediments and faunal communities in the Bay more than a decade after their occurrence. Likely ecological impacts arising from any future proposed dredging programmes need to be carefully considered and these need to be weighed up against social and economic benefits that may be derived from such programmes or projects. Where such impacts are unavoidable, mitigation measures applied must follow international best practice and seek to minimize impacts to the ecology of the Bay. Even relative small dredging operations, such as those undertaken as part of the upgrade of the naval boatyard at Salamander Bay, can have very wide reaching impacts on the Bay and Lagoon.

13.1.3 Wastewater treatment in Saldanha Bay

Effluent from two wastewater treatment works (Saldanha and Langebaan) finds way into the Bay at present. The Saldanha Wastewater Treatment Works (WWTW) operates on an exemption issued by the Department of Water Affairs and Forestry (DWAF) in terms of the Water Act of 1956 which authorises the release of a total volume of 958 000 m³ into the Bok river (and ultimately Saldanha Bay) per year. Until recently the Langebaan WWTW did not discharge any effluent into the sea as all of it was used to irrigate the local golf course. However, increasing volumes of effluent received by this plant is yielding more water than is required for irrigation and some of this is now discharged into the Bay. This is an illegal activity in terms of the National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008), which prohibits the discharging of effluent into a Marine Protected Area (MPA). A directive has been issued to the municipality to correct this. There are also 16 sewage pump stations in Saldanha and 27 sewage pump stations in Langebaan many of which are situated very close to the waters' edge. These pump stations have periodically malfunctioned in the past (often due to power failures) with the result that raw untreated sewage directly flowing into the Bay threatening human health and mariculture operations. To address this problem, nearly all pump stations have been upgraded since 2012 and several pump stations have also been fitted with emergency generators. Approximately 200 conservancy tanks are mostly situated in Langebaan and are emptied by the municipality on a regular basis and do not pose a direct threat to the Langebaan Lagoon.

Effluent data compared to applicable legal limits shows that neither the Saldanha nor the Langebaan WWTWs are able to keep up with the ever increasing supply of wastewater generated by the surrounding industry and residential areas, a fact that is evidenced by chronic non-compliance with the applicable wastewater standards (revised General Discharge Limit of the General and Special

Standard, *Government Gazette* No. 36820– 6 September 2013). Thirty six million Rand have been set aside for the upgrades to upgrade the Saldanha Bay WWTW is to double the treatment capacity and to ensure that additional inputs from the IDZ can be adequately treated in future. . A consultant has been appointed to conduct a feasibility study to determine the best possible options for the re-use of treated effluent during the winter months to prevent future overflow of effluent. Furthermore, the SBM is currently in the process of appointing a consulting engineer for proposed R5 million upgrades to the plant over the next two years. The NWA allows the disposal of effluent into the municipal system and the responsibility lies with the local municipalities to adequately treat the effluent. There are no national standards to regulate the quality of effluent that is delivered to the municipalities by the industries and local by-laws are not sufficient to regulate the volume and quality of effluent received by the industry (Eddy, 2003).

Apart from the necessity to upgrade municipal wastewater treatment facilities, local government must first and foremost ensure that the quantity and quality of effluent is controlled at the source to relief the pressure on municipal sewage systems. This can be done by means of stricter by-laws, which regulate the water quality required when industrial wastewater enters the municipal wastewater treatment system. Finally, it is strongly recommended that the local municipality should embark on an educational mission to create awareness among residents to reduce waste disposed down the drain to an absolute minimum.

13.1.4 Fish factories

It appears that at least two out of three operational fish processing plants do not monitor their effluent for compliance purposes, an issue that should be addressed as a matter of urgency. Sea Harvest has applied for a Coastal Waters Discharge Permit (CWDP) and operates under a water use license issued in November 2011 but which has expired and it is unknown whether a new or updated license was issued.

Inspection of Sea Harvest's expired water use license has revealed that the license was issued for a reverse osmosis plant rather than to a fish processing plant and is hence not suitable to regulate the type of effluent discharged by Sea Harvest. Sea Harvest has adjusted its water monitoring programme in accordance with the new licence conditions and as a result, is no longer collecting data on ammonia nitrogen, dissolved organic carbon, faecal coliforms or *E. coli*. Ammonia nitrogen levels in Sea Harvest's effluent have in the past, without exception, exceeded the 6 mg/l threshold level in the General Discharge Limits of the revised General and Special Standard (*Government Notice* No. 36820 –6 September 2013). Data collected between March 2010 and December 2014 show average ammonia nitrogen levels of 99 ± 86 mg/l with a maximum of 474 mg/l measured in September 2012 (Figure 3.45). It is thus recommended that Sea Harvest resumes measuring ammonia nitrogen and that the authorities rectify the error in the permit that has been issued.

It is also strongly recommended that chemical oxygen demand (COD) is monitored in future to establish how much oxygen will be required by bacteria to breakdown the organic waste in the effluent. Maintaining COD at acceptable levels can prevent anoxic conditions in the receiving marine environment, especially in Small Bay which is considered a sheltered environment with limited mixing capacity

ICMA 69(5)(d) requires that any person who wishes to discharge wastewater into the coastal environment and who has applied for a General Authorization/CWDP must be compliant with any relevant waste standards as specified in the NWA and other legislation dealing with waste, unless the Water Use License/General Authorisation states otherwise. Until all operations have been issued a CWDP, authorities should focus their efforts on ensuring that effluent discharges meet the absolute minimum requirements, i.e. the revised General Discharge Limits as per the General and Special Standards of 2013. Given the high organic loading of these effluents, as indicated by the historic water quality data, these discharges have presumably contributed significantly to organic loading in the Bay, particularly in Small Bay.

Although the available data do not show this, it is quite likely that the volume of effluent discharged to the Bay from the other fish processing factories had also tailed off sharply in recent years owing to the fact that pelagic fish stocks (sardine and anchovy) had temporarily relocated eastwards beyond the reach of fishing vessels stationed in Saldanha Bay (now cantered off Gansbaai) (Note that this was a major contributing factor for the temporary closure of one of these plants). Now that these fish stocks have returned to the West Coast, volumes of effluent discharged to the Bay from this source is set to increase again and it is strongly recommended that both the volume and quality of all effluent discharged from fish processing facilities in Saldanha be carefully monitored.

13.1.5 Mariculture

Saldanha Bay is the only natural sheltered embayment in South Africa and as a result it is regarded as the major area for mariculture. A total area of approximately 165 ha has been allocated to ten mariculture operators within Saldanha Bay. Nine operators hold rights to farm mussels but only six exercise this right. Six operators farm oysters and but also have the right to cultivate abalone, scallops, red bait or seaweed. These farms have been shown to cause organic enrichment and anoxia in sediments under the rafts owing to contamination by the farmed animals themselves, faeces, and fouling species. Monitoring of their impacts on benthic communities in the Bay is being undertaken by the Department of Agriculture Forestry and Fisheries (DAFF) but the results of this have yet to be made available to the public.

Southern Atlantic Sea Farms attempted to pioneer Atlantic salmon in Saldanha Bay. During the pilot phase of this project, however, it was found that the location was not suitable for Atlantic salmon due to the susceptibility of this species to amoebic gill disease, which combined with frequent low dissolved oxygen events lead to high mortality rates. The project was therefore terminated this year. Southern Cross Salmonid Farm and Viking Aquaculture are currently both proposing marine offshore cage farming in Saldanha Bay. While the former farm is applying for EA to start production immediately, Viking Aquaculture will produce less than 50 000 tons (i.e. no EA required) and will be granted a Scientific Investigations and Practical Experiment Permit.

New Alien and Invasive Species Regulations and Invasive Species Lists were promulgated on 1 August 2014 in terms of the National Environmental Management: Biodiversity Act (No. 10 of 2004) (NEMBA). These regulations and lists specify that any restricted activities related to an alien species legally introduced prior to the promulgation of these regulations are exempted from the requirement of a permit (and therefore a risk assessment). In the light of recent efforts to culture

alien species in the marine environment, these new regulations raise concerns with regards to the introduction of alien species into novel environments. For example, it is of concern that salmon, previously only farmed on land (low risk) can now be introduced into the marine environment (higher/unknown risk) without a permit/risk assessment in terms of NEMBA.

13.1.6 Shipping, ballast water discharges and oil spills

Shipping traffic and ballast water discharges to the Bay are currently monitored by the Port of Saldanha. Data indicate a steady growth in the numbers of vessels visiting the Bay and a concomitant increase in the volume of ballast water discharged to the Bay. Associated with this increase in shipping traffic, is an increase in the incidence and risk of oil spills, an increased risk of introducing alien species to the Bay, increased volume of trace metals entering the Bay, and direct disturbance of marine life and sediment in the Bay. Of particular concern is the potential input of trace metals to the Bay from this source. Trace metal concentrations in ballast water discharged to Saldanha Bay have in the past (1996), been shown to exceed South Africa Water Guidelines. Whether this is still the case is unknown, given that the concentrations of these contaminants in ballast water discharges has not been assessed in recent years.

To address environmental impacts and risks from the discharge of ballast water, the International Convention for the Control and Management of Ship's Ballast Water and Sediments of 2004 (BWM Convention) was ratified by 30 states, including South Africa. It took almost a decade until the Draft Ballast Water Management Bill was published in the *Government Gazette* in April 2013 (Notice 340 of 2013), aimed to implement the BWM Convention. The Bill sets out how ballast water is to be discharged, all ships are expected to have a ballast water management plan, and to keep an up to date ballast water record book. Vessels constructed after 2009 are required to be designed such that accumulation of sediments is prevented and removal of sediments is facilitated.

It is of utmost importance that the Transnet Port Authority ensures that the requirements of this Bill are implemented in the interim until the Draft Bill has been promulgated.

13.2 Water quality

13.2.1 Temperature, salinity and dissolved oxygen

From a water quality perspective, key physico-chemical changes that have resulted from anthropogenic impacts on the Bay include modification in circulation patterns and wave exposure gradients in the Bay, leading to a reduction in water movement and exchange between the Bay and the adjacent marine environment.

There is currently no continuous monitoring of physico-chemical parameters (temperature, salinity and dissolved oxygen) taking place in Saldanha Bay that provides data that are readily accessible to the SBWQFT. It is strongly recommended that continuous (at least hourly) monitoring of temperature and (if possible) oxygen be implemented at a minimum of three locations in the Bay, including two stations in Small Bay (one specifically in the Yacht Club Basin), and one station in Big Bay using similar methodology and station locations to that employed by the Council for Scientific and Industrial Research (CSIR) (1999). It should be possible to download this data remotely and it should be analysed on a regular basis. Furthermore, it would be beneficial to obtain such data from both surface and bottom waters (i.e. 1 m and 10 m) to enable on-going comparisons with historical data.

So far, Anchor Environmental Consultants deployed temperature loggers in Small Bay near North Buoy in April 2014-2015. No funds are available at this point in time to regularly monitor salinity and dissolved oxygen.

13.2.2 Chlorophyll a and Nutrients

There is currently no regular monitoring of chlorophyll a or nutrient concentrations (specifically nitrogen and ammonia) taking place in Saldanha Bay. It is strongly recommended that monthly monitoring of these parameters be implemented at a minimum of the same two stations identified for temperature, salinity and oxygen monitoring. This may require manual samples to be collected on a monthly basis and sent for laboratory analysis. Ongoing data analysis and interpretation should form a part of such monitoring programs. These data would be invaluable in calibrating existing hydrodynamic and biological production models that have been developed for the Bay.

13.2.3 Currents and waves

There is clear evidence of altered current strengths, circulation patterns and wave energy within Saldanha Bay, which are ascribed to the construction of the ore terminal and causeway. The wave exposure patterns have also been altered as a result of harbour developments in Saldanha Bay, resulting in areas of the Bay becoming more sheltered. Long term changes in the patterns of current flow and wave energy should be quantified through a formal dedicated study to be conducted approximately every five years.

13.2.4 Trace metal concentrations in biota (Department of Environmental Affairs Mussel Watch Programme and Mariculture Operators)

The concentrations of metals in the flesh of mussels used to be monitored by the Mussel Watch Programme (DAFF). Data are available for the period between 1997-2001 and 2005-2007 but not since this time apparently due to a backlog in processing of samples. No new data were received for the 2013/2014 period; however, the programme is due to resume in late 2014. In the interim, Anchor Environmental Consultants collected mussel samples from the same five sites during the field survey in April 2014. The mussel samples collected from the shore are analysed for the metals cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), iron (Fe) and manganese (Mn), hydrocarbons and pesticides. Data on trace metals concentrations in shellfish from the mariculture farms in the Bay were also obtained from the DAFF (courtesy of the farm operators).

Concentrations of trace metals in marine filter feeders in Saldanha Bay suggest that concentrations of trace metals are high along the shore and are frequently above published guidelines for foodstuffs. Concentrations offshore are much lower and are less of a concern. This may be linked with higher growth rates for farmed mussels, and the fact that the cultured mussels feed on phytoplankton blooms in freshly upwelled, uncontaminated water.

Metal contamination poses a very serious risk to the health of people harvesting mussels from the shore (large quantities of shellfish are harvested and consumed by recreational and subsistence fishers from the shore of the Bay) and high concentrations of trace metals along the shore points to the need for management interventions to address this issue. It is vitally important that this monitoring continues in the future and that data are made available to the public. It is also imperative that this Mussel Watch Program be revamped and possibly extended to cover other species as well (e.g. fish).

13.2.5 Microbiological monitoring (Faecal coliform)

Water samples are currently analysed fortnightly for faecal coliform and *E. coli* concentrations from 20 stations in Saldanha Bay and Langebaan Lagoon. The microbial monitoring program provides evidence that while some of the monitoring sites in Small Bay still have faecal coliform counts in excess of the safety guidelines for both mariculture and recreational use, there is an overall trend of improving compliance for which the relevant authorities should be commended. However, the situation in Small Bay remains a concern, with three sites exceeding the levels for safe mariculture practices, and two sites exceeding the levels for safe recreational activities in 2014. The increasing trend in faecal coliform counts at the Langebaan North site is also cause for concern, and although microbial counts are still within the recreational use guidelines, this is the only site outside of Small Bay that exceeded the mariculture guidelines.

Given the current importance and likely future growth of both the mariculture and tourism industries within Saldanha Bay, it is imperative that sewage treatment and storm water facilities are upgraded to match the rate of development in order to prevent any further degradation of water quality within the Bay. Continued monitoring of bacterial indicators (intestinal *Enterococci* in particular), with regular analysis and interpretation of data is also required and should be undertaken at all sites on a bimonthly basis.

The older DWAF water quality guidelines for recreational use have recently been revised following an international review of guidelines for coastal waters, which highlighted several shortcomings in those developed by South Africa. The revised guidelines (DEA 2012) are based on counts of intestinal *Enterococci* and *E. coli*, and require that both types of bacteria be enumerated at least every two weeks. It is highly recommended that enumeration of *Enterococci* be included in the Saldanha water sampling programme in place of faecal coliforms as several studies have shown faecal coliforms and *E.coli* to be relatively poor indicators of health risks in marine waters. These organisms are also less resilient than *Enterococci* (and other pathogenic bacteria) so if analysis is focussed on coliforms, risk can be underestimated due to mortality occurring in the time taken between collection and analysis. Guidelines state that samples should be collected 15-30 cm below the surface, on the seaward side of a recently broken wave. Samples to be tested for *E. coli* counts should be analysed within 6-8 hours of collection, and those to be tested for intestinal *Enterococci*, within 24 hours. Analyses should be completed by an accredited laboratory, preferably one with ISO 17025 accreditation.

13.3 Sediments

13.3.1 Particle size, total organic carbon (TOC) and trace metals

Sediment monitoring in the Bay has revealed that key heavy metal contaminants (Cd, Pb and Cu) are high at a number of sites in Small Bay, to the extent that they are almost certainly impacting on benthic fauna and possibly other faunal groups in the Bay. These contaminants are typically associated with the finer sediment fraction and are highest in areas adjacent to the Ore Jetty near the Mussel Farm and the Yacht Club.

Sediment monitoring (particle size, total organic carbon (TOC) and trace metals) should continue to be conducted annually at the same suite of stations that have been monitored since 1999 along with additional stations added since this time (e.g. those in Langebaan Lagoon). Dredging in the Bay should be avoided if at all possible, and appropriate precautions need to be taken when dredging becomes necessary to ensure that suspended trace metals do not contaminate cultured and wild seafood in the Bay.

13.3.2 Hydrocarbons

Poly-aromatic hydrocarbons were considered to pose no threat since the first survey was conducted in 1999. Assessment undertaken in 2015 suggested that this is still the case, however, considerable fluctuations in TPH levels have been recorded in recent years. In the previous survey (2014) high concentrations of TPH were recorded at sites adjacent to the Ore Jetty. The most likely explanation for the high TPH levels is that a pollution incident associated with shipping activities or operational activities on the jetty itself took place. TPH levels have decreased in 2015 and present no major concern, however, it is recommended that TPH monitoring within the vicinity of the ore terminal is continued annually so as to identify the occurrence of pollution incidents, like that recorded in 2014, and assess the ecological implications for the Bay.

13.3.3 Hydrocarbons

Poly-cyclic, poly-nuclear compounds and pesticides were considered to pose no threat during analysis conducted in 1999. Assessment undertaken on a small number of samples in 2010 and 2011 suggested that this was still the case, however subsequent monitoring has shown a dramatic increase in total petroleum hydrocarbon (TPH) levels such that the international threshold concentrations were exceeded.. In the latest survey (2014) very high concentrations of hydrocarbons were observed at sites adjacent to the multipurpose quay and the base of the ore jetty. The chemical composition of the hydrocarbons found in sediments at these sites suggests that the contaminant is mostly likely weathered diesel. This suggests that there may have been a pollution incident associated with the shipping activities alongside the jetty or with operational activities on the jetty itself. The monitoring has shown that there is indeed a need for immediate concern as hydrocarbon levels in the sediments have increased and remain above the recommended thresholds. Further investigation and implementation of corrective management action to prevent further contamination is urgently required.

13.4 Aquatic macrophytes in Langebaan Lagoon

Congruent with global patterns, seagrass (*Zostera capensis*) beds have experienced a radical reduction in size with associated fragmentation of large beds. This phenomenon has been attributed to direct and indirect anthropogenic changes such as physical disturbance, pollution, specifically eutrophication and most recently, seagrass biomass was found to be lower in warmer waters (University of Cape Town, Cloverly Lawrence *pers. comm.* 2014). The dramatic decline in seagrass beds has been shown to have profound negative impacts on species diversity and composition and is very likely to induce change in higher trophic groups within the affected ecosystem. Aerial photographs showing changes of seagrass beds in Langebaan Lagoon over time are only available for the period 1960 to 2007. Recognising the importance of seagrass beds to provide habitat heterogeneity in the lagoon, it is strongly recommended that aerial photographs should continue as soon as possible, such that monitoring of seagrass beds can be continued. This would be especially interesting if combined with future water temperature monitoring in the lagoon to ascertain if temperature fluctuations influence seagrass bed sizes and distribution patterns.

13.5 Benthic macrofauna

Monitoring of benthic macrofaunal communities over the period 1999-2015 has revealed a relatively stable situation in most parts of the Bay and Lagoon with the exception of 2008 when a dramatic shift in benthic community composition occurred at all sites. This shift involved a decrease in the abundance and biomass of filter feeders and an increase in shorter lived opportunistic detritivores. This was attributed to the extensive dredging that took place during 2007-2008. Aside from this Bay-wide phenomenon, localised improvements in health have been detected in the yacht club basin and at Salamander Bay following construction of the boat dock. Notable improvements in the health of benthic communities include the return of the suspension feeding sea-pen *Virgularia schultzei* to Big Bay and Langebaan Lagoon since 2004, as well as an increase in the percentage biomass of large, long lived species such as the tongue worm *Ochaetostoma capense*, and several gastropods. Certain

areas of Small Bay that experience reduced water circulation patterns in (e.g. near the Small Craft Harbour and near mussel rafts) which results in the accumulation of fine sediment, organic material and trace metals (aggravated by anthropogenic inputs) still have impoverished macrofauna communities. In order to ensure the continued improvement in the health of the Small Bay marine environment it is recommended that stringent controls are placed on the discharge of effluents into Small Bay to facilitate recovery of benthic communities and ecosystem health as a whole. The regularity (annually) and intensity of benthic macrofauna monitoring should continue at all of the current stations.

13.6 Rocky intertidal

Key changes in the rocky intertidal ecosystem reflect the regional invasion by the Mediterranean mussel *Mytilus galloprovincialis* and the North American barnacle *Balanus glandula* which compete for space on most of the rocky intertidal substrata in the bay at the expense of the native species. Their spread throughout the Bay has significantly altered natural community structure in the mid and lower intertidal, particularly in wave exposed areas.

A total of 116 taxa were recorded from the eight study sites, most of which had been found in previous survey years. The faunal component was represented by 23 species of filter-feeders, 28 species of grazers, and 17 species of predators and scavengers combined. The algal component comprised 35 corticated (foliose) seaweeds, six ephemerals, five species of encrusting algae, and two species of kelp.

One of the greatest threats to rocky shore communities in Saldanha Bay is the introduction of alien species via shipping, and their potential to become invasive. During the present survey, it was confirmed that two additional alien barnacle species were present: *Amphibalanus amphitrite* and *Menesiniella regalis*.

In general, rocky shore communities were relatively stable with only minor changes over the years. However, the establishment of the two new alien species must be monitored closely in continued annual rocky shore surveys.

13.7 Fish

Long-term monitoring of juvenile fish assemblages by means of experimental seine-netting in the surf zone has revealed some concerning trends in recent years.

The significant declines in white stumpnose abundance at all sites throughout the system in recent years suggest that the protection afforded by the Langebaan MPA may not be enough to sustain the fishery at the current high effort levels. Commercial fishing effort and white stumpnose catch has increased dramatically over the period 2003-2015, particularly in the recent part of this period. It is likely that recreational fishing effort for white stumpnose has also increased. The low white stumpnose abundance in recent years may simply be a result of natural variability in recruitment strength (possibly at decadal time scales greater than the monitoring record). However, given the

findings of Arendse (2011) who assessed the adult stock to be overexploited using data collected during 2006-08 already, this could indicate that recruitment overfishing is occurring and a precautionary approach is warranted. The consistent declining trend in juvenile white stumpnose abundance in the nursery surf-zone habitats since 2007, with the three lowest abundance estimates emanating from the last three annual surveys, strongly supports the implementation of the harvest control measures recommended by Arendse (2011); namely a reduction in bag limit from 10 to 5 fish per person per day and an increase in size limit from 25 cm TL to 30 cm TL. This is the second time we are making this recommendation in the State of the Bay Report, despite it previously receiving vocal opposition from local anglers after the 2013/14 report was published. Anchor Environmental has no vested interests in the white stumpnose resource or the fishery and are making this recommendation based on our scientific interpretation of the catch and survey data.

The 2013-2015 sampling events recorded average recruitment of common species such as harders, gobies and silversides within Big Bay and Langebaan Lagoon sites that are comparable with data from earlier surveys. In Small Bay, however, with the exception of harders and silversides, estimated abundance of key species was well below average, with very low white stumpnose density and a complete absence of black tail for the first time in the 11 year sampling record. This follows the trend observed since 2010/11 and it is somewhat concerning that the estimated abundance of some key species is decreasing in the areas of maximum anthropogenic disturbance within Small Bay, whilst they are stable or increasing in other less disturbed areas of Big Bay and Langebaan Lagoon.

In the data set collected to date, the average density of commercially important fish, such as white stumpnose and harders, was much higher at Small Bay sites compared to Big Bay and Lagoon sites. Since 2011, however, estimated densities of these species were similar and low in both Big Bay and Small Bay. Over the period 2005-2010, the average white stumpnose density calculated from all seine net surveys was 1.2 fish.m⁻² in Small Bay, over the period 2011-2015 this dropped to 0.03 fish.m⁻² compared with the long term average of 0.09 fish.m⁻² in Big Bay and 0.05 fish.m⁻² in Langebaan lagoon. The juveniles of other species were historically also more abundant in Small Bay. This gives an indication of the importance of Small Bay as a nursery habitat for the fish species that support the large and growing fisheries throughout the Bay. Small Bay is often viewed as the more developed or industrialized portion of the Bay and is considered by many as a 'lost cause'. These data provide a strong argument to stamp out such negative thinking and to continue lobbying strongly for enhanced protection of this portion of the Bay. The concerning trend in decreasing white stumpnose recruitment throughout the Bay makes it even more critical that the quality of what is demonstrably the most important white stumpnose nursery habitat is improved. With the exception of white stumpnose, the current status of fish and fisheries within Langebaan Lagoon appear to be satisfactory.

Fish sampling surveys should be conducted annually at the same sites selected during the 2015 study for as long as possible. This sampling should be confined to the same seasonal period each year for comparative purposes. Additional data on daily catch records from anglers (West Coast National Park and fishing clubs) was collected by the DAFF in the past. This initiative has apparently been restarted by SANParks and we look forward to access to this information in the future as it will contribute to an improved understanding of the overall health of fish populations in the Bay.

13.8 Birds

An alarming decrease in the abundance of both resident and migrant waders utilising Langebaan Lagoon was evident over the period 2000-2015 and is believed to be a function of increased human utilisation of the area and possible reduction in available food. Similar declines are evident in some bird species (Cape cormorants, bank cormorants, Cape gannets and African penguins) breeding on the offshore islands in the Bay. This is believed to be a function of reductions in their food supply (largely pelagic fish e.g. pilchard or rock lobster) outside of the Bay and human disturbance within the Bay.

Populations of key bird species are currently monitored annually on the offshore islands within the Saldanha Bay area, whilst bird populations in Langebaan Lagoon are monitored twice per annum. These bird counts are conducted as part of an on-going monitoring programme, managed by the Avian Demography Unit of the University of Cape Town and Oceans and Coasts (DEA). It is highly recommended that the status of key species continue to be monitored in future and that these data be made available and used as an indication of environmental conditions in the area.

13.9 Alien invasive species

To date, 92 marine species have been recorded as introduced to South African waters, mostly through shipping activities or mariculture. 70 of these occur on the South Africa west coast, and at least 30 of these are known to occur in Saldanha Bay and/or Langebaan Lagoon. The presence of one new alien species – the European porcelain crab *Porcellana platycheles* - has been confirmed in Saldanha Bay in the last year. It was first found on Schaapen Island in 2012 but its identity was confirmed only recently. Many of these alien species are considered invasive, including the Mediterranean mussel *Mytilus galloprovincialis*, the European green crab *Carcinus maenas* and the recently detected barnacle *Balanus glandula*. An additional 39 species are currently regarded as cryptogenic (of unknown origin) but very likely introduced, 20 of which have been recorded from Saldanha Bay.

Populations of the Western Pea crab *Pinnixa occidentalis*, first detected in the Bay in 2004, seem to have stabilised in terms of its abundance in the Bay but seems to be expanding its distribution outside of the Bay (now present in Danger Bay as well). Populations of the Mediterranean mussel *Mytilus galloprovincialis* and acorn barnacle *Balanus glandula* are by far the most dominant animal species on rocky shores in the Bay. Populations of *Mytilus* appear to be growing rapidly, while populations of *Balanus* seem to be declining. These two species compete directly with one another for space on the shore, with expanding populations of *Mytilus* displacing those of *Balanus*. Aliens are considered to represent one of the greatest threats to rocky shore communities in Saldanha Bay, owing to their potential to become invasive, thereby displacing naturally occurring indigenous species. Thus, changes in the population of these species in Saldanha Bay should be carefully monitored annually to measure the impacts that they have on the native biota.

13.10 Danger Bay

Initiation of baseline sampling of sediment, benthic macrofauna and fish in Danger Bay in 2014 and the follow-up surveys in 2015 provided data that confirm this is a more exposed and dynamic environment than Saldanha Bay and suggest that this site is better suited for a regional marine outfall than the Bay itself. Discharge of organically and chemically enriched effluent from the proposed regional marine outfall is still expected to have a discernable impact on the physical environment and biological communities within a zone of impact. Ongoing collection of comprehensive baseline data on macrobenthic communities in Danger Bay to capture the natural variability is essential for objective and quantitative assessment of expected impacts. Field observations during the 2014 and 2015 surveys indicate that there is extensive subtidal reef and associated kelp bed ecosystems in Danger Bay in close proximity to the proposed pipe end locations and adjacent to the sandy substratum habitat that was sampled. Dispersion modelling of effluent from the proposed regional marine outfall is not yet available, but there is a real possibility that the zone of impact may extend to these reefs. We therefore recommend that baseline sampling be expanded to include this subtidal reef habitat in Danger Bay.

13.11 Summary of environmental monitoring requirements

In summary, the environmental monitoring currently implemented in Saldanha Bay and Langebaan Lagoon (e.g. sediment, benthic macrofauna, birds, rocky intertidal, fish populations) should continue with some small adjustments or additions, however, monitoring of other environmental parameters that are not currently assessed on a regular basis (e.g. temperature, oxygen, salinity, stormwater quality) require structured, maintained monitoring to be implemented.

Table 11.1. Tabulated summary of Environmental parameters reported on in the State of the Bay: Saldanha Bay, Danger Bay and Langebaan Lagoon.

Parameter monitored	Time period	Anthropogenic induced impact	
WATER QUALITY			
Physical aspects (temperature, salinity, dissolved oxygen, nutrients and chlorophyll)	1974-2000, 2010-2011, 2014-2015	Dissolved oxygen levels in bottom water in Small Bay are very much lower than they were historically or at least prior to port development. This is attributed to organic loading in the Bay and reduced flushing time. No clear changes are evident with any other physico-chemical parameters.	
Current circulation patterns and current strengths	1977 vs. 1991	Reduced wave energy, and impaired circulation and rate of exchange in Small Bay Increased current strength alongside obstructions (e.g. ore terminal)	
Microbiological (faecal coliform)	1999-2015	Faecal coliform counts in Small Bay frequently exceed safety levels in the past but have shown dramatic improvements in recent years. Big Bay and Langebaan Lagoon mostly remain within safety levels for faecal coliform pollution but coliform concentrations in these areas are increasing. Faecal coliform may underestimate actual harmful microbiological concentrations. There is a need to	

Parameter monitored	Time period	Anthropogenic induced impact	
		monitor intestinal <i>Enterococci</i> instead.	
Trace metal contaminants in water	1997-2008, 2014-2015	Concentrations of cadmium, copper, lead, zinc, iron and manganese in mussel flesh are frequently above the safety guidelines for food stuffs. Any future dredging events should be prevented as far as possible owing to elevated metal concentration in sediments.	
SEDIMENTS			
Particle size (mud/sand/gravel)	1977-2015	The mud fraction in the sediments in the Bay was highly elevated when the State of the Bay surveys commenced in 1999 relative to the period prior to port construction. The situation has improved considerably since this time at most sites, however, levels of mud in the sediment remain highly elevated at some sites (e.g. the near the mariculture rafts and ore terminal).	
Total organic carbon (TOC)	1974-2015	Similar trends as for %mud. Elevated levels of TOC at the Yacht Club basin and near the mariculture rafts (negative impacts) are of particular concern.	
Total organic nitrogen (TON)	1974-2015	Similar trends as for %mud and TOC. Elevated levels of TOC at the Yacht Club basin and near the mariculture rafts (negative impacts) are of particular concern.	
Trace metal contaminants in sediments	1980-2015	Cadmium, lead, copper and nickel are currently elevated considerably above historic levels. Concentrations were highest in 1999 following major dredge event. Pb, Cu, Ni elevated in 2008-2015 at Yacht Club and multipurpose terminal, which may be related to lead ore exports and maintenance dredging.	
BENTHIC MACROFAUNA			
Species abundance, biomass, and diversity	1999-2015	Benthic macrofauna communities in Saldanha Bay and Langebaan Lagoon Bay are highly sensitive to dredging activities and drop dramatically immediately after each major dredging event. Macrofauna communities are currently increasing in abundance and biomass since the last major event in 2009/2010.	
ROCKY INTERTIDAL AND INTRODUCED SPECIES			
Impact of alien mussel and barnacle introductions	1980-2015	Alien mussel and barnacle have displaced the local mussel and other native species from much of the shore leading to decreased species diversity (negative). One new alien crab species found. The establishment of these species must be closely monitored.	
FISH			
Community composition and abundance	1986-2015	With the exception of white stumpnose, the current status of fish and fisheries within Big Bay and Langebaan Lagoon appear to be satisfactory. Abundance of most species in Small Bay has been declining for several years, though, and is of some concern	
BIRDS			
Population numbers of key species in Saldanha Bay and islands	1977-2015	Decreasing populations of Cape, Bank and White-breasted Cormorants are attributed to construction of causeway and increasing human disturbance. African Black Oystercatcher populations have recovered dramatically, now stabilising	

Parameter monitored	Time period	Anthropogenic induced impact	
Population numbers of key species in Langebaan Lagoon	1976-2015	Populations of migrant and resident waders utilising Langebaan Lagoon have decreased dramatically over the last 30 years, attributed to offsite impacts on breeding grounds and local impacts (habitat changes) and disturbance in the lagoon. Modest increases that were evident for some species in recent years (2013-2014) seem to have stopped and/or been reversed.	
DANGER BAY	2014	Currently undisturbed. Ongoing collection of comprehensive baseline data on macrobenthic communities, sediments and fish populations in Danger Bay to capture the natural variability is essential for objective and quantitative assessment of expected impacts.	

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