THE STATE OF

SALDANHA BAY AND LANGEBAAN LAGOON

2016

September 2016

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Technical Report

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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)

History

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 myself 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. At our initiative and as mentioned last year, an Inter-Governmental Task Team was formed and this body is currently making positive headway in management of this region and is an example of positive interaction between us as an NGO and the various tiers of Government.

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.

All funds are contributed to the Trust on a voluntary basis by industry and local government and these bodies are to be commended for their foresight and support of the work being done.

Challenges

I must quote from last year`s foreword, **"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."**

Bearing this in mind, we were forced to revise our work plan for this year, due to financial constraints. Some of our monitoring has had to be scaled down in terms of frequency and intensity. The part-time post of, "Operations Manager" has been shelved indefinitely and these services are now only utilised on specific pre-determined projects, when required.

Strategy & Monitoring

A "Strategic" planning session was held at the beginning of the year which led to a specialist meeting with, "Government & Scientists" and followed up by a "Contributors Meeting". The first was to ensure that the information that we will be gathering is relevant to both the scientific community as well as to local and provincial government. This has given us a template for the monitoring that we hope to be doing over the next decade. The second meeting was to share the proposed monitoring plan with our contributors and to get the assurance that they were in fact in agreement and supportive of the work we intend doing, with their funds.

Closing

I would like to thank Anchor Environmental for their commitment to this project, particularly Dr. Barry Clark who is always willing to assist wherever and whenever feasibly possible.

I must also thank the present Board of Trustees for their regular input and guidance. Special thanks must go to the Chairperson, Mr. Christo van Wyk, who truly remains passionate and committed to what we do, despite often trying circumstances.

Thank you for your time and kind regards,

Jimmy Walsh.

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) and Christo van Wijk (Metsal).

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 2016 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 TON) 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.

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 2.7% 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 rising, especially those visiting the West Coast National Park (WCNP) (Average rate of 16% 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. 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.

Further proposed developments that were added to this year's report include, infrastructure to supply Eskom and the industry with additional electricity (i.e. a Floating Power Plant (FPP), Liquefied Natural Gas (LNG) Import Facilities and a gas fired independent power plant), the Elandsfontein phosphate mine and Transnet National Port Authority (TNPA) projects under the auspices of Operation Phakisa to fast track development the marine transport and manufacturing industry (a Vessel Repair Facility, Mossgas Jetty and a Floating Dry Dock).

The Saldanha Bay Industrial Development Zone (SBIDZ) was declared on 13 October 2013 and Environmental Authorisation was granted on November 2015. This gives the SBIDZ licensing Company (Saldanha Bay Industrial Development Zone LiCo) authorisation to develop an oil and gas offshore service complex within the Saldanha Bay IDZ. 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.

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 more than 24 million tons of ballast water being discharged in 2016. 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 only, 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. A combined 430 ha of sea space are currently available for aquaculture production in Outer Bay, Big Bay and Small Bay, of which 251 ha have been leased to 12 individual mariculture operators. Only 60% of these concession areas are actively farmed for mussels, oysters and finfish, mostly in Small Bay. 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. After many years of slow but consistent growth in Saldanha Bay, DAFF is now proposing to establish a new sea-based Aquaculture Development Zone (ADZ) in Saldanha Bay with the support of finances and capacity allocated to the Operation Phakisa Delivery Unit. This has the potential to significantly expand the mariculture footprint and some of the associated impacts in Saldanha Bay and will need to be carefully monitored in future.

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, 16 of the 20 monitoring stations in the Bay are rated as having 'Excellent' water quality, one site (Langebaan North) is rated as 'Good', while three are rated as 'Fair'. There is a concerning trend of increasing faecal coliform levels at Pepper Bay and the authorities are advised to remain vigilant. Noticeable improvements were evident at Langebaan North, the Beach at the Caravan Park and Hoedjiesbaai Beach. Faecal coliform counts at all four sites in Big Bay were well within both the 80^{th} 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 the 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; although concentrations of lead and cadmium frequently rise above the limit for foodstuff which is concerning.

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 of 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 and 2016. Key areas of concern regarding trace metal pollution within Small Bay include the Yacht Club Basin where cadmium and copper exceeded recommended thresholds two years in a row and enrichment factors (EF) continue to be high, as well as adjacent to the Multi-purpose terminal where levels of cadmium and lead dropped just below internationally accepted guidelines, but still have extremely high enrichment factors for all trace metals measured. 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 findings in 2016 remain unchanged from 2015 and present 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, *Callichirus kraussi* 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 1999-2016 has revealed a relatively stable situation in most parts of Small Bay. 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. 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 although it is clear from 2016 results that this site remains disturbed. In addition, site SB14 adjacent to the multi-purpose terminal, and the liquid petroleum gas (LPG) site, both show signs of elevated abundance and low biomass in the 2016 results and are indicative of disturbance by dredging activities. 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.

Results from a baseline survey for the Elandsfontein monitoring sites, initiated this year, indicate that the macrofaunal communities present at the head of the Lagoon are significantly different to Langebaan Lagoon and Saldanha Bay (Small Bay and Big Bay). A clear trend in changing macrofaunal communities is evident from the marine dominated Saldanha Bay through the sheltered Lagoon to the very sheltered, shallow and possibly freshwater/estuarine influenced Elandsfontein area. In terms of the concerns raised around potential impacts that the proposed phosphate mine at Elandsfontein may have on groundwater quality and flows to Langebaan Lagoon, ongoing collection of baseline data on macrobenthic communities in Elandsfontein to capture natural variability, is essential for objective and quantitative assessment of any impacts should they occur.

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

With the exception of white stumpnose, the current status of fish and fisheries within Saldanha Bay and Langebaan Lagoon appear to be satisfactory. Long-term monitoring by means of experimental seine-netting has revealed no statistically significant, negative trends since fish sampling began in 1986-87. If anything, abundance of key fish species at sites within or in close proximity to the Langebaan Marine Protected Area (MPA) over the long term appears to be increasing which is very encouraging. Certainly, work by Kerwath *et al.* (2009), Hedger *et al.* (2010) and da Silva *et al.* (2013) has clearly demonstrated the benefits of the Langebaan MPA for white stumpnose, elf and smooth houndsharks and the protection of harders from net fishing in the MPA undoubtedly benefits this stock in the larger Bay area.

The 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 white stumpnose catch 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 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. The consistent declining trend in juvenile white stumpnose abundance in the nursery surf-zone habitats since 2007 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 third 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. A recent (2016) analysis of commercial and recreational linefish catch data and the net survey data by a team of fisheries scientists supports this recommendation.

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 1.1 fish.m^{-2} in Small Bay, over the period 2011-2016 this dropped to 0.04 fish.m^{-2} compared with the long term average of 0.08 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 economic 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. These benefits should be quantified by an economic study of the recreational fisheries. The value of Small Bay as a fish nursery and the economic value of the resultant fisheries could then be quantitatively considered when the environmental impacts of the proposed future industrial developments within Small Bay are assessed.

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 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.

Due to the fact that the bird counts for five out of nine Coordinated Waterbird Counts (CWAC) sites in the Langebaan Lagoon were not available for summer 2016, this section of the bird chapter was not updated in this year's edition. Please refer to AEC 2015 Chapter 11 for more detail on this component.

Alien Invasive Species

To date, 92 marine species have been recorded as introduced to South African waters, mostly though 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.

The Alien Invasive Species Chapter was not updated in this year's edition due to the lack of funding to collect imperical data. Please refer to AEC 2015 Chapter 12 for more detail on this Chapter.

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.
Aquaculture	The sea-based or land-based rearing of aquatic animals or the cultivation of aquatic plants for food
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

ADZ	Aquaculture Development Zone
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
DoE	Department of Energy
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EEM	Elandsfontein Exploration and Mining (Pty) Ltd
EIA	Environmental Impact Assessment
EMF	Environmental Management Framework
EMMP	Environmental Management and Maintenance Plan
EMPr	Environmental Management Programme
FPP	Floating Power Plant
ICMA	National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008)

IDZ	Industrial Development Zone
CNG	Compressed Natural Gas
LNG	Liquefied Natural Gas
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
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
TOC	Total Organic Carbon
TON	Total Organic Nitrogen
TPH	Total Petroleum Hydrocarbon
TSS	Total Suspended Solids
VRF	Vessel Repair Facility
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 Vondeling).

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 Sate 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). Owing to the fact that the SBWQFT relies on voluntary contributions, and the fact that funds were particularly limited in 2016, some of the components of the State of the Bay monitoring programme, specifically the Rocky

Intertidal surveys, were been omitted from the 2016 report, while the scope of the sediment quality and soft-bottom macrofauna surveys was restricted to Small Bay and the immediate vicinity of the Iron Ore Terminal. Data on water bird numbers in Langebaan Lagoon, normally sourced from the Avian Demography Unity at the University of Cape Town, were also not available for 2016 and have also been omitted from this volume. This report does, however, include information on trends in all of the parameters reported on in the previous reports (2006, 2008, 2009, 2010, 2011, 2012, 2013-4, and 2015). It 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.

Chapter Nine 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 Ten provides detailed information on the status of key bird species utilising the offshore islands around Saldanha Bay as well as providing an indication of the national importance of the area for birds.

Chapter Eleven 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 Twelve 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 2016 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;
- Updated information on metal exports from the Saldanha Bay Multipurpose and Iron Ore Terminals;
- New and updated information on new and existing development proposals for Saldanha (the Saldanha Bay Industrial Development Zone, the Sishen-Saldanha Oreline expansion project, the development of liquid petroleum gas facilities in Saldanha Bay, a proposal for the development of a Floating Power Plant in the Bay, development of Liquefied Natural Gas Import Facilities, a proposal for the development of a Combined Cycle Gas Turbine power plant, development of additional crude oil storage infrastructure, upgrades to the Salamander Bay Boat Park, development of the Elandsfontein phosphate mine, and the development of additional vessel repair facilities in the Port of Saldanha);
- New and updated information on shipping traffic and ballast water discharges; and
- New and updated information on the volumes and quality of waste water discharged into the Bay from the Transnet-NPA Desalination Plant, the Saldanha and Langebaan Water Treatment Works, 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; and
    - 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 exists 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.

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.

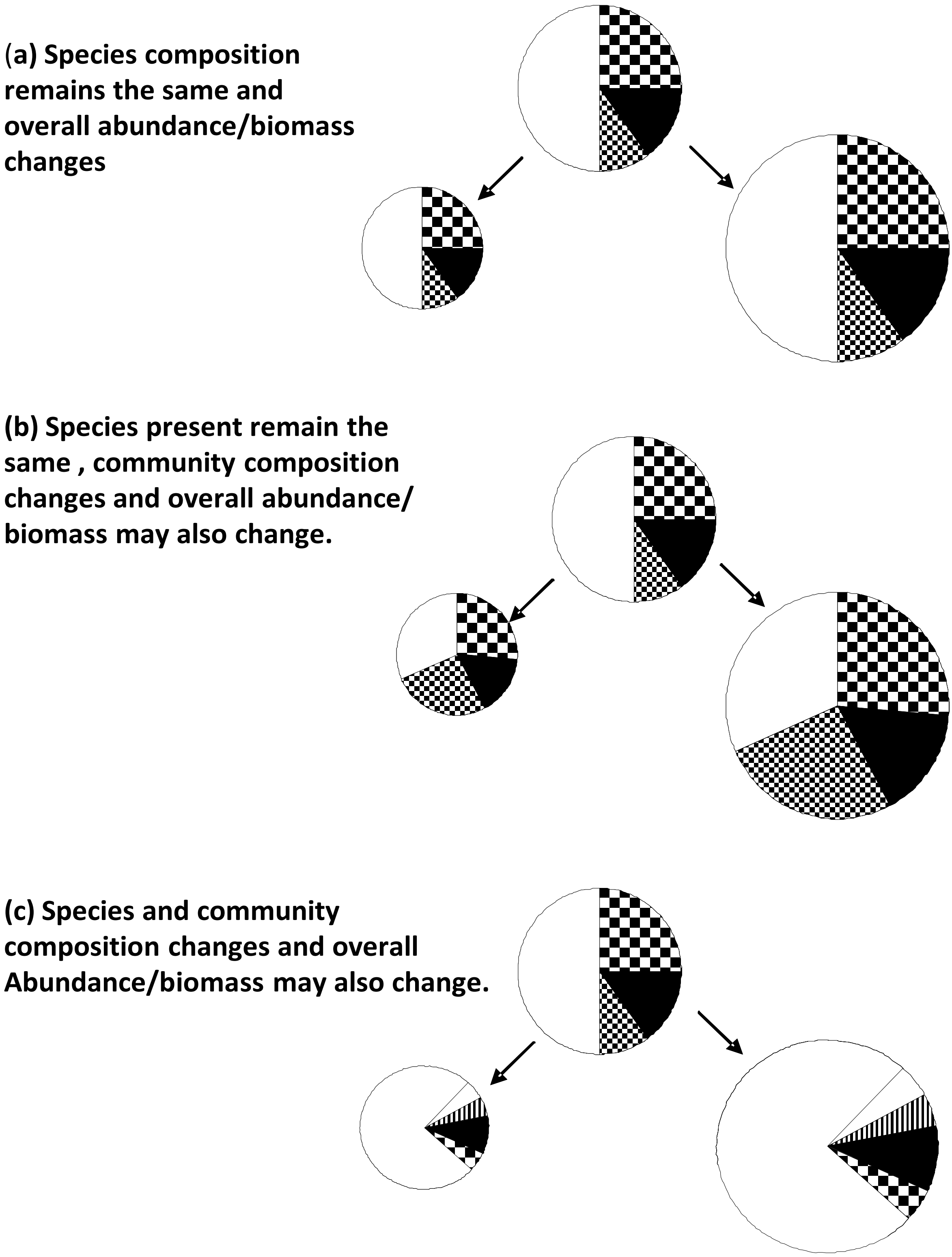

Figure 2.1. **Possible alterations in abundance/biomass and community composition. Overall abundance/biomass is represented by the size of the circles and community composition by the various types of shading. After Hellawell (1986).**

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 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 m^3/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 that were added to this year's report include, infrastructure to supply Eskom and the industry with additional electricity (i.e. a Floating Power Plant (FPP), Liquefied Natural Gas (LNG) Import Facilities and a gas fired independent power plant), the Elandsfontein phosphate mine and Transnet National Port Authority (TNPA) projects under the auspices of Operation Phakisa.

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 AEC 2015). 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. Furthermore, fine sediment can drift into the Langebaan Lagoon, changing the sediment composition, which directly and indirectly (change in macrofaunal assemblages) affect wader birds in the lagoon. 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. The implementation of Floating Power Plants could increase the risk of more frequent and higher magnitude oil spills.

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

Saldanha grew from a small fishing village into a town that supports multiple industries largely as a result of the sheltered nature of the Bay. The development of a large scale industrial port in Saldanha Bay commenced with the construction of an iron ore export facility in the 1970s. 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. 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.).

In the late 1990s, a Multi-Purpose Terminal (MPT) was completed, which was followed by an offshore fabrication facility. Existing facilities now include an oil import berth, three small craft harbours, a loading quay and a tug quay. Mariculture farms and several fish processing factories also make use of the Bay. Approximately 1 000 ha of Saldanha Bay was zoned for mariculture operations in 1997, the majority of which farm mussels and oysters. 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. Combined with increasing land-based effluent discharges into the bay, these developments have led to reduced water exchange and increased nutrient loading of water within the Bay.

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 By 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.

Future industrial development of Saldanha Bay will be strongly driven by Operation Phakisa, which was launched in July 2014 by the South African Government with the goal of boosting economic growth and creating employment opportunities. Operation Phakisa is an initiative that was highlighted in the National Development Plan (NDP) 2030 to address issues such as poverty, unemployment and inequality in South Africa. “Phakisa” means “hurry up” in Sesotho emphasising the government’s urgency to deliver. Operation Phakisa is a cross-sectoral programme, one of which is focused on unlocking the economic potential of South Africa’s oceans through innovative programmes. Four critical areas were identified to further explore and unlock the potential of South Africa’s oceans:

1. Marine transport and manufacturing
2. Offshore oil and gas exploration
3. Marine aquaculture
4. Marine protection services and ocean governance

In line with this development, Transnet and Transnet National Ports Authority (TNPA) have thus far initiated three developments in the Port of Saldanha Bay related to oil and gas services as well as marine infrastructure repair and fabrication. These developments are described in more detail in Section 3.2.11. Furthermore, the established Saldanha Bay aquaculture industry will be expanded through the Saldanha Bay Aquaculture Development Zone (ADZ) under the auspices of Operation Phakisa (Section 3.6).

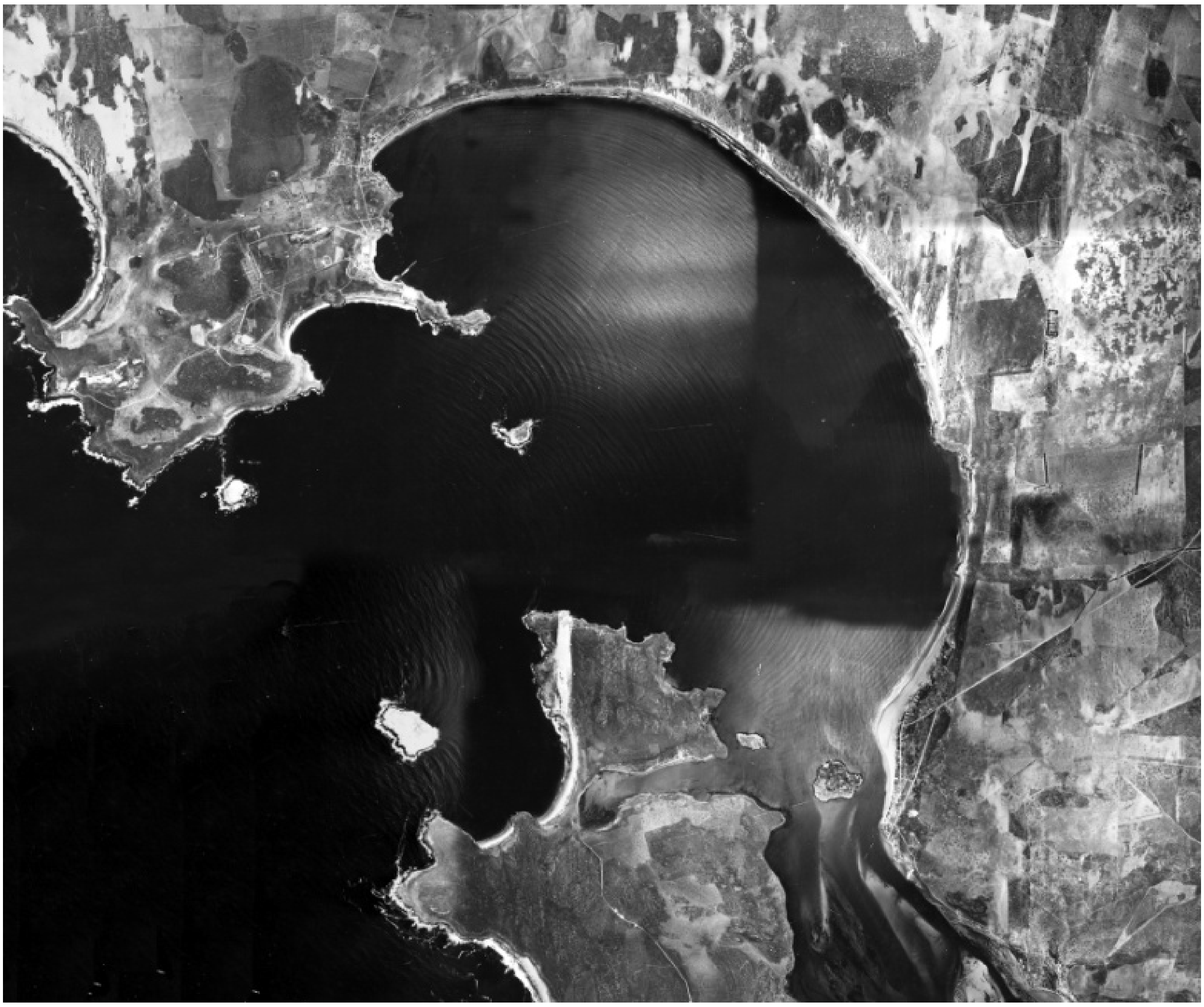

Figure 3.1 Composite aerial photo of Saldanha Bay and Langebaan Lagoon taken in 1960. (Source: Department of Surveys and Mapping). Note the absence of the ore terminal and causeway and limited development at Saldanha and Langebaan.

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.

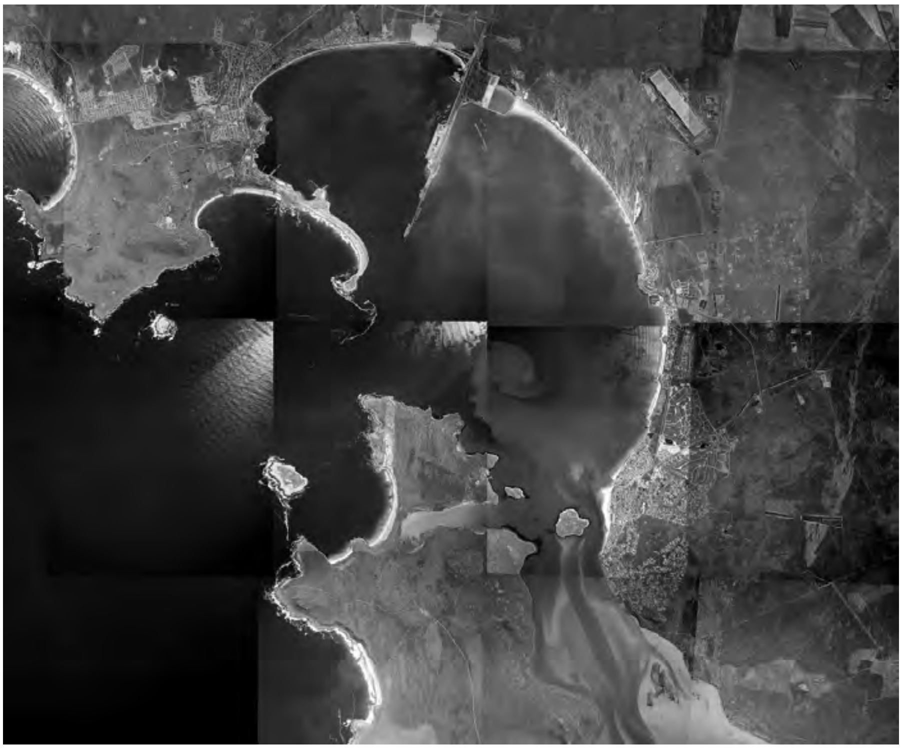

Figure 3.3. Composite aerial photo of Saldanha Bay and Langebaan Lagoon taken in 2007. (Source: Department of Surveys and Mapping). Note expansion in residential settlements particularly around the town of Langebaan.

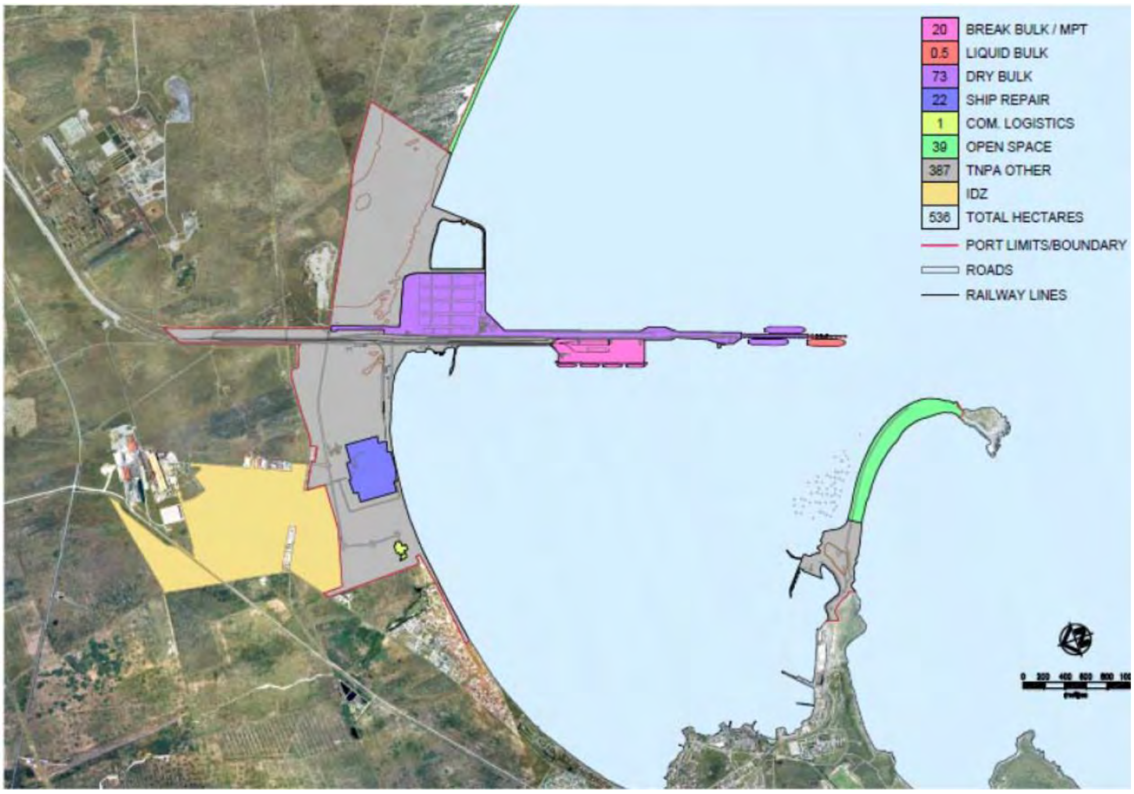

Figure 3.4. Current layout of Transnet Saldanha Bay Port (Source: Transnet National Port Authority 2013, Port Development Framework Plans).

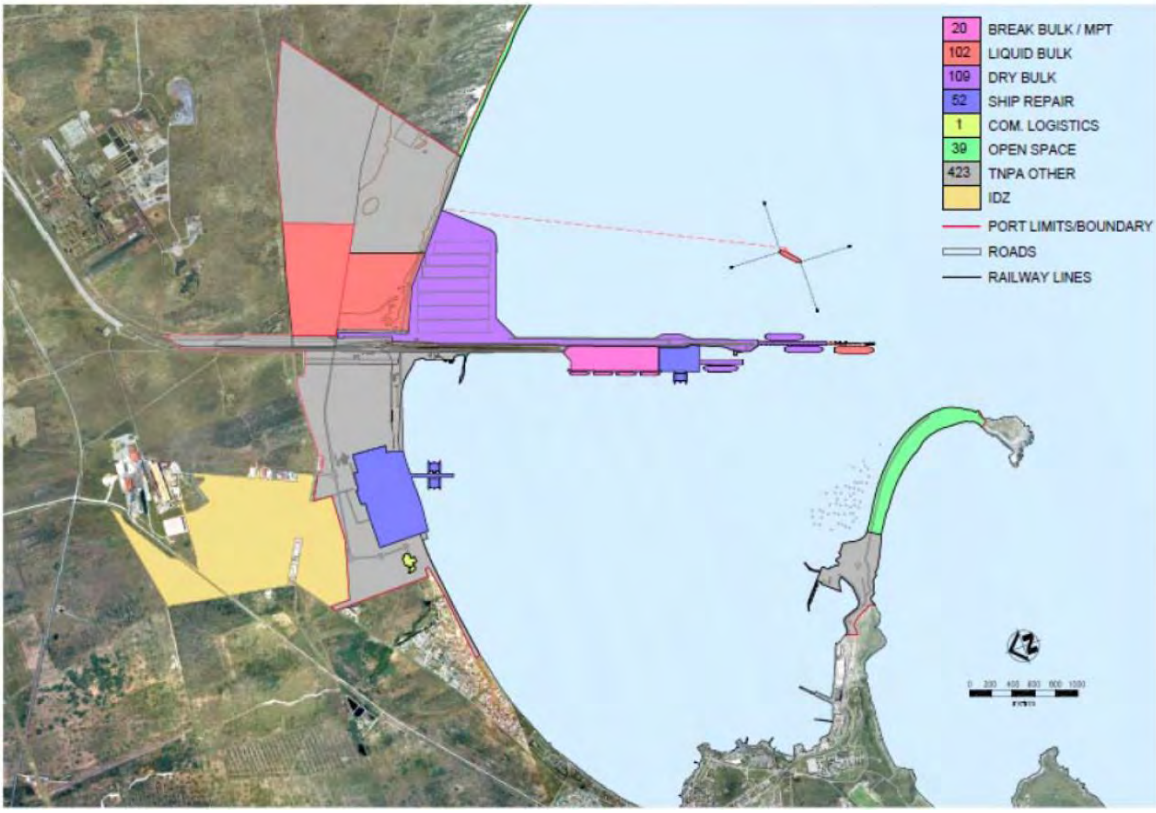

Figure 3.5. Short term layout (2019) of Transnet Saldanha Bay Port (Source: Transnet National Port Authority 2013, Port Development Framework Plans).

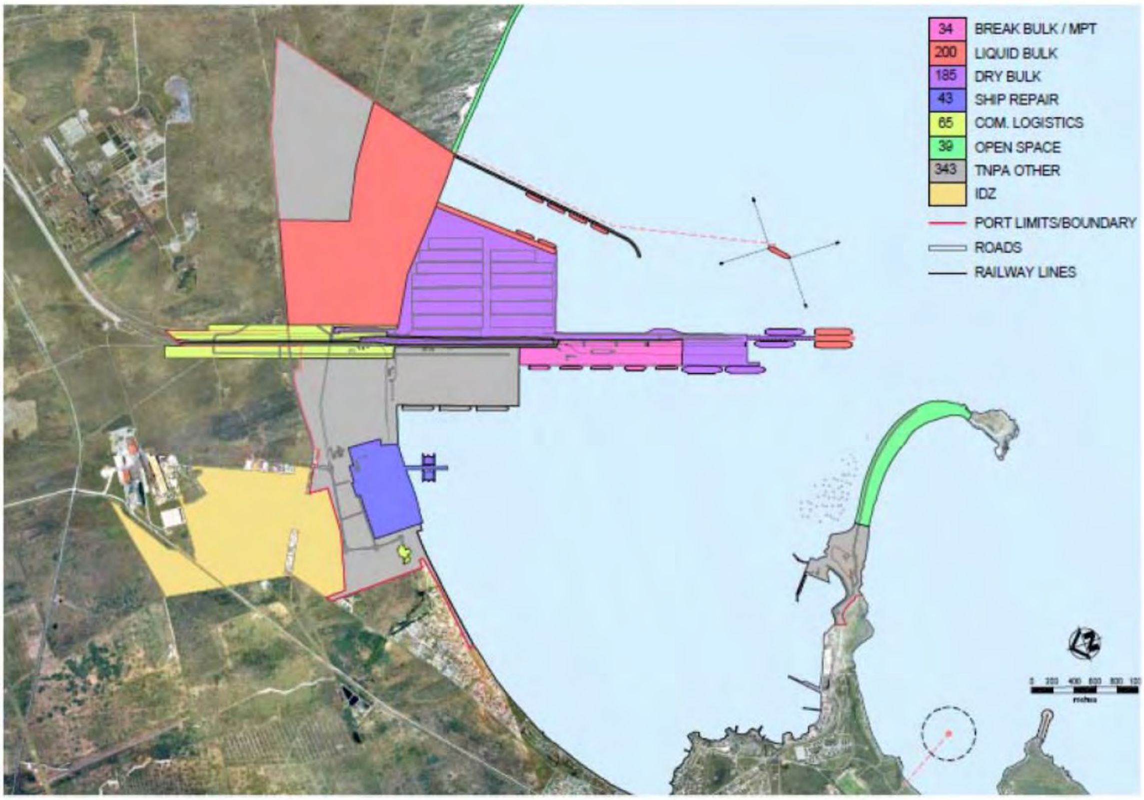

Figure 3.6. Long term layout of Transnet Saldanha Bay Port (Source: Transnet National Port Authority 2013, Port Development Framework Plans).

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 3.5).

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 (2005-2016) 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" guest[1] numbers are relatively constant throughout the year with a small peak in September.

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

International and overnight guest numbers are considerably lower than the visitor categories. Visitor numbers have been increasing at an average rate of 16% per annum since 2005[2], peaking in the 2015-2016 period with a total of almost 287 thousand visitors (Figure 3.10). 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 2015/2016 with 2041 guests.

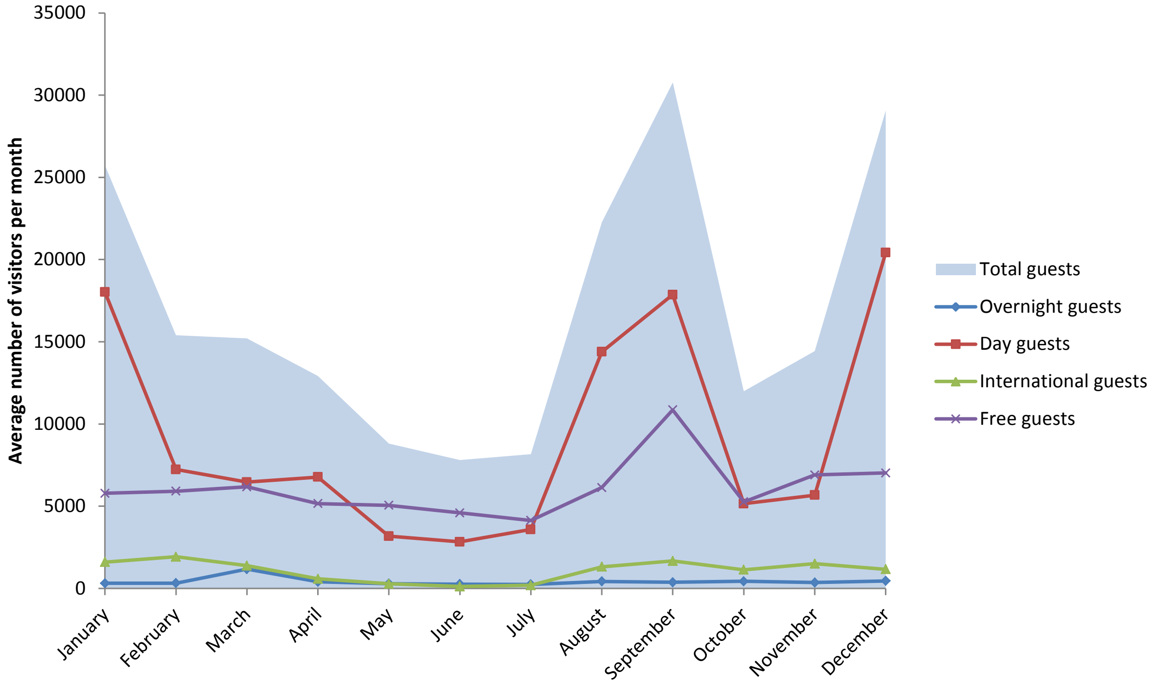

Figure 3.9. Monthly average numbers of tourists visiting the West Coast National Park between July 2005 and June 2016. Day guests include all South African visitors (adults and children) while Overnight guests refer to those staying in SANPARK accommodation. International guests include all SADC and non-African day visitors (adults and children) while the category 'Other' includes residents, staff, military, school visits, etc. (Source: Pierre Nel, WCNP).

[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.

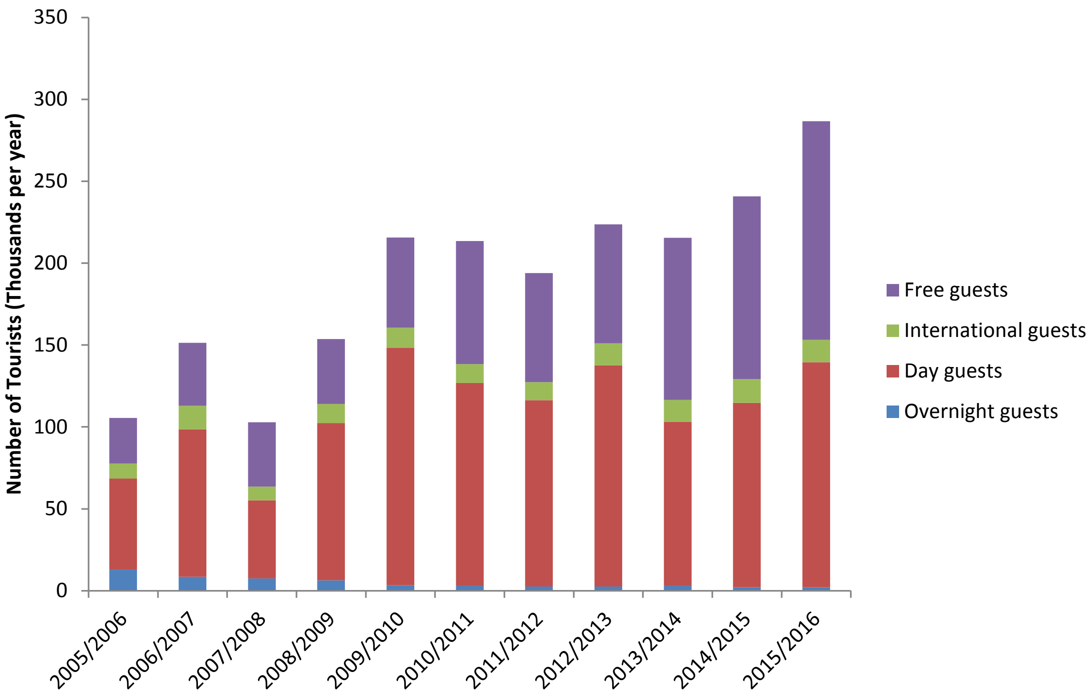

Figure 3.10. Numbers of tourists visiting the West Coast National Park in a rolling 12 month periods from July 2005 until June 2016. Day guests include all South African visitors (adults and children) while Overnight guests refer to those staying in SANPARK accommodation. International guests include 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 2011 Saldanha Municipality IDP has recently been revised and replaced with the 2012/2017 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 l 993) 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 3.5. Concern has been expressed over the fact that the impacts of the SBIDZ on the marine environment have not been adequate 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 3.5.3) 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
• Maintenance, repair, upgrade and conversion of rigs and other vessels (floating repairs, dry docking) • Repair of parts and structures • Inspection, certification	• Structures, subsea manifolds • Spare parts
Communal Services	**Supply & other Services**
• Property development • Customs clearance • Marketing & administrative functions • Security, medical, food & retail • Utilities, waste management, transport • Road and quay access	• 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 (Portion 2, Figure 3.11). On 16 November 2015 the Department of Environmental Affairs and Development Planning (DEA&DP) granted and issued an Environmental Authorisation (EA) for the project in terms of the National Environmental Management Act (No. 107 of 1998), as amended. This gives the SBIDZ LiCO authorisation to develop an oil and gas offshore service complex within the Saldanha Bay IDZ (SLR 2016). Construction of the project commenced during the first quarter of 2016. 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 3.5.3.3). 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 Misverstand 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 3.5.2). 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 3.5.4.1).

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 iron, lead, copper, zinc, and manganese. Most of the iron is exported from the iron ore terminal (Figure 3.12), while 5% 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 3.2.3). Iron ore exports have increased steadily from 20.7 to 55.2 million tons between 2003 and 2016 (note that annual export is calculated based on the fiscal year, i.e. April-March) (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 exponentially from 252 000 tons in 2011 to 2.8 million tons per annum in 2015/2016.

The export of combined lead, copper and zinc increased exponentially from 74 thousand tons in April 2008 to 183 thousand tons in March 2013 and has since fluctuated around the 100 thousand ton mark (Figure 3.14). Individual annual exports for lead, copper and zinc are only available for 2010/2011 to 2013/2014 (Figure 3.14). Lead exports remained stable between 2010 and 2013 before dropping by nearly a third 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 all other metal ores 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 tons 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 only recently but have gained momentum in the last three financial years. Exports from the MPT have increased exponentially from 95 thousand tons in 2013/2014 to 2.9 million tons in 2015/2016. 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) assured stakeholders 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 tons 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 the Portnet site and the iron ore jetty in Saldanha Bay shows a marked increase in 2016 (Section 5.10).

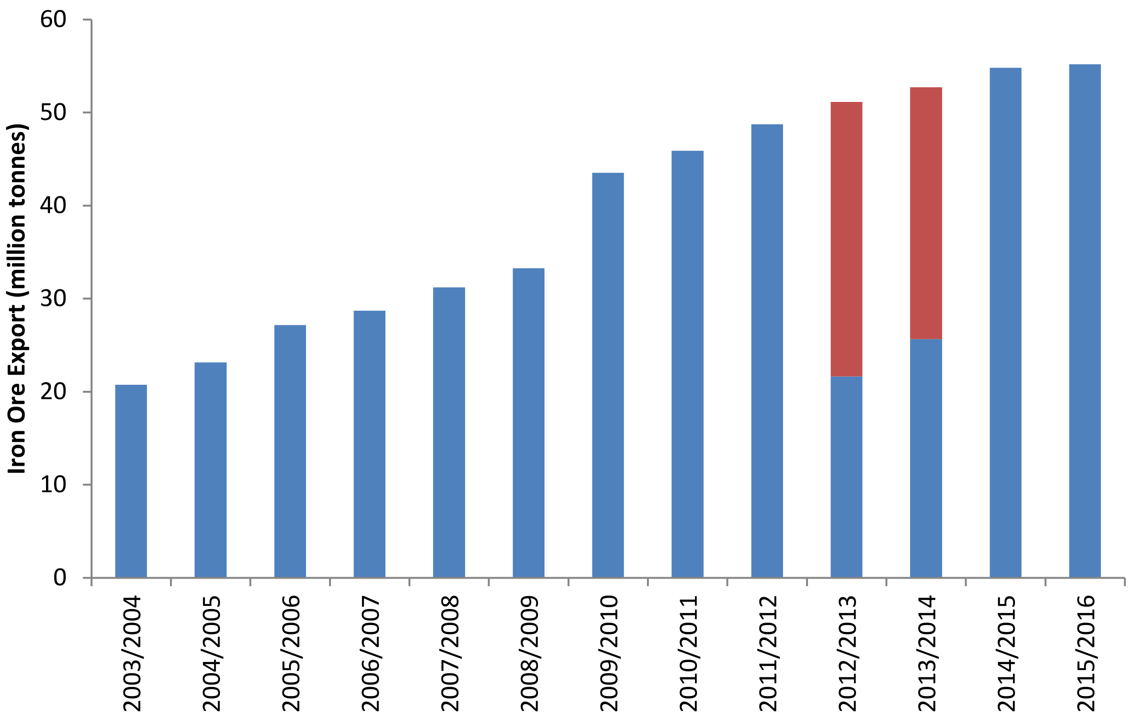

Figure 3.12 Annual exports of iron ore from the Iron Ore Terminal at the Port of Saldanha between April 2003 and March 2016. Extrapolation of data for the financial years 2012/2013 and 2013/2014 is indicated in red (Data provided by Rejean Viljoen, Transnet Port Authority 2016).

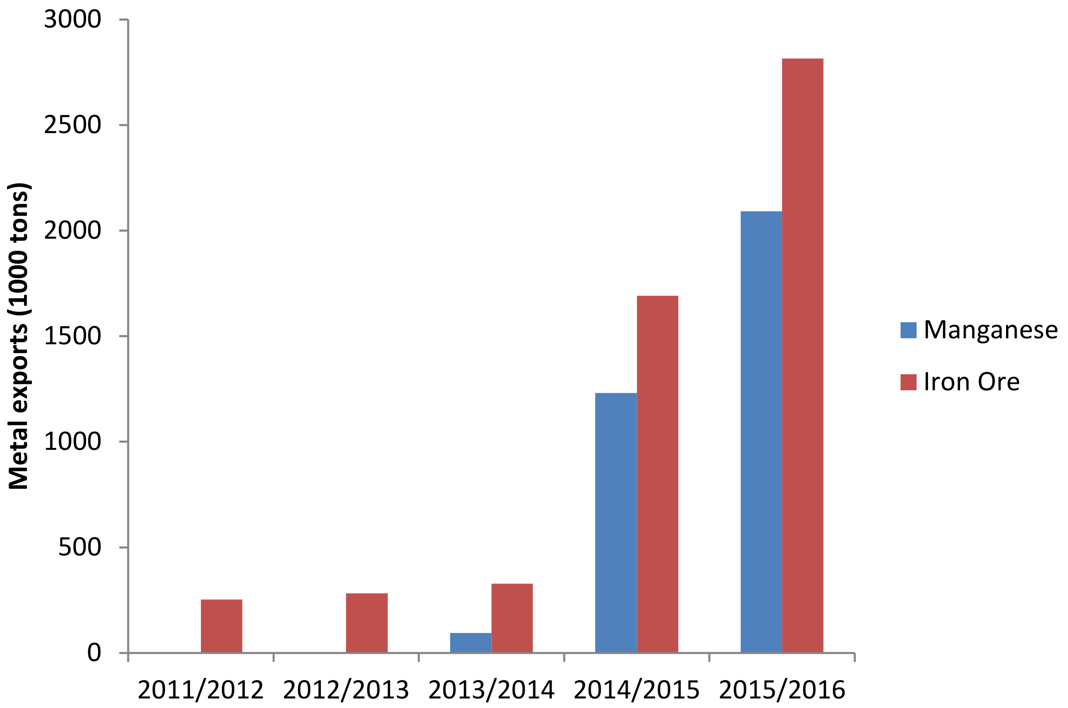

Figure 3.13 **Annual exports (April 2011 – March 2016) of manganese and iron ore from the Multipurpose Terminal at the Port of Saldanha Bay (Data provided by Rejean Viljoen, Transnet Port Authority 2016).**

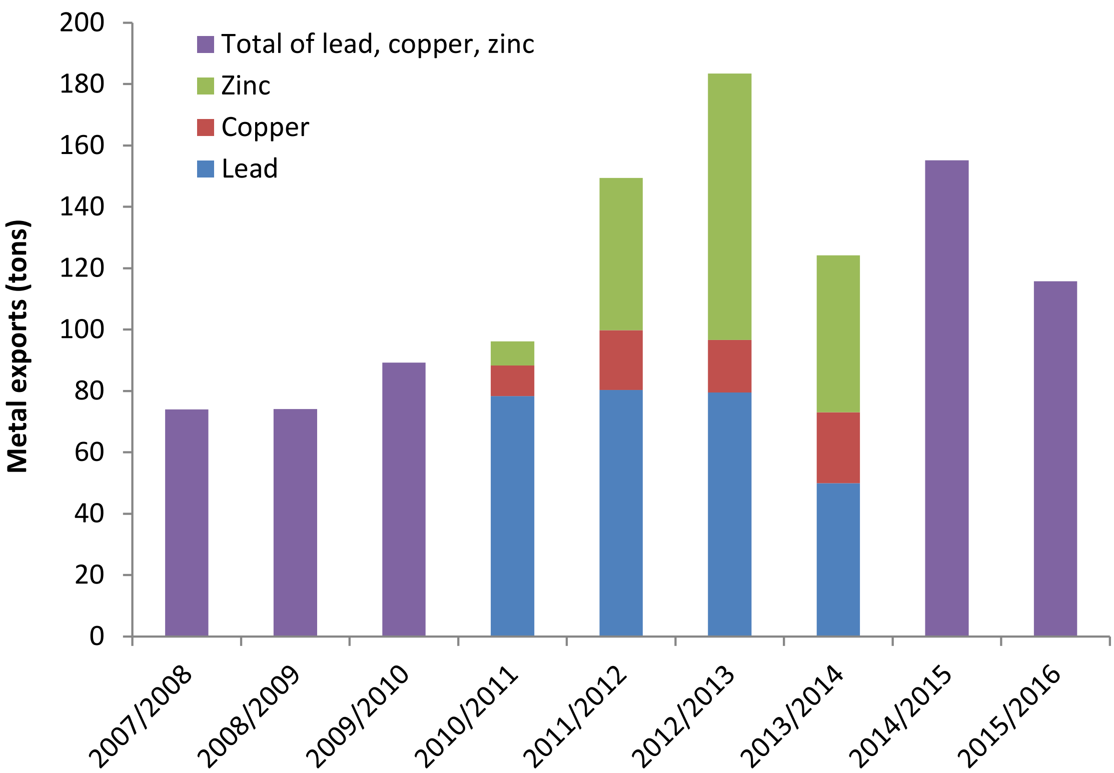

Figure 3.14 **Annual exports (April 2011 – March 2016) of lead, copper and zinc from the Multipurpose Terminal at the Port of Saldanha Bay. Note that separate data for these commodities was only available for April 2010-March 2014 (Data provided by Rejean Viljoen, Transnet Port Authority 2016).**

3.2.3 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 tons 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).

3.2.4 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 was 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 EMPr 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 was 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 (Frans Lesch, ILF Consulting Engineers, Project Manager at Avedia Energy Saldanha LPG plant, *Pers. Comm.* 2015) (refer to AEC 2014 for more information).

3.2.5 Floating Power Plant

The Department of Energy (DoE) has, in collaboration with Transnet, developed a two-phased approach to contribute towards meeting South Africa's electricity requirements. The first phase is to procure power from a Floating Power Plant (FPP) to be located within the Port of Saldanha Bay (note that the same is planned for Ngqura and Richards Bay). The second phase is to facilitate the import of Liquefied Natural Gas (LNG) to allow for the development of medium- to long-term gas power plants outside of the port boundaries (Section 3.2.6). The DoE appointed Environmental Resources Management Southern Africa (Pty) Ltd (ERM) as the independent Environmental Assessment Practitioner to conduct the EIA process for both phases for Saldanha. ERM published the Draft Scoping Report in November 2015. Excerpts and illustrations from the scoping report are provided below (ERM 2015b).

Floating Power Plants are special purpose marine vessels which are selfcontained power generation resources which only require a land-based transformer connection to produce and distribute power (Figure 3.15). The generating capacity of the FPPs is likely to range from 50 to 500 MW. The FPPs will have duel fuel capability technology (either engines or turbines), that can run either on liquid fuels or gaseous fuels. As there is currently no LNG infrastructure within the Port, it is anticipated that FPPs will initially be fuelled with imported liquid fuel such as distillate fuel oils or residual fuel oils or LPG (for more details refer to Section 3.4.2) until LNG facilities are developed (ERM 2015b). Fuel is typically supplied, once a week, from a bunker barge or tanker of a fuel supply vessel moored close to the Floating Power Plant. The Floating Power Plant will operate 24 hours per day for 365 days per year. Power would be evacuated via a switchyard and a 132 kV transmission line (approximately 7.5 km) to the Blouwater substation, both of which are managed by Eskom (Figure 3.16) (ERM 2015b). The proposed Floating Power Plant could produce up to 350 MW, which would be supplied to the national grid. The project has both land-based (terrestrial) and marine-based components, including the following:

- Floating Power Plant which may be a power barge or a self-propelled powership (marine);
- Mooring infrastructure in the form of anchors, dolphin structures and a piled temporary access jetty;
- Floating fuel storage facilities (marine);
- Connection of the fuel storage facility to the Floating Power Plant for the transfer of liquid fuel/gas on board (marine);

- Underground or aboveground power lines connecting the Floating Power Plant to a floating or terrestrial switchyard for the conversion of the power to a higher voltage (marine and terrestrial);
- Transmission line to Blouwater substation for distribution into the national power grid (terrestrial).

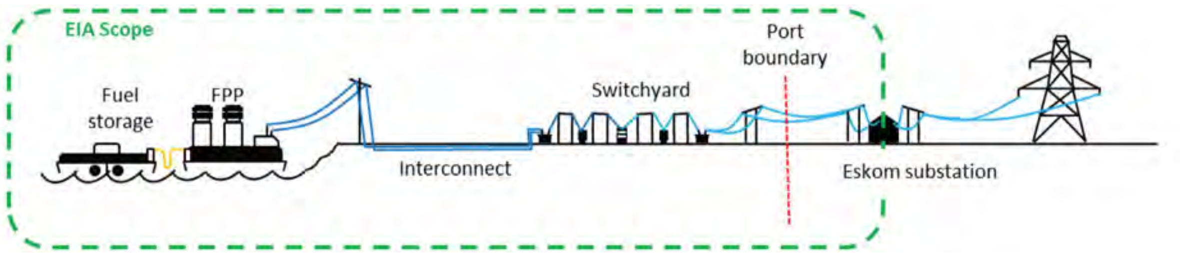

Figure 3.15 An illustration of the proposed FPP and the associated infrastructure required to supply power into the national grid (Source: EIA Scoping Report, ERM 2015b).

The key preliminary impacts on the marine environment were identified in the scoping report (ERM 2015b), including:

- Leaks or accidental releases during construction, operation and decommissioning activities could impact on the marine environment.
- Marine habitats, fauna and flora may be impacted by the FPP water supply taken from the sea.
- Depending on the technology selected, water used in the cooling process may be discharged into the marine environment 5-10 degrees colder and this may impact marine life.
- Noise may result from FPP related activities such as mooring of the vessels, power generation, refuelling etc.

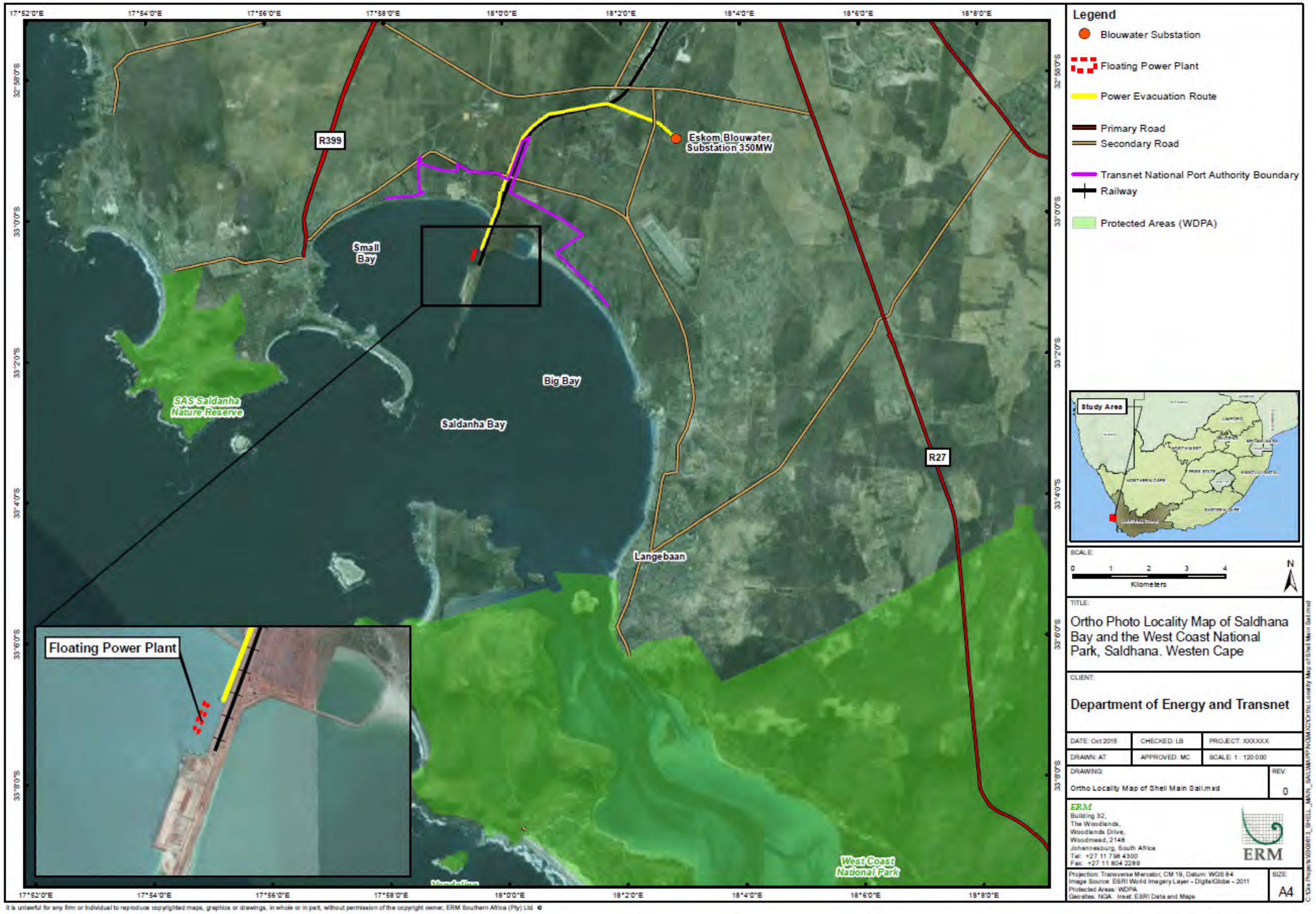

Figure 3.16 **Location and layout of the proposed Saldanha Bay Floating Power Plant (FPP) and distribution infrastructure (Source: EIA Scoping Report, ERM 2015b).**

3.2.6 Liquefied Natural Gas Import Facilities

The proposed Liquefied Natural Gas (LNG) Import Facilities aim to secure gas supplies to supplement land-based gas power plants, other industrial users and FPPs (ERM 2015b). This project constitutes phase two in national efforts to contribute towards meeting South Africa's electricity requirements. Phase two will allow for the development of medium- to long-term gas power plants outside of the port boundaries (Section 3.2.6) (ERM 2015a and 2015b). ERM provided stakeholders with a Background Information Document in October 2015 of which excerpts and illustrations are provided below (ERM 2015a). The facilities will provide for the importation, storage, regasification and the transmission of natural gas to a distribution hub, and will include both land-based (terrestrial) and marine-based components. Both, floating and landbased regasification technologies are currently considered for this project (Figure 3.17). Floating regasification would consist of the following components:

- A marine import facility consisting of a loading quay, berthing and mooring dolphins, access and services trestle and pipeline;
- A permanently moored Floating Storage and Regasification Unit (FSRU) (marine); and
- A gas pipeline connecting the fuel storage and regasification facility to a common gas distribution hub from which the gas will be distributed to the power plant and domestic users via pipeline.

Land-based regasification technology would consist of the following components:

- A marine import facility consisting of a loading quay, berthing and mooring dolphins, access and services trestle and pipeline;
- A dock at an existing facility in the port or a special purpose docking facility to be constructed for an LNG transport ship;
- A cryogenic gas pipeline connecting the LNG carrier to storage and regasification facilities on land; and
- A gas pipeline from the regasification unit to a gas distribution hub which will then distribute the gas further to a power plant and other gas users. Electricity is connected from the power plant to the national grid.

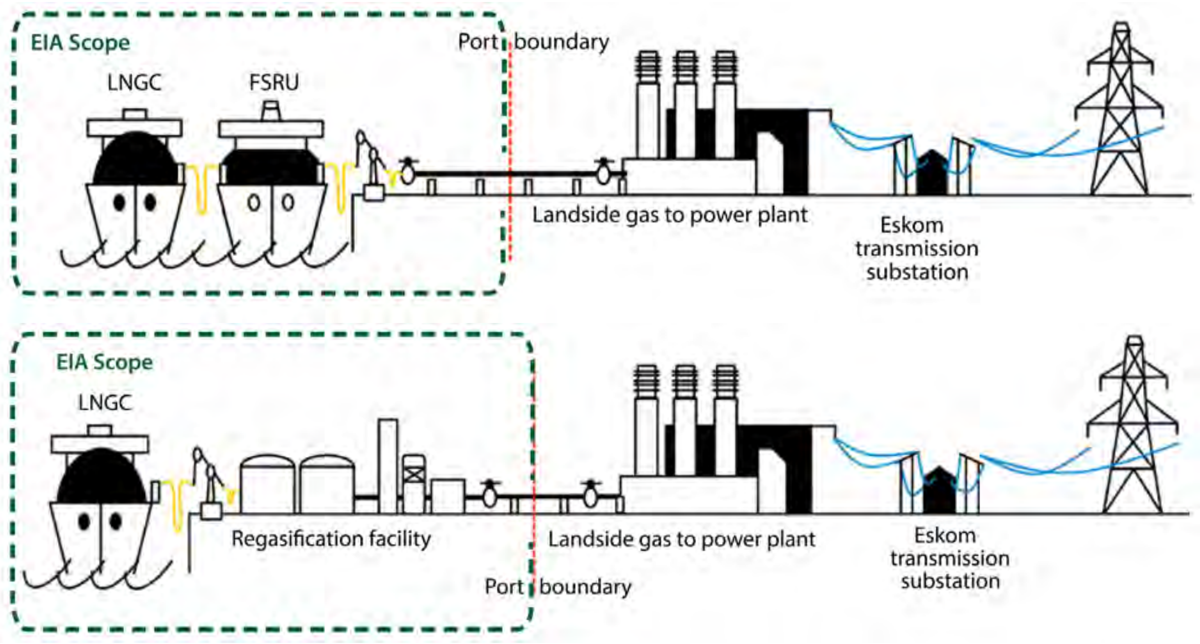

Figure 3.17 An illustration of the floating (top) and land-based (bottom) regasification technology (Source: Background Information Document, ERM 2015a).

3.2.7 Gas fired independent power plant

The International Power Consortium South Africa (Pty) Ltd ("IPCSA") have proposed the construction of a Combined Cycle Gas Turbine (CCGT) power plant (1507 MW net capacity) as a solution to medium to long-term sustainability of Arcelor Mittal's Saldanha Steel and surrounding economy (ERM 2015c). The Project requires Environmental Authorisation (EA) from the National Department of Environmental Affairs (DEA) under the National Environmental Management Act (NEMA) (Act No. 107 of 1998), as amended, through a Scoping and Environmental Impact Assessment (EIA) process. The Draft Environmental Impact Assessment (EIA) Report was released for a 30 day commenting period between 22 July and 25 August 2016 and has been revised since.

The project is primarily a Liquefied Natural Gas (LNG) power supply project to the Saldanha Steel Plant (ERM 2015c). LNG will be supplied by ship to the Port of Saldanha, where it will be regasified and then offloaded via a submersible pipeline either from a mooring area located offshore or a berthing location in the Port of Saldanha. Initial discussions have been held with Transnet National Ports Authority (TNPA) in Saldanha in this regard. It is anticipated that this project will connect to the Department of Energy's (DoE's) planned LNG import terminal in the Port of Saldanha (Section 3.2.6). Should this not occur a separate EIA will be undertaken to permit the marine component of the import of LNG.

3.2.8 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).

3.2.9 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 proposed constructing a breakwater at the same site (Special Forces Regiment 4 Boat Park in Salamander Bay) in 2014. Please refer to AEC 2015 for more detail on this project.

3.2.10 Elandsfontein phosphate mine

The Elandsfontein phosphate deposit is currently the second biggest known resource in South Africa. The deposit is located on the farm Elandsfontein 349, approximately 10 km to the east of Langebaan (Figure 3.18) (Braaf 2014). Two significant aquifers underlie the phosphate deposit namely the Langebaan Road Aquifer System (LRAS) (northern paleo-channel) and the Elandsfontein Aquifer System (EAS) (southern paleo-channel) (Braaf 2014). Consequently, the phosphate deposits underlie the groundwater table (i.e. within the saturated zone) (GEOSS, Julian Conrad, *pers. Comm.* 2016).

The dominant application of phosphorus is in fertilisers and the demand in the agricultural sector is growing (Braaf 2014). Elandsfontein Exploration and Mining (Pty) Ltd (EEM) commissioned Braaf Environmental Practitioners to facilitate the environmental authorisation process for the proposed Elandsfontein Phosphate project. The Environmental Impact Assessment (EIA) process was completed in September 2014 and Environmental Authorisation (EA) was granted in February 2015 (Braaf Environmental Practitioners, Olivia Braaf, *pers. Comm.* 2016).

EEM intends to adopt an open-pit strip mining method sustaining a production rate of 1.5 million tons per annum over the next 20 years. The strip mining will take place in a number of discrete phases, which will reduce the overall mining, foot print:

a. topsoil is removed and stockpiled;
b. overburden layer is stripped and stockpiled;
c. phosphate ore is mined; then
d. the strip is backfilled with the overburden and slimes from the plant; and
e. the topsoil returned to the strip and rehabilitated.

Raw process water will be primarily supplied from within the pit. Additional water will be abstracted from the aquifer discharge pumping streams (Braaf 2014). For strip mining to take place, the water table is lowered by extracting groundwater from the underlying aquifer via a series of boreholes upstream of the mining site. Concern has been expressed over potential impacts that the proposed phosphate mine at Elandsfontein may have on groundwater quality and flows to Langebaan Lagoon.

Firstly, stormwater carrying water from spoil areas, slimes dams and mineral separation operations could potentially contaminate the ground water. Langebaan lagoon is not fed by overland streams or rivers due to the porous nature of the sediments and the arid conditions, but it has been suggested that groundwater plays a significant role in sustaining the marsh ecosystems (Valiela *et al*., 1990; Burnett *et al*., 2001). Diagnostic plants indicate significant contributions of groundwater (Adams and Bate, 1999). For example, Reeds (*Phragmites australis* and *Typha capensis*) occur at discrete points on the shoreline surrounding Langebaan lagoon. These plants can only survive in water or at least damp soil and are only able to tolerate salinity levels up to a maximum of 20-25 ppt (Adams and Bate 1999, Nondoda 2012). The salinity of the water in the lagoon is generally the same (or occasionally higher) than that of seawater – i.e. 35 ppt, and thus these species' are only found at sites where freshwater is seeping into the lagoon (i.e. the main groundwater input sites). The fauna and flora in the Lagoon are mostly marine and estuarine in nature, and while they are able to tolerate salinity (salt) levels anywhere between fresh water (i.e. zero parts per thousand) and normal seawater (35 parts per thousand), they are highly sensitive to salinities in excess of that.

Reducing freshwater inflow into Langebaan Lagoon as a result of the mining activities could result in hypersaline conditions, killing flora and fauna sensitive to salinities in excess of normal seawater. To mitigate impacts on groundwater flow, it was suggested that the extracted water is injected back into the system via boreholes downstream of the mining site. This mining method is predicted to use only a small proportion of the extracted water for mining and processing.

While it has been established from a groundwater assessment undertaken by Julian Conrad of Geohydrological and Spatial Solutions International (Pty) Ltd that the proposed mining operations are highly unlikely to have any impact on the groundwater flow, EMM have opted to take a precautionary approach and carefully monitor any potential impacts on Langebaan Lagoon in association with the SBWQFT. The State of the Bay monitoring activities undertaken by the SBWQFT have thus been expanded to incorporate monitoring of various biological and physico-chemical variables to establish an appropriate baseline against which any potential future changes in the Lagoon can be benchmarked. This includes monitoring of salinity and macrofauna assemblages at the top of the lagoon (see Section 8.7 for more details on this).

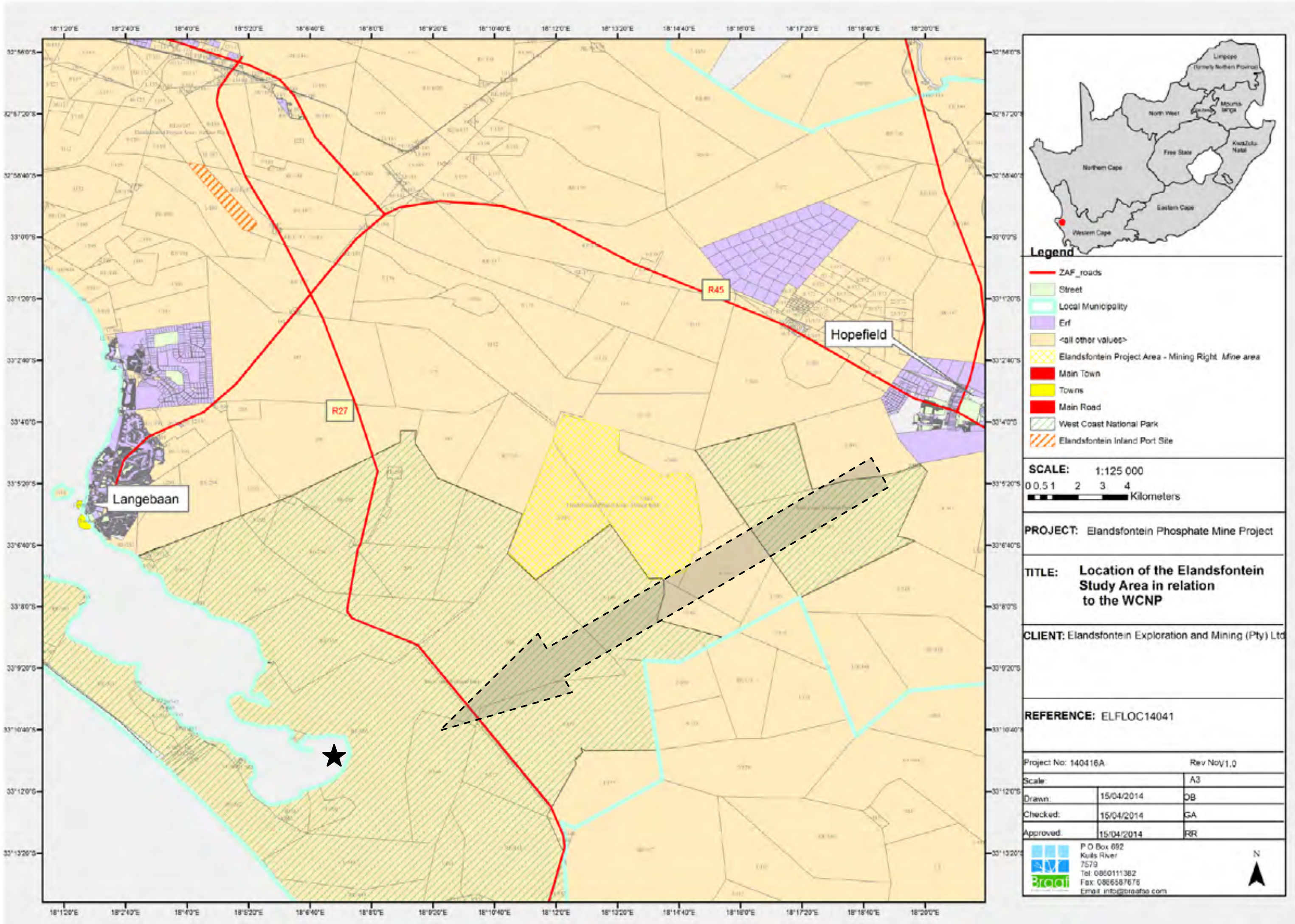

Figure 3.18 **Location of the Elandsfontein Study Area (Source: Braaf 2014). The arrow indicates direction of groundwater flow and the star location of salinity and macrofauna monitoring sites in Langebaan Lagoon.**

3.2.11 TNPA projects under the auspices of Operation Phakisa

Due to an increase in offshore activity in South Atlantic and West African waters, and the resulting demand for vessel repair facilities, the National Government and Transnet National Ports Authority (TNPA) proposed the development of new infrastructure at the Port of Saldanha in line with the objectives of Operation Phakisa. The new infrastructure is expected to include the following components:

1. a Vessel Repair Facility (VRF) for ships and oil rigs (Berth 205);
2. a 500 m long jetty at the Mossgas quay; and
3. a floating dry dock for inspection of Offshore Supply Vessels (OSV).

These three projects are described in more detail in Sections 3.2.11.1-3.2.11.3. The potential impacts on the marine environment associated with the VRF and the Mossgas Jetty are also summarised in Section 3.2.11.4. The development of Berth 205 and the Mossgas Jetty will require extensive dredging operations to allow large oil and gas vessels access to new berthing infrastructure. The total dredge area during construction for the long-term development scenarios for the Mossgas Jetty and Berth 205 was estimated by TNPA at approximately 2.6 million m^3. This equates to the second largest dredge event in the history of Small Bay and is comparable to the dredging which commenced in 1996 for the construction of the MPT (Refer to more information about dredging in Saldanha Bay in Section 3.3).

3.2.11.1 Vessel Repair Facility (VRF) at Berth 205

At present, Vessel Repair Facilities (VRFs) in Saldanha Bay are generally limited to minor repairs of fishing vessels, although a few offshore rigs have been repaired at Berths 203, 204 and the MPT. In order to harness the vessel repair business opportunity, dedicated and purpose built quays with associated bulk services and onshore back of port services are required. The location study identified the site immediately to the south of Berth 204 of the MPT (referred to here as Berth 205) as the preferred location, with the alternative being to the north (ARUP 2014) (Figure 3.19).

According to ARUP (2014), the southern location has a number of engineering and logistical advantages over the other sites considered:

- Berth 205 is adjacent to the navigation channel to the MPT and to the dredge channel to the Iron Ore Expansion berth, which will keep dredging to a minimum.
- The location is within the Port security boundary simplifying access.
- In the event of the market failing to materialise, the facility could be incorporated into the MPT or could serve as an additional bulk export facility.

Possible disadvantages are as follows:

- Future expansion would be prevented if the Iron Ore Expansion Project were to proceed, although it would be possible to expand into the MPT.
- Vessels under repair could be impacted by vessels travelling to and from the MPT.
- High airborne dust concentrations at this site may damage vessels unless regularly washed down.

3.2.11.2 Mossgas Jetty

In 2009, a study was undertaken to identify the options and costs for the extension of the Mossgas yard in order to provide a 500 metre long quay to form an offshore vessel repair facility (ZLH 2009). More recently, a pre-feasibility study reported an increasing demand for semi-submersibles, Floating Production Storage Offload Vessels (FPSOs) and jack-up platforms (ARUP 2016). This sparked the proposal of a complimentary offshore supply vessel repair facility adjacent to Mossgas Quay.

The pre-feasibility study considered three possible locations for the jetty (Figure 3.19):

- The eastern side of Mossgas Quay (preferred site)
- The western side of Mossgas Quay (alternative site)
- At the existing Mossgas Quay (not feasible)

The existing Mossgas Quay option was eliminated due to current port operations and existing lease agreements. The western side of the Mossgas Quay was not preferred due to cost limitations and the current location of the marina. As sediment transportation adjacent to Mossgas is predominantly from west to east, more frequent maintenance dredging and a longer groyne would be necessary if the jetty is constructed to the west (ARUP 2016). A jetty positioned to the east is preferable to developers as costs are projected to be lower, while activity will be further away from designated aquaculture areas and the Bluewater Bay residential area (Figure 3.19).

3.2.11.3 Floating dry dock for the inspection of Offshore Supply Vessels

A floating dry dock is essentially a semi-submersible vessel that is able to adjust its ballasting to increase its draft to allow a vessel to manoeuvre into the main dock barrel. The floating dry dock is then de-ballasted to raise the vessel out of the water. The floating dry dock may be manoeuvred into deeper water to service larger vessels, therefore reducing the depth of dredging required at the ship maintenance site.

3.2.11.4 Marine Environmental Impact Assessment

The proposed impact sites are already moderately disturbed by shipping, pollution (including iron ore dust) and maintenance dredging. Despite these existing impacts and pressures, Small Bay should not be regarded solely as an industrial port. This area still provides valuable goods and services to the Saldanha Bay-Langebaan Lagoon system as a whole and is essential for the healthy functioning of the area.

Anchor Environmental Consultants (Pty) Ltd. were appointed by CCA Environmental (Pty) Ltd. (CCA) to conduct a marine environmental screening study for the construction of the VRF at Berth 205 and a 500 m long jetty in the vicinity of the existing Mossgas Quay in the Port of Saldanha (Laird and Clark 2016).

Figure 3.19 **The Iron Ore Terminal (IOT), the Multi-Purpose Terminal (MPT), the Dry Bulk Terminal (DBT) and the Liquid Bulk Terminal (LBT) separating Big Bay and Small Bay. The preferred (green) and alternative (orange) position of the Berth 205 VRF and the preferred (yellow) and alternative (blue) options for the proposed Mossgas Jetty are indicated (Adapted from: ARUP 2016).**

The study found that based on data reviewed from the Saldanha State of the Bay Report (Anchor 2015) and from hydrological and sediment modelling (ZAA 2016), impacts from construction at the 'preferred' and 'alternative' sites are unlikely to differ within a development option (i.e. Mossgas Jetty east no different from Mossgas Jetty west and VRF north no different from VRF south) when viewed from a marine environmental perspective. In contrast, differences in the severity of some impacts are expected between the two projects (i.e. between Mossgas and the VRF at Berth 205).

For example, despite the fact that the proposed construction footprint at the Mossgas Jetty is 150% smaller than that at Berth 205, impacts were rated higher at the Mossgas Jetty due to the ecological importance of the intertidal and shallow subtidal area in the northern part of Small Bay and the relative scarcity of this habitat. Planned annual maintenance dredging at the Mossgas Jetty also elevated significance ratings by increasing the impact duration from short/medium-term to long-term. The shallow intertidal beach area in the northern section of Small Bay is crucially important for fish recruitment. If construction of the Mossgas Jetty is approved, up to 15% of the total nursery area in Small Bay will be lost. Although fish can potentially utilise similar habitat west of the proposed jetty, it is not clear whether this area will be sufficient to sustain increased densities of juvenile fish during a prosperous recruitment year. With the intention of preventing collapse of commercially important fish stocks such as white stumpnose (which are already declining in the Saldanha Bay-Langebaan Lagoon system), it was recommended that no further net loss of shallow intertidal beach habitat in Small Bay should be permitted after the completion of the Mossgas Jetty.

Other impacts that are considered as important include turbidity plumes created by dredging. The effects of increased Total Suspended Solids (TSS) in the water column during dredging can have severe impacts on the marine environment through the mobilisation of fine sediments, contaminants, nutrients and increased turbidity (Refer to Section 3.3 for more information). ZAA reported on the likely severity of an increased concentration of TSS at the dredge sites based on a settling rate of 0.45 mm/s (ZAA 2016). Due to the combination of mud and fine calcrete dust (which creates extensive white plumes when removed) known to be present in Small Bay, previous modelling studies applied settling rates of 0.1 and 0.2 mm/s for very fine (< 2 µm) and fine material respectively (Anderson 2008). The substantially higher settling rate applied for the Berth 205 and Mossgas project is likely to result in an underestimation of the extent of the turbidity plume. Although modelled dredge volume was elevated to anticipated 'worst case scenario' by ZAA, the settling rate may not have been conservative enough considering the presence of the calcrete layer between 3 and 17 m in subsurface marine substrata in the construction footprint (ARUP 2014 and 2016). Although deep sediments are unlikely to contain toxic levels of trace metals, excess fine sediments will intensify the impacts of smothering and increased turbidity. The study by Anchor Environmental therefore recommended that the sediment particle size included in the model is revised to take the estimated dredge volume of calcrete into account. For the construction phase, standard mitigation measures (i.e. real-time monitoring and installation of a silt curtain) for minimising the impact of turbidity plumes were recommended.

3.3 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.

3.4 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 Mossgas 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.

3.4.1 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 tons 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 (Zsilavecz 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 *Discinisca 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).

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 (DWAF 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 5.10).

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 (DWAF 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 500 ships visiting the port between July 2015 and June 2016 (Figure 3.20.). However, the number of vessels entering the port seems to have stabilised since 2011. 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 22.5 million tons of ballast water being discharged between July 2015 and June 2016 (Figure 3.21). Overall, iron ore tankers contributed 57% to the observed vessel traffic and 92% to the total water discharged between July 2015 and June 2016 (Figure 3.20. and Figure 3.21).

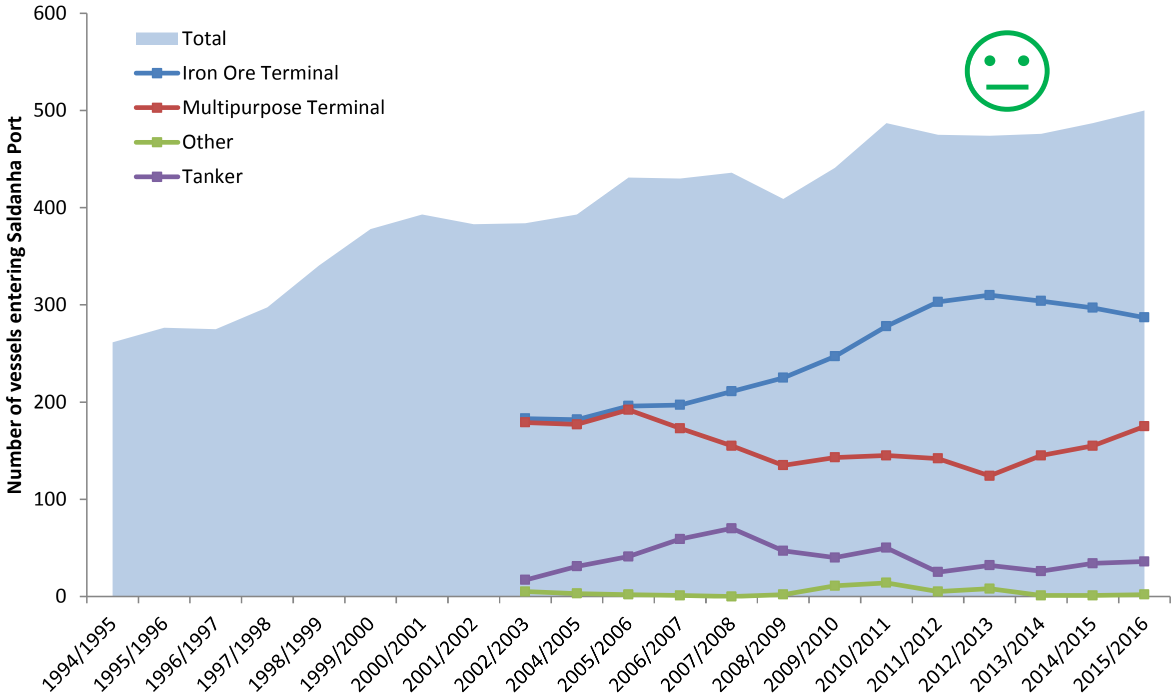

Figure 3.20. The numbers and types of vessels entering Saldanha Port. The total number of vessels entering Saldanha Port between July 1994 and June 2016 is shown as the blue area. The numbers of vessels docking at the iron ore terminal, the multipurpose terminal, tankers and other vessels are shown in blue, red, green and purple respectively. Data for the different types of vessels is only available from 2003 onward (Sources: Marangoni 1998, Awad *et al.* 2003, Transnet-NPA unpublished data 2003-2016).

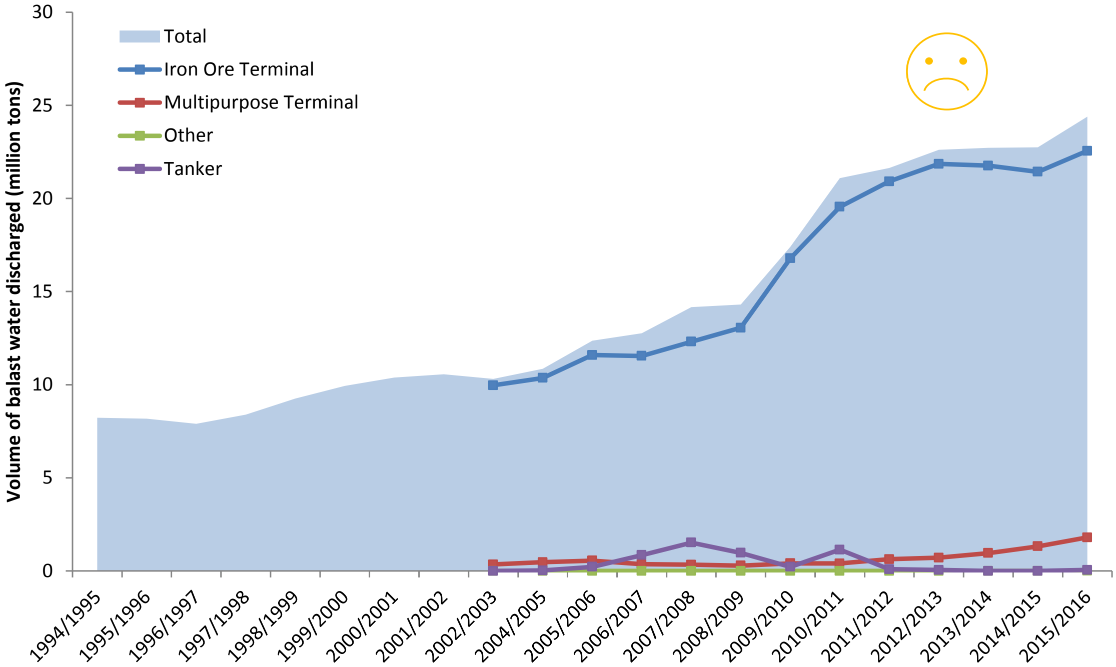

Figure 3.21 Volumes of ballast water discharged tons in Saldanha Port. The total amount of ballast water discharged in Saldanha Port between the years 1994 and June 2016 is shown as the blue area. Ballast water discharged by vessels docking at the iron ore terminal, the multipurpose terminal, tankers and other vessels are shown in blue, red, green and purple respectively. Data for the different types of vessels is only available from 2003 onward (Sources: Marangoni 1998, Awad *et al.* 2003, Transnet-NPA unpublished data 2003-2016).

3.4.2 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 tons
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 tons
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 tons.
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). The implementation of Floating Power Plants (FPPs) (Section 3.2.5) will increase the risk of oil spills (frequency and magnitude) unless the Environmental Management Programme contains effective mitigation measures and implementation is ensured.

3.4.3 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 aculeatusl*) (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).

3.5 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).

3.5.1 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 amended[3]), 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 1999[4]), 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 the 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)	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; Water should not contain materials from non-natural land-based sources which will settle to form putrescence; 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 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	Should not be more than 35 *Hazen units* above ambient concentrations (colour) Should not reduce the depth of the euphotic zone by more than 10 % of ambient levels measured at a suitable control site (turbidity)			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 *Dissolved oxygen*		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 *Dissolved oxygen*			
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 *E. coli.*)	-	-	Maximum acceptable count per 100 ml: 20 in 80 % of the samples 60 in 95 % of the samples	
Intestinal Enteroccoci[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)
Escherichia coli[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				≤ 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.

3.5.2 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.

3.5.2.1 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.

3.5.2.2 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 Voëlvlei 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 m^3 (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 m^3/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 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.

3.5.3 Sewage and associated wastewaters

3.5.3.1 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 O_2/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 grown, 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 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).

3.5.3.2 Management of treated effluent in Saldanha Bay

There are two wastewater treatment works (WWTW) that release treated effluent into the Saldanha/Langebaan marine environment, namely the Saldanha WWTW and the Langebaan WWTW (Figure 3.22.). Effluent from the Saldanha WWTW is released into the Bok River which empties into Small Bay, while the Langebaan WWTW releases effluent into the polishing ponds of the Langebaan Country Club Golf Estate from where some surplus effluent is allowed to drain into Saldanha Bay. There are also twenty seven sewage pump stations in Langebaan, many of which are near the edge of the lagoon. Sixteen sewage pump stations are located in Saldanha Bay, many of which are also located on the water's edge (Figure 3.22.). Problems are encountered when pump stations overflow due to malfunction or power failures, as raw sewage is then released directly into the Bay. This is dangerous for 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 and Langebaan commenced in 2012 and thus far nearly all pump stations have been upgraded (Figure 3.23). In 2015, the White City pump station and main line in Saldanha Bay were both upgraded (SBM, Gavin Williams, *pers. comm.* 2015) and implementation of upgrades will continue as and when required. Currently the feasibility of the construction of an emergency overflow sump at pump station 10 is being investigated to further mitigate the risk of sewage being discharged into the Bay. Furthermore, a tender is in the process of being awarded to supply the main pump station in Langebaan (Kaktus) with a new electrical panel (new motor control centre) and additional pumps. Construction is expected to commence in October 2016. The Langebaan sewer rising main is also under capacity and requires immediate upgrading. The Saldanha Bay Municipality is currently in the process of appointing a consulting Engineer for this project and appointment should be finalised before the end of September 2016 (SBM, Gavin Williams, *pers. comm.* 2016). Fifteen million Rand has been made available on the 2016-2017 Capital Budget for the implementation of this project and should be completed during 2017 (SBM, Gavin Williams, *pers. comm.* 2016). It is hoped that all these interventions will prevent future spills such as the one experienced in September 2015.

There are approximately 200 conservancy tanks in Langebaan, east of Club Mykonos (SBM, Elmi Pretorius, *pers. comm.* 2014). 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 3.22. **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).**

Figure 3.23 **Emergency generators that have been installed at various pump stations in Saldanha Bay and Langebaan (Source: SBM, Gavin Williams, 2016).**

3.5.3.3 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

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 control to which extent industries have to treat their effluent before it is directed into municipal wastewater treatment works. However, 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 m^3 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 upgrades to double the capacity of the Saldanha Bay WWTW for treating effluent from the IDZ is funded and managed by the Saldanha Bay IDZ. Construction started in 2015 and is projected to be completed in October 2016 (SBM, Gavin Williams, *pers. comm.* 2016). The project also includes the installation of by-pass lines which will allow for the cleaning of the existing maturation ponds on site (SBM, Gavin Williams, *pers. comm.* 2016). 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:

- 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) although these remain within the limits of the treatment capacity of the plant (= 5 Ml/day). Before 2008, the average daily volume discharged never exceeded 2625 m^3 (1/365th of the annual limit prescribed i.t.o. the WULA), but volumes of effluent released have been increasing steadily over time (Figure 3.25.). Between the years 2008-2012, the Saldanha WWTW was non-compliant only during the winter months. However, this average daily limit was exceeded 71% of the time since January 2013, reaching unprecedented levels of 3363 m^3 effluent in June 2014.

Concentrations of faecal coliforms in the effluent from the WWTW exceeded the allowable limit of 1000 org/100 ml on 31 occasions since 2003 (20% of the time) (Figure 3.34). The frequency of non-compliance increased dramatically in 2008, although at a lower concentration than previously recorded (3000 org/100 ml). Congruent with the consistently higher effluent volumes discharged since January 2013, allowable limits for faecal coliforms in the effluent were exceeded on 14 occasions, frequently reaching highs of 7257 org/100ml (maximum detectable limit 2419 org/100ml multiplied by three). 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 15% of the occasions on which measurements were made since April 2003 (Figure 3.35). While compliance had clearly improved between 2008 and 2014, the allowable limit has been exceeded 60% of the time since December 2014.

Chemical oxygen demand (COD) in filtered effluent exceeded the allowable limit of 75 mg/l 18% of the time since April 2003 (Figure 3.28). 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, compliance has improved substantially since the beginning of 2009 and the allowable limit was only exceeded on seven occasions at a much lower magnitude than in 2008.

Figure 3.24 **The pictures show the new aerator basin, digester and mechanical equipment at the Saldanha Waste Water Treatment Works (Source: SBM, Gavin Williams, 2016).**

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 83% of the time (Figure 3.29.). Overall, the degree of compliance has increased substantially since the highest values were recorded in the winter of 2006 (58.8 mg/l). The new reactor that has been installed at the WWTW with improved aeration is expected to address the high ammonia values (Gavin Williams, SBM, *pers. comm.* 2016). The existing aerators are also scheduled to be refurbished, and will hopefully also lead to a reduction in ammonia.

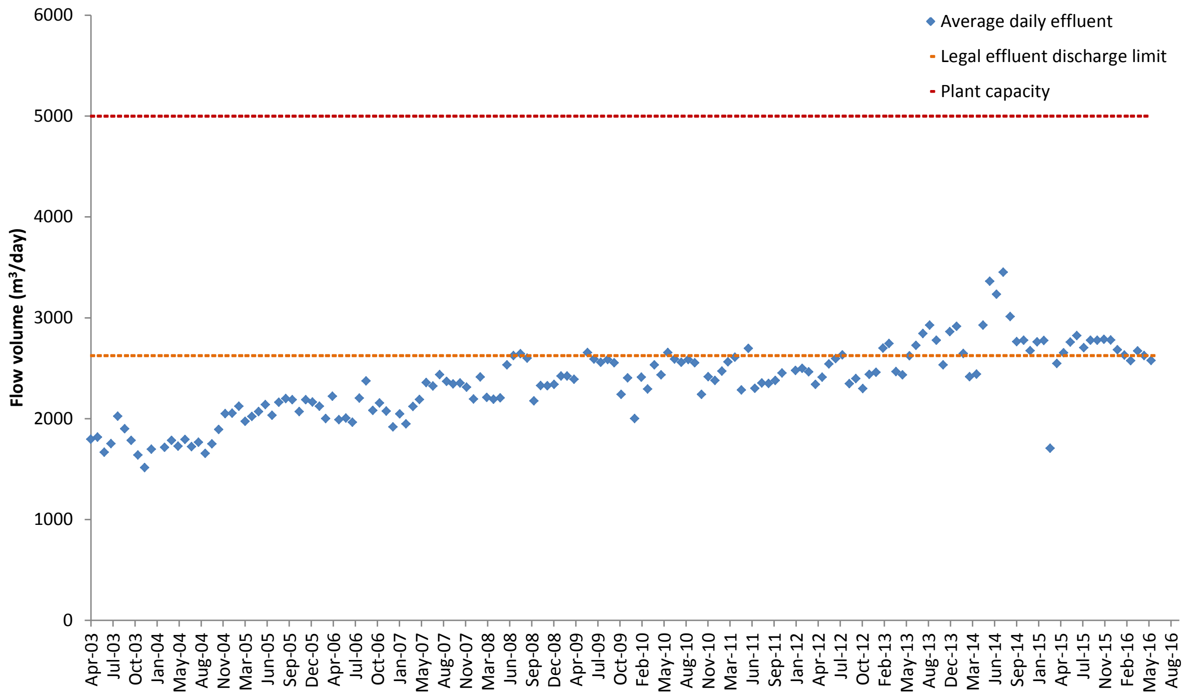

Figure 3.25. **Trend in effluent (m^3/month) released from the Saldanha Wastewater Treatment Works, April 2003-June 2016. Allowable discharge limits in terms of the exemption issued by DWS under the National Water Act (No. 36 of 1998) are represented by the dashed orange line and the design capacity of the plant by the red line (Source: Saldanha Bay Municipality).**

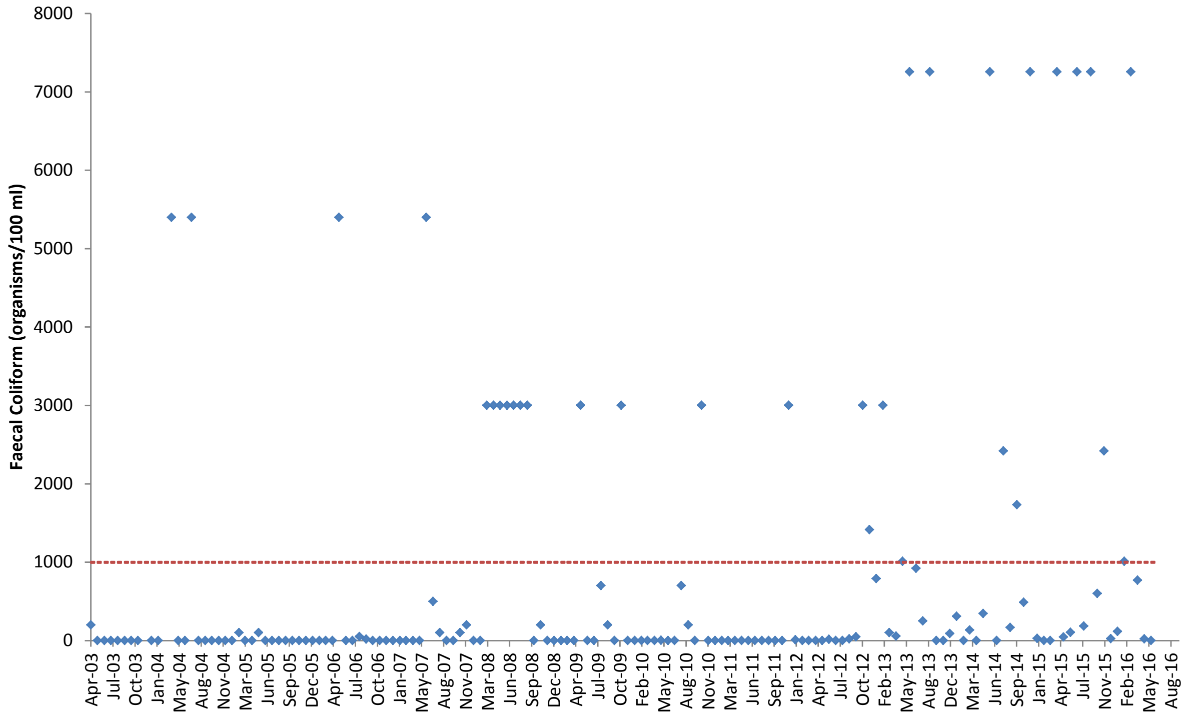

Figure 3.26 **Monthly trend in Faecal Coliforms (org/100ml) in effluent released from the Saldanha Wastewater Treatment Works, April 2003-June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

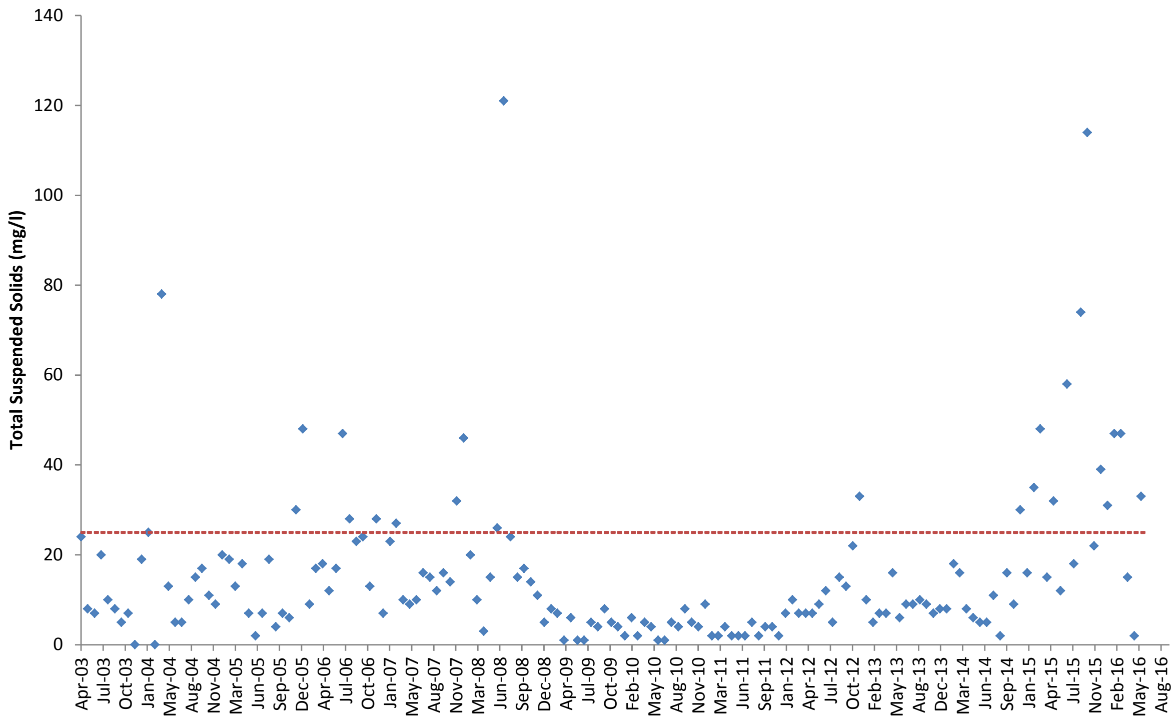

Figure 3.27 **Monthly trend in total suspended solids (mg/l) in effluent released from the Saldanha Wastewater Treatment Works, April 2003 – June 2016. Allowable limits as specified in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

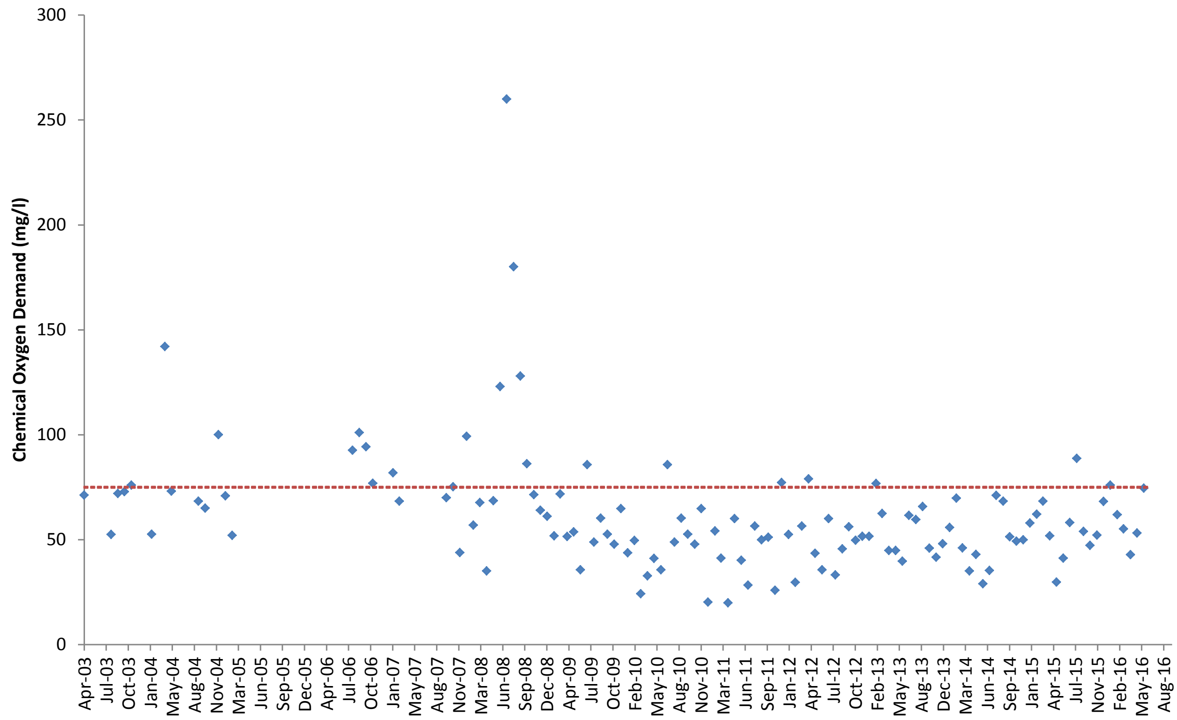

Figure 3.28 **Monthly trends in chemical oxygen demand (mg/l filtered) in effluent released from the Saldanha Wastewater Treatment Works, April 2003-June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

The Nitrate-Nitrogen limit of 15 mg/l was exceeded 16% of time. Overall, compliance has improved since 2010 where measurements have been consistently very low since beginning of 2014 (Figure 3.30).

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. Orthophosphate levels have dropped since February 2013 and the allowable limit of 10 mg/l was only exceeded on one occasion (Figure 3.31).

Permissible chlorine levels of 0.25 mg/l have been exceeded 59% of the time (Figure 3.32). 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.

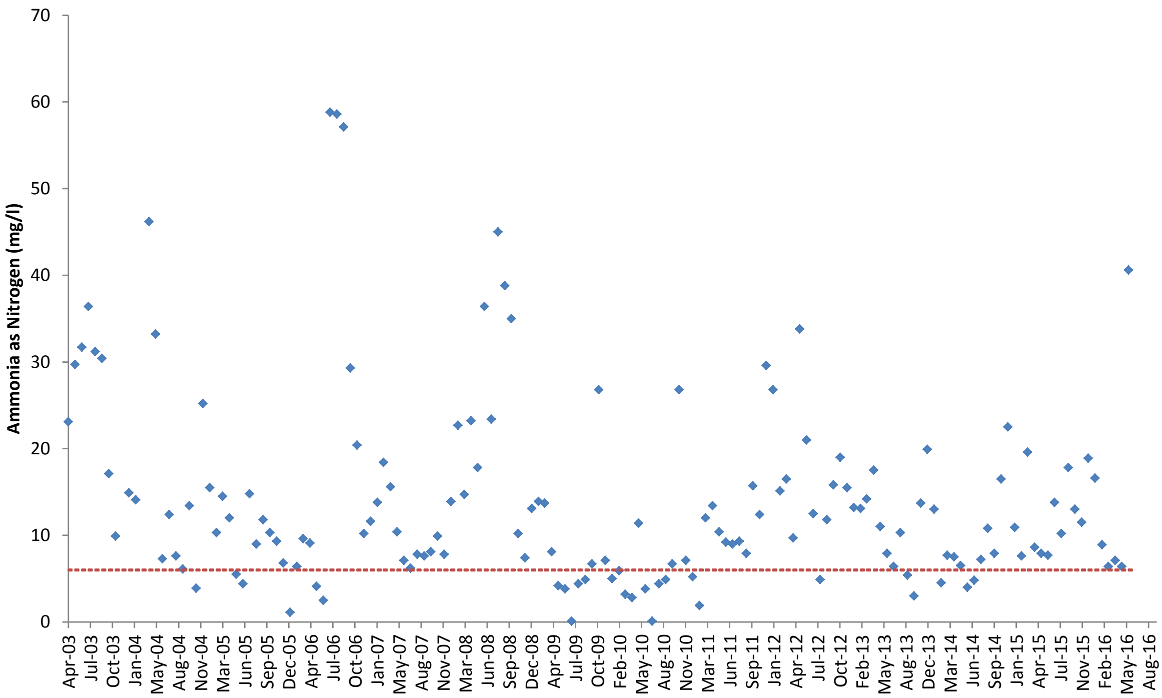

Figure 3.29. **Monthly trends in Ammonia Nitrogen (mg/l as N) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

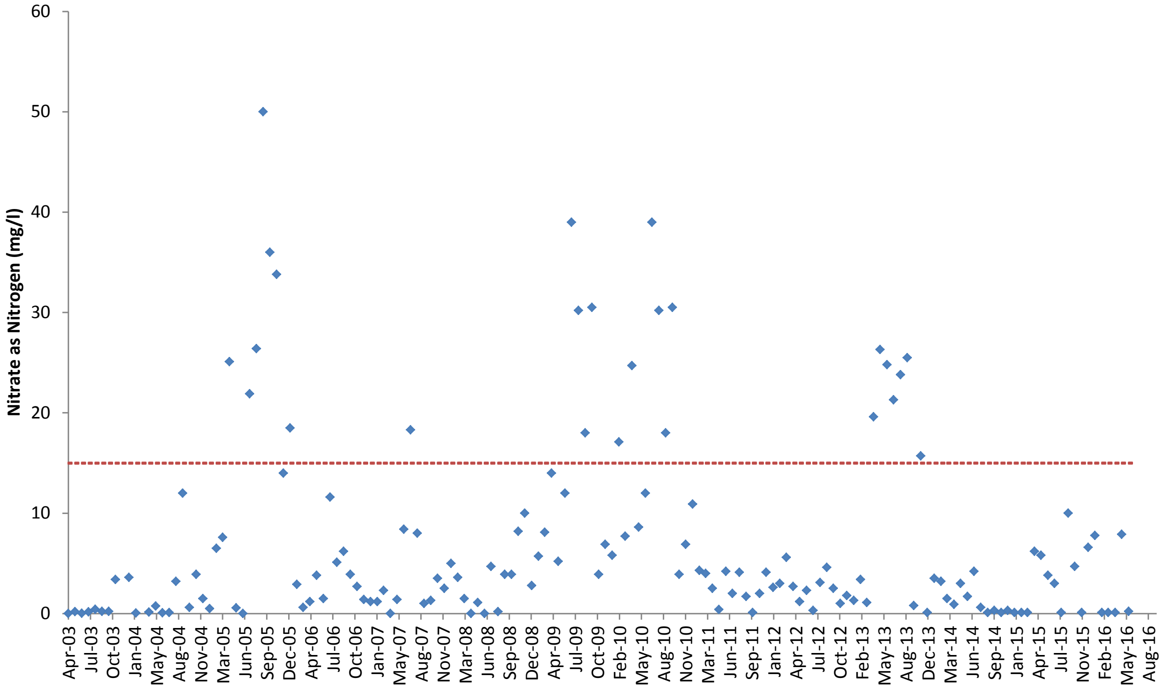

Figure 3.30 **Monthly trends in Nitrate Nitrogen (mg/l as N) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

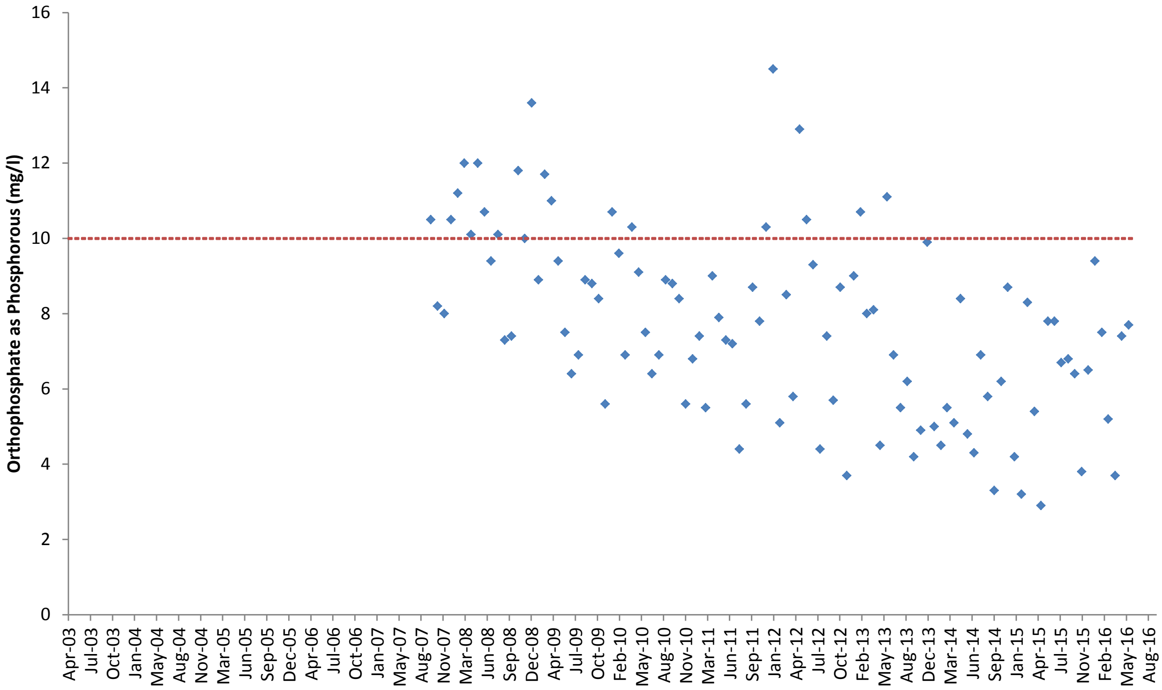

Figure 3.31 **Monthly trends in Orthophosphate (mg/l as P) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

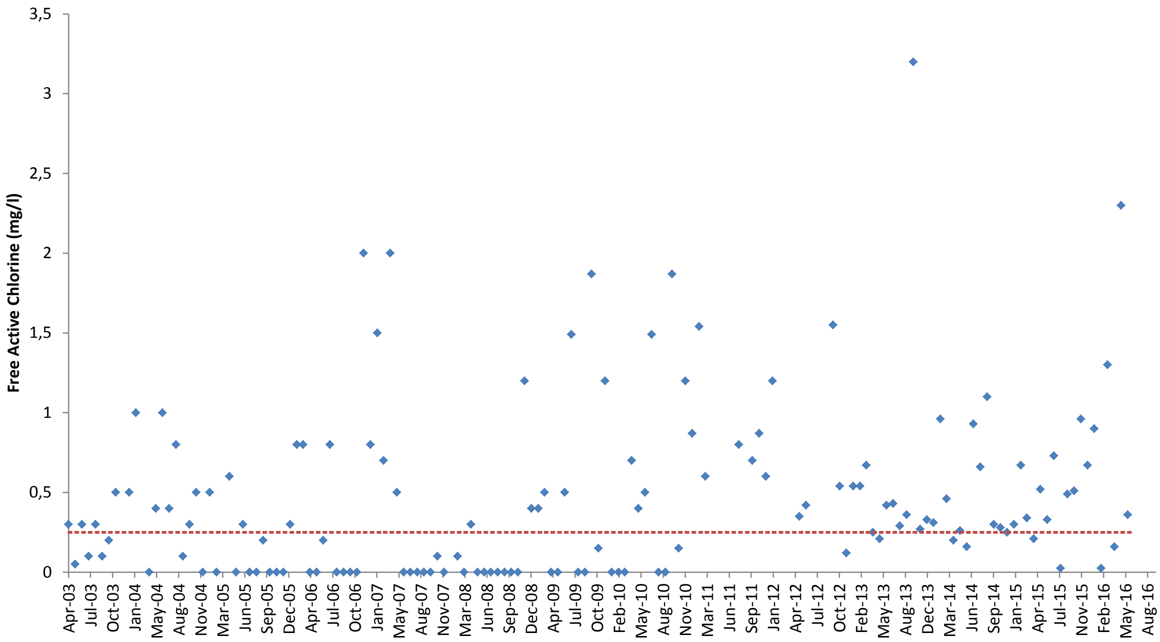

Figure 3.32 **Monthly trends in Free Active Chlorine (mg/l) in effluent released from the Saldanha Wastewater Treatment Works April 2003-June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line. An outlier of 12 mg/l measured for January 2008 was removed to show the trend more clearly (Source: Saldanha Bay Municipality).**

3.5.3.4 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 m^3 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.

Various upgrades are required to improve the overall performance of the treatment plant (SBM, Gavin Williams, *pers. comm.* 2016). Initial upgrades will include the installation of sludge drying beds and the upgrading of the existing aeration capacity of the plant. Future upgrades will include new infrastructure to increase the capacity of the plant to 5 ML. The tender for construction of the first phase of the contract is due to be advertised during the month of September 2016. In the meantime an emergency generator has been installed at the plant and is operational (SBM, Gavin Williams, *pers. comm.* 2016).

Furthermore, a consultant was 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. A draft report with proposals has been submitted to the SBM and will now be presented to the relevant authorities and affected parties for further comment (SBM, Gavin Williams, *pers. comm. September* 2016).

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 3.33. -Figure 3.36 and Figure 3.37 - Figure 3.40.

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 m^3 treated effluent per day, which is exceeded 93% of the time (Figure 3.33.). 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, mostly during the winter months. 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 23 occasions since June 2009 (27% of the time) (Figure 3.34). The frequency and magnitude of non-compliance events increased dramatically in 2013, with the allowable limit for faecal coliforms being exceeded on 18 occasions since December 2012, 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 Langebaan WWTW is unable to adequately process effluent volumes above the allowable limit.

TSS values exceeded the allowable limit of 25 mg/l on 11 occasions since 2009 (13% of the time) (Figure 3.35). Overall, TSS levels were highest at the beginning of 2015, frequently exceeding the allowable limit and reaching a maximum of 198 mg/l in March 2015. Since then, TSS levels have been decreasing steadily (Figure 3.35). 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 29% of the time since June 2009, reaching an all-time maximum of 130 mg/l in January 2015 (Figure 3.36). Compliance has generally worsened since reaching lowest levels in 2012, showing that the allowable limit was exceeded on 15 occasions since January 2013.

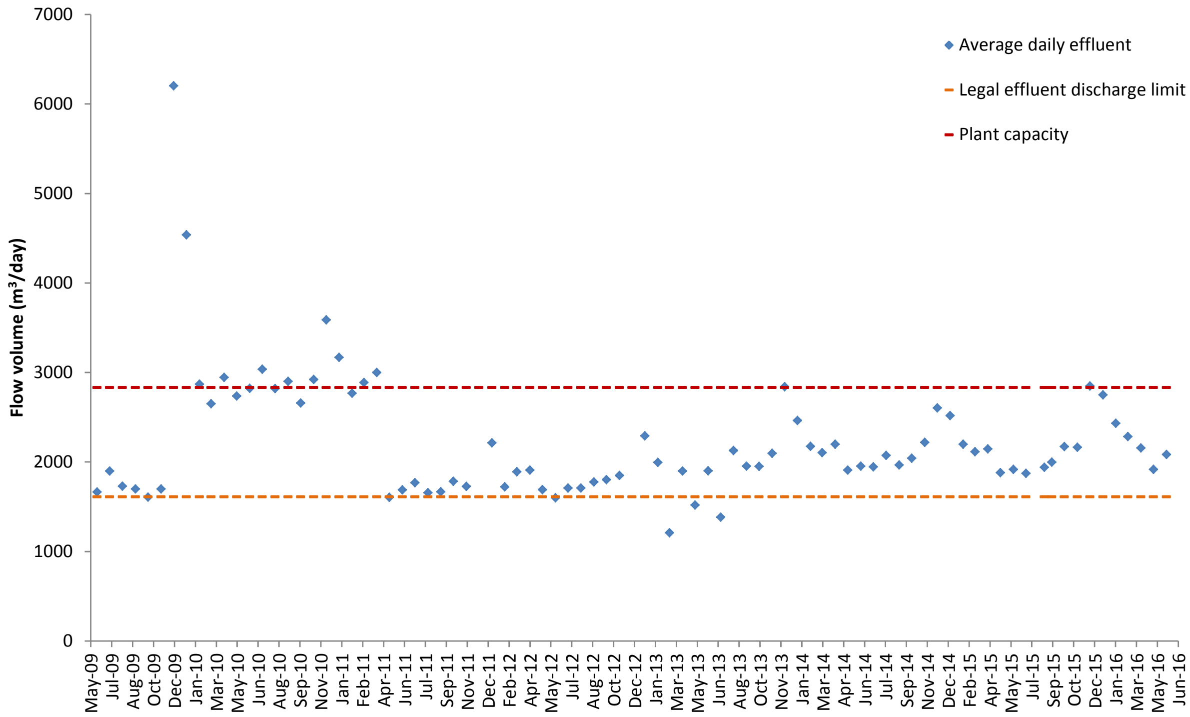

Figure 3.33. **Trends in the volume of effluent (m^3/month) released from the Langebaan Wastewater Treatment Works, June 2009 - June 2016. Allowable discharge limits in terms of the exemption issued by DWAF under the National Water Act (No. 36 of 1998) are represented by the dashed orange line and the design capacity of the WWTW by the red line (Source: Saldanha Bay Municipality).**

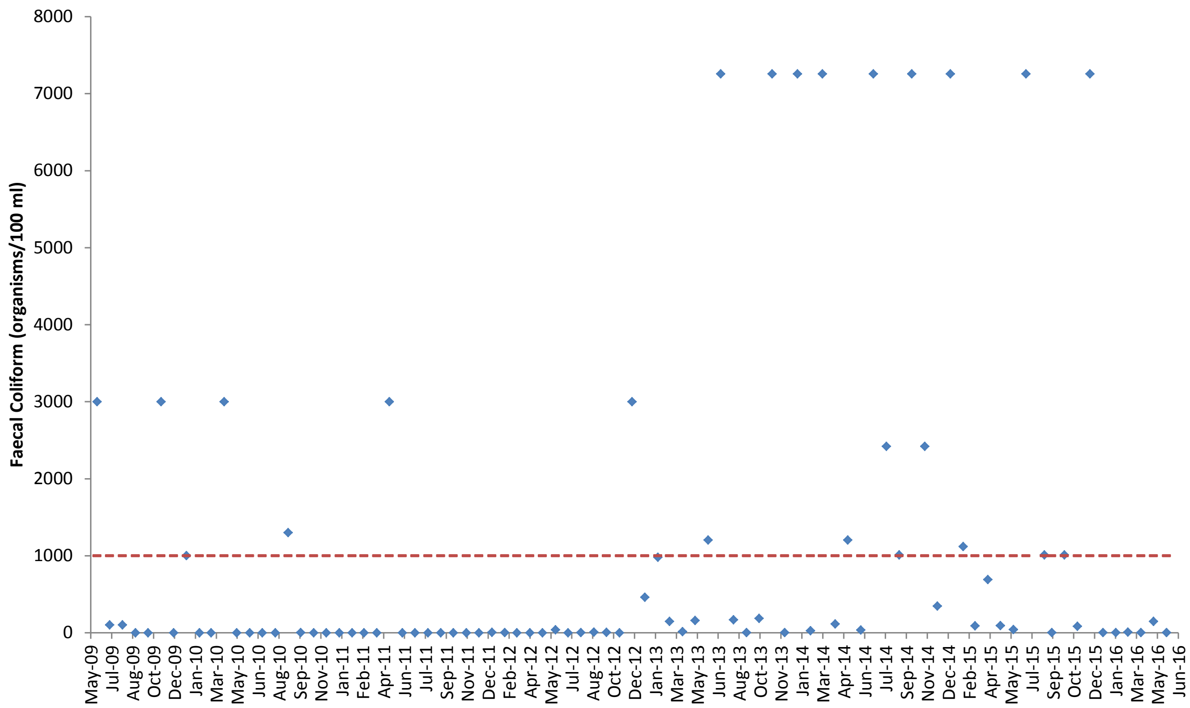

Figure 3.34 **Monthly trends in Faecal Coliforms (org/100ml) in effluent released from the Langebaan Wastewater Treatment Works, June 2009 - June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

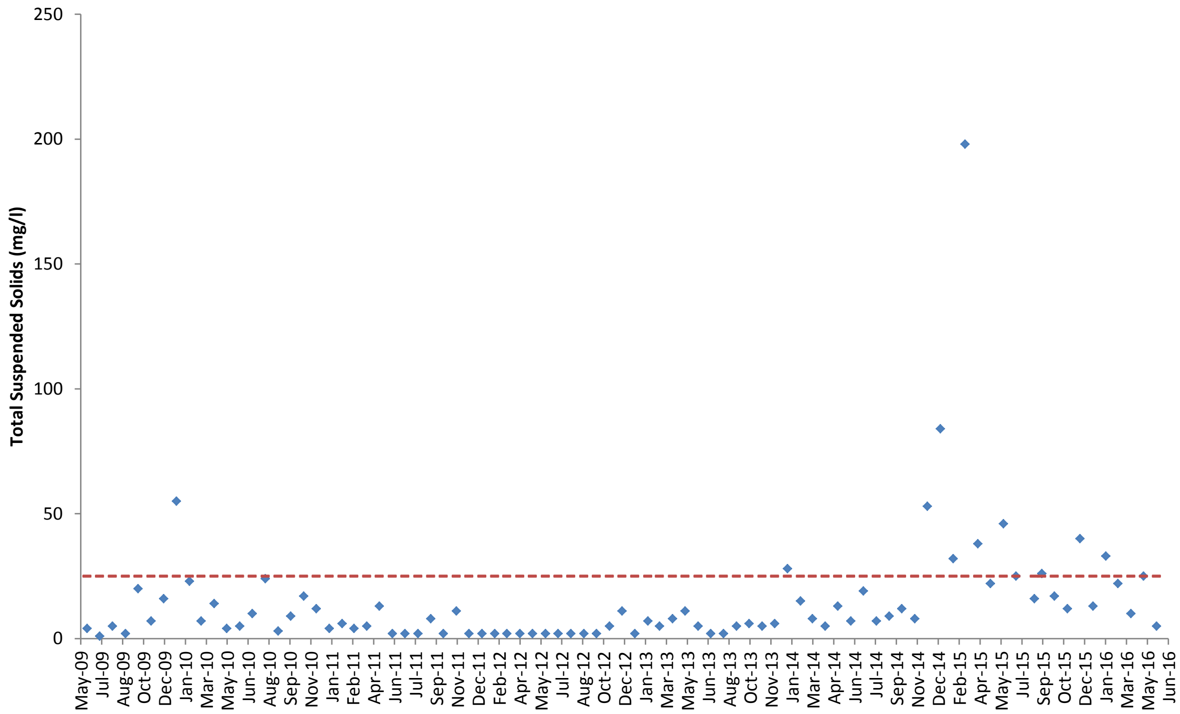

Figure 3.35 **Monthly trends in total suspended solids (mg/l) in effluent released from the Langebaan Wastewater Treatment Works, June 2009 - June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

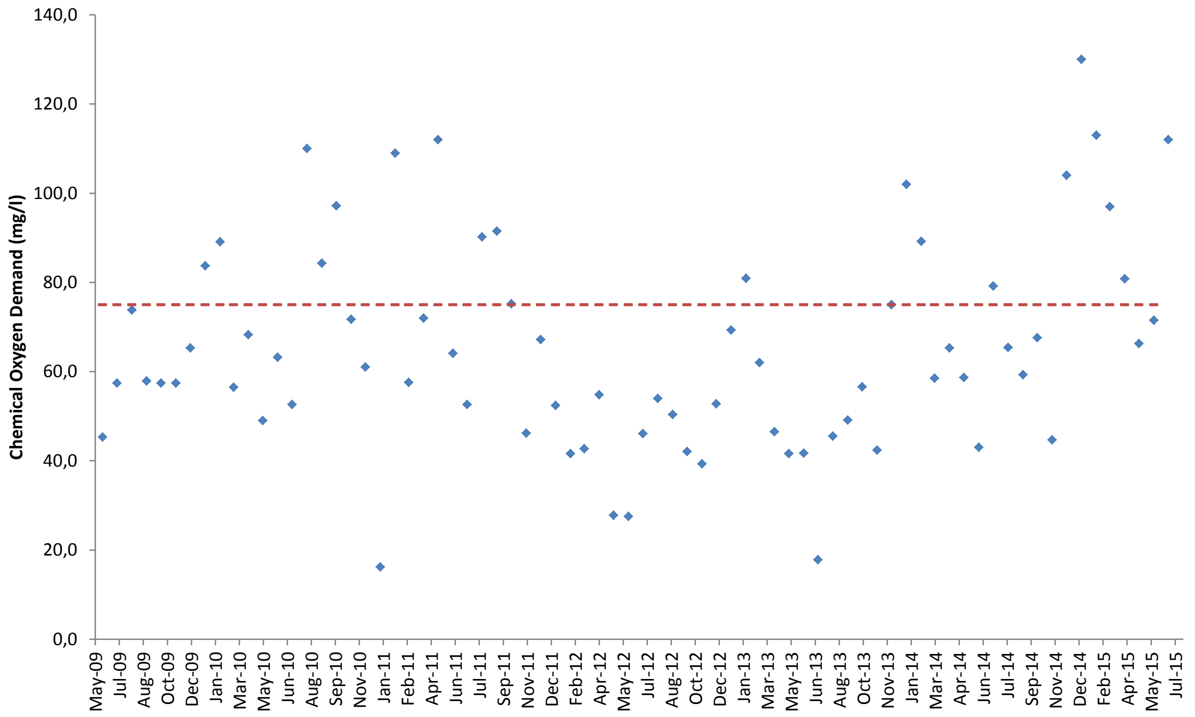

Figure 3.36 **Monthly trends in chemical oxygen demand (mg/l filtered) in effluent released from the Langebaan Wastewater Treatment Works, June 2009 - June 2016. Allowable limits as specified in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

Ammonia Nitrogen levels discharged from the Langebaan WWTW have exceeded the allowable limit of 6 mg/l 82% of the time since June 2009 (Figure 3.37.). 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 3.38). 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 in January 2014 (19.3 mg/l as N), which coincided with the peak in Ammonia Nitrogen, COD and faecal coliform numbers.

Orthophosphate concentrations fluctuate in a seasonal pattern similar to that seen at the Saldanha WWTW (Figure 3.39). 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 (11.6 and 10.1 mg/l) as well as in June and July 2015 (12.1 and 10.2 mg/l), however, with values of 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 3.40). As observed at the Saldanha WWTW, free active chlorine levels above the allowable limit are always detected immediately after a rise in faecal coliforms.

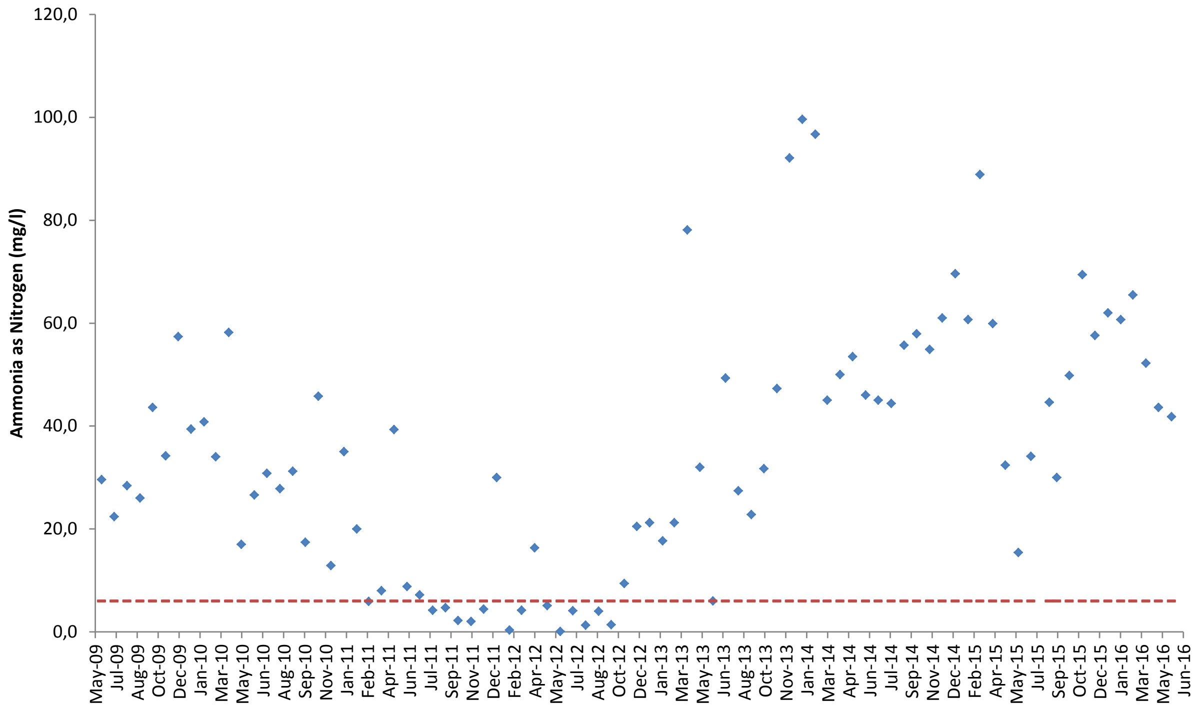

Figure 3.37. Monthly trends in Ammonia Nitrogen (mg/l as N) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).

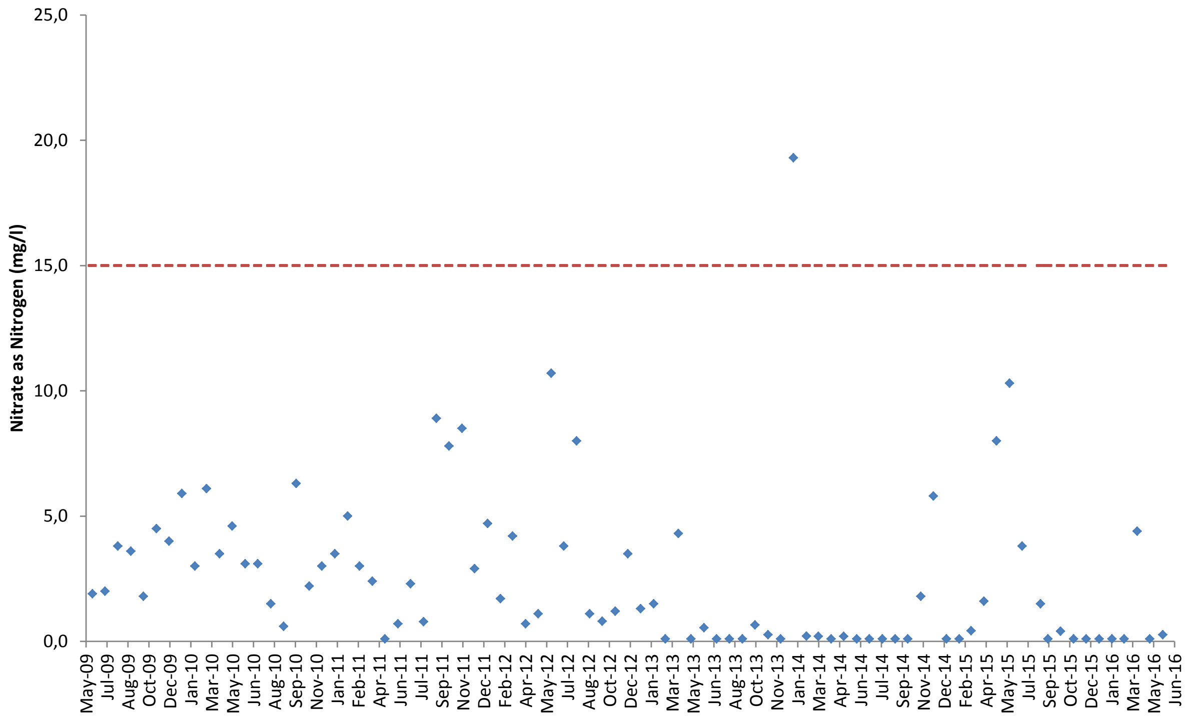

Figure 3.38 Monthly trends in Nitrate Nitrogen (mg/l as N) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).

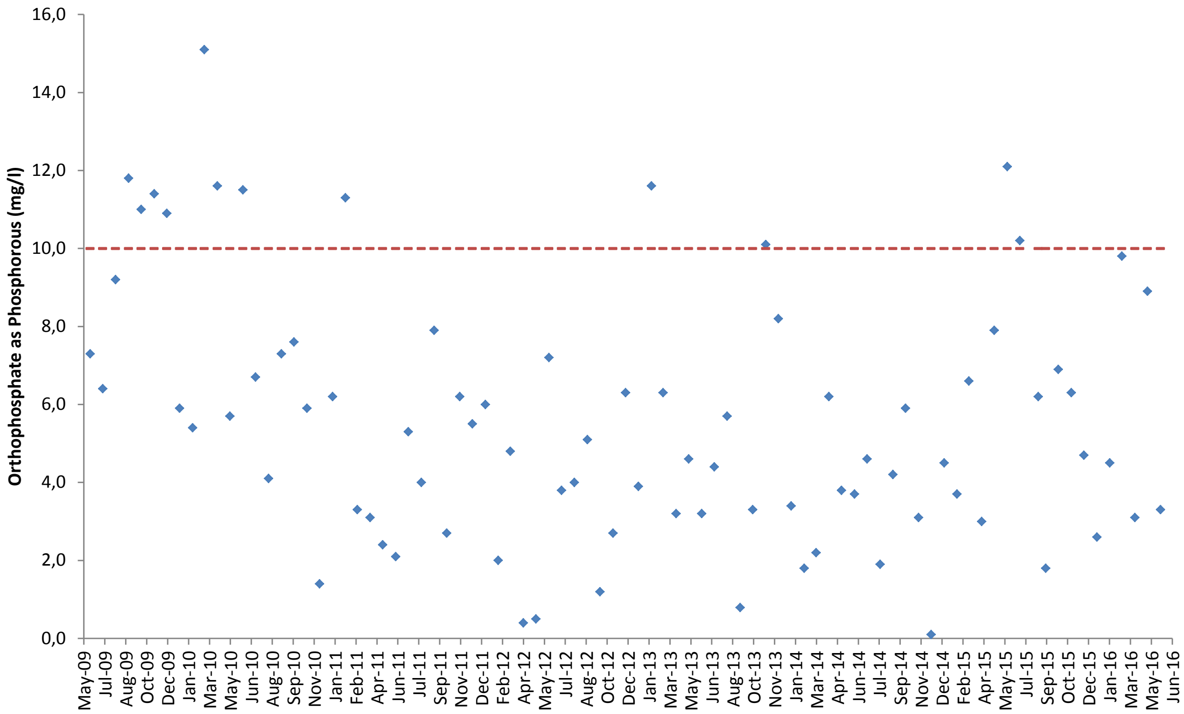

Figure 3.39 **Monthly trends in Orthophosphate (mg/l as P) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

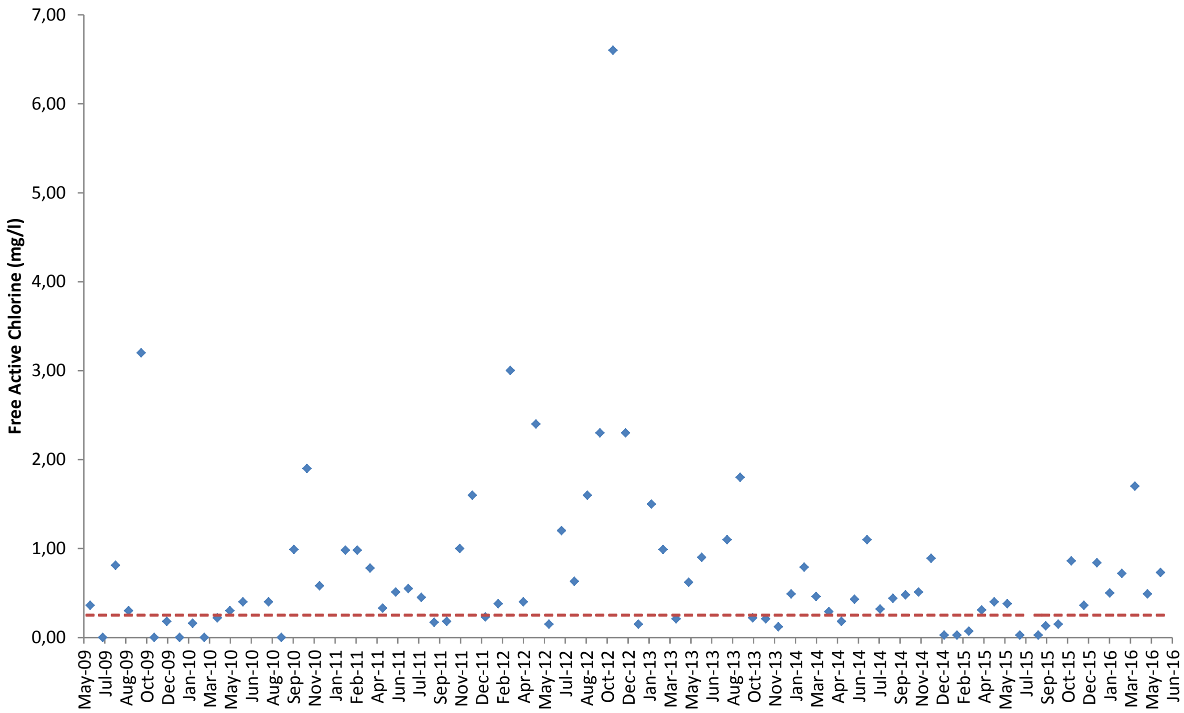

Figure 3.40 **Monthly trends in Free Active Chlorine (mg/l) in effluent released from the Langebaan Wastewater Treatment Works June 2009 - June 2016. Allowable limits in terms of a General Authorisation under the National Water Act (No. 36 of 1998) are represented by the dashed red line (Source: Saldanha Bay Municipality).**

3.5.3.5 Summary

The data shows that even though the WWTW at Saldanha and Langebaan are operating within the limits of their design capacity they are experiencing difficulties in keeping effluent quality parameters within allowable limits and conditions as set out in the NWA (Government Gazette No.36820, 6 September 2013) (Table 3.5.). 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, but will hopefully be addressed at the Saldanha WWTW at least, by the upgrades that have recently been implemented. Steadily increasing COD at Langebaan WWTW should also be closely monitored. Both, the Saldanha Bay and Langebaan WWTW, rising mains and pump stations are currently being upgraded to varying degrees (i.e. equipment replacement, additions and large scale capacity upgrades). Effluent quality should be monitored closely to detect short-term negative impacts during the construction phase and long-term positive impacts after implementation of the upgrades.

Table 3.6 Summary of effluent water quality discharged into Saldanha Bay and Langebaan Lagoon by the Saldanha and Langebaan Wastewater Treatment Works (Source: Saldanha Bay Municipality).

Parameter	Saldanha Bay WWTW		Langebaan WWTW	
	Trend	Compliance	Trend	Compliance
Flow volume	Stable	No	Increasing	No
E. coli	Stable	No	Stable	No
Total suspended solids	Increasing	No	Decreasing	No
Chemical oxygen demand	Stable	No	Increasing	No
Ammonia Nitrogen	Decreasing	No	Decreasing	No
Nitrate as Nitrogen	Decreasing	Yes	Decreasing	Yes
Orthophosphate	Decreasing	Yes	Stable	No
Free active chlorine	Stable	No	Stable	no

3.5.4 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 3.41.). All residential and industrial storm water outlets drain into the sea.

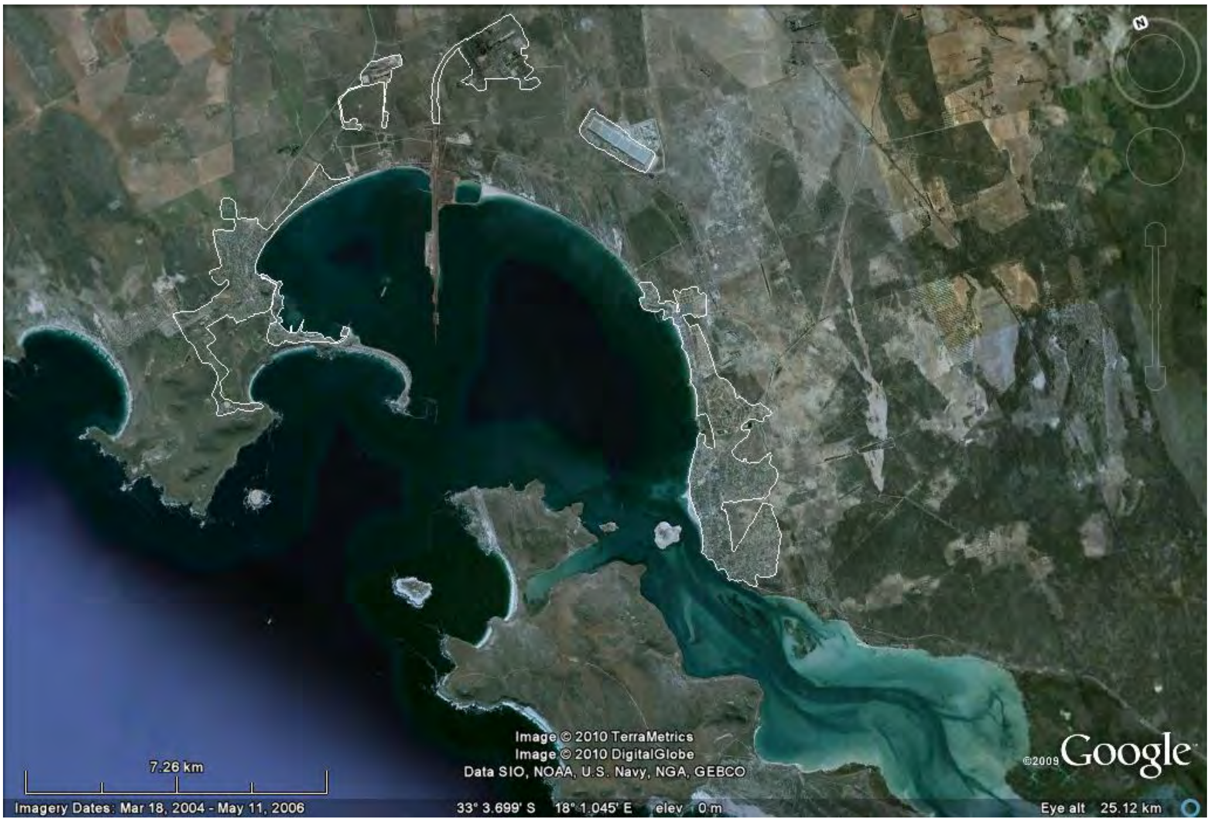

Figure 3.41. Spatial extent of residential and industrial areas surrounding Saldanha Bay and Langebaan Lagoon from which storm water runoff is likely to enter the sea (areas outlined in white). Note that runoff from the Port of Saldanha and ore terminal have been excluded as this is now reportedly all 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 3.41. and Table 3.7.). 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 3.7. **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

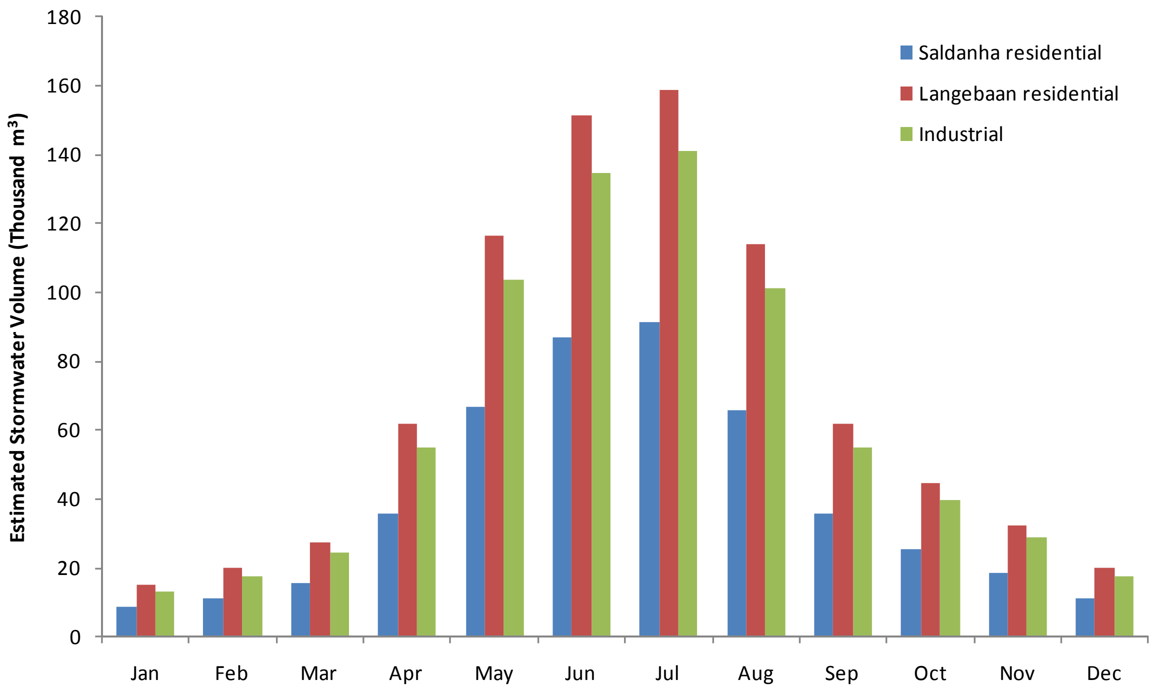

Figure 3.42. **Monthly estimated storm water volume (m^3) for Saldanha and Langebaan residential areas and industrial area. Note that runoff from the Port of Saldanha and ore terminal have been excluded as this is now reportedly all diverted to storm water evaporation ponds.**

3.5.4.1 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 3.8.). 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 3.8.). 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 3.8. 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 3.43). 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 tons per annum as proposed by Transnet (Section 3.2.3).

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

3.5.4.2 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.

3.5.5 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 3.44. 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 m^3, 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.

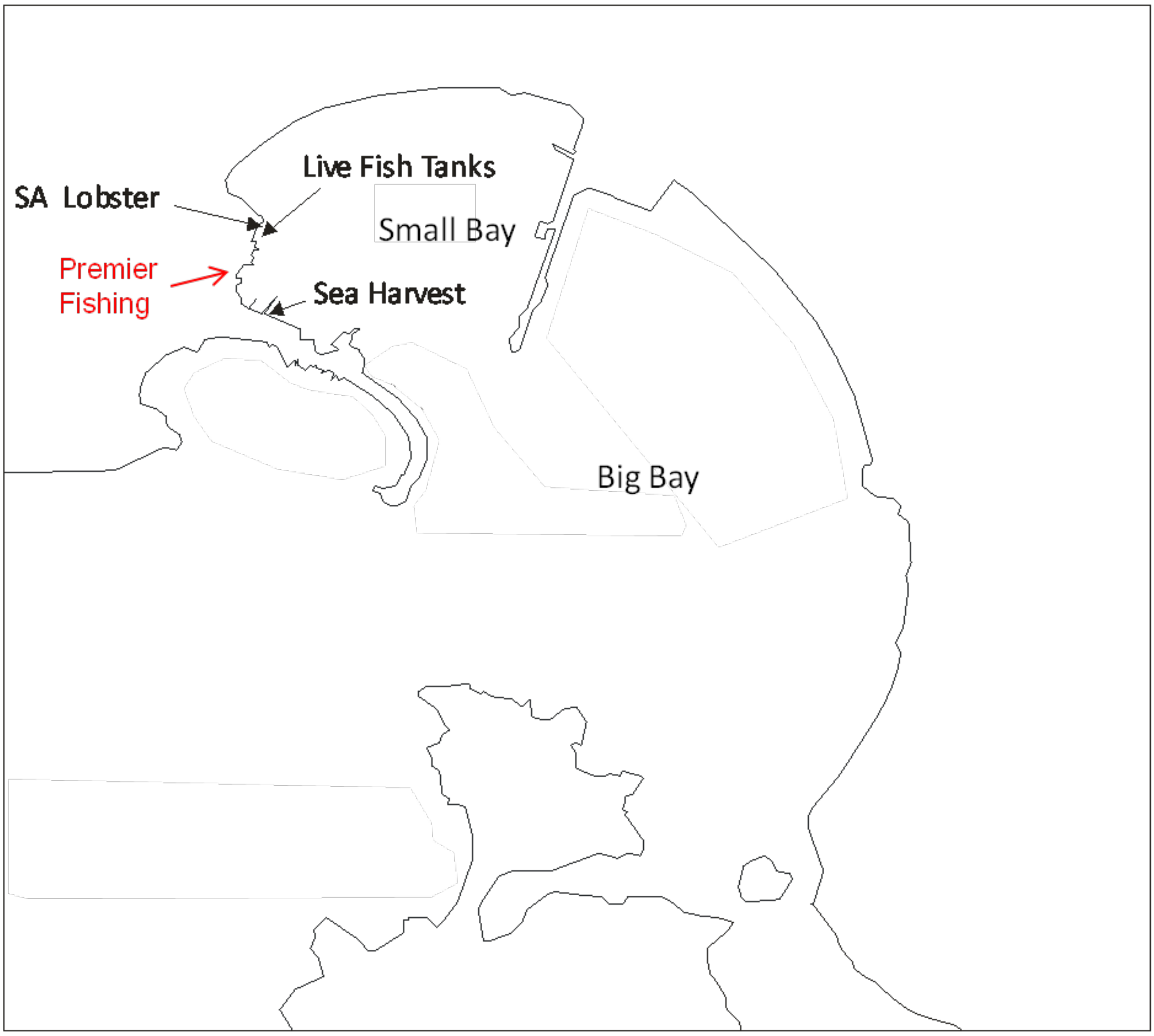

Figure 3.44. Location of seawater intakes and discharges for current and proposed seafood processing factories in Saldanha Bay. Current factories are indicated in black while the proposed Premier Fishing Fish Processing Plant is indicated in red.

3.5.5.1 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 (*Merlucius 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 3.9.).

Table 3.9. 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
E. coli. (CFU/100ml)	5	789	-

In 2014, the plant upgraded to ensure continuous operation and better solids handling capabilities (Sea Harvest, Site Engineer Nico Van Houwelingen, *Pers. comm.* 2014) (Refer to AEC 2014 and 2015 for a description of the facility prior to 2014). The two effluent streams are 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 contrashear 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 3.48). This issue will be addressed through the use of a different sanitising process. Initially, effluent quality did not improve following the upgrades to the plant (AEC 2015). However, the replacement of some components of the effluent discharge system seems to have contributed towards improving effluent quality in 2016 (see below).

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 (refer to AEC 2015 for more details). As a result monitoring conditions of the water use license are inadequate for the effluent generated by a fish processing plant (compare to effluent composition in Table 3.9) 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*) and temporarily adapted its monitoring programme to the requirements on the permit. As a result pH, conductivity, ammonia nitrogen, Kjeldahl nitrogen, dissolved organic carbon, faecal coliforms, and *E. coli* were no longer monitored in the effluent. While pH (always well within the general limit of 5.5-9.5), faecal coliform, *E.coli* and dissolved organic carbon are not of immediate concern (and are no longer monitored), the lack of data on ammonia nitrogen was 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. The State of Saldanha Bay and Langebaan Lagoon 2015 (AEC 2015) therefore recommended that monthly ammonia nitrogen monitoring should be re-instated. Furthermore the report recommended that Sea Harvest should start monitoring chemical oxygen demand (COD). Sea Harvest indeed implemented the recommendations in November 2015. Kjeldahl nitrogen (no legally defined limit), faecal coliform (General Authorisation limits not exceeded since early 2013) and *E.coli* are no longer monitored and have not been included in this year's report.

Average daily fresh fish processing effluent volumes discharged into Small Bay between July 2004 and June 2016 by Sea Harvest is shown in Figure 3.45. 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 m^3 in 2004, increased to 6738 m^3 in 2006 and dropped to a minimum of 703 m^3 in 2013. A steady increase in effluent volume is evident since then. Correspondingly, the maximum daily limit of 3546 m^3 as specified by the water use license has not been exceeded since 2013 (Figure 3.45). 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 May this year, which allows continuous flow rate measurements and has been 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, 157 measurements 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 volume[5] and compared to the prescribed annual effluent limit of 758 847 m^3 (Figure 3.46). It can be concluded with reasonable confidence that the annual effluent volume has not exceeded the prescribed limit since 2013.

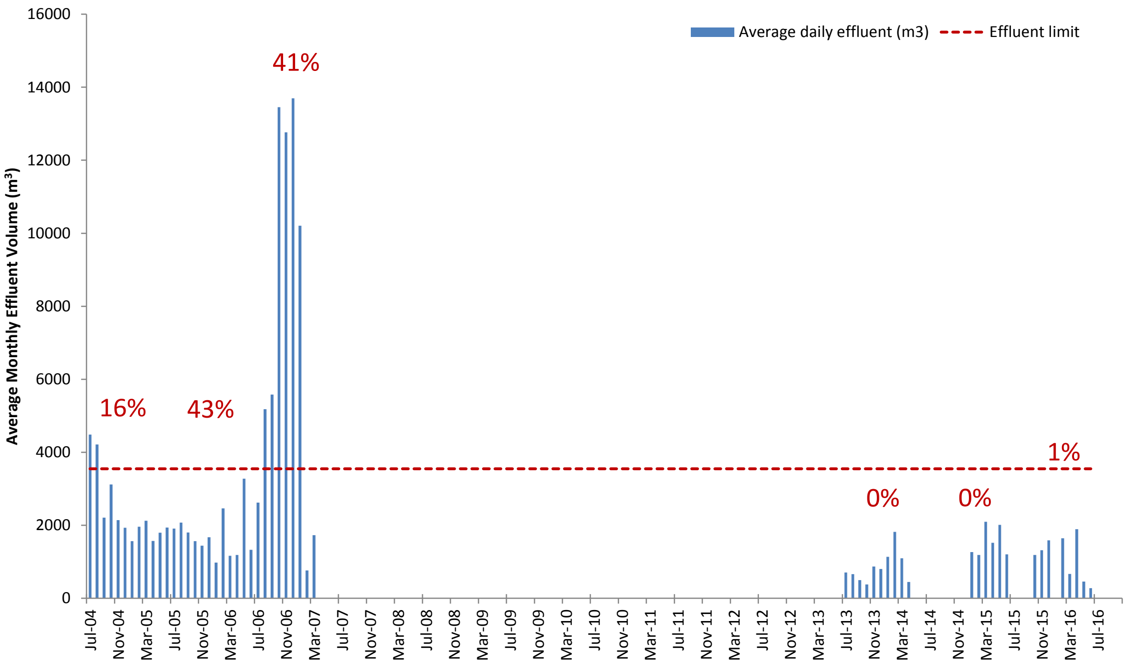

Figure 3.45. **Average daily fresh fish processing effluent volume discharged into Small Bay by Sea Harvest from July 2004 - June 2016. Data was not available for the period May 2007 – August 2013. The red dotted line shows the maximum daily limit prescribed by the water use license. The red numbers 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.

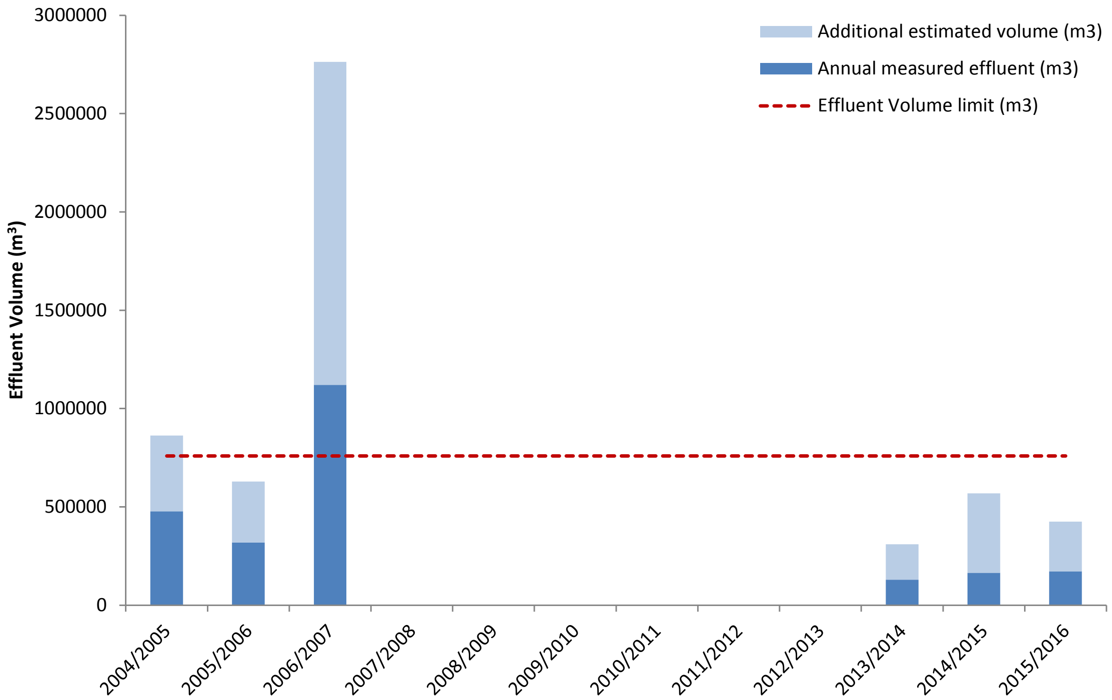

Figure 3.46 **Estimated Fresh fish processing effluent volume discharged into Small Bay per year by Sea Harvest from July 2004 - June 2016. Data was not available for the period May 2007 – August 2013. The annual maximum limit of 758 847 m^3 is indicated as the red dashed line. Additional estimated volume 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).**

Levels of TSS are extremely high and since measurements commenced in 2010, compliance with the revised General Discharge Limit of 25 mg/l was only achieved in October 2013 (14 mg/l) (Figure 3.47). Trends in TSS since 2010 suggest that concentrations fluctuate over time and it appears that peak concentrations are decreasing in magnitude (Figure 3.47). However, overall concentrations have remained very high since 2010 and further drastic improvements to effluent quality are required to meet the limits prescribed by the General Authorisation.

The revised General Discharge Limit for ammonia nitrogen is 6 mg/l, which is exceeded 95% 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. Results for December 2015-June 2016 look particularly promising (note that no data could be obtained for January and February 2016), which could be due to a change in sanitising protocols... However, substantial improvements are still required to meet the General Limits in terms of the General Discharge Authorisation.

A salinity (ppt) limit at the end of the pipe is not specified in the revised General Discharge Authorisation. Fish processing involves the use of freshwater and sea water and salinity (ppt) is therefore lower than what is expected in the receiving environment (Figure 3.49). It is however evident that salinity has increased since January 2015 (see AEC 2015 for conductivity (mS/m) trends prior to January 2015), approaching levels expected in the receiving environment. This is likely due to the increasing use of seawater for fish processing.

Sea Harvest has been measuring COD since November 2015. COD is extremely high (average 957±313 mg/l) and indicates that a large amount of oxygen is required to breakdown the organic waste in the effluent. Sea Harvest has not been able to meet the requirements of the General Authorisation (<75 mg/l) (Figure 3.50). Improving COD to 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

Oil and grease was monitored monthly between March 2015 and December 2015 (Figure 3.51). Values exceeded the General Authorisation limit of 2.5 mg/l at all times, with a very high average of 27±25 mg/l, reaching a maximum of 91 mg/l in September 2015. Sea Harvest discontinued the monitoring of this effluent component in December 2015 and it is strongly recommended that monitoring continues as soon as possible.

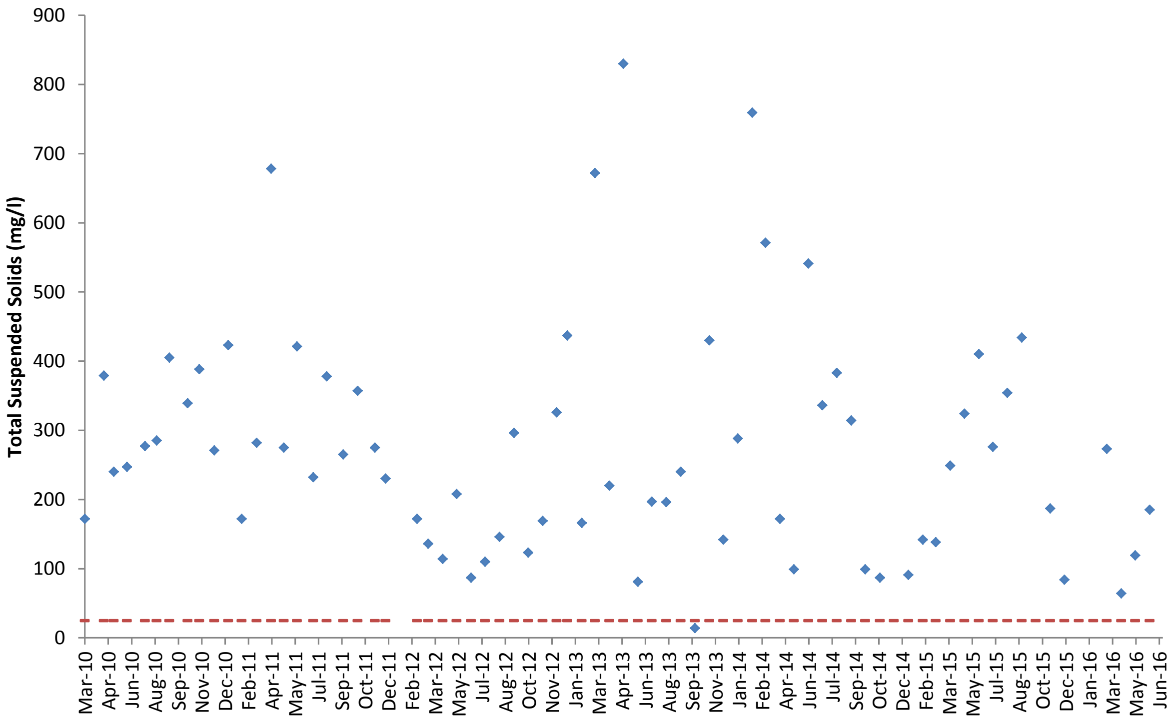

Figure 3.47 Monthly trends in total suspended solids (mg/l) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010 to June 2016. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (25 mg/l) (Government Notice No.36820 –6 September 2013). (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).

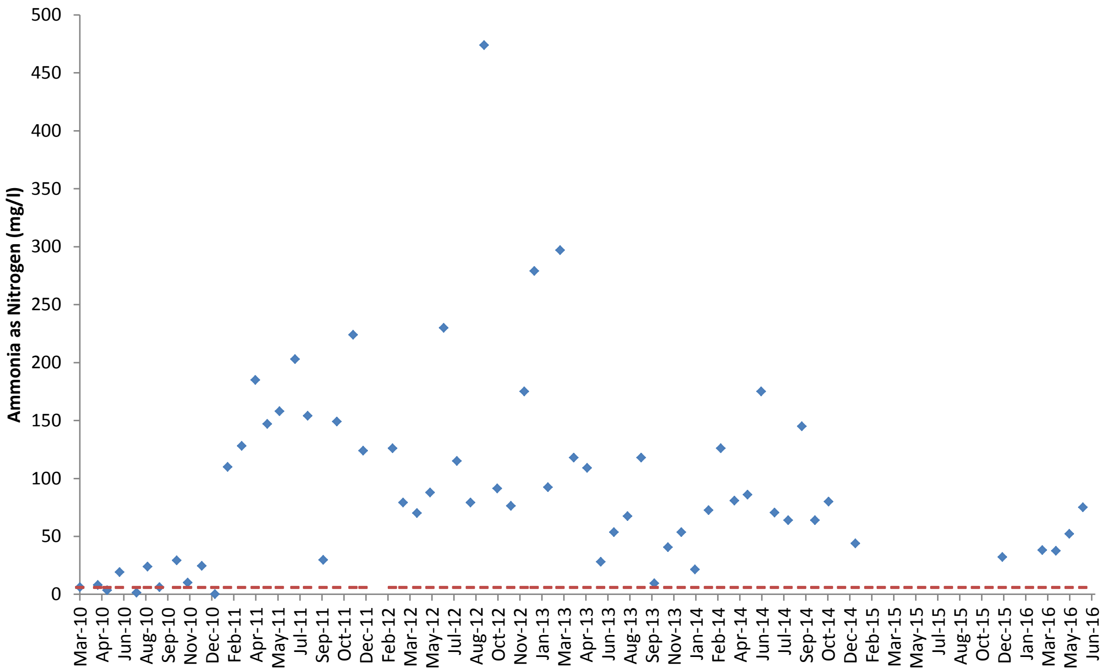

Figure 3.48 **Monthly trends in ammonia nitrogen (mg/l) in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2010to June 2016. The red dashed line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (6 mg/l) (Government Notice No.36820 –6 September 2013). Note that no data was collected from February – November 2015). (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).**

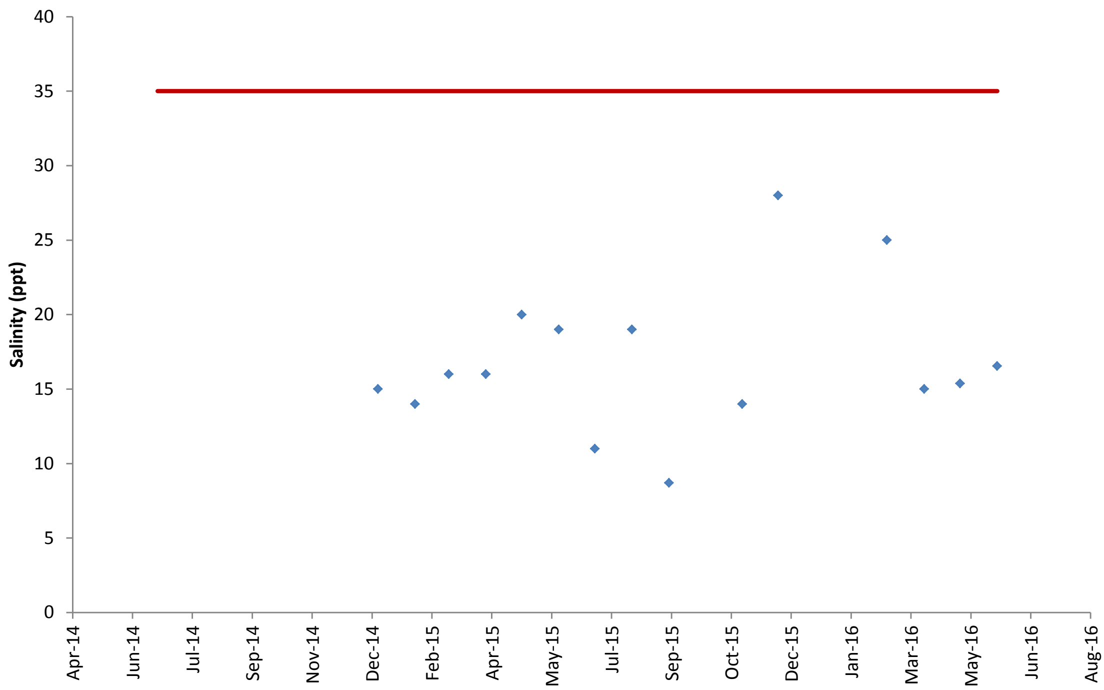

Figure 3.49 **Monthly salinity (ppt) trends in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period January 2015 to June 2016. The red line indicates the salinity of typical seawater. (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).**

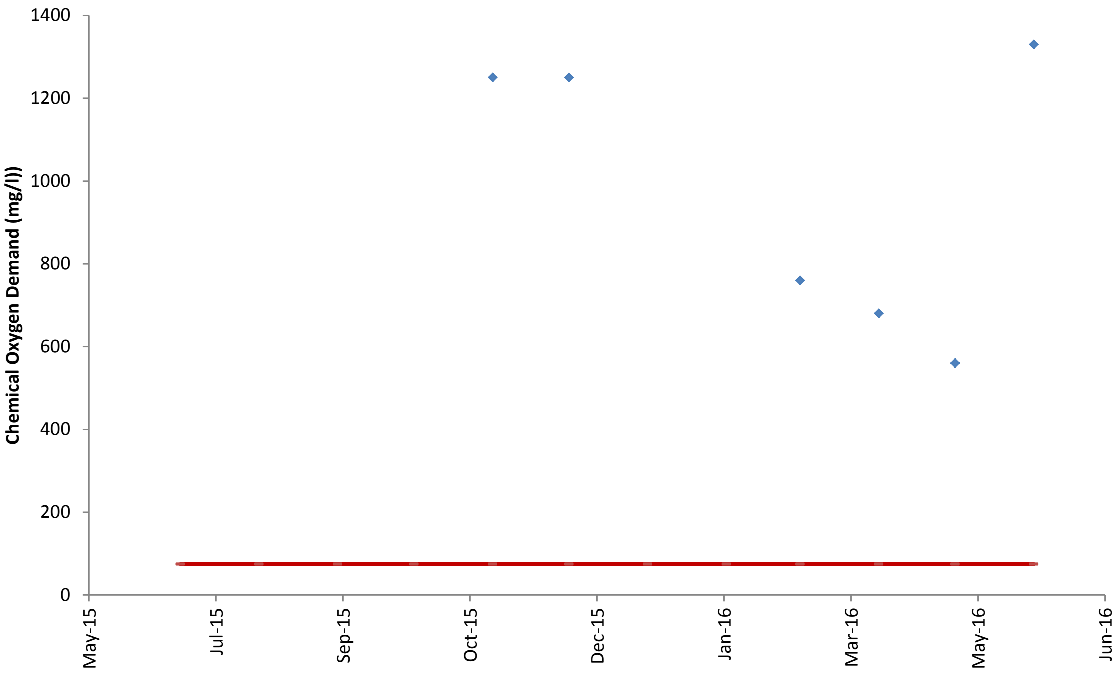

Figure 3.50 **Monthly chemical oxygen demand (COD) trends in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period November 2015 to June 2016. The red line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (75 mg/l) (Government Notice No.36820 –6 September 2013). (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).**

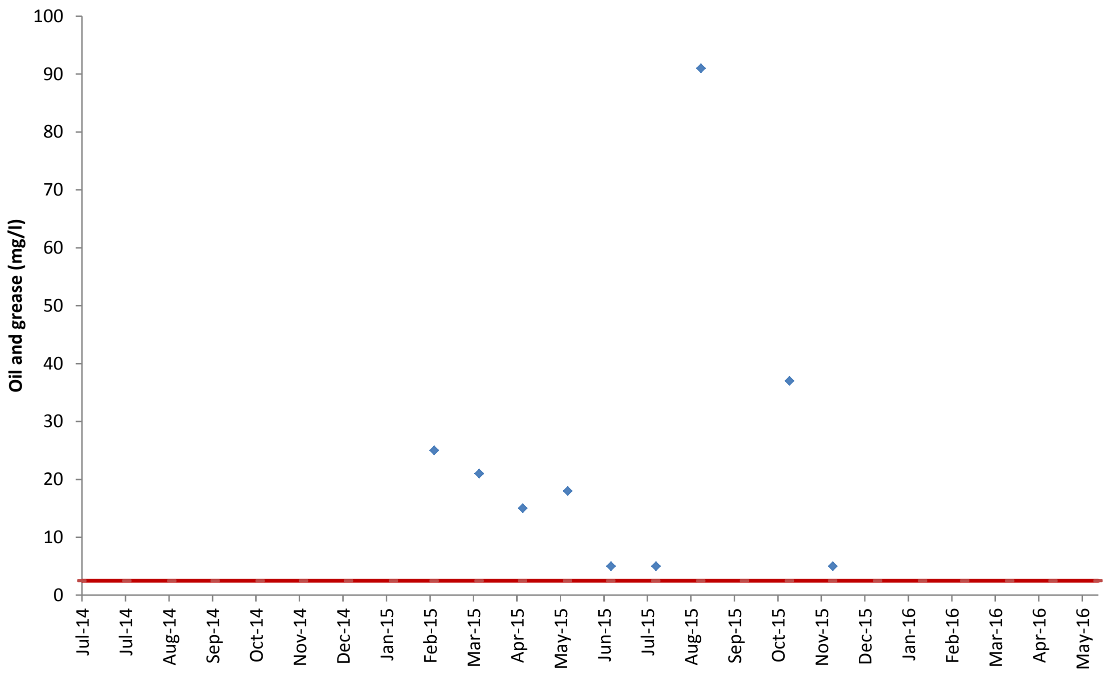

Figure 3.51 **Monthly oil and grease trends in the effluent discharged from the Sea Harvest fresh fish processing (FFP) plant into Small Bay in the period March 2015 to December 2015. The red line indicates the limit prescribed by the General Discharge Limit of the revised General and Special Standard (2.5 mg/l) (Government Notice No.36820 –6 September 2013). (Source: Frank Hickley, Risk Control Manager at Sea Harvest fish Processing Plant).**

In conclusion, 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, ammonia nitrogen, COD and oil and grease. Some improvements can be observed for TSS and ammonia nitrogen in the effluent; however, further drastic improvements are required to meet the minimum requirements in terms of the NWA Regulations. Considering that oil and grease is a contaminant commonly found in fish processing plant effluent, it is highly recommended that Sea Harvest continues monitoring as soon as possible.

3.5.5.2 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).

3.6 Marine aquaculture

Saldanha Bay and is a highly productive marine environment and constitutes the only natural sheltered embayment in South Africa (Stenton-Dozey *et al.* 2001). These favourable conditions have facilitated the establishment of an aquaculture industry in the Bay. A combined 430 ha of sea space are currently available for aquaculture production in Outer Bay, Big Bay and Small Bay (Table 3.11), of which 251 ha have been leased to 12 individual mariculture operators (Table 3.11, Table 3.10 and Figure 3.52.). Only 60% of these concession areas are actively farmed for mussels, oysters and finfish, mostly in Small Bay (Table 3.11).

The Department of Agriculture, Forestry and Fisheries (DAFF) is currently driving accelerated development of the aquaculture sector in South Africa with the aim to create jobs for marginalised coastal communities, and contribute towards food security and national income. The development of the aquaculture sector is considered a sustainable strategy to contribute to job creation and the local economy, and was therefore identified as a key priority of Operation Phakisa (Section 3.2).

With the support of finances and capacity allocated to the Operation Phakisa Delivery Unit, DAFF proposes to establish a new sea-based Aquaculture Development Zone (ADZ) in Saldanha Bay. The aim is to (a) encourage investor and consumer confidence (b) create incentives for industry development (c) provide marine aquaculture services, (d) manage the risks associated with aquaculture; and € provide skills development and employment for coastal communities.

SRK Consulting (Pty) Ltd. (SRK) was appointed as the independent consultant to develop a framework for the Saldanha Bay ADZ and undertake the Environmental Impact Assessment (EIA) process. Areas for potential aquaculture expansion across Saldanha Bay, as well as potential species, culture options and infrastructure requirements were developed during the project definition phase in August 2016. It is anticipated that the Draft Basic Assessment Report (BAR) will be completed by the end of October 2016 (SRK Consulting, Jessica du Toit, pers. comm., 2016). The proposed ADZ covers a combined 1715 ha of new sea space in the Outer Bay and Big Bay (each bay is divided into northern and southern parts) (Table 3.11, Figure 3.53). It is thought that Small Bay has reached its carrying capacity due to the fact that poor flushing of the artificially confined bay coincides with increasing volumes of land-based effluent discharges. No additional aquaculture has therefore been proposed for Small Bay (SRK Consulting 2016b).

Table 3.10. Details of marine aquaculture rights issued in Saldanha Bay (BB and SB refer to Big Bay and Small Bay respectively) (Sources: Aquaculture Rights Register Department of Agriculture Forestry and Fisheries, Transnet Property, Geo-Spatial data)).

	Products								
Company	Mussels	Oysters	Abalone	Scallops	Red Bait	Seaweed	Finfish	Area (Location*)	Duration of right
Blue Ocean Mussel (previously trading as Blue Bay Aquafarm (Pty) Ltd.	x	x						52.1 ha (SB)	2002-2016
Blue Sapphire Pearls CC	x	x	x			x		10 ha (SB)	2010-2024
Imbaza Mussels (Pty) Ltd (previously trading as Masiza Mussel Farm (Pty) Ltd)	x	x		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			5 ha (SB) 10 ha (BB)	2010-2024
West Coast Oyster Growers CC	x	x						10 ha (BB) 15 ha (SB)	2010-2024
West Coast Seaweeds (Pty) Ltd	x	x						10 ha (SB)	2010-2024
African Olive Trading 232 (Pty) Ltd	x							30 ha (SB) Port of Saldanha	2013-2028
Aqua Foods SA (Pty) Ltd	x	x						Port of Saldanha 10 ha (BB) 10 ha SB	2014-2030
Southern Atlantic Sea Farms (Pty) Ltd.							x	Port of Saldanha 15 hectares (Outer Bay - North)	2014-2029
Salmar Trading (Pty) Ltd.		x						10 ha (BB) 5 ha (SB)	2016-2031
Molapong Aquaculture (Pty) Ltd.							x	1 ha (Outer Bay - south) 4.1 ha (BB)	2016-2032

Table 3.11 Current and future mariculture in Saldanha Bay (Source: Adapted from SRK Consulting 2016b).

Area	Currently allocated	Concession areas	Currently farmed	New Areas	Total future
Outer Bay - North	37	15	1	299	336
Outer Bay - South	10	1	0	315	325
Big Bay - North	254	65	25	584	838
Big Bay - South	4	4,1	1	517	521
Small Bay	125	166,1	125	0	125
Total	**430**	**251,2**	**152**	**1715**	**2145**

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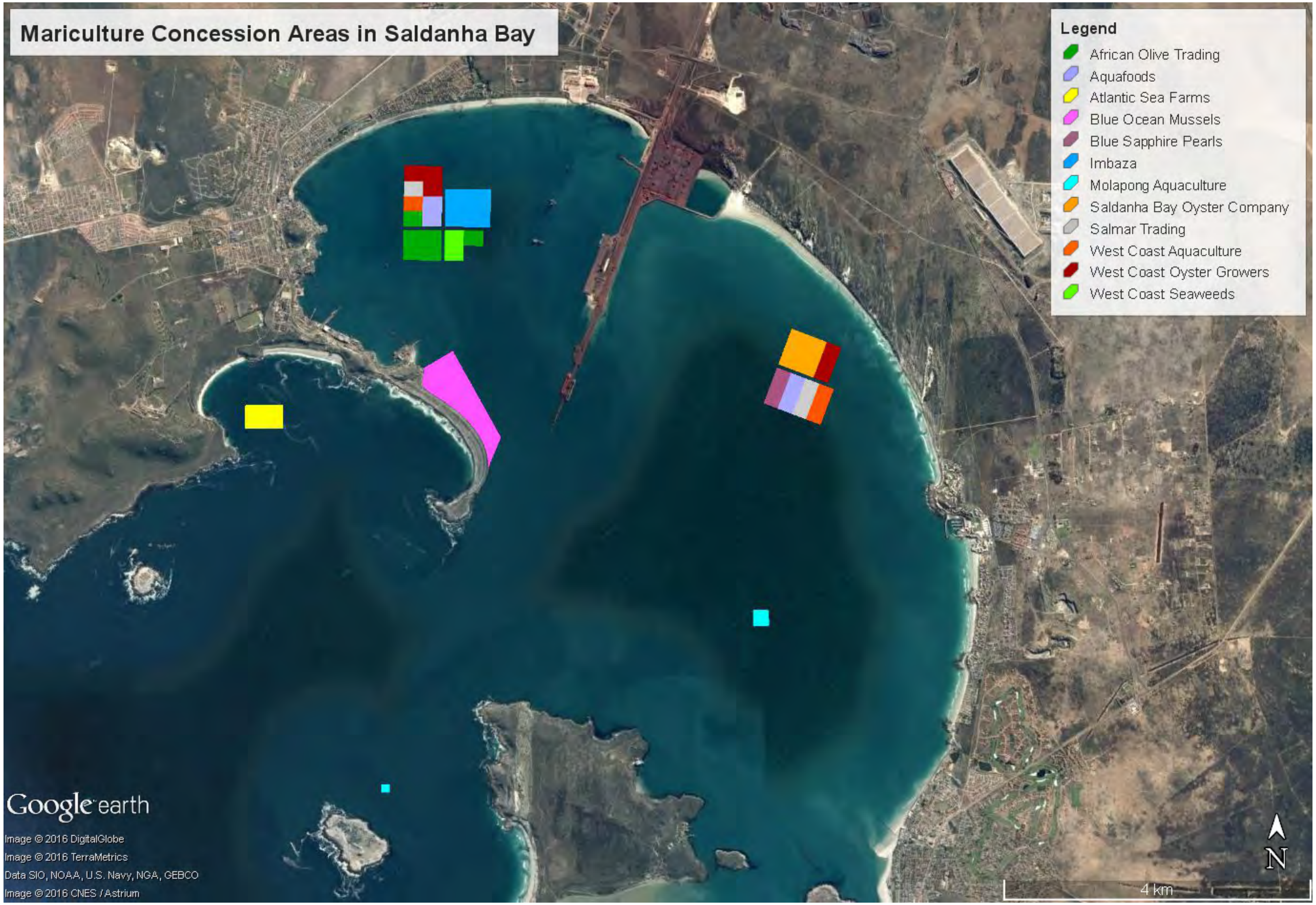


Figure 3.52. Mariculture concession areas in Saldanha Bay 2016 (Source: Transnet Property, Geo-Spatial: Western Region, Burton Siljeur).

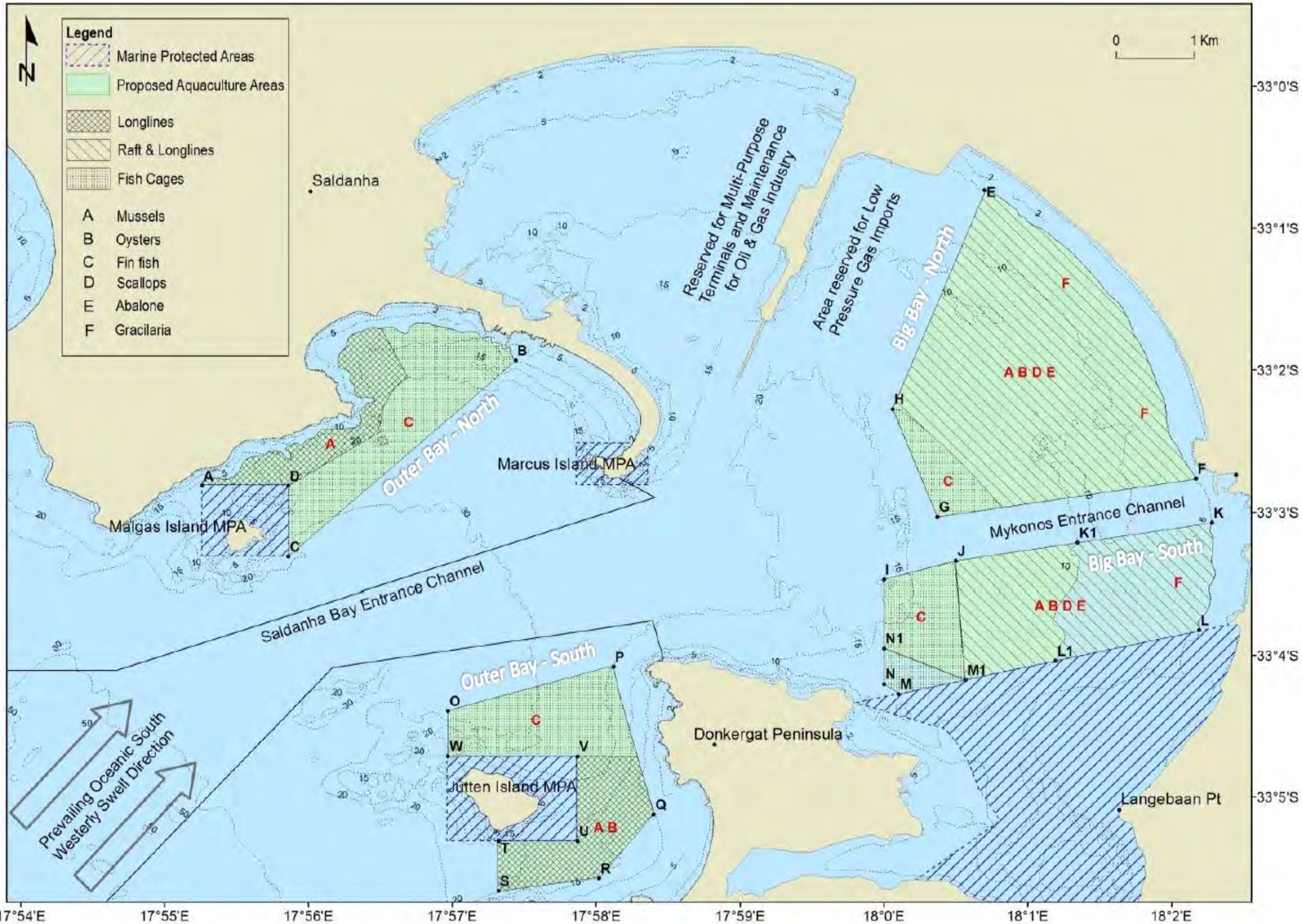


Figure 3.53 Proposed Saldanha Bay Aquaculture Development Zone areas, species and production methods (Source: SRK Consulting 2016b).

3.6.1 Aquaculture sub-sectors

Most established operators hold rights to farm mussels (*Mytilus galloprovincialis* and *Choromytilus meridionalis*) and the pacific oyster *Crassostrea gigas*, while fin fish rights (*Salmo salar* and *Oncorhynchus mykiss*) have only been issued to two farms since 2014 (Table 3.10). Abalone, scallops, red bait and seaweed are currently not cultured on any of these farms, although some of the farms have the right to do so (Refer to AEC 2014 and AEC 2015 for details on individual farms). At the time of writing, most of the farming occurs in Small Bay (Table 3.11) and only oysters are cultured in Big Bay by the Saldanha Bay Oyster Company and West Coast Oyster Growers.

It has been recommended that species that have been cultivated successfully in Saldanha Bay should remain the key species farmed in the proposed Saldanha Bay ADZ. It has been proposed that new shellfish or finfish species will be exclusively indigenous to South Africa, as they do not require comprehensive risk assessments and are likely to have a lower impact on the marine ecology of Saldanha Bay and Langebaan Lagoon. New species include Abalone (*Haliotis midae*), South African scallop (*Pecten sulcicostatus*), white stumpnose (*Rhabdosargus globiceps*), kabeljou (*Argyrosomus inodorus*) and yellow tail (*Seriola lalandi*). A preliminary conceptual spatial plan was developed as part of the project definition phase, which shows where each species would be farmed and which farming method would be suitable (Figure 3.53).

3.6.1.1 Shellfish 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 exponentially since 2007, peaking in 2015 at 1758 tons (Figure 3.54.). Mussel production has doubled since 2012, which can be attributed to the establishment of a new mussel farm and the conversion of an oyster farm to a mussel farm (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).

Ongoing 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.

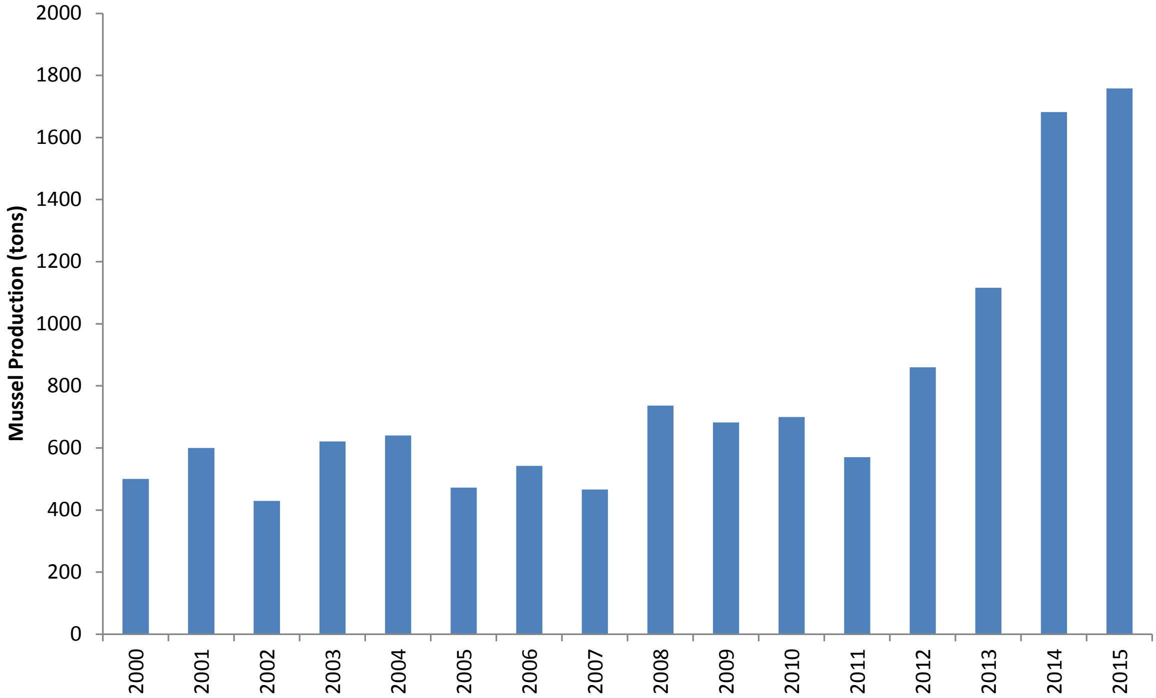


Figure 3.54. Annual mussel production (tons) in Saldanha Bay between 2000 and 2015 (source: Department of Agriculture, Forestry and Fisheries 2015).

3.6.1.2 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 (*Onchorhynchus 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 and AEC 2015 for details on proposed finfish farms in Saldanha Bay.

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 re-circulation 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.

It has been suggested that indigenous finfish species such as white stumpnose, kabeljou and yellow tail may be more resistant to these natural conditions and present a viable option when farmed in Big Bay or the Outer Bay (SRK Consulting, 2016a and SRK Consulting, 2016b).

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.

3.7 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 earlier editions of the State of the Bay Report (AEC 2014, 2015).

[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.

3.7.1 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 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 clean-up as construction material washes ashore (SBM, Environmental Officer, Nazema Duarte, *pers. comm.* 2015).

Figure 3.55. 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). An initiative for the establishment of a Special Management Area in Saldanha Bay is gradually gathering momentum and has the potential to assist with this and is described in some detail below. Other initiatives that also have an important role to play in this respect include the establishment of development set back lines and the preparation of an Environmental Management Framework for Saldanha have been described in previous editions of the State of the Bay Report (AEC 2014, 2015).

4.1.1 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)).

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 thermistor 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 was to maintain this array in situ for as long as possible but unfortunately the thermistor string had disappeared (lost or stolen) when we sought to retrieve it to download the accumulated data earlier this year. The thermistor string has since been replaced but unfortunately the data for 2015-2016 has been lost. 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 cm.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 cm.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 cm.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 cm.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 cm.s^{-1}, either eastwards or westwards) and in the remainder of the Bay, a slow (5 cm.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 (5-20cm.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.

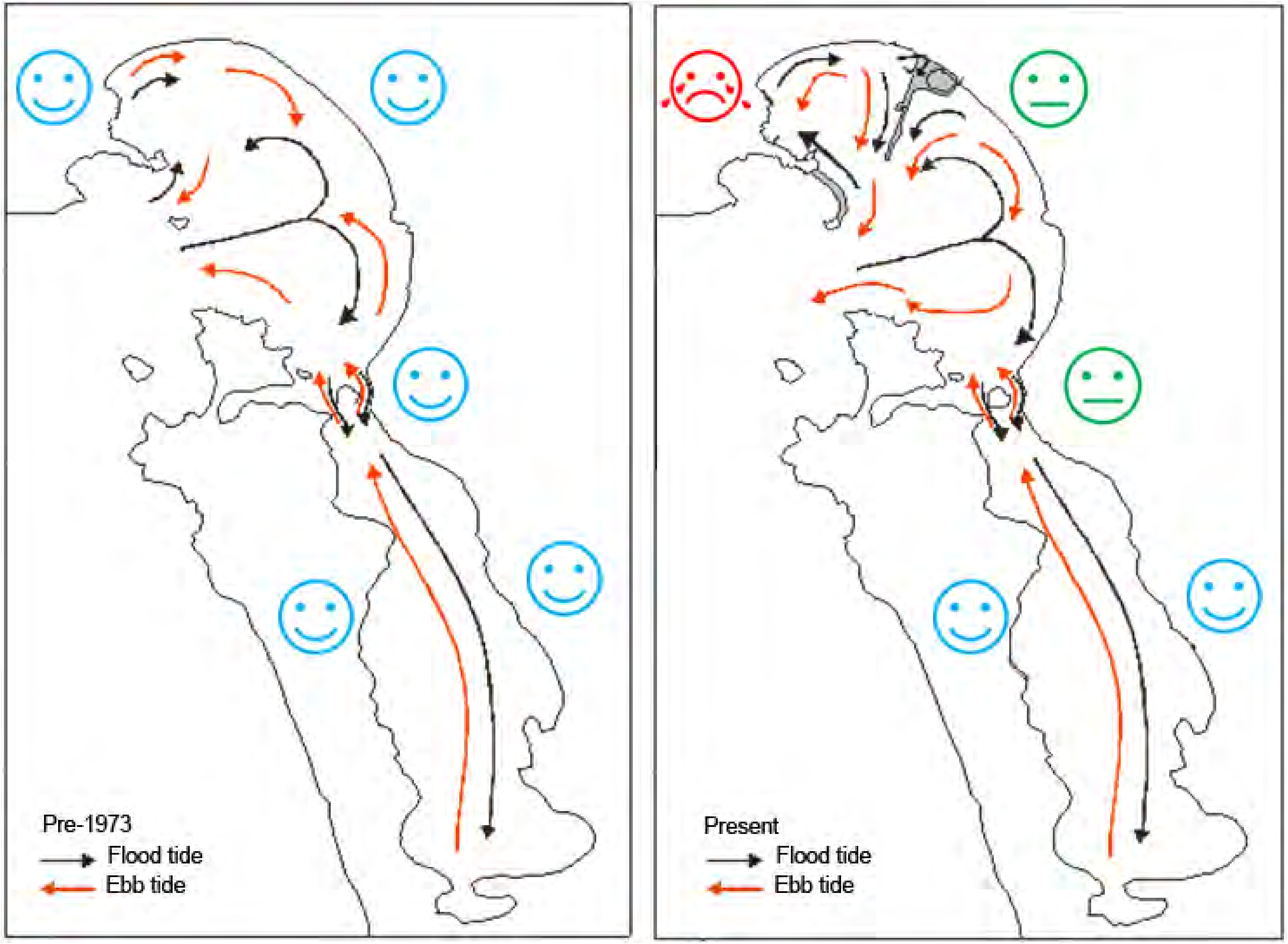


Figure 5.1 **Schematic representation of the surface currents and circulation of Saldanha Bay prior to the harbour development (Pre-1973) and after construction of the causeway and iron-ore terminal (Present) (Adapted from: Shannon & Stander 1977 and Weeks *et al*. 1991a).**

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).

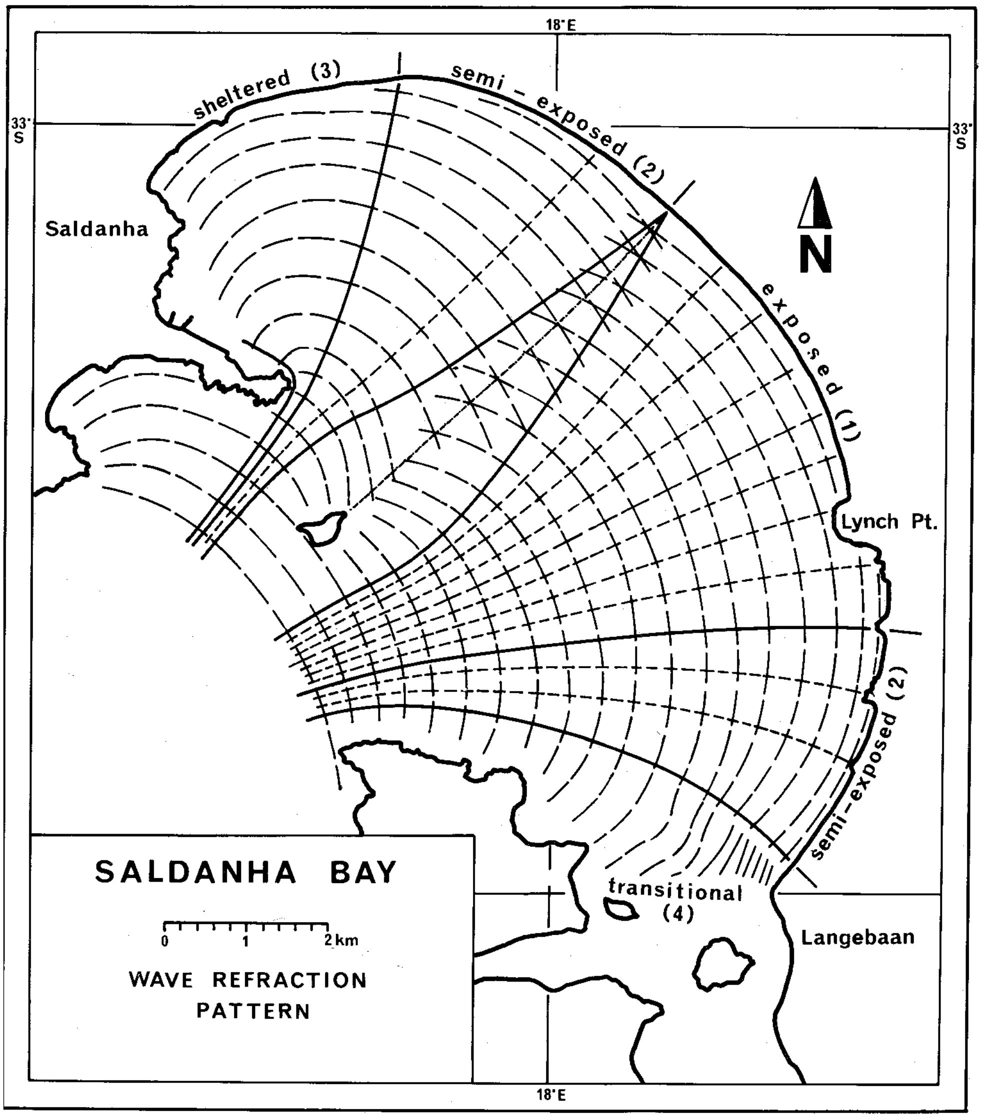


Figure 5.2 **Predicted wave field in Saldanha Bay showing wave height and direction prior to harbour development (Source: Flemming 1977).**

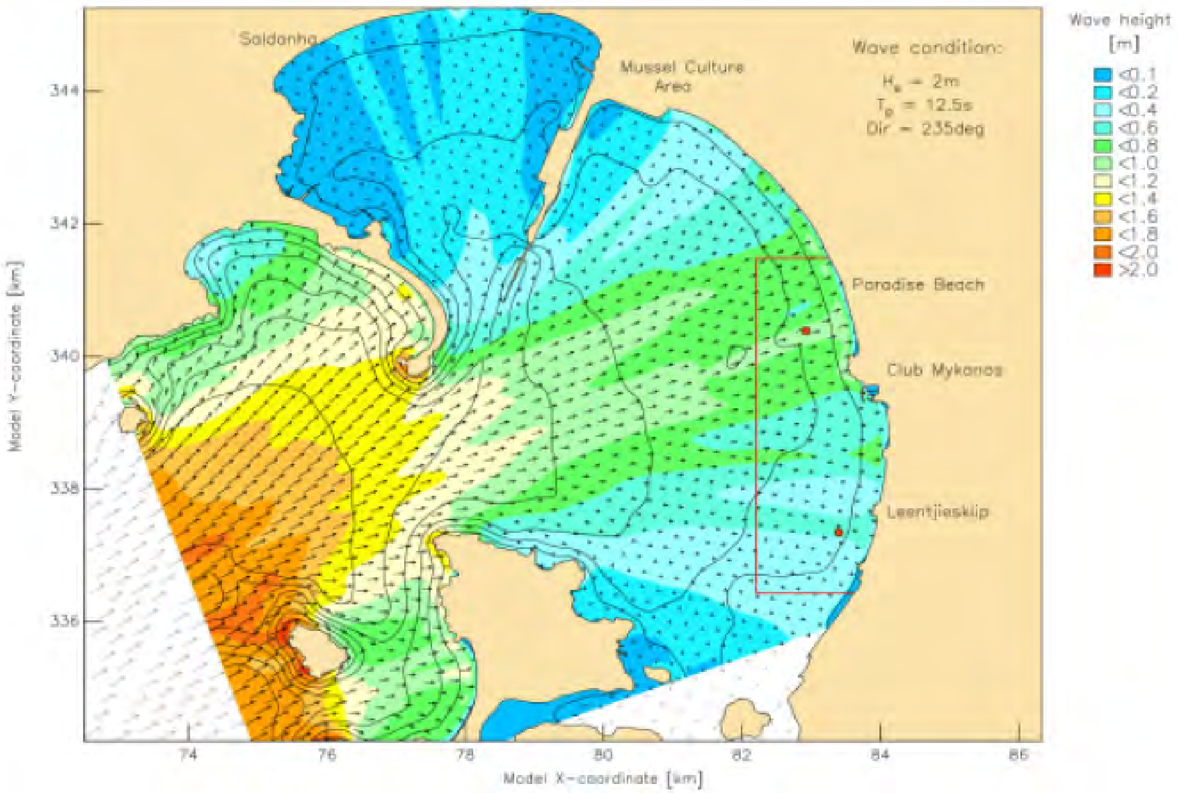


Figure 5.3 **Predicted wave field in Saldanha Bay showing wave height and direction after the construction of the causeway and the iron-ore Terminal (Source: WSP Africa Coastal Engineers, 2010).**

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 16.0-18.5°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).

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.

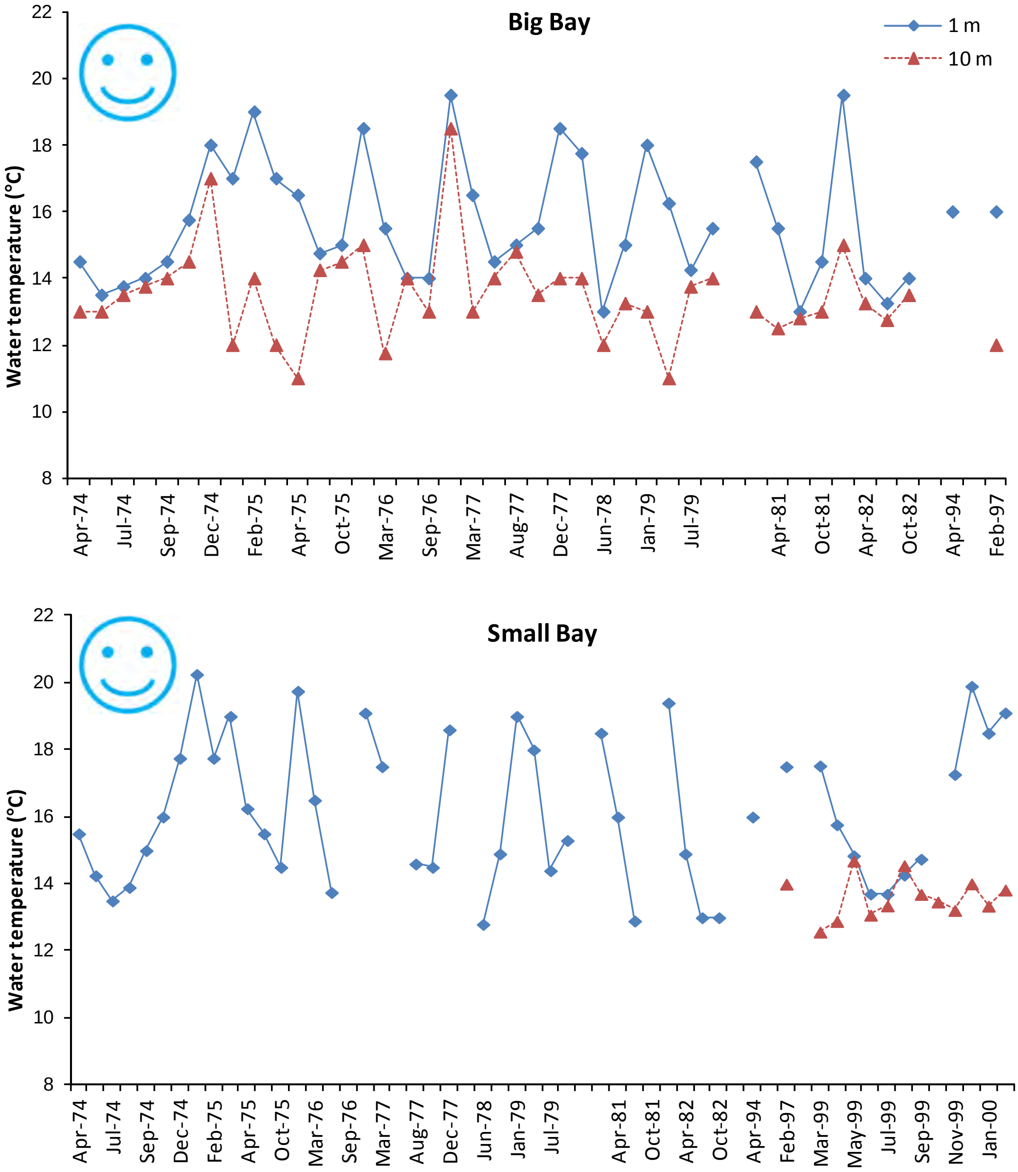


Figure 5.4 **Water temperature time series at the surface and at 10m depth for Big Bay and Small Bay, Saldanha Bay (Data: Monteiro *et al.* 1990, Monteiro & Brundrit 1990. Monteiro *et al.* 2000 and Shannon & Stander 1977).**

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.

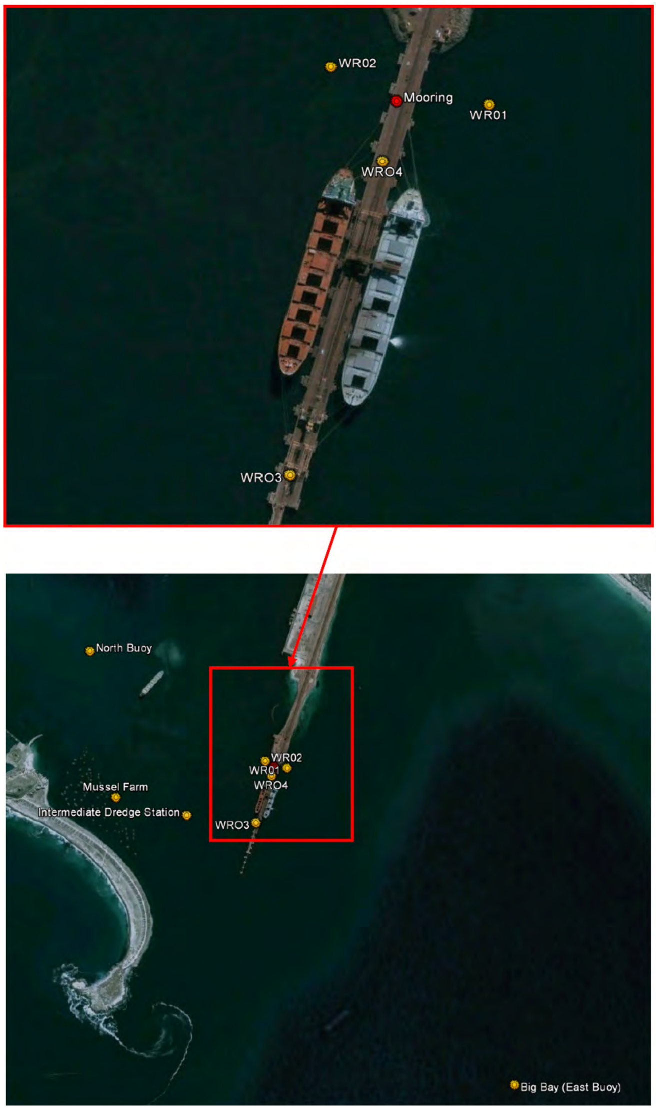


Figure 5.5 **Water quality monitoring stations adopted for the RO plant baseline survey undertaken by the Council for Scientific and Industrial Research (Source: van Ballegooyen *et al.* 2012).**

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.

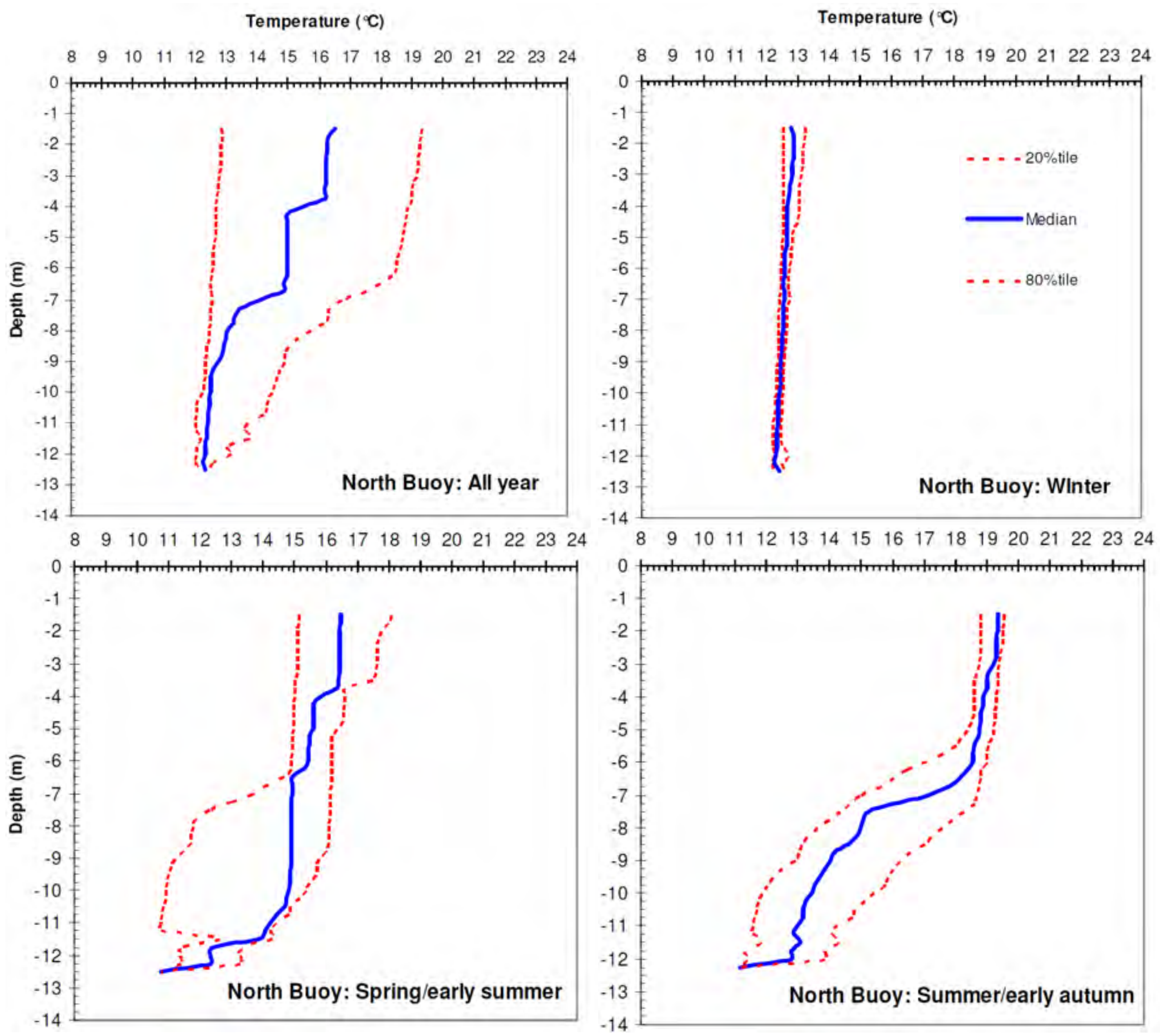


Figure 5.6 **Seawater temperature median profiles at North Buoy for all seasons (winter, spring/early, summer and summer/early autumn). The 20 and 80 percentile limits of the profiles are indicated by the dotted red lines (Source: van Ballegooyen *et al.* 2012).**

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 adverts 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. Coupled with vertical mixing, this 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.

With a view to continuing the long term temperature data set at North Buoy, five Vemco mini-loggers, programmed to record temperature every six minutes were deployed at 2.0 m, 4.5 m, 7.0 m, 9.5 m and 12.0 m depth on the 12 April 2014. These thermistors were retrieved and serviced on the 22 April 2015, and data for this period are shown in Figure 5.8. Unfortunately the thermistor string was missing when we attempted to retrieve it in April 2016 (lost or stolen) which means that data accumulated since this time has been lost. The thermistor string has since been replaced, however, and we look forward to seeing new data again next year.

The data from 2014/2015 show 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^{o}C) or surface (13-20^{o}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.

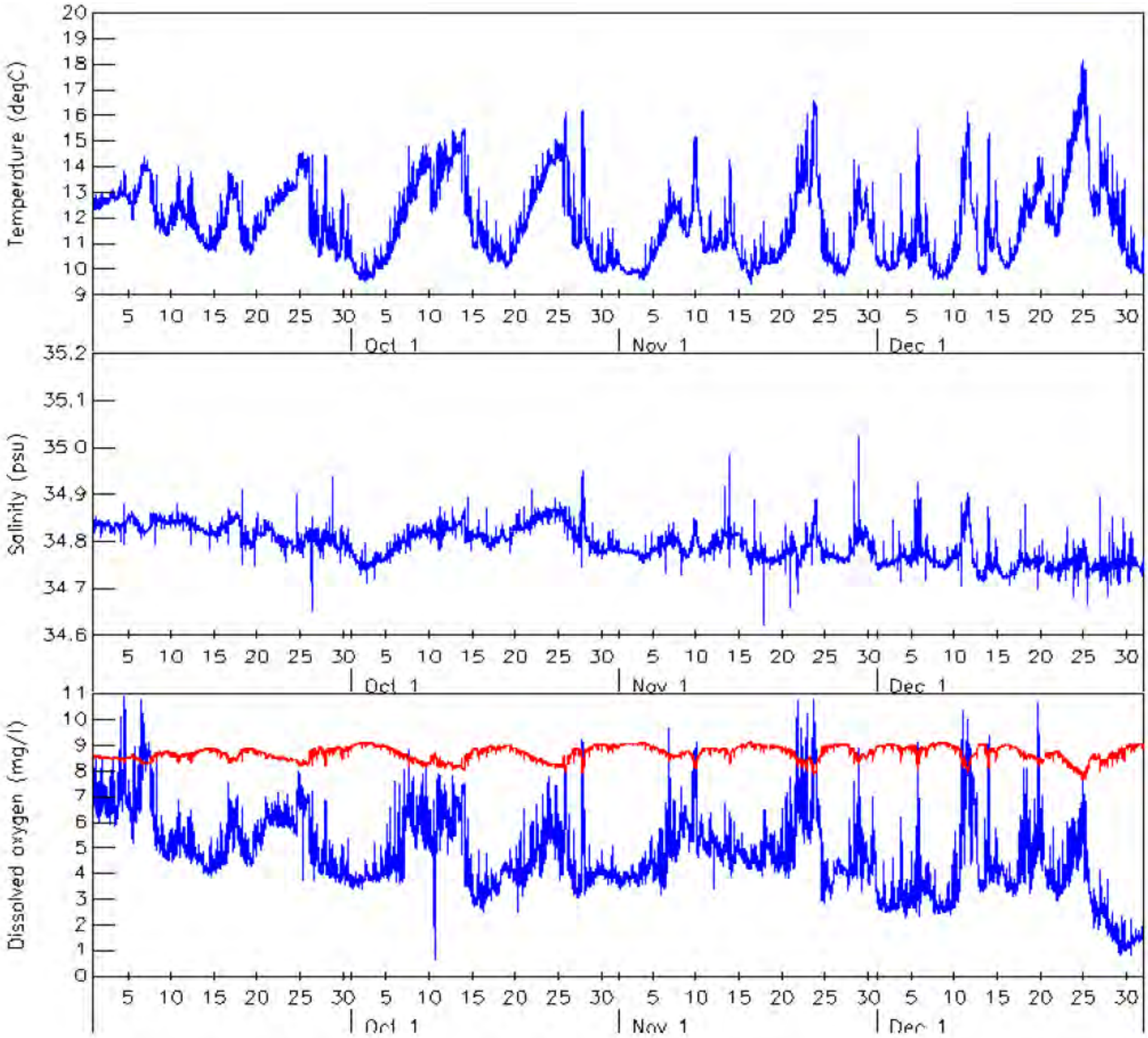


Figure 5.7. **Time series of water temperature, salinity and dissolved oxygen concentration from the mooring site (33° 01.679'S: 17° 59.143'E) for spring/early summer (Source: van Ballegooyen *et al.* 2012).**

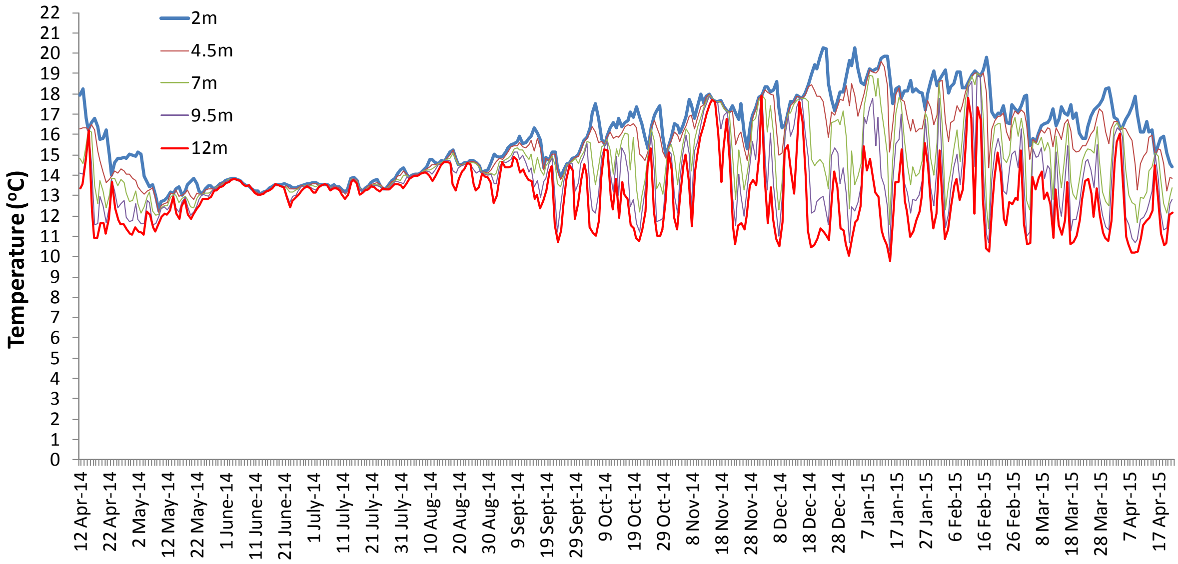


Figure 5.8 **North buoy temperature time series for the period 12 April 2014 - 22 April 2015. The average daily temperature is shown (Vemco miniloggers moored at five different depths in the water column recorded temperature every six minutes).**

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).

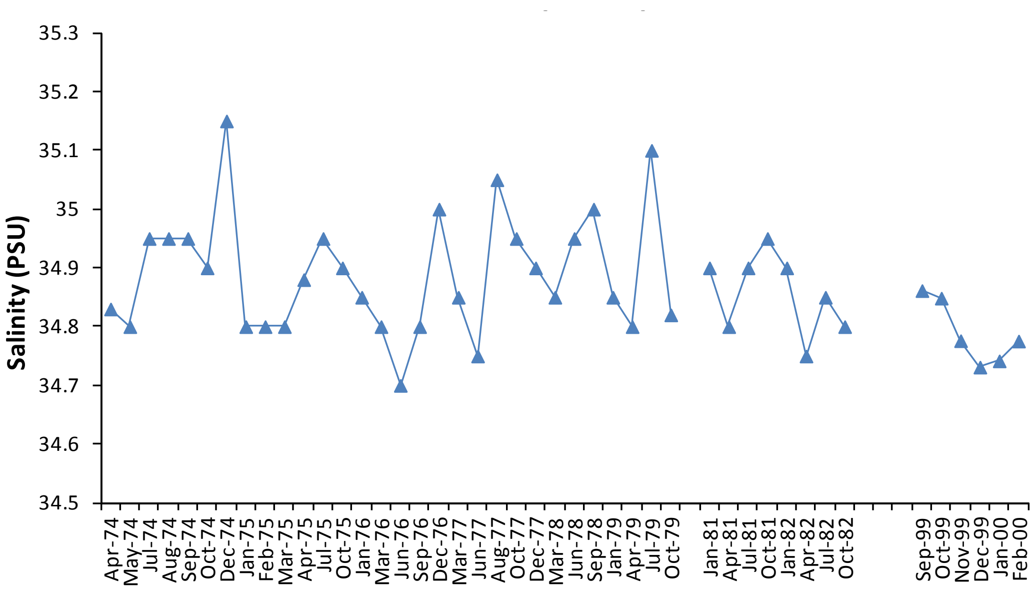


Figure 5.9 **Time series of salinity records for Saldanha Bay (data sources: Shannon & Stander 1977, Monteiro & Brundrit 1990, Monteiro *et al*. 1990 and Monteiro *et al*. 2000).**

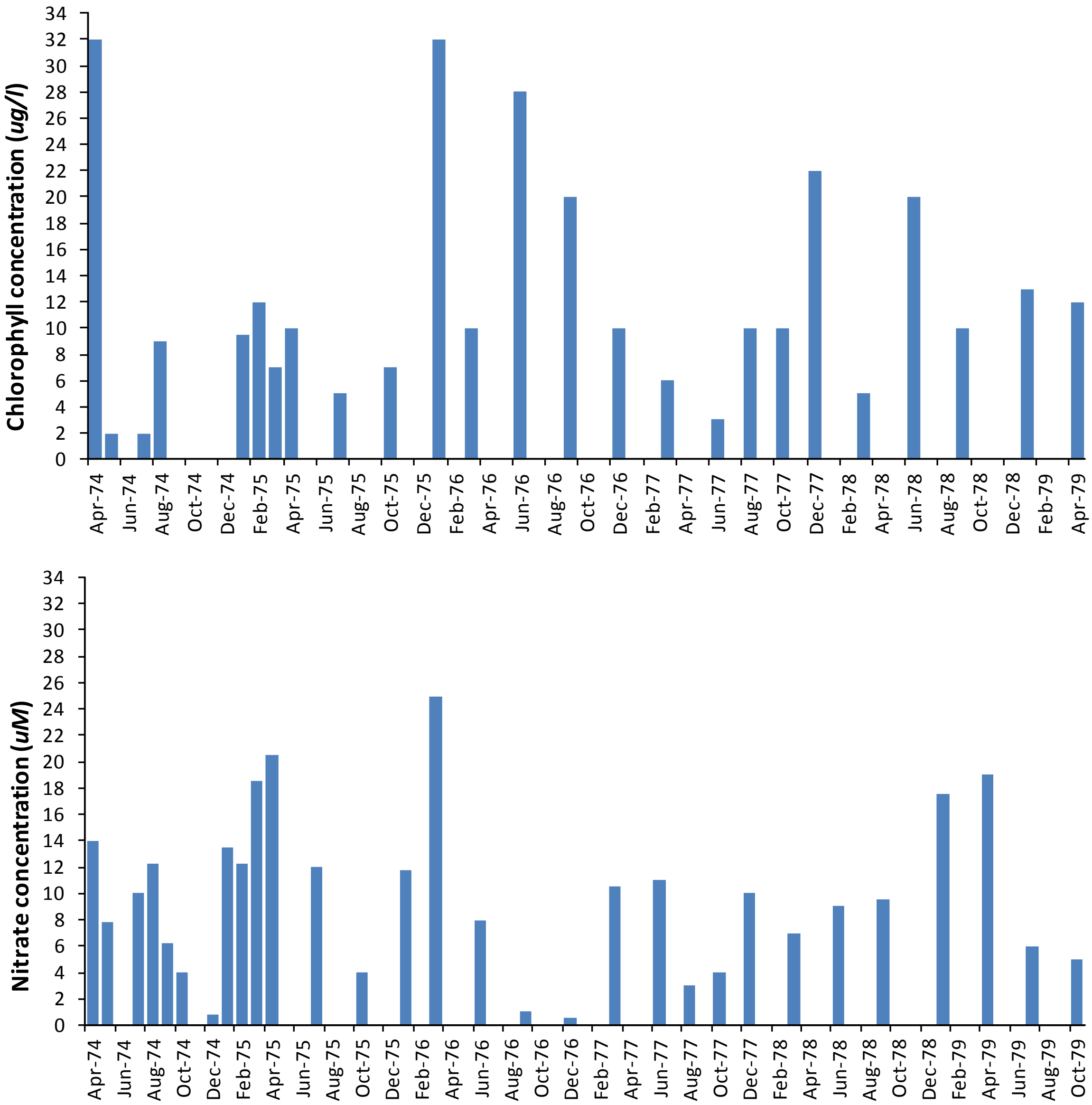


Figure 5.10 **Time series of chlorophyll and nitrate concentration measurements for Saldanha Bay (Data source: Monteiro & Brundrit, 1990).**

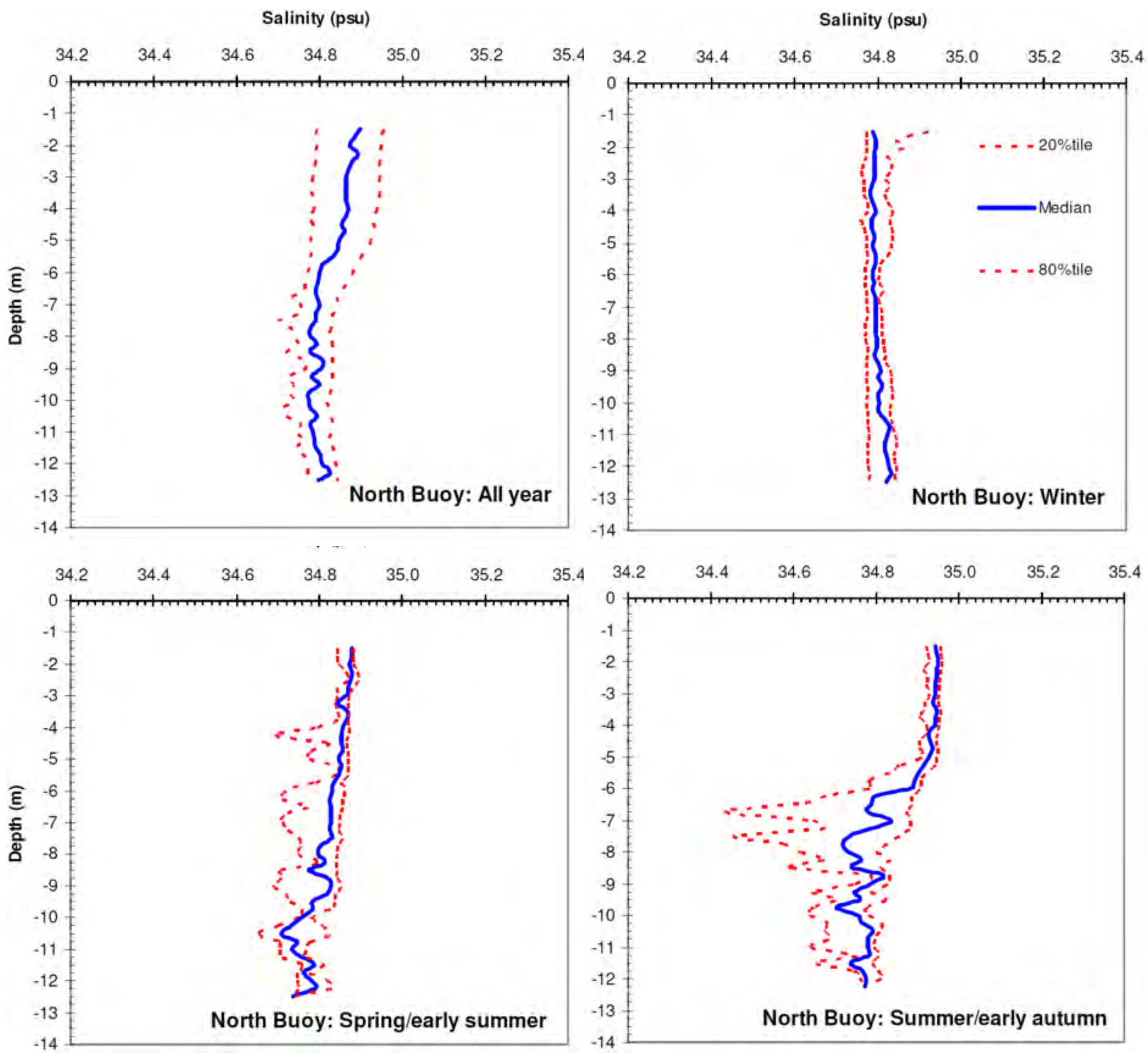


Figure 5.11 **Salinity median profiles at North Buoy in Small Bay for all seasons (winter, spring/early, summer and summer/early autumn). The 20 and 80 percentile limits of the profiles are indicated by the dotted red lines (Source: van Ballegooyen *et al.* 2012).**

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.

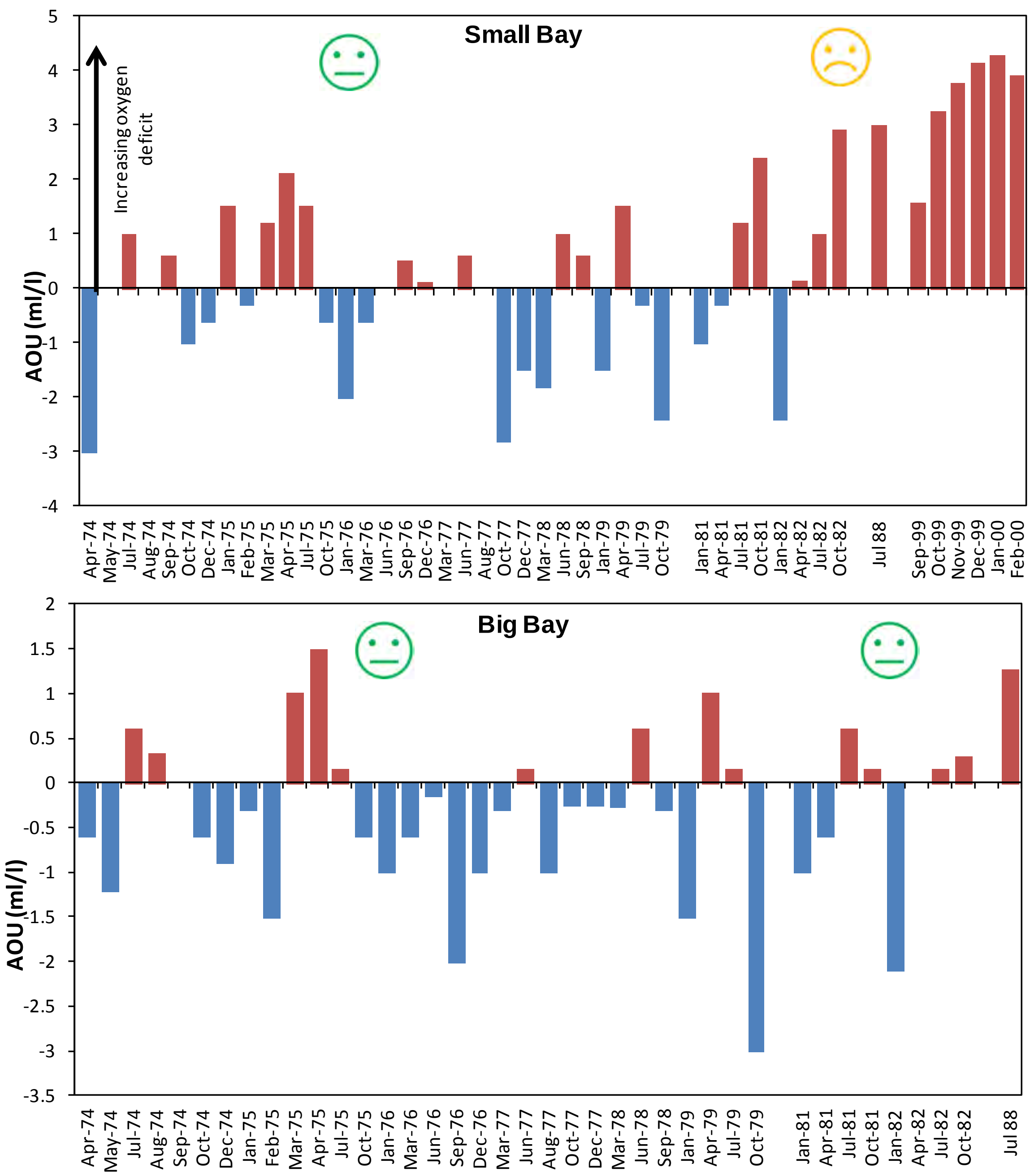


Figure 5.12 **Apparent oxygen utilization time series for Small Bay and Big Bay in Saldanha Bay. Positive values in red indicate an oxygen deficit (Data sources: Monteiro *et al.* 1990 and 2000).**

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.

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).

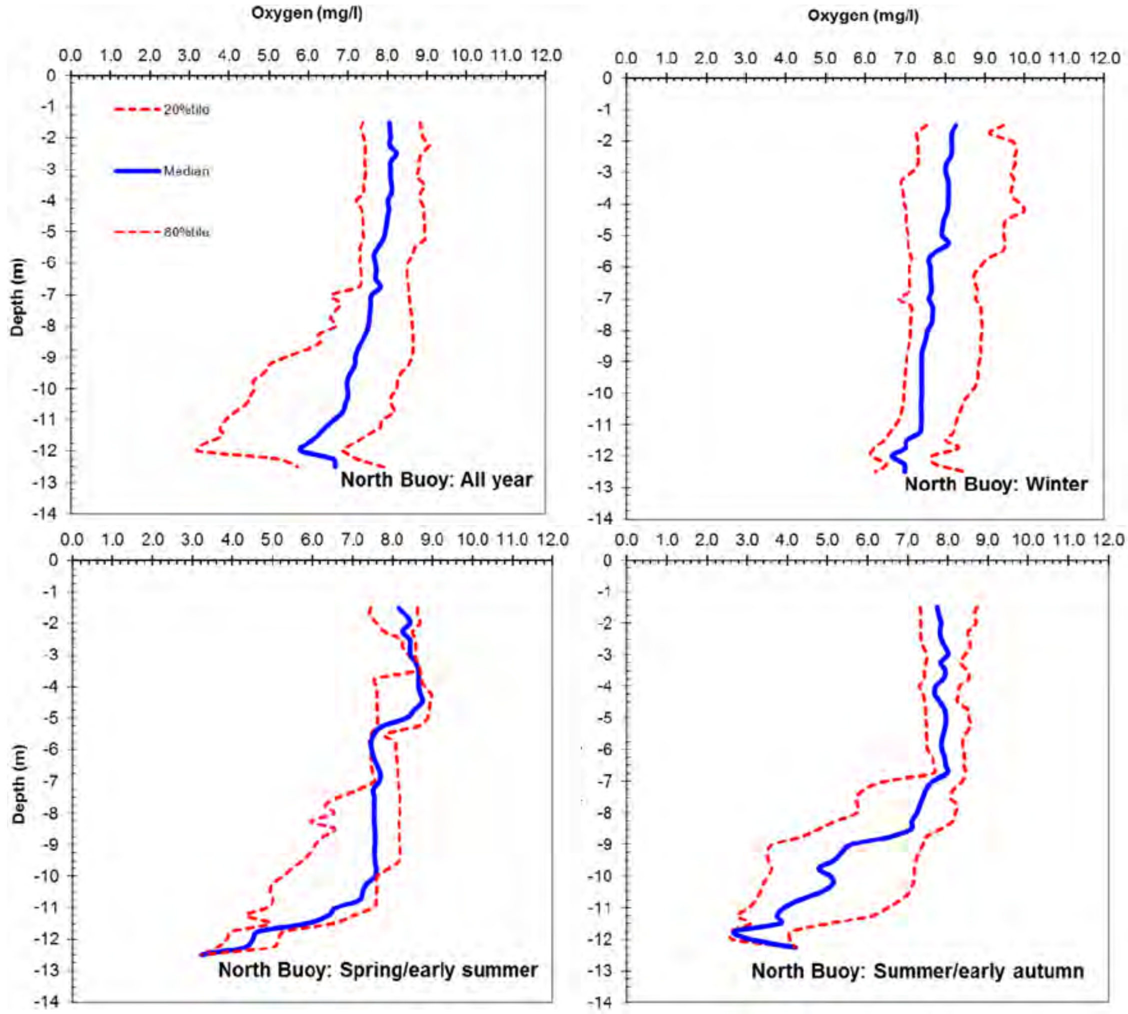


Figure 5.13 **Dissolved oxygen concentration median profiles at North Buoy for all seasons (winter, spring/early, summer and summer/early autumn). The 20 and 80 percentile limits of the profiles are indicated by the dotted red lines (Source: van Ballegooyen *et al.* 2012).**

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).

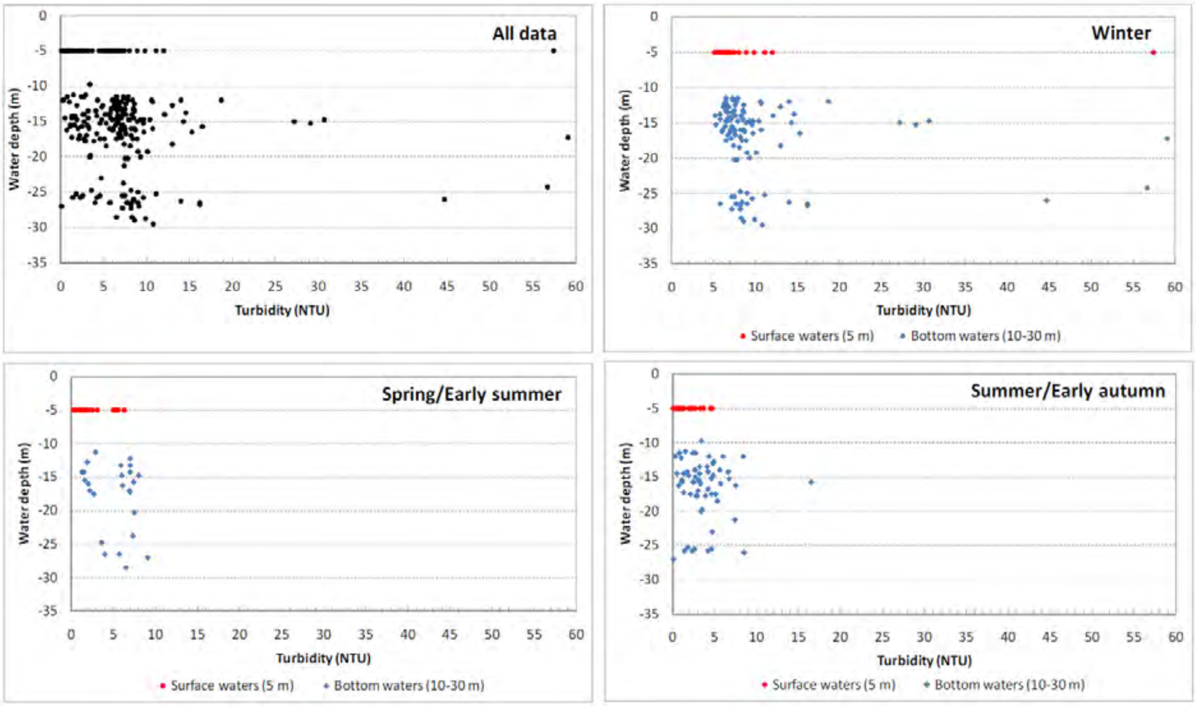


Figure 5.15 Turbidity (NTU) plotted as a function of depth and season (red –surface; blue – bottom) (Source: van Ballegooyen *et al.* 2012).

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-nitrilopropionamide 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.

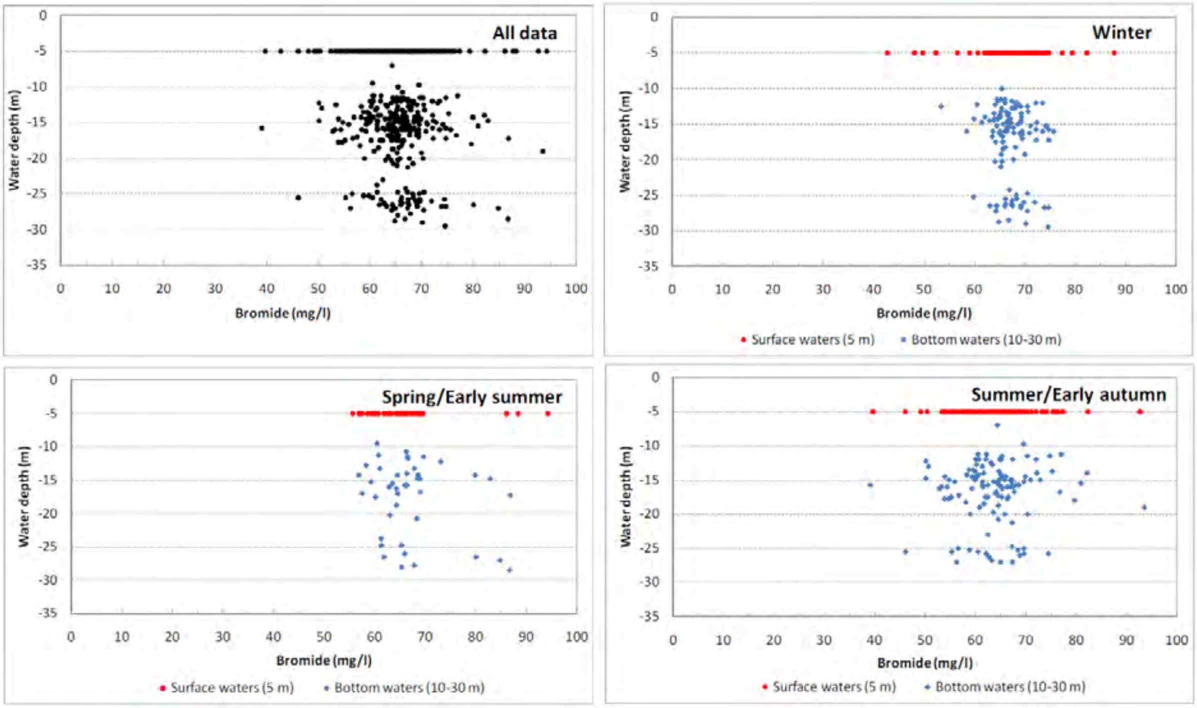


Figure 5.16 Bromide concentrations as measured at all stations in winter, spring/early summer and summer/early autumn (Source: van Ballegooyen *et al.* 2012).

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 a 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.

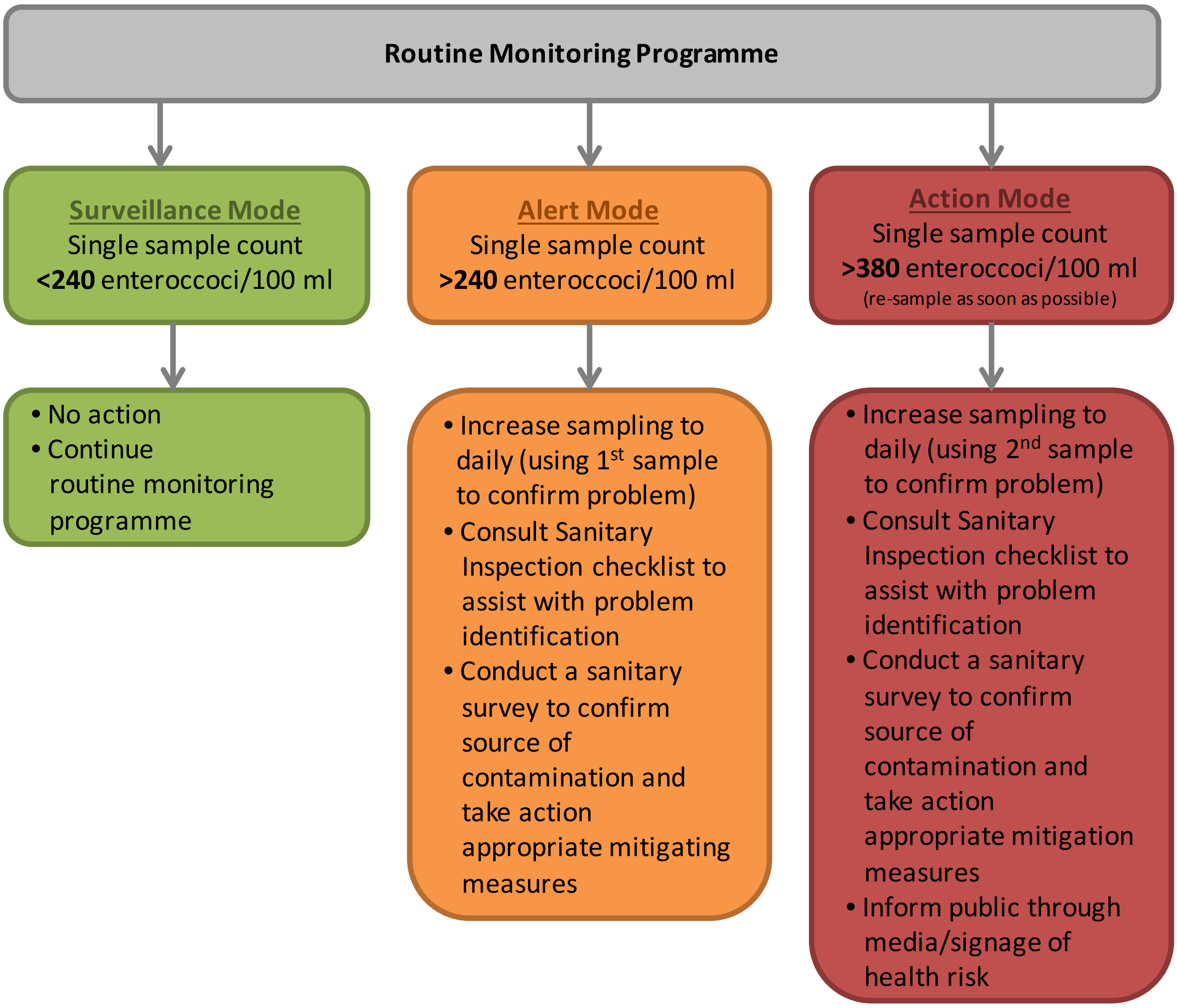


Figure 5.17 An illustration of the proposed routine monitoring programme to be trialled in South Africa. Source: South African Water Quality Guidelines for Coastal Marine Waters (DEA 2012).

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)	*E. coli.* (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* (DWAF 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 DWAF 1995 guidelines (DWAF 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 December 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. Data presented covers a complete calendar year to account for seasonal differences, thus 2016 data will be included in the 2017 report. 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. 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), although some sites have again deteriorated since 2014. Based on the 2015 *E. coli* data, 16 of the 20 sampled stations were categorized as having excellent water quality. Langebaan North (Site 15) was ranked as having ‘Good’ water quality, which dropped from ‘Excellent’ in 2014. Water quality also dropped at Hoedtjies Bay Beach (Site 7), Mykonos Harbour (Site 13) and Langebaan Main Beach (Site 16). Reasons behind this deterioration should be investigated and any contributing sources immediately dealt with. Marked improvements were detected at Pepper Bay (Site 6), Caravan Park Beach (Site 8), the Bok River Mouth (Site 9) and Leentjiesklip (Site 14). Ongoing efforts to maintain the good water quality at the popular swimming and water sport sites must be continued.

Table 5.4 **Sampling site compliance for <u>recreational use</u> based on <u>*E. coli* counts</u> 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. '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	Fair	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
	2. Small Craft Harbour	Ex.	Fair	Good	Ex.	Ex.	Ex.	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Good	Ex.	Ex.	Ex.
	3. Sea Harvest - Small Quay	Fair	Fair	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.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
	5. Pepper Bay - Big Quay	Poor	Fair	Poor	Fair	Fair	Fair	Fair	Poor	Ex.	Ex.	Fair	Ex.	Ex.	Good	Ex.	Ex.	Ex.
	6. Pepper Bay - Small Quay	Poor	Fair	Fair	Good	Ex.	Good	Ex.	Ex.	Good	Ex.	Good	Good	Ex.	Good	Fair	Fair	Ex.
	7. Hoedjies Bay Hotel - Beach	Fair	Fair	Poor	Fair	Good	Poor	Poor	Good	Fair	Ex.	Fair	Fair	Poor	Poor	Fair	Good	Fair
	8. Beach at Caravan Park	Fair	Fair	Fair	Poor	Ex.	Fair	Poor	Ex.	Good	Poor	Fair	Fair	Fair	Poor	Good	Fair	Ex.
	9. Bok River Mouth - Beach	Poor	Fair	Poor	Poor	Poor	Poor	Poor	Ex.	Fair	Poor	Poor	Good	Ex.	Poor	Fair	Good	Ex.
	10. General Cargo Quay - TNPA	Ex.	Fair	Ex.	Ex.	Ex.	Ex.	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
Big Bay	11. Seafarm - TNPA	Ex.	Fair	Ex.	Ex.	ND	ND	Ex.	Ex.	Ex.	ND	Ex.	ND	ND	Ex.	Ex.	Ex.	Ex.
	12. Mykonos - Paradise Beach	Ex.	Fair	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
	13. Mykonos - Harbour	Fair	Fair	Ex.	Ex.	Fair	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Fair	Ex.	Ex.	Good	Fair
	14. Leentjiesklip	ND	ND	Good	Fair	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Fair	Ex.	Good	Ex.
Langebaan Lagoon	15. Langebaan North - Leentjiesklip	Ex.	Fair	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Poor	Good	Ex.	Good
	16. Langebaan - Main Beach	ND	ND	Fair	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Good	Ex.	Ex.	Ex.	Ex.	Ex.	Fair
	17. Langebaan Yacht Club	ND	ND	ND	ND	ND	Poor	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.	Good	Ex.	Ex.
	18. Tooth Rock	ND	ND	ND	ND	ND	Fair	Ex.	Ex.	Ex.	Ex.	Fair	Ex.	Ex.	Ex.	Ex.	Ex.	Ex.
	19. Kraalbaai North	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Ex.	Ex.	Ex.	Ex.
	20. Kraalbaai South	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Ex.	Ex.	Ex.	Ex.

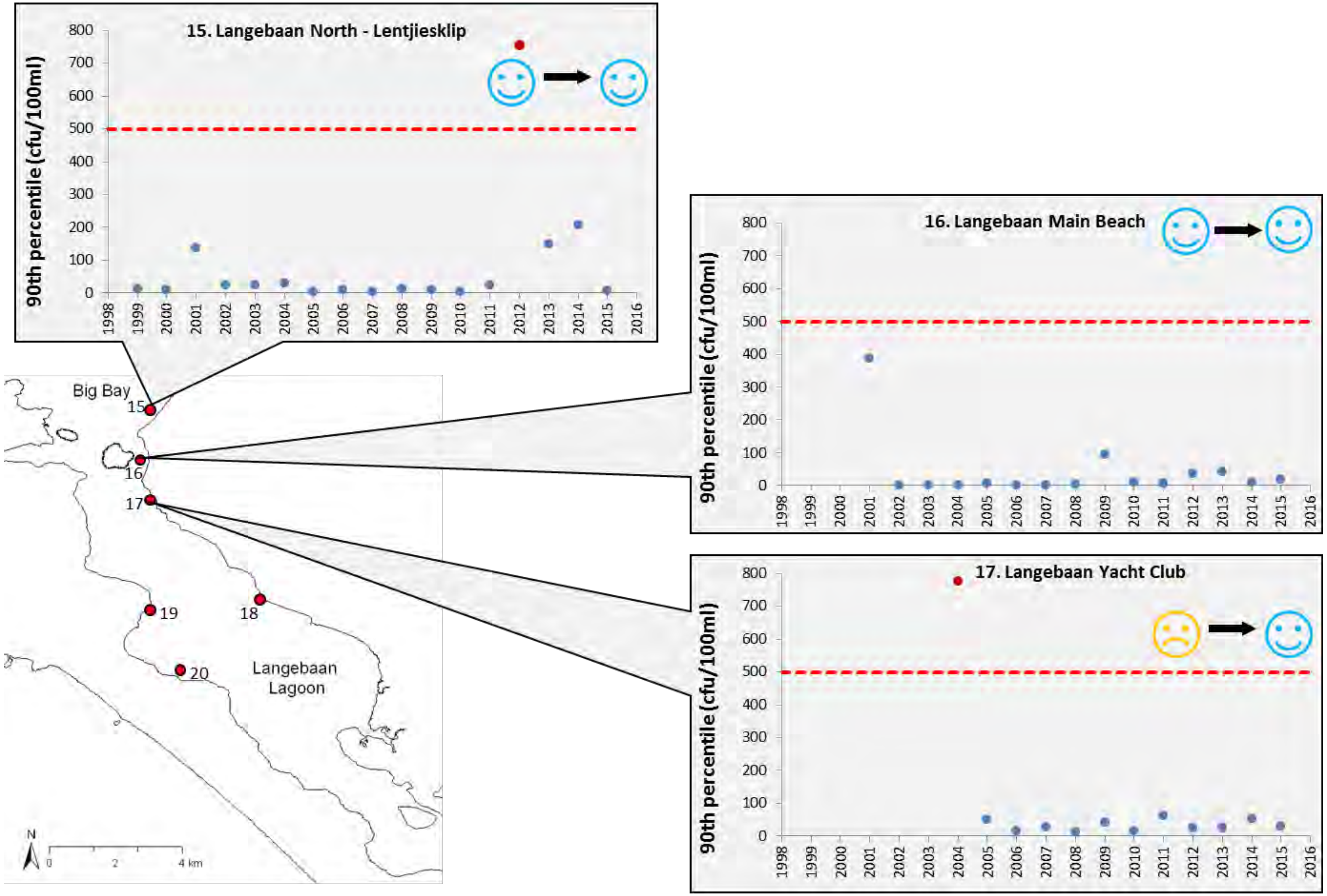


Figure 5.18 Hazen method 90th percentile values of *E.coli* counts at three of the 6 sampling stations within Langebaan Lagoon (Feb 1999 - Dec 2015). The red line indicates the Hazen method 90th percentile contact recreation limit of *E.coli* counts (500 colony-forming units/100 ml) above which water 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.

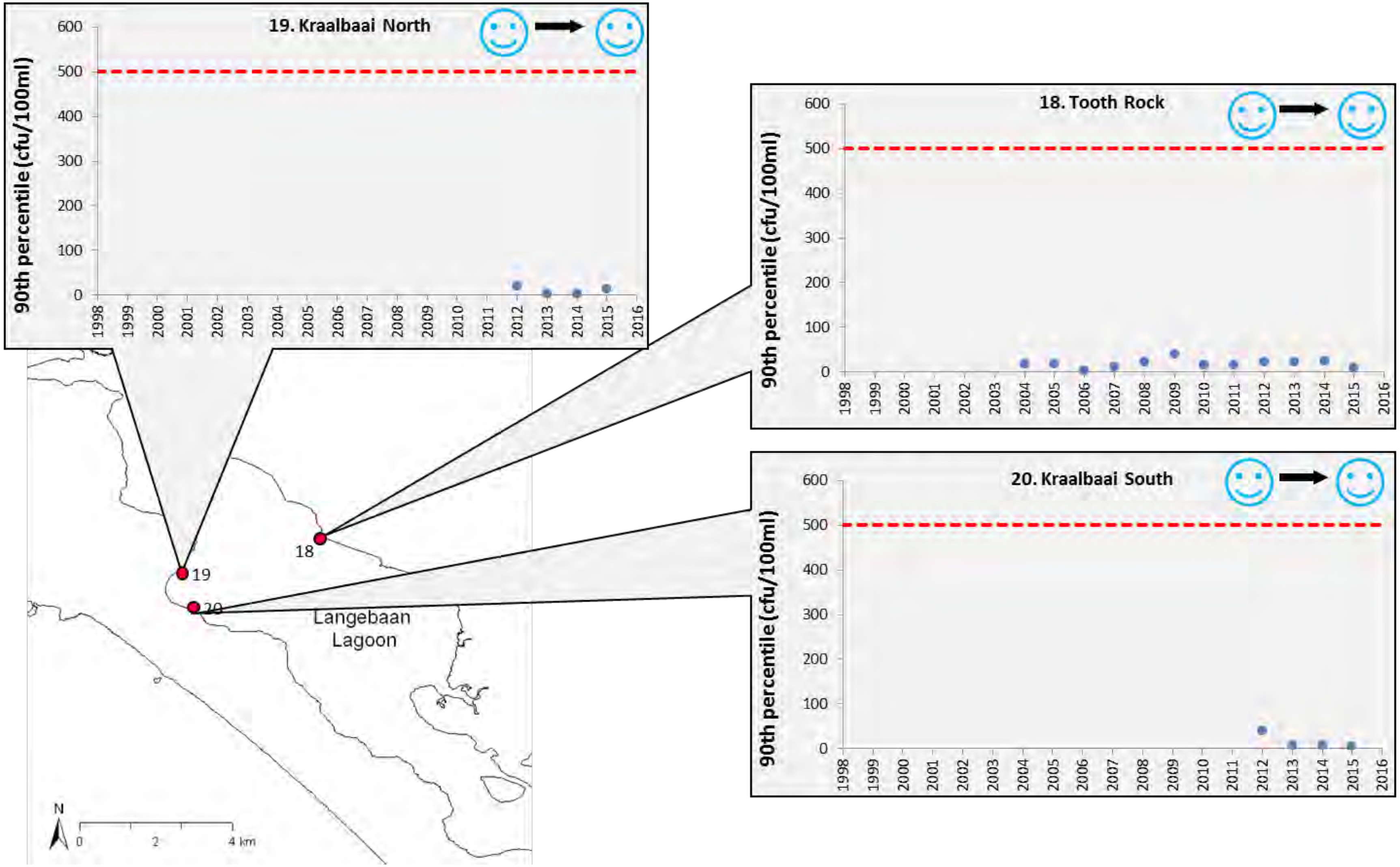


Figure 5.19 Hazen method 90th percentile values of *E.coli* counts at three of the 6 sampling stations within Langebaan Lagoon (Feb 1999 - Dec 2015). The red line indicates the Hazen method 90th percentile contact recreation limit of *E.coli* counts (500 colony-forming units/100 ml) above which water 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.

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. Nine out of the 10 sites in Small Bay (Sites 1-9) were not compliant in respect of the 80th and 95th percentile mariculture guideline limits for faecal coliforms (Figure 5.20, Figure 5.21 and Figure 5.22). Only the General Cargo Quay (Site 10) met the required standards. These data indicate that there remains a serious issue of water quality with respect to mariculture operations within Small Bay. The areas of particular concern are Hoedjies Bay, Caravan Park Beach and the Bok River Mouth which have not shown any improvement towards meeting guidelines over the last 15 years, and continue to exceed the guidelines by a substantial margin (Figure 5.21 and Figure 5.22).

As samples are collected in shallow coastal waters close to sources of contamination (storm water drains etc.), concentrations of microbiological contaminants in the samples are likely to be higher than those near the offshore mariculture rafts. Nevertheless, the exceedance of mariculture water quality guidelines in near-shore waters remains a concern, particularly in light of the proposed additional mariculture development in the area. Land-based mariculture facilities that may become established in the IDZ will need to extract water from Small Bay. The prevailing poor water quality near-shore will force sea water abstraction further offshore at an increased cost.

At the other sites within Small Bay, water quality has either remained well within the guideline limits (e.g. 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 improvement has 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 remain above guideline levels at three of these four sites, but they have come down considerably and do not exceed the guidelines by such a large margin as they once did (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 percentile limits for mariculture (Figure 5.23), although Mykonos Harbour fell above the 95th percentile limit. 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 nearly every year since 2004, with the exception of the Mykonos Harbour site when levels were marginally exceeded only in 2009 and 2011.

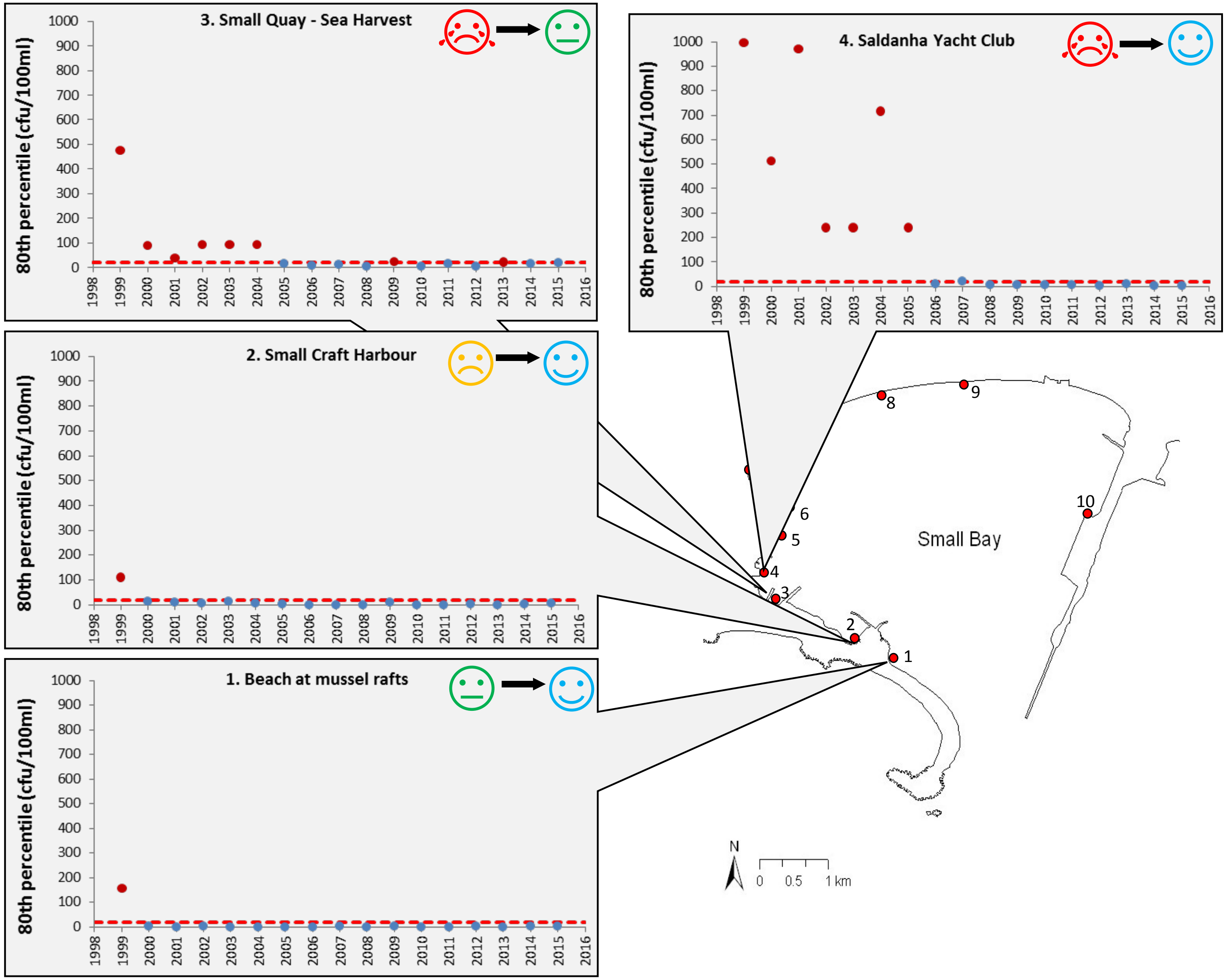


Figure 5.20 **80th percentile values of faecal coliform counts at four of the 10 sampling stations within Small Bay (Feb 1999 - Dec 2015). The red line indicates the <u>80th percentile mariculture limit of faecal coliforms</u> (20 colony-forming units/100 ml). Red data points indicate 80th percentile 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.**

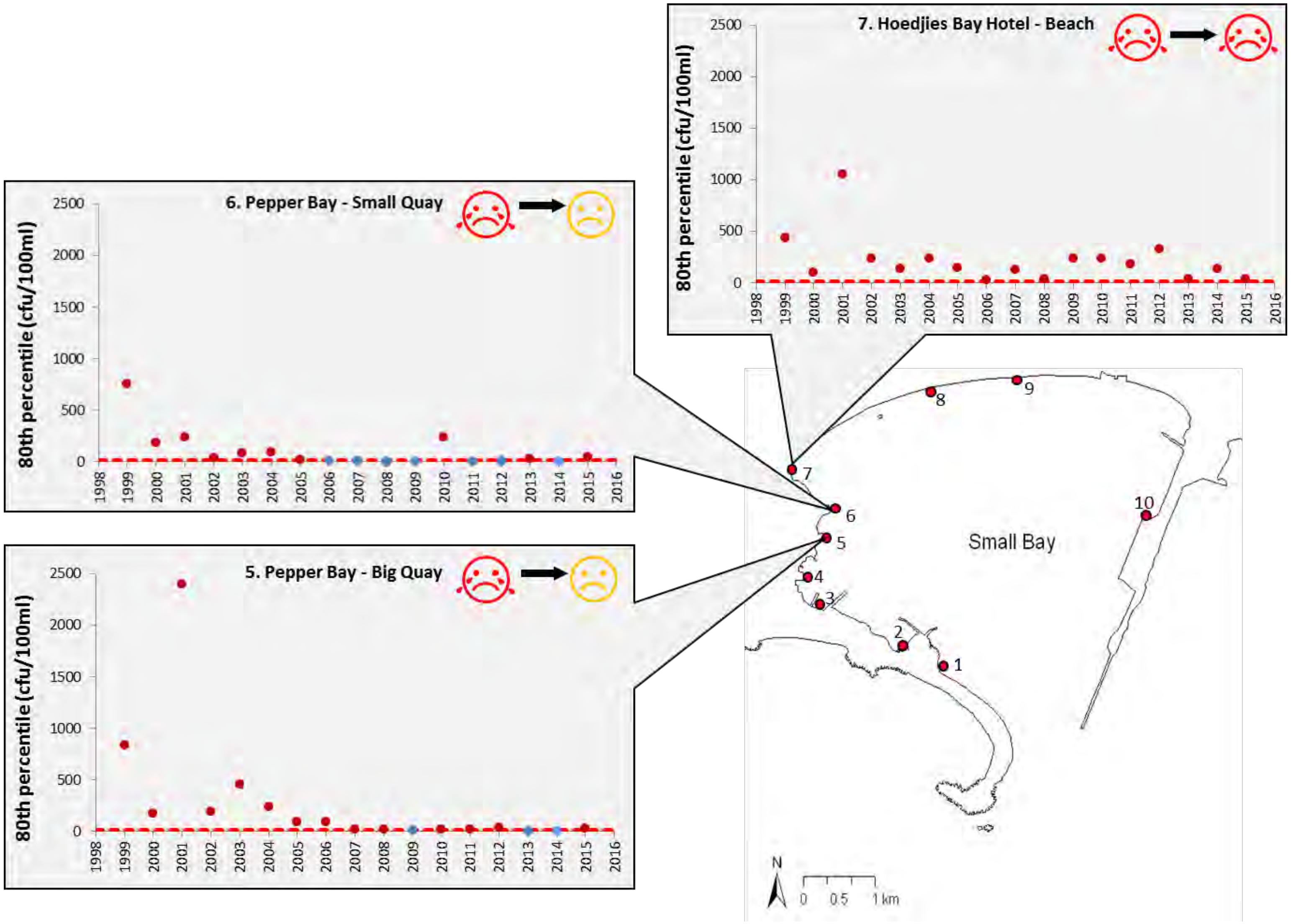


Figure 5.21 80th percentile values of faecal coliform counts at three of the 10 sampling stations within Small Bay (Feb 1999 - Dec 2015). The red line indicates the <u>80th percentile mariculture limit of faecal coliforms</u> (20 colony-forming units/100 ml). Red data points indicate 80th percentile 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.

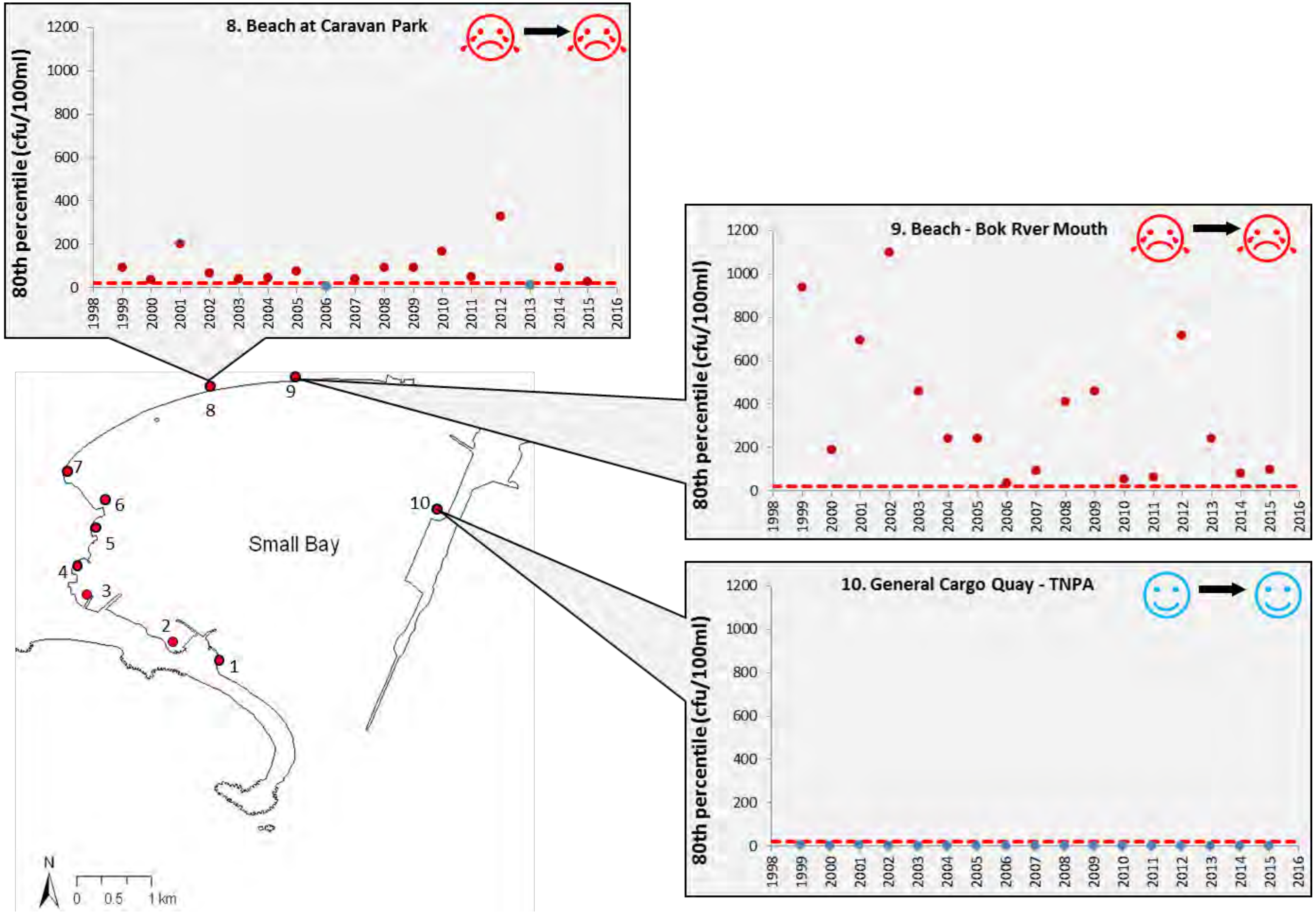


Figure 5.22 80th percentile values of Faecal coliform counts at three of the 10 sampling stations within Small Bay (Feb 1999 – Dec 2015). The red line indicates the <u>80th percentile mariculture limit of faecal coliforms</u> (20 colony-forming units/100 ml). Red data points indicate 80th percentile 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.

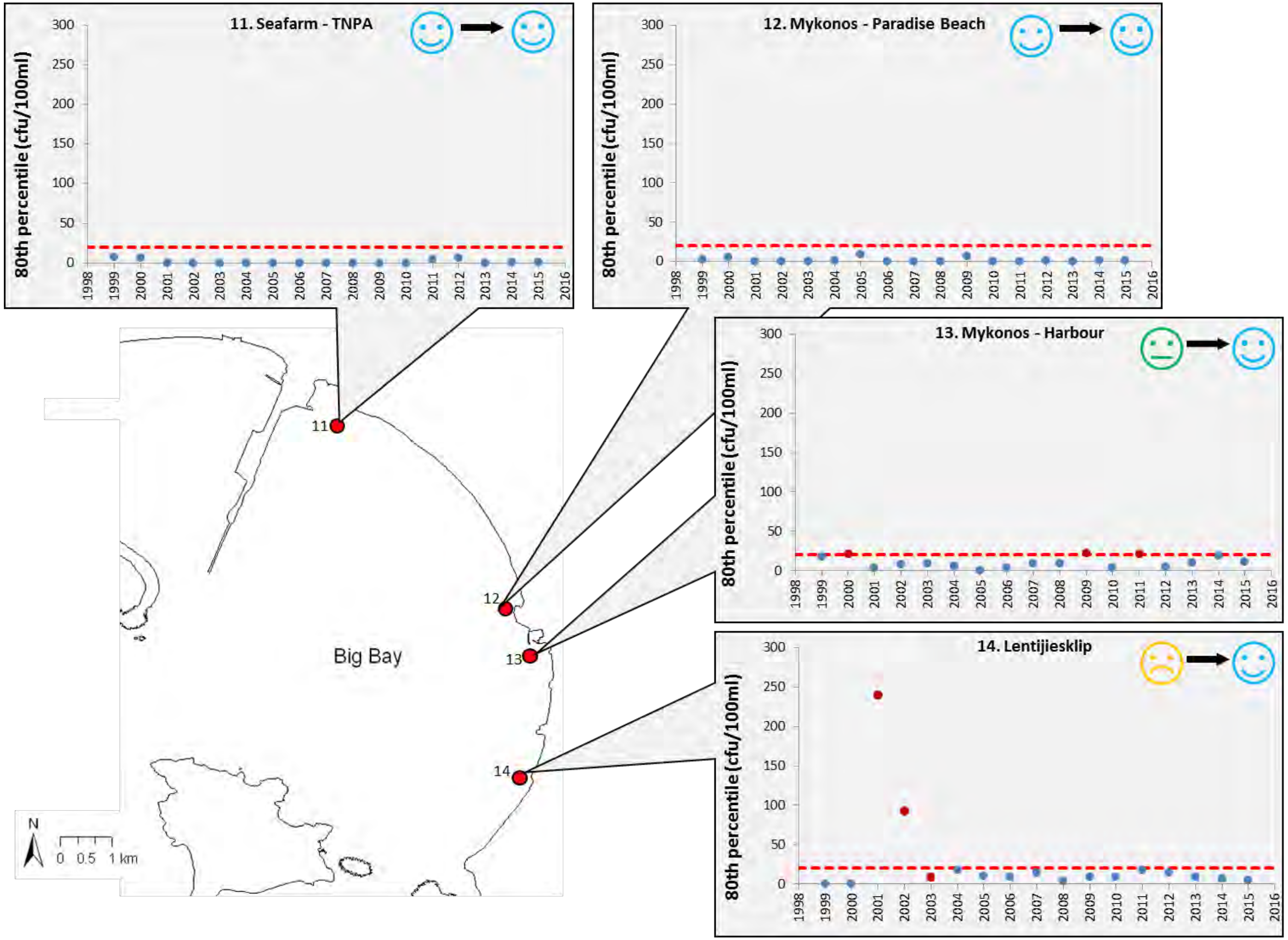


Figure 5.23 80th percentile values of Faecal coliform counts at the four sampling stations within Big Bay (Feb 1999 - Dec 2015). The red line indicates the 80th percentile mariculture limit of faecal coliforms (20 colony-forming units/100 ml). Red data points indicate 80th percentile values exceeding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

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 and 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).

5.10.1 Mussel Watch Programme

In 1985 the MCM initiated the 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 continued the programme by collecting mussel samples from the same five sites annually during the field surveys from 2014 to 2016. The mussel samples were analysed for the metals lead (Pb), cadmium (Cd), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn) and mercury (Hg) in 2016.

Data from the Mussel Watch Programme and from the annual State of the Bay field trips are represented in Figure 5.25 to Figure 5.33 below. The maximum legal limits prescribed for each contaminant in shellfish for human consumption in South Africa (as stipulated by the Regulation R.500 of 2004 published under the Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972) are listed in Table 5.5 and indicated in red text on each series of graphs. Where limits have not been specified in national legislation, those adopted by other countries have been used (Table 5.5).

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.

Mercury concentrations within mussel tissues were measured for the first time in 2016. Mercury was undetectable in tissue collected from the Mussel Rafts and Portnet but exceeded safe limits at the Fish Factory and at Saldanha Bay North measuring 0.7 ppm and 1.0 ppm respectively (Figure 5.24). The source of contamination at these sites is currently unknown.

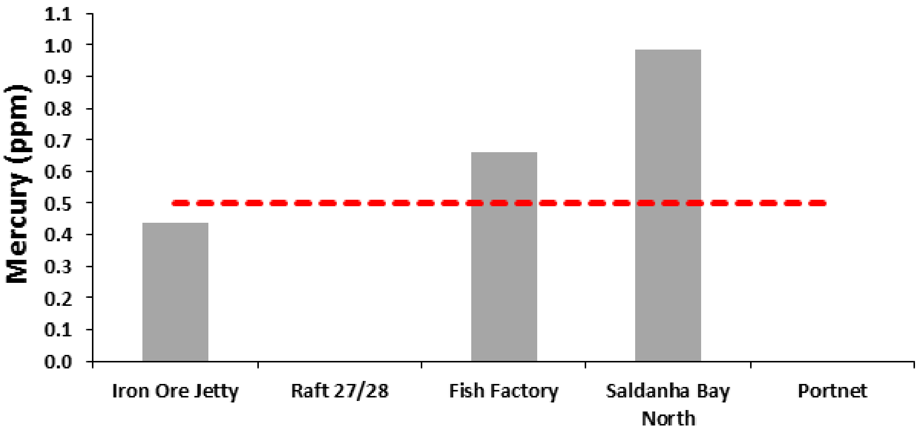


Figure 5.24 **Mercury concentrations in mussels collected from five sites in Saldanha Bay by Anchor in 2016. The recommended maximum limit for mercury in seafood (0.5 ppm) is shown as a dotted red line.**

Data showed that concentrations of lead in mussels at the Portnet site were consistently above the regulatory limit for foodstuffs, with values averaging 119 ppm over the whole data series (Figure 5.25). Values spiked to very high levels at this site in May 1999 (252 ppm) and October 2001 (714 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, lead concentrations were found to be extremely high. Although concentrations dropped to an average of 1.3 ppm over all the sites in 2014, they increased to 7.6 ppm in 2015 and 33.4 ppm in 2016. While the situation is greatly improved from 2007, especially at the Portnet site, the average level of lead in mussels at this site is still over 14 times the value deemed as being safe for human consumption and over five times the limit at the mussel rafts. This is extremely concerning considering that mussels on the rafts are produced for human consumption.

Concentrations of cadmium frequently exceeded the regulatory limit of 3 ppm at all sites (Figure 5.26). 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 ppm in April 2007 at the Mussel Rafts. The concentration of cadmium in mussels tissue collected at all sites in 2016 averaged 5.3 ppm and was found to be 5.2 ppm at the mussel rafts, which is high relative to the safe limit of 3 ppm.

Zinc concentrations in mussel tissue collected in 2016 were higher than the 150 ppm regulatory limit listed by the Canadian Authorities (Table 5.5) at the Iron Ore Jetty, Portnet, Fish Factory and Saldanha Bay North; while those at the Mussel Raft were below this value (Figure 5.27). Zinc contamination at Saldanha Bay North shot up from 236 ppm in 2015 to 743 ppm in 2016. In contrast with lead, cadmium and zinc, concentrations of copper remained well below the specified level of 70 ppm at all sites in 2016. The maximum value recorded for copper was 6.4 ppm at Saldanha Bay North, dropping from a maximum of 11 ppm at the Fish Factory in 2015. No regulatory limits exist for manganese, which reached a maximum of 11.3 ppm at Portnet in 2015 (Figure 5.29). Manganese concentrations also increased at the Iron Ore Terminal, likely due to the increase of manganese export volume from 1 231 thousand tons in 2014 to 2 090 thousand tons in 2015 (see Chapter 5).

In 2016 iron concentrations in mussel tissue had increased from 2015 values at all sites except for the Fish Factory site (Figure 5.30). Iron concentrations were highest at Saldanha Bay North and lowest at the Mussel Raft. As there are no official limits outlined 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. Iron poisoning may be associated with the ingestion of more than 10-20 mg/kg of human body weight (http://www.webmd.com/a-to-z-guides/iron-poisoning) but no cases of acute toxicity from regular foodstuffs (excluding supplements) have ever been recorded. As Iron ore is processed in Saldanha Bay on a large scale and iron ore residue is apparent on all structures in the vicinity of the Saldanha Steel processing plant, 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.

The high level of trace metals in nearshore bivalves in Small Bay remains a human health concern, especially due to the high concentrations of lead and cadmium. Signs warning of the health risks of consuming coastal mussels in this area and discouraging their collection should be posted in areas where these bivalves are easily accessible (e.g. Hoedjiesbaai).

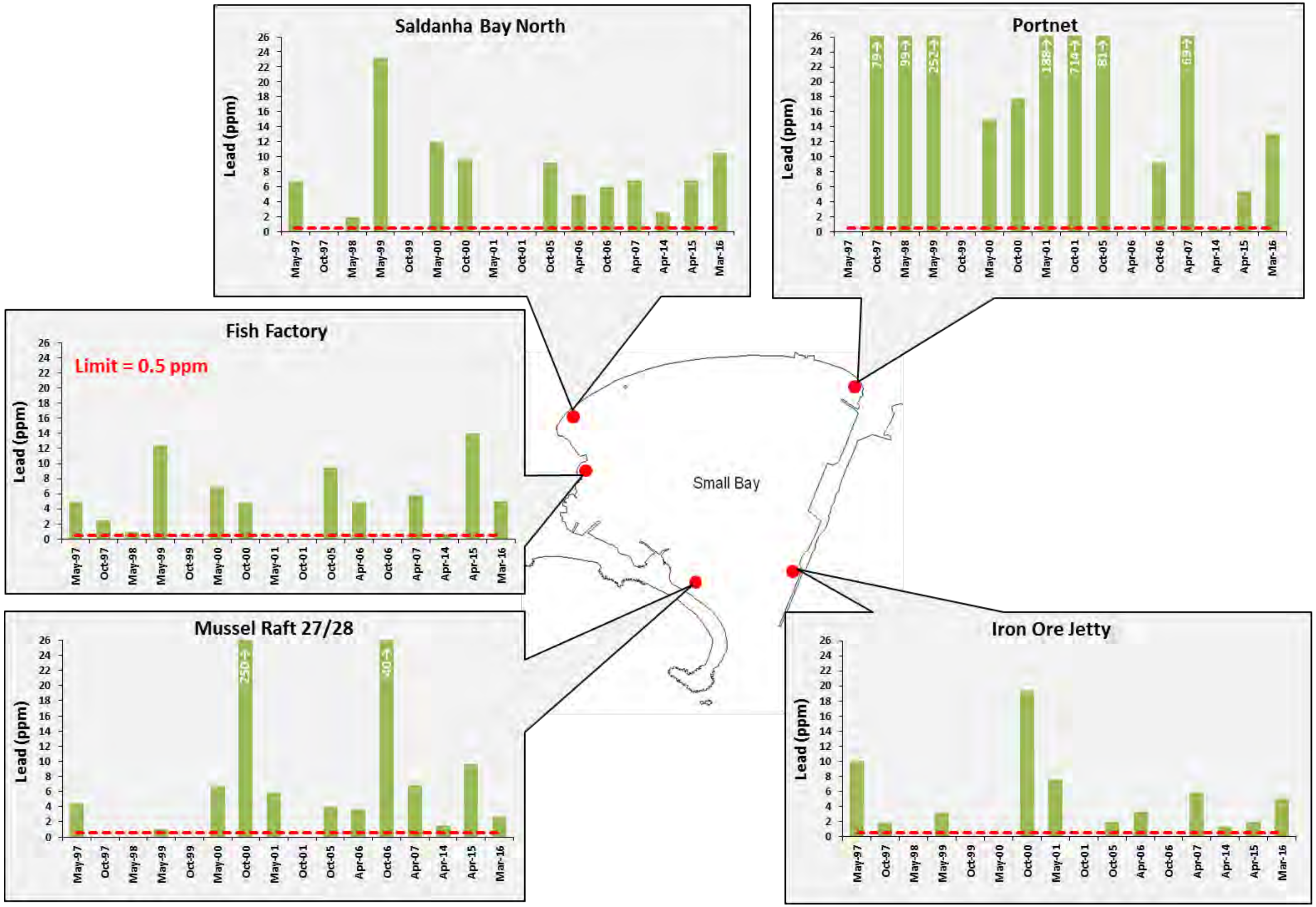


Figure 5.25 Lead concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor from 2014 to 2016. The recommended maximum limit for lead in seafood (0.5 ppm) is shown as a dotted red line. Values exceeding 26 ppm are indicated by text on the data bars.

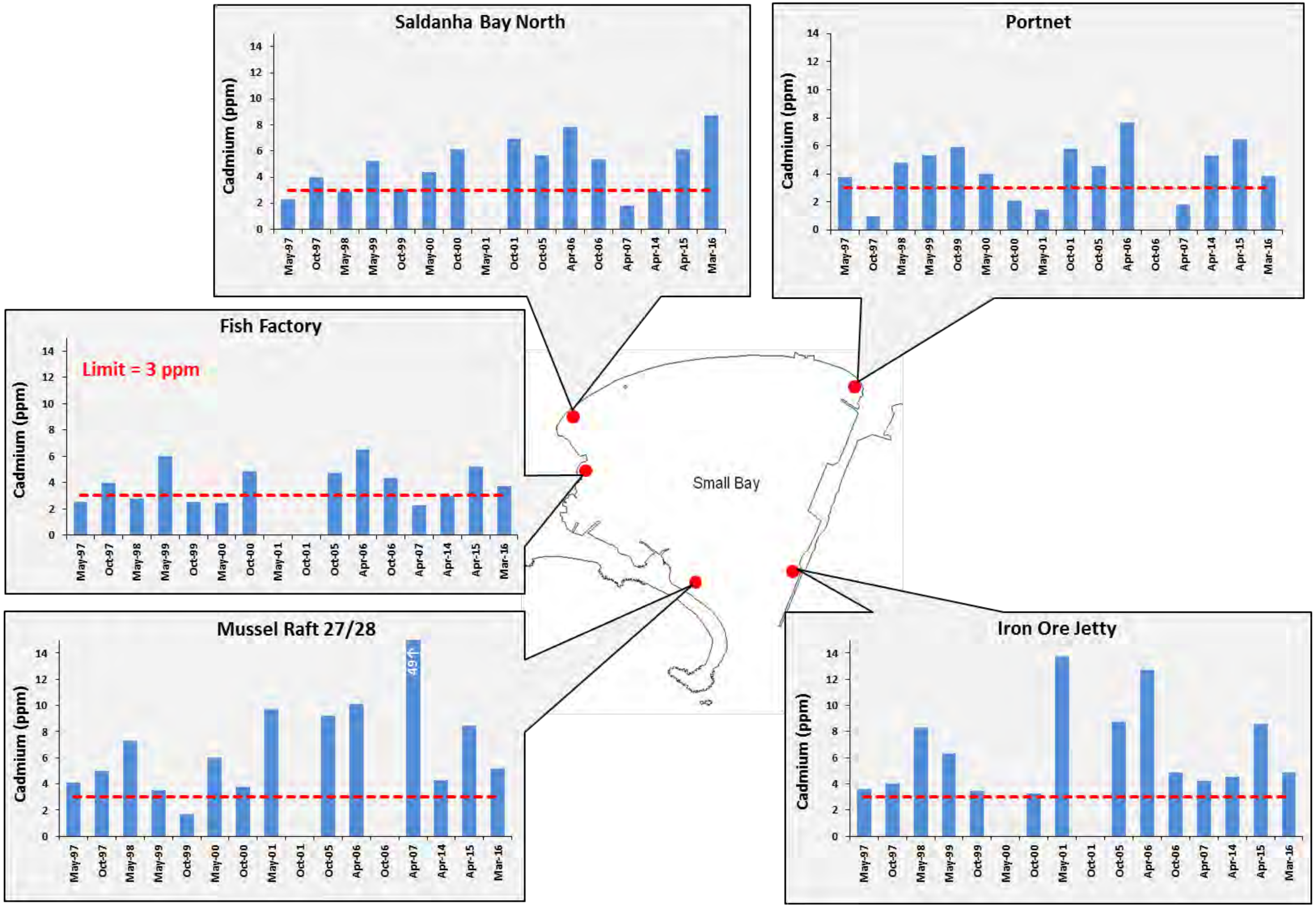


Figure 5.26 **Cadmium concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, DEA) and by Anchor from 2014 to 2016. The recommended maximum limit for cadmium in seafood (3 ppm) is shown as a dotted red line. Values exceeding 14 ppm are indicated by text on the data bars.**

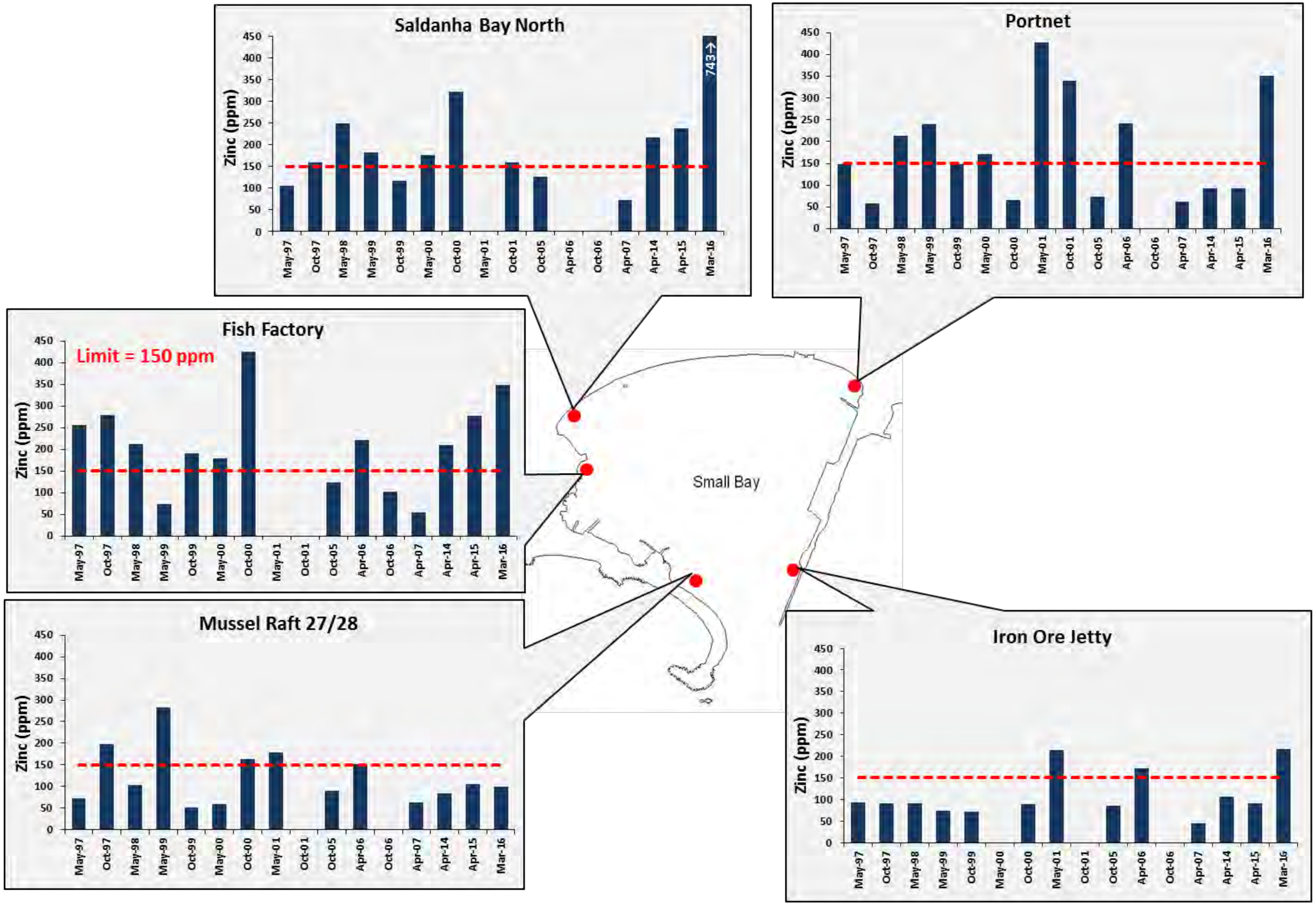


Figure 5.27 Zinc concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (source: G. Kiviets, Department of Environmental Affairs) and by Anchor from 2014 to 2016. The recommended maximum limit for zinc in seafood (150 ppm) is shown as a dotted red line. Values exceeding 450 ppm are indicated by text on the data bars.

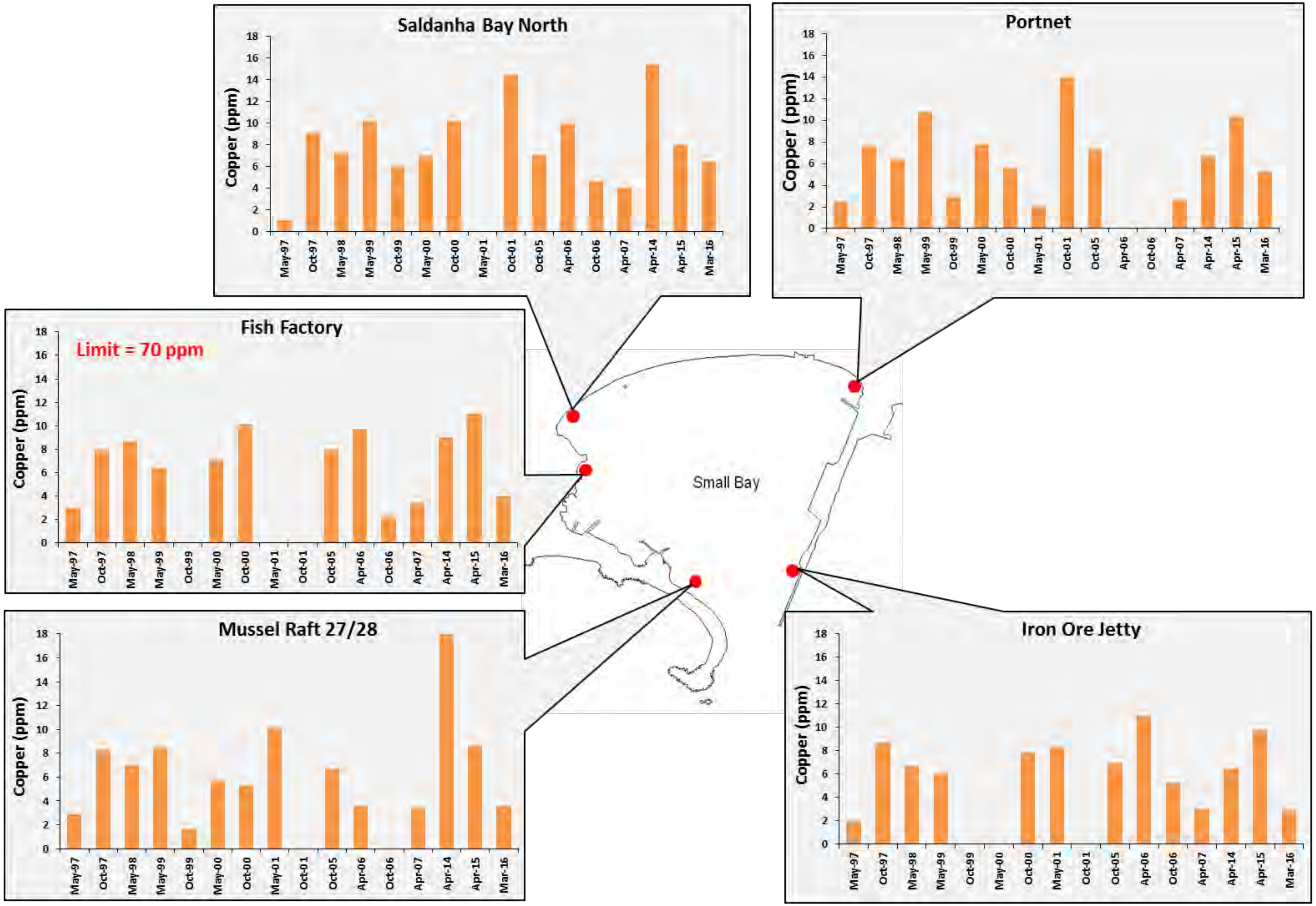


Figure 5.28 Copper concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor from 2014 to 2016. The recommended maximum limit for copper in seafood is 70 ppm.

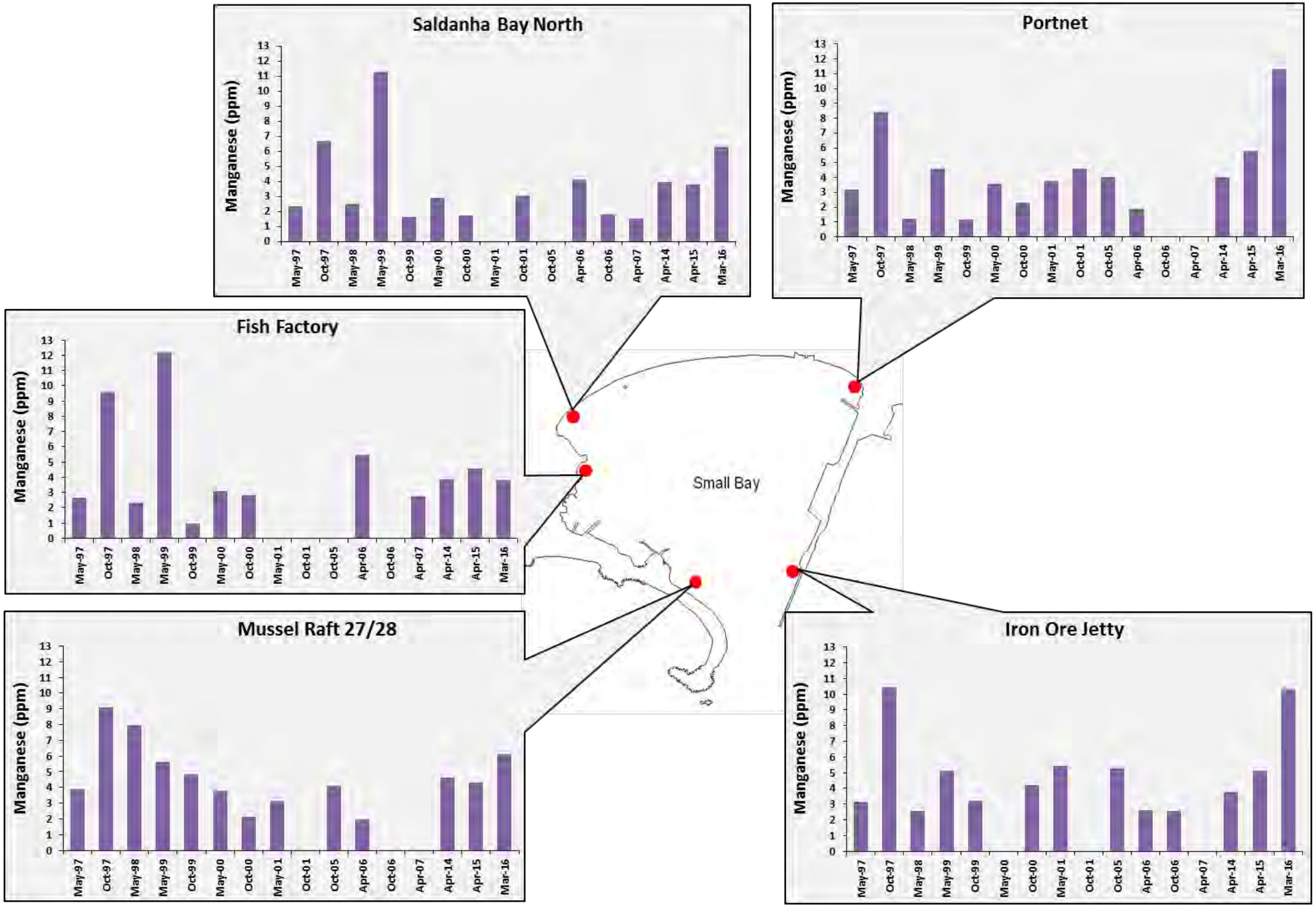


Figure 5.29 Manganese concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor from 2014 to 2016. No limits are specified for manganese.

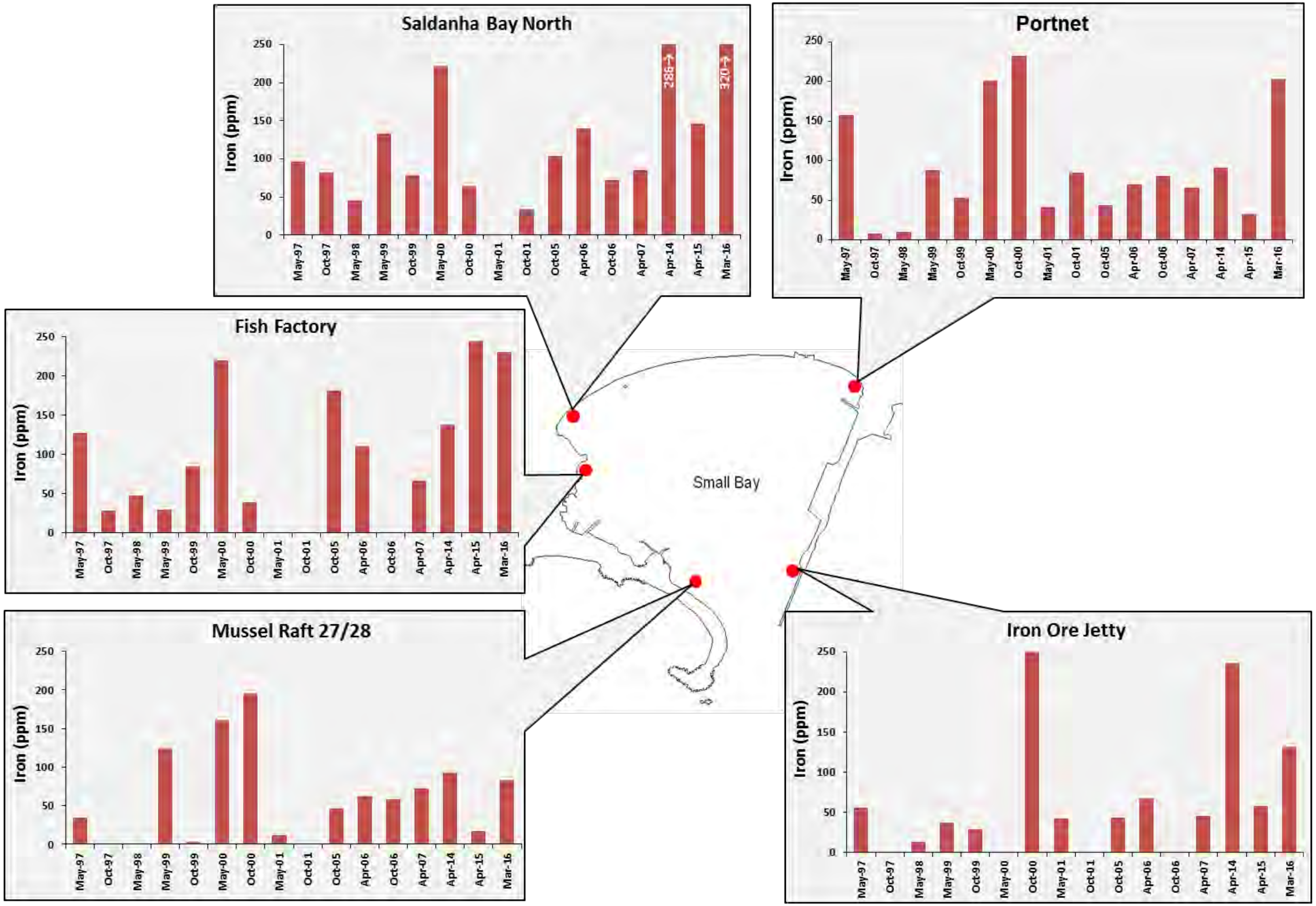


Figure 5.30 Iron concentrations in mussels collected from five sites in Saldanha Bay from 1997-2007 as part of the Mussel Watch Programme (Source: G. Kiviets, Department of Environmental Affairs) and by Anchor from 2014 to 2016. No limits are specified for iron.

5.10.2 Mariculture bivalve monitoring

A combined 430 ha of sea space are currently available for aquaculture production in Saldanha Bay, of which 251 ha have been leased to 12 individual mariculture operators (Figure 5.31) for mussels, oysters, finfish and algae (Figure 5.32). Although only 60% of these concession areas are actively farmed, proposed expansion of the ADZ includes an additional 1715 ha of concessions in Outer Bay and Big Bay combined. 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 eight aquaculture farms in Saldanha Bay. Figure 5.33 shows data for mussels and Figure 5.34 shows data for oysters from February 1987 to December 2015. Gaps in the data exist depending on the frequency of monitoring and the year each company was founded.

Figure 5.31 **Mariculture concession areas in Saldanha Bay in 2016 coded by concession ownership (Source: Transnet Property, Geo-Spatial: Western Region, Burton Siljeur).**

Figure 5.32 Mariculture concession areas in Saldanha Bay in 2016 coded by species farmed (Source: Transnet Property, Geo-Spatial: Western Region, Burton Siljeur).

5.10.2.1 Mussels farmed in Small Bay

Prior to 2000, concentrations of lead were generally above the regulatory limit with especially high levels in 1988 at Blue Bay Aquafarm, West Coast Oyster Growers and Striker Fishing (5.3 ppm, 14.1 ppm and 3.9 ppm respectively). From 2000 onwards, lead concentrations were mostly within the regulatory limit (i.e. less than 0.5 ppm); although mussels 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 0.99 ppm and at West Coast Oyster Growers in 2014 and 2015 with a maximum value of 1.71 ppm (Figure 5.33). Although high, these values were still lower than the average of 7.6 ppm measured in nearshore mussel samples in 2015 and interestingly also substantially lower than the measurement of 9.7 ppm taken from Mussel Raft 27/28 in April 2015 (see Section 5.10.1, Figure 5.25).

Data received from mussel farms showed that cadmium concentrations never exceeded the prescribed limit of 3 ppm (Figure 5.33), while data from mussels collected off Mussel Raft 27/28 by DAFF and Anchor showed that values exceeded this limit over successive years (Figure 5.26). Reasons for this discrepancy are still to be determined.

Mercury concentrations submitted to DAFF 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 Ocean Mussels in 1994 and West Coast Aquaculture in 2009 (1.7 ppm and 1.1 ppm respectively). Since 2009, no exceedance has been recorded and all samples collected contained less than 0.02 ppm of mercury (Figure 5.33). Mussel samples were analysed for arsenic for the first time in 2012. Scant data exist for 2012 and 2013 and arsenic was dropped from the suite of aquaculture farm measurements in September 2013. All four of the nine aquaculture farms assessed met the regulatory requirements (< 3 ppm) over this period (Figure 5.33).

Overall, data from the mussel farms discussed above suggest that trace metal contamination in the deeper parts of Saldanha Bay, where the aquaculture farms are located, is lower 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.

5.10.2.2 Oysters farmed in Big Bay

All oyster mariculture is currently situated in Big Bay and at the Marcus Island causeway as indicated in Figure 5.32. The regulatory limit of 0.5 ppm applies to shellfish for human consumption and the two samples analysed in 1988 were well above this concentration. Sampling in 2006 revealed that lead concentrations in oysters had decreased to almost zero; although these values rose above recommended levels in 2007 (Figure 5.34). Over recent years exceedance was observed at Blue Ocean Mussels, West Coast Aquaculture and frequently at West Coast Oyster Growers. Maximum lead concentration over this period was recorded at West Coast Oyster Growers with a value of 1.78 ppm.

Until 2014 concentrations of cadmium had not exceeded the regulatory limit of 3 ppm, but in November 2015 the maximum value of 6.44 ppm was recorded at West Coast Oyster Growers. The three other farms that submitted cadmium data at the time were unaffected and met target values. Subsequently, all values have fallen below the required concentration.

Mercury concentrations have largely been within the regulatory limit of less than 0.5 ppm, apart from two spikes above this level. These readings were recorded at Blue Ocean Mussels in 2011 and the Saldanha Bay Oyster Company in 2007 (1 ppm and 1.1 ppm respectively). Since 2011, no exceedance has been recorded and all samples collected contained less than 0.05 ppm of mercury (Figure 5.34).

Samples were analysed for arsenic for the first time in 2012 but this metal was dropped from the suite of aquaculture farm measurements in 2014. Two out of the five aquaculture farms assessed met the regulatory requirements (< 3 ppm) between 2012 and 2013. Both Saldanha Bay Mussel Farmers and Saldanha Bay Oyster Company exceeded the regulatory limit with concentrations of 10 ppm and 3.5 ppm respectively. Based on these data, it is recommended that the annual analysis of arsenic in the tissue of bivalves at all aquaculture farms within Saldanha Bay be reinstated.

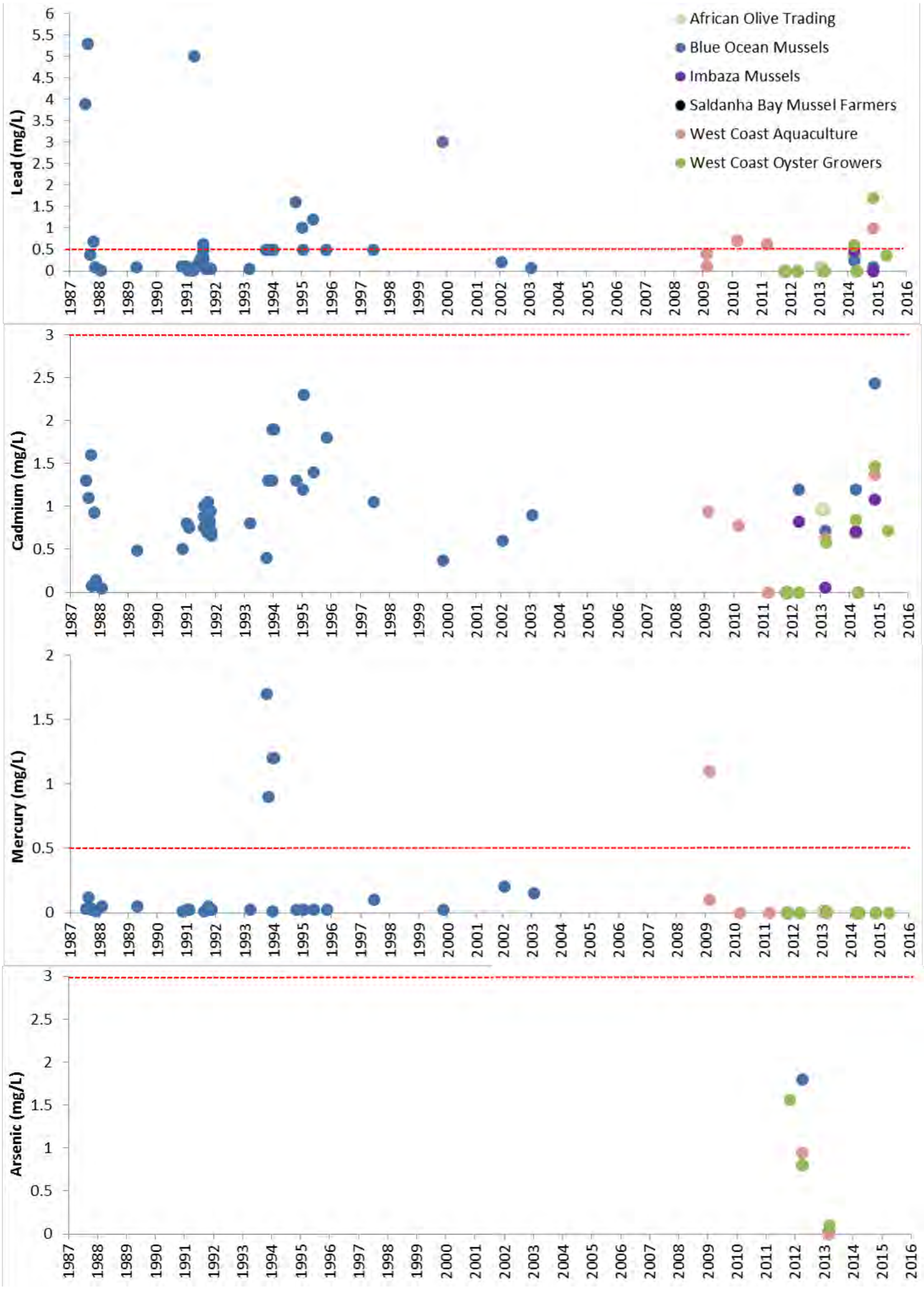


Figure 5.33 **Concentrations of lead, cadmium, mercury and arsenic in mussels from six commercial culture operations in Saldanha Bay from 1988 to 2016. Recommended maximum limits for trace metals in seafood as stipulated in South African legislation are indicated by a dotted red line.**

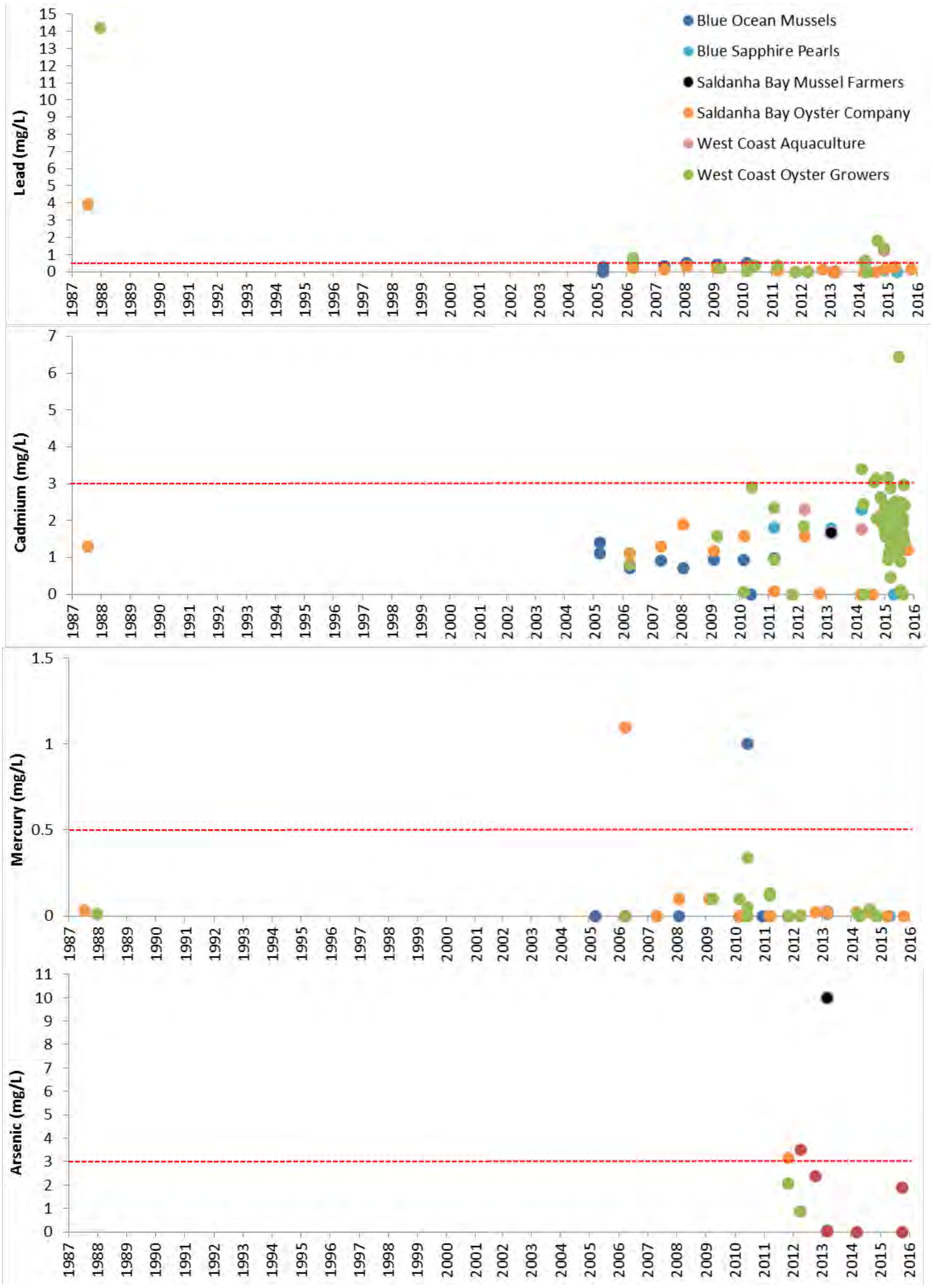


Figure 5.34 **Concentrations of lead, cadmium, mercury and arsenic in oysters from six commercial culture operations in Saldanha Bay from 1988 to 2016. Recommended maximum limits for trace metals in seafood as stipulated in South African legislation are indicated by a dotted red line.**

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, 16 of the 20 monitoring stations in the Bay are rated as having ‘Excellent’ water quality, one site (Langebaan North) is rated as ‘Good’, while three are rated as ‘Fair’. There is a concerning trend of increasing faecal coliform levels at Pepper Bay and the authorities are advised to remain vigilant. Noticeable improvements were evident at Langebaan North, the Beach at the Caravan Park and Hoedjiesbaai Beach. Faecal coliform counts at all four sites in Big Bay were well within both the 80th 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 and cadmium) above published guidelines for foodstuffs. In comparison, data collected by mariculture operators in Saldanha Bay clearly show that concentrations offshore are lower; although concentrations of lead and cadmium frequently rise above the limit for foodstuff which is concerning. 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 in Saldanha Bay and Langebaan Lagoon are strongly influenced by the wave energy and 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 were 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 because 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 to 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 m^3 of material was removed from an area of approximately 3 000 m^2 between Caisson 3 and 4 near the base of the

Iron ore terminal on the Saldanha side, and a 275 m^2 area in Salamander Bay was dredged to accommodate an expanded SANDF Boat park. The former programme seems to have had a minimal impact on 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 2016. 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. This is certainly a positive development as it suggests that sediments in the Bay may be reverting back to a more natural condition where sediments were comprised of mostly sand with a very small mud fraction.

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 2016

Sediment samples were collected and analysed for particle size composition, Total organic carbon (TOC), Total organic nitrogen (TON) and trace metals. During April 2016 sediment samples were collected from a total of 16 sites, 10 in Small Bay, 3 in Big Bay and 3 in Elandsfontein, at the head of Langebaan Lagoon (Table 6.1 and Table 6.9). Elandsfontein results from the head of the Langebaan Lagoon will be reported separately at the end of this chapter as these sites are 2016 baseline results that inaugurate the WQT monitoring programme related to EEM phosphate mining in the vicinity (See Chapter 3: Section 3.2.10).

Samples collected comprised predominantly sand (particle size ranging between 63 µm and 2000 µm). Sites located in Big Bay had on average the highest proportion of mud (2.51%), followed by Small Bay (1.54%) (Table 6.1). An overall decrease in mud and increase in sand in both Small and Big Bay sites are evident compared to 2015 results. No gravel (particles exceeding 2000 µm) was found across all samples sites.

Table 6.1. **Particle size composition and percentage total organic carbon (TOC) and total organic nitrogen (TON) in surface sediments collected from Small Bay and Big Bay in 2016 (Particle size analysed by Scientific Services and TOC and TON for Small Bay and Big Bay analysed by the Council for Scientific and Industrial Research).**

	Sample	Gravel (%)	Sand (%)	Mud (%)	TOC (%)	TON (%)	C:N
Small Bay	**Average**	**0**	**98.46**	**1.54**	**1.19**	**0.17**	**7.59**
	SB1	0	97.40	2.60	5.25	0.64	9.50
	SB2	0	99.50	0.50	0.28	0.05	7.00
	SB3	0	99.20	0.80	0.21	0.03	7.12
	SB5	0	99.80	0.20	0.22	0.04	7.24
	SB8	0	98.90	1.10	0.42	0.07	7.11
	SB9	0	96.00	4.00	0.98	0.16	7.33
	SB10	0	99.60	0.40	0.24	0.04	6.48
	SB14	0	97.80	2.20	2.47	0.36	7.93
	SB15	0	97.70	2.30	1.49	0.19	8.98
	SB16	0	98.70	1.30	0.91	0.15	7.10
Big Bay	**Average**	**0**	**97.49**	**2.51**	**0.67**	**0.12**	**7.01**
	BB21	0	98.10	1.9	0.53	0.09	7.21
	BB22	0	97.40	2.6	0.68	0.10	7.64
	LPG1	0	97.00	3.0	1.22	0.22	6.43

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, multi-purpose 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 (1977-2016) 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 decreased at all sites in 2016 and as expected, sites under the mussel farms (SB9) and along the ore jetty (SB14 & SB15) have a higher mud fraction than other sites in the Bay, albeit the lowest since 2011 (Table 6.1, Figure 6.3).

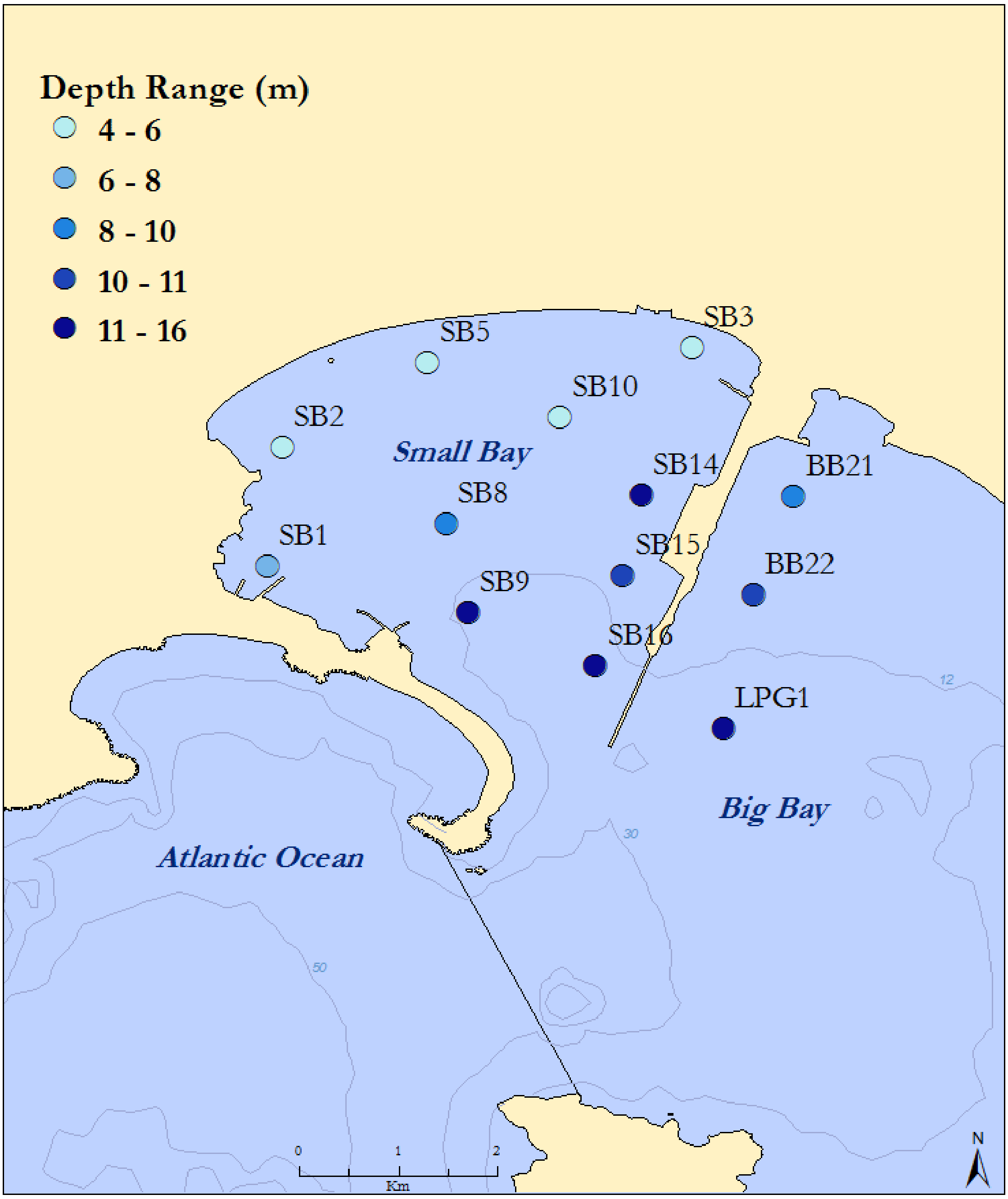


Figure 6.1 **Sediment sampling sites and respective depth ranges (m) in Saldanha Bay for 2016.**

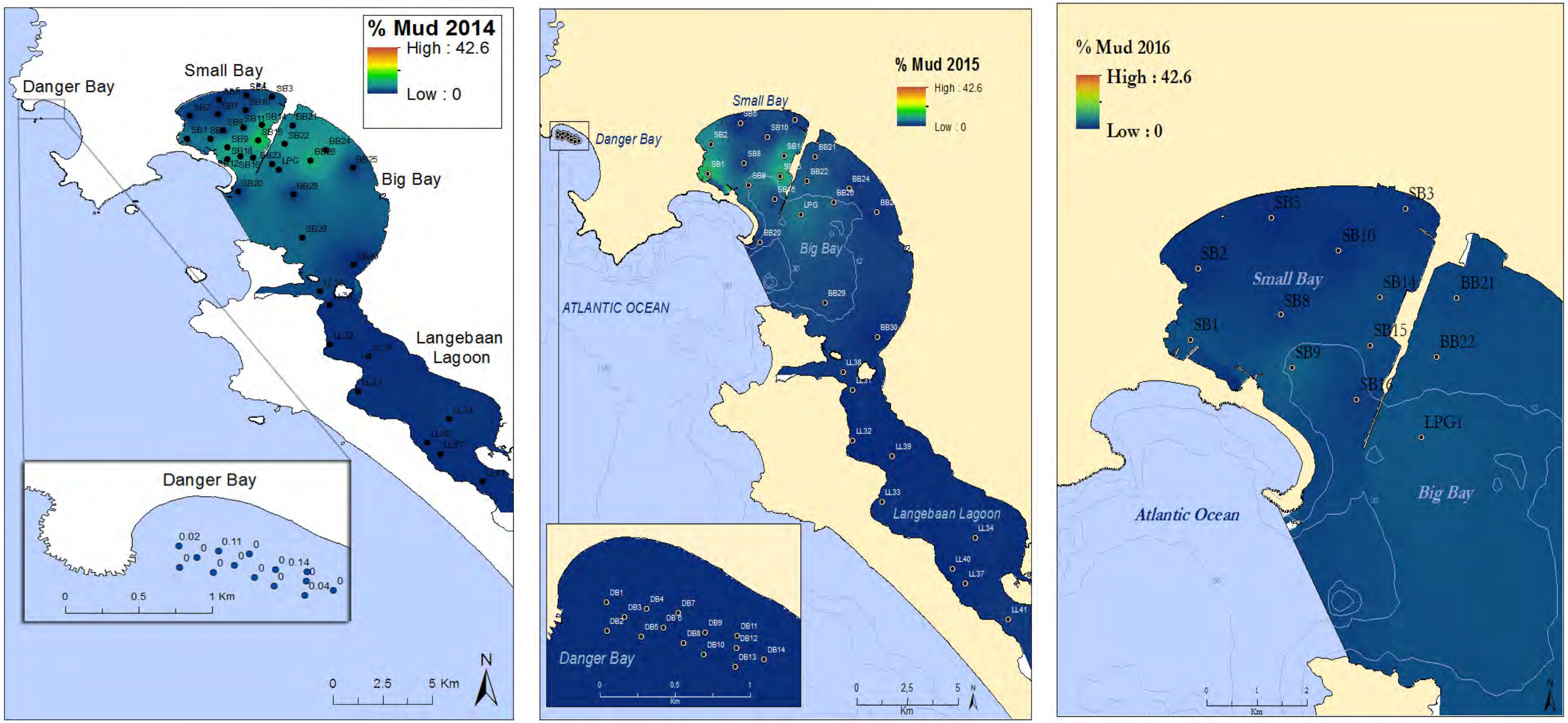


Figure 6.2 Variation in the percentage mud in sediments in Saldanha Bay, Danger Bay and Langebaan Lagoon as indicated by the 2014 (left), 2015 (centre) and 2016 (right) survey results.

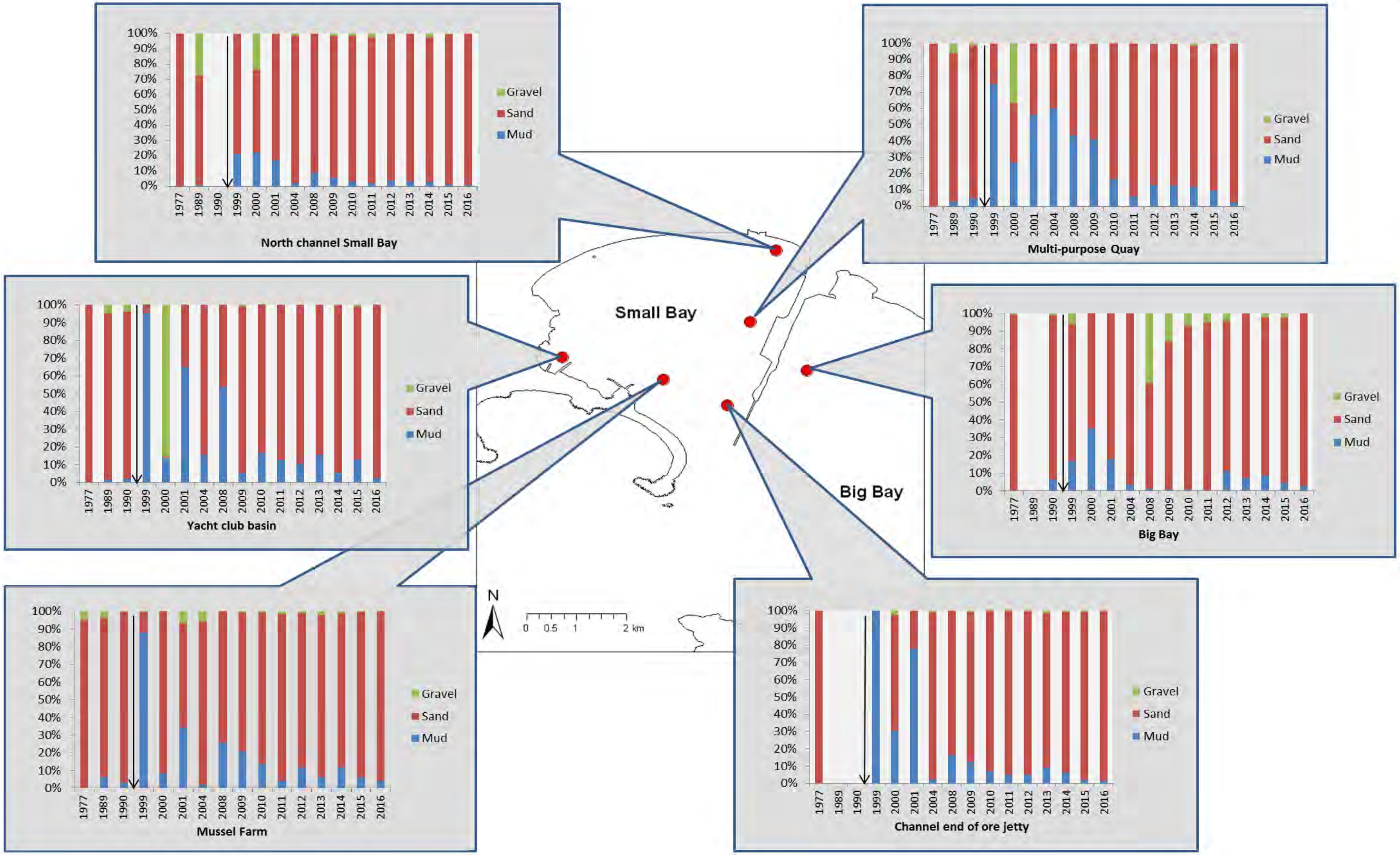


Figure 6.3 Particle size composition (percentage gravel, sand and mud) of sediments at six localities in the small bay area of Saldanha Bay between 1977 and 2016.

6.1.2 Total organic carbon (TOC) and nitrogen (TON) in sediments 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 (H_2S). Sediments high in H_2S 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, 2008-2016), 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 2016 are presented in Figure 6.4 and Figure 6.5. The spatial trends in TOC and TON recorded in 2016 correspond with previous 2013, 2014, and 2015 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. The only difference in both TOC and TON compared to 2015 were decreased levels at the Liquid Petroleum Gas (LPG1) site near the entrance of Big Bay in the 2016 samples.

6.1.2.2 Spatial trends in the C:N ratio

The C:N ratio results from 2014-2016 were somewhat variable. In 2014 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 6.6A). 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 6.6B). Eight of the fourteen sites in Danger Bay were above the expected range for marine productivity that was, however, linked to low nitrogen levels recorded in Danger Bay rather than terrestrial sourced nitrogen enrichment. In 2016 only one site (SB1 –Yacht Club Basin) was above the expected range for marine sediments, and is most likely due to terrestrial enrichment while two sites (SB5 and SB10)were below the expected range and could likely be due to a build-up of nitrogen in this area prior to a bloom event.

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 2015 and 2016, Bok River sites in 2014) is probably more informative than a temporal analysis.

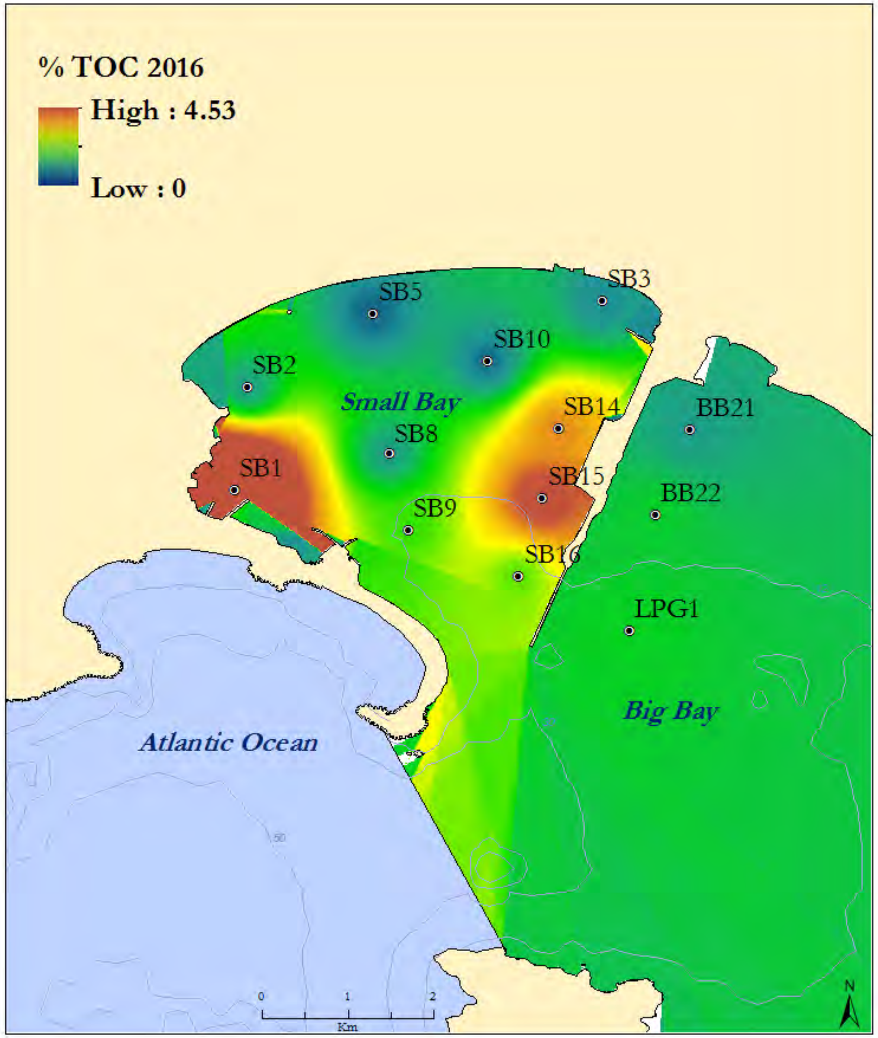


Figure 6.4 Total organic carbon in Saldanha Bay as indicated by the 2016 survey results.

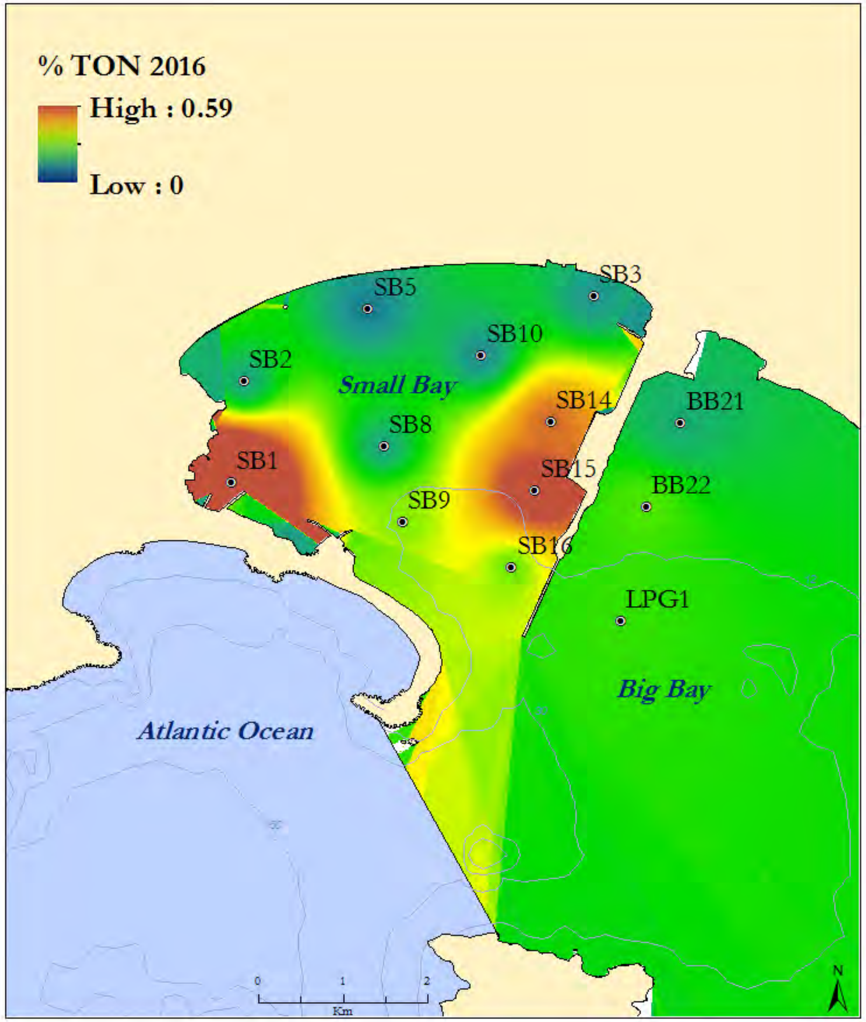


Figure 6.5 Total organic nitrogen in Saldanha Bay as indicated by the 2016 survey results.

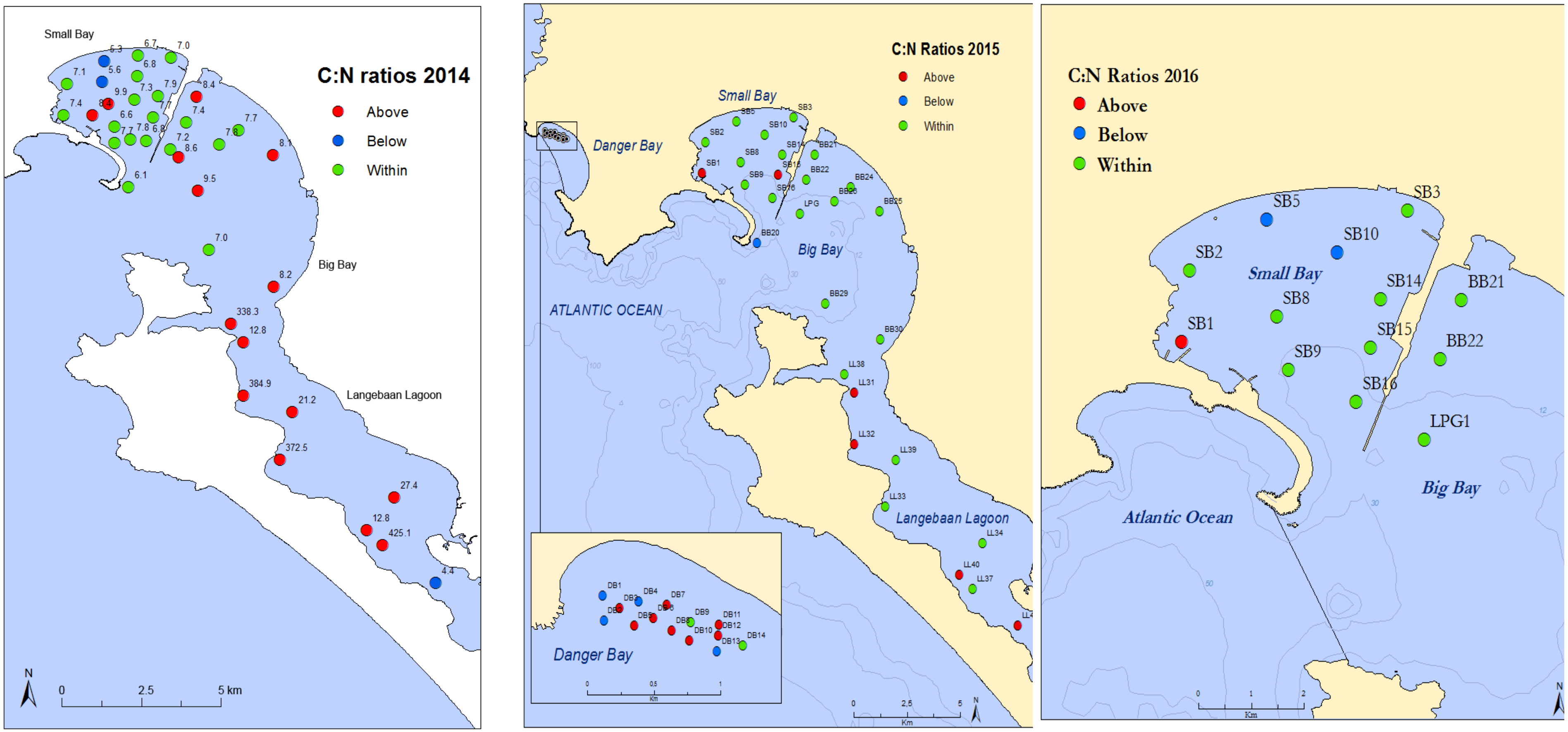


Figure 6.6 C:N ratios at different sites surveyed in Saldanha Bay and Langebaan Lagoon in 2014, 2015 & 2016 (red = exceeds the range expected for marine production, green = within the range expected for marine production and blue = below range expected for marine production).

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 2016 (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. There was very little change evident in 2016, with all areas exhibiting a slight decrease in TOC except for North Channel-Small Bay and the multi-purpose quay where small increases were noted.

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 the concentration 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 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 indicting some of the lowest recordings of TON since 1999. In 2015 TON concentration 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. In 2016 TON has decreased slightly at all areas except in North Channel- Small Bay and Big Bay areas where very slight increases have occurred.

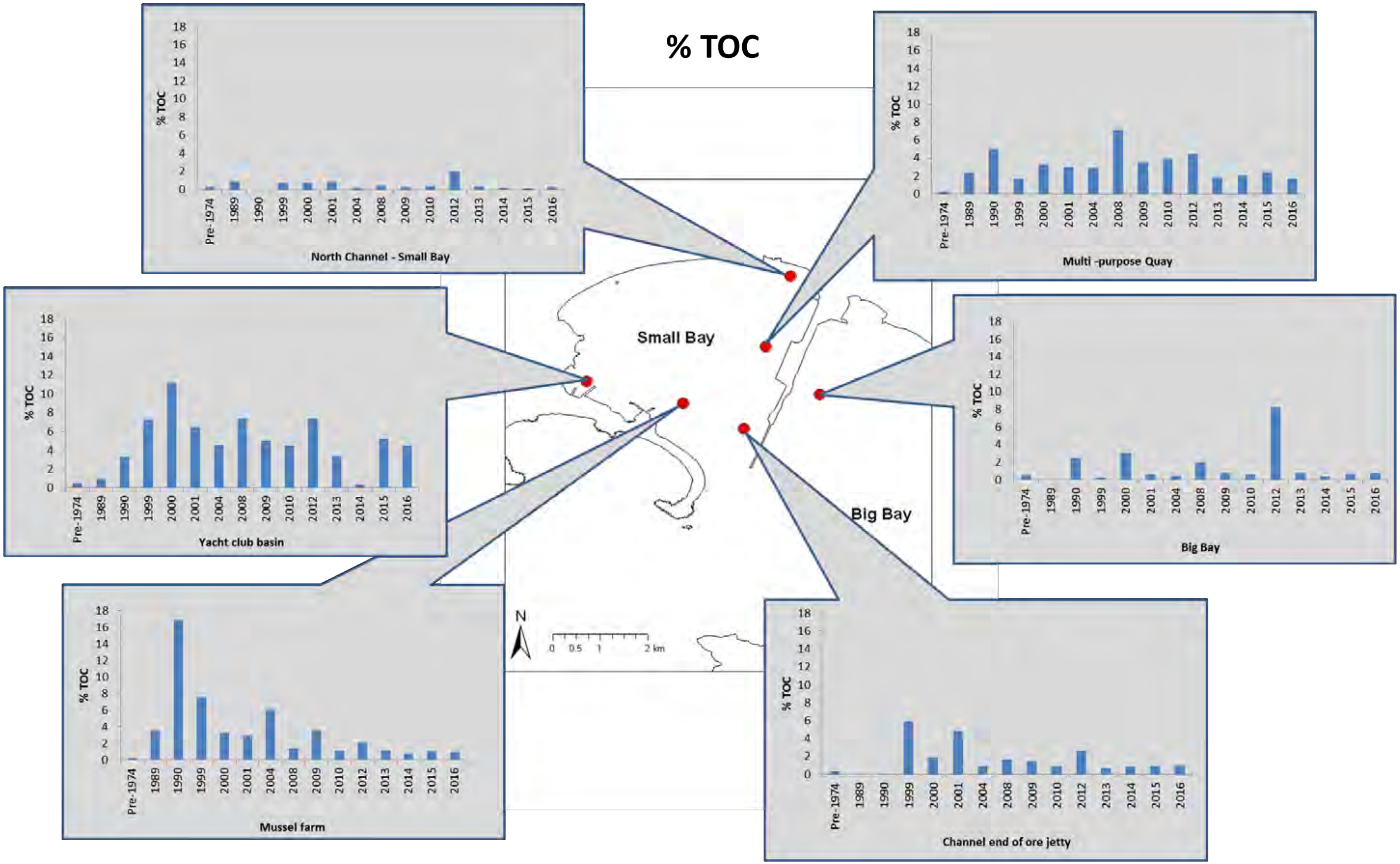


Figure 6.7 **Total organic carbon percentage occurring in sediments of Saldanha Bay at six locations between pre-1974 and 2016.**

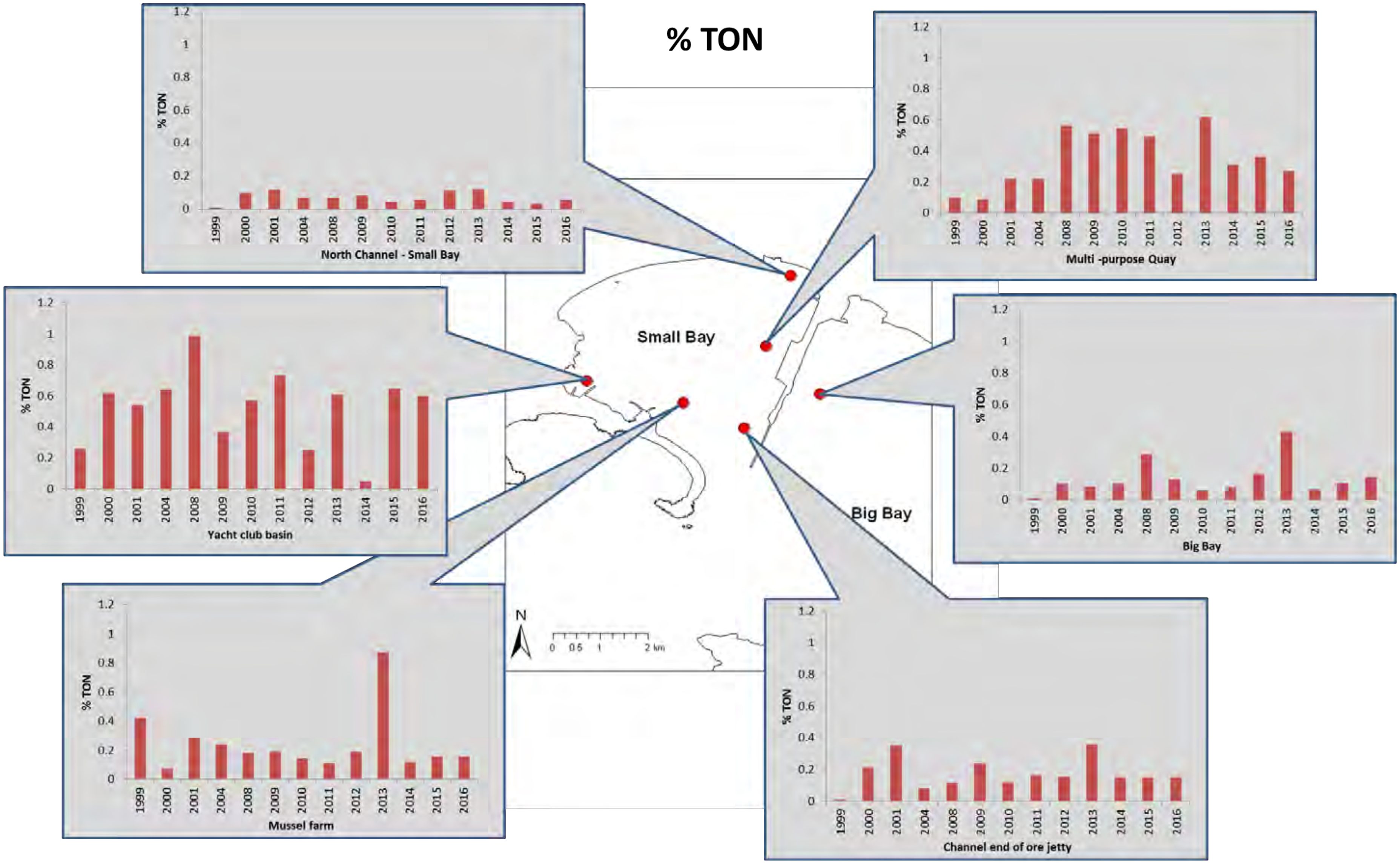


Figure 6.8 **Total organic nitrogen percentage occurring in sediments of Saldanha Bay at six locations between 1999 and 2016.**

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 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 2015 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 interpretation of results for 2016

Sediments were analysed for concentrations of aluminium (Al), iron (Fe), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb), and manganese (Mn). 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 (HNO_3) / Perchloric Acid ($HClO_3$)/ Hydrogen Peroxide (H_2O_2)/ Microwave digestion and JY Ultima Inductively Coupled Plasma Optical Emission Spectrometer. Trace metal concentrations recorded in the sediments of Saldanha Bay 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 2016. Values that exceed sediment quality guidelines are highlighted in red font. ND indicates no data.**

	Sample #	Al	Fe	Cd	Cu	Ni	Pb	Mn
***ERL Guideline (mg/kg)**		-	-	1.2	34	20.9	46.7	56.50
Small Bay	SB1	14211	1.14	3.10	44.57	13.45	27.47	53.72
	SB2	4263	0.47	0.58	4.06	2.07	8.63	35.15
	SB3	2276	0.28	0.33	1.88	0.65	12.89	20.90
	SB5	1428	0.19	0.30	11.13	1.40	5.42	18.94
	SB8	2761	0.31	0.45	0.48	0.85	5.76	17.67
	SB9	4605	0.63	0.65	1.85	3.23	8.08	25.78
	SB10	1854	0.25	0.28	0.26	0.35	7.50	18.09
	SB14	6447	0.71	1.14	10.74	4.54	38.30	29.71
	SB15	7330	0.77	0.98	5.32	5.21	20.30	34.46
	SB16	4463	0.49	0.74	ND	2.50	7.77	20.82
Big Bay	BB21	3290	0.39	0.54	ND	1.72	6.06	22.53
	BB22	4857	0.53	0.60	ND	2.17	6.62	30.44
	LPG	4330	0.44	0.71	ND	2.62	4.87	24.19

In 2016, Cd concentrations were highest, and exceeded ERL guidelines, in the vicinity of the Yacht Club Basin (Figure 6.9; Table 6.3). The highest Cu concentrations were also recorded at the Yacht Club Basin and also exceeded ERL guidelines (Figure 6.10; Table 6.3). Nickel concentrations were slightly elevated 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. 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 influences, for example a high concentration of mud or organic carbon.

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 these elements 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. 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 photographical process. The likely sources of Cd to the marine environment are in emissions from industrial combustion processes, 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 area where this is particularly concerning is site SB1 (near the Yacht Club Basin) as the level of contamination at this site exceeds the ERL limits for the second year in a row. Furthermore the enrichment values for this site 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 Saldanha Bay 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 2016 (Table 6.4).

Nickel

Ni values measured in 2016 were slightly elevated at the yacht club and alongside the Ore Jetty within Small Bay (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 Pd concentrations were recorded in Small Bay, particularly in the vicinity of the multi-purpose quay and the yacht club (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 organism 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 (47.9), however, the concentration of lead was below recommended ERL toxicity limits (Table 6.4). Normalized metal/aluminium ratios revealed that lead 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.

Manganese

Mn concentrations were highest near the yacht club basin 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 these areas 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 concentration 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 2016 relative to sediments from 1980.**

	Sample	Cd	Cu	Pb
	1980 average	0.075	0.41	0.8
Small Bay	SB1	41.4	108.7	34.3
	SB2	7.7	9.9	10.8
	SB3	4.4	4.6	16.1
	SB5	4.0	27.1	6.8
	SB8	6.1	1.2	7.2
	SB9	2.1	4.5	10.1
	SB10	3.7	0.0	9.4
	SB14	15.2	26.2	47.9
	SB15	13.0	13.0	25.4
	SB16	9.9	ND	9.7
Big Bay	BB21	7.1	ND	7.6
	BB22	8.0	ND	8.3
	LPG	9.5	ND	6.1

Table 6.5 **Normalized values for Cadmium, Copper, Nickel, Lead and Manganese in sediments collected from Saldanha Bay in 2016.**

	Sample #	Cd:Al	Cu:Al	Ni:Al	Pb:Al	Mn: Al
Small Bay	SB1	2.18	31.37	9.47	19.33	37.80
	SB2	1.36	9.52	4.86	20.23	82.46
	SB3	1.46	8.24	2.84	56.65	91.83
	SB5	2.12	77.89	9.78	37.94	132.63
	SB8	1.65	1.75	3.09	20.87	64.00
	SB9	1.40	4.02	7.02	17.55	55.99
	SB10	1.50	1.42	1.86	40.43	97.56
	SB14	1.77	16.66	7.05	59.41	46.08
	SB15	1.33	7.26	7.10	27.69	47.01
	SB16	1.66	ND	5.59	17.40	46.64
Big Bay	BB21	1.63	ND	5.23	18.42	68.48
	BB22	1.24	ND	4.47	13.63	62.67
	LPG	1.64	ND	6.04	11.25	55.87

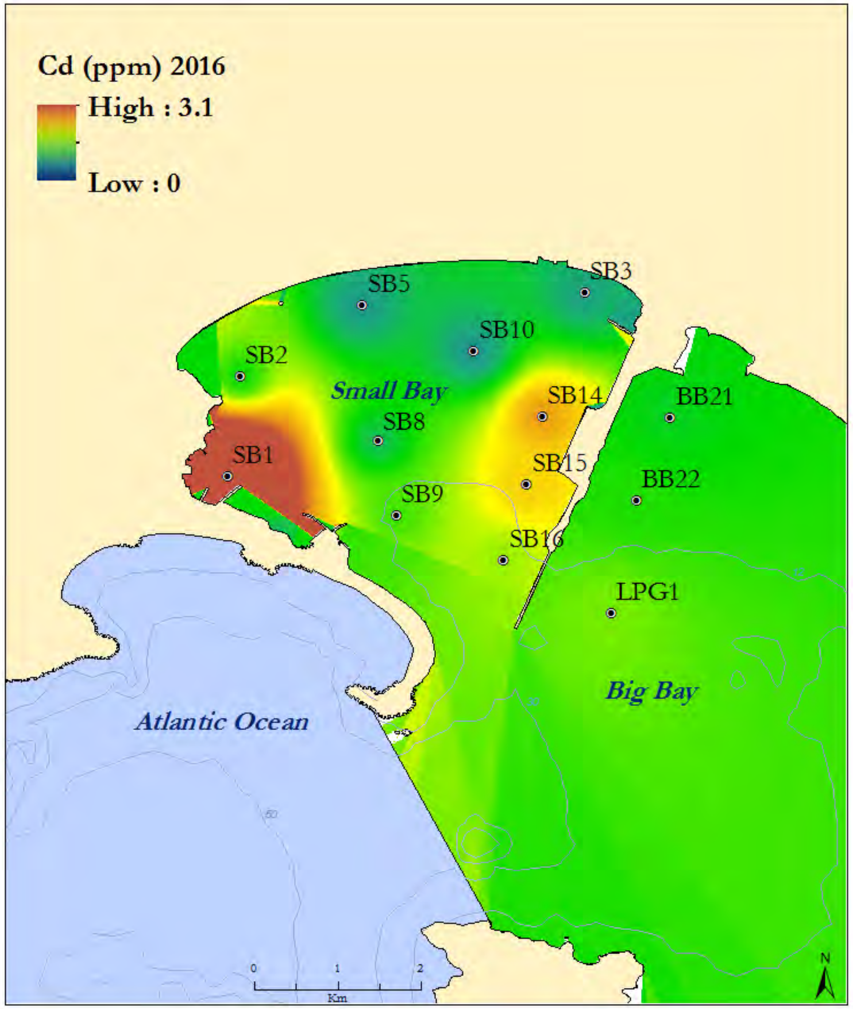


Figure 6.9 Spatial interpolation of cadmium values based on values measured in Saldanha Bay in 2016.

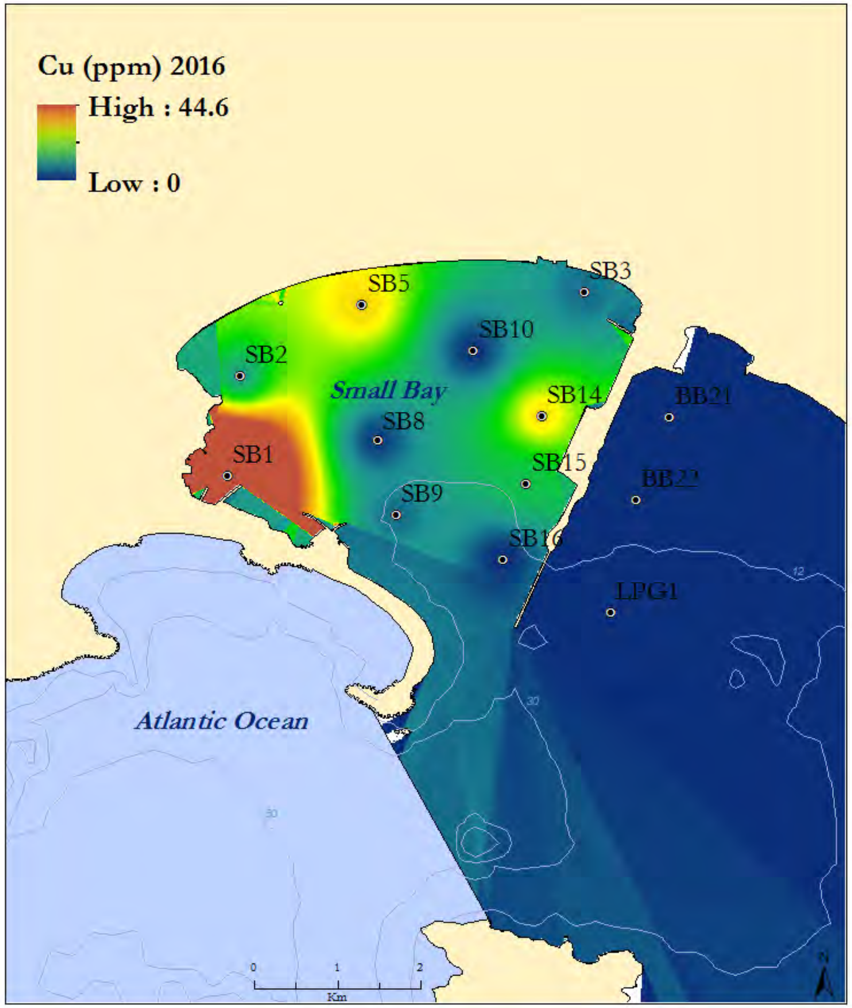


Figure 6.10 Spatial interpolation of copper values based on values measured in Saldanha Bay in 2016.

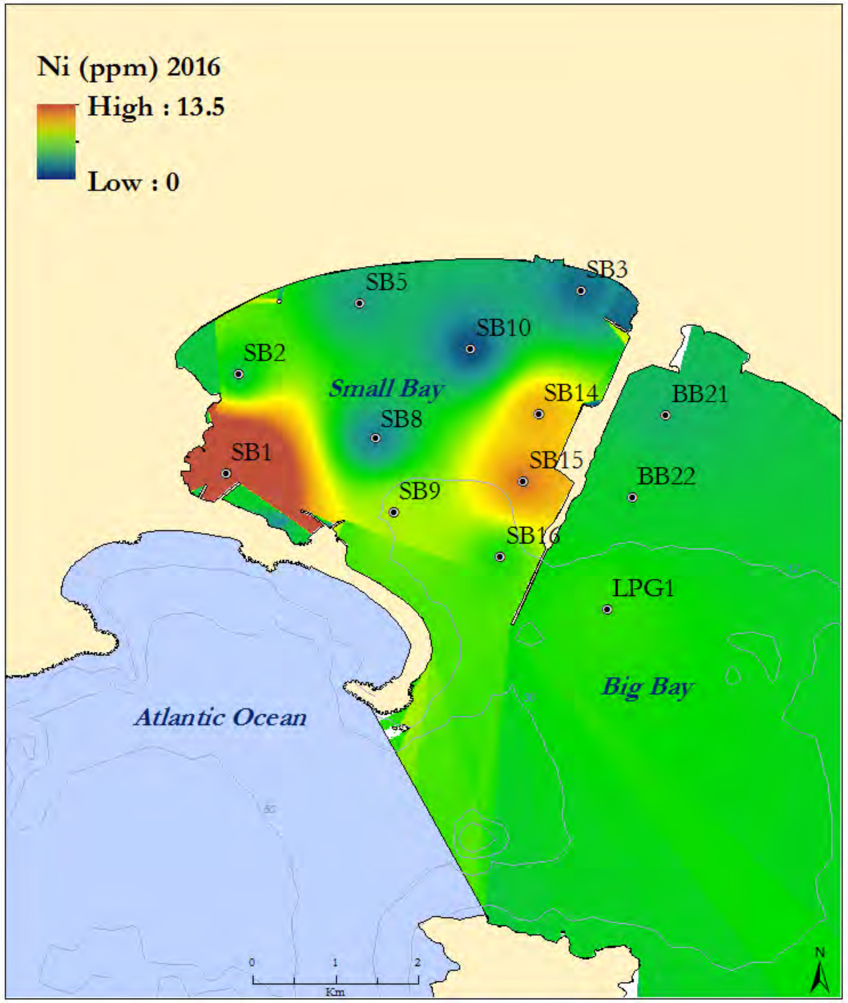


Figure 6.11 Spatial interpolation of nickel values based on values measured in Saldanha Bay in 2016.

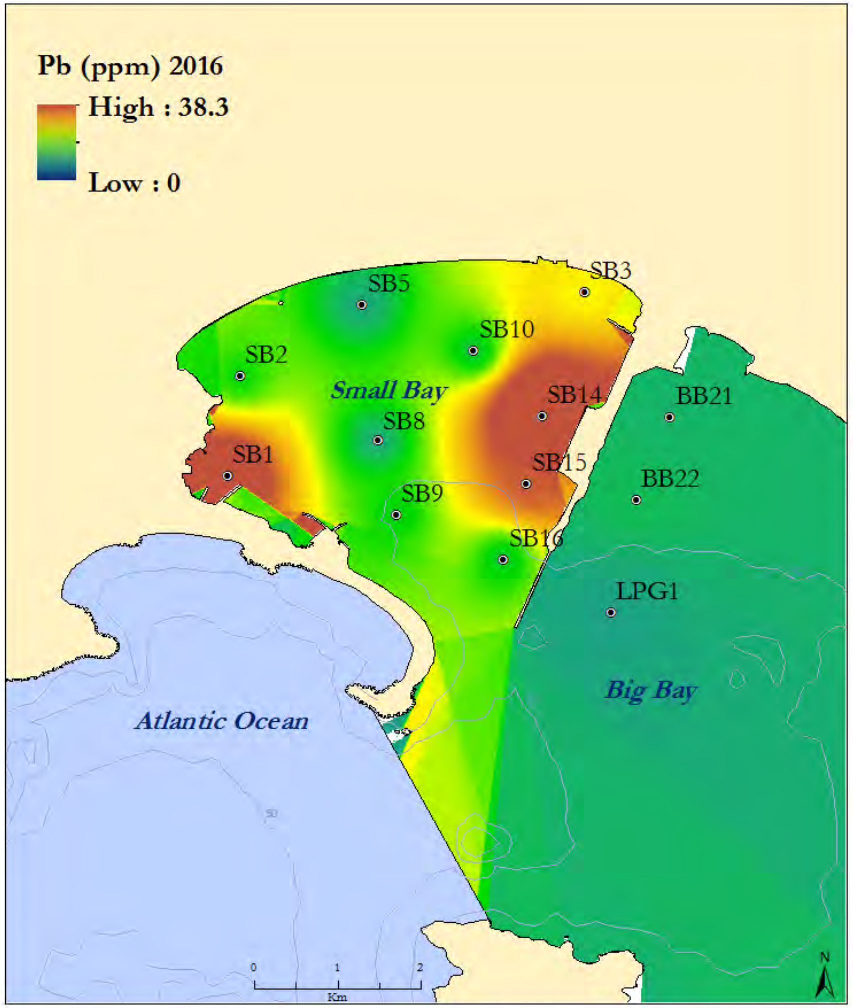


Figure 6.12 Spatial interpolation of lead values based on values measured in Saldanha Bay in 2016.

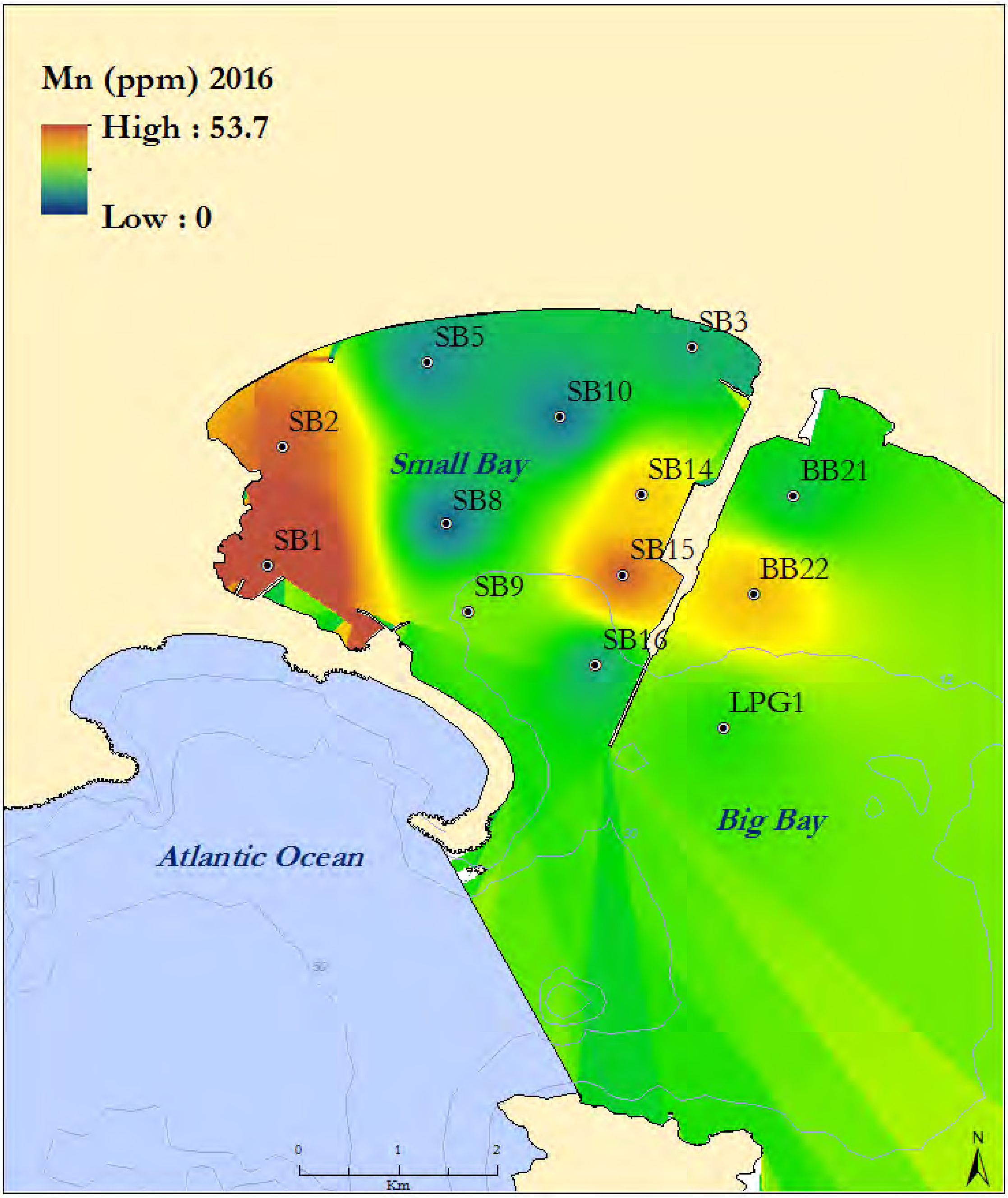


Figure 6.13 **Spatial interpolation of manganese values based on values measured in Saldanha Bay in 2016.**

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 guidelines is discussed below.

Cadmium

There was a considerable increase in the concentration of Cadmium detected in the sediments of Saldana 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, and this pattern has remained the same in 2016, however, the Multi-purpose Quay still exceeds 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, 2015 and 2016 (Figure 6.15). Copper concentration observed during 2014 decreased at all sites from the 2013, in 2015 all sites increased and in 2016 all sites decreased again with exception of the Yacht Club Basin.

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. In 2016 Nickel concentrations decreased at all six sites again and remain below ERL limits.

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 through 2016. 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 within 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 and 2016 with exception of SB15 where a small increase occurred. The two sites located along the ore terminal within Big Bay, however, have shown consistent increases from 2013 to 2015, followed by a decline in 2016. 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 SB14 and SB15 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, and 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 and in 2016 a decrease at all six sites. 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.

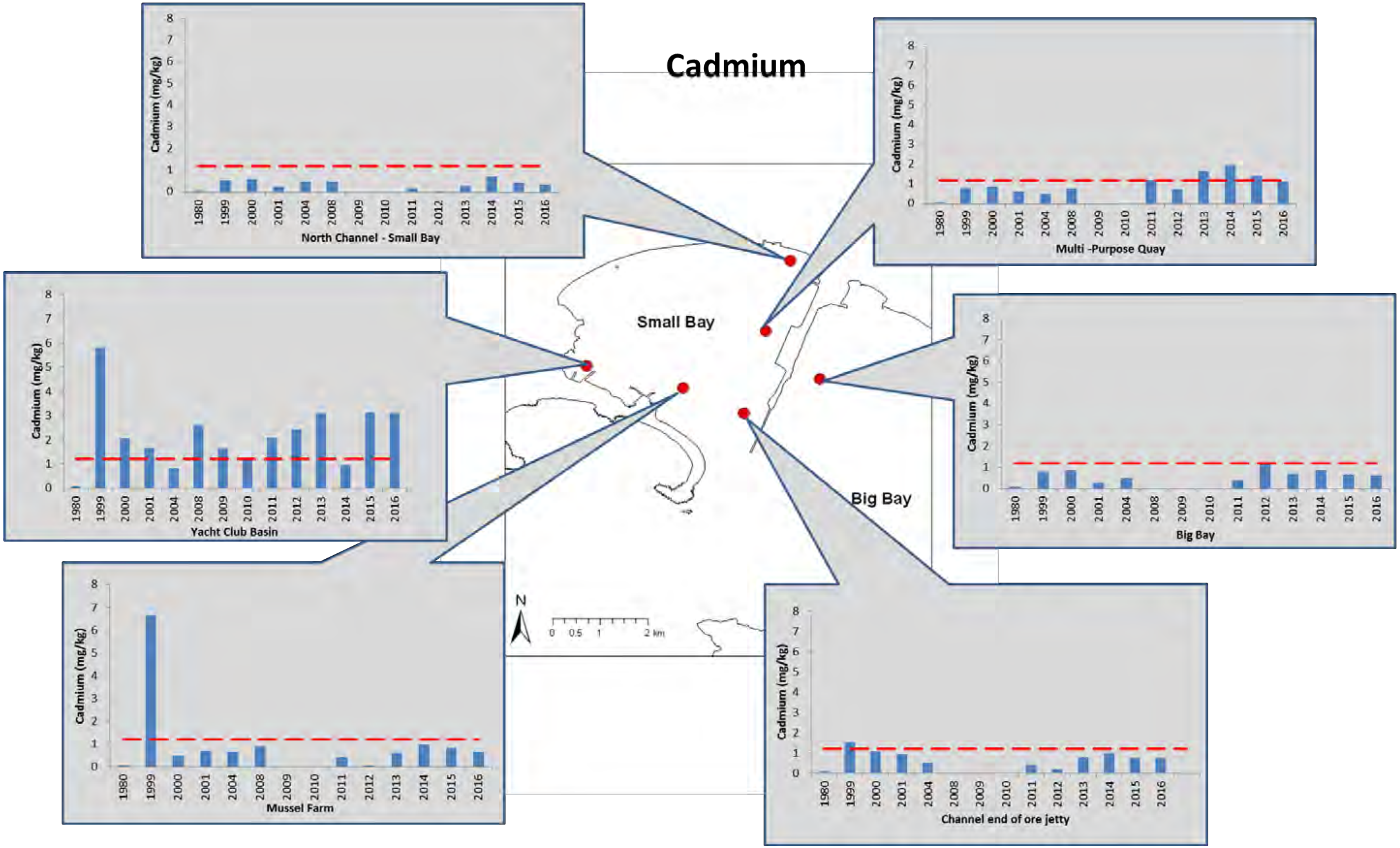


Figure 6.14 **Concentrations of Cadmium (Cd) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2016. Dotted lines indicate Effects Range Low values for sediments.**

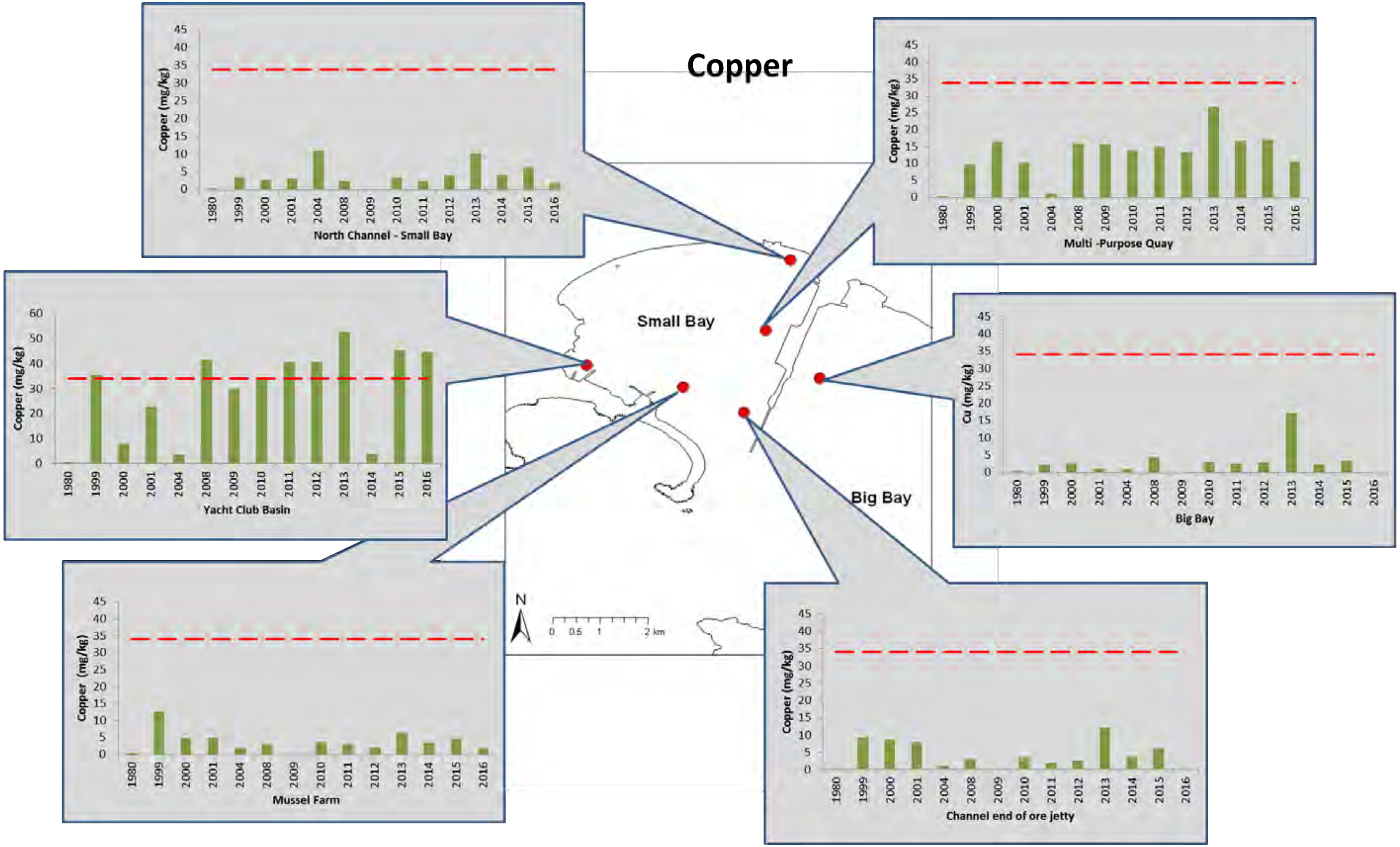


Figure 6.15 Concentrations of Copper (Cu) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2016. Dotted lines indicate Effects Range Low values for sediments.

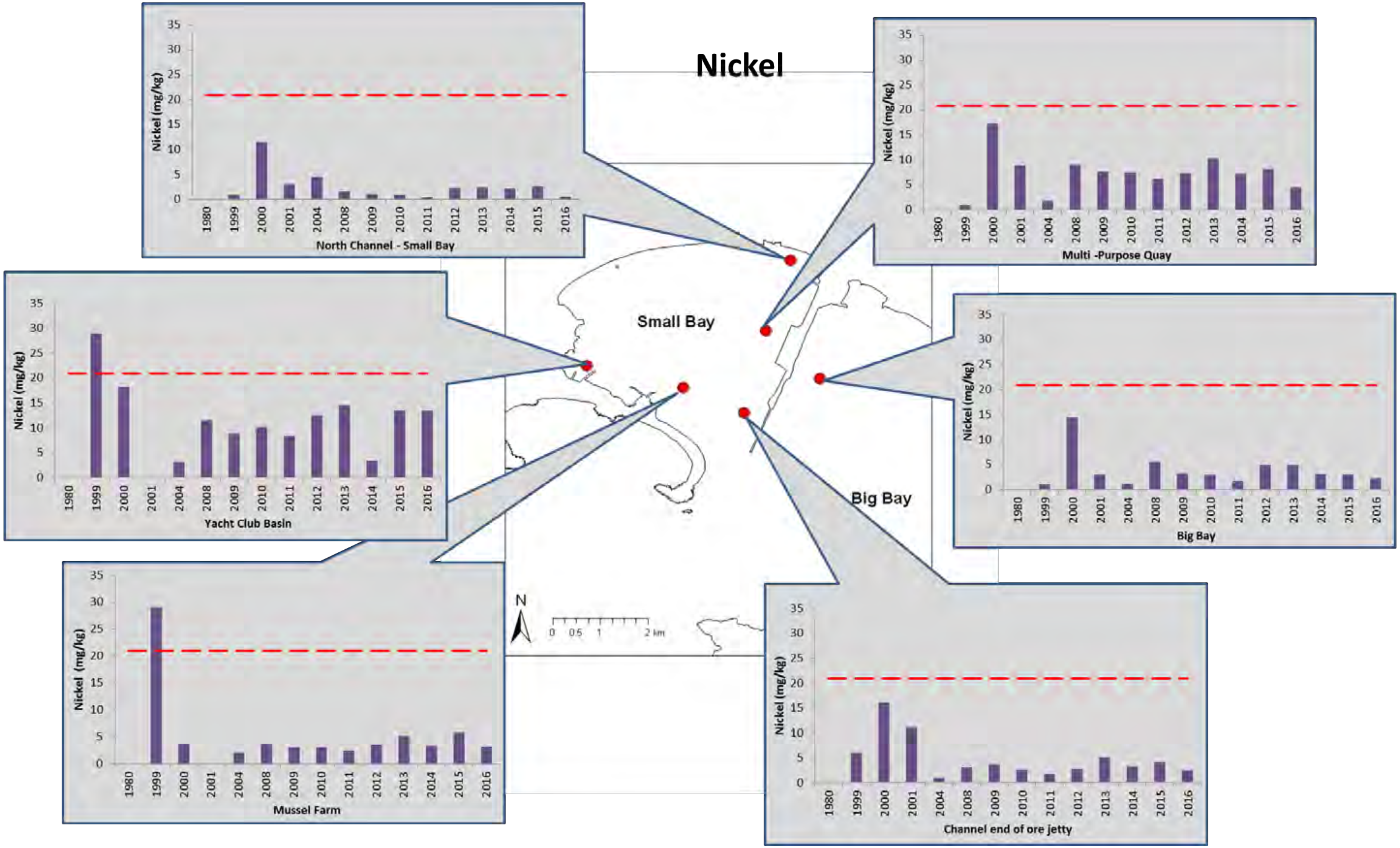


Figure 6.16 Concentrations of Nickel (Ni) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2016. Dotted lines indicate Effects Range Low values for sediments.

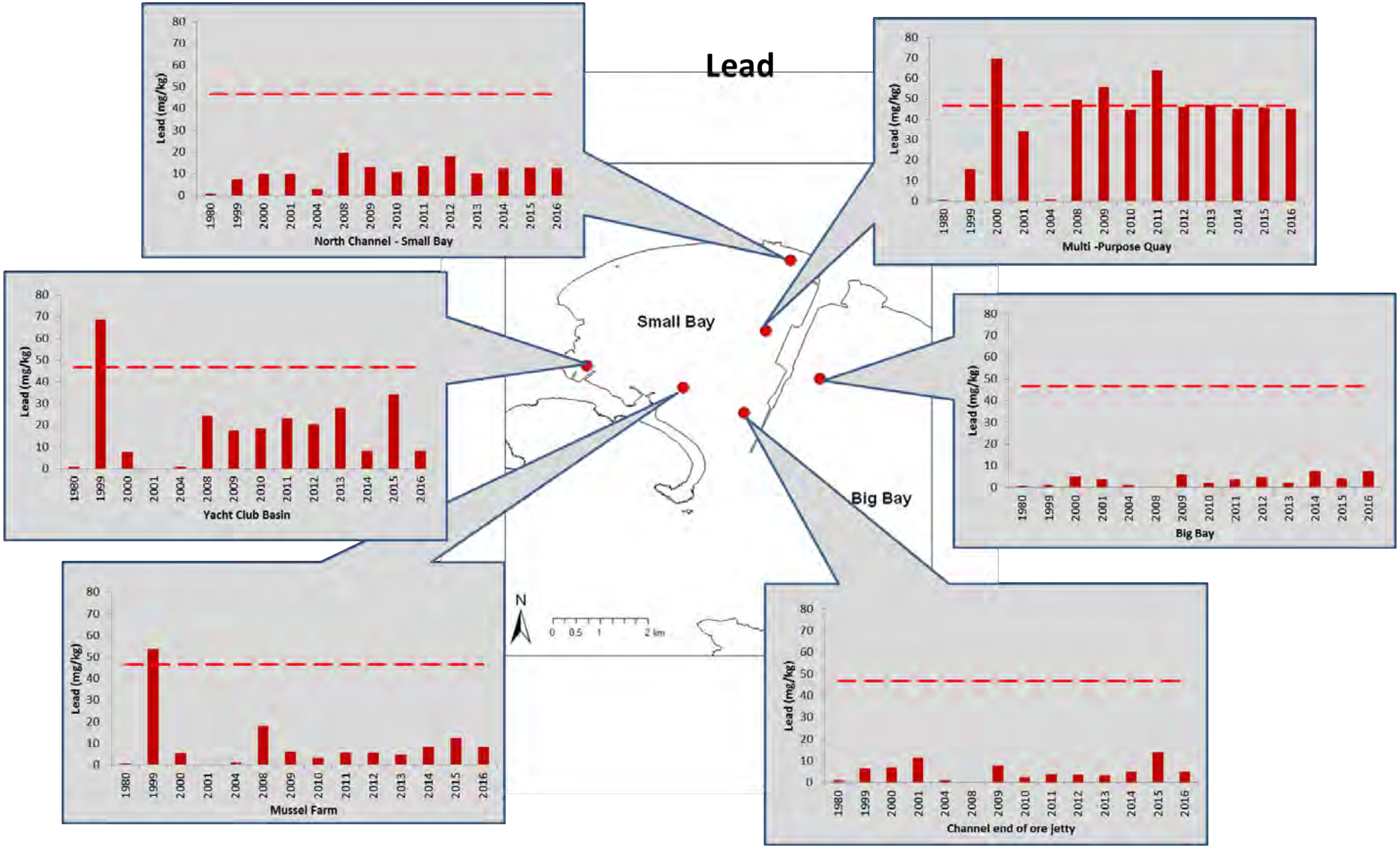


Figure 6.17 **Concentrations of Lead (Pb) in mg/kg recorded at six sites in Saldanha Bay between 1980 and 2016. Dotted lines indicate Effects Range Low values for sediments.**

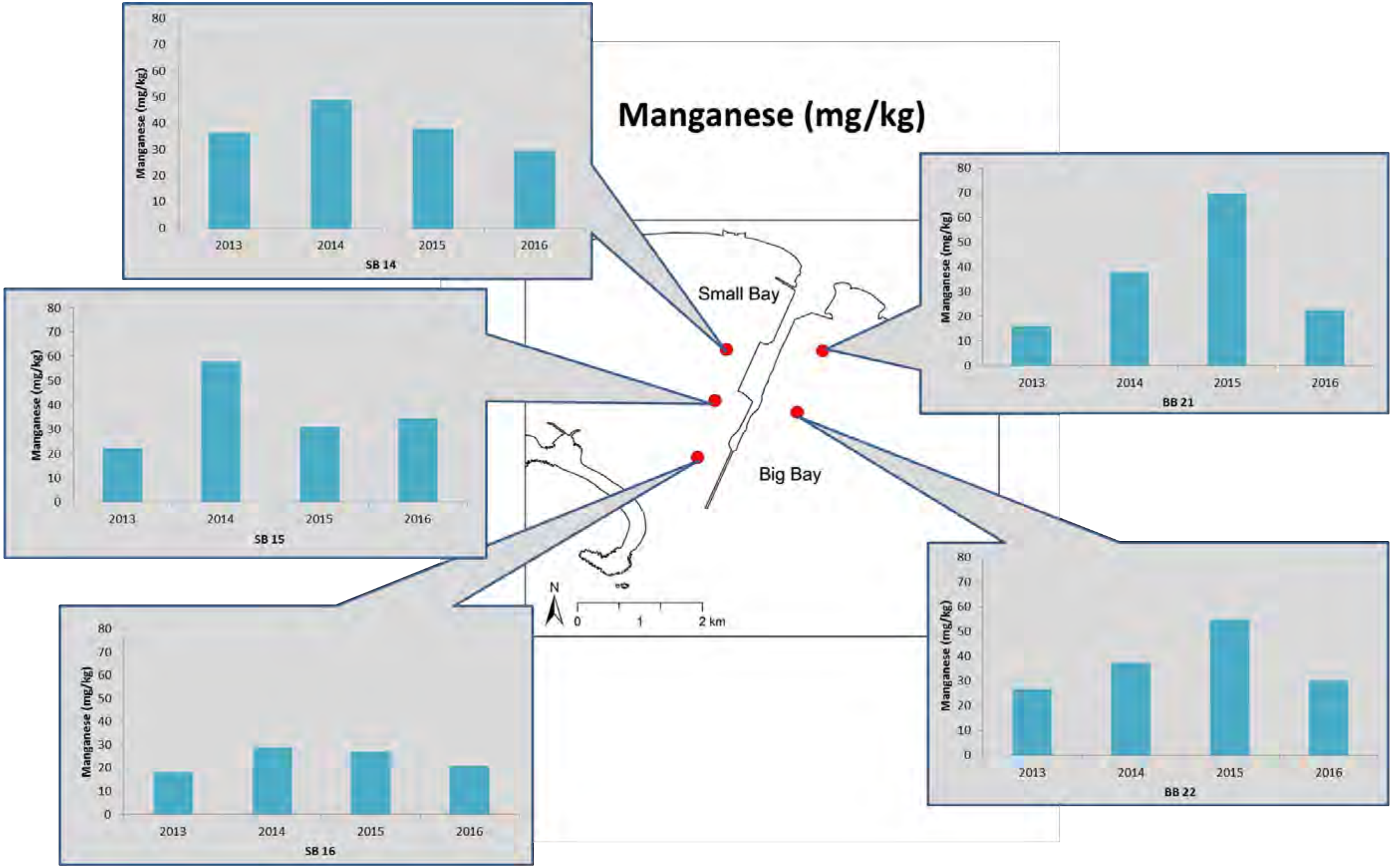


Figure 6.18 **Concentration of manganese (Mn) in mg/kg recorded at five sites in Saldanha Bay between 2013 and 2016.**

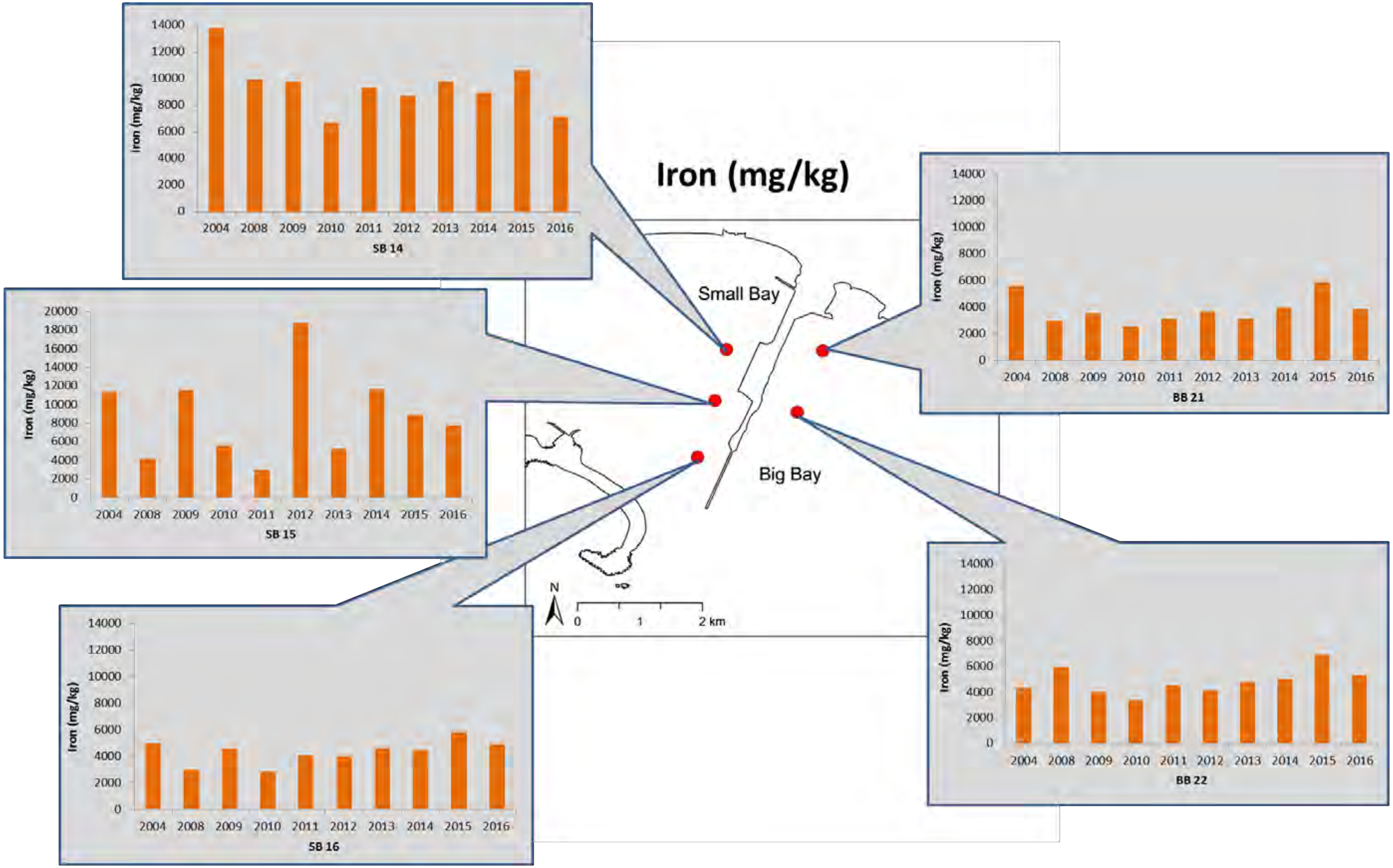


Figure 6.19 **Concentrations of Iron (Fe) in mg/kg recorded at five sites in Saldanha Bay between 2004 and 2016.**

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 2011-2016 from five stations in Saldanha Bay. Values in red indicate exceptionally high total petroleum hydrocarbon levels. ND indicates no data available.

	2011	2012	2013	2014	2015	2016
SB14	<20	34	130	19	<38	<38
SB15	<20	35	ND	53	<38	<38
SB16	<20	24	28	14649	<38	<38
BB21	<20	20	32	20	<38	<38
BB22	<20	17	27	<0.2	<38	<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. In 2015 TPH concentrations decreased to below the detection limit of 38mg/kg and remain at this level at all five sites in 2016.

Table 6.7 **Sediment Quality guidelines and Poly-aromatic hydrocarbons concentrations measured in sediment samples collected from Saldanha Bay in April 2016.**

Hydrocarbon (mg/kg)	ERL*	ERM**	SB14	SB15	SB16	BB21	SB22
Acenaphthene	**0.016**	**0.5**	<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
Anthracene	**0.0853**	**1.1**	<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
Benzo(a) pyrene	**0.43**	**1.6**	<0.002	<0.002	<0.002	<0.002	<0.002
Benzo(b) flouranthene	-	-	<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
Benzo(k) flouranthene	-	-	<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
Dibenzo(a.h) anthracene	**0.0634**	**0.26**	<0.1	<0.1	<0.1	<0.1	<0.1
Flouranthene	**0.6**	**5.1**	<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
Indeno(1.2.3-c.d) pyrene	-	-	<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
Phenanthrene	**0.24**	**1.5**	<0.002	<0.002	<0.002	<0.002	<0.002
Pyrene	**0.665**	**2.6**	<0.002	<0.002	<0.002	<0.002	<0.002
Total PAH	**4**	**44.7**	-	-	-	-	-

*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 2016 had undetectable PAH levels at all sites (Table 6.7). Analysis of the carbon ranges of TPH further support no levels above detection limit (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 2016 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, C_{10}-C_{28} (diesel fuels), C_{28}-C_{40} (lubricants, motor oil and grease) and the total amount of TPH.**

Site	C10-C28 (mg/kg)	C28-C40 (mg/kg)	Total (mg/kg)
SB14	<38	<38	<38
SB15	<38	<38	<38
SB16	<38	<38	<38
BB21	<38	<38	<38
BB22	<38	<38	<38

6.1.5 Elandsfontein Phosphate Mine Environmental Monitoring

As outlined in Section 3.2.10 of this report, three environmental monitoring sites (Eland1, Eland 2, and Eland3) have been established at the head of Langebaan Lagoon with a view to monitoring any changes or perturbations caused by Elandsfontein Phosphate Mine on groundwater input to the Lagoon. Sediment samples were collected in April 2016 have been analysed for grain size composition, total organic carbon and Uranium concentration, while continuous monitoring of water temperature and salinity was initiated in October 2016. The intention is to continue with this monitoring for the lifetime of mine at least.

At all three sampling sites in the Lagoon, sediments were found to be composed primarily of sand (grains sizes in the range 2000-63 μm), with a low carbon content (avg. 2.28% TOC) and low levels of Uranium (below detection limits at all sites, Table 6.9).

Table 6.9 **Baseline monitoring measurements in sediment particle size (%), total organic carbon (% TOC) and trace metal Uranium (Ur) concentration (ppm) at Elandsfontein, Langebaan Lagoon in April 2016. All samples analysed by Scientific Services.**

	Sample	Gravel (%)	Sand (%)	Mud (%)	TOC (%)	Uranium (ppm)
Elandsfontein	Average	0	99.5	0.50	2.28	<5
	Eland1	0	99.7	0.30	1.95	<5
	Eland2	0	99.7	0.30	1.96	<5
	Eland3	0	99.1	0.90	2.94	<5

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, *Callichirus kraussi* and the mudprawn *Upogebia capensis* (Siebert & Branch 2005). *Zostera capensis* falls within the submerged macrophyte category. The primary abiotic factors influencing salt marsh distributions are salinity and water availability (Pan *et al*., 1998). Salt marshes with a great water availability (high rainfall and intertidal zones) that is not limited will be more influenced by sediment salinity than by water availability in terms of zonation patterns (Krüger and Peinemann, 1996). Sediment moisture limits the growth of xerohalophytes (Zedler *et al*., 1986) and may be determined by depth to the water table (Bornman *et al*., 2008). Salt marsh communities are generally comprised of herbs, shrubs and grasses within areas that are tidally inundated (Nybakken, 2001). Within traditional salt marshes, plant communities occur along distinct zones following a tidal gradient and elevation pattern (Hughes and Paramor, 2004; Perry and Atkinson, 2009). Salt marsh species occur in a hostile environment. Few species are able to cope in such environments and as a result, species diversity is low. Salt marshes tend to be associated with euhaline (30 to 35 ppt) conditions. Many salt marsh species are able to cope in euhaline environments, however, growth rates tend to decrease (Price *et al*., 1988) and germination occurs only when the surrounding water salinity decreases (Smart and Barko, 1980). The species found to exist within salt marshes are determined by the specific habitats, controlled by inundation and salinity gradients (Adams and Bate, 1994). Salt marsh communities show a distinct zonation pattern along tidal inundation and salinity gradients, whereby different plant species and different vegetation colours are seen (Adams and Ngesi, 2002). Salt marshes have been divided into three predominant zones, i.e. the subtidal, intertidal and supratidal zones (Figure 7.2). These zonations are influenced by biotic interactions and by spatial and temporal gradients (Noe and Zedler 2001; Rogel *et al*., 2001). The subtidal and intertidal zones are characterised by stress tolerances, especially by high salt gradients, while the supratidal zone may be characterised by competition (Emery *et al*., 2001).

Sand and mud pawns 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 *Callichirus 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).

In 2013, van der Linden created a detailed vegetation map of the area surrounding Langebaan Lagoon as part of her M.Sc. project at Nelson Mandela Metropolitan University (van der Linden 2013). The data were made available for use in this study and are presented in Figure 7.2. These data provide a very useful baseline "snapshot" for the distribution of the various vegetation communities around the lagoon at this time against which future changes can be measured (e.g. as a result of changes in groundwater flow to the lagoon). However, it must be borne in mind that there may be a certain amount of natural variation in these communities and without additional historic data it may not be possible to distinguish natural from induced change in future. Some more detailed studies on long terms changes in salt marsh and submerged macrophytes (*Zostera*) have been undertaken in the past and are summarised in the sections that follow.

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

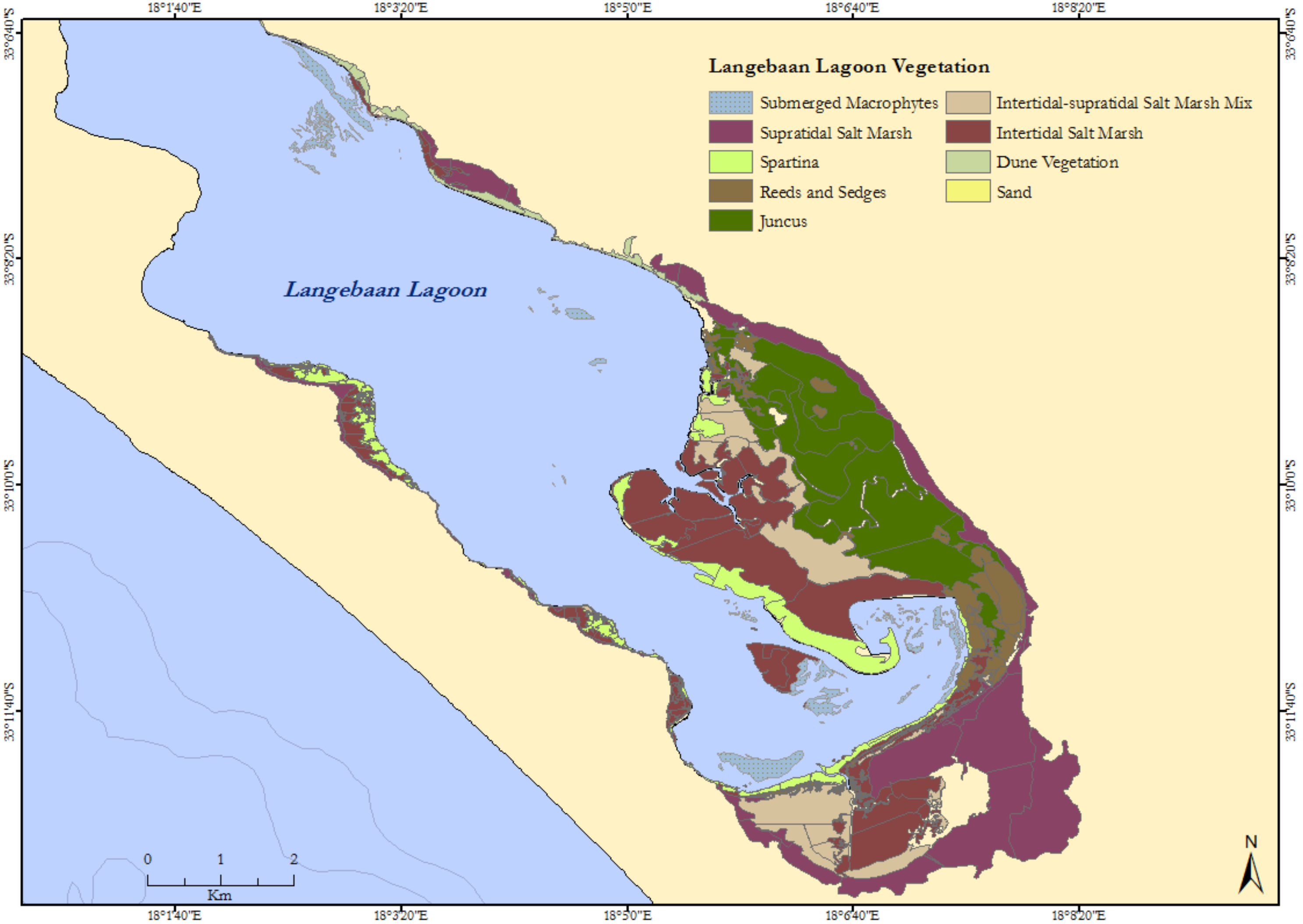


Figure 7.2 Vegetation and habitat structure at Langebaan Lagoon (Source: Shapefiles provided by van der Linden 2013).

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 7.3.). 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 7.3.). 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 km^2 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 *Siphoneria 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.

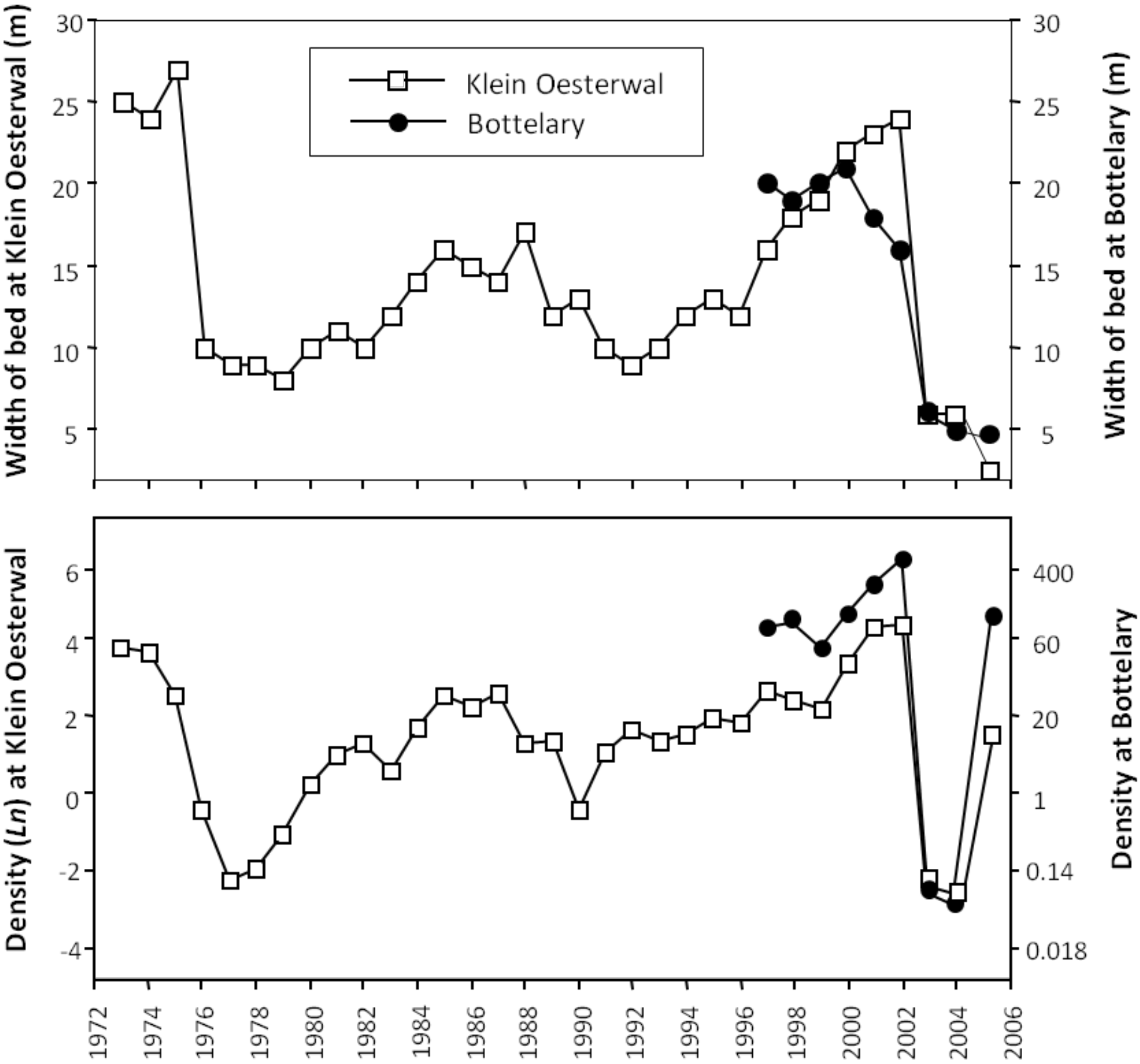


Figure 7.3. Width of the *Zostera* beds and density of *Siphonia* at Klein Oesterwal and Bottelary in Langebaan Lagoon, 1972-2006.

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 *Callichirus 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.

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 m^2 per annum. Total loss during this period was estimated at 325 000 m^2, or 8% of the total (Figure 7.4.,). 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).

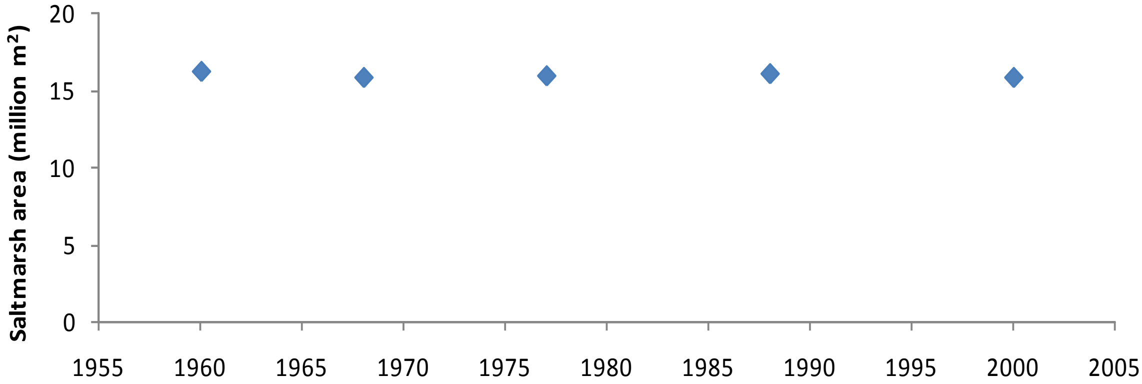


Figure 7.4. Change in saltmarsh area over time in Langebaan Lagoon. (Data from Gerricke 2008)

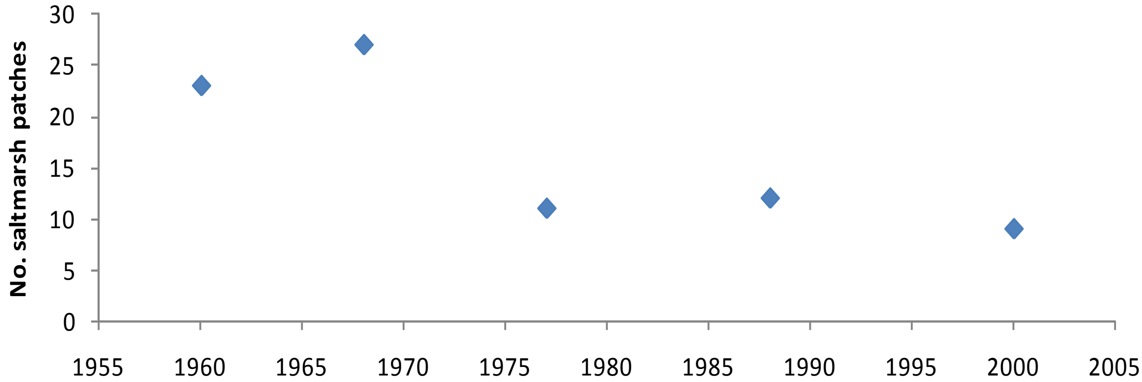


Figure 7.5. Change in the number of discrete saltmarsh patches over time in Langebaan Lagoon. (Data from Gerricke 2008).

8 BENTHIC MACROFAUNA

8.1 Background

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 from 1999 to 2016 (with the addition of new sites at Elandsfontein), 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 2008-2015 do, however, provide benthic macrofauna data from Saldanha Bay and Langebaan Lagoon that are comparable with those collected in 2016. 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 m^2 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 m^2 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 0.24m^2. 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 1999-2016 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 the study areas concerned and as such, can be compared with one another.

8.3 Approach and methods used in monitoring benthic macrofauna in 2016

8.3.1 Sampling

Due to constraints in the 2016 SBWQFT budget, macrofauna samples were collected from a select number of sites in 2016, most of which are located in Small Bay, where there is greatest cause for concern with regards to the health of the environment. In addition, this year's report includes baseline results from three new sites at Elandsfontein, located at the head of Langebaan Lagoon. Concern has been raised over potential impacts that the proposed phosphate mine at Elandsfontein may have on groundwater quality and flows to Langebaan Lagoon (See Section 3.2.10 for more details on this). The State of the Bay monitoring activities have therefore been expanded to include monitoring of benthic macrofauna at these three sites in order to establish an appropriate baseline against which any potential future changes in the Lagoon can be benchmarked. In total, 16 sites were sampled for benthic macrofauna in 2016, 13 of which were in Small Bay and the remaining three in Langebaan Lagoon (five replicates at each site). The localities and water depth ranges of the Small Bay sites are illustrated in Chapter 6 (Section 6.1) and the localities for the Elandsfontein sites are shown in Figure 8.1.

Figure 8.1 Elandsfontein sampling sites located near Geelbek at the head of Langebaan Lagoon.

Samples were collected from sites in Small Bay using a diver-operated suction sampler, which sampled an area of 0.08 m^2 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 m^2 per site. Five hand-cores were collected each of the Elandsfontein sites, totally 0.13 m^2, and were retained as separate replicate samples. All macrofauna abundance and biomass data were ultimately standardised per unit area (m^2). These methods correspond exactly with those employed in 1999, 2004 and 2008-2015 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 2016 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:

$$H' = - \Sigma ipi(\log pi)$$ [7]

The diversity (H') value for each site was plotted geographically and this was used to interpolate vales 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.

[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 2016 Benthic macrofauna survey results

8.4.1 Species diversity

Variations in species diversity (represented by the Shannon Weiner Index, H') for Saldanha Bay are presented in Figure 8.2. Diversity was highest in Small Bay at sites SB 2, SB9 and SB 16 and was lowest around the ore terminal at sites SB 14 and SB 3 in Small Bay and at the Liquid Petroleum Gas (LPG) site in Big Bay. The cause of the decline in diversity at the sites adjacent of the ore terminal and the LPG site is not clear but it is worth noting that these sites are all located in close proximity to the discharge point for the Transnet desalination plant and there may be some link. It is well known that high levels of disturbance associated with pollution can result in a small number of opportunistic, short-lived or r-selected species colonising the affected area and preventing a more diverse community comprising longer living k-strategist species from becoming established.

8.4.2 Community structure

Ordination plots prepared from the 2016 macrofauna abundance data, are presented in Figure 8.3. Significant spatial dissimilarities exist between sites located in Small Bay and those in the Lagoon at Elandsfontein – a well-established result which has been shown in previous versions of the report. Upon closer inspection, sites within Small Bay itself also show some spatial grouping of their own with sites in the northern reaches of the bay (SB 2, SB 3, SB 5, and SB 10) forming a separate cluster from those further south. 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 at Elandsfontein and in moderate numbers at the northern Small Bay sites but are largely absent from the Big Bay sites (LPG, BB 21 and BB 22) and the southern Small Bay sites in proximity the ore terminal. It should be noted that these differences are also partly explained by the difference in the physical and environmental parameters present at the head of the Lagoon near Elandsfontein (freshwater ingress, strong tidal currents and generally coarse sediment) 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 capensis* were notably more abundant at the three Big Bay sites than Small Bay.

Species that contributed significantly to the dissimilarity between the Saldanha Bay and Elandsfontein samples include *Upogebia capensis* (which is replaced by *Upogebia africana* as one moves south towards the head of the Lagoon) and the predatory whelks *Nassarius* sp. that were relatively abundant in Small Bay and Big Bay, but either rare or absent from Elandsfontein samples. Other species such as the sand prawn *Callichirus kraussi*, the isopod *Natatolana hirtipes*, the crown crab *Hymenosoma orbiculare* (detritivores, scavengers or predators) were more abundant in the lagoon samples.

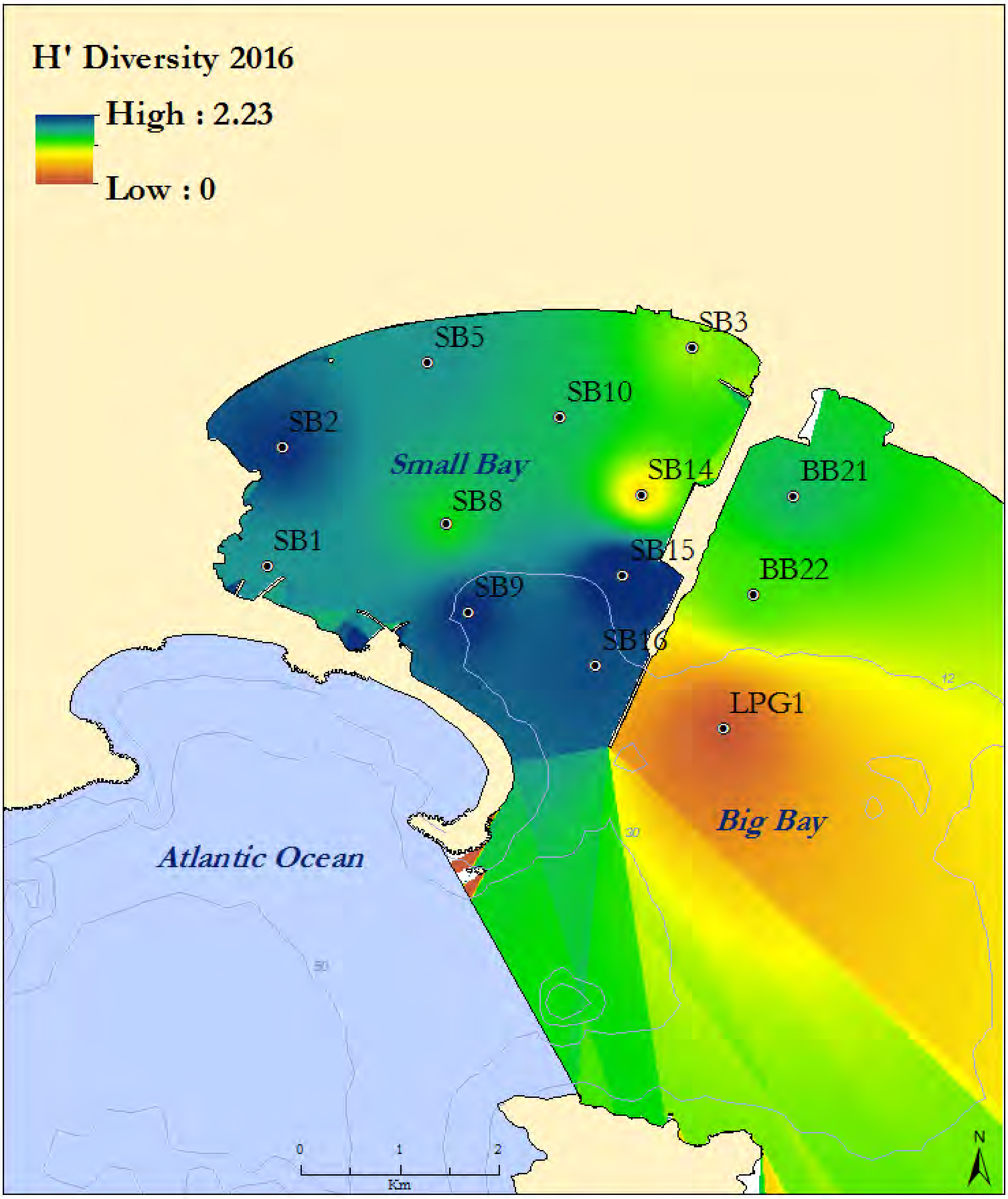


Figure 8.2 Variation in the diversity of the benthic macrofauna in Saldanha Bay as indicated by the 2016 survey results (H' = 0 indicates low diversity, H' = 2.23 indicates high diversity).

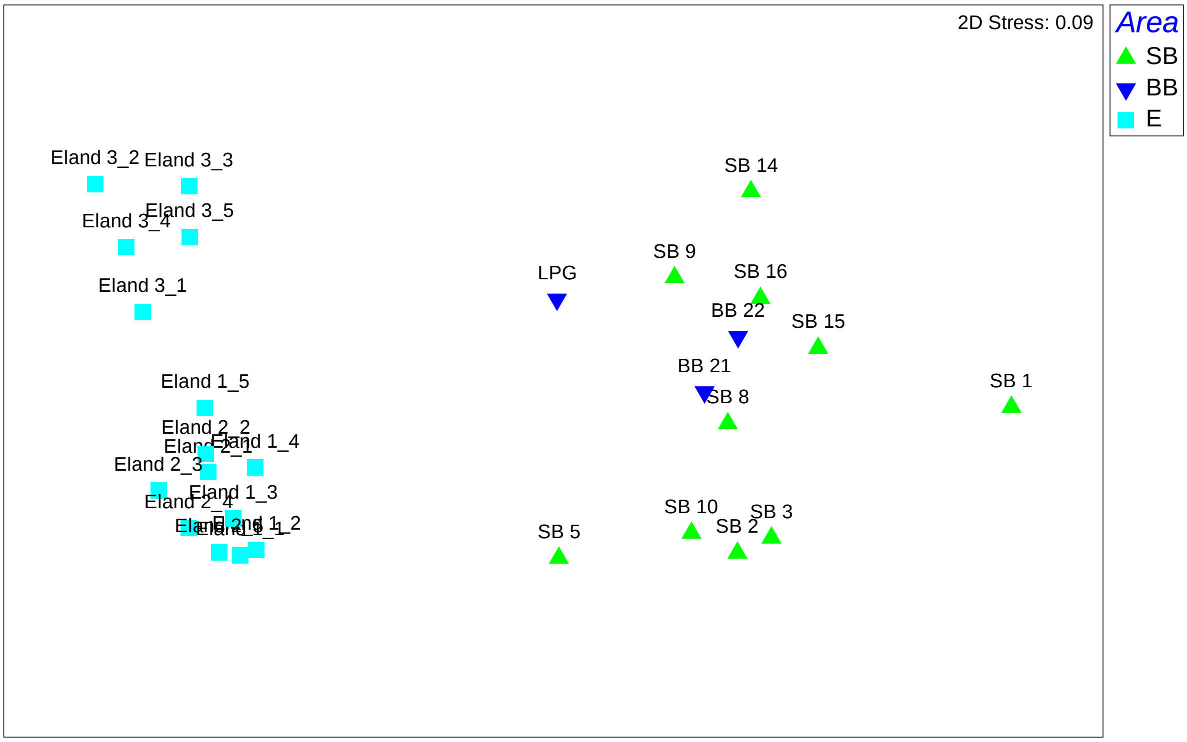


Figure 8.3 **Ordination plots showing similarity amongst sample sites based on benthic macrofauna abundance in 2016. Symbols on the ordination plots are as follows: Small Bay (SB), Big Bay (BB) and Elandsfontein (E).**

Species composition can sometimes be more easily understood at higher taxonomic or functional group (essentially feeding mode) levels. Macrofaunal abundance and biomass results for each of the sites sampled in Saldanha Bay are shown in Figure 8.4. Crustaceans (this diverse group includes prawns, shrimps, mysids, crabs, amphipods and isopods) were the dominant taxonomic group at all sites. The next most abundant taxonomic group were polychaetes, and a relatively greater abundance of these worms were found at the Small Bay sites in comparison to those in Big Bay. Filter feeders were by far the dominant functional group in Small bay and Big bay with a greater average abundance in the latter area. Detritivores were numerically more abundant at Small Bay sites in comparison to Big Bay. Total biomass of benthic macrofauna was lowest at sites SB 1, SB 14 and LPG. This indicates that, despite their relatively high abundance, the fauna present are mostly small, short-lived r-selected species, the total biomass of which is much lower than for the larger k-selected species found at other sites in the bay – a clear sign of disturbance in the benthic environment at sites SB 1, SB 14 and LPG. In further support of this observation, each of these sites are located outside the cluster of the southern Saldanha Bay sites in the MDS plot (Figure 8.3), indicating dissimilarity in benthic macrofauna at a community structure level too.

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.

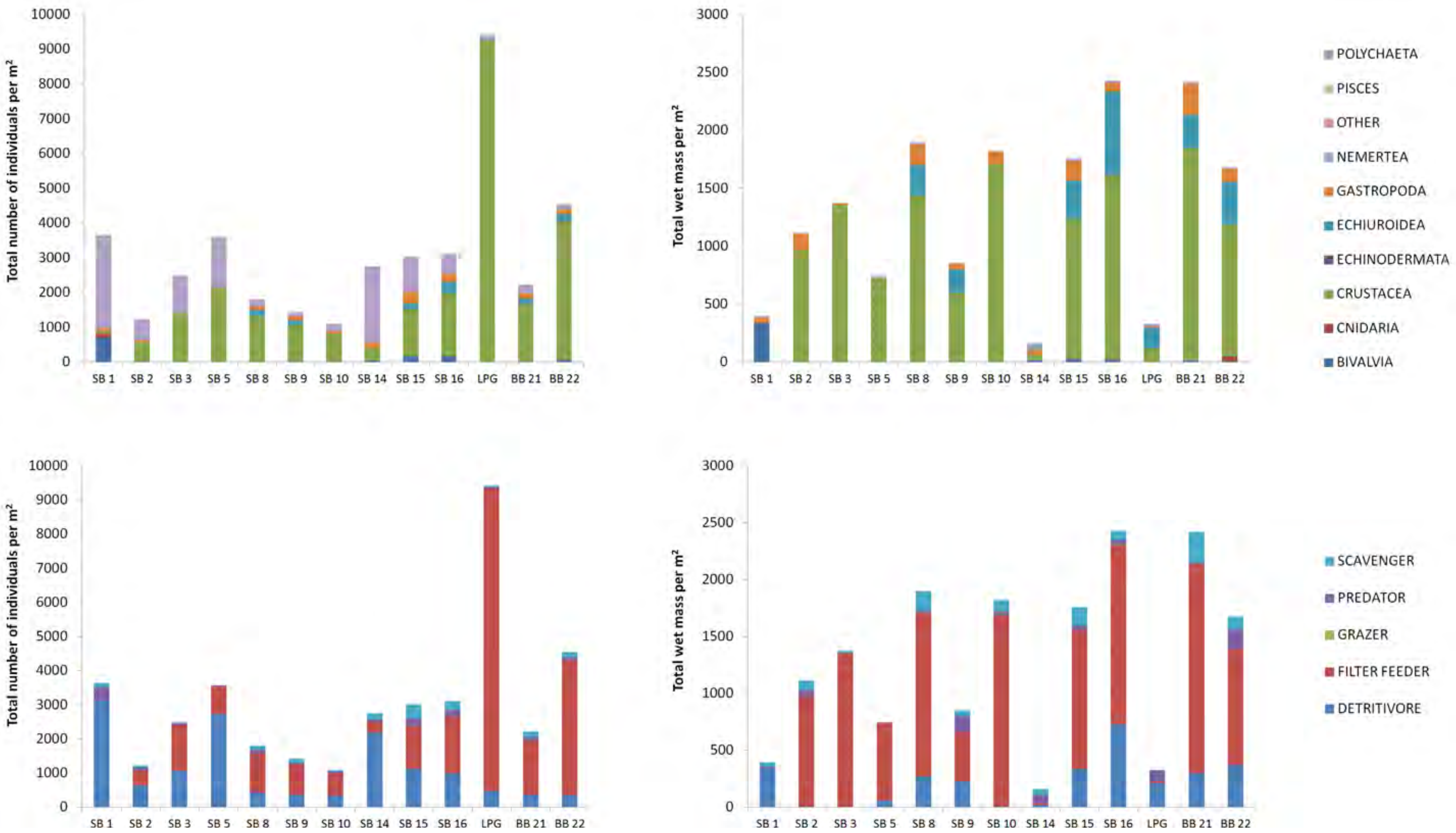


Figure 8.4 **Total abundance and biomass (g/m²) of benthic macrofauna by functional and taxonomic group at sites sampled in Saldanha Bay in 2016 (SB – Small Bay, BB – Big Bay, LPG – Liquid Petroleum Gas Terminal).**

8.5 Abundance, biomass and community composition

Changes in the abundance and biomass of benthic macrofauna in Small Bay are shown in Figure 8.5. 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. There does not appear to be any obvious trend over time when looking at Small Bay alone. The only major perturbation (trough) evident is that in 2012 which could possibly be a delayed environmental response to the dredging event which took place in 2009 and 2010 when 7300 m^3 of material was removed from the Saldanha Side of the ore terminal but we cannot be certain. In 2016 both abundance and biomass increased slightly in Small Bay. There are some subtle 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 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 2008 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. This happens to coincide with the second major dredging event to have occurred since construction of the port in 1973, where 50 000 m^3 of seabed material was removed from the area of the Mossgas Quay and the Multi-purpose Terminal in 2007/2008. Filter feeders tend to be more sensitive to levels of suspended sediment that the other feeding groups, and this certainly lends weight to the argument that these periods 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.

8.6 Community structure

In this and previous reports, multivariate analysis has revealed clear differences in the macrofaunal communities inhabiting Small Bay 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 for Small Bay.

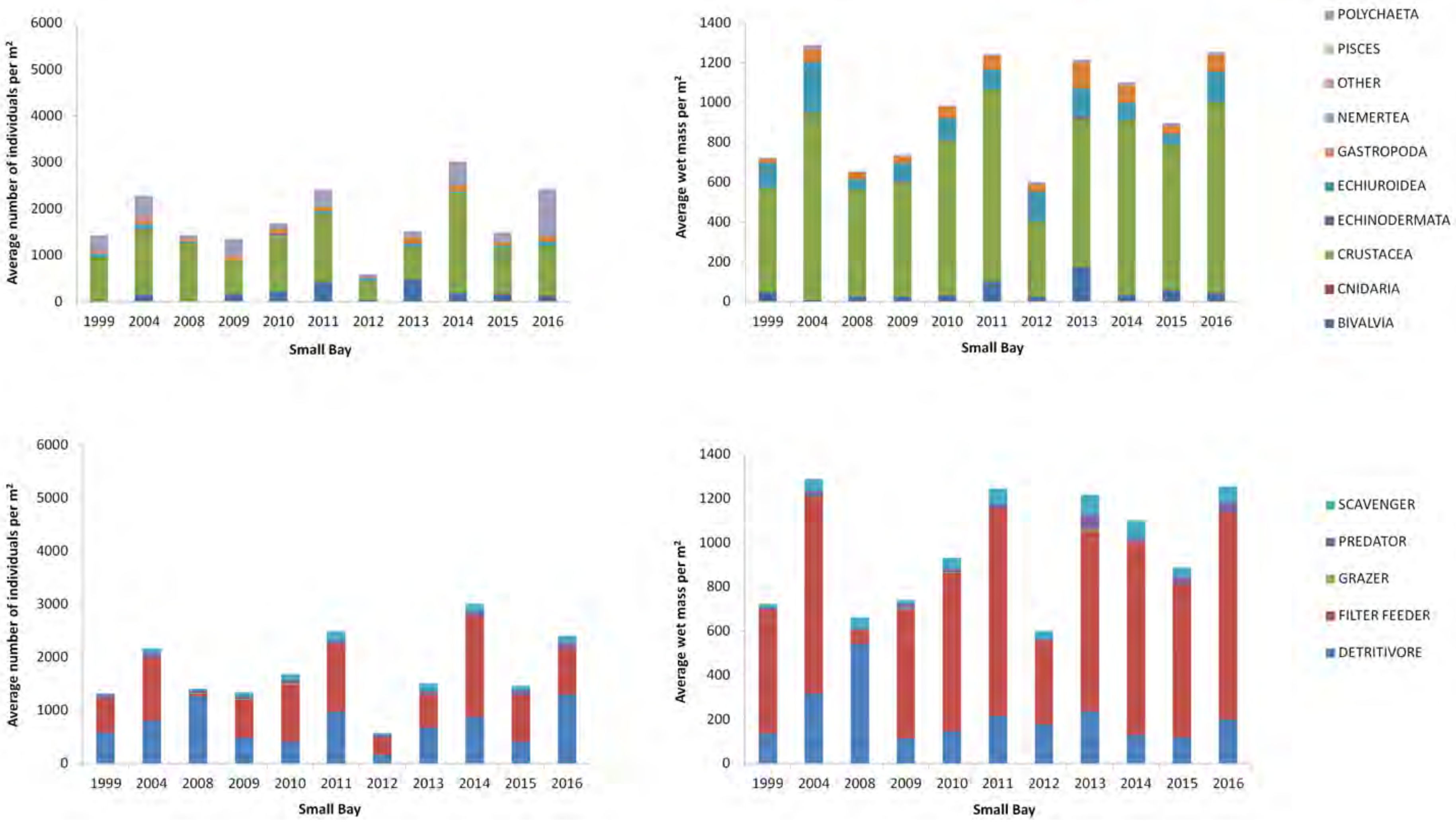


Figure 8.5 **Overall trends in the abundance and biomass (g/m^2) of benthic macrofauna in Small Bay as shown by taxonomic and functional groups.**

The 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 8.6). 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.

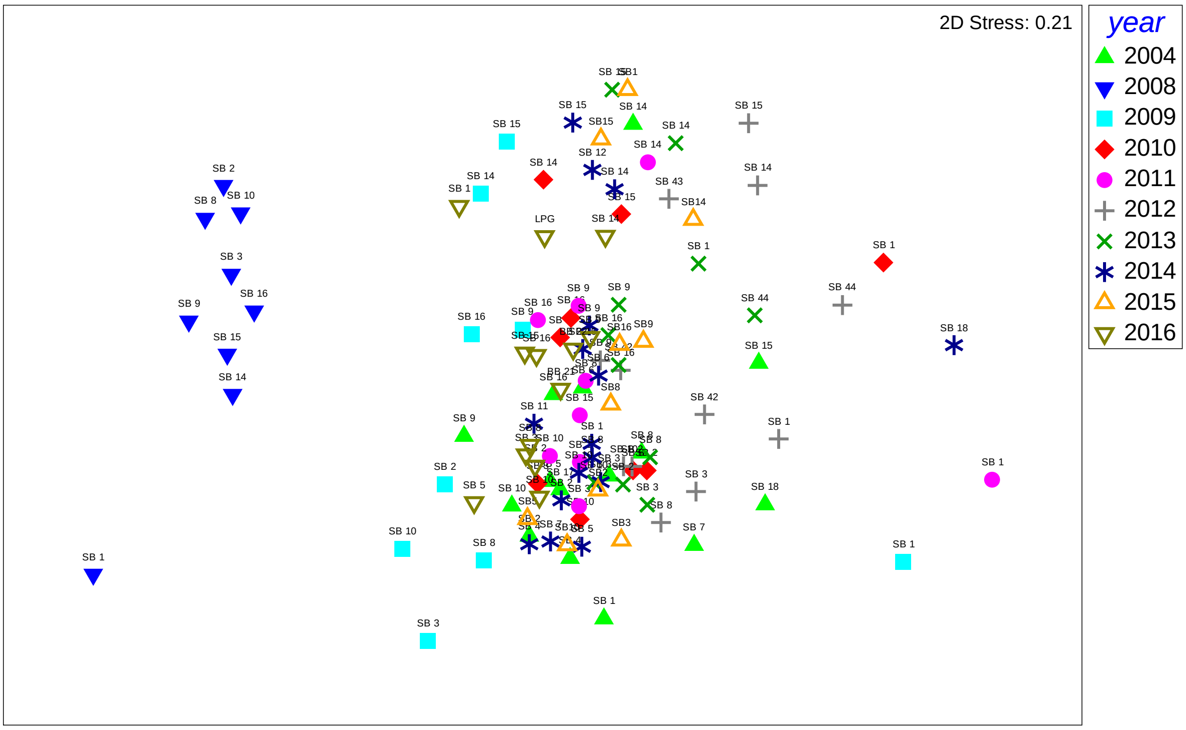


Figure 8.6 **MDS plots showing differences in community structure amongst benthic macrofauna assemblages in Small Bay in the period 2004-2016.**

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 2009-2016 suggests that the smaller 2009 dredging event had a limited impact with little change in macrobenthic community structure over the last six years.

8.7 Elandsfontein 2016 baseline survey results

The State of the Bay monitoring activities have been expanded to include monitoring of benthic macrofauna at three new sampling sites near the head of the Lagoon. Concern has been raised around potential impacts that the proposed phosphate mine at Elandsfontein may have on groundwater quality and flows to Langebaan Lagoon. Hence the objective to establish an appropriate baseline of the present benthic macrofauna community structure against which any potential future changes in the Lagoon can be benchmarked. The first set of 2016 baseline results are presented here in context of the entire Saldanha Bay/Langebaan Lagoon system.

The results from the Elandsfontein samples can be best interpreted and understood in the context of the rest of the Saldanha Bay/Langebaan Lagoon system – particularly the nearby Langebaan Lagoon monitoring sites. Unfortunately these sites were not sampled in 2016, due to constraints in the SBWQFT budget. As a substitute, 2015 macrofauna data from the Langebaan Lagoon monitoring sites were used in a comparative exercise with the 2016 data – the results of which are shown in Figure 1.7.

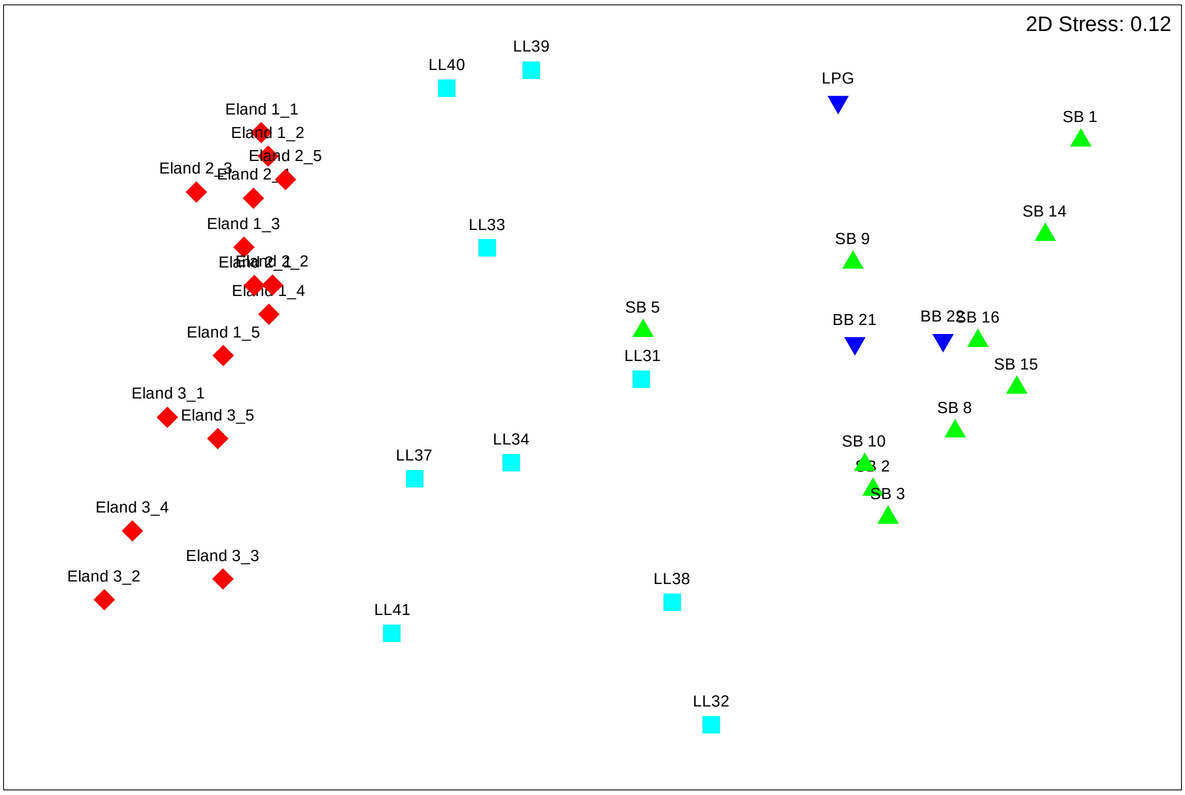


Figure 8.7 **Ordination plots showing similarity amongst sample sites based on benthic macrofauna abundance in 2016. Symbols on the ordination plots are as follows: Small Bay (SB), Big Bay (BB), Langebaan Lagoon (LL) and Elandsfontein (Eland).**

It is evident that significant spatial dissimilarities in macrofaunal community composition exist between samples from Saldanha Bay (Small Bay and Big Bay), Langebaan Lagoon and Elandsfontein with each area forming a distinct cluster. The 2015 Langebaan Lagoon cluster falls directly between the Saldanha Bay and Elandsfontein clusters which means that the macrofaunal community composition at the Elandsfontein sites are most similar to that present in Langebaan Lagoon (71.4 % dissimilarity) and in turn are most dissimilar (93%) to that in Saldanha Bay. This suggests that a spatial trend in macrofaunal communities exists from the marine dominated Saldanha Bay through the sheltered lagoon to the very sheltered, shallow and possibly freshwater/estuarine influenced Elandsfontein area.

In total 20 species (consisting of polychaetes and crustaceans - Figure 8.8) were recorded at Elandsfontein, of which five are found nowhere else in the system namely the polychaetes *Caulleriella acicula* and *Scoloplos johnstonei*; the crabs *Danielella edwardsii* and *Paratylodiplax algoensis*; and the isopod *Notanthura caeca*. Diversity at Elandsfontein is low in comparison to rest of the system and is likely an artefact of low cumulative sampling effort, this being the first survey. Additional species are likely to be detected 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.

Macrofaunal abundance and biomass results for Elandsfontein, broken down into taxonomic and functional feeding groups, are shown in Figure 8.8. There does not appear to be any significant difference in abundance and biomass of macrofauna at each of the three sites, however, on a community composition level, site Eland_3 does form a separate cluster to Eland_1 and Eland_2 (Figure 1.7). A simper analysis reveals 64% dissimilarity with the amphipod, *Urothoe grimaldii*, the prawns *Upogebia africana* and *Callichirus kraussi*, and the polychaetes *Notomastus latericeus* and *Orbina angrapequensis* contributing >50% to this dissimilarity. This is likely to be explained by the difference in physical conditions present at each of the sites. From Figure 8.1, it can be seen that Eland_3 is situated directly opposite the “mouth” of the channel from Langebaan Lagoon and appears to be mostly marine, whereas Eland_1 and Eland_2 are located further east, closer to the source of freshwater in what appears to be a more estuarine habitat. Interpretation of water quality data from a conductivity, temperature and depth (CTD) instrument deployed in the vicinity and further sampling in years to come would provide further insight into our findings thus far.

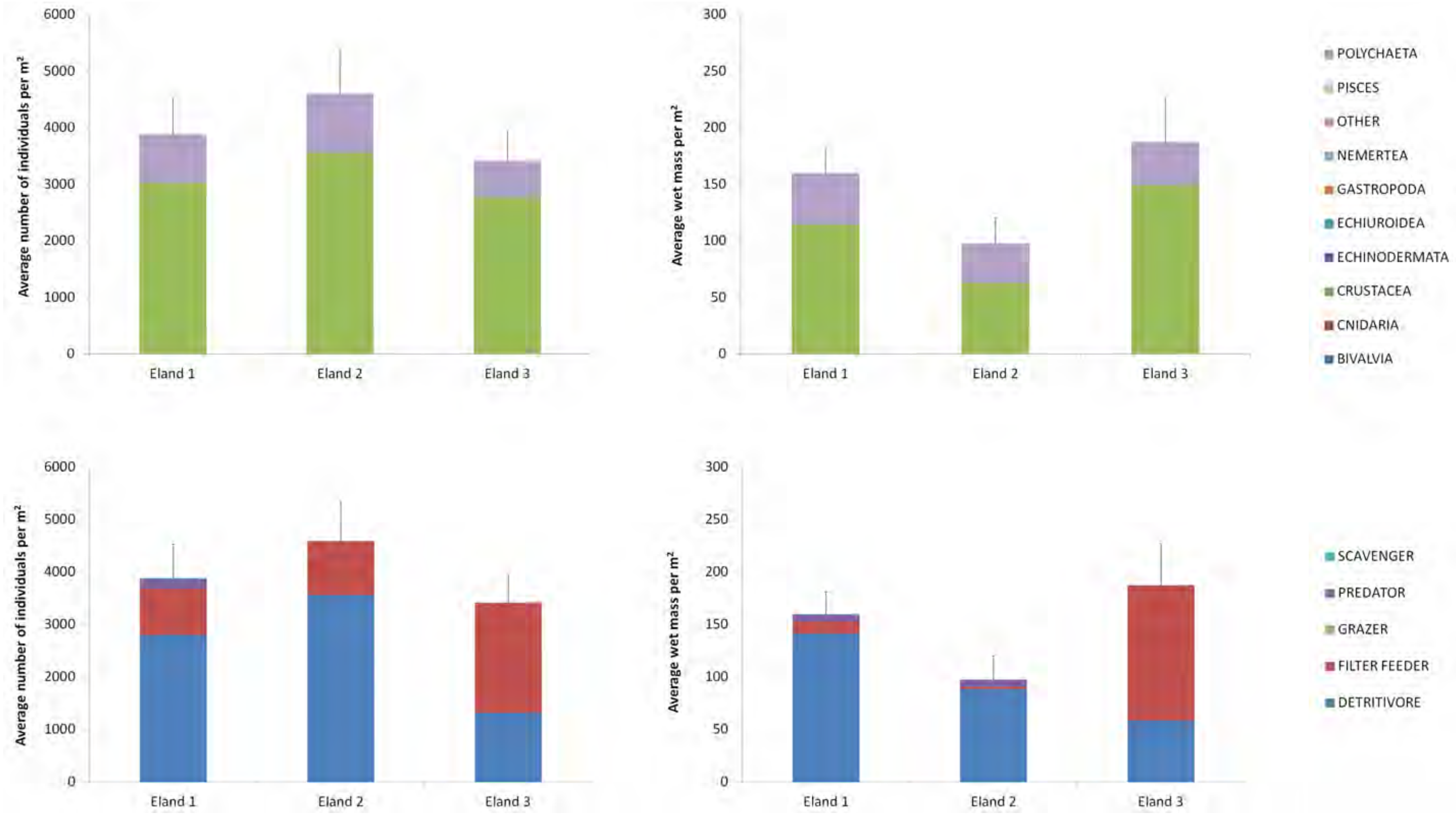


Figure 8.8 **Average abundance and biomass (g/m2) of benthic macrofauna by functional and taxonomic from sampling sites at Elandsfontein in 2016 - error bars are + 1 Standard Error (n=5).**

8.8 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). Results for 2016 are only available for Small Bay and indicate an increase in both abundance and biomass. Through time, 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 in Small Bay, 2016, is a very positive sign and points to an overall increase in the health of the Bay. Results from the Elandsfontein baseline survey show that the macrofaunal community present at these sites are most similar to that present in Langebaan Lagoon. A spatial comparative analysis revealed clear trend macrofaunal communities from the marine dominated Saldanha Bay through the sheltered Lagoon to the very sheltered, shallow and possibly freshwater/estuarine influenced Elandsfontein area. Furthermore, physical habitat and associated macrobenthic biota appear to be driving dissimilarity with the Elandsfontein sites themselves. In terms of the concerns raised around potential impacts that the proposed phosphate mine at Elandsfontein may have on groundwater quality and flows to Langebaan Lagoon, ongoing collection of baseline data on macrobenthic communities in Elandsfontein to capture natural variability, is essential for objective and quantitative assessment of any impacts should they occur.

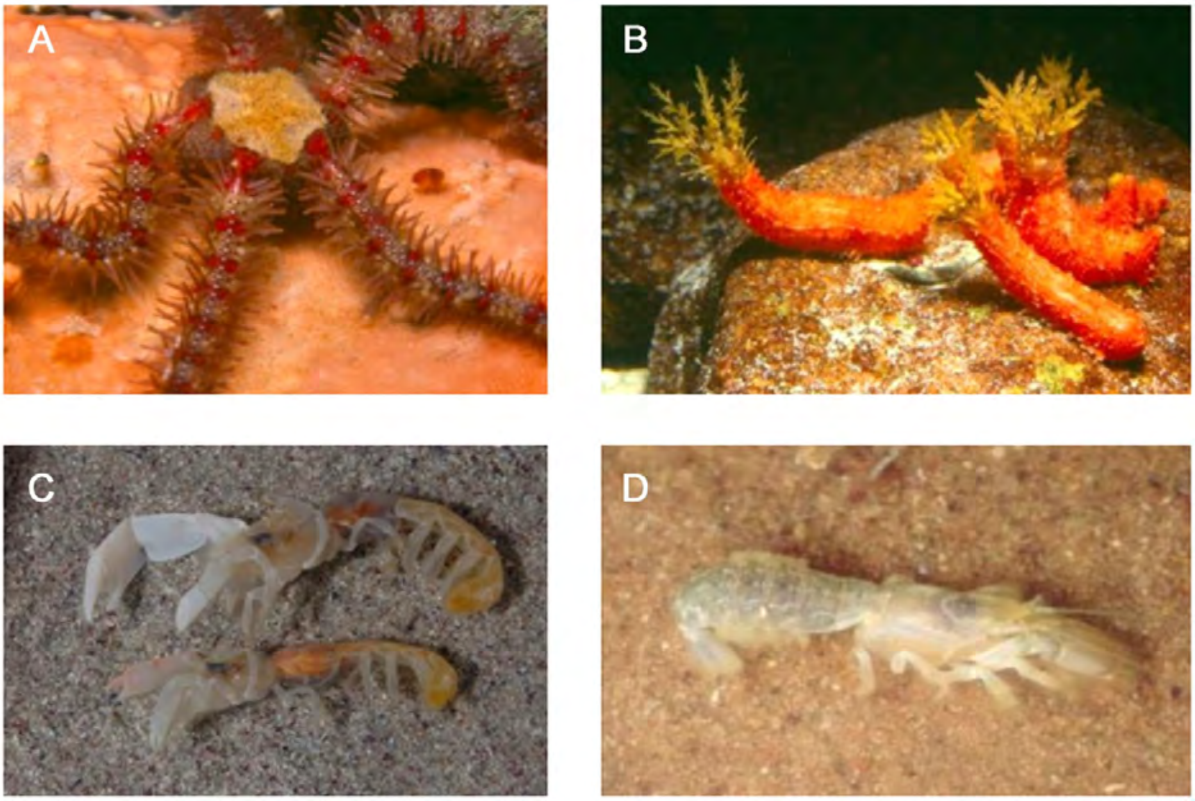


Figure 8.9. **Benthic macrofauna species frequently found to occur in Saldanha Bay and Langebaan Lagoon, photographs by: Charles Griffiths.** ***A – Ophiuroidea, B - Pseudonella insolens*, C - *Callichirus kraussi , D – Upogebia capensis*.**

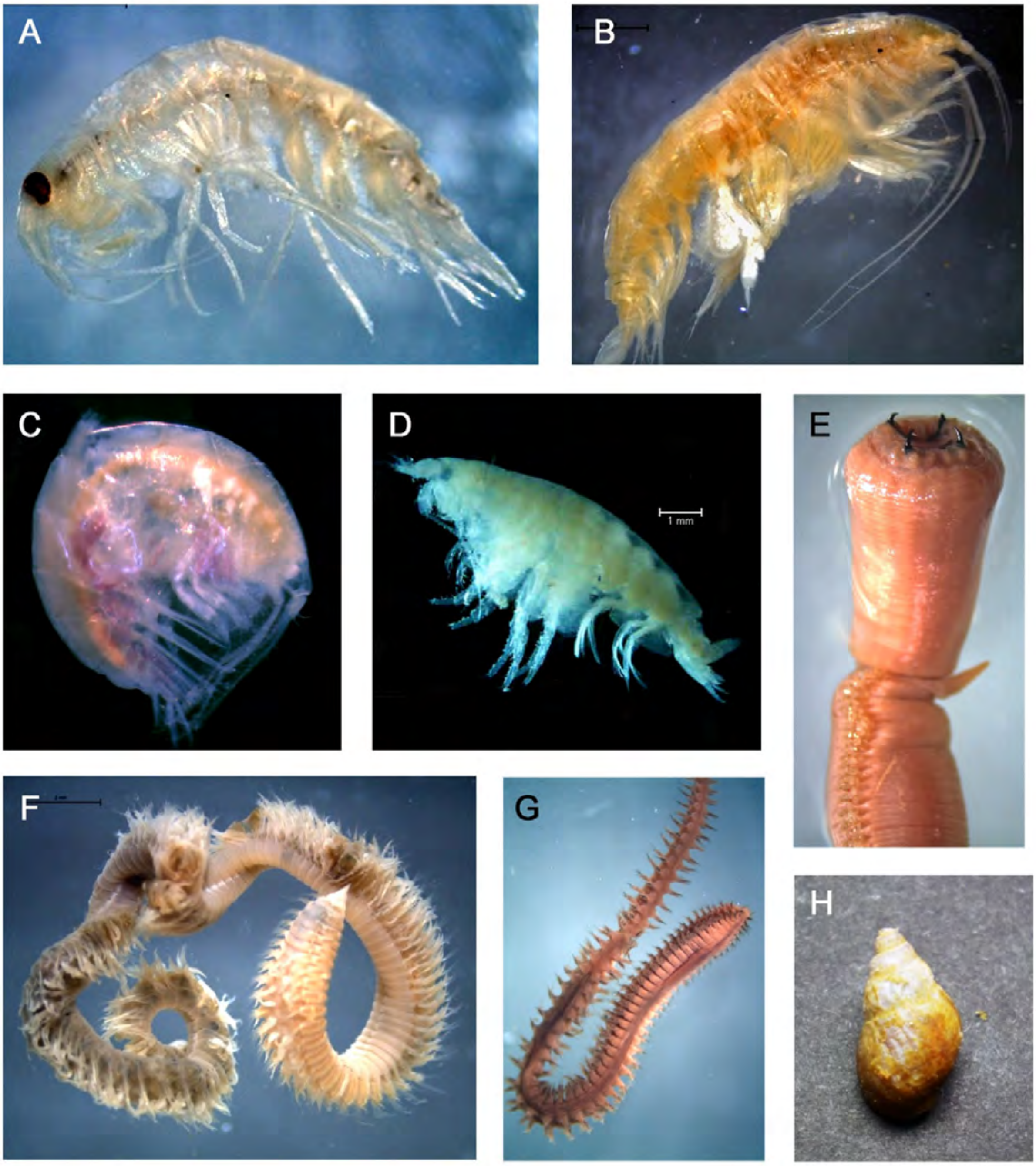


Figure 8.10. **Benthic macrofauna species frequently found to occur in Saldanha Bay and Langebaan Lagoon, photographs by: Nina Steffani and Aiden Biccard. A – *Paramoera capensis*, B – *Ampelisca brevicornis*, C – *Ampelisca palmata*, D – *Hippomedon normalis*, E – *Glycera tridactyla*, F – *Orbina angrapequensis*, G – *Nephtys hombergii,* H – *Nassarius vinctus*.**

9 FISH COMMUNITY COMPOSITION AND ABUNDANCE

9.1 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 *Spodyliosoma 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 data 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 (unpublished data). 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 of these studies include evidence that the Langebaan lagoon Marine Protected Area (MPA) effectively protects white stumpnose, during the summer months that coincides 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 fishery 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 fishery 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).

Recent studies 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, Parker in prep.). Arendse (2011) 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. Parker *et al* (in prep) provide an updated analysis of angler survey data, commercial linefish catch returns and the juvenile white stumpnose catch in the seine net surveys, that conclusively demonstrate substantial declines in both adult and juvenile abundance estimates over the last decade. These authors also urge that a reduction in bag limit and increase in size limit are required to sustain the Saldanha Bay white stumpnose fishery.

Experimental seine-net sampling of near shore fish assemblages at a number of sites throughout the Saldanha-Langebaan system was first undertaken explicitly as part of the "State of the Bay" programme in 2005, and has since been undertaken annually over the period 2008-2016. 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 and 2015 State of the Bay reports.

This report presents and summarizes the data for the 2016 seine-net survey and investigates trends in the fish communities by comparing this with data from previous seine-net surveys (1986/87, 1994, 2005, 2008-2015) in the Saldanha- Langebaan system.

9.2 Methods

9.2.1 Field sampling

Experimental seine netting for all surveys covered in this report was conducted using a beach-seine net, 30 m long, and 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 9.1). Large hauls were sub-sampled on site, the size of the sub-sample estimated visually and the remainder of the catch released alive.

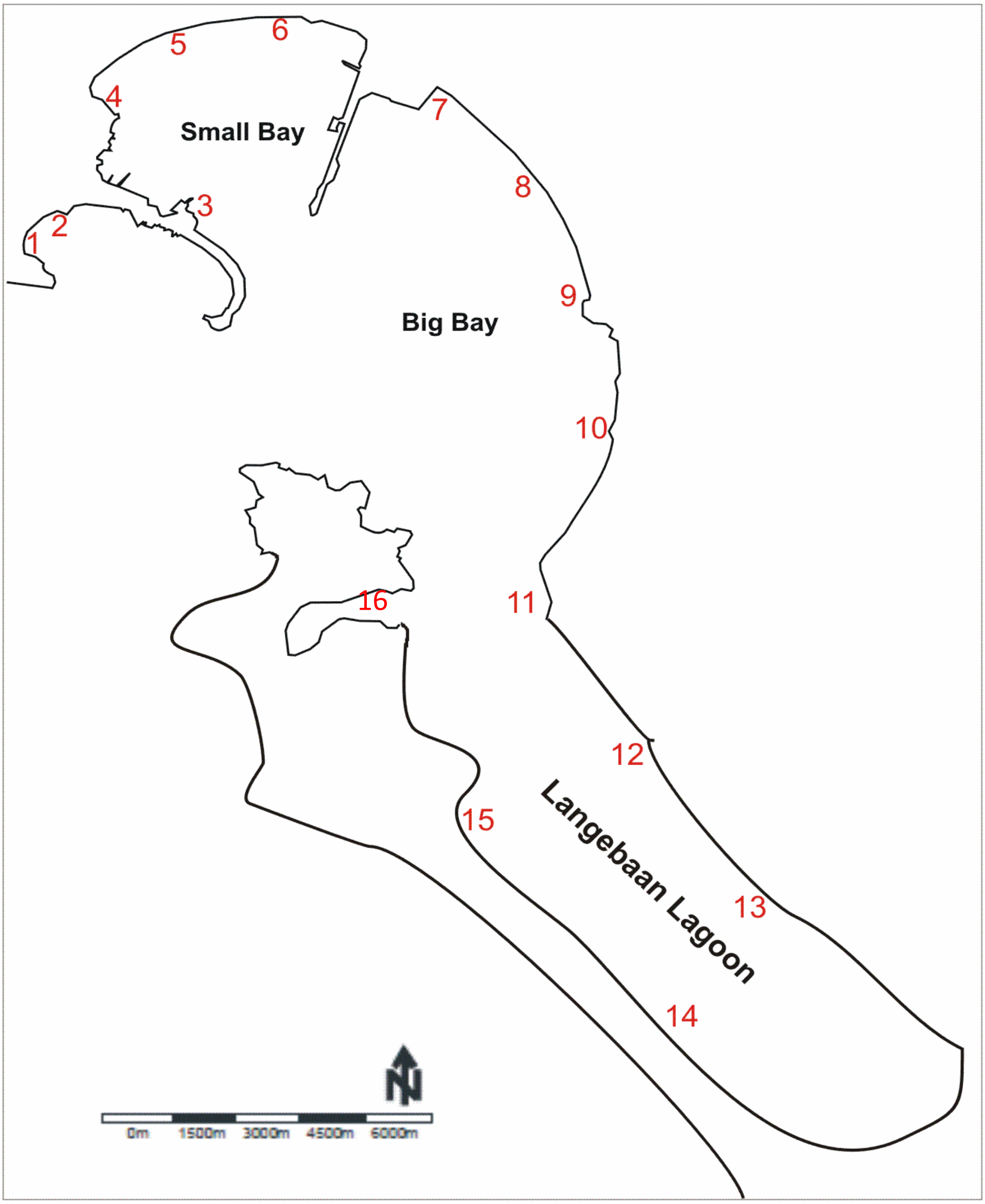


Figure 9.1 **Sampling sites within Saldanha Bay and Langebaan lagoon where seine net hauls were conducted during the 2005 and 2007-2016 annual sampling events. 1: North Bay west, 2: North Bay east, 3: Small craft harbour, 4: Hoedjiesbaai, 5: Caravan site, 6: Blue water Bay, 7: Sea farm dam, 8: Spreeuwalle, 9: Lynch point, 10: Strandloper, 11: Schaapen Island, 12: Klein Oesterwal, 13: Bottelary, 14: Churchaven, 15: Kraalbaai, 16: Rietbaai.**

9.2.1.1 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 sampled. 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.

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.

9.3 Results

9.3.1 Description of inter annual trends in fish species diversity

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. Catch composition and abundance of each species caught in Small Bay, Big Bay and the Lagoon during each of the different surveys are shown in Table 9.1 and Table 9.2. Considering data from all surveys conducted to date, a greater diversity of species has been captured in Big Bay (35), and in Small Bay (33) than the Lagoon (24). 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 9.2). 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 9.2). In 2016 samples only 11 species were recorded in Small Bay which is the lowest to date, however, this is only 1 fewer than in 2009, 2010 and 2015 and is probably just natural variation in the icthyofaunal diversity. Overall there is no clear trend in species richness over time in any of the three parts of the Bay (Figure 9.2).

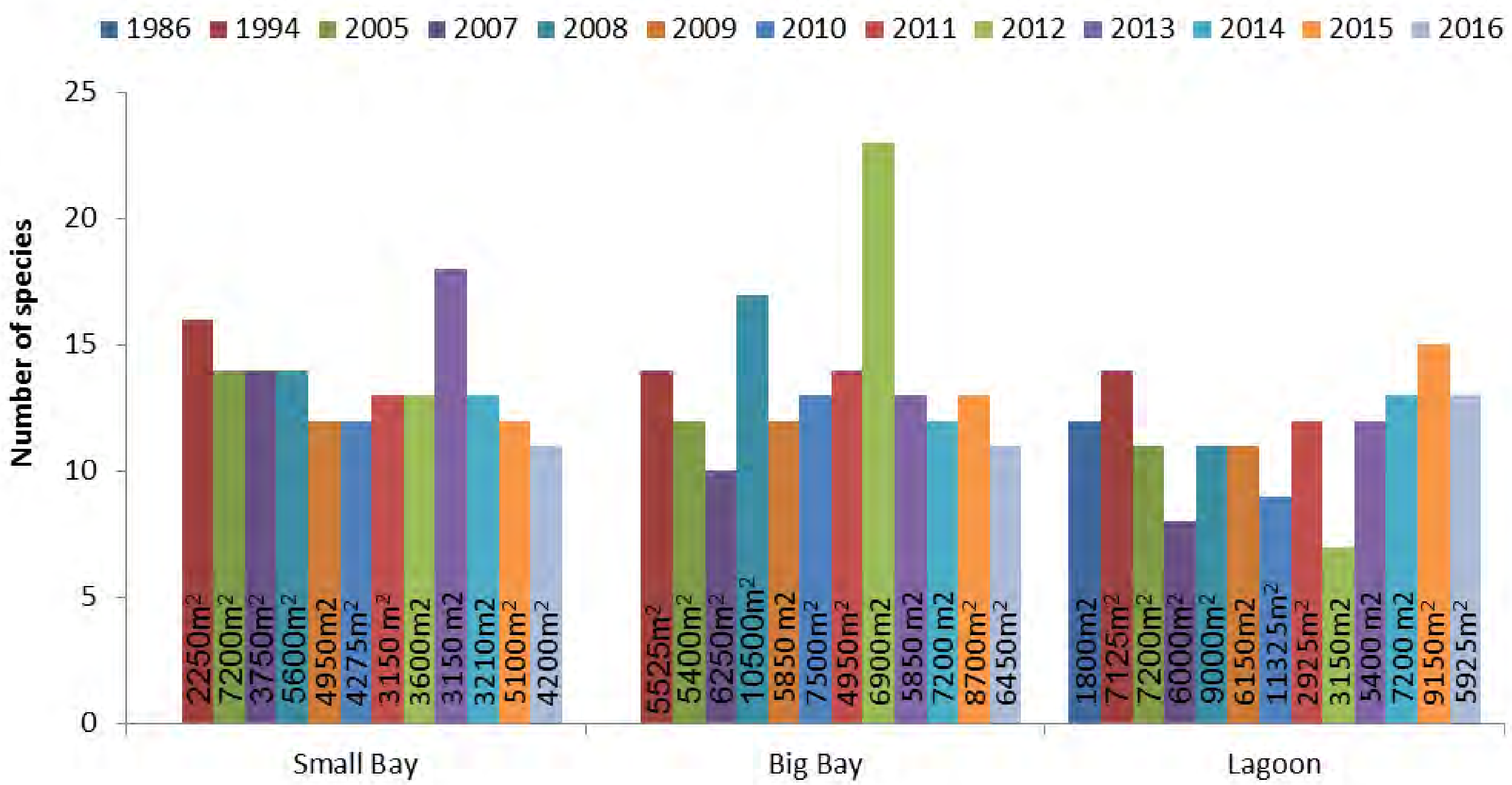


Figure 9.2 Fish species richness during 13 seine-net surveys in Saldanha Bay and Langebaan lagoon conducted over the period 1986-2016. The total area netted in each area and survey is shown. Note: The low species richness for Langebaan lagoon during 2012 is an artefact due to low sampling effort.

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. Within Small Bay, eight species occurred in all earlier surveys, but blacktail was absent for the first time in 2015, whilst pipefish that was only absent in the 2005 sample was again missing in the 2015 samples. Both blacktail and pipefish occurred in 2016 Small Bay samples. Gurnard, captured in all of the first six surveys but not over the period 2011-2014, was sampled at three sites in Small Bay during the 2015 survey, but was again absent in 2016. Four of the 35 species recorded in Big Bay occurred in all surveys (gurnard, Cape sole, harders and white stumpnose). Three more species, silversides, False Bay klipvis and elf are only absent in one survey each (2007, 1994, 2009 and 2014 respectively), whilst sandsharks were not caught in Big Bay during the 2014 and 2016 surveys. 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 seasonally or 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 12 sampling events average species richness has been similar in Small Bay and Big Bay (14 species) and slightly lower in the lagoon (11 species) (Figure 9.2).

9.3.2 Description of inter-annual trends in fish abundance 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 9.3). 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 sampling years. Overall, the catches made during the 2012 survey 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. Over the years 2014-2016 the overall abundance of fish has compared favourably with earlier surveys (Figure 9.4).

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 9.4). 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. The concerning trend in white stumpnose and blacktail abundance over the period 2012-2015 in Small Bay has, however, reversed, with the third highest white stumpnose abundance and second highest blacktail abundance recorded in 2016 Small Bay samples.

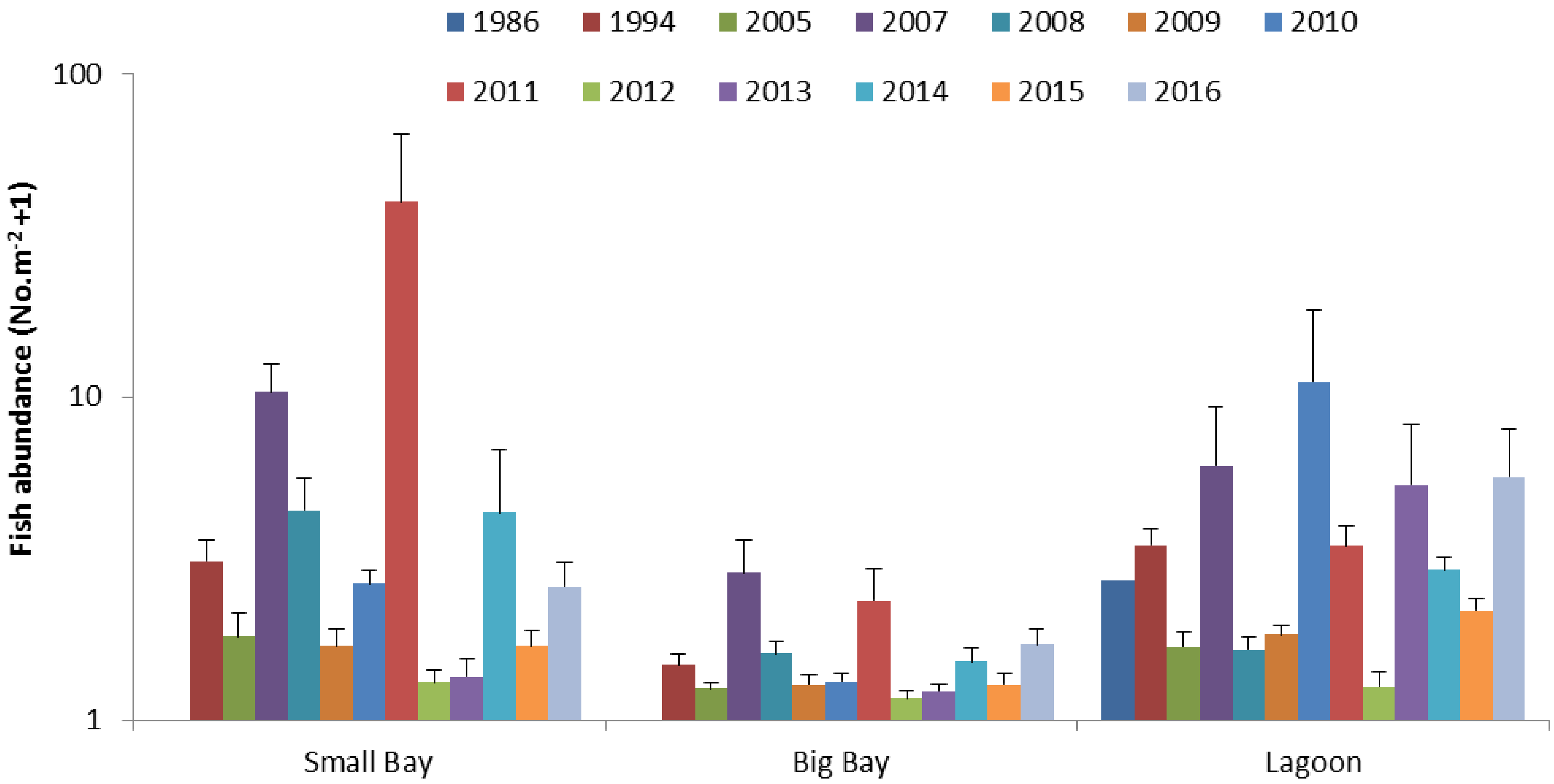


Figure 9.3 **Average fish abundance (all species combined) during thirteen seine-net surveys conducted in Saldanha Bay and Langebaan lagoon. (Error bars show one Standard Error of the mean). The data are transformed (x + 1) and displayed on a logarithmic axis.**

Within Big Bay too, average harder density observed during the 2013-2016 sampling was comparable to earlier surveys, but the abundance of white stumpnose and Cape sole remain low (Figure 9.4). White stumpnose abundance within Big Bay had recovered from the very low 2013 & 2014 estimates, but remained well below the long term average (Figure 9.4). After a two year absence, juvenile elf returned in good numbers in Big Bay in 2016, with the second highest abundance estimates to date. 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 2016 samples reveal better recruitment of most species to surfzone nursery habitats in all areas of the Bay and Lagoon, particularly encouraging was the improved white stumpnose and blacktail abundance estimates in Small Bay and the increase in elf recruits in Big Bay. The estimated abundance of the more common species in Langebaan lagoon during 2013-2016 compared favourably with earlier surveys (Figure 9.4). The exception in all cases was still white stumpnose. White stumpnose estimated abundance in Small Bay in 2016 (approximately 1 fish in every 8 m^2 of surfzone habitat) was still well below the 2007 peak abundance of 5 $fish.m^{-2}$, whilst Big Bay and Langebaan lagoon abundance estimates remained low compared to the average recorded during earlier surveys.

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 that 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 improved recruitment of most species seen during the 2016 survey suggests improved environmental conditions that facilitated survival of eggs, larvae and juveniles during the preceding summer. The continued low abundance estimates of juvenile white stumpnose however, suggest that the spawning capacity of the adult stock may be compromised.

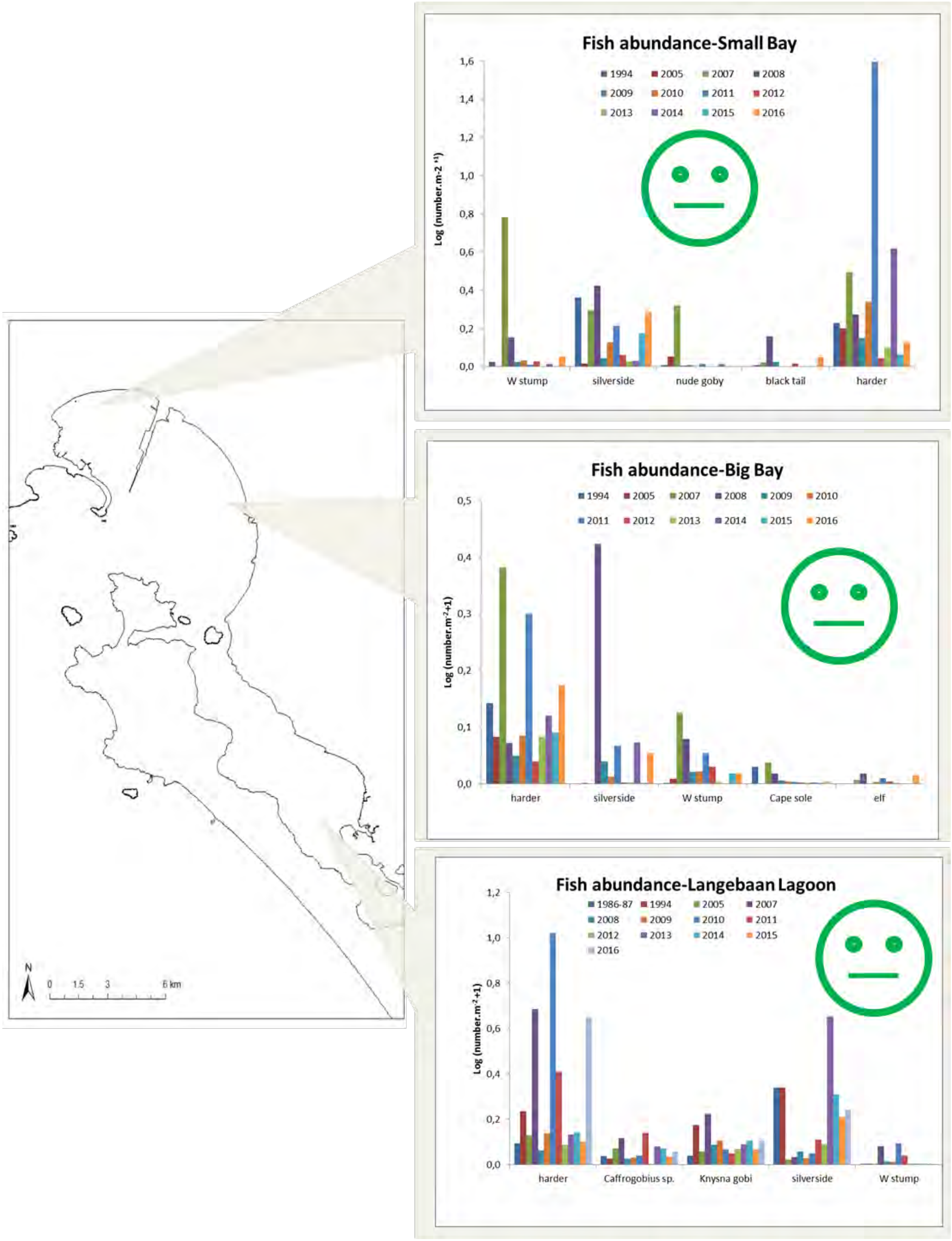


Figure 9.4 **Abundance of the most common fish species recorded in annual seine-net surveys within Saldanha Bay and Langebaan Lagoon (1986/87, 1994, 2005 & 2007-2016).**

9.3.3 Status of fish populations at individual sites sampled in 2015/2016

The average abundance of the four most common species in catches made during all earlier surveys and the most recent 2016 survey at each of the sites sampled is shown in Figure 9.5 Figure 9.6, and Figure 9.7. 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 silversides at most Small Bay sites in the 2016 survey were comparable to those recorded in earlier surveys, whilst harder abundance was lower than average at all sites (Figure 9.5). The average abundance of gobies at all sites is however; significantly lower than the average recorded over the previous twelve surveys. White stumpnose abundance during the 2016 survey was lower than the historical average at all sites, but not significantly so at the Bluewater Bay site where catches were close to average. At all the Big Bay sites, catches of harders and silversides during 2016 were either less than or greater than the historical average with no clear spatial trend (Figure 9.6). White stumpnose catches at four of the Big Bay sites were similar to or greater than the long-term average, but at the Seafarm dam and Leentjies klip sites that historically had the greatest abundance of white stumpnose amongst the Big Bay sites, catches were significantly down (Figure 9.6). Catches of silversides, harders and gobies at lagoon sites during 2016 were similar to the long term average; whilst white stumpnose density was significantly lower (Figure 9.7).

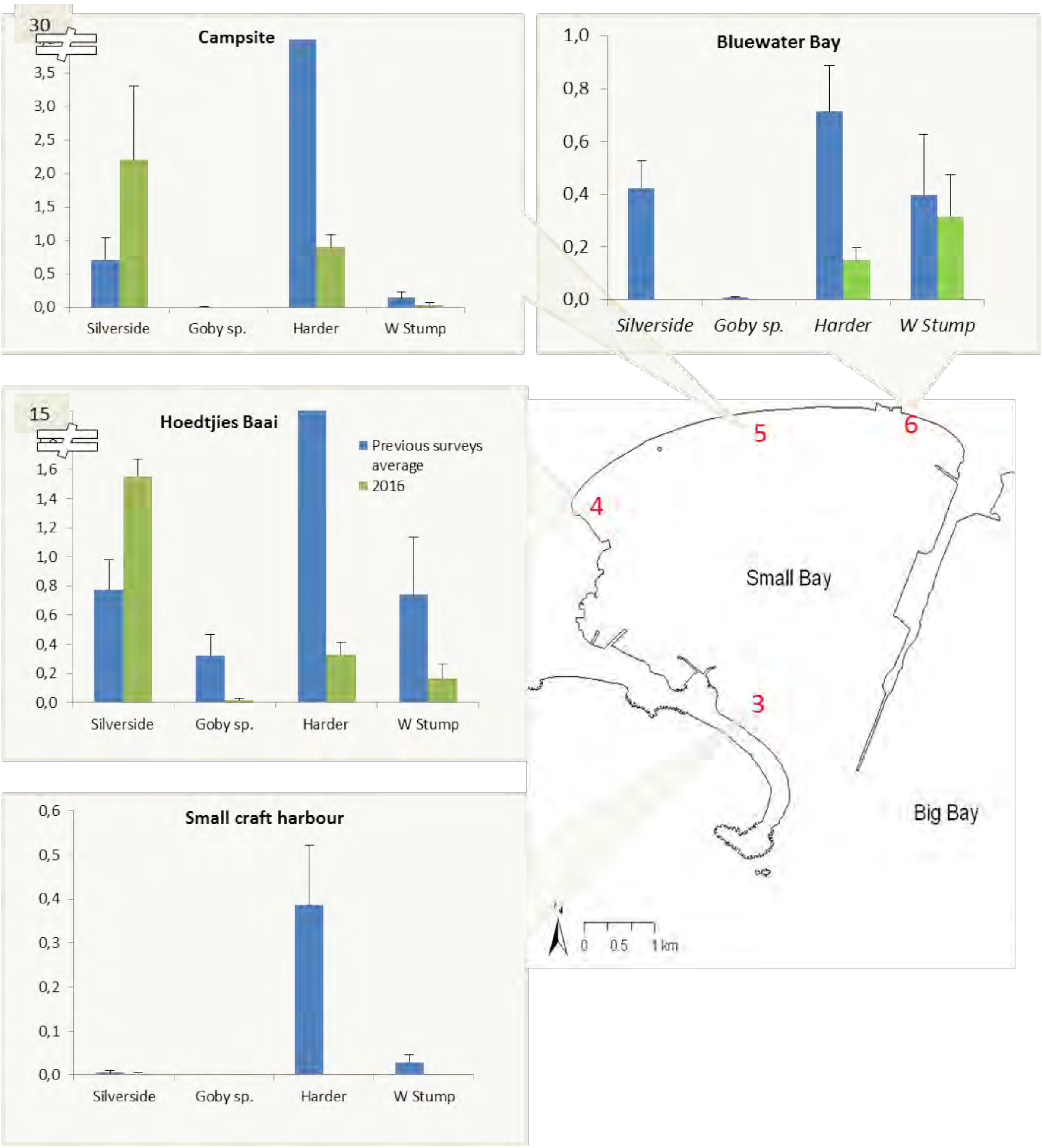


Figure 9.5 **Average abundance (No.fish.m^{-2}) of the four most common fish species at each of the sites sampled within Small Bay during the earlier surveys (1994, 2005, 2007-2015) and during the 2016 survey. Errors bars show plus 1 Standard error.**

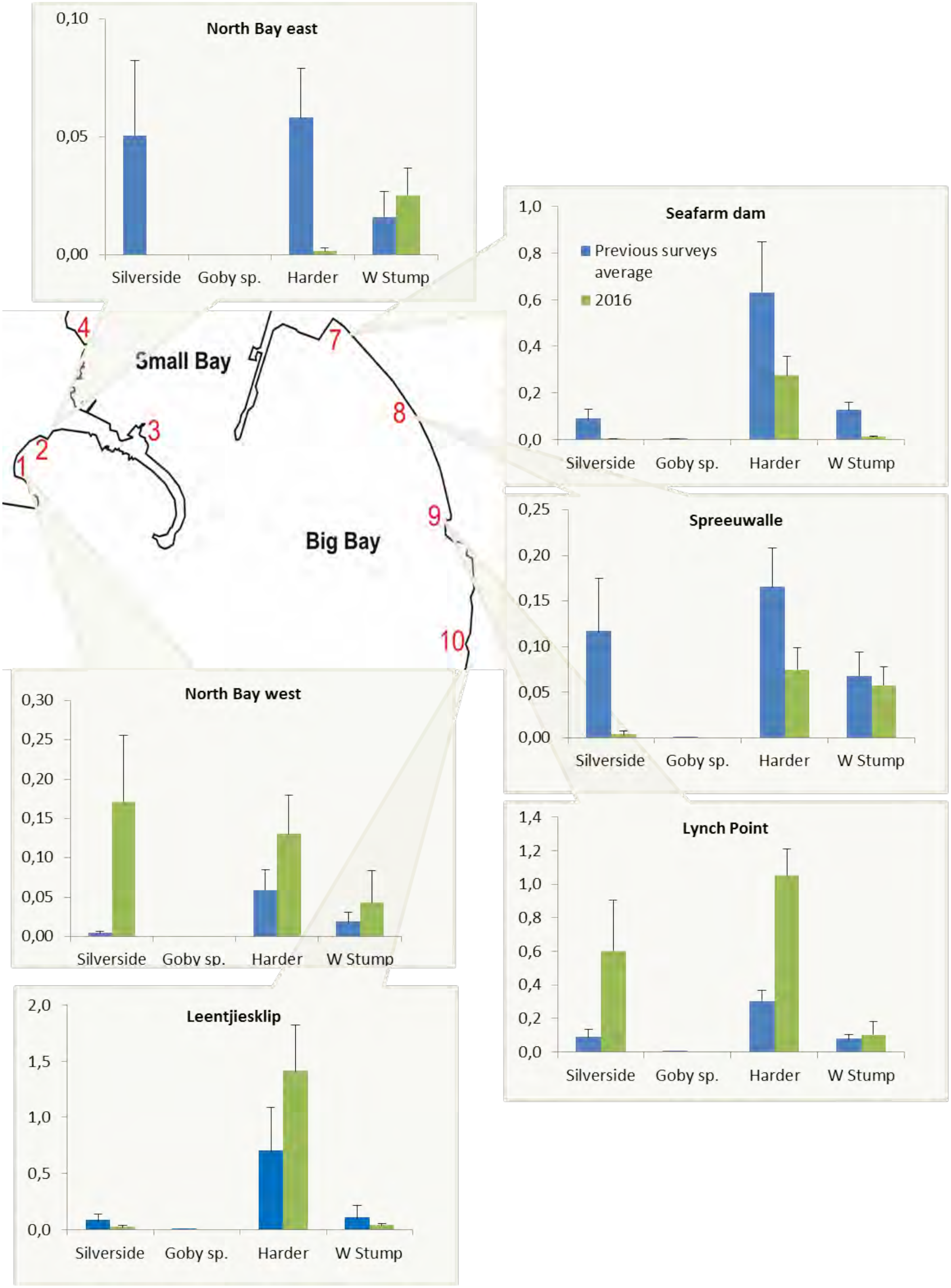


Figure 9.6 **Average abundance (#fish.m^{-2}) of the four most common fish species at each of the sites sampled within Big Bay during the earlier surveys (1994, 2005, 2007-2015) and during the 2016 survey. Errors bars show plus 1 Standard error.**

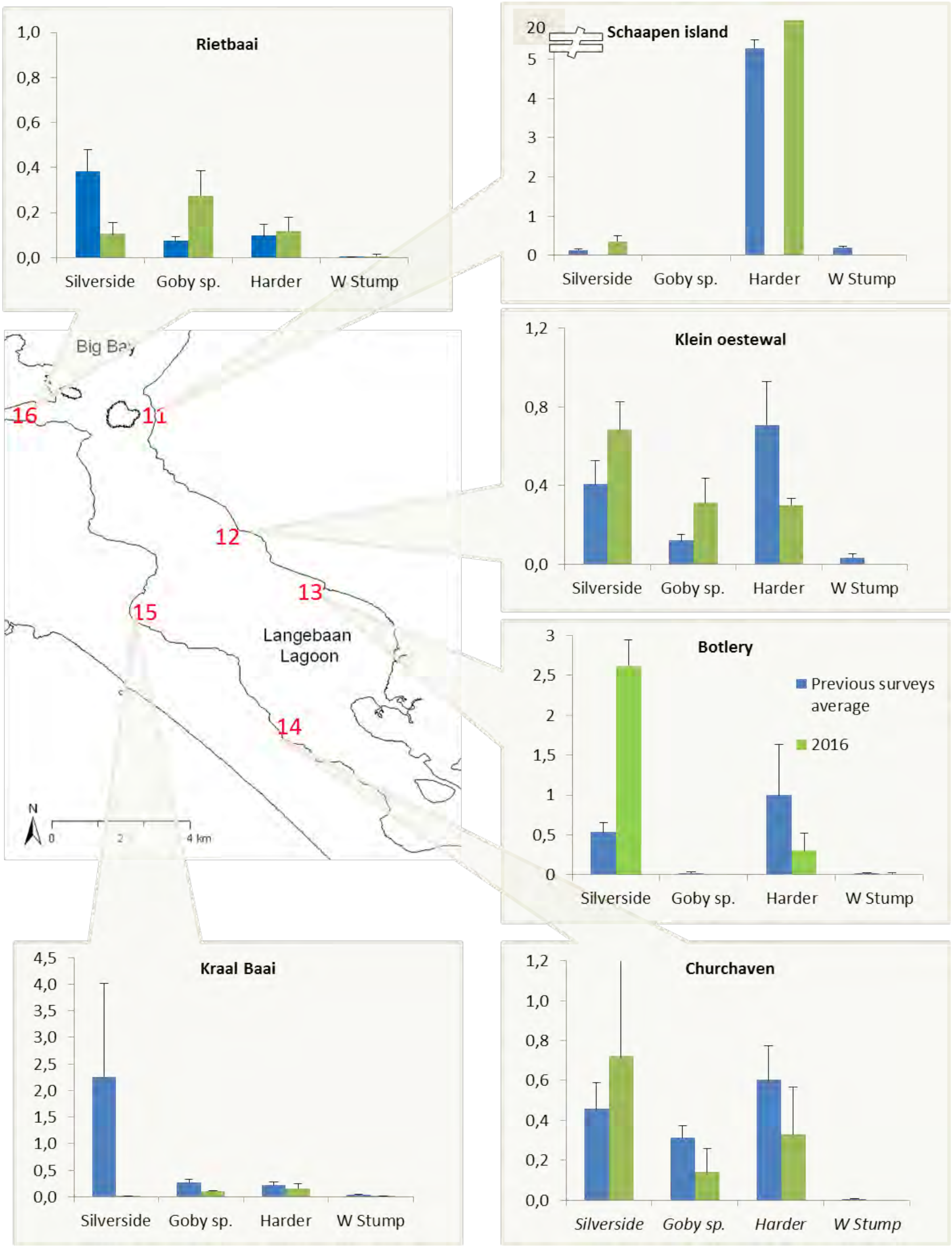
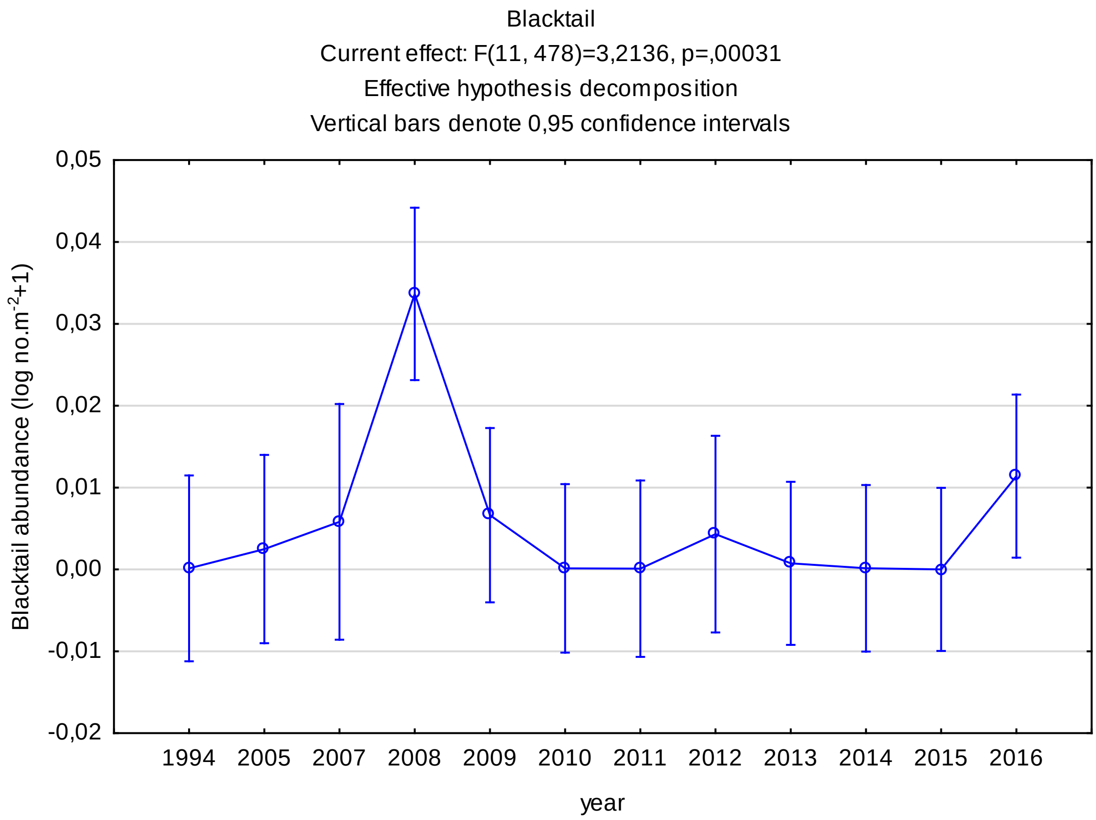


Figure 9.7 Average abundance (#fish.m^{-2}) of the four most common fish species at sites sampled within Langebaan lagoon during the earlier surveys (1994, 2005, 2007-2015) and during the 2016 survey. Errors bars show plus 1 standard error.

9.4 Temporal trends in key fishery species

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 most of the dominant species in Small Bay in surveys over the period 2008-2015 and a notable decrease in white stumpnose abundance throughout the system over this same period. The 2016 survey revealed some encouraging signs of increased white stumpnose recruitment in Small Bay, but this species remained scarce in Big Bay and Langebaan Lagoon. 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 in abundance 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 9.8, Figure 9.9 & Figure 9.10.). The density of blacktail juveniles in sampled habitats was significantly higher in 2008 than in all other years except 2007 and after an absence of blacktail recruits in the 2015 samples, above average recruitment was observed in 2016 (Figure 9.8). 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 9.8.). The abundance of juvenile harders in 2016 hauls was higher than average and only significantly less than that recorded in 2011. Estimated white stumpnose abundance in 2007 was significantly greater than all other years, whilst the estimated abundance during 2013-2015 surveys was less than during nearly all other survey years. Despite a small increase in abundance of juvenile white stumpnose, the 2016 white stumpnose estimate remained low and was not significantly different from the abundance estimates recorded post 2008. 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, 2012 & 2016. 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.



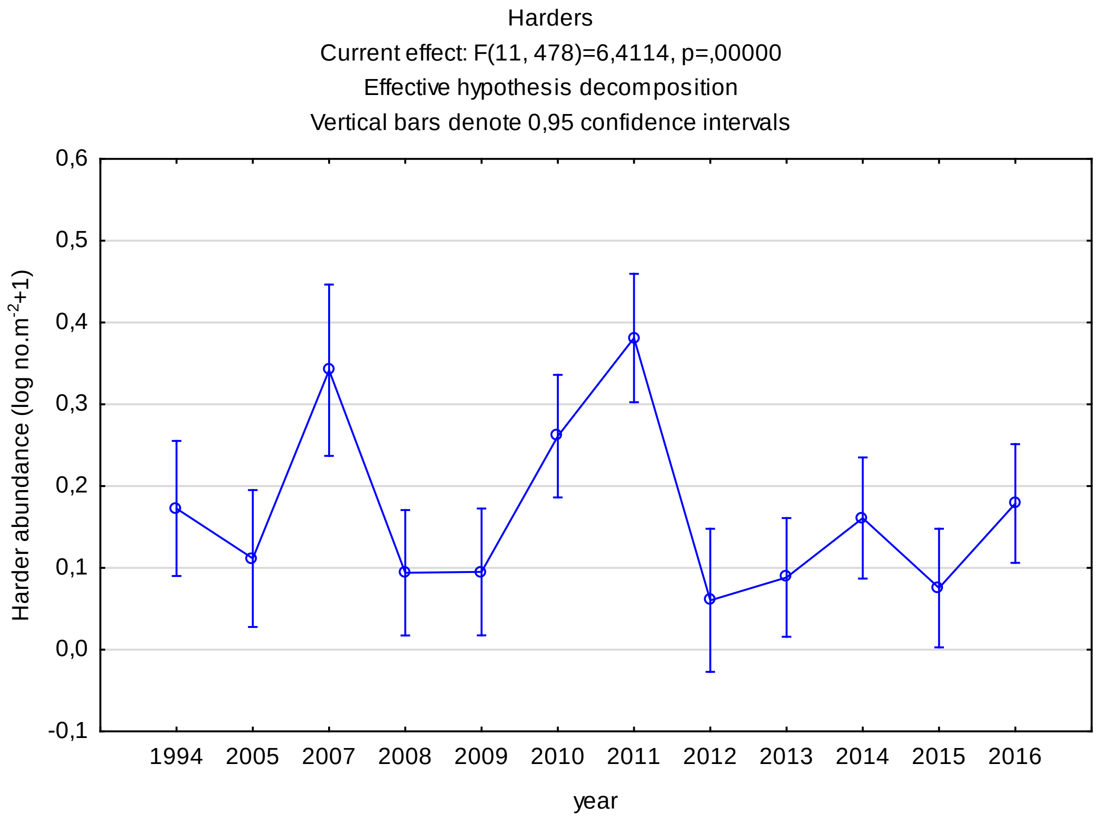
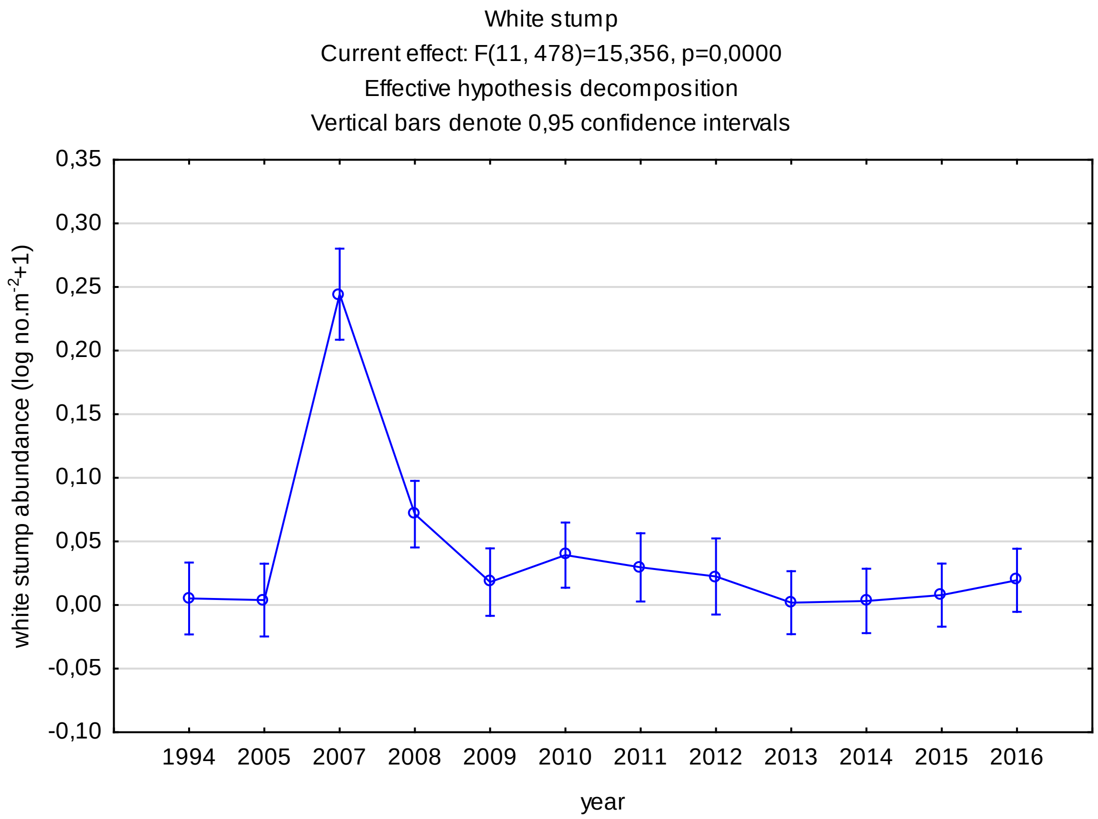


Figure 9.8 **ANOVA results comparing the average annual density of blacktail and harders at all sites sampled in all surveys (1994-2016).**



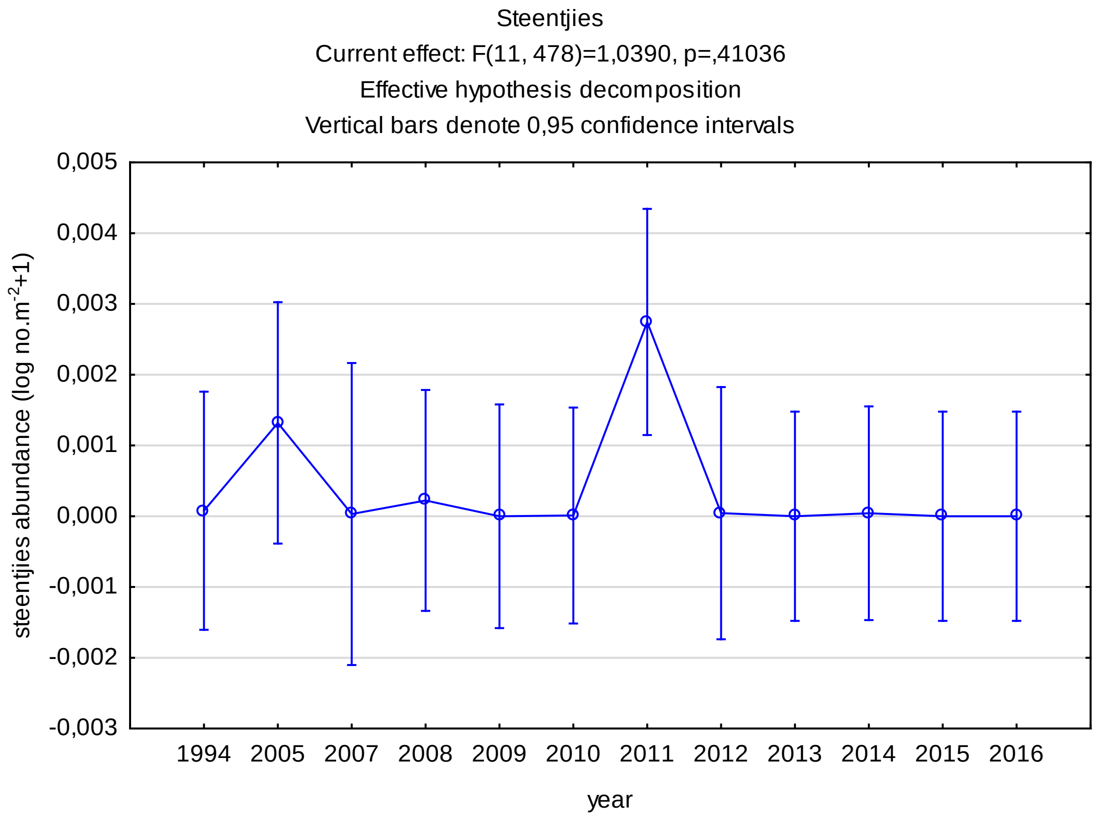


Figure 9.9 **ANOVA results comparing the average annual density of white stumpnose and steentjies at all sites sampled in all surveys (1994-2016).**

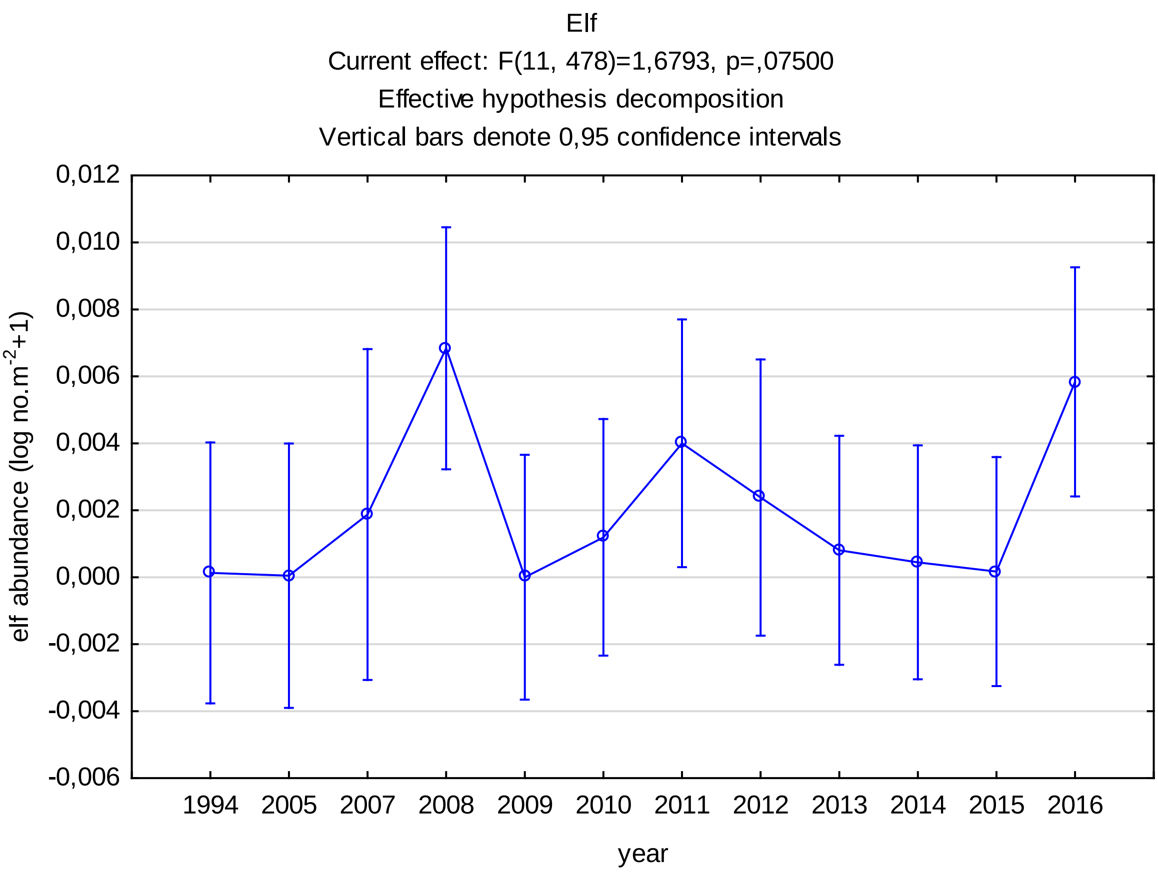


Figure 9.10 **ANOVA results comparing the average annual density of elf at all sites sampled in all surveys.**

9.5 Stock status of white stumpnose

The 2013-2016 seine net surveys 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 represent 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 implemented. This recommendation was reiterated in the 2015 report and analysis of commercial catch return data indicating a decline in catch-per-unit-effort (a measure of abundance) of adult white stumpnose was presented in conjunction with the evidence of poor recruitment from the seine net survey data. The 2016 survey revealed an encouraging increase in juvenile white stumpnose abundance in Small Bay, but when considering the Bay-Lagoon system as a whole, recruitment was still relatively poor. A more rigorous statistical analysis of the seine net survey data and the commercial catch return data by a team of fisheries scientists confirms the observed decline in both juvenile (seine net data) and adult white stumpnose abundance in Saldanha Bay over the last decade (Figure 9.11) (Parker *et al* in prep.). These authors recommend bag and size limit adjustments to ensure the sustainability of the Saldanha Bay white stumpnose fishery. Ongoing monitoring in the form of fishery and recruitment (seine net) surveys and an economic assessment of the recreational fishery to investigate implications of different management options is also recommended (Parker *et al* in prep.).

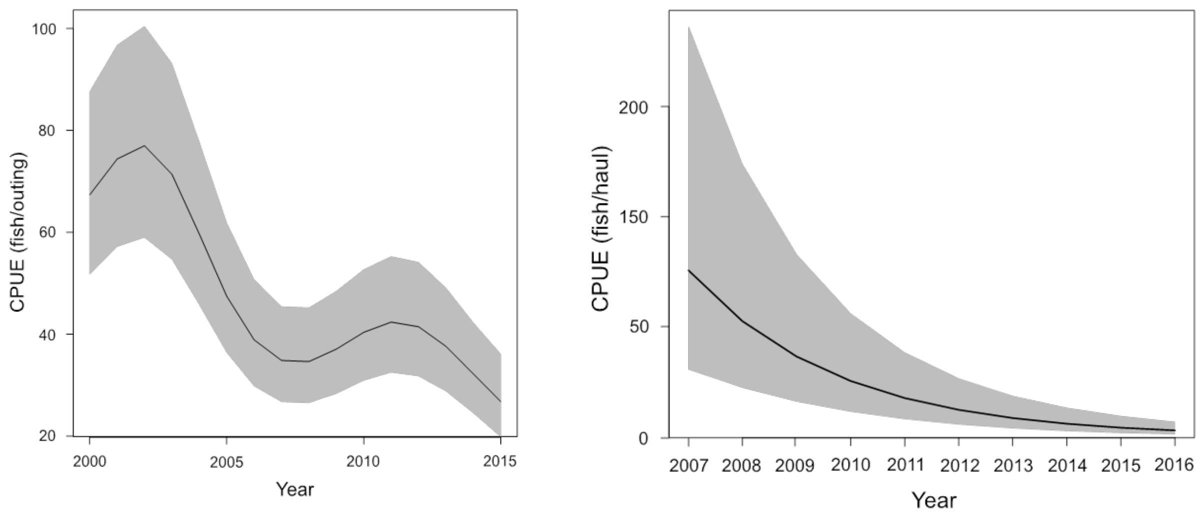


Figure 9.11 **Evidence of a decline in white stumpnose juvenile and adult abundance in Saldanha Bay. Left: Annual commercial boat CPUE estimates (± 95% CI). Right: Annual beach seine net CPUE estimates (± 95% CI) Source: Parker *et al* (in prep.)**

9.6 Conclusion

With the exception of white stumpnose, the current status of juvenile fish communities within Saldanha Bay-Langebaan lagoon appears satisfactory. Persistent declines in the abundance of common species within Small Bay recorded over the period 2011-2015 have reversed, with encouraging signs of recovery of white stumpnose and blacktail in 2016. The strong elf recruitment in Big Bay, evident in the 2016 sampling bodes well for the recreational fishery in coming years. 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 sampling began in 1986-87 has, with the exception of white stumpnose, not been detected for the principal species found in Saldanha 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 white stumpnose catch 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. The consistent declining trend in juvenile white stumpnose abundance in the nursery surf-zone habitats since 2007, and the observed declines in commercial linefish CPUE, 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 third time Anchor Environmental are making this recommendation in the State of the Bay Report and these recommendations are now also supported by a more statistically comprehensive analysis of fishery dependent and survey data (Parker *et al* in prep.).

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 1.1 fish.m^{-2} in Small Bay, over the period 2011-2016 this dropped to 0.04

fish.m^{-2} compared with the long term average of 0.08 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. These benefits should be quantified by an economic study of the recreational fisheries. The value of Small Bay as a fish nursery and the economic value of the resultant fisheries could then be quantitatively considered when the environmental impacts of the proposed future industrial developments within Small Bay are assessed.

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 the 2015 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 appear to be an isolated stock and there is good on site management presence in the form of SAN Parks 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.

Table 9.1 Average abundance of fish species (number.m^{-2}) recorded during annual beach seine-net surveys in Small Bay, Saldanha.

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	Mar-16
Argyrozona argyrozona	Silverfish								0,0002				
Atherina breviceps	Silverside	1,3084	0,0410	0,9690	1,6505	0,1088	0,3397	0,6420	0,1539	0,0644	0,0745	0,5024	0,941
Caffrogobius sp.	Goby	0,0160	0,1294	1,0888	0,0162	0,0194	0,0039	0,0307	0,0007	0,0011	0,0295	0,0011	0,005
Cancelloxus longior	Snake eel								0,0002	0,0008		0,0003	
Cheilidonichthys capensis	Gurnard	0,0022	0,0082	0,0003	0,0004	0,0006	0,0007					0,0014	
Chorisochismus sp?	Suckerfish sp.									0,0006			
Clinus heterodon	West coast Klipvis									0,0072			
Clinus latipennis	False bay klipvis					0,0004	0,0006			0,0017			0,009
Clinus robustus	Robust klipvis									0,0008			
Clinus sp. larvae	Klipvis larvae				0,0004								
Clinus superciliosus	Super klipvis	0,0080	0,0028	0,0090	0,0142	0,0030	0,0017	0,0250	0,0588	0,0003	0,0868	0,0003	0,016
Clinus venustris	Bluntnose klipvis									0,0017			
Cynoglossus capensis	Tongue fish											0,0003	
Dasyatis chrysonota	Blue Stingray									0,0011			
Diplodus sargus capensis	Black tail	0,0022	0,0178	0,0532	0,4437	0,0617	0,0011	0,0007	0,0390	0,0069	0,0014		0,122
Etrumeus terres	Red eye sardine	0,0009											
Gilchristella aestuaria	Estuarine round herring		0,0026										
Gonorhynchus gonorhynchus	Beaked sand eel		0,0001		0,0004								
Haploblepherus pictus	Dark Shy Shark					0,0002		0,0019	0,0011		0,0006		
Heteromycteris capensis	Cape sole	0,0049	0,0017	0,0162	0,0022	0,0258	0,0108	0,0185	0,0042	0,0039	0,0053	0,0192	0,008
Lithognathus sp	Steenbras sp.		0,0079										
Liza richardsonii	Harder	0,6951	0,5847	2,1429	0,8742	0,4181	1,1895	38,4739	0,1075	0,2625	3,1544	0,1601	0,346
Mustelus mustelus	Smoothhound shark	0,0027		0,0009									

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	Mar-16
Myliobatis aquila	Eagle ray	0,0013	0,0004	0,0079				0,0004					
Parablennius cornutus	Blenny									0,0014			
Pomatomus saltatrix	Elf	0,0009		0,0013	0,0003			0,0007			0,0030	0,0008	
Poroderma africanum	Striped catshark	0,0009											
Psammogobius knysnaensis	Knysna sand gobi						0,0028		0,0037	0,0011	0,0071	0,0088	0,0186
Raja clavata	Thornback skate			0,0011									
Rhabdosargus globiceps	White stumpnose	0,0618	0,0079	5,0564	0,4191	0,0562	0,0822	0,0244	0,0640	0,0019	0,0318	0,0074	0,131
Rhabdosargus holubi	Cape stumpnose												
Rhinobatos blockii	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	0,0007
Spondyliosoma emarginatum	Steentjie	0,0013	0,0092		0,0003			0,0237			0,0002		
Syngnathus temminckii	Pipe fish	0,0022		0,0037	0,0257	0,0004	0,0035	0,0033	0,0148	0,0069	0,0011		0,0012
Trachurus trachurus	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**	**1,60**
Number of species	**35**	**16**	**14**	**14**	**15**	**12**	**12**	**13**	**13**	**18**	**13**	**12**	**11**
Number of hauls	**127**	**5**	**12**	**6**	**12**	**12**	**12**	**12**	**9**	**12**	**11**	**12**	**12**
Total area sampled (m2)	**50435**	**2250**	**7200**	**3750**	**5600**	**4950**	**4275**	**3150**	**3600**	**3150**	**3210**	**5100**	**4200**

Table 9.2 **Average abundance of fish species (number.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	Mar-16
Argyrozona argyrozona	Silverfish											0,0001	
Atherina breviceps	Silverside	0,0003	0,0025		0,1257	0,0946	0,0289	0,1679	0,006	0,00611	0,18303	0,0037	0,134
Blennophis	Blenny sp.		0,0001		0,0001								
Brama brama	Angelfish								1E-04				
Caffrogobius sp.	Goby				0,0002	0,0031		0,0005	1E-04		0,00014		
Callorhinchus capensis	St joseph	0,0017							0,0002				
Cancelloxus longior	Snake eel		0,0001				0,0003	0,0004	0,0008	0,0001	0,0001	0,0001	2E-04
Cheilidonichthys capensis	Gurnard	0,0021	0,0079	0,0005	0,0054	0,0022	0,0001	0,0063	0,0001	0,0007	0,0014	0,0014	5E-04
Cheilidonichthys kumu	Bluefin gurnard								0,0002				
Chorisochismus sp?	Suckerfish sp.				0,0001								
Clinus latipennis	False Bay klipvis		0,0017	0,0003	0,0007	0,0007	0,0002	0,0002	0,0009	0,0006	0,0032	0,0011	5E-04
Clinus sp. larvae	Klipvis larvae				0,0027					0,00018	0,00194		
Clinus superciliosus	Super klipvis	0,0037			0,0017	0,0006	0,0002		0,0011	0,0012		0,0001	2E-04
Cynoglossus capensis	Tongue fish											0,0002	
Dasyatis chrysonota	Blue stingray					0,0004	7E-05						
Diplodus sargus capensis	Blacktail			0,0004	0,0009								4E-04
Engraulis japonicus	Anchovy						0,0002						
Galeichthyes feliceps	Barbell								0,0001				
Gonorhynchus gonorhynchus	Beaked sand eel	0,0005								0,0004			
Haploblepherus pictus	Dark shy shark					0,0002							
Heteromycteris capensis	Cape sole	0,0725	0,0014	0,0897	0,0433	0,0141	0,0107	0,0086	0,006	0,00426	0,00542	0,00265	0,01
Liza richardsonii	Harder	0,3877	0,2098	1,4077	0,1805	0,1201	0,2153	0,9968	0,0951	0,2099	0,3185	0,2319	0,492
Mustelus mustelus	Smoothhound shark	0,0013	0,0001						4E-04				

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**	**Mar-16**
Myliobatis aquila	Eagle ray	0,0049		0,0003									
Parablennius cornutus	Blenny							0,0002					
Pomatomus saltatrix	Elf	0,0005	0,0001	0,0159	0,0430		0,0068	0,0217	0,0101	0,0026	0,0008	0,0005	0,035
Psammogobius knysnaensis	Knysna sand gobi			0,0006				0,0006				0,00012	
Rhabdosargus globiceps	White stumpnose	0,003	0,0207	0,3358	0,2012	0,0501	0,051	0,1341	0,072	0,00704	0,00056	0,04356	0,047
Rhabdosargus holubi	Cape stumpnose							0,0007	0,0046				
Rhinobatos blockii	Bluntnose guitar fish	0,0066	0,0022	0,0029	0,0019	0,0001	0,0009	0,0009	0,0013	0,0002		0,0001	
Sardinops sagax	Sardine								0,0007				
Sarpa salpa	Streepie								0,0002				
Spondyliosoma emarginatum	Steentjie	0,0004	0,0004		0,0003				0,0002				
Syngnathus temminckii	Pipe fish	0,0002			0,0004	0,0002	0,0002	0,0002	0,0007	0,0002	0,0004		
Trachurus trachurus	Horse mackerel				0,0001				0,0002		0,0003		
Zeus faber	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**	**0,718**
Number of species	**36**	**14**	**12**	**10**	**17**	**12**	**13**	**14**	**23**	**13**	**12**	**13**	**11**
Number of hauls	**192**	**14**	**12**	**6**	**18**	**18**	**18**	**18**	**16**	**18**	**18**	**18**	**18**
Total area sampled (m2)	**81075**	**5525**	**5400**	**6250**	**10500**	**5850**	**7500**	**4950**	**6900**	**5850**	**7200**	**8700**	**6450**

10 BIRDS

10.1 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 saltpans 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).

This chapter presents time series data on the numbers of sea birds breeding on islands in Saldanha Bay. In previous editions of the State of the Bay report, this chapter has also presented data on numbers of water birds in Langebaan Lagoon, normally sourced from the Avian Demography Unity at the University of Cape Town. These data were unfortunately not available for 2016 and have thus been omitted from this volume.

10.2 Birds of Saldanha Bay and the islands

10.2.1 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), 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.

The Department of Environmental Affairs (DEA) conducts counts of seabirds on all islands to track population trends of each of these species over time. Each island is visted several times a year to ensure that each species is counted during its peak breeding season. The maximum counts for each species obtained in a calendar year are then used to estimate population sizes. All islands are visited roughly three times per calendar year with the exception of Malgas (nine times) and Vondeling (less than three times due to accessibility) (Rob Crawford, Department of Environmental Affairs, *pers. comm.* 2016). Section 10.2.1.1 shows long-term trends of each of these important seabirds and the African Black Oystercatcher, using the data collated by the DEA.

10.2.1.1 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 10.1.). 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 310 breeding pairs in 2015 (Figure 10.1.). 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.

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 2 000 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.

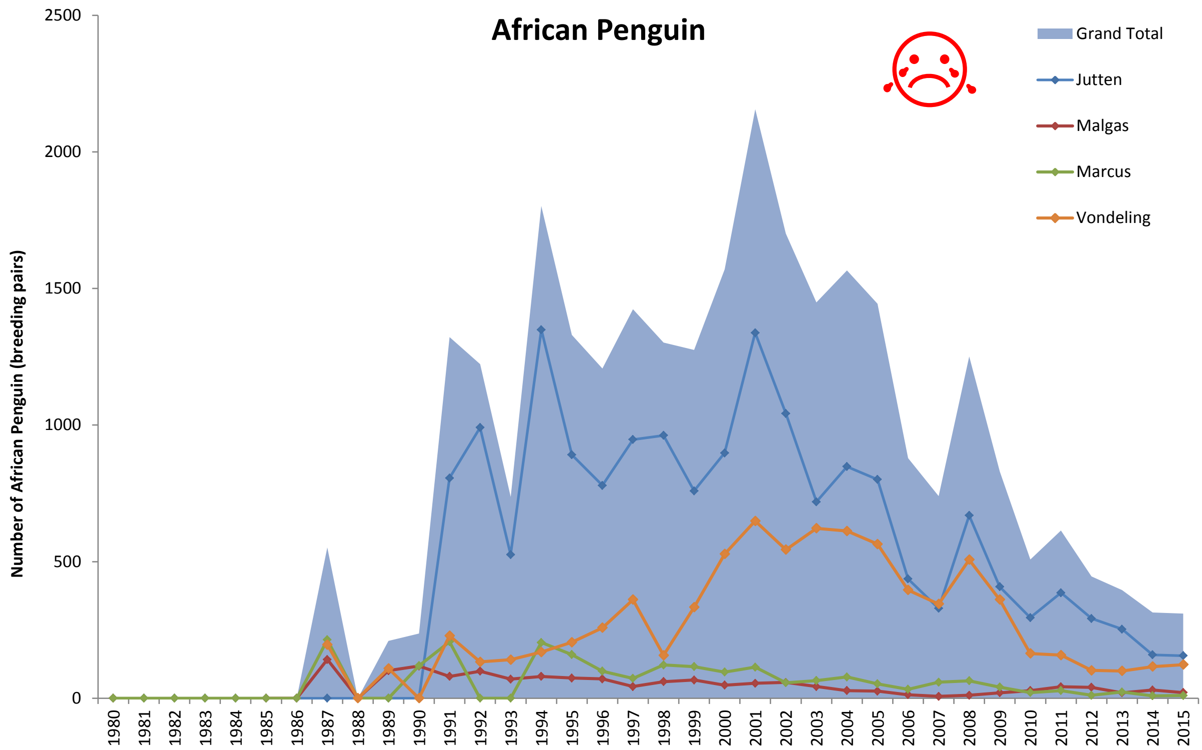


Figure 10.1. **Trends in African Penguin populations at Jutten, Malgas, Marcus and Vondeling islands in Saldanha Bay from 1980-2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).**

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 10.2.), 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 10.2.). Recent counts suggest that numbers are now well below those at the start of the comprehensive counting period.

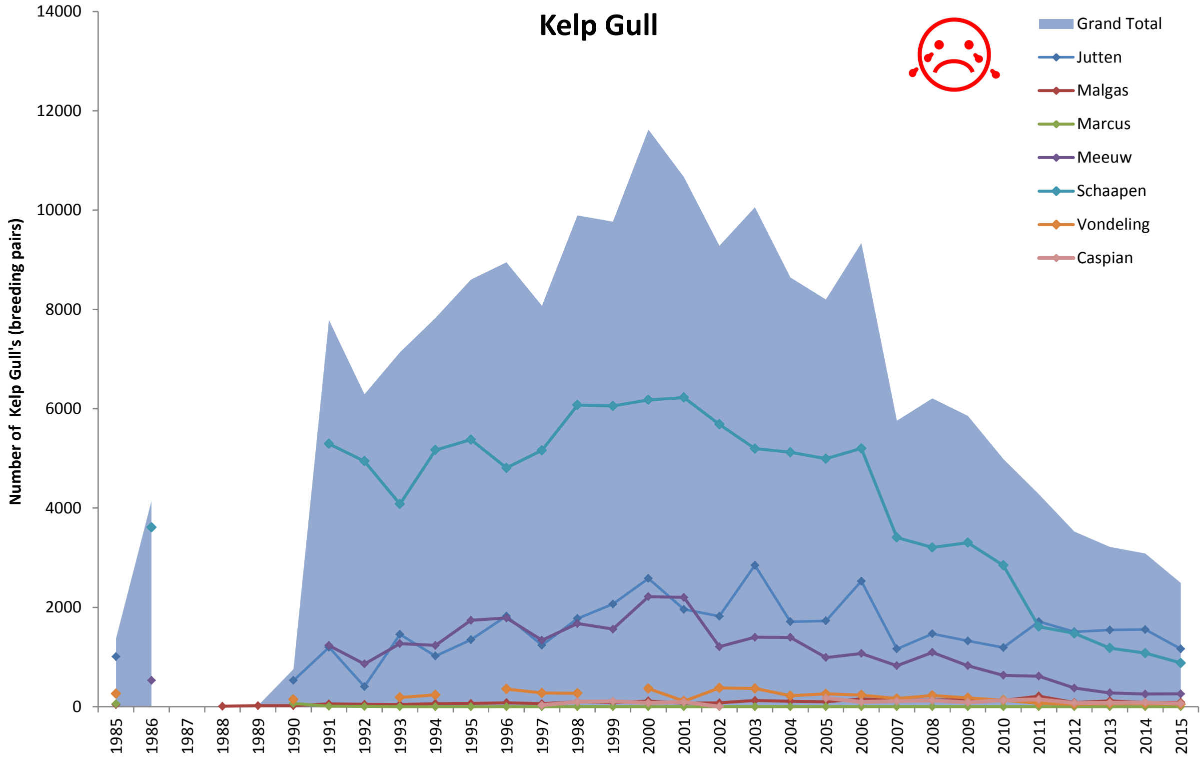


Figure 10.2. **Trends in breeding population of Kelp gulls at Jutten, Malgas, Marcus, Meeuw, Schaapen, Vondeling and Caspian Islands in Saldanha Bay from 1985 – 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).**

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 discernible 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 28 pairs in 2015 (Figure 10.3.). The total number of breeding pairs recorded in 2015 was 116.

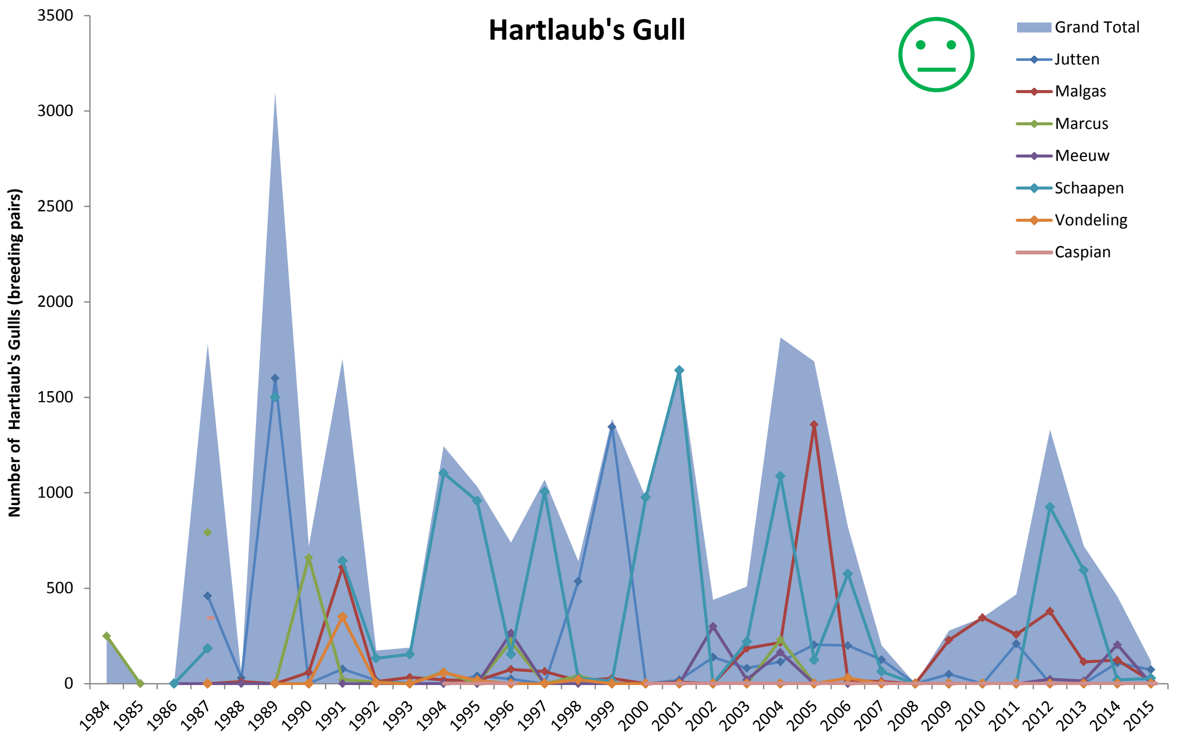


Figure 10.3. Trends in breeding population of Hartlaub's Gulls at Jutten, Malgas, Marcus, Meeuw, Schaapen, Vondeling and Caspian Islands in Saldanha Bay from 1984 – 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).

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. The steady increase in Swift Tern numbers between 2002 and 2005 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 retuned again in 2012-2014, with 543 breeding pairs recorded on Malgas, Jutten and Schaapen Islands in 2014 (Figure 10.4.). Numbers of Swift terns were low again in 2015, however.

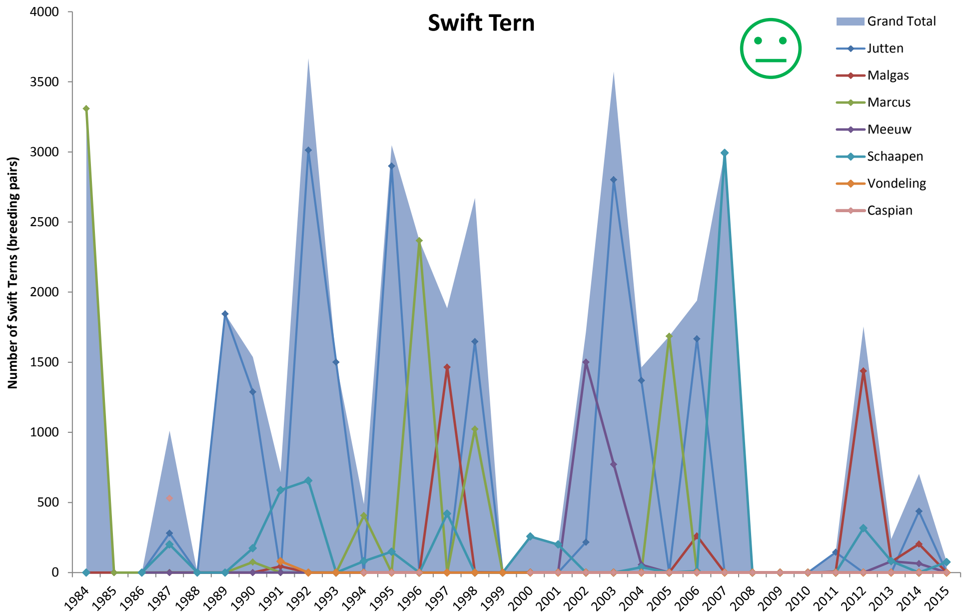


Figure 10.4. Trends in breeding population of Swift Terns at Jutten, Malgas, Marcus, Meeuw, Schaapen, Vondeling and Caspian Islands in Saldanha Bay from 1984 - 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).

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.

While population sizes of other seabirds on island in Saldanha are counted directly, Cape Gannet numbers are estimated from aerial photographs taken each year by the DEA. Nesting sites are outlined on the aerial photographs (distinction is made between roosting and nesting sites) and the total area is calculated by using a planimeter. During peak breeding season (usually in November), the DEA visits Malgas Island to estimate average nesting density per square metre by sampling 25 random 2 m^2 plots. Mean nesting density is then multiplied by the total nesting area to obtain an estimate of the number of Cape Gannet breeding pairs.

The bird colony at Malgas Island has shown population fluctuation since the early 1990's and a steady decline since 1996 (Figure 10.5.). 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 the declining to around 100 thousand pairs in 2013 (Data provided by Makhado *et al* 2016). 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 pusilus 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. 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 been declining steadily year on year since then.

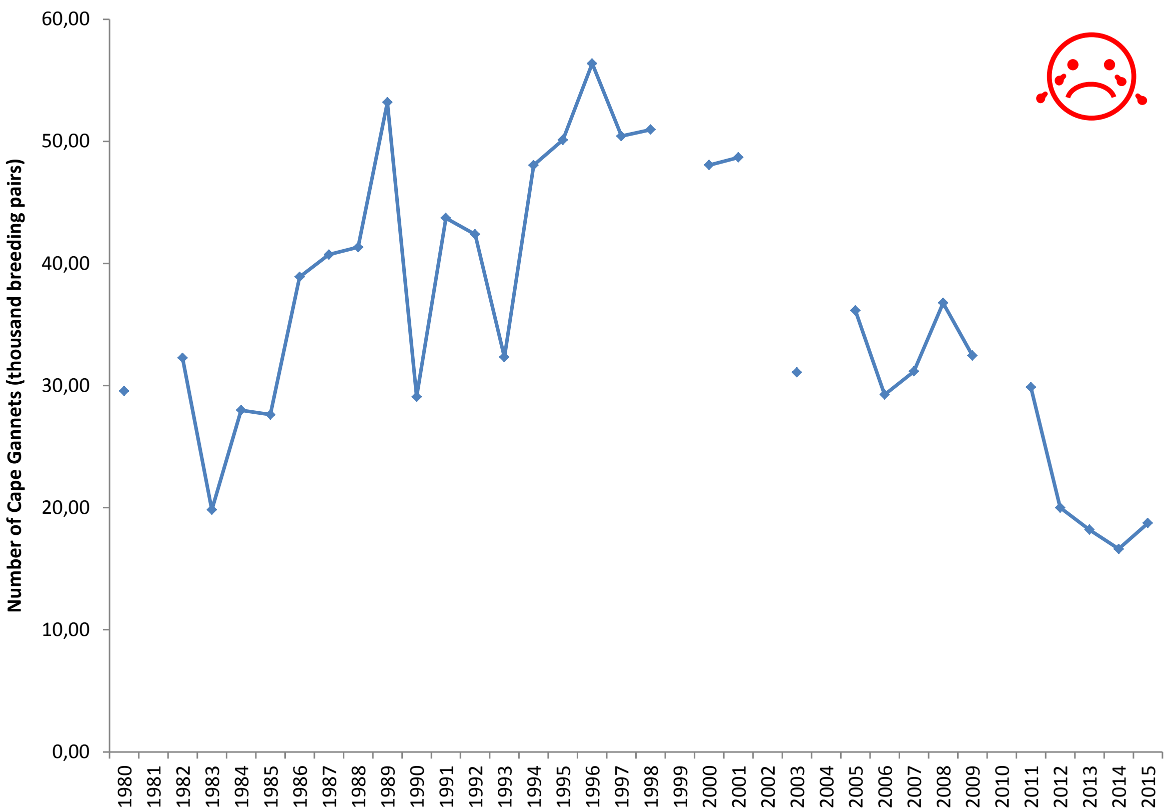


Figure 10.5. Trends in breeding population of Cape Gannets at Malgas Island, Saldanha Bay from 1980 – 2014 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).

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 bibarbatus*, 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 10.6.). Overall, the number of breeding pairs has declined substantially since the 1990s. In 2013, a total of only 801 breeding pairs were recorded, representing the lowest level recorded to date (Figure 10.6.). Although numbers of breeding pairs recovered in 2014 to a total of 8286 (Jutten Island contributing 77%), it remains to be seen if populations will continue to decline over time (in 2015, 5656 breeding pairs were counted).

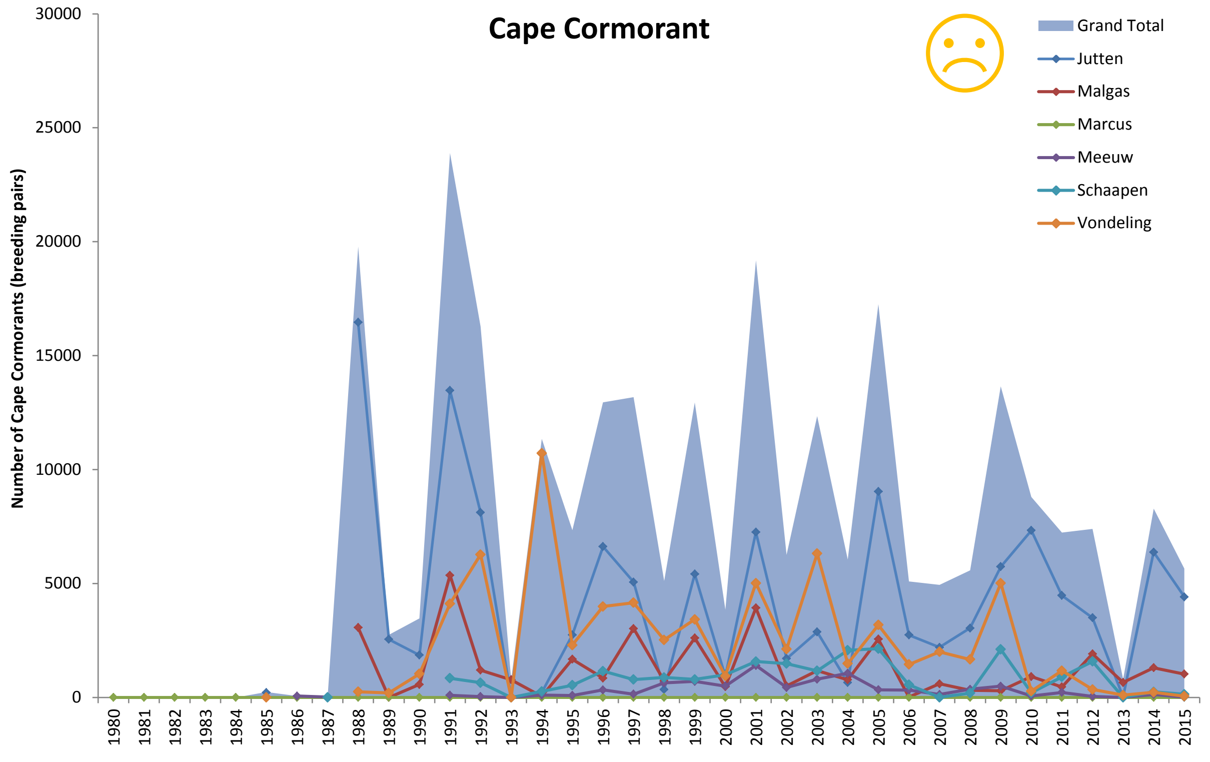


Figure 10.6. **Trends in breeding population of Cape Cormorants at Jutten, Malgas, Marcus, Meeuw Schaapen, and Vondeling islands in Saldanha Bay from 1980 – 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Oceans & Coasts, Department of Environmental Affairs).**

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 a 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 has declined steadily since 2003 on all the islands. Overall, the population in Saldanha Bay has declined drastically by approximately 89% since 1990 (Figure 10.7.). These 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.

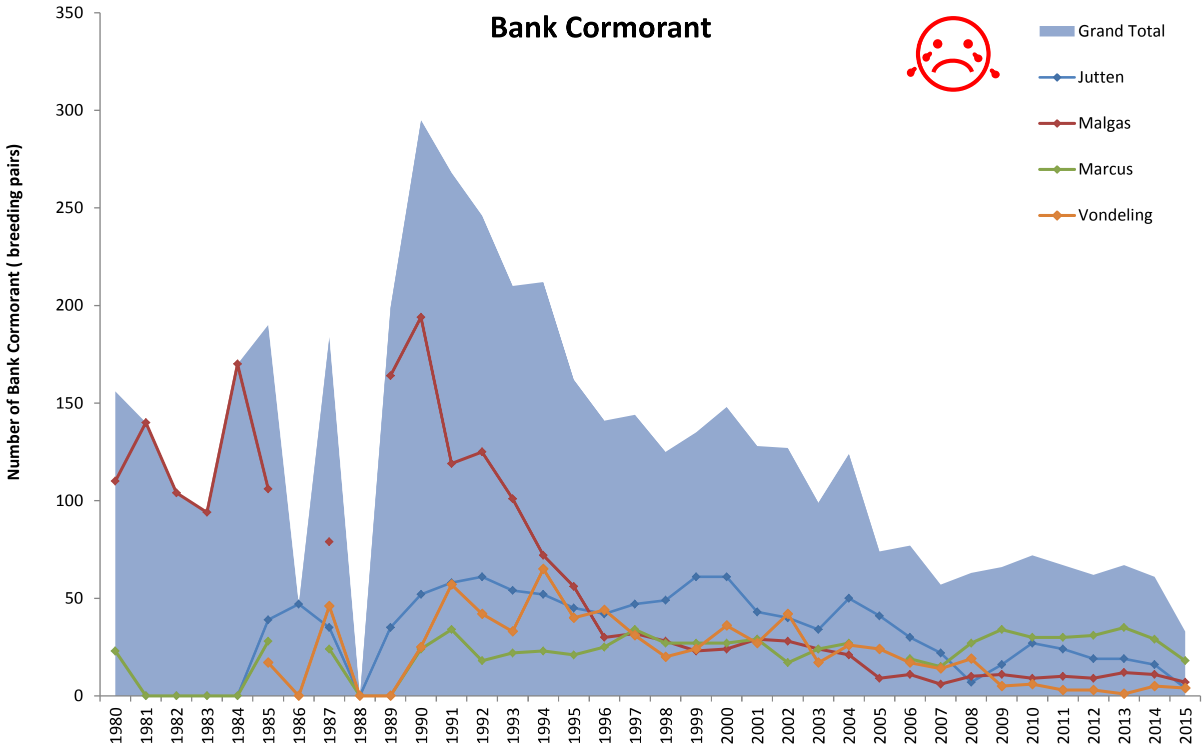


Figure 10.7. **Trends in breeding population of Bank Cormorants at Jutten, Malgas, Marcus and Vondeling islands in Saldanha Bay from 1980 – 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Oceans & Coasts, Department of Environmental Affairs).**

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 10.8.). Currently, numbers of white-breasted cormorant are at their lowest point since 1988 (22 breeding pairs) and it remains to be seen whether this decline marks the beginning of a negative 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.

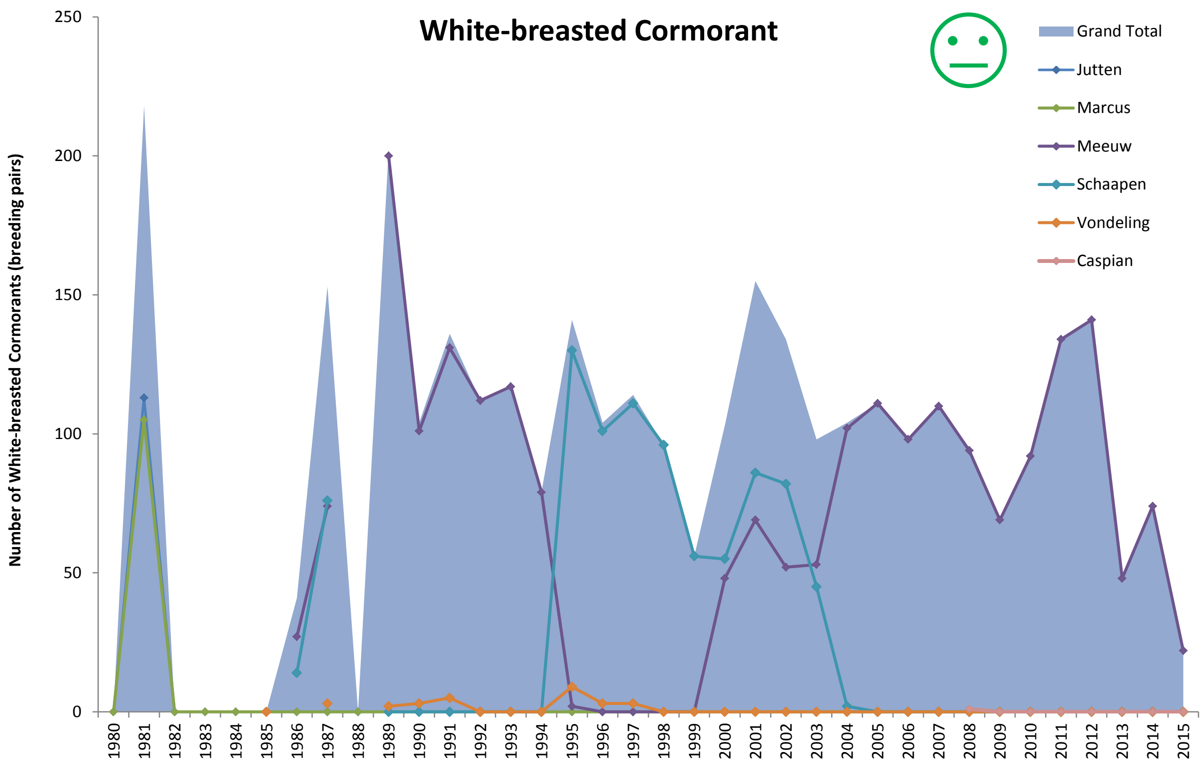


Figure 10.8. Trends in breeding population of White-breasted Cormorants at Jutten, Marcus, Meeuw, Schaapen, Vondeling and Caspian islands in Saldanha Bay from 1980 – 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).

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 10.9.). Since then, numbers have shown considerable interannual variations with an overall slow but decreasing trend (Figure 10.9.).

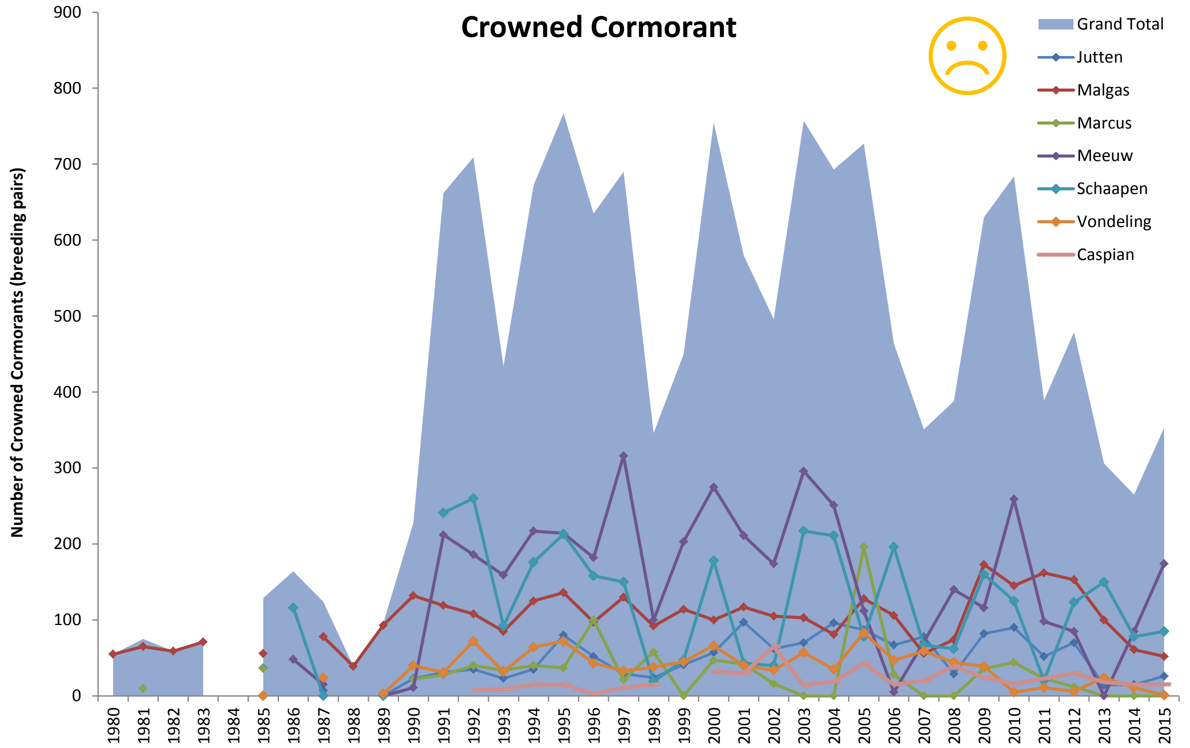
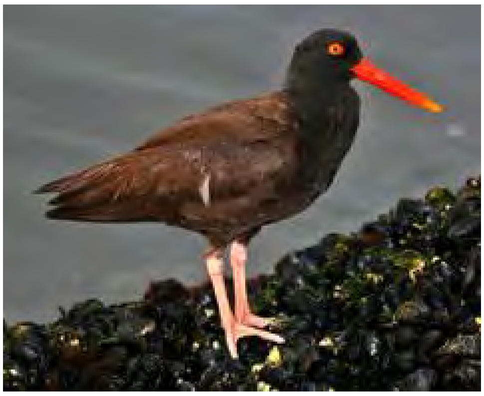


Figure 10.9. Trends in breeding population of Crowned Cormorants at the Jutten, Malgas, Marcus, Meeuw, Schaapen, Vondeling, and Caspian islands in Saldanha Bay from 1980 – 2015 measured in number of breeding pairs (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).



The **African Black Oystercatcher** *Haematopus moquini* is endemic to southern Africa. It is listed as Near Threatened in the IUCN's a Red Data List, owing to its small population and limited range (Birdlife International 2011). The African black oystercatcher breeds in rocky intertidal and sandy beach areas from Namibia to the southern KwaZulu-Natal coast. Their global numbers increased dramatically from the 1980s, which was attributed 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 their range. African Black Oystercatchers are resident on the islands, where highest numbers are encountered at Marcus, Malgas and Jutten Islands (Figure 10.10.). The islands in Saldanha Bay contribute a fair proportion to the global population that was estimated at 6670 in 2007 (Loewenthal 2007). The population stabilised in the early 2000s and has been steadily declining ever since (Figure 10.10.). 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. Continuous pressures are exerted on breeding success of these birds through human-induced habitat degradation, uncontrolled dogs predating on chicks and the drowning of chicks hiding from humans and their associated pets (Loewenthal 2007). In spite of the sad passing of the two champions of the Oystercatcher Conservation Project (Prof. Phil Hockey and Dr Douglas Loewenthal), regular censuses of oystercatchers in Saldanha Bay are still conducted by the DEA.

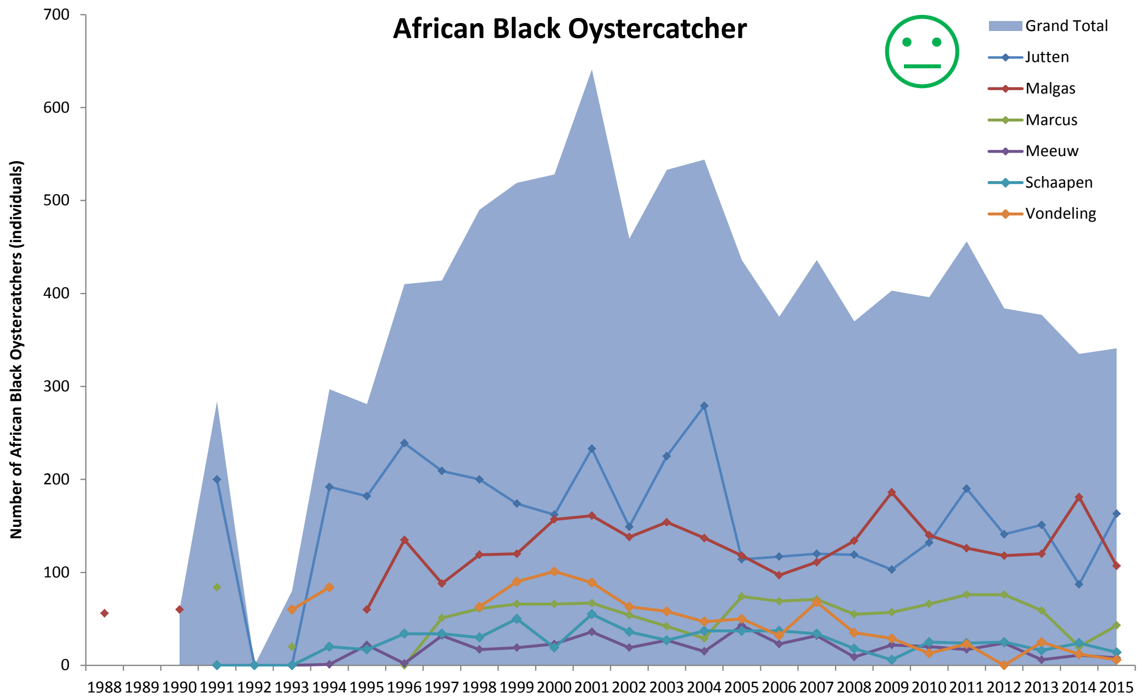


Figure 10.10. Trends in breeding population of African Black Oystercatchers on Jutten Malgas, Marcus Meeuw, Schaapen and Vondeling Islands from 1988 - 2015. (Data source: Makhado *et al* 2016, Department of Environmental Affairs: Oceans & Coasts).

10.3 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 as reported in previous versions of the State of the Bay Report 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.

11 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.

11.1 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 and 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 consider 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.

11.1.1 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 2.7% in Saldanha over the period 2001 to 2011 (Statistics South Africa 2014). Numbers of tourists visiting the area every year have also increased on average by 16% 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 particularly 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.

11.1.2 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 discernible 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.

11.1.3 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 m^3 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 it 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 issue mechanical and electrical equipment upgrades to the pump stations in Saldanha and Langebaan commenced in 2012 and thus far nearly all pump stations have been upgraded. In 2015, the White City pump station and main line in Saldanha Bay were upgraded (SBM, Gavin Williams, *pers. comm*. 2015) and implementation of upgrades will continue as and when required. 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 to upgrade the Saldanha Bay WWTW 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.

11.1.4 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. 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, ammonia nitrogen, COD and oil and grease. Some improvements are evident for TSS and ammonia nitrogen in the effluent; however, further drastic improvements are required to meet the minimum requirements in terms of the NWA Regulations. Considering that oil and grease is a contaminant commonly found in fish processing plant effluent, it is highly recommended that Sea Harvest continues monitoring as soon as possible.

11.1.5 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 combined 430 ha of sea space are currently available for aquaculture production in Outer Bay, Big Bay and Small Bay, of which 251 ha have been leased to 12 individual mariculture operators. Only 60% of these concession areas are actively farmed for mussels, oysters and finfish, mostly in Small Bay. 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. After many years of relatively static mariculture in Saldanha Bay, DAFF is proposing establishing a sea-based Aquaculture Development Zone (ADZ) in Saldanha Bay with the support of finances and capacity allocated by the Operation Phakisa Delivery Unit. It is likely that this will result in a large expansion in aquaculture production in Saldanha Bay with some potentially significant impacts on the environment.

No new alien species will be introduced for the ADZ to avoid the Alien and Invasive Species Regulations and Invasive Species Lists, which 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). However, in the light of recent efforts to culture exempt alien species in the marine environment, 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. It is recommended that farming of alien finfish such as Atlantic salmon and trout is done responsibly and with strict mitigation measures in place to prevent escapes.

11.1.6 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.

11.2 Water quality

11.2.1 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.

Anchor Environmental Consultants deployed temperature loggers in Small Bay near North Buoy in 2014/2015 and a salinity meter in Langebaan Lagoon in 2016. The temperature loggers were lost/stolen in 2015 but have now been replaced. Unfortunately, funds for monitoring of oxygen levels in Small and Big Bay have not yet been secured but it is hoped that this can be done soon.

11.2.2 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.

11.2.3 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.

11.2.4 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 the programme has since been discontinued. Since 2014 Anchor Environmental Consultants has been collecting mussel samples from the same five sites during the field survey for trace metal analysis. 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 qualities 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 Programme be revamped and possibly extended to cover other species as well (e.g. fish). As the high level of trace metals in nearshore bivalves in Small Bay is a human health concern, signs warning of the health risks of consuming coastal mussels in this area and discouraging their collection should be posted in areas where these bivalves are easily accessible (e.g. Hoedjiesbaai).

11.2.5 Microbiological monitoring (Faecal coliforms and Enterococci)

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 five sites exceeding the levels for safe mariculture practices, and three sites bordering on minimum requirements for safe recreational activities in 2015. There is a concerning trend of increasing faecal coliform levels at Pepper Bay and the authorities are advised to remain vigilant. Noticeable improvements were evident at Langebaan North, the Beach at the Caravan Park and Hoedjiesbaai Beach. Faecal coliform counts at all four sites in Big Bay were well within both the 80th 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 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 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.

11.3 Sediments

11.3.1 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. While there was a general decrease in trace metal concentrations in most sites sampled in 2016, Cd and Cu still remain above ERL guidelines in Small Bay (Yacht Club Basin) and enrichment factors for Cd, Pb and Cu remain extremely high. 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), total organic nitrogen (TON) 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) when budg*et al*lows. When budgetary constraints are in place, as in 2016, a sub-set of sites in Small Bay and Big Bay should continue to be monitored so that continuity in monitoring high impact areas is maintained. 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.

11.3.2 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 remained the same in 2016 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.

11.4 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. Similarly it is recommended that a programme to monitor changes in reeds (Phragmites) be initiated as this will assist in identifying any changes in groundwater inflows to Langebaan Lagoon in future.

11.5 Benthic macrofauna

Monitoring of benthic macrofaunal communities over the period 1999-2016 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.

11.6 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 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.

11.7 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. 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. A recent analysis of commercial and recreational linefish catch data and the net survey data by a team of fisheries scientists (Parker *et al.* in prep) strongly supports the implementation of some harvest control measures and recommends that a an economic study be undertaken to assess the value of the recreational fishery and the impacts of different management options.

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 1.1 fish.m^{-2} in Small Bay, over the period 2011-2016 this dropped to 0.04 fish.m^{-2} compared with the long term average of 0.08 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 2016 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.

11.8 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.

11.9 Alien invasive species

To date, 92 marine species have been recorded as introduced to South African waters, mostly though 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.

11.10 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 discernible 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.

11.11 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	Rating
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 monitor intestinal *Enterococci* 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)	1977-2016	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.	
Total organic carbon (TOC)	1974-2016	Elevated levels of TOC at the Yacht Club basin and near the mariculture rafts (negative impacts) are of particular concern.	

Parameter monitored	Time period	Anthropogenic induced impact	Rating
Total organic nitrogen (TON)	1974-2016	Similar trends as for 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	1980-2016	Cadmium, lead, and copper are currently elevated considerably above historic levels. Concentrations were highest in 1999 following major dredge event. Pb, Cu, Ni elevated in 2008-2015 and Cd, Cu, and Pb in 2016 at Yacht Club and multipurpose terminal, which may be related to lead ore exports and maintenance dredging.	
BENTHIC MACROFAUNA			
Species abundance, biomass, and diversity	1999-2016	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	1986-2016	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	1977-2016	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	
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	2014-2015	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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