OM'KUMOH AiJ
Joint Venture

Baseline Study of the Benthic and Rocky shore Biodiversity for the New Oil Receiving Jetty in the SADC Gateway Port Area in Walvis Bay

October 2018

ANCHOR environmental

Green Team Consultants

Anchor Environmental Consultants (PTY) Ltd and Green Team Consultants CC
Report No. 1790/4

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BASELINE STUDY OF THE BENTHIC AND ROCKY SHORE BIODIVERSITY FOR THE NEW OIL RECEIVING JETTY IN THE SADC GATEWAY PORT AREA IN WALVIS BAY

OCTOBER 2018

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TABLE OF CONTENTS

LIST OF ACRONYMS

Acronym	
BCLME	Benguela Current Large Marine Ecosystem
BCS	Benguela Current System
CC	Closed Corporation
CD	Chart Datum
CITES	Convention on International Trade in Endangered Species
CMECS	Coastal and Marine Ecological Classification Standard
CTD	Current, Temperature, Depth
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
EIS	Environmental Information Service
EMP	Environmental Management Plan
ERL	Effects Range Low
ERM	Effects Range Median
ESIA	Environmental and Social Impact Assessment
FGDC	Federal Geographic Data Committee
GHG	Greenhouse Gas
IAP	Interested and Affected Party
IBA	Important Bird Area
IFC	International Finance Corporation
IUCN	International Union f or the Conservation of Nature
JV	Joint Venture
MME	Ministry of Mines and Energy
MPA	Marine Protected Area
N/A	Not applicable
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
PAH	Poly-aromatic hydrocarbons
(PTY) Ltd	Proprietary Limited
TOC	Total Organic Carbon
SADC	Southern African Development Community
SADCO	Southern African Data Centre for Oceanography
WB	Walvis Bay

DOCUMENT CONTROL

Statement of Purpose

The purpose of this document is to produce a supplementary marine baseline report for the marine environment at the National Oil Storage Facility Jetty in Walvis Bay. This project is a Joint Venture (JV) between Anchor Environmental Consultants (Pty) Ltd (Anchor) and Green Team Consultants CC (Green Team) and is being undertaken for Om'kumohAIJ JV. This report is in context of the provisions of ecological, marine, environmental and geospatial technology best practices.

Confidentiality

This report contains Confidential Information provided by Anchor Environmental Consultants (Pty) Ltd and Green Team Consultants CC JV and should not be disclosed to third parties or personnel not directly involved in this project.

SPECIALIST DECLARATION

I, Dr Barry M Clark, declare that -

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of regulations and guidelines that have relevance to the proposed activity;
- I will comply with all applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority; and
- all the particulars furnished by me are true and correct.

Dr Barry M Clark 09th October 2018

Anchor Environmental Consultants (Pty) Ltd & Green Team Consultants cc Joint Venture

EXECUTIVE SUMMARY

The Ministry of Mines and Energy (MME) on behalf of the Government of Namibia is implementing the National Oil Storage Facilities Project to increase the strategic fuel reserve capacity and the security of fuel supply for Namibia. A new petroleum product receiving terminal is being constructed as part of this project to the north of the Walvis Bay Port area. An Environmental Impact Assessment (EIA) was undertaken for this development, and the accompanying Environmental Management Plan (EMP) included requirements for baseline studies to be undertaken prior to project implementation. The EIA incorporated a number of specialist studies, including a marine specialist scoping report, to identify potential impacts of the project. A pre-construction baseline survey was conducted for benthic and intertidal beach biodiversity in 2015 (Botha 2015) and this report is supplementary to those data.

Additional quantitative information collected in June 2018 includes:

- Sandy beach macrofaunal data and sediment particle size information
- Rocky intertidal data of flora and fauna present on the shore
- Benthic macrofaunal data
- Benthic heavy metal and hydrocarbon analysis within and around the proposed dredge channel
- Benthic particle size distribution data within and around the proposed dredge channel
- Water quality profiling in the dredge area
- Coastal bird survey data
- Surf-zone fish data
- Habitat mapping within a 30 km radius of the Oil and Gas Jetty

It is recommended that an annual monitoring programme is implemented for the operational lifetime of the oil and gas terminal. Field work should be conducted during the same month as the baseline survey and the same methods should be used to ensure that results are comparable. Benthic sediment samples should be collected and analysed for heavy metals and hydrocarbons to monitor for pollution impacts. In terms of ecological monitoring, rocky intertidal surveys and sandy beach surveys should be conducted annually, but due to the low abundance of benthic macrofauna and surf-zone fish, these aspects may be dropped from the scope of work. Due to the elevated levels of cadmium, copper and nickel in benthic sediments, it is recommended that a biomonitoring programme is initiated within each mariculture facility to monitor the safety of bivalves for human consumption.

1 INTRODUCTION

1.1 Terms of Reference (ToR)

The Ministry of Mines and Energy on behalf of the Government of Namibia is implementing the National Oil Storage Facilities Project to increase the strategic fuel reserve capacity and the security of fuel supply for Namibia. A new petroleum product receiving terminal is being constructed as part of this project to the north of the Walvis Bay port area (Figure 1.1). An Environmental Impact Assessment (EIA) for this development was undertaken by Botha *et al*. (2013), and included a specialist scoping study on potential impacts of the project on the marine environment (Hooks and Duvenhage 2013). The subsequent Environmental Management Plan (EMP) included requirements for baseline studies to be undertaken prior to project implementation (Botha *et al*. 2015a).

The authors of the marine scoping report highlighted the fact that "information on benthic and seashore communities in the Walvis Bay area is limited" and recommended that a "pre-construction baseline survey on benthic and intertidal beach biodiversity be conducted that would serve as a pre-development reference for follow up monitoring surveys to assess any impacts resulting from dredging and or fuel spillage events" (Hooks and Duvenhage 2013). This was undertaken in 2015 (Botha 2015) and this report is supplementary to those data. This study is based on review of previous environmental studies, the EIA and EMP for Walvis Bay, the scientific literature, and extensive field studies of the jetty and the surrounding area.

The broad objectives of this project are to:

- produce habitat maps compatible with geographic information system tools,
- document representative marine life within a 30 km radius of the National Oil Storage Facility Jetty,
- highlight and address information gaps,
- identify vulnerable species and habitats, and
- recommend suitable habitat monitoring.

1.2 Study Team

Anchor Environmental Consultants (Pty) Ltd/Green Team Consultants Joint Venture was appointed on 07th March 2018 by Om'kumoh AIJ JV on behalf of the Ministry of Mines and Energy to carry out a Baseline Study of the Benthic and Rocky shore Biodiversity for the New Oil Receiving Jetty in the SADC Gateway Port Area in Walvis Bay from 02nd April 2018 to 25th October 2018, as part of recommendations and requirements from the subsequent Environmental Management Plan (EMP) prior to project implementation. The project team is summarised in the table below. Staff holding key positions such as study leadership, task leadership, reviewers, and specialist teams are listed.

Project position	Person	Speciality	Highest qualification	Work experience
Team leader	Dr Barry Clark	Marine ecologist, fish expert	PhD Zoology	25 years
Lead author	Dr Megan Laird	Marine ecologist, invertebrate taxonomist	PhD Zoology	5 years
Second author	Dr Kenneth Hutchings	Marine ecologist and Commercial Class IV diver).	PhD Zoology	10 years
Technical support	Dr Dhanya Muralidharam Nambiar	Marine ecologist, fish expert	PhD Zoology	25 years
Technical support	Michael S Lukubwe	Geographical Information System (GIS) Expert	M.Sc. GIS	8 years
Technical support	Ganesan Singh Rajasekar	Geographer , GIS expert	M.Sc. Geography	20 years
Stakeholder consultation	Sakaria Hivulwa Nalusha	Geologist, Sampler	B.Sc. Geology	6 years

1.3 Information gaps

The scoping study described the shoreline between Walvis Bay and Langstrand (Long Beach) as consisting of sandy upper shores with a large section of mixed rocky and sandy intertidal beach from just south of the Guano Platform (Bird Island) to just north of the Langstrand camp site (Hooks and Duvenhage 2013). No quantitative surveys were undertaken but a list of fauna and flora that occur in the area was provided. Offshore habitats are described as including most soft sediment (sandy) habitats with scattered inshore reefs. Samples of sediment were collected with a Van Veen grab from 12 sites and an indication of the abundance (sparse/present/abundant/super-abundant) of different species present in each sample was provided in the EIA report (Botha *et al*. 2013). Rocky and sandy shores as well as offshore soft sediment habitat and surf-zone fish were surveyed in this study to provide comprehensive data before the tanker berth becomes operational. These were compared to existing data to determine whether seasonal variance is detectable in this area.

1.4 Ongoing monitoring

Ongoing environmental monitoring activities according to the Environmental Management Plan at the Tanker Berth and Tank Farm include:

- Dredged Sediments Monitoring
- Water Quality
- Noise Impact on Mammals
- Waste Water Disposal and Waste Management
- Coastal Protection
- Turbidity Monitoring

Results are briefly summarised in this report, however, long-term data comparisons do not fall within the terms of reference for this study.

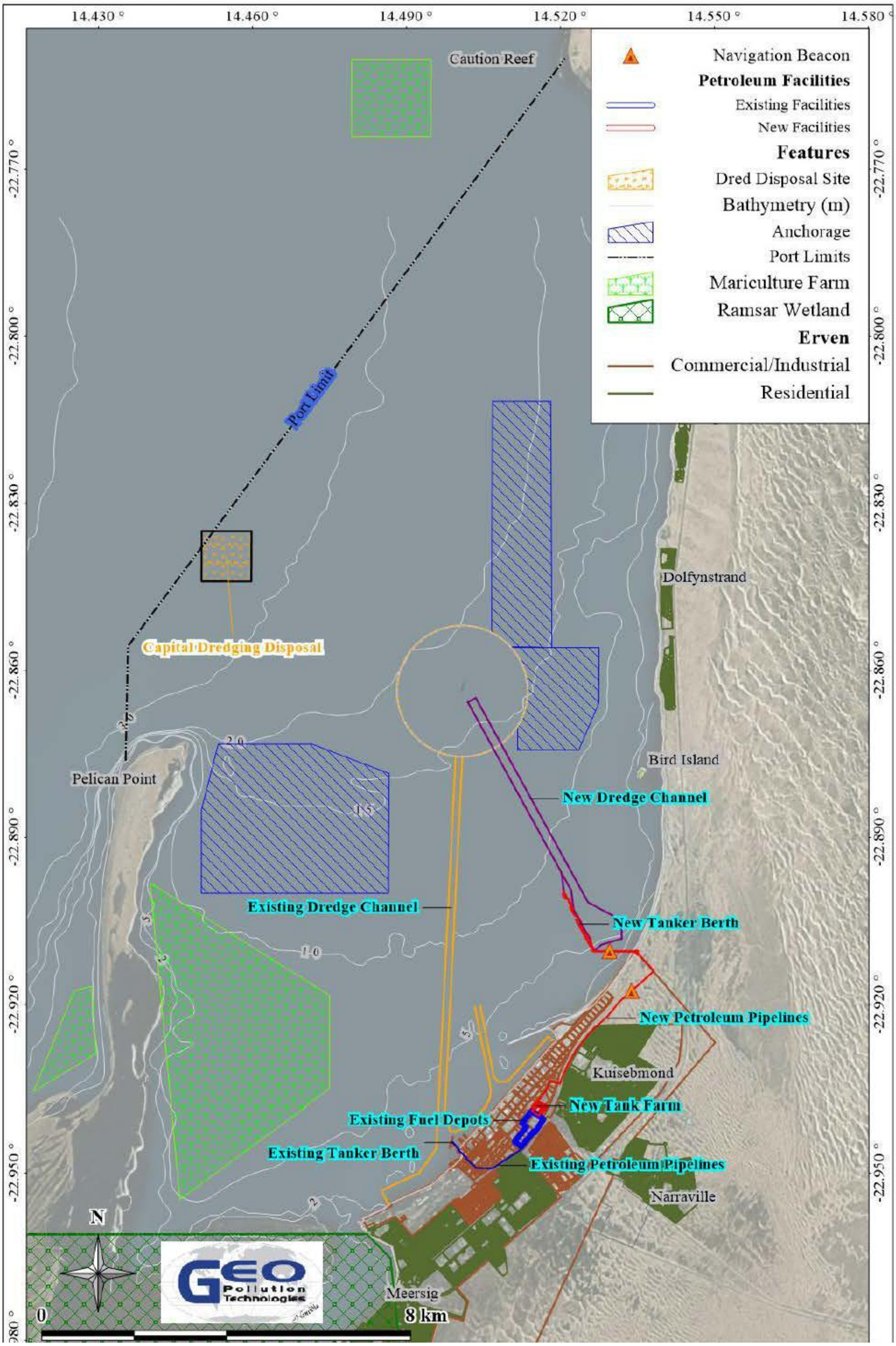

Figure 1.1. The location of existing facilities as well as the proposed new oil and gas terminal (jetty) at Walvis Bay (Botha 2015).

2 PUBLIC PARTICIPATION

Stakeholder participation was ongoing throughout the study period. Key Stakeholders were identified at national, regional and local level. The team took the approach of first identifying the various national and regional government sectors possibly active within the region. Due to the difficulty in finding relevant persons, where team members had knowledge of existing relevant contacts, these were added to the Stakeholder list. In some cases, departments and offices were physically visited upon providing a letter of authorization from the client. The Stakeholder list was progressively built up after a number of changes and additions and includes various directorates within ministries, as well as associations, clubs and private organizations.

All identified Interested and Affected Parties (IAPs) were invited to the Stakeholder meeting that was held in conjunction with the Walvis Bay Environmental Management and Advisory Forum (WEMAF) on 17 May 2018 at Walvis Municipality, Namib Conference Room. A complete list of Stakeholders and comments are provided in Appendix 7.

3 DESCRIPTION OF THE AFFECTED ENVIRONMENT

A brief description is provided below. More detailed information can be found in the EIA report (Botha *et al*. 2013) and the marine scoping study (Hooks and Duvenhage 2013).

3.1 Study area

Walvis Bay is situated on the south-western coast of Namibia at Walvis Bay. It is divided into four main areas; namely the Walvis Bay Ramsar Site, the Kuiseb Delta, the Dune Belt Area and the Walvis Bay Coastline (Figure 3.1). It is flanked by ±60 kilometres of coastline with the Swakop River to the north and the Namib Desert sand dunes and gravel plains to the east. To the south lies the Namib Naukluft Park with the Walvis Bay wetlands (± 12 600 hectare), which was listed as a Ramsar Site in 1995, and the adjoining delta of the ephemeral Kuiseb River (Uushona and Makuti 2008).

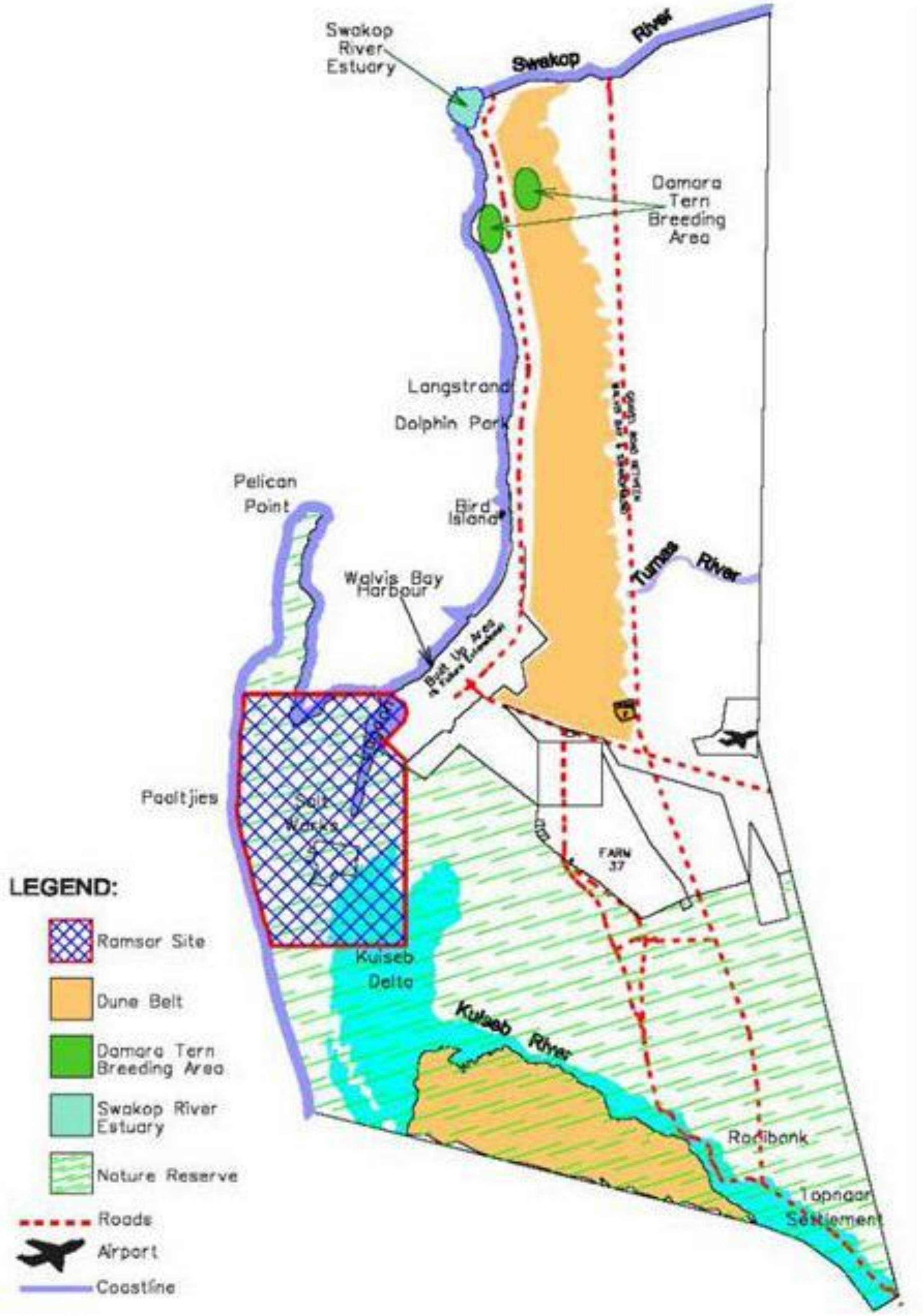

Figure 3.1. Map showing the biodiversity areas and zones of Walvis Bay (Uushona and Makuti 2008).

3.2 Oceanography

The Benguela Current System (BCS) is a major eastern boundary current system dominated by wind-driven upwelling. Coastal upwelling at Lüderitz results in cold, nutrient rich water from depths of greater than 200 m entering Walvis Bay. These nutrients support blooms of phytoplankton that provide food for zooplankton and pelagic fish. As nutrients and oxygen diminish, blooms die off and organic matter sinks to the seafloor. This contributes to the anoxic conditions characteristic of Walvis Bay. As the fallout rate of dead organisms is higher than the decomposition rate, a layer of greenish ooze accumulates in the Bay at depths below three meters.

The water depth in the Bay ranges from -35 m Chart Datum (CD) at the northern Port boundary to approximately -0.5 m CD at the entrance to the Lagoon (Navionics 2018). Swell direction is predominantly south-westerly (SADCO 2018) with waves progressively decreasing in height towards the Lagoon, which lies sheltered behind Pelican Point. The dominant south-westerly winds result in a longshore southward clockwise circulation of surface waters in the Bay, although anti-clockwise circulation occurs about a third of the time (COWI 2003). At Pelican Point, the predominant current direction is northward, as is the inshore current along the east side of the Bay (COWI 2003).

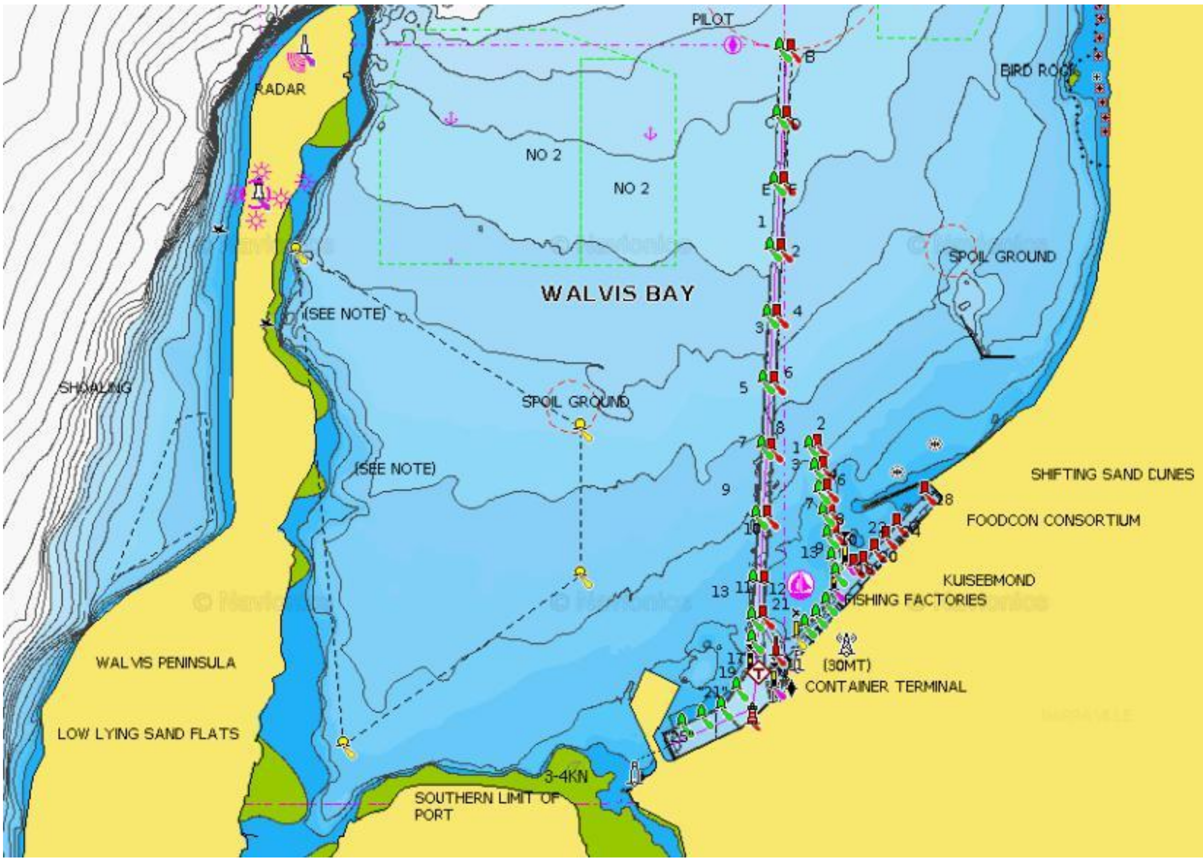

Figure 3.2. Depth isobaths within the Port of Walvis Bay (Navionics 2018).

3.3 Climate

Walvis Bay is situated in the most arid part of the hyper-arid Namib Desert. The coastal climate is strongly moderated by upwelling of cold, nutrient rich water from the Benguela system. The area is characterised by mild summers and cool winters and coastal fog occurs throughout the year. Long-term mean annual rainfall is less than 20 mm. Wind is the single most important physical agent and affects wave action, transport of sediments onto the shoreline and further inland, and the shape and movement of surrounding sand dunes (Uushona and Makuti 2008). The dominant wind direction is from the south-west, although gentle winds from the south and strong north-easterly "Berg winds" occur in autumn.

3.4 Biodiversity

The Walvis Bay Coastline is designated as an Important Bird Area (IBA) which has up to 450 birds per kilometre of shore, the highest linear count of birds anywhere in Southern Africa. The Swakop River Estuary is one of only two of its kind along the Namib central coast and is on the major migratory flyway of hundreds of thousands of migratory birds. This wetland provides a complex environment for a wide variety of plants, birds, reptiles, fish and a number of other animals (Uushona and Makuti 2008).

The Walvis Bay wetlands were proclaimed as a Ramsar Site in 1995 and are regarded as the most important coastal wetlands in Southern Africa in terms of birdlife. The Kuiseb Delta holds significant ecological and cultural value and constitutes an important part of the area used by the indigenous Topnaar community. The dune belt area hosts a high diversity of desert adapted flora and fauna and is the main habitat of the endemic Damara tern (Uushona and Makuti 2008).

More than 27 species of whales and dolphins occur off the coast of Namibia (Best 2007). Of these, five cetacean species are found within Walvis Bay, all currently of least concern according to the IUCN Red List;

- the humpback whale *Megaptera novaeangliae,*
- the southern right whale *Eubalaena australis*,
- the pygmy right whale *Caperea marginata*,
- the Benguela Current endemic Heaviside's dolphin *Cephalorhynchus heavisidii*, and
- a local population of the common bottlenose dolphin *Tursiops truncatus*.

The only cetaceans observed during the field survey were a pod of bottlenose dolphins frolicking in the waves off Langstrand. Should it be required, further information on the distribution of cetacean species can be sourced from the specialist report (Gridley and Elwen 2013).

Four main species of shark occur along the coastal area from Pelican Point to Swakopmund (Envirosolutions 2005);

- the spotted gullyshark *Triakis megalopterus* (Near Threatened),
- the bronze whaler *Carcharhinus brachyurus* (Near Threatened),
- the smooth-hound shark *Mustelus mustelus* (Vulnerable), and
- the broadnose seven-gill cow shark *Heptranchias perlo* (Near Threatened).

The Namibian coastal waters are home to five species of turtles, all of which are listed on the IUCN Red List of Threatened Species and are controlled through CITES (no trade);

- the leatherback turtle *Dermochelys coriacea* (Vulnerable),
- the green sea turtle *Chelonia mydas* (Endangered), and
- the hawksbill sea turtle *Eretmochelys imbricata* (Critically Endangered)
- the loggerhead turtle *Caretta caretta* (Vulnerable), and
- the olive ridley turtle *Lepidochelys olivacea* (Vulnerable).

No sharks or turtles were observed during the field study. Fish, invertebrates and birds are discussed in the relevant sections below.

3.5 Social and Economic Activities

Walvis Bay has approximately 60 000 citizens and is a buzzing industrial and tourism centre. Most people are employed in the fishing industry and sea salt processing, both of which take place at the modern harbour terminal. The salt fields to the south of Walvis Bay cover an area of over 4 500 hectares and annually produce 650 000 metric tonnes of high quality salt (Uushona and Makuti 2008).

Walvis Bay is linked to Namibia's rail, air and road network, making the Port ideally situated to service most of its landlocked SADC neighbours. The harbour in Walvis Bay caters for fishing and cargo vessels and provides facilities for smaller boats and yachts. Various cruise liners make Walvis Bay one of their regular port of calls. Walvis Bay has an international airport, which is an ideal connection for north-south Namibian travellers and links directly to the pristine expanse of the Namib-Naukluft/Sossusvlei tourist attractions to the south (Uushona and Makuti 2008).

Artisanal scale beach purse-seine fishing takes place from the beaches north of Walvis Bay (Batty *et al*. 2005). Mariculture operations are also established in the bay, the most active being the farming of oysters. There is an oyster farm located in the primary evaporation pond of the saltworks, and others positioned in the designated marine farm area in the lee of Pelican Point. Major losses were experienced in 2008 due to sulphur eruptions.

Walvis Bay and the Lagoon are becoming increasingly important for ecotourism, specifically boat tours to view seals, dolphins, whales, pelicans and the guano platform. Holiday accommodation brings in big business as the 'season' stretches over 90% of the year. The esplanade along the eastern shore of the Lagoon provides a recreational area for sportspeople, holiday makers and birders alike and it affords the opportunity to view birds and marine life at a close range.

4 SAMPLING METHODS

4.1 Site selection

Surveying of faunal and floral communities associated with key habitat types in the study area including sandy beach macrofauna, rocky intertidal macrofauna, surf zone fish, sub-tidal soft bottom macrofauna, and seabirds and shore birds were carried at the sites listed in Table 4.1.

Table 4.1. Sample site coordinates as recorded during the field survey.

Site	Area	Distance from Jetty/dredge channel (± km)	Substrate	Latitude	Longitude
B1	Oil Jetty South	1.5	Sandy beach	22° 55.163'S	14° 31.509'E
B2	Oil Jetty North	0.5	Sandy beach	22° 54.363'S	14° 32.189'E
B3	Guano Platform	2.5	Sandy beach	22° 53.360'S	14° 32.398'E
B4	Dolphin Beach	8	Sandy beach	22° 51.208'S	14° 32.369'E
B5	Long Beach	11	Sandy beach	22° 48.022'S	14° 32.558'E
RS1	Naval Base	2.5	Rocky shore	22° 55.485'S	14° 30.986'E
RS2	Guano Platform	4	Rocky shore	22° 52.550'S	14° 32.370'E
RS3	Dolphin Beach	5.5	Rocky shore	22° 51.771'S	14° 32.282'E
RS4	Super Tubes	6.5	Rocky shore	22° 50.372'S	14° 32.316'E
RS5	Long Beach	12	Rocky shore	22° 48.698'S	14° 32.552'E
G1	South of dredge channel	0.5	Benthic grab	22° 54.703'S	14° 31.179'E
G2	Dredge channel	0	Benthic grab	22° 54.400'S	14° 31.588'E
G3	North of dredge channel	0.3	Benthic grab	22° 54.026'S	14° 31.812'E
G4	Northern control	0.8	Benthic grab	22° 53.758'S	14° 31.885'E
G5	South of dredge channel	0.5	Benthic grab	22° 54.373'S	14° 30.959'E
G6	Dredge channel	0	Benthic grab	22° 54.087'S	14° 31.314'E
G7	North of dredge channel	0.3	Benthic grab	22° 53.796'S	14° 31.517'E
G8	Northern control	0.8	Benthic grab	22° 53.484'S	14° 31.657'E
G9	South of dredge channel	0.5	Benthic grab	22° 53.414'S	14° 30.427'E
G10	Dredge channel	0	Benthic grab	22° 52.989'S	14° 30.561'E
G11	North of dredge channel	0.3	Benthic grab	22° 52.694'S	14° 30.652'E
G12	Northern control	0.8	Benthic grab	22° 52.434'S	14° 30.641'E

Five sandy beach sites were sampled for 1) macrofauna, 2) sediment particle size, and 3) surf-zone fish. Sites were chosen based on the availability of sandy beach habitat within the identified 30 km area of interest and were positioned between 2 km and 6 km apart. Similarly, five rocky intertidal sites were selected based on the availability of rocky shore habitat. These sites were positioned between 1.5 km and 6 km apart (Figure 4.1). Bird surveys were conducted along the coast from RS1 to B5.

Twelve benthic grab sites were sampled parallel to the coast. These were spaced around the proposed dredge channel according to the following criteria:

- ±500 m south-west of the proposed dredge channel
- In the centre of the proposed dredge channel
- ±300 m north-east of the proposed dredge channel
- ±800 m north-east of the proposed dredge channel

This design was selected to allow the comparison of data before and after construction to quantify impacts of the disturbance.

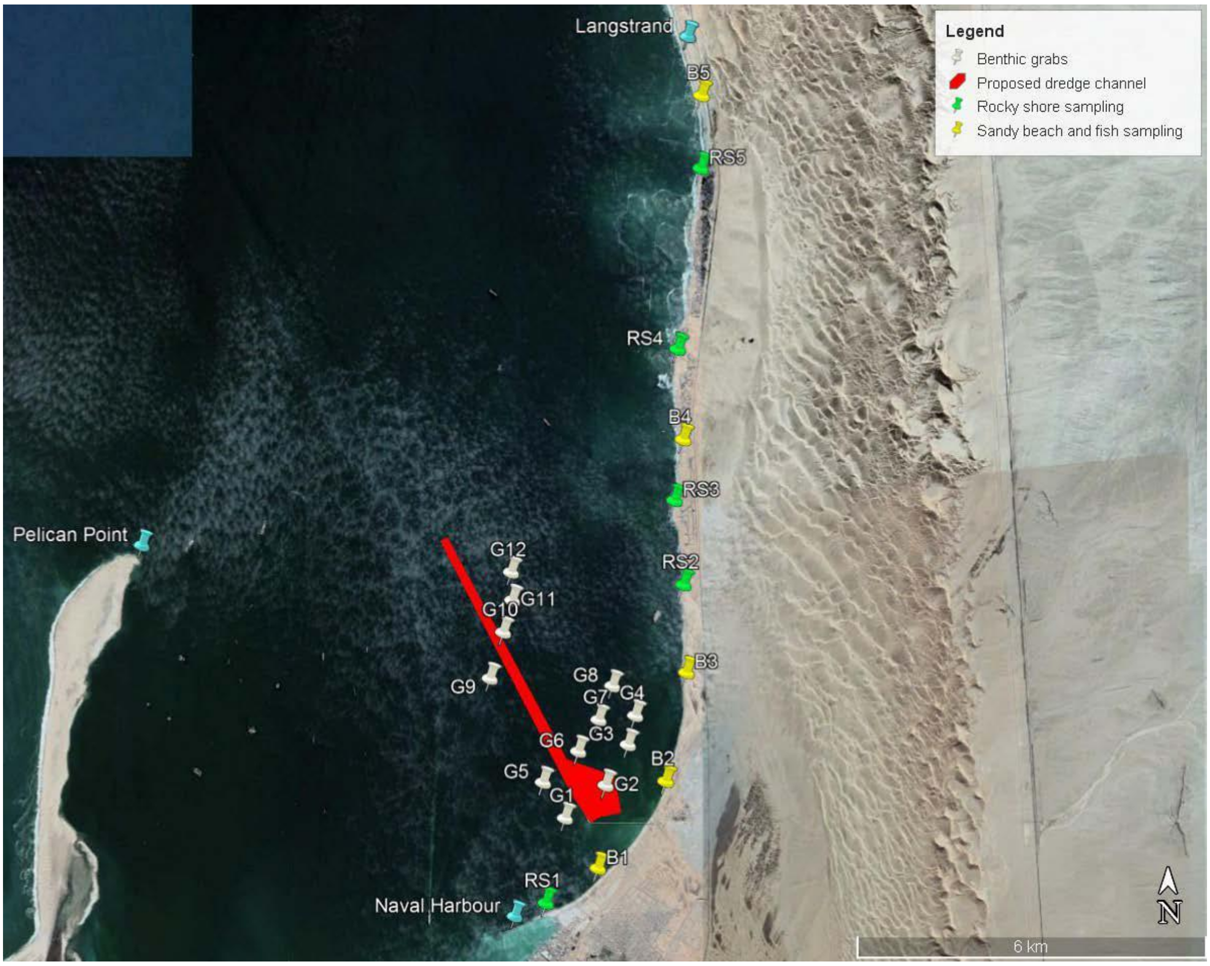

Figure 4.1. Sites sampled in June 2018 are indicated on the satellite image (Google Earth 2018).

4.2 Sandy Beach Survey

Sandy beach macrofauna were sampled at five sites between the Walvis Bay Naval Base (B1 just south of the oil terminal) and B5 approximately 13 km away at the northern end of Langstrand (Figure 4.1). At each site, a sampling grid consisting of three replicate transect lines extending from the drift line to the low water mark was setup and 10 stations sampled along each transect (30 samples per beach site). At each sampling station, 0.1 m^2 quadrat samples were excavated to a depth of 30 cm, and the sediments washed in 1 mm mesh sieve bags (Figure 4.2). All fauna retained in the sieves were retained and preserved in 90% ethanol. Samples were taken at stations 1, 5 and 10 at each of the five beach sites at spring low tide and analysed for sediment particle size. All macrofauna within the samples were identified, counted and weighed (wet weight).

Beach slope, wave height and period, surf zone width, and swash frequency were recorded in the field. Using the physical data collected, the dimensionless fall velocity (or Dean's value, Ω) was calculated for each beach indicating the beach morphodynamic state. Dean's value Ω was calculated as follows: wave height (cm) / [wave period (s) x sand settling velocity ($cm.s^{-1}$)]

Wright and Short (1984) classified beaches as dissipative with Ω > 6 and reflective with Ω < 1. Beaches between one and six are termed intermediate. A quantitative value, defining the exposure of each beach, was obtained using McLachlan's (1980) exposure rating system.

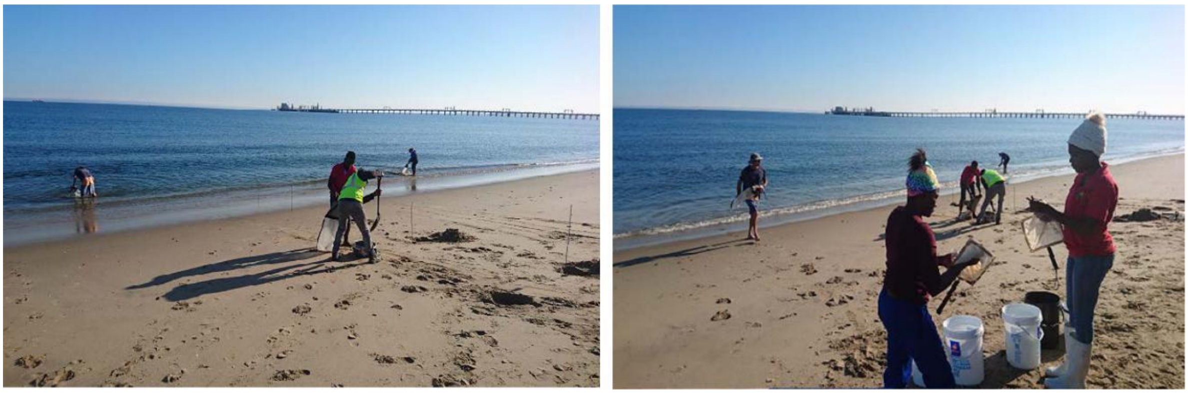

Figure 4.2. Sandy beach surveys were conducted at five sites within the study area.

4.3 Surf-zone Fish Survey

Surf-zone fish were sampled on the 12 June 2018 at the five sandy beach sampling sites (Figure 4.3). Three replicate hauls covering approximately 300 m^2 each were conducted at each site using a beach-seine net, 25 m long, 2 m deep, with a stretched mesh size of 12 mm. Hauls were made approximately 50 m apart at each of the five sites sampled with a total of 15 hauls conducted. The net was deployed from a small inflatable boat 30-60 m from the shore. The net was then hauled shoreward and the catch collected in the cod end (Figure 4.3). The area swept by the net for each haul was calculated by multiplying the distance the net was deployed offshore by the mean width of the haul. All fish caught were identified and measured. Fish were returned to the water alive after measuring.

Figure 4.3. Surf-zone fish surveys were undertaken at five sites along the shoreline in the study area using a beach seine net.

4.4 Rocky Intertidal Survey

Sampling was undertaken at five sites at spring low tide in three shore height zones: high, mid and low. Five 100 x 50 cm quadrats were randomly placed on the shore and the percentage cover of all biota was identified in the field by specialist ecologists. The quadrat was subdivided into 171 smaller squares with 231 points to aid in the estimation of the percentage cover. Individual mobile organisms in each quadrat were counted to calculate densities within the quadrat area ($0.5m^2$). Percentage cover refers to the space that organisms occupy on the rock surface, while abundance refers to the number of organisms present. Species were recorded as primary (occurring on the rock) and secondary (occurring on other benthic fauna or flora) cover. The primary and secondary cover data for both mobile and sessile organisms were combined and down-scaled to 100%.

Sampling was non-destructive, i.e. the biota were not removed from the shore, and smaller infaunal species (e.g. polychaetes, amphipods, isopods) that live in the complex matrix of mussel beds or dense stands of algae were not recorded by this survey protocol. Some algae and invertebrates that could not be easily identified to generic or species level in the field were recorded under a general heading (e.g. colonial bryozoan). For further analysis, intertidal species were categorized into six functional groups: grazers (mostly limpet species), filter-feeders (including sessile suspension feeders such as mussels and barnacles), predators (such as carnivorous whelks and anemones), corticated algae, ephemeral foliose algae and kelps. Biotic indices were calculated to measure community structure. Rocky intertidal summary data are presented in Appendix 3.

Figure 4.4. Ecologists surveying the rocky intertidal at Walvis Bay.

4.5 Subtidal Benthic Macrofaunal Survey

Benthic sediment samples were collected from 12 stations using a Van Veen grab with a bite of 0.085 m^2 deployed from the working vessel Pumba. Three samples, each consisting of three grabs were collected from each sampling station (nine grabs total per station). Each sample was placed in a 1 mm mesh bag and agitated until all fine sediment was removed. The remaining contents were placed in a sample jar and fixed with 5% formalin. Samples were extracted from the residual sediment in the laboratory where they were identified, counted and weighed. These samples were then stored in 70% ethanol to build up a reference collection for future studies. Data are listed in Appendix 4.

4.6 Water Quality

CTD profiles were undertaken using a SBE 19plus V2 SeaCAT Profiler CTD from Sea-Bird Scientific (Figure 4.5 – centre). This instrument measured temperature (°C), conductivity (mS/cm), salinity (PSU), dissolved oxygen (mg/l), turbidity (NTU) and pH at a rate of 4 Hz, i.e. 1 sample every 0.25 seconds. The CTD was lowered through the water column from the surface to the bottom at each site and then retrieved. Data collected were used to calculate mean values for each of the above physico-chemical parameters at 1 m depth intervals through the water column at each site. These raw data are tabled in Appendix 5 and summary plots are shown in Section 6.5.1.

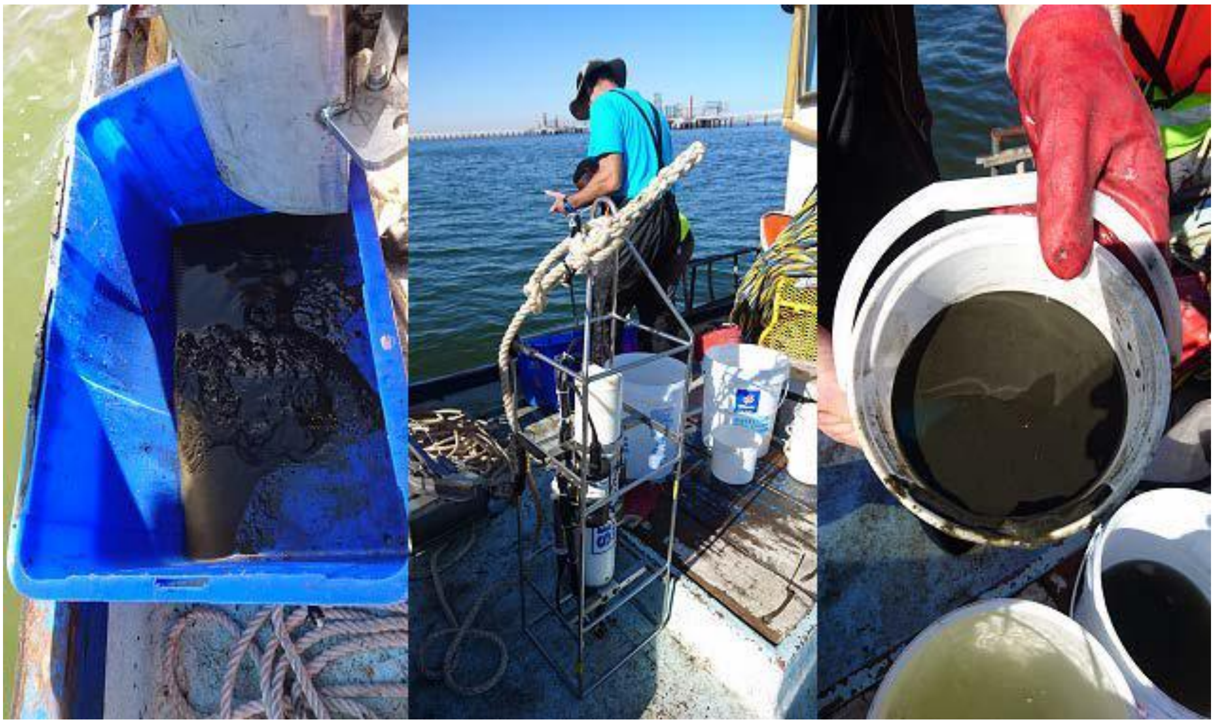

Figure 4.5. The Van Veen grab was used to collect benthic sediment for the subtidal benthic macro-faunal survey. The CTD was deployed at each site to record conductivity (salinity), temperature, dissolved oxygen, pH and turbidity at different depths throughout the water column.

4.7 Seabirds and Shorebirds

Birds were surveyed at each sandy beach site on the day of sampling. All sea and shore-birds encountered along the shoreline and over the sea at each sampling site were identified and counted by trained observers using binoculars.

Figure 4.6. Pelicans feeding in the Walvis Bay Lagoon.

5 HABITAT MAPPING

The Benguela Current Large Marine Ecosystem (BCLME) programme addresses marine and coastal conservation planning in the Benguela region (i.e. Angola, Namibia and South Africa) with the objective of enabling the use of conservation planning at an operational level. In order to allow for the sustainable use of the marine environment without jeopardising biodiversity and the integrity of marine habitats, each habitat type needs to be mapped and classified according to sensitivity. Classification of habitats can be carried out through the analysis of the faunal composition and its relation to environmental variables such as water depth and benthic substrates (Buhl-Mortensen *et al*. 2015). A broad-scale approach is sufficient to achieve this objective by identifying biologically valuable areas and assessing the health status of these areas.

The mapping presented in this report includes the distribution of coastal and offshore habitats through the identification and collection of existing physical data and ground-truthing data, and synthesis in GIS format. GIS layers used to produce the protected areas map were sourced from Environmental Information Service of Namibia (EIS 2018).

5.1 Ground-truthing

The coastal habitat within a 30 km radius of the National Oil Storage Facilities was classified into six habitat types: rocky shore, sandy beach, offshore reef, artificial substrate, salt pans and estuarine environment. Broad habitat types were initially assigned according to Google Earth imagery. These were then ground-truthed during the field survey in June 2018 and adjusted accordingly. Ground-truthed habitat maps are presented in Figure 5.1 to Figure 5.3. Benthic sand constituted the majority of Walvis Bay offshore area (white shading). The northern area consisted exclusively of sandy beach habitat (yellow shading), the longest stretch of which is appropriately named Langstrand or 'long beach' (Figure 5.2 – left). Just south of Langstrand, the habitat was classified as 'mixed' with sandy beach making up the high shore and rocky shore interspersed with sand in the low shore. Benthic sand was found to be dominant offshore, with interspersed rocky reefs. Further south, the dominant coastal substrate was again found to be sandy beach (Figure 5.2 – right), with artificial substrata making up the majority of the coastal habitat beyond the Naval Base (Figure 5.3). Estuarine habitat was found at the southernmost extent of Walvis Bay with salt pans further inland (pink shading). Pristine sandy beaches were seen towards the southern tip of the spit at Pelican Point (Figure 5.1).

Figure 5.1. Habitat types in and around the study area.

Figure 5.2. Detailed mapping of habitat types in the vicinity of the study area. The coast was divided into three sections; the most northerly section including Langstrand (left), the impact site (right), and the Walvis Bay Lagoon (Figure 5.3).

Figure 5.3. Detailed mapping of habitat types at the mouth of the Walvis Bay Lagoon.

5.2 Protected Areas

Marine Protected Areas (MPAs) are spatially-delimited areas of the marine environment that are managed and serve to protect marine and coastal habitats, conserve biodiversity as well as sustain fisheries (Edgar *et al*. 2007, Sink *et al*. 2012). MPAs are crucial to the livelihoods of people who utilise the marine environment and are pivotal in facilitating local economic development via employment, ecotourism and conservation. Furthermore, MPAs are increasingly being used as a tool for the achievement of various targets associated with conservation of biodiversity, fisheries management, tourism and research (Sink *et al*. 2012). Coastal Protected Areas and Marine Protected Areas surrounding Walvis Bay are indicated in Figure 5.4. Shape files were provided by the Environmental Information Service of Namibia (EIS 2018).

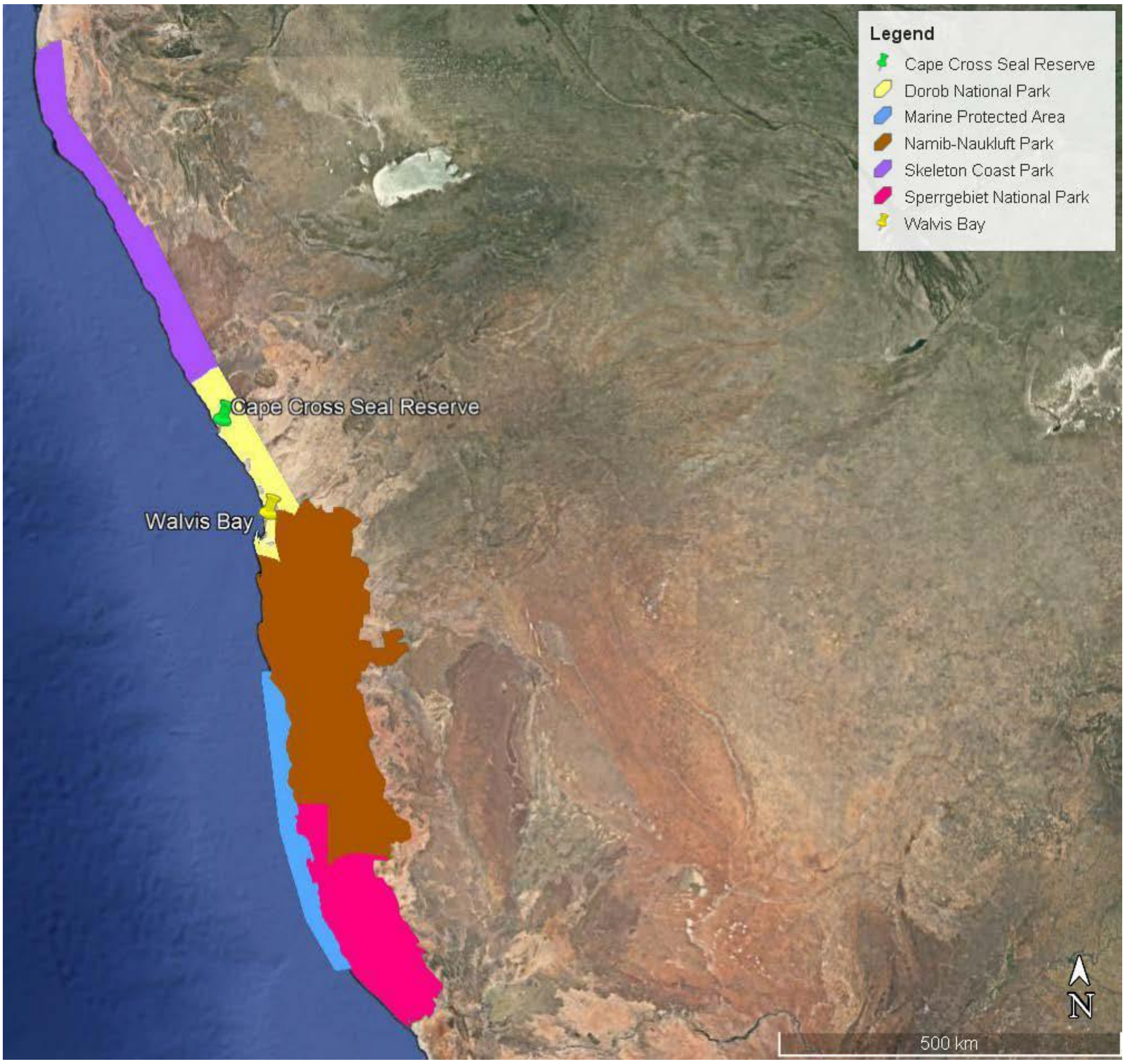

Figure 5.4. Coastal Protected Areas and Marine Protected Areas surrounding Walvis Bay.

5.3 Habitat Sensitivity

The International Finance Corporation (IFC) Performance Standards (2012) were used to assess broad-scale coastal sensitivity. The IFC has eight Performance Standards (PS) on environmental sustainability which provide guidance on how to avoid, mitigate and manage risks and impacts. This is achievable through:

- Assessment and management of environmental risks and impacts - Performance Standard one (PS1) highlights the importance of managing social and environmental performance throughout the life of a project.
- Resource efficiency and pollution prevention - Performance Standard three (PS3) aims to minimise adverse impacts on human health and the environment by promoting sustainable use of resources and reducing project-related pollution.
- Biodiversity conservation and sustainable management of living natural resources - Performance Standard six (PS6) concerns the protection and conservation of biodiversity, including genetic, species and ecosystem diversity.

An environmental management system must be implemented from project inception to assess potential environmental impacts, recommend mitigation, and detail appropriate management. For this project, an Environmental Impact Assessment (EIA) was undertaken by Botha *et al*. (2013), and included a specialist scoping study on potential impacts on the marine environment (Hooks and Duvenhage 2013). The subsequent Environmental Management Plan (EMP) included requirements for specialist baseline studies to be undertaken prior to project implementation to allow for the assessment of impacts as well as ongoing monitoring through construction and operational phases (Botha *et al*. 2015a).

5.3.1 Biodiversity Conservation

Performance Standard six (6) addresses the protection and conservation of ecosystems, habitats, species and communities. Habitats are subdivided as follows:

- Modified habitat – areas that may contain a large proportion of non-native flora and/or fauna, and/or where human activity has led to ecological modifications. Impacts should be minimised in these areas.
- Natural habitat – areas with viable flora and/or fauna assemblages of native origin, and/or where human activity has not modified primary ecological functions and species composition. The habitat should not be converted or degraded unless there is no viable alternative, consultation with affected parties has occurred, and any conversion or degradation is mitigated. Mitigation will involve no net loss of biodiversity.
- Critical habitats – areas with high biodiversity value. No project activities are to be implemented in these habitats, unless no other viable alternative exists, the project does not lead to measureable adverse impacts on the biodiversity values for which the "critical" status was designated, and the project does not lead to a net reduction in global/national/regional population of any Critically Endangered/Endangered species, and a

robust, long-term monitoring program is implemented (to be described in a Biodiversity Action Plan with net gains to be achieved).

Critical habitats include:

- habitats of significant importance to Critically Endangered/Endangered species;
- habitats of significant importance to endemic and/or restricted-range species;
- habitats supporting globally significant concentrations of migratory and/or congregatory species;
- highly threatened and/or unique ecosystems; and/or
- areas associated with key evolutionary processes.

The coastline within the study area was assessed according to the International Finance Corporation (IFC) Performance Standards (2012) detailed above. Pelican Point was rated as 'Critical' due to the numerous seal colonies (restricted range) that depend on the peninsula as a breeding area. The Walvis Bay Lagoon and Estuary were also rated as 'Critical' habitat, primarily owing to the large number of endemic and migratory species supported by these two areas. The Harbour and Naval Yard constitute 'Modified' habitat, which is indicated by orange shading in Figure 5.3. The remaining areas (rocky shore, sandy beach and offshore reef) were categorised as 'Natural' habitat, which makes up the greater part of the study area considered in this report (30 km radius from the base of the Oil Tanker Jetty).

Small sections of rocky intertidal habitat are positioned along sandy beaches that extend from Walvis Bay northwards towards Swakopmund. As sandy beaches are highly dynamic, these habitats are less sensitive to disturbance than rocky shore environments. Sandy beaches are also quicker to recover from disturbance than rocky habitats. Relatively few species occur on sandy beaches in comparison to rocky shores due to the unstable and harsh nature of beaches. Those species that do occur on sandy beaches are hardy and well adapted to life in these environments (Branch and Branch 2017). As the rocky intertidal habitat in this area experiences sand inundation and scouring due to sediment movement, the associated species are more tolerant to disturbance than those living on rocky shores that are not adjacent to large sandy patches.

Rocky reefs are scarce along this coastline, while sandy benthos is the dominant subtidal habitat in the Bay. Sandy benthic habitats are generally not as diverse as offshore rocky reefs; however, they do host an assemblage of species not found in rocky areas.

5.4 Coastal and Marine Ecological Classification Standard (CMECS)

The U.S. Federal Geographic Data Committee (FGDC) promotes the coordinated development, use, sharing, and dissemination of geospatial data. The Coastal and Marine Ecological Classification Standard (CMECS) is a catalogue of terms that provides a means for classifying ecological units (e.g. sand, lagoon, water) and is one of the standards endorsed by the FGDC (CMECS 2012). CMECS was developed primarily for application in the territorial waters of the United States; however, the approach can be successfully applied in other areas (CMECS 2012). This classification system was applied to the habitat types identified in Walvis Bay to facilitate the assessment, monitoring, protection, and management of biotic assemblages, protected species, and important ecosystem components.

CMECS characterizes marine and coastal environments in terms of two settings and four components (Table 5.1). Two broad based settings are used to partition coastal and marine environments - the Biogeographic Setting (BS) and the Aquatic Setting (AS). The BS identifies ecological units (e.g. ecoregions) based on species aggregations and features influencing the distribution of organisms. The coastal and marine environment is divided into three Systems: marine, estuarine, and lacustrine (lakes). Secondary and tertiary layers of the AS describe Subsystems within the Marine System (i.e. Nearshore, Offshore, and Oceanic) and within the Estuarine System and Marine Nearshore Subsystem (i.e. Tidal Zones). Components provide specific tools for describing sampling sites. Four components define the attributes of environmental units and biota within each setting: the Water Column Component (WC), the Geoform Component (GC), the Substrate Component (SC), and the Biotic Component (BC).

For this report, ecoregions were classified according to the Marine Ecoregions of the World (MEOW) as outlined in Spalding *et al.* (2007), while ecological units were assigned to each habitat type according to CMECS units (Table 5.1). Classification unit divisions are presented in Table 5.2.

Table 5.1. CMECS classification for Walvis Bay.

Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Realm	System	Layers	Tectonic Setting	Origin	Biotic setting
Province	Subsystem	Salinity	Physiological setting	Class	Biotic Class
Ecoregion	Tidal Zone	Temperature	Level 1 Geoform	Subclass	Biotic Subclass
		Hydroform	Level 2 Geoform	Group	Biotic Group
		Biochemical feature		Subgroup	Biotic Community

Table 5.2. Walvis Bay habitat types divided according to CMECS units.

Habitat type	Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Offshore Reef	**Realm**: Temperate Southern Africa **Province**: Benguela **Ecoregion**: Namib	**System**: Marine **Subsystem**: Nearshore **Tidal Zone**: Subtidal	**Layers:** • Marine Nearshore Surface Layer - Euhaline Cool Water • Upper water column - Euhaline cool water • Pycnocline - n/a • Lower water column - Euhaline cool water **Hydroform Class**: Boundary current **Hydroform Type**: Eastern Boundary Current (EBC) **Hydroform Class**: Buoyancy Flow **Hydroform Type**: Upwelling **Hydroform Class**: Deep boundary current **Biochemical features**: • Benthic Boundary Layer • Chlorophyll Maximum • Chlorophyll Minimum • Euphotic Zone • Halocline • Nepheloid Layer • Neustonic Layer • Oxygen Minimum • Oxycline • Surface Mixed Layer	**Tectonic Setting**: n/a **Physiographic setting**: • Continental shelf • Continental shore Complex • Bay	**Origin**: Geologic substrate **Class**: Rock **Subclass**: Bedrock	**Biotic setting**: Benthic biota **Class**: Faunal bed **Subclass**: Attached fauna **Group**: Attached anemones **Community**: *Anthothoe stimpsonii, Bunodactis reynaudi* **Group**: Mobile molluscs on hard/mixed substrate **Community**: Limpets etc. **Group**: Attached mussels **Community**: *Mytilus galloprovincialis* **Group**: Filamentous algal bed **Communities**: *Cladophora* sp. **Group**: Leathery/Leafy Algal Bed **Communities**: *Rhodymenia obtusa* etc.

Habitat type	Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Pelagic Water and Benthic Sand	**Realm**: Temperate Southern Africa **Province**: Benguela **Ecoregion**: Namib	**System**: Marine **Subsystem**: Nearshore **Tidal Zone**: Subtidal	**Layers:** • Marine Nearshore Surface Layer - Euhaline Cool Water • Upper water column - Euhaline cool water • Pycnocline - n/a • Lower water column - Euhaline cool water **Hydroform Class**: Boundary current **Hydroform Type**: Eastern Boundary Current (EBC) **Hydroform Class**: Buoyancy Flow **Hydroform Type**: Upwelling **Hydroform Class**: Deep boundary current **Biochemical features**: • Benthic Boundary Layer • Chlorophyll Maximum • Chlorophyll Minimum • Euphotic Zone • Halocline • Nepheloid Layer • Neustonic Layer • Oxygen Minimum • Oxycline Surface Mixed Layer	**Tectonic Setting**: n/a **Physiographic setting**: • Continental shelf • Continental shore Complex • Bay	**Origin**: Geologic substrate **Group**: Sandy mud **Subgroup**: Sandy silt **Class**: Organic substrate **Subclass**: Organic mud	**Biotic setting**: Planktonic Biota **Class**: Zooplankton **Subclass**: Mixed zooplankton Aggregation **Communities**: *Gastrosaccus* sp. **Class**: Phytoplankton **Subclass**: Dinoflagellate phytoplankton **Group**: Dinoflagellate bloom **Subclass**: Diatom phytoplankton **Group**: Diatom Bloom **Communities**: Navicula, Rhizosolenia, Nitschia, Campylosira, Melosira. **Biotic setting**: Benthic Biota **Class**: Faunal Bed **Subclass**: Soft sediment fauna **Group**: Larger deep-burrowing fauna (>2mm) **Communities**: Cumacea, *Bivalvia* sp, *Harmothoe* sp. **Group**: Small surface burrowing fauna **Communities**: *Nereis lamellosa* **Group**: Diverse soft sediment epifauna **Communities**: *Discinisca tenuis, Sigambra parva* **Group**: Small tube-building fauna **Communities**: *Ampelisca anomala, Lagis neapolitana* **Group**: Soft Sediment Brittle stars **Communities**: *Ophiothrix* sp.

Habitat type	Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Sandy Beach	**Realm**: Temperate Southern Africa **Province**: Benguela **Ecoregion**: Namib	**System**: Marine **Subsystem**: Nearshore **Tidal Zone**: Intertidal	**Layers:** • Marine Nearshore Surface Layer - Euhaline Cool Water • Upper water column - Euhaline cool water • Pycnocline - n/a • Lower water column - Euhaline cool water **Hydroform Class**: Tidal Flow **Hydroform Type**: Semi-diurnal Tidal Flow **Hydroform Class**: Wave-driven current **Hydroform Type**: Longshore current **Hydroform Class**: Wave **Hydroform Type**: Anthropogenic wave **Hydroform Type**: Coastally trapped wave **Hydroform Type**: Surf zone **Hydroform Type**: Surface wave **Hydroform Type**: Surface wind wave **Hydroform Type**: Surface swell **Biochemical features**: • Euphotic Zone • Surface Mixed Layer	**Tectonic Setting**: n/a **Physiographic setting**: • Bay **Geoform Origin**: Geologic **Level 1 Geoform**: Beach **Type**: Mainland beach **Type**: Wave dominated beach **Level 1 Geoform**: Dune field **Type**: Beach ridge **Level 1 Geoform**: Shore **Type**: Foreshore **Type**: Backshore **Level 1 Geoform**: Slope	**Origin**: Geologic substrate **Class**: Unconsolidated mineral substrate **Subclass**: Fine unconsolidated substrate **Group**: Slightly gravelly **Subgroup**: Slightly gravelly sand	**Biotic setting**: Benthic Biota **Subclass**: Soft sediment fauna **Group**: Small surface burrowing fauna **Communities**: Amphipoda, Isopoda, Polychaeta, Bivalvia

Habitat type	Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Rocky Intertidal	**Realm**: Temperate Southern Africa **Province**: Benguela **Ecoregion**: Namib	**System**: Marine **Subsystem**: Nearshore **Tidal Zone**: Intertidal	**Layers:** • Marine Nearshore Surface Layer - Euhaline Cool Water • Upper water column - Euhaline cool water • Pycnocline - n/a • Lower water column - Euhaline cool water **Hydroform Class**: Tidal Flow **Hydroform Type**: Semi-diurnal Tidal Flow **Hydroform Class**: Wave-driven current **Hydroform Type**: Longshore current **Hydroform Class**: Wave **Hydroform Type**: Anthropogenic wave **Hydroform Type**: Coastally trapped wave **Hydroform Type**: Surf zone **Hydroform Type**: Surface wave **Hydroform Type**: Surface wind wave **Hydroform Type**: Surface swell **Biochemical features**: • Euphotic Zone Surface Mixed Layer	**Tectonic Setting**: n/a **Physiographic setting**: • Bay **Geoform Origin**: Geologic **Level 1 Geoform**: Shore **Type**: Foreshore **Type**: Backshore **Level 1 Geoform**: Slope **Type**: Pavement area **Level 2 Geoform**: Tidepool **Origin**: Biogenic **Level 2 Geoform**: Mollusc Reef **Type**: Patch mollusc reef	**Origin**: Geologic substrate **Class**: Rock **Subclass**: Bedrock **Class**: Shell substrate **Subclass**: Shell reef substrate **Group**: Mussel Reef Substrate	**Biotic setting**: Benthic/Attached Biota **Class**: Reef biota **Subclass**: Mussel Reef **Communities**: *Perna perna, Semimytilus algosus, Mytilus galloprovincialis* **Class**: Faunal bed **Subclass**: Attached fauna **Group**: Attached anemones **Community**: *Anthothoe stimpsonii, Bunodactis reynaudi* **Group**: Barnacles **Community**: *Chthamalus dentatus* **Group**: Brittle starts on hard/mixed substrates **Community**: Ophiuroidea **Group**: Mobile crustaceans on hard/mixed substrate **Community**: *Pilumnoides rubus* **Group**: Mobile molluscs on hard/mixed substrate **Community**: *Afrolittorina knysnaensis, Nucella dubia,* limpets **Group**: Attached mussels **Community**: *Perna perna, Semimytilus algosus, Mytilus galloprovincialis* **Class**: Aquatic Vegetation Bed **Subclass**: Benthic macroalgae **Group**: Canopy-forming algal bed **Communities**: *Laminaria pallida* **Group**: Filamentous algal bed **Communities**: *Cladophora* sp. **Group**: Leathery/Leafy Algal Bed **Communities**: *Nothogenia erinacea* etc.

Habitat type	Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Artificial Areas	**Realm**: Temperate Southern Africa **Province**: Benguela **Ecoregion**: Namib	**System**: Marine **Subsystem**: Nearshore **Tidal Zone**: Intertidal	**Layers:** • Marine Nearshore Surface Layer - Euhaline Cool Water • Upper water column - Euhaline cool water • Pycnocline - n/a • Lower water column - Euhaline cool water **Hydroform Class**: Tidal Flow **Hydroform Type**: Semi-diurnal Tidal Flow **Hydroform Class**: Wave-driven current **Hydroform Type**: Longshore current **Hydroform Class**: Wave **Hydroform Type**: Anthropogenic wave **Hydroform Type**: Coastally trapped wave **Hydroform Type**: Surf zone **Hydroform Type**: Surface wave **Hydroform Type**: Surface wind wave **Hydroform Type**: Surface swell **Biochemical features**: • Euphotic Zone Surface Mixed Layer	**Physiographic setting**: • Bay **Geoform Origin**: Geologic **Origin**: Anthropogenic **Level 1 Geoform**: Artificial bar **Type**: Harbour Bar **Level 1 Geoform**: Dredge deposit **Type**: dredge deposit shoal **Level 2 Geoform**: Breakwater/jetty **Type**: Groin **Level 1 Geoform**: • Dredged channel • Harbour • Mooring field • Pipeline area **Level 2 Geoform**: • Buoy • Breachway • Bulkhead • Dock/pier • Dredge disturbance • Boat ramp • Outfalls/intakes • Rip Rap Deposit • Wharf	**Origin**: Anthropogenic Substrate **Class**: Anthropogenic Rock **Subclass**: Anthropogenic Rock Reef Substrate **Class**: Anthropogenic wood **Subclass**: Anthropogenic Wood Reef Substrate **Class**: Construction materials **Subclass**: Construction Reef **Class**: Metal **Subclass**: Metal Reef	**Biotic setting**: Benthic biota **Class**: Faunal bed **Subclass**: Attached fauna **Group**: Attached anemones **Community**: *Anthothoe stimpsonii, Bunodactis reynaudi* **Group**: Barnacles **Community**: *Chthamalus dentatus* **Group**: Mobile crustaceans on hard/mixed substrate **Community**: *Pilumnoides rubus* **Group**: Mobile molluscs on hard/mixed substrate **Community**: *Afrolittorina knysnaensis, Nucella dubia,* limpets **Group**: Attached mussels **Community**: *Perna perna, Semimytilus algosus, Mytilus galloprovincialis* **Group**: Filamentous algal bed **Communities**: *Cladophora* sp. **Group**: Leathery/Leafy Algal Bed **Communities**: *Nothogenia erinacea* etc.

Habitat type	Biogeographic setting (BS)	Aquatic setting (AS)	Water Column Component (WC)	Geoform Component (GC)	Substrate Component (SC)	Biotic Component (BC)
Estuary	**Realm**: Temperate Southern Africa **Province**: Benguela **Ecoregion**: Namib	**System**: Estuarine **Subsystem**: Estuarine open water **Tidal Zone**: Subtidal	**Layers:** • Estuarine open water surface layer - Mesohaline • Upper water column - Polyhaline moderate temperature water • Pycnocline - Present • Lower water column - Euhaline cool water **Hydroform Class**: Density Flow **Hydroform Class**: Residual current **Hydroform Type**: Reverse Estuarine Flow **Hydroform Class**: Tidal Flow **Hydroform Type**: Semi-diurnal Tidal Flow **Hydroform Class**: Microscale Lens **Hydroform Type**: Small freshwater plume **Biochemical feature**: • Boundary Layer • Euphotic Zone • Halocline • Neustonic Layer • Thermocline • Turbidity Maximum	**Tectonic Setting**: n/a **Physiographic setting**: Lagoonal Estuary **Level 1** **Geoform Type**: • Bay Mouth Bar • Delta • Delta plain • Lagoon **Level 2** **Geoform Type**: • Flood type delta • Spit • Pilings • Salt pond complex	**Origin**: **Class**: Unconsolidated mineral substrate **Subclass**: Fine unconsolidated substrate **Group**: Mud **Subgroup**: Silt	**Biotic setting**: Planktonic Biota **Class**: Zooplankton **Subclass**: Fish Meroplankton **Group**: Fish spawning and larval aggregation **Communities**: Mullet etc. **Class**: Phytoplankton **Subclass**: Dinoflagellate phytoplankton **Group**: Dinoflagellate bloom **Class**: Emergent wetland **Subclass**: Emergent tidal marsh **Group**: Low and intermediate salt marsh **Communities**: *Salsola* shrubs etc. **Subclass**: Vegetated Tidal Flats **Group**: Vegetated salt flat and panne **Community**: *Trianthema hereroensis*

6 RESULTS AND DISCUSSION

6.1 Rocky Intertidal

Rocky intertidal areas can be influenced by natural forces such as tides and wave exposure, as well as anthropogenic disturbances such as dredging and construction. Natural variation results in seasonal patterns in areas which experience noticeable changes in seawater temperature, availability of nutrients and sunlight. If conditions remain relatively constant in an area, as is experienced in Walvis Bay, seasonal changes are less noticeable and are unlikely to be the main drivers of the suite of species living along the shore. In order to determine whether the rocky intertidal is negatively impacted during future development, it is necessary to document the diversity and abundance of existing invertebrate assemblages in their 'natural state'. Although existing anthropogenic pressures continually affect this habitat (e.g. marine pollution, bait collecting), the state of the habitat before construction and operation of the tanker berth are documented. These data will then be compared to data collected post construction and during operation to enable quantification of the developmental impact and to identify appropriate remedial action.

Rocky shores can be divided into distinct bands according to the amount of time each section is exposed to the air. These zones (moving in a seaward direction) are named the littorina zone, the upper balanoid zone, the lower balanoid zone, the cochlear/limpet zone, and the infratidal zone. For this study, the shore was divided into three sections; the high (littorina), mid (balanoid) and low (infratidal) zones. Species that are more tolerant to desiccation (drying out) are found near the high-water mark, while those that cannot tolerate long periods of water recession are found near the low-water mark. A further influencing factor on the distribution of organisms on the rocky shore is the degree of exposure to wave action, with significant differences noted between sheltered and exposed areas (Bustamante *et al*. 1997). For this reason, Walvis Bay rocky shore sites were all located in the sheltered bay to control for variation owing to exposure.

6.1.1 Vertical zonation

Previous rocky shore areas surveyed include the rocky intertidal opposite the Guano Platform (Hooks and Duvenhage 2013), Dolphin Park and Langstrand (Ssemakula 2010), and Wlotzkasbaken (Pulfrich and Steffani 2007). See Table 6.1 for a comparison of species found. The June 2018 rocky intertidal survey at Walvis Bay identified 55 different invertebrate species including grazers, predators, filter-feeders, and algae (Table 6.1). The rocky shores were represented by low-lying sand inundated platforms interspersed between long sandy beaches. Typical high, mid and low zones are illustrated in Figure 6.1.

Due to the harsh conditions experienced in the high shore, this zone was mostly devoid of life. The Southern periwinkle (*Afrolittorina knysnaensis*) and the flat-bladed alga (*Porphyra capensis*) were found sparsely scattered over the rocks. The upper balanoid zone was dominated by animals, in particular limpets and barnacles, while the granular limpet (*Scutellastra granularis*), the variegated topshell winkle (*Oxystele antoni*), and the whelk (*Nucella dubia*) were recorded in the lower balanoid. Due to increased grazing pressure, seaweed was sparse in the lower balanoid zone, however, some sea lettuce (*Ulva* spp.) and scattered patches of diatoms (microalgae) were occasionally present.

Figure 6.1. Photographs of a typical high, mid and low rocky shore site at Walvis Bay (from left to right).

The 'cochlear zone' did not feature in this region and limpets were instead spread along the whole expanse of the shore depending on their species specific tolerance to desiccation. The infratidal zone was inhabited by organisms that cannot withstand long periods of exposure, such as delicate algal species (e.g. *Ceramium* spp., *Rhodymenia obtusa* and *Mazzaella capensis*), echinoderms (e.g. brittlestars, sea cucumbers and urchins) and cnidarians (e.g. sea anemones).

6.1.2 Functional groups

Rocky intertidal species were categorized into six functional groups: grazers (mostly limpet species), filter-feeders (including sessile suspension feeders such as mussels and barnacles), predators (such as carnivorous whelks and anemones), corticated algae, ephemeral foliose algae and kelps (Figure 6.2). In terms of percentage cover, filter feeders dominated the shores, followed by algae (counted by attachment points, not canopy cover). Predators and grazers covered a much smaller area of the shore (Figure 6.2).

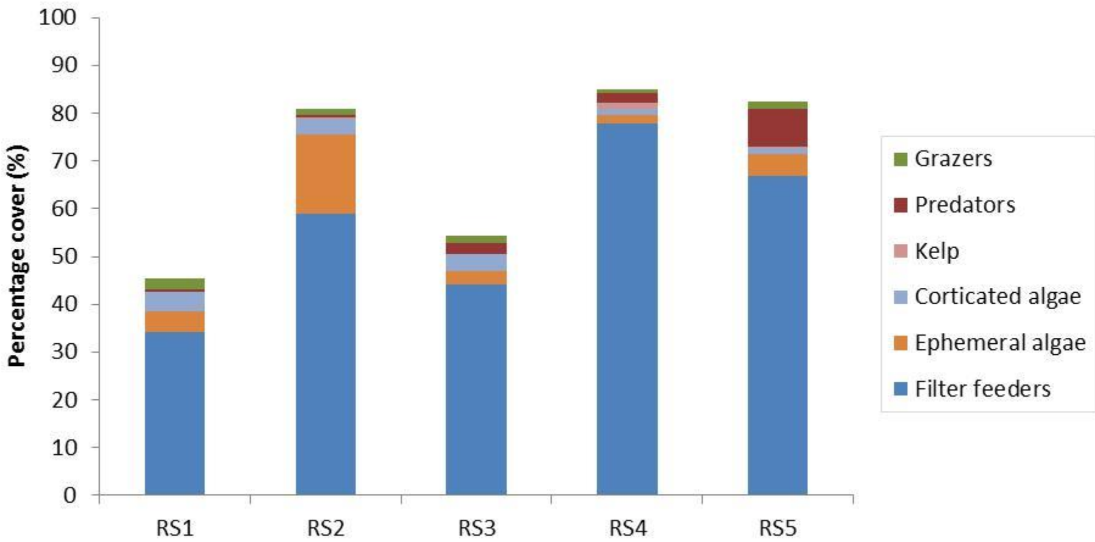

Figure 6.2. Total percentage cover (averaged across the whole shore) of the six functional groups at the five rocky intertidal study sites.

The diversity of intertidal macroalgal species and rocky shore biota are generally relatively low on the west coast, although biomass tends to be high due to an abundance of nutrients. At Walvis Bay, filter feeders contribute substantially to the faunal community due to the abundance of kelp particulates from the healthy kelp beds, seabird guano from the artificial offshore platform, and plankton which are supported by upwelled nutrients. Three species of mussel were found to be well established on the rocky shores of Walvis Bay; the invasive black mussel (*Mytilus galloprovincialis*), the native brown mussel (*Perna perna*), and the small bisexual mussel (*Semimytilus algosus*). They typically formed a thick mussel bed, at times higher than 20 cm off the rock (Figure 6.3). The resulting habitat matrix provided a complex environment for other invertebrate species such as amphipods (not typically sampled in rocky intertidal transects due to their small size) and brittlestars.

Figure 6.3. Thick mussel beds consisting of the invasive black mussel (*Mytilus galloprovincialis*), the native brown mussel (*Perna perna*), and the small bisexual mussel (*Semimytilus algosus*).

Although rocky intertidal areas constitute relatively scarce habitat along this stretch of coast, none of the species found during the survey are vulnerable locally or regionally. Generally, the Walvis Bay communities were healthy but the presence of two of alien invasive species, the Mediterranean mussel and the bisexual mussel, were noted.

Table 6.1. Species of grazers, predators, filter-feeders and algae (kelp, ephemerals and corticated) found in the rocky intertidal during the June 2018 survey as well as historical surveys.

Species name	Common name	June 2018 (Anchor *et al.* 2018)	Oct 2013 Hooks & Duvenhage (2013)	Nov 2010 (Semakula 2010)	Oct 2007 (Pulfrich & Steffani 2007)
GRAZERS					
Afrolittorina knysnaensis	Southern periwinkle	X			X
Cymbula granatina	Granite limpet	X			
Cymbula miniata	Pink-rayed limpet		X		
Helcion dunkeri	Slim rayed limpet	X			
Scutellastra argenvillei	Argenville's limpet	X			
Scutellastra granularis	Granular limpet	X	X	X	X
Siphonaria capensis	Cape false limpet	X	X		X
Parechinus angulosus	Cape urchin	X		X	
Oxystele antoni	Variegated topshell	X			
Paridotea reticulata	Reticulate kelp louse		X		
Tricolia capensis	Pheasant periwinkle	X			
PREDATORS					
Anthothoe stimpsonii	Striped anemone	X			
Bunodosoma capense	Knobbly anemone		X		
Bunodactis reynaudi	Sandy anemone	X		X	
Nereis sp.	Segmented worm		X		
Nucella dubia	Common dog whelk	X			
Ophiuroidea	Brittlestars	X	X	X	
Pilumnoides rubus	Kelp crab	X			
FILTER FEEDERS					
Choromytilus meridionalis	Black mussel		X	X	X
Chthamalus dentatus	Toothed barnacle	X	X	X	X
Discinisca tenuis	Disc lamp shell	X			
Encrusting Bryozoa	Lace animals	X			
Mytilus galloprovincialis	Mediterranean mussel	X	X	X	X
Notomegabalanus algicola	White dwarf barnacle	X	X		
Octomeris angulosa	Eight-shell barnacle	X			
Pentacta doliolum	Cask sea cucumber	X		X	
Perna perna	Brown mussel	X	X	X	X
Roweia frauenfeldi	Horseshoe sea cucumber		X		
Semimytilus algosus	Bisexual mussel	X	X	X	X
Sponge	Sponge	X			

Species name	Common name	June 2018 (Anchor *et al.* 2018)	Oct 2013 Hooks & Duvenhage (2013)	Nov 2010 (Semakula 2010)	Oct 2007 (Pulfrich & Steffani 2007)
KELP					
Laminaria pallida	Split-fan kelp	X	X		
EPHEMERAL ALGAE					
Callithamnion collabens	Aristocratic plume-weed	X			
Centroceras spp.	Curl-claw algae	X			
Ceramium spp	Fine red algae	X			X
Cladophora spp.	Fine green algae	X			
Diatoms	Microalgae	X			
Ectocarpus sp.	Fine string algae	X			
Porphyra capensis	Flat-bladed alga	X	X		
Ulva spp.	Sea lettuce	X	X		X
CORTICATED ALGAE					
Ahnfeltiopsis polyclada	Tough red algae	X			
Bryopsis myosuroides	Green sea moss	X			
Carpoblepharis flaccida	Flaccid kelp weed	X			
Caulacanthus ustulatus	Spiky turf weed	X	X	X	X
Chaetomorpha linum	Green hair weed	X	X		
Chondria capensis	Cape chondria	X			
Chylocladia capensis	Iridescent red algae	X			
Delisea flaccida	Membranous red	X			
Gelidium vittatum	Red ribbons	X			
Gracilaria gracilis	Gracilaria		X		
Gracilariopsis longissima	Thin dragon beard				X
Grateloupia capensis	Tattered rag weed	X			
Grateloupia longifolia	Rippled ribbon-weed				X
Gymnogongrus dilatatus	Dilated gymnogongrus	X			
Hypnea ecklonii	Straight-tipped hypnea	X			
Hypnea spicifera	Green tips	X			
Mazzaella capensis	Spotted mazzealla	X			
Nothogenia erinacea	Hedgehog seaweed	X			
Pachymenia carnosa	Red rubber-weed				X
Petalonia fascia	Fan-shaped brown algae	X			
Polyopes constrictus	Constricted polyopes	X			
Polysiphonia urbana	Epiphytic red algae	X			
Polysiphonia virgata	Kelp fern	X			
Rhodymenia obtusa	Broad wine weed	X			
Sarcothalia scutellata	Forked red algae	X			
Tayloriella tenebrosa	Intertidal turf	X			

6.1.3 Diversity indices

The following diversity indices were determined to measure community structure:

Species number (S) - total number of species present.

Percentage/biotic cover - the percentage of intertidal rocky surface that is covered by biota (fauna and flora).

Evenness (J') - expresses how evenly the individuals are distributed among the different species, in other words, whether a shore is dominated by individuals of one or a few species (low evenness) or whether all species contribute evenly to the abundance on the shore (high evenness). The index is constrained between 0 and 1 where the index increases towards 1 with less variation in communities.

Shannon-Wiener diversity index (H'[loge] or d) - a measurement of biodiversity taking into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness.

Diversity indices are graphed in Figure 6.4. Rocky shore Sites 4 and 5 were found to have the highest average number of species (~20), while Site 3 had the lowest (~15). Although there appears to be an increase in the number of species found within the more northern rocky shore habitats, it is not clear whether this is a function of anthropogenic influence, water quality, or wave exposure. Average biotic cover, evenness and Shannon-Wiener diversity showed no clear trends across the rocky intertidal sites.

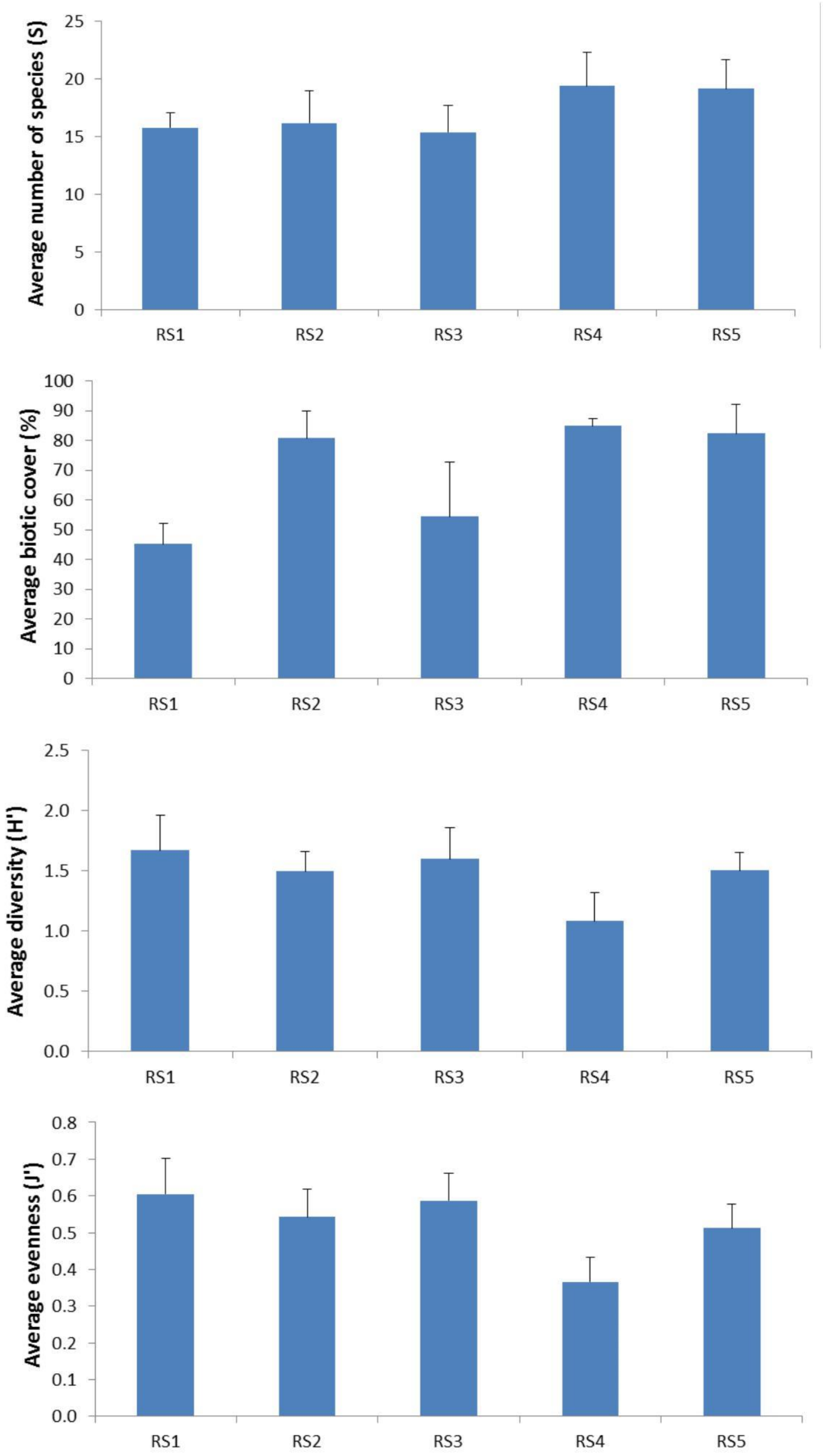

Figure 6.4. Rocky intertidal data averaged across replicates and displayed as biotic indices of 'species number' (S), 'biotic cover' (N), 'diversity' (d) and 'evenness' (J'). Error bars indicate standard deviation.

6.2 Sandy Beaches

6.2.1 Beach state and morphometrics

Data on key physical parameters measured at the five sampled beach sites during June 2018 are presented in Table 6.2. Sediments at the two sites closest to the oil and gas jetty (B1 and B2) were coarser than those on beaches further away to the north. Despite B1 and B2 beaches being more sheltered from wave action than the sites further north, they were classified as reflective beaches and this may be at least partly a result of construction activities. Sediment textural group was however all classified as “Slightly Gravelly Sand” at sites 1-4 and as “Sand” only at Site 5 (Table 6.2). The beach sediments were moderately well sorted at all sites and were either fine skewed or symmetrical with the exception of site B2 near the base of the jetty, where sediments were coarse skewed, possibly a reflection of jetty construction impacts (Table 6.2).

Within Walvis Bay shelter from the prevailing south-west swells is greatest near the Port and decreases to the north past Langstrand. This was reflected in the observed apparent wave height at the time of the 2018 sampling with wave height at the southern sites been negligible and increasing to approximately 1.5 m at site B5 (Table 6.2). Wave period, the time interval in seconds between waves reaching the shore varied across sites sampled on different days and ranged from 9-15 seconds (Table 6.2). Dean’s values (Ω, morphodynamic state) was less than 1 at the two southern sites and these were classified as reflective beaches, whilst the three beach sites to the north were classified as intermediate with increasing Dean’s values (1.5-4.19) (Table 6.2). Beach width at the three southern sites was narrow (22-27 m) and the intertidal slope was relatively steep (Table 6.2). Intertidal slope decreased and beach width increased at the two northern sites B4 and B5 (Table 6.2). When rated on McLachlan’s (1980) exposure scale, the most southern site B1 was classified as ‘Very Sheltered’ and the most northern site B5 as ‘Exposed’. The three beach sites in between (B2, B3 & B4) were classified as ‘Sheltered’ beaches.

6.2.2 Beach macrofauna

During our survey conducted in June 2018, 6 200 macrofaunal organisms from 28 taxa were collected from the five beach sampling sites in Walvis Bay; with an average abundance of 380 ind.m^{-2}. (14 639 m^{-1} of beach) and an average biomass of 4 g.m^{-2} (168 g.m^{-1}) across all sites (Table 6.4). Total average abundance and biomass (all species) was greatest at the most northern, exposed site B5 and much lower, (approximately half) at the other four sites to the south (Figure 6.5). Both abundance and biomass of sandy beach macrofauna was dominated by polychaetes and isopods, that combined contributed more than 90% to the total. Polychaete abundance was variable along the increasing exposure gradient from south to north, but isopod abundance declined noticeably (being much more abundant at the two sheltered southern sites) and amphipod abundance increased with increasing exposure (Figure 6.5).

The dominant species that were common across all sites included the polychaete *Scolelepis squamata*, the isopods *Eurydice kensleyi* and *Excirolana natalensis*, and the surf-zone mysid *Gastrosaccus namibensis*. The amphipod *Talorchestia* sp. was also fairly common at sheltered sites B1-4 but was absent from the exposed B5 site, although two other amphipod species *Heterophoxus opus* and *Bathyporeia sp.* were abundant at B5 but absent from the other sites. The bivalve *Donax* *serra* was also only found at the exposed northern site. Overall macrofauna diversity was highest at the very sheltered and sheltered southern sites B1 and B2 due to the relatively high number of different polychaete and amphipod species found at these sites. Biomass was however, lowest at the three sheltered southern sites and highest at the exposed northern site B5 where just eight species were found (Table 6.4). In terms of functional groups, detritivores and scavengers dominated the macrofaunal abundance and biomass across all sites (Figure 6.5).

Two previous surveys sampled sandy beach macrofauna in Walvis Bay (McLachlan 1985 and Donn and Cockcroft 1989), and one survey was conducted at Wlotzkasbaken (Pulfrich and Steffani 2007). McLachlan (1985) and Donn and Cockcroft (1989) rated Langstrand beach sites as exposed, reporting an exposure score of 13 and 11 respectively. This indicates that their sites were very similar to Site B5 (just past Langstrand), which was scored at 11 on McLachlan's exposure rating during the June 2018 survey. The mean particle size reported in these two earlier studies (250-291 µm) was also very similar to what was found at Site B5 (258-339 µm). The Langstrand sites sampled in these earlier studies were, however, narrower and steeper than Site B5 and similar to Site B4.

In terms of sandy beach macrofauna, the dominant species and abundance estimates are comparable to those found in our recent 2018 survey (Table 6.3). Diversity was much higher in the 2018 survey, however, McLachlan (1985) reported just eight marine taxa and Donn and Cockcroft (1989) reported nine taxa from their Langstrand samples, compared to the 28 taxa found in June 2018. This result is most likely linked to increased sampling effort, with the 2018 survey sampling five sites versus the one or two sampled in the earlier studies. Most of the species reported in the earlier surveys, with the notable exception of the isopod *Tylos granulatus,* were recorded in our 2018 samples (Table 6.3).

It is noteworthy that only the earlier survey by McLachlan (1985) recorded *T. granulatus* and this species was absent from Langstrand by the time of the Donn and Cockcroft (1989) survey. *T. granulatus* is strictly nocturnal and exhibits lunar and semi-lunar behavioural rhythmicity (Kensley 1972 and 1974). During the day *T. granulatus* remains buried up to 40 cm under the sand above the Spring High Water Mark. The population status of *T. granulatus*, remains mostly unknown, but there is circumstantial evidence suggesting that certain populations may be severely threatened and others have completely disappeared. It has been suggested that *T. granulatus* should be assigned a Red Data Book status of perhaps "Vulnerable" or "Low Risk" (Brown 2000). The range of *T. granulatus* once extended across the whole southern African west coast stretching far north into Namibia, but has now been reduced to probably less than half that. Human-induced disturbance (in the form of light pollution, vehicles, construction and development) in the coastal zone is hypothesised to be responsible for the reduction in *T. granulatus* abundance and distribution (Brown
& Odendaal 1994). Another noticeable change is the apparent reduction in white mussel biomass on the Langstrand beach that Donn and Cockcroft (1989) report as comprising 83% of the total biomass (compared with just 0.4% in our samples). This species is harvested by anglers for bait and the low biomass recorded in 2018 could be due to overexploitation over the preceding 30 years (this large bivalve species has been extirpated from numerous beaches near to Cape Town due to overexploitation).

Table 6.2. Key physical parameters measured at beach sampling sites in Walvis Bay during June 2018.

	Site B1	Site B2	Site B3	Site B4	Site B5
Sediment particle size (µm)					
Station 1	217	266	356	319	258
Station 5	378	604	254	351	309
Station 10	481	330	292	305	339
Average	358.5	400.0	300.8	324.9	301.8
Sediment name	Slightly Gravelly Sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Slightly Gravelly Sand	Sand
Sorting (sediment)	Unimodal, Moderately Well Sorted	Unimodal, Moderately Well Sorted	Unimodal, Moderately Well Sorted	Unimodal, Moderately Well Sorted	Unimodal, Moderately Well Sorted
Skewness (sediment)	Fine Skewed	Coarse skewed	Fine Skewed	Symmetrical	Symmetrical
Wave Height (m)	0.2	0.2	0.8	1.4	1.5
Wave period (s)	15	14	13	14	9
Slope (V:H)	1:6	1:11	1:8	1:21	1:28
Beach width (m)	22.5	27	26	45	54
Deans parameter	0.3	0.2	1.50	2.22	4.19
Morph. State	Reflective	Reflective	Intermediate	Intermediate	Intermediate
Exposure score	5	6	6	9	11
Beach type	Very Sheltered	Sheltered	Sheltered	Sheltered	Exposed

Table 6.3. **Sandy beach macrofauna recorded in the study area in June 2018, at Wlotzkasbaken, north of Swakopmund, in October 2007 (Pulfrich and Steffani 2007), and at Langstrand in July 1988 (Donn and Cockcroft 1989) and in 1985 (McLachlan 1985).**

Species	Common name	Anchor *et al.* (2018)	Pulfrich & Steffani (2007)	Donn and Cockcroft (1989)	McLachlan (1985)
Africorchestia quadrispinosa	Beach hopper	X			
Aphelochaeta filiformis	Bristle worm	X			
Bathyporeia sp	Amphipod	X			
Cerebratulus fuscus	Ribbon worm		X		
Cirriformia tentaculata	Thread-gilled worm	X			
Diptera larvae	Fly	X	X		
Donax serra	White mussel	X	X	X	X
Eulalia sp	Bristle worm	X			
Eurydice kensleyi	Right-angled beach louse	X	X		
Eurydice longicornis	Isopod			X	X
Excirolana latipes	Wide-foot beach louse	X			X
Excirolana natalensis	Natal beach louse	X		X	X
Gastrosaccus namibensis	Surf mysid	X	X	X	X
Glycera alba	Glycerine worm	X			
Gregariella petagnae	Half-hairy mussel		X		
Heterophoxus opus	Amphipod	X			
Insect A		X			
Latigammaropsis afra	Amphipod	X			
Lumbrineris sp.	False earthworm		X		
Nassarius plicatellus	Shielded dogwhelk	X			
Nemertea	Unsegmented worms	X	X	X	
Nepthys capensis	Sand worm	X			
Nepthys hombergi	Sand worm	X			
Nereis splendida	Bristle worm	X			
Onuphis sp.	Bristle worm		X		
Paramoera capensis	Big-eyed amphipod		X		
Prionospio sexoculata	Shell-boring spionid	X			
Protomystides capensis	Ring worm	X			
Pseudharpinia excavata	Amphipod			X	
Scolelepis squamata	Shell-boring spionid	X	X	X	X
Scoloplos madagascariensis	Bristle worm	X			
Socarnes septimus	Amphipod	X			
Talorchestia spp	Beach hopper	X	X	X	X
Tanaid A		X			
Tylos granulatus	Pill bug			XX	
Velella velella	Sea raft blue bottle				
Verdeia subchelata	Amphipod	X			

Table 6.4. Average abundance and biomass of macrofauna at five sandy beach sites sampled in Walvis Bay during June 2018.

	Average abundance per m^2					Average biomass per m^2				
Sandy beach site	**B1**	**B2**	**B3**	**B4**	**B5**	**B1**	**B2**	**B3**	**B4**	**B5**
Exposure/Distance from impact site (m)	**S**	**S**	**S-E**	**E**	**E**	**1**	**0.5**	**2.5**	**6.5**	**12.5**
Africorchestia quadrispinosa	0	0.28	0	0.56	0	0	0.0070	0	0.0129	0
Aphelochaeta filiformis	0	0.28	0	0	0	0	0.0004	0	0	0
Bathyporeia sp	0	0	0	0	1.11	0	0	0	0	0.0013
Cirriformia tentaculata	0	0.28	0	0	0	0	0.1168	0	0	0
Diptera larvae	0	0	0	8.06	0	0	0	0	0.0231	0
Donax serra	0	0	0	0	0.28	0	0	0	0	0.0750
Eulalia sp	0.28	0	0	0	0	0.00003	0	0	0	0
Eurydice kensleyi	245.83	207.78	58.33	12.78	55	0.6534	0.4432	0.1876	0.0838	0.2566
Excirolana latipes	0.56	0.28	0.28	0	0	0.0628	0.0504	0.0017	0	0
Excirolana natalensis	21.94	11.11	8.61	115.56	41.25	0.8759	0.4076	0.2910	2.7064	1.0061
Gastrosaccus namibensis	9.17	60.56	18.33	7.78	59.72	0.0373	0.2794	0.0824	0.0409	0.1603
Glycera alba	1.67	0	0	0	0	0.0022	0	0	0	0
Heterophoxus opus	0	0	0	0	15.56	0	0	0	0	0.0654
Insect A	0	0	0	0.28	0	0	0	0	0.0116	0
Latigammaropsis afra	0	0	0.83	0	0	0	0	0.0001	0	0
Nassarius plicatellus	0	0.28	0	0	0	0	0.0406	0	0	0
Nemertea	1.94	3.33	0	0	1.11	0.0262	0.0276	0	0	0.0242
Nepthys capensis	5	1.39	0	0	0	0.0191	0.0036	0	0	0
Nepthys hombergi	0.56	0.28	0	0	0	0.0052	0.0569	0	0	0
Nereis splendida	0	0.28	0	0	0	0	0.0020	0	0	0
Prionospio sexoculata	0	0.83	0	0	0	0	0.0004	0	0	0
Protomystides capensis	0	0	0.28	0	0	0	0	0.0003	0	0
Scolelepis squamata	45.56	105	151.11	26.67	581.67	0.8239	1.1883	1.8932	0.3134	7.6963
Scoloplos madagascariensis	0.28	1.94	0	0	0	0.0013	0.0018	0	0	0
Socarnes septimus	0	0.28	0	0	0	0	0.0004	0	0	0
Talorchestia spp	0.42	2.22	1.11	5	0	0.0026	0.0238	0.0054	0.0401	0
Tanaid A	0	0	0.28	0.28	0	0	0	0.0002	0.0003	0
Verdeia subchelata	0	0	0.28	0	0	0	0	0.0004	0	0
Total (no.m^{-2})	**333.2**	**396.4**	**239.4**	**176.9**	**755.7**	**2.5**	**2.6**	**2.5**	**3.2**	**9.3**
Total (no.m^{-1})	**7497**	**10703**	**6226**	**7963**	**40808**	**56**	**72**	**64**	**145**	**501**
Number of species	**12**	**17**	**10**	**9**	**8**					

Table 6.5. **Sandy beach macrofauna recorded on Langstrand in earlier surveys. The unit of measurement is number per running meter (No.m^{-1}).**

Taxa	McLachlan (1985)	Donn & Cockcroft (1989)	
		Transect 1	Transect 2
Amphipodds sp.	190	240	30
Donax serra		240	210
Eurydice longicornis	310	4 515	1 560
Excirolana natalensis	1 425	5 070	1 980
Gastrosaccus namibiensis	840	12 780	7 290
Pontogeloides latipes	150	195	30
Pseudharpinia excavata		315	
Scolelepis squamata	2 800	3 225	180
Talorchestia quadrispinosa	1	90	120
Tylos granulatus	1		
Total	**5 717**	**26 670**	**11 400**
No. species	**8**	**9**	**8**

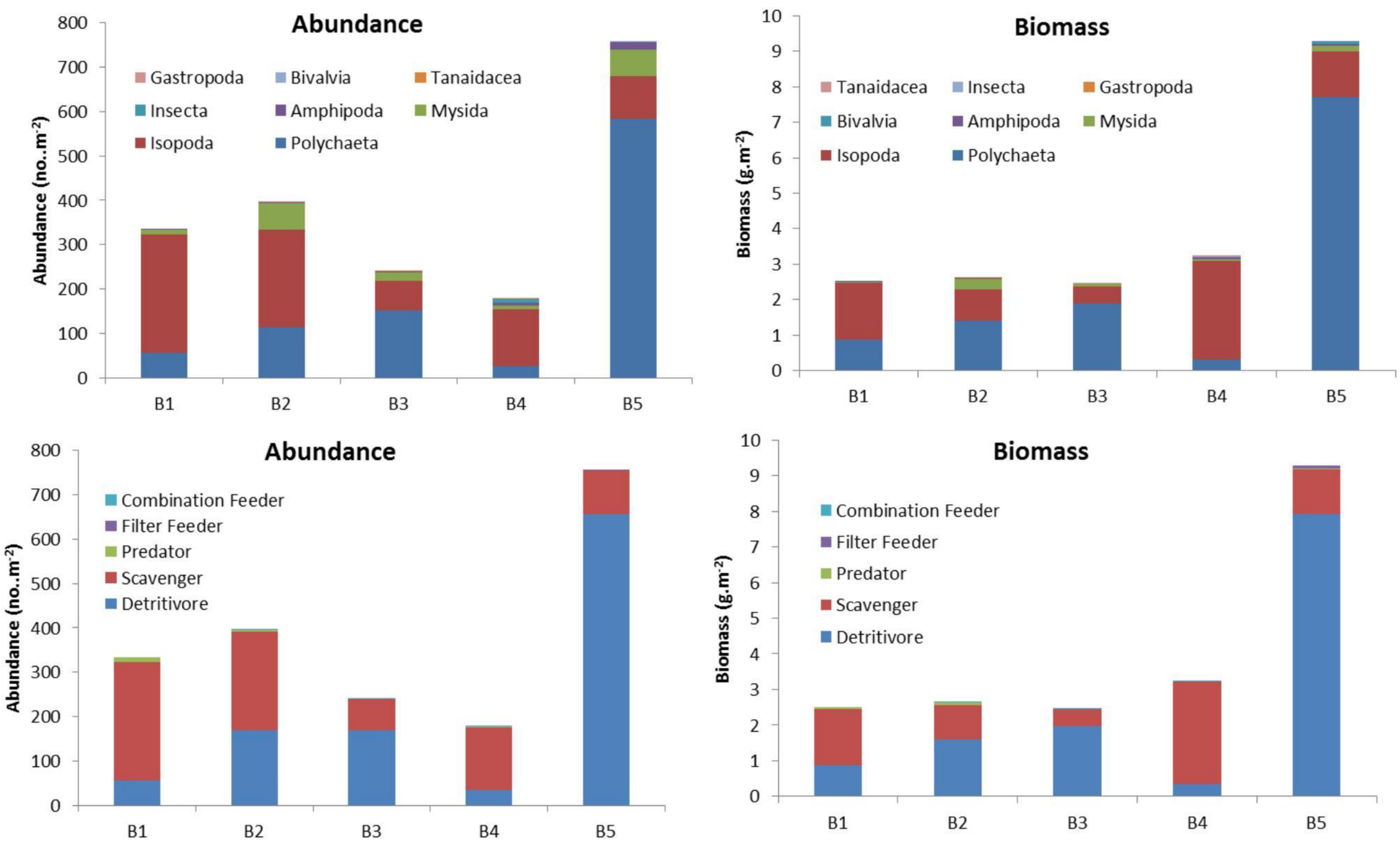

Figure 6.5. **Abundance and biomass of sandy beach macrofauna by taxonomic (top) and functional (bottom) groups.**

6.3 Surf-zone Fish

Sea conditions on the day fish sampling was conducted were calm, waves were non-existent at site B1, very small (10-20 cm) at B2 and B3, and of moderate size (up to 1.5 m) at sites B4 and B5 to the north, as the sheltering influence of Pelican Point diminished. Sites B4 and B5 had narrow surf-zones (10 m and 50 m respectively). The water was extremely clear (>10 m visibility) and cool (13-14°C) and catches were low, with nine of the 15 hauls not yielding any fish. A total of 36 fish, representing four families and four species were caught in the remaining six hauls conducted (Table 6.6, Figure 6.6).

Three of the four species caught are important in the catches of recreational and/commercial net fisheries in Namibia (Holtzhausen et al 2001, Stage & Kirchner 2005). The remaining species, the Cape silverside *Atherina breviceps,* is a small shoaling fish and is an important prey species for piscivorous birds and fish. Southern mullet *Chelon richardsonii* dominated (64%) the catches overall, whilst *A. breviceps* was the next most abundant species. Three juvenile galjoen *Dichistius capensis* and a single juvenile west coast steenbras *Lithognathus aureti,* were also caught (Table 6.6). The bulk of the west coast steenbras population exists in the nearshore at <10 m depth, with juveniles occurring in the intertidal surf zone (McLachlan 1986). By inference, spawning occurs in the surf zone and eggs and larvae from both populations drift northwards (Holtzhausen 2000). Only a single southern mullet was caught at the two sites adjacent to the oil terminal (B1 and B2) but better catches were taken at sites to the north, where the surf-zone was better developed and habitat heterogeneity increased (the most diverse catch was made at B4 where rocky reef flanked the small sandy bay).

Table 6.6. Fish community composition, for the five sites sampled with a beach seine net on the 12 June 2018. The female size (TL unless specified) at 50 % maturity are from the following sources: 1: Lamberth (2013), 2: Whitfield 1998; 3: Bennett & Griffiths (1986) 4: Holtzhausen (2000).

Species/Site	Common name	B1	B2	B3	B4	B5	Total	Size range (mm)	Maturity L_{50} (mm)
Chelon richardsonii	Southern mullet	no catch	1	1	3	18	23	65-243	245-283 [1]
Atherina breviceps	Cape silverside			9			9	65-115	40 (SL)[2]
Dichistius capensis	Galjoen				3		3	80-85	340 [3]
Lithognathus aureti	West coast steenbras				1		1	132	410-495 [4]
Total catch		0	1	10	7	18	36		
Diversity			1	2	3	1	4		

Figure 6.6. Fish species caught during seine net sampling on the 12 June 2018 in the Walvis Bay surf zone. West Coast steenbras *Lithognathus aureti* (top), galjoen *Dichistius capensis* (middle left), silverside *Atherina breviceps* (middle right) and southern mullet *Chelon richardsonii* (bottom).

Size frequency data show that nearly all the southern mullet, galjoen and west coast steenbras caught were juveniles, below the size of 50% maturity (L_{50}, Table 6.6). It is well established that surf zone habitats are important nursery areas for coastal marine fishes (e.g. Lasiak 1985, Clark 1994). This study supports the finding of Romer (1988), that Langstrand beach is utilized by juvenile mullet and west coast steenbras as a nursery. The presence of abundant suitable prey items for juvenile fish (principally beach mysids, amphipods and bivalves) and predator avoidance were considered important factors in the suitability of Namibian surf zones as fish nursery habitats (Romer 1986). Although not caught in our survey, Kirchner *et al*. (2001) also identified the Central Namibian Coast (West Coast Recreational Area) as an important spawning and nursery ground for silver kob. The presence of juvenile galjoen indicates that this is also nursery habitat for this species.

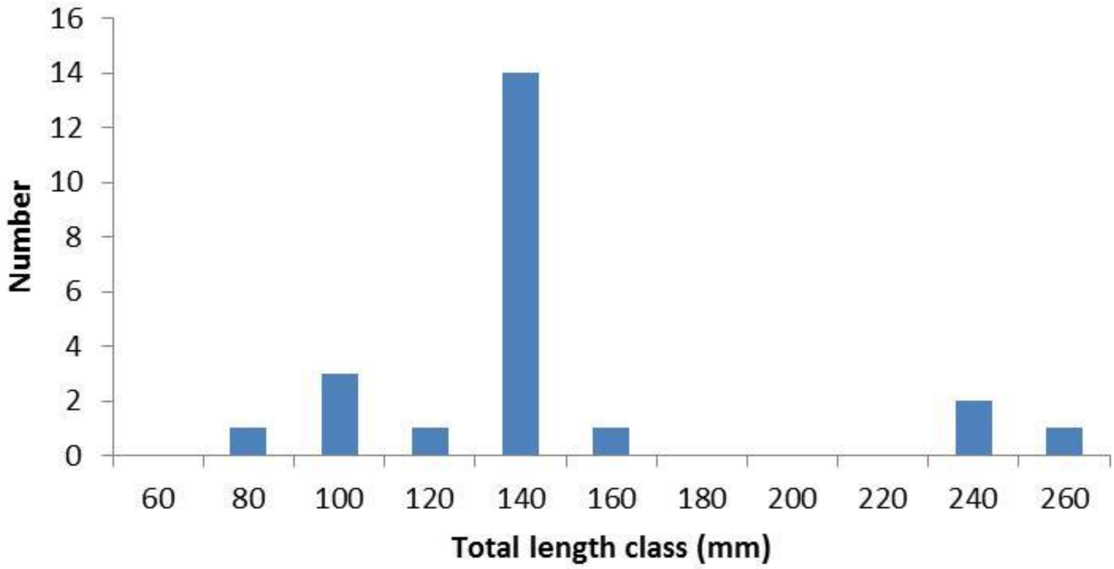

Figure 6.7. Length frequency composition of southern mullet *Chelon richardsonii* during seine net sampling on the 12 June 2018 in the Walvis Bay surf zone.

Several previous surveys have collected data on surf-zone fish survey off the central Namibian coast including the work of McLachlan (1986) and Romer (1988) at Langstrand; and a survey undertaken by Pisces Environmental to the north of Swakopmund in 2015 (Pulfrich 2015).

The Romer (1988) survey used two beach seine nets, a larger net similar in size to that used in this survey (35 m) but with a larger stretched mesh of 40 mm; and a smaller (10 m by 1 m, 2 mm stretched mesh) net. With the larger net, a total of 10 hauls were made at Langstrand, landing 233 fish from four species, galjoen, west coast steenbras, southern mullet and flathead mullet (Table 6.7). Three of these species were also recorded in our 2018 survey. The size range of species caught by Romer (1988) using the large net were comparable to that reported here for the same species (except the one galjoen), whilst the catch rate was substantially higher (285 fish in 18 hauls versus 36 fish in 15 hauls) due to the large number of southern mullet caught at Langstrand (78% of the total catch). The small mesh net was only used at Langstrand where some 58 young of the year westcoast steenbras (33-84 mm SL) and southern mullet (42-93 mm SL) were caught in 12 hauls. From the surf zone off Langstrand beach near Walvis Bay, McLachlan (1986) recorded galjoen, West Coast steenbras, flathead mullet (*Mugil cephalus*), and southern mullet.

The Pulfrich (2015) survey comprised 19 hauls between Mile 9 and Wlotzkasbaken using the a similar beach seine net (30 m long, 2 m deep, 12 mm stretch mesh) to the one used in this 2018 survey. Sea conditions during this survey were reported as turbid and warm. A total of 134 fish from nine species were caught in this survey, which included the four species caught in our 2018 survey (Table 6.8). Additional species caught that were not landed in our 2018 survey included silver kob, blacktail, and elf. These three important linefish species (Kirchner *et al*. 2000) are expected to also occur in the Walvis Bay study area as are sandsharks and the blenny that was reported by Pulfrich (2015).

Table 6.7. Surf-zone fish sampled by Romer (1986) using beach seine nets at Langstrand during June 1986.

Taxa	Common name	Length range (cm)	Total number
40 mm mesh			
Dichistius capensis	Galjoen	30	1
Lithognathus aureti	West Coast steenbras	20-25	9
Mugil cephalus	Flat head mullet	29	1
Chelon richardsonii	Southern mullet	16-24	222
2 mm mesh			
Lithognathus aureti	West Coast steenbras	3.3-8.4	58
Chelon richardsonii	Southern mullet	4.2-9.3	29

Fish data from earlier surveys in the region indicates that there have not been major changes in the fish community composition utilizing the nearshore surf zone nursery areas in Walvis Bay. The relatively low numbers of fish in our 2018 catches are partly attributed to the prevailing oceanographic conditions, namely clear and cool water caused by unusual berg winds (easterlies) at the time of our survey. Ongoing overexploitation of fish stocks could, however, also have played a role in reducing the spawner biomass and reproductive output of inshore Namibian fish stocks (Holtzhausen *et al*. 2001, Kirchner 2001). Two sulphur eruption/low oxygen events that occurred in February and March 2018 and resulted in large fish kills in the study area (*pers. comm*. UNAM Zoology Department), may also have contributed. These events occurred after the spring summer spawning season and would have substantially reduced the abundance of juvenile fish in the nearshore habitats of Walvis Bay prior to the June 2018 survey.

Table 6.8. Surf-zone fish sampled by Pulfrich (2015) using beach seine nets at five sites north of Swakopmund during February 2015.

Taxa	Common name	Length range (mm)	Total number
Argyrosomus inodorus	Silver kob	215-385	25
Atherina breviceps	Silverside	25-185	55
Dichistius capensis	Galjoen	125-245	9
Diplodus capensis	Black tail/dassie	308	1
Lithognathus aureti	West Coast Steenbras	195-235	3
Chelon richardsonii	Harder	100-200	33
Pomatomus saltatrix	Elf	235-315	5
Rhinobatos blochii	Bluntnose guitar fish	793	1
Scartella emarginata	Maned blenny	54-68	2

The recent and historical fish survey data reveals that a fairly low diversity of fishes utilize the nearshore zone of the central Namibian coast, but confirms the importance of the shallow surf zone within Walvis Bay as a nursery area for several commercially important species. The value of the surf-zone habitat for juvenile fish improves to the north (away from the oil and gas terminal) as exposure to the predominant south-westerly swells increases and a surf-zone develops. The surf-zone and increased habitat heterogeneity due to the presence of rocky shore and reefs provides both shelter from predation and increased food availability for fish.

6.4 Coastal Birds

An avian specialist report identified bird species that may potentially be impacted by the proposed development, most likely by fuel spillage or collision with new infrastructure (Scott and Scott 2013).

- Endangered: Cape gannet, African penguin, great crested grebe and Yellow-nosed albatross.
- Near Threatened: Crowned cormorant, bank cormorant, Cape cormorant, African black oystercatcher, chestnut-banded plover, black-necked grebe, maccoa duck, Damara tern.
- Vulnerable: Greater flamingo, lesser flamingo, great white pelican, Caspian tern, Hartlaub's gull, white-chinned petrel.
- Least concern: Pied avocet, grey plover, white-fronted plover, turnstone, sanderling, curlew sandpiper, kelp gull, swift tern, common tern.

For this study, the most abundant coastal bird species observed within the study were Cape Cormorants *Phalacrocorax capensis,* several thousand of which roost nightly on the guano platform between sites B3 and B4 (Table 6.9). This artificial platform, specifically built as a commercial venture to harvest guano in the 1930s is also one of only three breeding localities for great white pelicans *Pelecanus onocrotalus* (about 150-200 pairs usually breed on the platform) in Southern Africa (Underhill undated). Pelicans bred on the platform for the first time in 1949 after the sandy islets at Sandwich Harbour, about 60 km farther south where they used to breed became linked to the mainland, allowing access to predators (Underhill undated). Whitebreasted Cormorant *Phalacrocorax carbo lucidus*; also utilize the Walvis Bay guano platform for breeding with about 700 nesting pairs recorded making it the largest Whitebreasted Cormorant colony in the world (Underhill undated). Approximately 100 pairs of Crowned Cormorants nest on the supports underneath the guano platform; this is the northernmost breeding colony of this species along the west coast of Africa; the next nearest colony is at Oyster Cliffs, some 250 km farther south. Greater Flamingos *Phoenicopterus ruber* sometimes roost on the platform in large flocks (up to 150 birds). The African Black Oystercatcher *Haematopus moquini* and Turnstone *Arenaria interpres* occur regularly on the platform, with occasional visits from other wader species (Underhill undated).

Kelp gulls *Larus dominicanus* were common and were observed roosting and feeding on the shore throughout the study area, whilst Hartlaubs gulls *Chroicocephalus hartlaubii* were also fairly common near Langstrand. White fronted plovers *Charadrius marginatus* were seen on sandy beaches throughout the study are with no clear pattern in their distribution. A pair of African black oystercatchers, a grey heron *Ardea cinerea,* and a little egret *Egretta garzetta* were observed feeding on rocky shores. See the avian specialist report for a detailed account of birds associated with the lagoon and estuary (Scott and Scott 2013).

Table 6.9. Birds recorded in the study area during the rocky shore and sandy beach surveys.

Scientific name	Common name	B1 to B2	B2 to B3	B3 to RS2	RS2 to RS3	RS3 to B4	B4 to RS4	RS4 to B5
Larus dominicanus	Kelp gull	10	130	34	40	50	78	90
Phalacrocorax capensis	Cape cormorant	0	6	100	0	~2 000	32	16
Charadrius marginatus	White fronted plover	6	2	2	2	5	2	0
Pelecanus onocrotalus	Great white pelican	0	0	1	0	0	0	0
Haematopus moquini	African oyster catcher	0	0	0	2	0	0	0
Chroicocephalus hartlaubii	Hartlaubs gull	0	0	0	0	20	50	2
Egretta garzetta	Little Egret	0	0	0	0	0	0	1
Ardea cinerea	Grey heron	0	0	0	0	0	0	1
Number of species		**2**	**3**	**4**	**3**	**4**	**4**	**5**

The field survey was undertaken during the austral winter and paleo-artic migrant waders are be expected to utilize the shore during the austral summer, although the lagoon and salt work wetlands to the south of Walvis Bay provide a much more favourable habitat for waders than the mixed sandy beach-rocky shore habitat of the study area. The Walvis Bay wetlands are a Ramsar site and an average of 156 000 water birds from 48 species were recorded between 1997 and 2005 in these wetlands (Wearne and Underhill 2005) This site supports the largest number of waders of any wetland in southern Africa (Wearne and Underhill 2005). Some notes on the ecology of the more common coastal bird species observed in the study area are provided below.

The Kelp Gull *Larus dominicanus* breeds primarily on offshore islands, as well as a small number of mainland sites. This is the largest gull in the Benguela region and it is a common resident in coastal habitats and adjacent wetlands although it is known to follow trawlers up to 100km offshore and may fly up to 50km inland in search of food. Kelp gull numbers increased in many areas up until about 2000, probably in response to an increase in availability of food as a result of the introduction and spread of the invasive alien mussel species *Mytilus galloprovincialis.*

Hartlaub's Gull, *Chroicocephalus hartlaubii*, is about the 10th rarest of the world's roughly 50 gull species but is still considered a common resident 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). This species is known to occasionally hybridize with the grey headed gull *Chroicocephalus cirrocephalus* particularly on the central Namibian coast (Sinclair *et al*. 2011).

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).

The Cape Cormorant is regarded as Near Threatened owing to a decrease in the breeding population during the late 1970s (Crawford 2007). Numbers decreased again 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 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). It breeds in rocky intertidal and sandy beach areas from Namibia to the southern KwaZulu-Natal coast. Oyster catcher populations have improved in many areas where establishment of the invasive black mussel has increased its food supply.

6.5 Offshore Habitat

6.5.1 Water Quality

6.5.1.1 Physico-chemical properties

CTD profiles revealed near identical water column characteristics across the twelve sampled sites with the exception of the three deeper sites within the dredge channel alongside the jetty (G2, G6 and G10), where low dissolved oxygen and high turbidity was recorded (Table 6.10). Water column profiles revealed a rapid decline in water temperature from the sun-warmed surface layer of approximately 15.5°C with water below 8 m depth being ±2°C colder. There was little variation in the depth of the thermocline between sampled sites but more variation in temperature in the deeper water below the thermocline (Figure 6.8). Salinity measurements showed little variation through the water column and fill within a narrow range around a mean of 35.2 PSU (Figure 6.8).

Sufficient DO in sea water is essential for the survival of nearly all marine organisms. Low oxygen (hypoxic conditions) or zero oxygen (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 Southern African west coast, results from the decay of large plankton blooms under calm conditions (Jarre *et al*. 2015). Once all the oxygen in the water is depleted, anaerobic bacteria (not requiring oxygen) continue the decay process, causing the characteristic sulphurous smell. Such low-oxygen conditions are typical on the west coast of Southern Africa and it has been well established that upwelling events can transport cold, low-oxygen water to the nearshore environment (Andrews and Hutchings 1980, Bailey and Chapman 1985, Taunton-Clark 1985).

Dissolved Oxygen (DO) mirrored the temperature profile and declined rapidly from the well oxygenated surface waters to extremely low levels (close to zero $mg.l^{-1}$) recorded below 9 m water depth (anoxic). By 7 m depth DO levels dropped below a concentration of 2 $mg.l^{-1}$ (Figure 6.8), which is considered to be the minimum concentration for the survival of most marine life. Walvis Bay has a retentive circulation pattern and is situated downstream of an extensive area of intense upwelling, which makes it particularly susceptible to anoxia. Persistent low oxygen conditions are found in subsurface water with regular, natural "hydrogen sulphur eruptions" causing widespread mortality of marine life (Gilchrist 1916, Copenhagen 1953, Jarre *et al*. 2015).

pH was constant at most depths but did decline slightly in the near bottom waters, probably reflecting the presence of hydrogen sulphide (Figure 6.8). In contrast to temperature and salinity, turbidity also increased dramatically below the thermocline and attained high levels in the near bottom waters, probably due to a combination of suspended organic material (diatom ooze) and sulphur reducing bacteria (Schulz *et al*. 1999).

Table 6.10 Average water quality characteristics from CTD profiles taken at twelve subtidal sampling sites.

Site	Temperature (C)	Salinity (PSU)	Dissolved oxygen (mg/l)	Turbidity (NTU)	pH
WB_G1	14.85	35.23	3.70	2.23	6.85
WB_G2	14.25	35.13	1.83	13.41	7.68
WB_G3	14.94	35.24	3.03	5.05	7.81
WB_G4	15.17	35.24	3.81	5.75	7.88
WB_G5	15.25	35.24	5.38	3.22	8.11
WB_G6	14.13	35.23	1.34	14.97	7.58
WB_G7	14.86	35.22	3.18	4.56	7.86
WB_G8	14.85	35.23	3.20	5.09	7.88
WB_G9	14.52	35.22	3.57	5.03	7.90
WB_G10	14.06	35.00	2.35	7.39	7.90
WB_G11	14.32	35.22	2.97	5.55	7.95
WB_G12	14.18	35.22	2.66	6.34	7.92

The following risk assessment tool for dredging activities is currently being used to monitor Total Suspended Solids (TSS) for the National Oil Storage Facilities Project. Concentrations are measured in the top three meters of the water column to determine ecological responses to ongoing dredging (Botha *et al*. 2015b):

- < 20 mg/l or 80th percentile of background levels – desirable low risk scenario.
- 20-80 mg/l for continuous periods of three days or longer – lower threshold for possible adverse ecological effects.
- 80-100 mg/l for more than six hours – probable adverse effects, mitigation measures must be considered.
- 150 mg/l – proven negative impacts, cease dredge operations.

An independent specialist measured the turbidity, electrical conductivity and temperature of water during the trial dredging program in June 2015 to gather baseline data and estimate TSS (Brinkman 2015). The 80th percentile of the background values for TSS were calculated at 25 mg/l for T3, 41 mg/l for T6 and 41 mg/l for T7 (see Figure 6.9 for sample sites). The turbidity threshold for the contractor was set at 80 mg/l, although values below 150 mg/l were recommended in the EIA. Real-time monitoring during August to October 2015 and November to December 2015 indicated that turbidity did not exceed the recommended limit during dredging (Brinkman 2015 & 2016).

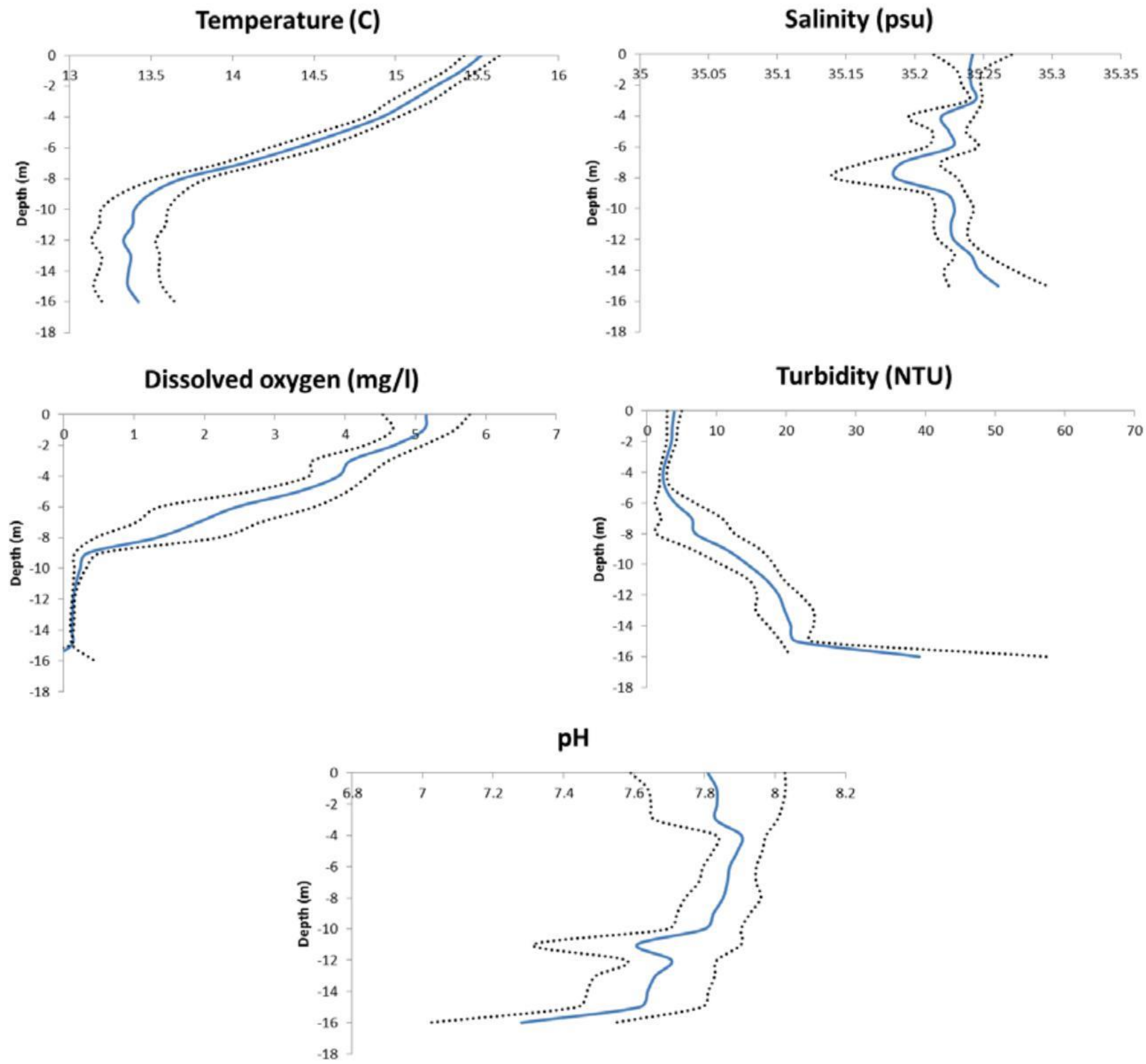

Figure 6.8 Water quality profiles obtained from CTD dips at 12 sampled sites. Solid blue line is the average measurement for each 1m depth bid across all sites and the dotted lines show 95% confidence intervals.

6.5.1.2 Heavy metals in solution

Recommended water quality guidelines for toxic substances in coastal areas of the BCLME region were published in 2006 (CSIR 2006) and are listed in Table 6.11. Water samples were collected at nine sites between December 2010 and April 2011 for environmental monitoring of the Walvis Bay Harbour Capital Dredging Project (Botha 2011). Over this period, 15 water quality samples were collected at Site W3, located just east of the existing Walvis Bay Harbour dredge channel, within Mariculture Area 1 and in close proximity to the National Oil Storage Facility Jetty (see Botha 2011). Water from this site showed heavy metal concentrations that exceeded BCLME water quality guideline values for copper, lead and zinc during this time (Botha 2011).

Table 6.11. Recommended water quality guidelines for toxic substances in coastal areas of the BCLME region (CSIR 2006). Concentrations measured in 2010/2011 are also listed (Botha 2011).

Toxic substances (mg/l)	BCLME WQG	Maximum concentration recorded	Number of samples exceeding WQG in 2010/2011
Cadmium	0.0055	<0.0004	0
Cobalt	0.001	<0.001	0
Copper	0.0013	0.018	3
Mercury	0.0004	0.00028	0
Lead	0.0044	0.01	1
Nickel	0.07	0.07	0
Vanadium	0.1	0.1	0
Zinc	0.015	0.015	2

The ongoing Water Quality Monitoring Plan required by the EMP involves the collection of ten water samples at the following five sites: T3 Buoy 6, T5 Fairway, T6 Bird Island N, T7 Bird Island S, and Spoil Site (Figure 6.9). Results showed slightly elevated copper and zinc concentrations in two of the three water samples collected during September 2015 (Brinkman 2015). Copper exceeded the BCLME guideline values at T3 Buoy 6, while zinc exceeded the guideline value at T3 Buoy 6 and at the Spoil Site. Benzene was detected at the Spoil Site, while toluene was detected at all three locations, although both substances were below BCLME recommended guideline values. Volatile organic hydrocarbons exceeded BCLME guideline values at T3 Buoy 6. Site T3 Buoy 6 was found to have the most parameters above BCLME guideline values, indicating poor water quality (Brinkman 2015). None of the water samples collected during the November 2015 to January 2016 period exceeded the BCLME guidelines (Brinkman 2016). In August 2016, Mercury and Vanadium were present at T3 Buoy 6, which and showed a slight increase from baseline sampling results. Mercury exceeded the BCLME guideline value at this site. Poly Aromatic Hydrocarbons, namely fluorine and phenanthrene, were present in the analysis results for the first time. TPH fractions (C10 to C12) were also detected and increased above the baseline values at all sampling locations. At the Spoil Site, vanadium, TPH fractions (C10-C12), styrene, fluorene and biphenyl was detected and increased from baseline results (Brinkman 2017a&b). At sampling location T6 Bird Island, vanadium, TPH fractions (C10-C12) and (C21-30), fluorene and styrene and biphenyl were detected and showed an increase from baseline results. All other parameters analysed at all sampling locations remained below the detection limits (Brinkman 2017a&b).

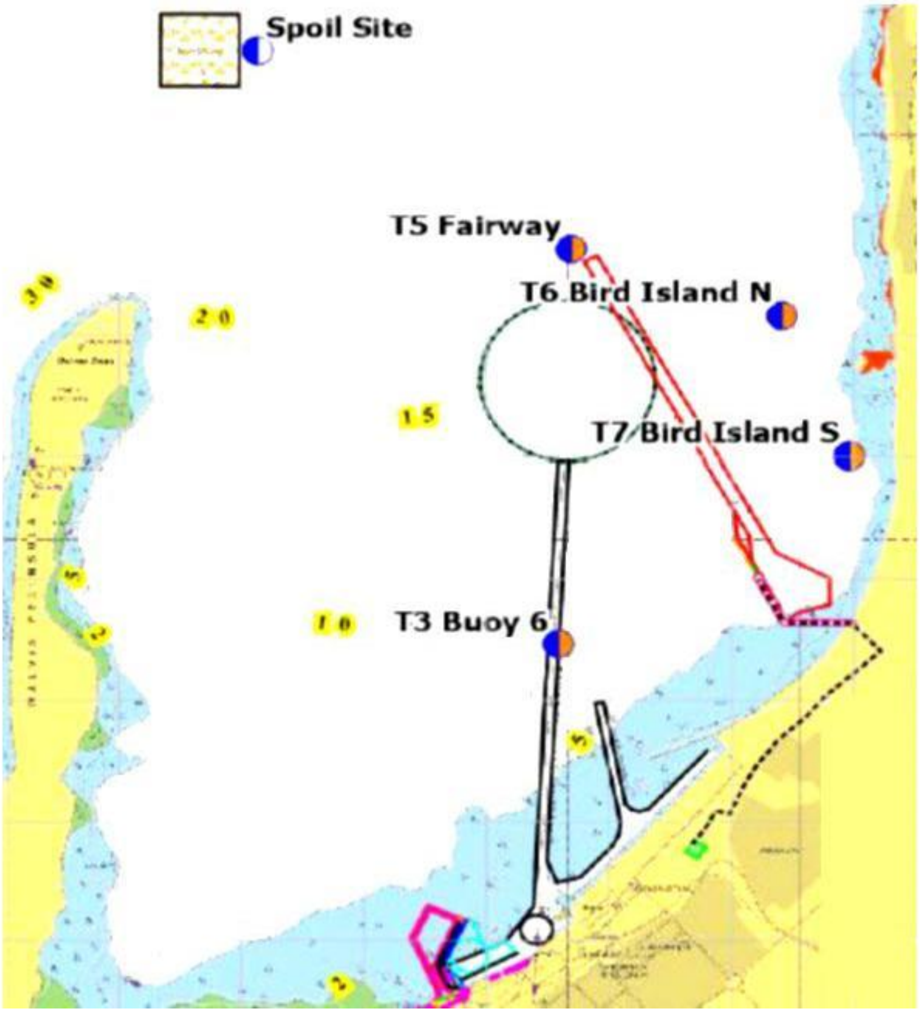

Figure 6.9. Five water quality sampling sites.

Real-time monitoring of heavy metal concentrations in water may be useful for monitoring during dredging; however, heavy metals attached to benthic sediments are more useful in predicting likely construction impacts when disturbed (see Section 6.5.4.2). As a result, heavy metal analysis of water samples was not undertaken for this study.

6.5.2 Plankton

Plankton consists of marine plants (phytoplankton) and animals (zooplankton) that constitute the primary marine food web. Classification depends on size, habitat type and length of planktonic life. In the Benguela ecosystem, zooplankton exhibit relatively low species diversity, high abundance and limited endemism (Maartens 2003). Of the estimated three million bacterial species worldwide, only about three thousand have been described (Maartens 2003). Phytoplankton found at Langstrand by McLachlan (1985) included dinoflagellates as well as diatoms of the genera *Navicula, Rhizosolenia, Nitschia, Campylosira* and *Melosira*. Zooplankton of the genus *Gastrisaccus* were also recorded (McLachlan 1986).

6.5.3 Offshore Reef

Offshore reef in the study area at Walvis Bay was characterised by low-relief rocky platforms scattered over a predominantly sandy bottom, predisposing them to periodic scouring and cover by sand and unconsolidated sediments. Although kelp occurs sparsely offshore, the benthic communities inhabiting these reefs are dominated by sand-tolerant and deposit feeding species (Pulfrich & Steffani 2008). Reports on the benthic biota of nearshore reefs are restricted primarily to research undertaken in the vicinity of Lüderitz (Pulfrich 1998; Pulfrich and Penney 1998, 1999, 2001; Pulfrich and Steffani 2008). A diving survey conducted just north of Walvis Bay recorded reef-building tube worms, rock boring bivalves, sea anemones, large indigenous mussels *Perna perna*, and the predatory gastropod *Stramonita haemastoma* (Pulfrich & Steffani 2008). Rocky reefs were densely covered by encrusting coralline algae, red foliose algae (*Rhodymenia obtusa*, *Rhodymenia natalensis*, *Ceramium capense* and *Polyopes constrictus*), and green algae (e.g. *Cladophora flagelliformis*). Epiphytic species (*Hypnea ecklonii* and *Carpoblepharis flaccida*) were found growing on the canopy-forming kelp *Laminaria pallida* (Pulfrich & Steffani 2008). A follow-up survey in 2009 recorded additional species including polychaetes (*Nereis* spp., *Naineris laevigata* and *Pherusa swakopiana*), isopods (*Amakusanthura africana*), amphipods (*Maera hinderella*), boring bivalves (*Petricola bicolor* and *Gregariella petagnae*), sea anemones (*Actinia* sp.), barnacles, brittle stars and encrusting bryozoans (Pulfrich and Steffani 2009).

6.5.4 Benthic Sediment

It is important to monitor biological components of the ecosystem in addition to physico-chemical and eco-toxicological variables, as biological indicators provide a direct measure of the state of the ecosystem in space and time. 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 Walvis 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 heavy 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.

6.5.4.1 Sediment particle size

The benthic sediment in Walvis Bay was predominantly fine mud (see Appendix 4, Table 12.3). Contaminants such as metals and organic toxic pollutants are predominantly associated with fine sediment particles (mud and silt). This is because fine grained particles have a relatively larger surface area to which pollutants bind. Higher proportions of mud, relative to sand or gravel, can thus lead to high organic loading and heavy metal contamination. A disturbance to natural wave action and current patterns may result from the construction of a jetty, and an increase in the proportion of mud, could result in higher organic loading and dangerous levels of metal retention. 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. It is therefore important to include sediment particle size analysis in future monitoring for this project.

6.5.4.2 Heavy metals

Heavy 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 such as 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 Total Organic Carbon (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 BCLME program reviewed international sediment quality guidelines in order to develop a common set of guidelines for the coastal zone of Angola, Namibia and west coast of South Africa (Table 6.12). These guidelines include 'probable effect concentrations' and 'recommended guideline values' (CSIR 2006). The National Oceanic and Atmospheric Administration (NOAA) also published a series of sediment screening values for the marine environment, which cover a broad spectrum of concentrations from toxic to non-toxic levels as shown in Table 6.12 (Buchman 1999). Values are measured in mg/kg of dry weight, which is equivalent to parts per million (ppm). 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 10^{th} 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 50^{th} percentile of sediment concentrations reported in literature that co-occur with a biological effect (Buchman 1999).

The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (1972) and the 1996 Protocol to the London Convention regulate the deliberate disposal of waste materials in the marine environment. Participating countries are encouraged to develop National Action Lists (NAL) that include sediment quality guidelines to assess if sediment identified for dredging (and subsequent dumping) is of a suitable quality for unconfined open water disposal. The guidelines published for South Africa are summarised in Table 6.12 (DEA 2012).

Table 6.12 Summary of Benguela Current Large Marine Ecosystem (BCLME) and National Oceanic and Atmospheric Administration (NOAA) metal concentrations in sediment quality guidelines.

Heavy metal (mg/kg or ppm)	BCLME (marine ecosystems)		NOAA (marine ecosystems)		National Action List (dumping)	
	Recommended Guideline Values	Probable Effect Concentration	ERL	ERM	Special care	Prohibited
Cadmium (Cd)	0.68	4.21	1.2	9.6	1.5 – 10	> 10
Copper (Cu)	18.7	108	34.0	270.0	50 – 500	>500
Lead (Pb)	30.2	112	46.7	218.0	100 – 500	> 500
Nickel (Ni)	15.9	42.8	20.9	51.6	50 – 500	> 500
Zinc (Zn)	124	271	150.0	410.0	150 – 750	> 750

All values from samples collected in June 2018 were lower than those recorded from benthic sediment samples collected for the preconstruction baseline survey in 2015 (Botha 2015), with the exception of copper (Table 6.13). Heavy metal concentrations in the sediment drill samples collected between November 2013 and April 2014 contained arsenic, cadmium, copper and nickel concentrations that exceeded BCLME guidelines, while probable effect concentrations were exceeded for cadmium (Botha 2015b). The final sediment samples were collected in August 2016. Four of the five samples collected from the dredge area exceeded the BCLME probable effect concentration for sediments (Brinkman 2017a). The elevated cadmium concentration is consistent with the pre-construction baseline results.

Sediments collected in 2013/2014 were found to contain carbonate shell fragments and had calcium carbonate concentrations varying from a maximum of 13.4% in the upper sediment layer to 1% in the deeper sediments (Botha 2015b). Silt was characterised by high phosphate content (> 1000 ppm recorded in a fifth of the samples), while sand samples had slightly elevated concentrations of titanium, zirconium and uranium, indicative of a heavy mineral sand component (Botha 2015b).

Table 6.13. Heavy metal concentrations at each of the five Walvis Bay monitoring sites (Brinkman 2015, 2016, 2017a&b). Red highlights indicate concentrations above BCLME water quality guidelines (recommended), while asterisks (*) indicate values above BCLME water quality guidelines (probable effect) for the natural environment. Averages are compared to samples taken for the preconstruction baseline survey during 2013/2014 (Botha 2015).

Samples (ppm)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
BCLME (recommended)	**7.24**	**0.68**	**52.3**	**18.7**	**15.9**	**30.2**	**124**
BCLME (probable effect)	**41.6**	**4.21**	**160**	**108**	**42.8**	**112**	**271**
Average (2013/2014)	**-**	**1.9***	-	12.62	10.89	5.58	34.47
Site 1	10	6.9*	46	13	14	6.7	21
Site 2	8.5	11*	65	16	18	4.1	27
Site 3	8.4	6.0*	43	16	17	8.1	42
Site 4	4.7	3.5	40	16	14	12	39
Site 5	-	0.5	13	4.9	5.6	-	-
Average (Sept 2015)	**7.9**	**5.58***	**41.4**	**13.18**	**13.72**	**7.73**	**32.25**
Site 1	13	3.7	41	20	17	7.4	46
Site 2	17	5.9*	47	22	19	9.2	45
Site 3	16	8.0*	49	21	18	8.1	41
Site 4	12	5.8*	40	20	14	7	33
Site 5	11	5.9*	37	20	13	6.2	30
Average (Aug 2016)	**13.8**	**5.86***	**42.8**	**20.6**	**16.2**	**7.58**	**39**

In 2018, sediments at grab site G11 exceeded the South African NAL guideline for offshore dumping; however, all other sites fell below prohibition levels. All sites bar one fell within the special care category for cadmium, while G4 was the only other site recommended for special care due to the concentration of copper within the sediment (Table 6.14).

The ERL values represent the most conservative screening concentrations for sediment toxicity proposed by the NOAA, thus heavy metal results were compared to ERL values as well as to BCLME values for this study. None of the values for zinc and lead were found to exceed the ERL in 2018, although concentrations of cadmium, copper and nickel were found to be elevated at many of the sites (Table 6.14). Heavy metal concentrations exceeded BCLME guidelines at all sites in 2018 for cadmium and at most sites for copper and nickel, while only two sites were exceeded for lead and none for zinc.

Table 6.14. Heavy metal concentrations at each of the twelve Walvis Bay Grab sites (G1 to G12). Red highlights indicate concentrations above NOAA ERL values, asterisks (*) indicate values above BCLME water quality guidelines (recommended) for the natural environment, and bold highlights indicate values within special care limits. Averages are compared to samples taken for the preconstruction baseline survey (Botha 2015).

Samples	Cd (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
ERL	**1.2**	**34.0**	**20.9**	**46.7**	**150.0**
BCLME (recommended)	**0.68**	**18.7**	**15.9**	**30.2**	**124**
NAL (special care)	**1.5 – 10**	**50 – 500**	**50 – 500**	**100 – 500**	**150 – 750**
G1	1.0*	18.4	11.2	7.4	27.9
G2	**5.0***	17.4	18.8*	12.4	33.1
G3	**9.6***	37.3*	26.6*	20.6	68.2
G4	**7.0***	**50.2***	25.4*	45.1*	91.1
G5	**5.1***	46.9*	24.0*	31.5*	85.7
G6	**3.5***	11.5	15.8	8.4	21.6
G7	**7.1***	37.0*	18.3*	25.3	52.3
G8	**6.4***	24.0*	13.8	21.3	36.0
G9	**8.5***	16.9	18.8*	7.0	26.0
G10	**5.4***	17.4	21.4*	8.4	34.6
G11	**11.0***	18.3	22.2*	6.2	30.7
G12	**7.6***	18.5	19.2*	9.6	24.5
Average (June 2018)	**6.43***	4.84	19.63*	16.94	44.31
Average (2013/2014)	**1.9***	12.62	10.89	5.58	34.47

6.5.4.3 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 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 are from estuaries and coastal areas, and in areas with intense vessel traffic and oil treatment (Nikolaou *et al*. 2009). Marine sediment samples from Walvis Bay were analysed for the presence of hydrocarbons. PAH concentrations at all five sites were well below ERL values stipulated by NOAA (see values in Appendix 4).

Sediments collected in 2013/2014 were found to contain minor amounts of petroleum hydrocarbons in the range of 1 to 5 ppm. These were mostly diesel range organics and heavy fuel oils/lube oils that fall into category C12-C-22 and C30-C40 respectively (Botha 2015b). No volatile organic compounds or semi-volatile organic compounds were detected in 2013/2014 samples (Botha 2015b).

6.5.4.4 Organics

Total Organic Carbon (TOC) 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 is 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 does not 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. WSP reported that surface sediments collected during the 2013/2014 survey contained up to 2.7% TOC, while sediments below three metres had low TOC values between 0.3 and 0.07% (Botha 2015b). Surface TOC values for the survey conducted in June 2018 are much higher than those reported from previous surveys and results are presented in Table 6.15. TOC was found to be high at most sites, with G12 being the highest (96%) and G1 the lowest (9%).

Table 6.15. Percentage Total Organic Carbon (TOC) at each of the twelve Walvis Bay Grab sites (G1 to G12).

Samples	% TOC
G1	9.48
G2	14.55
G3	37.96
G4	39.63
G5	33.33
G6	33.75
G7	48.71
G8	21.11
G9	65.41
G10	35.57
G11	61.90
G12	96.52

6.5.5 Benthic Macrofauna

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 (compared to 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.

Figure 6.10. Images of an amphipod, a lamp shell (both filter feeders) and a predatory nerid worm.

Numerous studies report on the benthic fauna of Walvis Bay Lagoon (CSIR 1992, COWI 2003, Tjipute and Skuuluka 2006); however, little data exist for the bay. The marine scoping study for the tanker berth reported on species found during benthic grab sampling of 12 sites within the proposed dredge channel (Hooks and Duvenhage 2013). They recorded a total of 21 species with abundance increasing towards the shore (Table 6.16). Interestingly, during the June 2018 study only nine species were recorded from the benthic grab material, four of which were segmented polychaete worms (Table 6.17). The dramatic drop in macrofaunal diversity and abundance may be due to dredge events that have occurred between the two sampling periods, although low oxygen events and sulphur eruption may also have contributed to this decline.

Table 6.16. Species list comparison for samples collected in October 2013 and June 2018.

Phylum	Taxa	Species	Common name	Anchor *et al.* (2018)	Hooks and Duvenhage (2013)
Arthropoda	Amphipoda	*Ampelisca anomala*		X	
Arthropoda	Branchiopoda	*Discinisca tenuis*		X	
Arthropoda	Cumacea	Cumacea		X	X
Arthropoda	Decapoda	Macruran			X
Arthropoda	Ostracoda	Ostracod			X
Mollusca	Bivalvia	*Afrophaxas decipiens*			X
Mollusca	Bivalvia	*Bivalvia* sp.		X	
Mollusca	Bivalvia	*Lucinoma* sp.			X
Mollusca	Bivalvia	*Venerupis corrugata*	Pullet carpet shell		X
Mollusca	Gastropoda	*Nassarius* sp.			X
Echinodermata	Asteroidea				X
Echinodermata	Ophiuroidea	*Amphipholis squamata*			X
Echinodermata	Ophiuroidea	*Ophiothrix* sp		X	X
Echinodermata	Ophiuroidea	Ampharetidae			X
Annelida	Polychaeta	*Glycera* sp.			X
Annelida	Polychaeta	*Harmothoe* sp		X	
Annelida	Polychaeta	*Lagis neapolitana*		X	
Annelida	Polychaeta	*Micronephthys sphaerocirrata*			X
Annelida	Polychaeta	*Nereis lamellosa*		X	
Annelida	Polychaeta	*Nereis* sp.			X
Annelida	Polychaeta	Syllidae			X
Annelida	Polychaeta	*Prionospio sexoculata*			X
Annelida	Polychaeta	*Sigambra parva*		X	

Table 6.17. Average species abundance and biomass recorded per square metre of benthic habitat in and around the proposed dredge area at Walvis Bay Oil and Gas Jetty.

Taxa	Species	Functional group	Average abundance (individuals per m^2)	Average biomass (g per m^2)
Amphipoda	*Ampelisca anomala*	Filter feeder	0.17	0.0001
Bivalvia	*Bivalvia* sp.	Filter feeder	0.35	0.0030
Branchiopoda	*Discinisca tenuis*	Filter feeder	2.25	0.3053
Cumacea	Cumacea	Filter feeder	4.68	0.0258
Ophiuroidea	*Ophiothrix* sp	Scavenger	185.97	21.6775
Polychaeta	*Harmothoe* sp	Predator	0.52	0.0009
Polychaeta	*Lagis neapolitana*	Predator	0.35	0.0277
Polychaeta	*Nereis lamellosa*	Predator	0.17	0.0003
Polychaeta	*Sigambra parva*	Predator	1.39	0.0362

6.5.5.1 Functional groups

Sites were divided into four categories: south of the proposed dredge channel (G1, G5, G9), within the dredge channel (G2, G6, G10), 300 m north of the dredge channel (G3, G7, G11), and 500 m north of the dredge channel (G4, G8, G12). The abundance and biomass of biota in the majority of the grab samples was extremely low, with three exceptions. Site G1 (south of the dredge area) had the highest number of individuals (2 169 per m^2) as well as the highest biomass per square meter (Figure 6.11 and Figure 6.12). These consisted mostly of brittle stars with numbers in excess of 350 individuals per grab. It is suspected that the invertebrates were feeding on some rotting matter on the seafloor at this site. Site G10 (within the proposed dredge channel) had the second highest abundance and biomass, with 46 individuals per m^2 and 0.47 g/m^2 respectively. Site G5 (south of the dredge channel) also had a notable abundance of biota (predators and filter feeders) totalling 20 individuals per m^2 and 0.47 g/m^2 respectively. All other sites were almost devoid of life due to anoxic conditions (Figure 6.11).

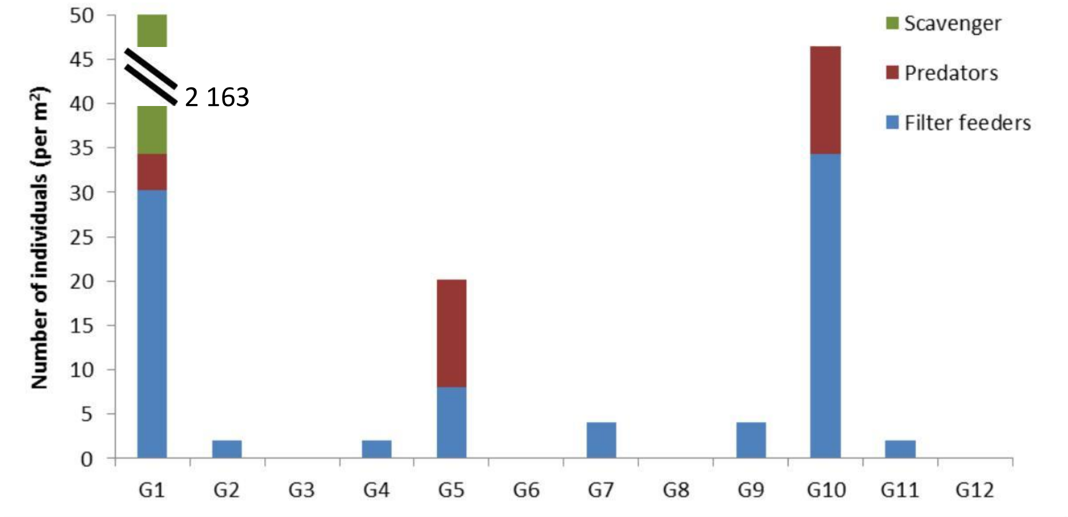

Figure 6.11. Average abundance (individuals/m^2) of benthic macrofauna by functional group.

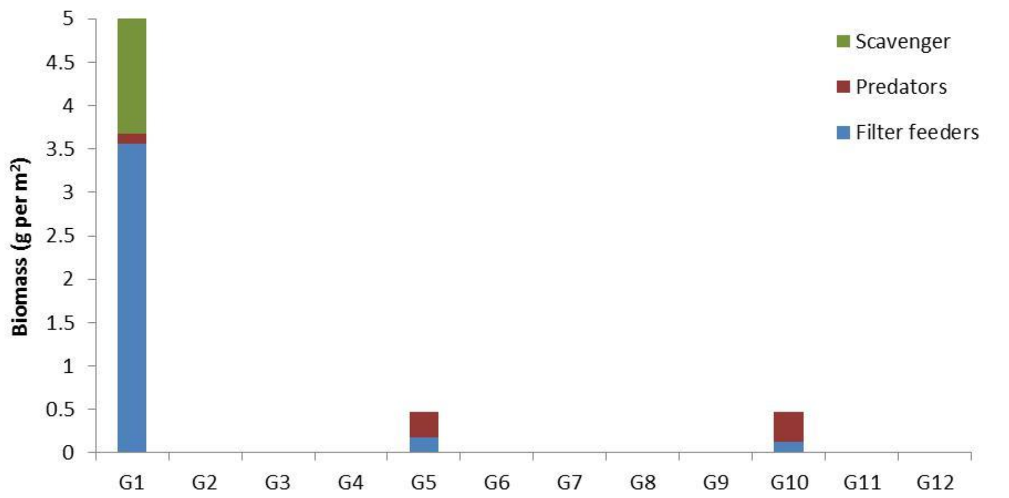

Figure 6.12. Average biomass (g/m^2) of benthic macrofauna by functional group.

7 ENVIRONMENTAL MONITORING AND REPORTING

Ongoing monitoring is recommended for the construction phase as well as for the operational lifetime of the oil and gas terminal as outlined in the EMP (Botha *et al*. 2015a). The EIA recommends specialist monitoring programmes for marine mammals, benthic and rocky shore biodiversity, and avifauna. During dredging and construction, a water quality monitoring program is required to monitor and control the suspension of sediments (Botha 2013).There has been nine Water Quality Monitoring Reports completed by Geo Pollution Technologies (Pty) Ltd prior this study. According to the reports, although a number chemicals were detected during these nine cycles, none of the chemicals analaysed for were elevated above BCLME guideline values. The degree of fluctuations in the chemical concentrations are insignificant to generate concern and no trend in the water quality parameters tested can be discerned (Faul 2016).

Applicable environmental monitoring and reporting as outlined in the EMP must be implemented (Botha *et al*. 2015a) as summarised below.

Construction phase

- Real time turbidity monitoring of the runoff at the point of backflow. Monitoring of runoff volume and quality and comparison with Water and Sediment Quality Guidelines for the BCLME Region as outlined in the EIA (Botha *et al*. 2013).
- Compilation of a monthly report of bi-weekly visual monitoring of the shoreline including visual inspections and photographic record keeping.
- Implementation of a noise monitoring programme for marine mammals prior to construction and throughout the duration of construction activities.

Construction and Operational phases

- The underwater noise monitoring programme initiated before and during construction must be continued for at least a year after operations commence.
- Daily sightings of dolphins must be recorded. If possible the species, size of pod, duration of stay in area, and location to be noted.
- All encounters with marine animals that are entangled in waste and mammals that are found dead must be recorded and reported.
- All evidence of birds colliding with any structure related to the development must be recorded. Where possible, the species must be identified and photographed. An incident report containing training details and information relating to bird collisions should be compiled biannually.
- Monitoring of suspension of dredged sediments during dredge activities and comparison with Water and Sediment Guideline for the BCLME Region as outlined in the EIA (Botha *et al*. 2013). Real time turbidity monitoring sites must include the main entrance channel for ships (Buoy 6), the fairway, near Bird Island, and the location of the 3rd (future) tanker berth (Botha *et al*. 2015a).
- Water sample analysis for heavy metals and tributyltin (TBT) just before, during and after dredging of a marine sediment volume of >100 000 m^3.
- Heavy metal, TBT, hydrocarbon and PAH analysis of bed sediments prior to dredging of an initial marine sediment volume >5 000 m^3 and for every subsequent 100 00 m^3.

- Recording of ballast water exchange in the ship log. This must be verified each time a tanker ship moors at the berth and included in a biannual report.
- A register of hazardous waste disposal and spills/leaks should be kept including the type of waste, the volume as well as the disposal method/facility. All data to be compiled in a biannual report.
- Compilation of a final report on all monitoring information following completion of construction and annually during the operational life of the project.

Decommissioning phase

- A register of waste produced and disposal methods.
- A report should be compiled of any fauna and flora that established itself on the infrastructure including all actions to be taken to relocate or deal with the situation.
- Monitoring of underwater noise levels and marine mammals must be conducted if deemed necessary by a marine mammal specialist.
- Report forms for any spills or leaks are to be completed.

The marine specialist study undertaken during the scoping phase of this project recommended an initial reference (baseline) survey, and two subsequent surveys; one 1.5 years after commencement of the activity and another three years post commencement (Hooks and Duvenhage 2013). Due to the lack of long term data, we recommended annual ecological monitoring of rocky intertidal, sandy beach, and surf-zone fish. Due to the low abundance of benthic macrofauna, however, it is recommended that these aspects be dropped from the scope of work. Unless continuous (i.e. weekly or monthly) monitoring is specified in the EMP, field work should be conducted in the same month as this baseline survey (June) and the same methods should be used to ensure that results are comparable. Sampling methods are outlined in Section 4 of this report and sample sites to be monitored are outlined in Table 4.1.

In terms of physico-chemical monitoring, water and sediment analyses should continue. Prior to and during the 2010/2011 dredging period, water quality samples were collected throughout the Bay (Botha 2011). Water samples were analysed for arsenic (As), antimony (Sb), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), mercury (Hg), lead (Pb), molybdenum (Mo), nickel (Ni), selenium (Se), tin (Sn), vanadium (V) and zinc (Zn). Concentrations of copper, lead and zinc exceeded the BCLME guideline values on a number of occasions (Botha 2011), therefore, it is recommended that sampling at these sites continue for the life of the operation.

Bivalves bio-accumulate heavy metals in their flesh to higher levels than are present in the environment and can pose a threat to people that collect and consume these organisms. Due to the elevated levels of cadmium, copper and nickel in benthic sediments and high levels of lead and cadmium found during previous bio-monitoring tests (Botha 2011), it is recommended that a bio-monitoring programme is initiated within each mariculture facility to monitor the safety of bivalves for human consumption. This should entail collection and analysis of mussels (*Mytilus galloprovincialis* or *Perna perna*) and/or oysters (*Crassostrea gigas* from oyster rafts) for heavy metal content (Cd, Cu, Pb, Ni, Zn and Hg) at a minimum of five sites around the Bay. Historically, oyster tissue samples were collected from two locations at the mariculture farm near Pelican Point and mussel samples were collected from three sites around the Bay (Langstrand, Bird Island, the entrance to the Lagoon) and from one site at the mariculture farm at Pelican Point for dredging activity monitoring (Botha 2011). These monitoring sites should be maintained for future monitoring programmes.

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9 APPENDIX 1 – SANDY BEACH DATA

Table 9.1. Particle size distributions for the sandy beach sites Beach 1 (B1) to Beach 5 (B5).

Samples	% +2000µ	% +1000µ	% +850µ	% +710µ	% +500µ	% +425µ	% +300µ	% +212	% +150	% +63µ	% -63µ
WB B1_1m	2.99	1.35	0.77	1.93	9.25	8.29	15.22	8.09	7.71	43.93	0.48
WB B1_5m	0.19	0.19	0.45	1.86	21.07	18.82	35.07	15.99	3.73	2.06	0.58
WB B1_10m	1.03	1.34	1.45	10.13	33.80	20.31	21.96	7.29	1.45	0.72	0.52
WB B2_1m	0.25	0.17	0.17	0.42	4.43	5.18	37.96	27.68	13.21	9.20	1.34
WB B2_5m	3.66	4.86	5.62	14.31	43.10	14.05	10.73	2.21	0.34	0.51	0.60
WB B2_10m	0	0.07	0.13	0.54	11.41	10.60	48.79	17.99	5.97	3.89	0.60
WB B3_1m	2.90	1.19	1.84	4.74	22.92	10.28	21.34	16.67	6.19	10.74	1.19
WB B3_5m	0.49	0.25	0.16	0.49	4.17	5.56	26.49	36.55	13.25	11.69	0.90
WB B3_10m	0	0.63	0.45	1.25	6.70	5.00	31.79	39.73	9.64	4.64	0.18
WB B4_1m	0.55	2.63	0.97	1.73	12.47	9.63	30.75	22.92	9.21	8.45	0.69
WB B4_5m	0.42	1.05	0.63	3.02	22.35	10.54	24.95	23.05	8.85	5.06	0.07
WB B4_10m	0	0.65	0.50	1.30	13.17	9.79	31.39	24.33	10.30	7.99	0.58
WB B5_1m	0	0	0	0.16	1.21	1.94	32.90	45.03	11.32	7.03	0.40
WB B5_5m	0	0.31	0.15	0.69	10.33	5.71	36.08	34.70	9.95	1.54	0.54
WB B5_10m	0	0.93	0.86	2.64	13.61	8.63	35.38	27.99	7.78	1.71	0.47

10 APPENDIX 2 – FISH CATCH DATA

Table 10.1. The number of fish caught at each sein net site Beach 1 (B1) to Beach 5 (B5). Three replicate hauls were made at each site.

Number of individuals	Site	B1			B2			B3			B4			B5		
Year/species	**Common name**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Atherina breviceps	Cape silverside	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0
Chelon richardsonii	Southern mullet	0	0	0	0	1	0	0	1	0	2	0	1	0	1	17
Dichistius capensis	Galjoen	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
Lithognathus aureti	West Coast steenbras	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Total		**0**	**0**	**0**	**0**	**1**	**0**	**0**	**10**	**0**	**6**	**0**	**1**	**0**	**1**	**17**
Number of species		**0**	**0**	**0**	**0**	**1**	**0**	**0**	**2**	**0**	**3**	**0**	**1**	**0**	**1**	**1**

Table 10.2. The average length of fish caught in each sein net haul.

Average length	Site	B1			B2			B3			B4			B5		
Year/species	**Common name**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Atherina breviceps	Cape silverside	-	-	-	-	-	-	-	84.5	-	-	-	-	-	-	-
Chelon richardsonii	Southern mullet	-	-	-	-	79	-	-	65	-	232.5	-	225	-	116	117.3
Dichistius capensis	Galjoen	-	-	-	-	-	-	-	-	-	82.7	-	-	-	-	-
Lithognathus aureti	West Coast steenbras	-	-	-	-	-	-	-	-	-	132	-	-	-	-	-

11 APPENDIX 3 – ROCKY INTERTIDAL DATA

Table 11.1. Percentage of rocky intertidal biota averaged across tidal height. Data for five transects are given for each of the five rocky shore sites Rocky Shore 1 (RS 1) to Rocky Shore (RS5).

Percentage cover	RS1_1	RS1_2	RS1_3	RS1_4	RS1_5	RS2_1	RS2_2	RS2_3	RS2_4	RS2_5	RS3_1	RS3_2	RS3_3	RS3_4	RS3_5	RS4_1	RS4_2	RS4_3	RS4_4	RS4_5	RS5_1	RS5_2	RS5_3	RS5_4	RS5_5
SUBSTRATE	**46.94**	**54.30**	**51.69**	**55.17**	**65.17**	**25.23**	**19.89**	**3.59**	**21.34**	**25.56**	**25.77**	**28.73**	**56.34**	**47.50**	**69.29**	**17.84**	**15.94**	**16.27**	**11.88**	**12.85**	**7.35**	**7.94**	**20.05**	**22.85**	**29.23**
Rock	46.82	52.92	51.43	53.80	64.41	24.83	19.42	3.36	21.34	25.56	23.13	28.19	54.95	42.71	32.72	0.41	0.83	0.68	2.16	9.02	3.56	2.98	19.49	22.71	29.23
Sand	0.12	1.38	0.26	1.37	0.77	0.40	0.48	0.24	0	0	2.65	0.53	1.39	4.79	36.57	17.43	15.11	15.59	9.72	3.84	3.79	4.96	0.56	0.14	0
GRAZERS	**2.57**	**2.64**	**2.05**	**2.60**	**0.99**	**1.55**	**0.86**	**0.21**	**3.27**	**0.99**	**1.89**	**2.45**	**2.38**	**0.90**	**1.09**	**0.76**	**0.69**	**0.74**	**0.86**	**1.34**	**1.28**	**1.37**	**1.60**	**1.59**	**1.88**
Afrolittorina knysnaensis	0.14	0.07	0.14	0.07	0.07	0.56	0.06	0.14	0.76	0.33	0.29	0.43	0.64	0.14	0.14	0.07	0.07	0.07	0.07	0.07	0.57	0.27	0.56	0.58	0.14
Cymbula granatina	0	0	0.26	0.40	0	0.22	0	0	0	0	0	0.13	0	0	0.13	0.28	0	0.07	0	0.13	0	0	0	0	0.20
Helcion dunkeri	0.06	0.06	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0.07	0	0	0	0	0	0
Scutellastra argenvillei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0.26	0.13	0.27	0	0	0	0	0
Scutellastra granularis	2.31	2.24	1.52	2.13	0.77	0.22	0.11	0.07	0.07	0.13	1.46	1.28	1.32	0.41	0.54	0.14	0.35	0.07	0.13	0.33	0.28	0.41	0.62	0.72	0.42
Siphonaria capensis	0.06	0.20	0.13	0	0	0.55	0.69	0	2.45	0.53	0.14	0.55	0.41	0.28	0.28	0.21	0.28	0.27	0.40	0.53	0.43	0.69	0.42	0.29	0.99
Parechinus angulosus	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxystele antoni	0	0.07	0	0	0.07	0	0	0	0	0	0	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0.13
Tricolia capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0
PREDATORS	**0.14**	**0.07**	**1.19**	**0.87**	**0.26**	**0**	**0.44**	**0.59**	**0.34**	**0.97**	**2.21**	**1.33**	**3.06**	**4.40**	**0.13**	**1.27**	**1.77**	**3.57**	**2.31**	**1.24**	**3.66**	**4.26**	**12.22**	**5.03**	**15.31**
Anthothoe stimpsonii	0	0	0	0.13	0	0	0.11	0.35	0.11	0.12	0.52	0.26	0.28	0.14	0.13	0.56	0.68	1.46	0.73	0.55	0.90	0.51	0.06	0.44	0.20
Bunodactis reynaudi	0.14	0.07	1.19	0.74	0.26	0	0.22	0.12	0	0.36	1.69	1.07	2.78	4.26	0	0.57	0.42	1.71	1.19	0.55	2.26	3.22	10.38	4.25	13.80
Nucella dubia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.07	0	0	0	0	0	0.07	0
Ophiuroidea	0	0	0	0	0	0	0.11	0.12	0.22	0.48	0	0	0	0	0	0.14	0.67	0.33	0.40	0.14	0.38	0.52	1.77	0.27	1.30
Pilumnoides rubus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0	0	0

Percentage cover	RS1_1	RS1_2	RS1_3	RS1_4	RS1_5	RS2_1	RS2_2	RS2_3	RS2_4	RS2_5	RS3_1	RS3_2	RS3_3	RS3_4	RS3_5	RS4_1	RS4_2	RS4_3	RS4_4	RS4_5	RS5_1	RS5_2	RS5_3	RS5_4	RS5_5
FILTER FEEDERS	**37.05**	**37.22**	**38.80**	**30.85**	**26.71**	**58.78**	**60.58**	**59.50**	**54.73**	**60.61**	**65.16**	**62.15**	**33.66**	**35.81**	**24.28**	**77.02**	**79.19**	**74.22**	**78.98**	**79.24**	**82.06**	**78.50**	**62.66**	**61.26**	**49.72**
Chthamalus dentatus	14.63	10.36	27.82	9.81	9.39	32.33	5.98	33.12	30.72	28.80	31.75	29.78	26.49	9.64	10.34	6.36	24.17	20.16	20.99	17.86	27.49	21.26	22.08	28.50	4.12
Discinisca tenuis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0.14	0.13	0.13	0	0	0	0	0	0
Encrusting Bryozoa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.26	0.07	0.23	0.21	0	0.11	0
Mytilus galloprovincialis	0	0	0	0	0	25.53	53.43	25.09	21.64	30.45	1.92	1.19	0.94	2.69	0.42	0.28	0.20	1.07	0.67	0.61	1.00	5.49	5.55	0.58	5.60
Notomegabalanus algicola	0.14	0.20	0.33	0.53	0.28	0.22	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0
Octomeris angulosa	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pentacta doliolum	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	0
Perna perna	19.30	26.53	10.65	17.76	6.78	0.70	0.57	1.30	2.37	1.35	26.16	26.05	0.97	6.94	0.07	0.90	1.03	0.93	3.55	1.71	0.13	0.39	0.99	2.58	0.66
Semimytilus algosus	2.98	0	0	2.75	10.26	0	0	0	0	0	5.26	5.13	5.27	16.39	13.39	69.34	53.65	51.79	53.38	58.99	53.00	51.05	34.05	29.38	39.34
Sponge	0	0	0	0	0	0	0.55	0	0	0	0.06	0	0	0	0.07	0	0	0	0	0	0.23	0.10	0	0	0
EPHEMERALS	**10.73**	**2.14**	**4.30**	**1.91**	**2.70**	**12.66**	**15.66**	**32.10**	**14.43**	**8.92**	**0.68**	**0.66**	**2.02**	**6.25**	**4.40**	**0.62**	**1.39**	**3.08**	**2.26**	**1.62**	**4.75**	**6.41**	**2.16**	**7.41**	**2.29**
Callithamnion collabens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.22	0
Centroceras spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90	3.59	0	0.44	0.92
Ceramium spp	2.15	0.38	0	0	0	0	0	0	0	0	0.29	0	0	1.03	0	0.07	0	0	0.13	0.14	2.82	2.29	1.01	1.49	0.65
Cladophora spp.	2.15	0	0.39	0	1.54	0.44	0.11	0.24	0.45	0.24	0	0	0	0	0.27	0	0	0.26	0	0	0	0	0	0	0
Diatoms	0	0	1.06	0	0	8.95	5.77	2.89	9.34	0.56	0	0	0	0	0	0	0	0	0	0	0.45	0	0.89	0	0.52
Ectocarpus sp.	0	0	0	0	0	2.60	8.23	27.56	3.75	5.32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Porphyra capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.27	0.27	0	0	0.12	0.26	0	0
Ulva spp.	6.44	1.76	2.85	1.91	1.17	0.67	1.55	1.41	0.89	2.80	0.39	0.66	2.02	5.21	4.14	0.55	1.39	2.54	1.85	1.48	0.56	0.41	0	5.26	0.20
CORTICATED	**2.55**	**3.63**	**1.97**	**8.59**	**4.17**	**1.78**	**2.34**	**4.00**	**5.89**	**2.83**	**4.17**	**4.69**	**2.55**	**5.15**	**0.80**	**0.83**	**0.48**	**0.66**	**2.66**	**1.79**	**0.68**	**1.42**	**1.32**	**0.98**	**1.58**
Ahnfeltiopsis polyclada	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0
Bryopsis myosuroides	0.60	0.25	0.26	0.41	0.64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carpoblepharis flaccida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0.26	0	0.11	0.10	0	0	0
Caulacanthus ustulatus	0.64	3.13	1.32	1.86	0.84	0	0	0	0	0	1.46	3.22	1.99	0.96	0.40	0.69	0.21	0.27	1.73	1.66	0	0.96	0.56	0	1.32

Percentage cover	RS1_1	RS1_2	RS1_3	RS1_4	RS1_5	RS2_1	RS2_2	RS2_3	RS2_4	RS2_5	RS3_1	RS3_2	RS3_3	RS3_4	RS3_5	RS4_1	RS4_2	RS4_3	RS4_4	RS4_5	RS5_1	RS5_2	RS5_3	RS5_4	RS5_5
Chaetomorpha linum	0	0	0	0	0	0	0.33	0	0	0	0	0	0	0.07	0	0	0	0	0	0	0	0	0	0	0
Chondria capensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.27	0	0	0	0	0	0	0	0	0	0
Chylocladia capensis	0	0	0	0	0.26	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delisea flaccida	0	0	0	0	1.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gelidium vittatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.14	0.13	0.13	0.66	0.14	0	0	0	0.77	0
Grateloupia capensis	1.19	0	0.13	3.98	0.77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gymnogongrus dilatatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0.45	0	0	0	0
Hypnea ecklonii	0	0	0	0	0	0	0	0.12	0	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypnea spicifera	0	0	0	0	0	1.78	0.70	0	0.07	0.52	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0
Mazzaella capensis	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0
Nothogenia erinacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0.34	0	0	0	0	0	0	0	0	0	0	0
Petalonia fascia	0.12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polyopes constrictus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0.76	0	0.13
Polysiphonia urbani	0	0	0	0	0	0	0.77	2.83	2.13	1.33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polysiphonia virgata	0	0	0	0	0	0	0	0	0	0	2.07	1.07	0.56	3.44	0	0	0	0	0	0	0	0	0	0	0
Rhodymenia obtusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0	0
Sarcothalia scutellata	0	0	0	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tayloriella tenebrosa	0	0.25	0.26	2.20	0.51	0	0.55	1.06	3.69	0.85	0.52	0.40	0	0.34	0	0	0	0	0	0	0	0.35	0	0	0.13
KELP	**0**	**0**	**0**	**0**	**0**	**0**	**0.22**	**0**	**0**	**0.12**	**0.13**	**0**	**0**	**0**	**0**	**1.66**	**0.54**	**1.46**	**1.06**	**1.92**	**0.23**	**0.10**	**0**	**0.87**	**0**
Laminaria pallida	0	0	0	0	0	0	0.22	0	0	0.12	0.13	0	0	0	0	1.66	0.54	1.46	1.06	1.92	0.23	0.10	0	0.87	0

12 APPENDIX 4 – BENTHIC MACROFAUNAL DATA

Table 12.1. Number of individuals collected per square meter (m^2). Three replicates (A, B & C) were collected at each of the twelve Walvis Bay Grab sites (WB_G1 to WB_G12).

Site	Replicate	Amphipoda	Bivalvia	Branchiopoda	Cumacea	Ophiuroidea	Polychaeta			
		Ampelisca anomala	Bivalvia	*Discinisca tenuis*	Bodotriidae	*Ophiothrix* sp	*Harmothoe* sp	*Lagis neapolitana*	*Nereis lamellosa*	*Sigambra parva*
WB_G1	A	0	0	36	12	2164	0	0	6	6
	B	0	0	42	0	2424	0	0	0	0
	C	0	0	0	0	1921	0	0	0	0
WB_G2	A	0	0	0	6	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G3	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G4	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	6	0	0	0	0	0	0	0	0
WB_G5	A	0	0	0	0	0	6	0	0	0
	B	0	0	0	24	0	0	0	0	30
	C	0	0	0	0	0	0	0	0	0
WB_G6	A	0	0	0	0	0	0	0	0	0
	B									
	C	0	0	0	0	0	0	0	0	0
WB_G7	A	0	0	0	12	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0

Site	Replicate	Amphipoda	Bivalvia	Branchiopoda	Cumacea	Ophiuroidea	Polychaeta			
		Ampelisca anomala	Bivalvia	*Discinisca tenuis*	Bodotriidae	*Ophiothrix* sp	*Harmothoe* sp	*Lagis neapolitana*	*Nereis lamellosa*	*Sigambra parva*
	C	0	0	0	0	0	0	0	0	0
WB_G8	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G9	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	12	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G10	A	0	0	0	0	0	0	0	0	0
	B	0	12	0	91	0	12	12	0	12
	C	0	0	0	0	0	0	0	0	0
WB_G11	A	0	0	0	6	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G12	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0

Table 12.2. **Biomass of individuals collected per square meter (g/m^2) at each of the twelve Walvis Bay Grab sites (WB_G1 to WB_G12).**

Site	Replicate	Amphipoda	Bivalvia	Branchiopoda	Cumacea	Ophiuroidea	Polychaeta			
		Ampelisca anomala	Bivalvia	*Discinisca tenuis*	Bodotriidae	*Ophiothrix* sp.	*Harmothoe* sp	*Lagis neapolitana*	*Nereis lamellosa*	*Sigambra parva*
WB_G1	A	0	0	1.2588	0.0073	237.5685	0	0	0.0115	0.3248
	B	0	0	9.4267	0	249.8945	0	0	0	0
	C	0	0	0	0	271.2503	0	0	0	0
WB_G2	A	0	0	0	0.0127	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G3	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G4	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0.0024	0	0	0	0	0	0	0	0
WB_G5	A	0	0	0	0	0	0.0139	0	0	0
	B	0	0	0	0.5212	0	0	0	0	0.8812
	C	0	0	0	0	0	0	0	0	0
WB_G6	A	0	0	0	0	0	0	0	0	0
	B									
	C	0	0	0	0	0	0	0	0	0
WB_G7	A	0	0	0	0.0339	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
WB_G8	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0

Site	Replicate	Amphipoda	Bivalvia	Branchiopoda	Cumacea	Ophiuroidea	Polychaeta			
		Ampelisca anomala	**Bivalvia**	***Discinisca tenuis***	**Bodotriidae**	***Ophiothrix* sp.**	***Harmothoe* sp**	***Lagis neapolitana***	***Nereis lamellosa***	***Sigambra parva***
	C	0	0	0	0	0	0	0	0	0
WB_G9	A	0	0	0	0	0	0	0	0	0
	B	0	0	0	0.0388	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
	A	0	0	0	0	0	0	0	0	0
WB_G10	B	0	0.1055	0	0.2667	0	0.0188	0.9703	0	0.0594
	C	0	0	0	0	0	0	0	0	0
	A	0	0	0	0.0218	0	0	0	0	0
WB_G11	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0
	A	0	0	0	0	0	0	0	0	0
WB_G12	B	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0

Table 12.3. Particle size distribution at each of the twelve Walvis Bay Grab sites (WB_G1 to WB_G12).

Samples	% +2000µ	% +1000µ	% +850µ	% +710µ	% +500µ	% +425µ	% +300µ	% +212µ	% +150µ	% +63µ	% -63µ
WB_G1	4.42	8.34	0.74	1.23	3.19	2.82	8.34	18.16	17.67	12.27	22.82
WB_G2	0	0	0	0	0.62	0.31	0	0.62	5.86	16.05	76.54
WB_G3	0	0	0.26	0.26	0	0	0.26	1.30	1.81	11.92	84.20
WB_G4	0	0.24	0.24	0.24	0.24	0	0.24	0.71	1.66	16.63	79.81
WB_G5	0.72	0.24	0.24	0.24	1.19	0.95	3.10	8.35	11.69	21.48	51.79
WB_G6	0	0	0	0	0	0	1.19	10.45	25.97	26.57	35.82
WB_G7	0	0	0	0	0.68	0	0.34	1.02	2.03	12.20	83.73
WB_G8	0	0	0.36	0.36	0	0	0	0	0.72	6.88	91.67
WB_G9	0	0	0	0	0	0	0.47	0.47	0.47	3.29	95.31
WB_G10	0	0	0	0	0	0	0	0.29	0.59	14.37	84.75
WB_G11	0	0	0	0	0	0	0	0	0.48	3.37	96.15
WB_G12	0	0	0	0	0	0	0	0.75	2.24	5.22	91.79

Table 12.4. Heavy metal concentrations at each of the twelve Walvis Bay Grab sites (WB_G1 to WB_G12).

Samples	Al (%)	As (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Fe (%)	Mn (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
WB_G1	0.53	6.7	1.0	2.4	17.4	18.4	0.64	40.7	11.2	7.4	27.9
WB_G2	0.82	12.9	5.0	5.0	34.7	17.4	1.46	84.4	18.8	12.4	33.1
WB_G3	1.41	19.4	9.6	8.2	58.2	37.3	2.18	133.6	26.6	20.6	68.2
WB_G4	1.29	13.5	7.0	8.1	49.0	50.2	1.86	127.6	25.4	45.1	91.1
WB_G5	1.28	11.6	5.1	8.2	41.6	46.9	1.69	121.6	24.0	31.5	85.7
WB_G6	0.67	7.3	3.5	4.1	28.8	11.5	1.01	59.9	15.8	8.4	21.6
WB_G7	0.93	9.9	7.1	4.8	43.3	37.0	1.22	70.8	18.3	25.3	52.3
WB_G8	0.84	6.6	6.4	4.1	39.6	24.0	1.07	49.2	13.8	21.3	36.0
WB_G9	0.64	9.9	8.5	3.0	41.8	16.9	0.92	56.3	18.8	7.0	26.0
WB_G10	0.89	11.1	5.4	4.9	28.2	17.4	1.11	85.2	21.4	8.4	34.6
WB_G11	0.79	11.3	11.0	3.2	46.9	18.3	1.02	65.1	22.2	6.2	30.7
WB_G12	0.58	16.2	7.6	2.1	38.5	18.5	0.77	46.9	19.2	9.6	24.5

Table 12.5. Hydrocarbon concentrations at each of the twelve Walvis Bay Grab sites (WB_G1 to WB_G12). No Polycyclic Aromatic Compounds (PACs) were detected at any of the sites. All values are reported in µg/kg.

PACs	WB_G1	WB_G2	WB_G3	WB_G4	WB_G5	WB_G6	WB_G7	WB_G8	WB_G9	WB_G10	WB_G11	WB_G12
Naphthalene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Acenaphthene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Acenaphthylene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Flourene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Phenanthrene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Anthracene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Fluoranthene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Pyrene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo[a]anthracene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Crysene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo[k+b]fluoranthene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Benzo[g,h,i]perylene	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Dibenz[a,h]anthracene	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
ndeno[123-cd]pyrene	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20

13 APPENDIX 5 – CTD DATA

Table 13.1. Heavy metal concentrations at each of the twelve Walvis Bay Grab sites (WB_G1 to WB_G12).

Sites	Temperature (°C)	Salinity (PSU)	Dissolved oxygen (mg/L)	Turbidity (NTU)	pH
WB_G1	14.85	35.23	3.70	2.23	6.85
WB_G2	14.06	35.00	2.35	7.39	7.90
WB_G3	14.32	35.22	2.97	5.55	7.95
WB_G4	14.18	35.22	2.66	6.34	7.92
WB_G5	14.25	35.13	1.83	13.41	7.68
WB_G6	14.94	35.24	3.03	5.05	7.81
WB_G7	15.17	35.24	3.81	5.75	7.88
WB_G8	15.25	35.24	5.38	3.22	8.11
WB_G9	14.13	36.90	1.34	14.97	7.58
WB_G10	14.86	35.22	3.18	4.56	7.86
WB_G11	14.85	34.59	3.20	5.09	7.88
WB_G12	14.52	34.42	3.57	5.03	7.90
Average	**14.62**	**35.22**	**3.08**	**6.55**	**7.78**

14 APPENDIX 6 – STAKEHOLDER LIST

Table 14.1. A list of all the stakeholders contacted for this project.

Organisation	Name	Telephone	Department/Position/Affiliation
Ministry of Environment and Tourism	Theofilus Nghitila	+264 61 284 2701	Environmental Commissioner
Ministry of Environment and Tourism	Damian Nchindo	+264 61 2842701	Directorate of Environmental Affairs (DEA) - Review of EA
Ministry of Environment and Tourism	Ipeinge Mundjulu	+264 61 2842701	Directorate of Environmental Affairs (DEA) - Review of EA
Ministry of Environment and Tourism	Saima Angula	+264 61 2842701	Directorate of Environmental Affairs (DEA) - Review of EA
Ministry of Environment and Tourism	Hiskia Mbura	+264 61 2842701	Directorate of Environmental Affairs (DEA) - Review of EA
Ministry of Fisheries and Marine Resources	Dr Moses Maurihungirire	+264 61 205 3007	Permanent Secretary
Ministry of Fisheries and Marine Resources	Heidi Skrypzeck	+264 64 4101000	Directorate of Aquaculture and Inland Fisheries
Ministry of Fisheries and Marine Resources	Dr Anja Kreiner	+264 64 4101157	Senior Fisheries Biologist- National Marine Information and Research Centre, Swakopmund
Ministry of Fisheries and Marine Resources	Victor Libuku	+264 64 4101158	Fisheries Biologist- National Marine Information and Research Centre Swakopmund
Ministry of Works and Transport - Walvis Bay	Patrick Silishebo	+264 61-226848	Directorate of Maritime Affairs /Deputy Director: Marine Pollution Control and SAR
Namibian Navy	Shikuma Emmanuel	+264 81 2891129	Navigator
The Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC)-Henties Bay	Dr. Johannes Iitembu	+264 64 502616	Deputy Director: Academic Affairs and Research
The Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC)-Henties Bay	Andrew Namoonde	+264 64 502616	Renewable Energy Researcher
The Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC)-Henties Bay	Twalinohamba Akawa	+264 64 502654	Technologist
Confederations of Namibian Fishing Associations	R. Wolters	+264 811 244527	Executive Secretary
Namibian Marine Resources(Pty) Ltd		+264 64 204 200	Managing Director
Namibia Dolphin Project	Dr Simon Elwen	+264 81 687 6461	Director
Namibia Port Authority	Stefanus Gariseb	+264 64 2082376	Manager: SHREQ
Namibia Port Authority	Elzevir Gelderbloem	+264 64 2082376	Port Engineer
Municipality of Walvis Bay	David Uushona	+264 64 214 304	Manager :Solid Waste and Environmental Management
Municipality of Walvis Bay	Nangula Amutenya Amatsi	+264 64 214 305	Environmental Coordinator: Department of Water, Waste and Environmental Management
Municipality of Walvis Bay	Lovisa N. Hailaula	+264 64 214306	Environmental Officer, Environmental Management Section
Namibia Fish Consumption Promotion Trust	Victor Pea	+264 64204508	Chief Executive Officer
Desert Research Foundation (DRFN)	DR Martin B Schneider	+264-61-377500	Executive Director
NACOMA	Alex Alexander	+264 813699088	Senior Environmental Project Officer
Development Bank of Namibia	Theo Uvanga	+264-61-290 8104	Manager: Environmental and Social Development
Namibia Marine and Fisheries Institute	Cornelius Bundje	+264 64 270939	Director

15 APPENDIX 7 – STAKEHOLDER COMMENTS

Table 15.1. A list of all the stakeholder comments received and the response to each.

Name/Organization	Expectations	Response
Dr Anja Kreiner - Ministry of Fisheries and Marine Resources-National Marine Information and Research Centre, Swakopmund	Understand the baseline biodiversity in the project area and possible impacts on the project and others.	The inception report will be shared and the final document with relevant information will be shared with the Ministry of Fisheries and Marine Resources.
Walvis Bay Municipality - Environment and Waste Management	1.To understand more on the work of Anchor Green Team JV 2.Environmental friendly activities to be implemented 3.Send the Inception Report	1. Anchor Green Team JV was appointed to carry out the specialist study which is part of the EIA document. This is the final step before project implementation. 2. The study, together with the EMP document, will be used as a tool to implement recommendations. 3. The inception report and the final document will be shared publically.
Walvis Bay Municipality Youth Forum	To understand more about development of Walvis Bay Town and Coastal area.	Developmental issues will be directed to the municipality and all relevant authorities. We are contracted to carry out a marine specialist study for the upcoming development.
Suzuki Marine Coastal Tours	Need more information of the development of Walvis Bay Town and Coastal area	Developmental issues will be directed to the municipality and all relevant authorities. We are contracted to carry out a marine specialist study for the upcoming development.
Andrew Namoonde :The Sam Nujoma Marine and Coastal Resources Research Centre (SANUMARC)- Henties Bay	Final output of your project	The final document will be shared with all the relevant stakeholders.
Anna Kantema-Ministry of Works and Transport-Maritime Affairs	The effect of people industry on marine environment	This information is contained in the previous Environmental Impact Assessment (EIA) report. We refer you to Geopollution Technologies (Pty) Ltd who carried out the EIA.
Alex Alexander: NACOMA	Inform on the progress of the project	The final document will be shared with all the relevant stakeholders.
Titus Shuuya: Gobabeb Research Centre	Share all relevant information on reporting and field work	The final document will be shared with all the relevant stakeholders..

OM'KUMOH AiJ

Joint Venture

Green Team Consultants

ANCHOR environmental