PISCES ENVIRONMENTAL SERVICES (PTY) LTD

BASIC ASSESSMENT
FOR A MARINE OUTFALL AT
ROBBEN ISLAND, SOUTH AFRICA

Marine Ecological Assessment

Prepared for:

WSP in Africa

On behalf of

Robben Island Museum

September 2021

Andrea Pulfrich

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ABBREVIATIONS and UNITS

ANZECC	Australian and New Zealand Environment Conservation Council
BA	Basic Assessment
BAR	Basic Assessment Report
BOD	Biological Oxygen Demand
cm	centimetres
cm/s	centimetres per second
COD	Chemical Oxygen Demand
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DFFE	Department of Forestry, Fisheries and the Environment
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
EPA	(United States) Environmental Protection Agency
GPA	Global Programme of Action
GWWLs	General Waste Water Limits
GLV	General Limit Values (GN 665 of 2013)
HABs	Harmful Algal Blooms
HDPE	High Density Polyethylene
IUCN	International Union for the Conservation of Nature
km	kilometre
km^2	square kilometre
l/s	litres per second
m	metres
m^2	square metres
m^3	cubic metres
mm	millimetres
mg/l	milligrams per litre
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
ppt	parts per thousand
RIM	Robben Island Museum
SW	southwest
SSW	South-southwest
TAC	Total Allowable Catch
TOPS	Threatened or Protected Species
UNEP	United Nations Environment Programme
WHO	World Health Organisation
WWTW	Waste Water Treatment Works
µg/l	micrograms per litre
µM	microMols
°C	degrees Centigrade
%	percent

Expertise and Declaration of Independence

This report was prepared by Dr Andrea Pulfrich of Pisces Environmental Services (Pty) Ltd. Andrea has a BSc (Hons) and MSc degree in Zoology from the University of Cape Town and a PhD in Fisheries Biology from the Institute for Marine Science at the Christian-Albrechts University, Kiel, Germany.

As Director of Pisces since 1998, Andrea has considerable experience in undertaking specialist environmental impact assessments, baseline and monitoring studies, and Environmental Management Programmes relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents. She is a registered Environmental Assessment Practitioner and member of the South African Council for Natural Scientific Professions, South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist report was compiled as a desktop study on behalf of WSP in Africa, PO Box 2613, Cape Town. The compilation followed a review process of published (peer reviewed) and unpublished literature and the assessment of potential impacts based on proposed activities and identification of impacts (and their mitigation) within the available literature.

This specialist report was compiled on behalf of WSP for their use in preparing a Basic Assessment for the proposed marine outfall at Robben Island, South Africa undertaken by the Department of Public Works. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and WSP.

Andrea Pulfrich

Dr Andrea Pulfrich

1. GENERAL INTRODUCTION

The Robben Island Museum (RIM) plans to upgrade service facilities on Robben Island. As part of the upgrading, a Waste Water Treatment Works (WWTW) will be constructed and domestic effluent will be treated to General Limit Values (GN 665 of 2013) before discharge to the sea. The treated effluent will be discharged through an existing ocean outfall situated approximately 750 m south-east of Murray's Harbour at Robben Island. The existing marine outfall comprises a 200 mm diameter HDPE, which extends 465 m offshore to a depth of 8 m. The terminal end of the pipeline is fitted with a diffuser to aid in the dispersion of the effluent in the water column.

In 2016, WSP was appointed to design and implement the new wastewater treatment works, but due to a lack of funding, the project never progressed to the design development stage despite an Environmental Authorisation being secured for the proposed infrastructure in 2015 (DEA Ref: 14/12/16/3/3/3/83). This authorisation has since lapsed and a new authorisation is now required for an amended design as proposed by Element Consulting Engineers.

1.1. Scope of Work

This specialist report was compiled as a desktop study on behalf of WSP, for their use in preparing a Basic Assessment Report (BAR) for the proposed installation of a Waste Water Treatment Works and associated infrastructure for the release of treated effluent *via* the existing marine outfall on Robben Island, in Table Bay.

The Scope of Work for this study is to:

- Provide a description of the baseline marine biology in the project area, emphasising, but not limited to, sensitive and threatened habitats, and threatened or rare marine fauna and flora. All pertinent characteristics of the marine environment should be described including:
    - Marine Baseline Conditions
    - Waves, Tides and Currents
    - Surf-zone Currents and Processes
    - Upwelling and Nutrients
    - Turbidity and Organic Inputs
    - Low Oxygen Events
    - Rocky shore Communities
    - Sandy beach Communities
    - Pelagic Communities
    - Marine Mammals and Seabirds
    - Extractive and non-extractive uses of the area
    - Future-use scenarios
- Review all relevant, available local and international publications and information sources on the disturbances and risks associated with sewage effluents.
- Identify and describe all factors resulting from the construction and operation of the WWTW and associated infrastructure that may influence the marine and

coastal environments in the region, based on existing information and data collected during the site visit.

- Using the assessment criteria as supplied by WSP, assess the impacts of the proposed development on the marine biology of the project area during the construction and operational phases of the sewage plant. All identified marine and coastal impacts must be summarised, categorised and ranked in appropriate Impact tables, to be incorporated in the overall Basic Assessment (BA).
- Make recommendations for mitigation and monitoring of impacts.
- Compile an EMP for the marine aspects of the construction and operational phases of the disposal system.

1.2. Approach to the Study

As determined by the Scope of Work, this study has adopted a 'desktop' approach. Consequently, the description of the natural baseline environment in the study area is based on a review and collation of existing information and data from the scientific literature and previous reports conducted in the area. Information provided in the 2016 marine ecology specialist report has been revised and updated as necessary. In addition, contact was made with researchers from SANCCOB and the Earthwatch Programme on Robben Island for updated information on the island's seabirds. The information for the identification of potential impacts was drawn from various scientific publications and information sourced from the Internet. The sources consulted are listed in the Reference chapter.

All identified marine impacts are summarised, categorised and ranked in appropriate impact assessment tables, to be incorporated in the overall BA for the proposed project.

1.3. Assumptions and Limitations

The treated effluent generated by the new WWTW will be discharged through an existing ocean outfall situated approximately 750 m south-east of Murray's Harbour. There will therefore be no new construction activities undertaken below the high water mark as part of the proposed project. As all impacts relating to the construction phase are located above the high water mark, and therefore beyond the scope of this marine assessment, construction impacts have not been assessed as part of this study. An exception to this is potential construction impacts to breeding seabirds in the vicinity of the proposed WWTW.

It is assumed that at the time of the upgrade of the island's waste water handling facilities in 2001, an EIA and associated Environmental Management Plan were compiled. However, these documents could not be sourced to inform this study.

2. PROJECT DESCRIPTION

The Robben Island Museum (RIM) propose to upgrade the existing sewage handling system on Robben Island with the construction of a Waste Water Treatment Works (WWTW). The plant, which will be located adjacent to the existing sewage collection unit ~600 m south of Murray's Harbour in an area of ~2,500 m^2, will be partially submerged to a depth of approximately 2.5 m and have a footprint not exceeding 1,070 m^2. With a treatment capacity of approximately 108,000 m^3 per annum, the WWTW will treat all sewage and domestic waste water generated on the island to the South African Department of Water Affairs (DWA) General Limit Values (GLVs) effluent quality standards. The treated effluent will be transported *via* an existing pipeline to the existing sea outfall pipeline and discharged to sea (Figure 1). The estimated 120 m^3 of sludge produced annually as part of the treatment process will be dried on drying beds on the island, and either used as fertiliser or disposed of *via* the normal refuse system.

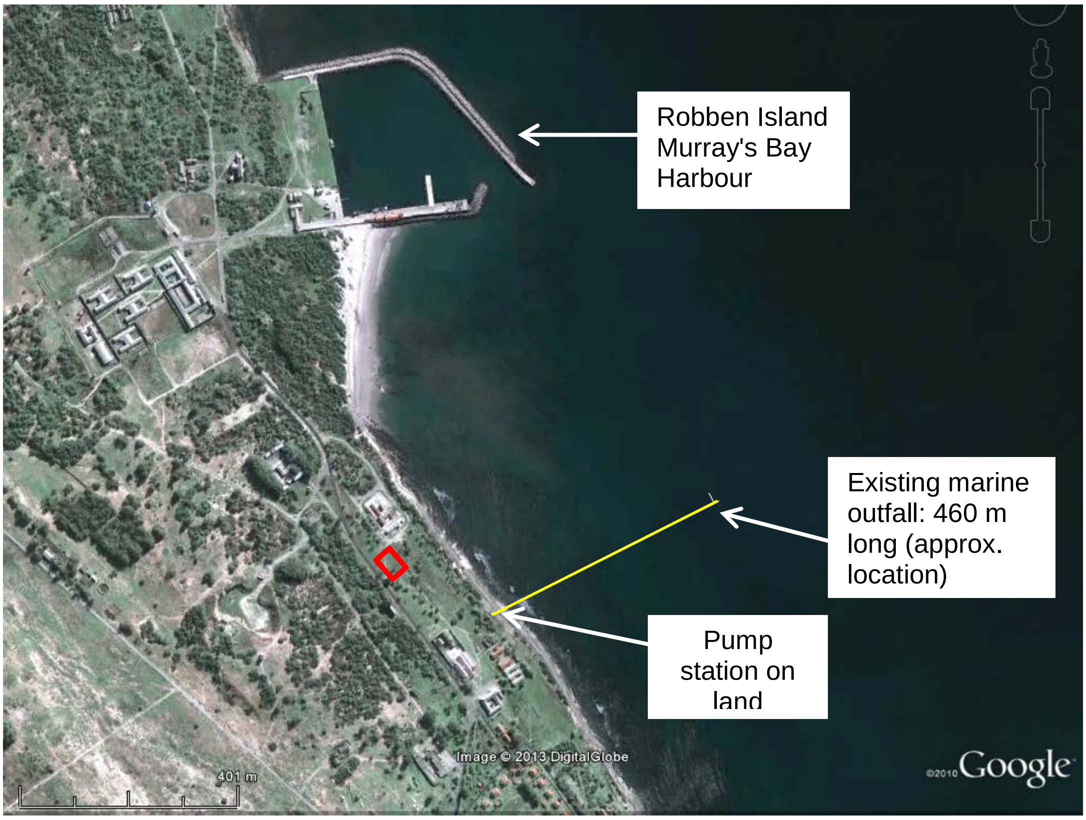

Figure 1: The location of the existing marine outfall in relation to Murray's Bay Harbour on Robben Island (adapted from WSP 2013). The location of the proposed sewage package plant is indicated by the red polygon.

A modular treatment plant, comprising relatively large chambers and based on a flow through system is proposed. The system enables long retention times thereby allowing the biological action of the bacterial colonies in the chambers to reduce sludge production to minimal levels, thus virtually eliminating the need for sludge removal. A maximum of 10 m^3 of dried sludge per year will be generated by the system, this dried sludge will either be spread out over an area of the island to provide fertiliser (if the tested sludge meets the requirements as defined by the South African Sludge Management Guidelines) or it will be transported to the Cape Town for onward disposal at a suitable landfill. Following initial screening and solids removal, the treatment process involves a number of inter-linked processes (Figure 2).

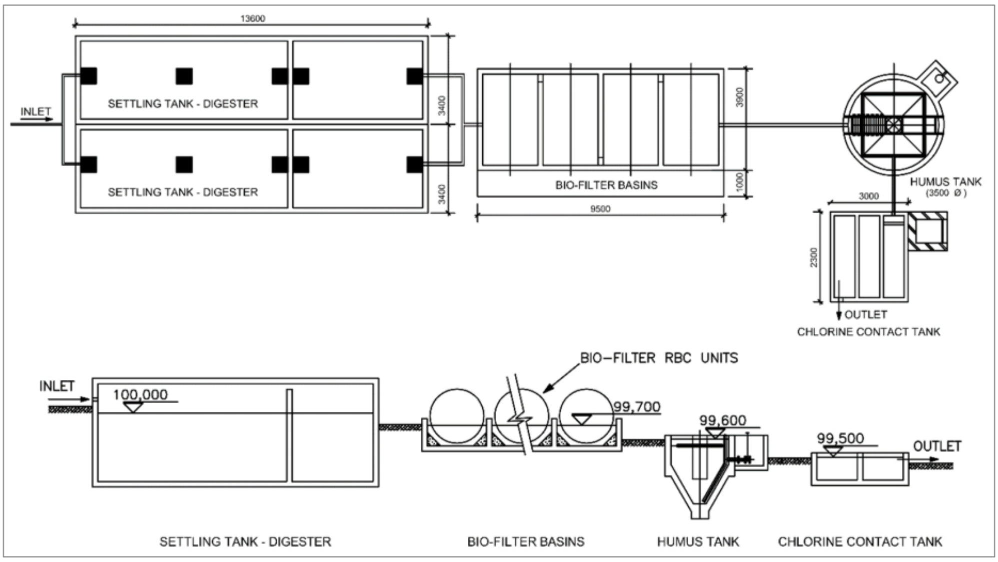

Figure 2: Schematic of the proposed modular waste water treatment process.

1. An **anaerobic primary settler** containing facultative bacterial colonies that initiate contamination reduction of the raw product through anaerobic oxidation and gross removal of organic material by settlement.
2. An **anoxic second settler**, which promotes de-nitrification and releases nitrogen to the atmosphere in undetectable quantities. Nitrate-rich sludge returned from the final settler enhances the efficiency of the de-nitrification process thereby improving the quality of the effluent.
3. An **aerobic bio-reactor** in which further organic reduction and ammonia nitrification is achieved under aerobic conditions using Rotating Biological Contactors (RBCs) within the aerobic reactor. The aerobic conditions are achieved by the rotation of discs, on which the micro-organism are attached and growing, at a low speed of approximately 3 to 4 RPM. This generates an oxygen-rich effluent flow, which completes the process of de-nitrification to nitrates. There will be six rotors, each capable of treating thirty kilolitres of domestic sewage per day.
4. A **secondary settling tank (humus tank)** in which de-nitrification is completed. Removal of the settled nitrate-rich sludge and return thereof to the anaerobic primary settler for digestion.
5. Final **disinfection by chlorine** dosing at 1 – 2 ppm with HTH calcium hyperchlorite. This ensures that any remaining microorganisms or pathogens are destroyed before the treated water is released into the environment.

The daily maximum wastewater effluent flow of 300 m^3/day will be discharged intermittently through the existing marine outfall pipeline at a constant design flow of 25 l/s. The pipeline was installed in 2001 as part of the construction of the current sewage collection and disposal facility. To ensure adequate dilution and to comply with the South African water quality guidelines for the coastal zone (DWAF 1995), the outfall was designed with a 10-m long diffuser comprising three sections tapering from 200 mm diameter, through 160 mm to 110 mm. The first diffuser section was fitted with a single 100 mm and the second and third sections with a single 110 mm port discharging horizontally to alternate sides of the main diffuser pipe thereby ensuring optimum hydraulic behaviour of the effluent. It must be emphasised that the current discharge was designed to comply with the South African water quality guidelines for the coastal zone, which assume adequate dilution of the effluent at the discharge point. The effluent composition (assuming no dilution) was thus in most cases considerably higher than the General Limit Values (Table 1). As the effluent will now be treated to General Limit Values before being discharged to sea***, the quality of effluent after the upgrade will be significantly improved relative to the originally designed discharge.***

Table 1: General Waste Water Limits (DWEA 2013), and effluent composition of existing marine outfall (WAMTECH & Rossouw 1999).

SUBSTANCE/PARAMETER	GENERAL LIMIT VALUES	CURRENT DISCHARGE
Faecal Coliforms (per 100 ml)	1,000	7,200,000
Chemical Oxygen Demand (COD)*	75 – after removal of algae	
Biological Oxygen Demand (COD)		344 mg/l
pH	5.5-9.5	7.4
Ammonia (ionised and unionised) as Nitrogen	6 mg/l	18 mg/l
Nitrate/Nitrite as Nitrogen	15 mg/l	
Chlorine as Free Chlorine	0.25 mg/l	
Suspended Solids	25 mg/l	308 mg/l
Ortho-Phosphate as phosphorous	4 ppt above intake to a maximum of 10 ppt	6 mg/l
Fluoride	10 mg/l	
Soap, oil or grease	1 mg/l	
Dissolved Arsenic	2.5 mg/l	
Dissolved Cadmium	0.02 mg/l	
Dissolved Chromium (VI)	0.005 mg/l	
Dissolved Copper	0.05 mg/l	0.27 mg/l
Dissolved Cyanide	0.01 mg/l	
Dissolved Iron	0.02 mg/l	
Dissolved Lead	0.3 mg/l	0.16 mg/l
Dissolved Manganese	0.01 mg/l	
Mercury and its compounds	0.1 mg/l	
Dissolved Selenium	0.005 mg/l	
Dissolved Zinc	0.02 mg/l	0.42 mg/l
Boron	0.1 mg/l	

* COD is typically higher than BOD

3. DESCRIPTION OF THE MARINE ENVIRONMENT

3.1. Geophysical Characteristics

Robben Island is roughly oval in shape, 3.3 km long in the north-south axis, and 1.9 km wide, with an area of 5.07 km². As the summit of an ancient, now submerged mountain, the island is linked by an undersea saddle to Blouberg. The island's flat profile is the product of wave action during a higher sea level stand, with its highest point (Minto Hill) lying only 24 m above sea-level. The island's lower strata consists of Precambrian metamorphic rocks belonging to the Malmesbury Group, overlain by a thick limestone and calcrete deposit much of which is covered by a thin veneer of Quaternary windblown sands and shell fragments (www.uct.ac.za/depts/geolsci/dlr/robben).

Robben Island has a total shoreline of 9 km of which 91% is rocky. A small pocket of fine sand occurs on the eastern shore of the island in Murray's Bay, just south of the Harbour. The rocky shores of the island are characterised by wave-cut platforms in the low-shore and steep storm beaches composed of large cobbles on the high-shore (Figure 3).

Figure 3: The shoreline of Robben Island is characterised by rocky platforms and steep cobble beaches (left) (Source: www.uct.ac.za/depts/geolsci/dlr/robben), with and isolated sandy beach south of Murray Harbour.

Robben Island lies within Table Bay, a log spiral bay anchored by rocky headlands at Mouille Point in the south and Blouberg in the north (Figure 4) (Steffani *et al.* 2003). The bay is relatively shallow with a maximum depth of 35 m at its centre. The seabed is characterised by large portions of partly exposed bedrock, which in places may be covered by a thin layer of coarse sediment. Fine sand is generally confined to the eastern nearshore region between Blouberg and the Port of Cape Town, although smaller pockets occur at the bay entrance and on the eastern shore of Robben Island (Woodborne 1983; Monteiro 1997). The major sources of the sand in Table Bay are seasonal (mainly winter) inputs from the Diep and Salt Rivers and local erosion of Malmesbury shales (Quick & Roberts 1993). Sediment is transported out of Table Bay by local wave and storm driven transport, with the overall residence time for surficial sediments estimated at 2-3 years (Monteiro 1997). The ecosystem types around Robben Island and within Table Bay were described in the 2018 National Biodiversity Assessment (Sink *et al.* 2019). The island itself and its surrounding shallow subtidal regions belong to the Cape Island and Cape Kelp Forest ecosystem types and fall within the Cape Bay ecosystem type. The associated substratum types are the Southern Benguela Islands, Southern Benguela Kelp Forest and Southern Benguela Bays, respectively (Figure 5). The outfall pipeline extends across all three of these ecosystem types and substratum types.

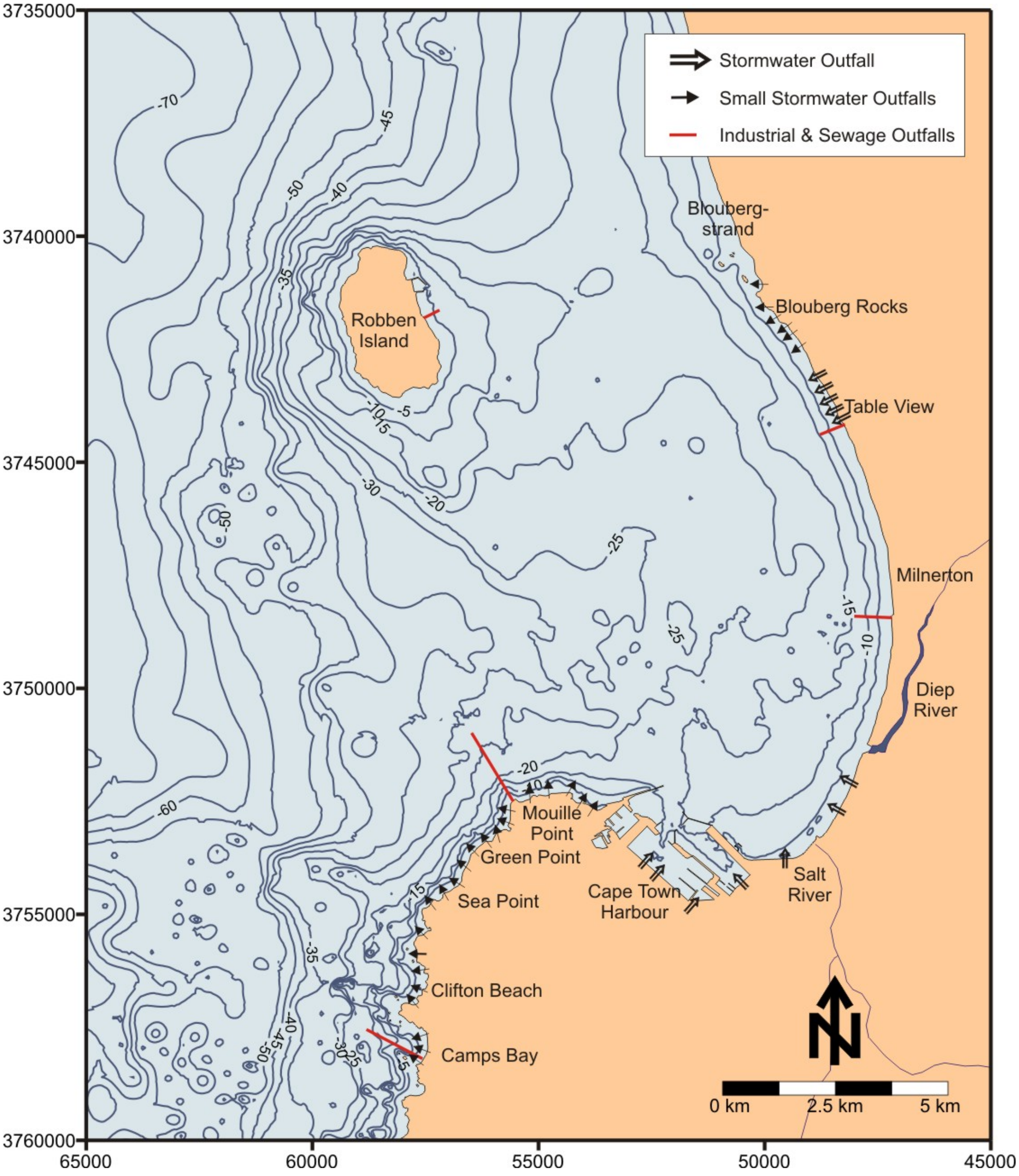

Figure 4: The bathymetry of Table Bay showing the undersea saddle linking Robben Island to Blouberg. The location of marine outfall pipelines and storm water discharges are also shown.

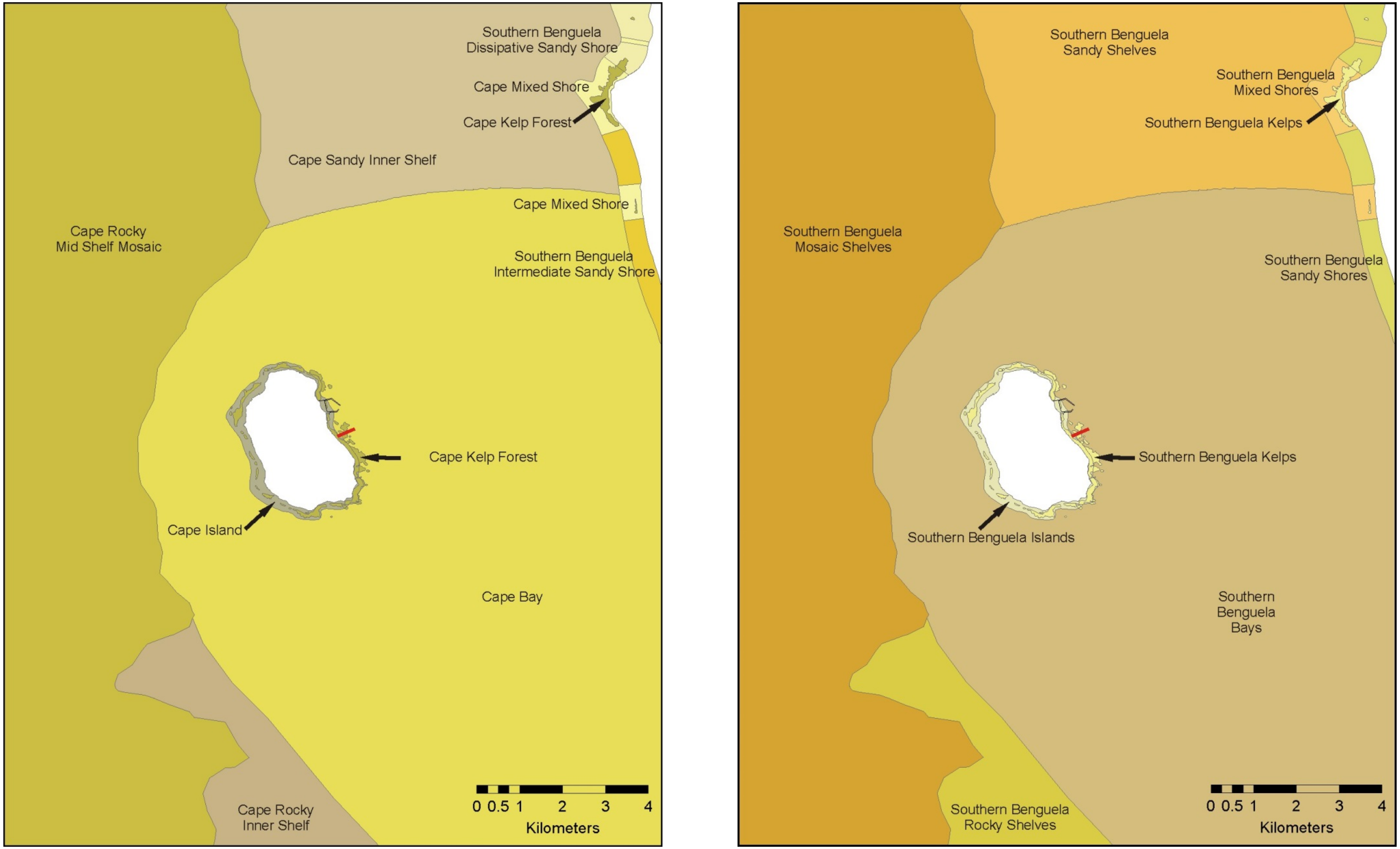

Figure 5: Marine Ecosystem Type (left) and Substratum Type (right) of Robben Island and Table Bay as assigned by Sink *et al.* (2019) in relation to the proposed waste water discharge pipeline (red line).

3.2. Biophysical Characteristics

Table Bay and Robben Island lie within the southern Benguela upwelling system (Figure 6). The circulation and water properties of the bay are thus characteristic of the region. Surface currents are mainly wind driven with typical velocities of 20 – 30 cm/s. Velocities generally decrease with depth to on average <5 cm/s near the seabed (Quick & Roberts 1993). During summer southeasterly wind conditions generate an anti-clockwise circulation pattern in the Bay with the current flowing out between Robben Island and Table View. Circulation patterns in the winter under predominantly northwesterly wind conditions are clockwise. Nearshore currents in the bay are wave driven, with virtually all swells throughout the year coming from the SW - S direction, generating northward flow. Winter swells, however, are strongly dominated by those from the SW - SSW, which occur almost 80% of the time, and typically exceed 2 m in height, averaging about 3 m, and often attaining over 5 m. The location of Robben Island in the bay will result in refraction of these waves around the island thereby generating localised changes in the wave direction. The eastern portion of the island, where the outfall is located, is well protected from these offshore swells, but will be subjected to significant sea waves generated within Table Bay by the prevailing moderate to strong southerly winds characteristic of the region. On the eastern shores of Robben Island, surface currents are highly variable and characterised by localised boundary currents along the outer edge of the kelp beds (Roberts 2002). As with most of the southern Africa West Coast the shores of Robben Island can thus be classified as exposed to very exposed, rating between 11-17 on the 20 point exposure scale (McLachlan 1980).

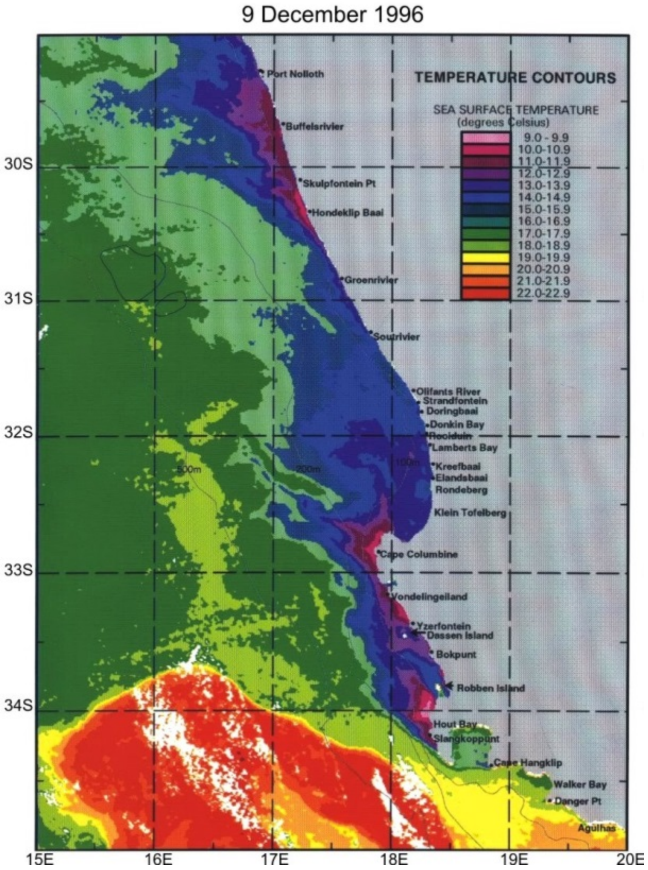

Figure 6: Satellite sea-surface temperature images showing upwelling intensity along the South African west coast in December 1996 (from Lane & Carter 1999).

Due to the generally low current velocities flushing periods in Table Bay are normally long with an average period of 4 days (Quick & Roberts 1993). In common with the rest of the southern African coast, tides are semi-diurnal, with a total range of some 1.5 m at spring tide, but only 0.6 m during neap tide periods.

3.3. Marine Ecology

The major force driving the ecology of the Table Bay region is coastal upwelling. During upwelling the comparatively nutrient-poor surface waters are displaced by cold, enriched deep water. The major contributing nutrients are various forms of nitrates, phosphates and silicates, with concentrations attaining 20 µM nitrate-nitrogen, 1.5 µM phosphate and 15-20 µM silicate (Chapman & Shannon 1985). Modification of these peak concentrations depends upon phytoplankton uptake which varies according to phytoplankton biomass and production rate. The range of nutrient concentrations can thus be large but, in general, concentrations are high.

The nutrients support dense stands of macroalgae such as kelps, which provide both a food source and habitat for a wide diversity of nearshore invertebrates and fish. The nutrients also support substantial seasonal primary phytoplankton production, which in turn serves as the basis for a rich food chain up through zooplankton, pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (hake and snoek), mammals (primarily seals and dolphins) and seabirds (jackass penguins, cormorants, pelicans, terns and others) (Field & Griffiths 1991).

High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters, resulting in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays (Bailey *et al*. 1985). Similarly, all the higher order consumers are subject to natural mortality, and a proportion of the annual production of all these trophic levels, particularly the plankton communities, die naturally and sink to the seabed.

Biogeographically, the coastline of Robben Island falls into the Southern Benguela Shelf Ecoregion, which extends from Cape Point to Lüderitz in Namibia, and includes the western edges of the Agulhas Bank (Sink *et al*. 2019) (Figure 7). In the context of the Southern Benguela System, the benthic communities in Table Bay are typical for the West Coast and not unique to the Bay. Marine ecosystems comprise a range of habitats each supporting a characteristic biological community. Habitats around Robben Island include:

- A sandy beach extending ~400 m south of Murray’s Harbour,
- Subtidal sandy substrates off the beach and beyond the subtidal extent of the coastal reefs,
- Rocky shores extending virtually all around the Island and into the subtidal,
- Kelp beds on rocky subtidal substrates around the Island,
- The water body around the island and in Table Bay, and
- Artificial surfaces of the harbour.

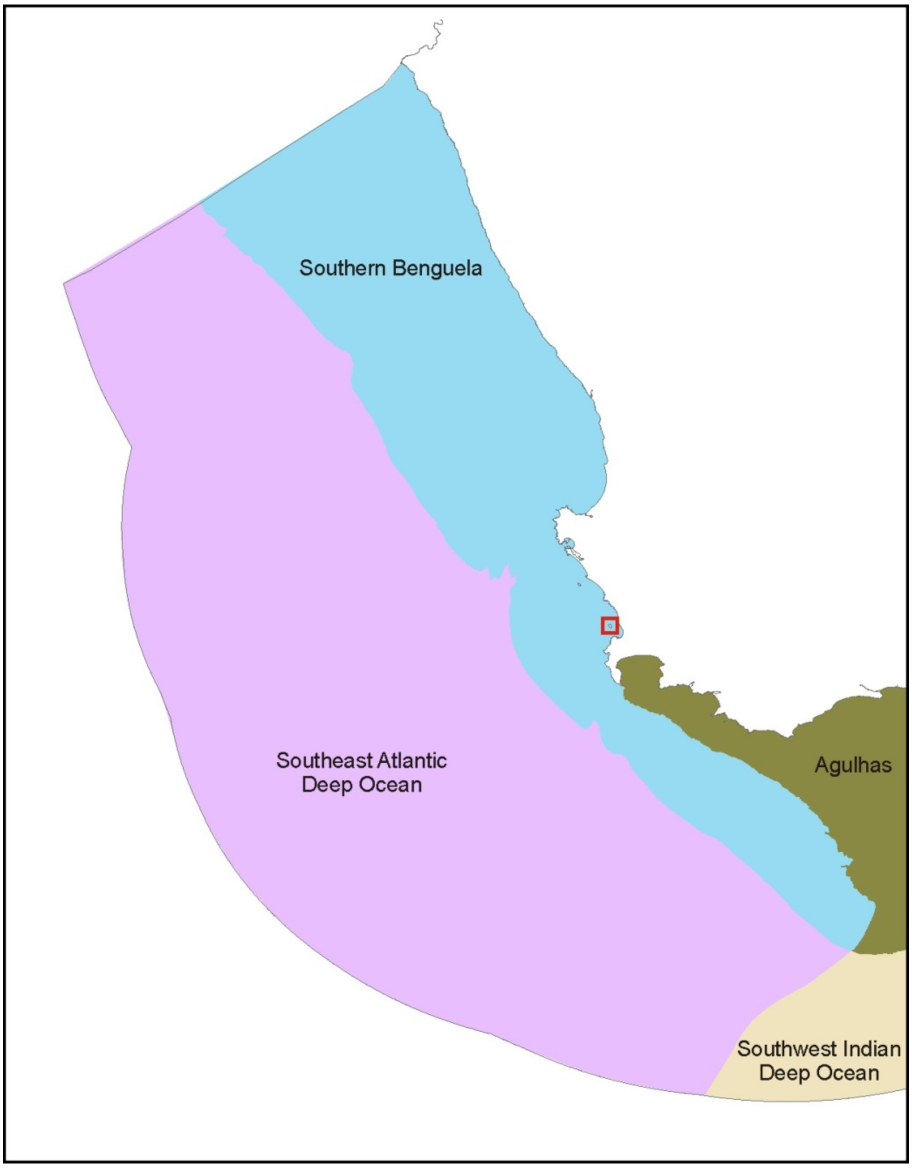

Figure 7: The South African inshore and offshore bioregions in relation to the project area (red square) (adapted from Sink *et al*. 2019).

The marine communities within these habitats are largely ubiquitous throughout the bioregion, being particular only to substrate type or depth zone. These biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability (even at small scales). The biological communities 'typical' of these habitats are described briefly below, focussing both on dominant, commercially important and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the marine outfall.

3.3.1 Sandy Beach Habitats and Biota

3.3.1.1 Intertidal Sandy Beaches

The composition of the biota of intertidal beaches is largely dependent on sand particle size, beach slope and degree of wave energy. Three morphodynamic beach types are described:

dissipative, reflective and intermediate beaches (McLachlan *et al.* 1993). Generally, dissipative beaches are flat with fine sand where the wave energy dissipates in the surf zone, resulting in less turbulent conditions in the intertidal zone. These beaches usually harbour the richest intertidal faunal communities. Reflective beaches are coarse grained (>500 µm sand) with steep intertidal beach faces. The relative absence of a surf zone causes the waves to break directly on the shore causing a high turnover of sand. The result is depauperate faunal communities. Intermediate beach conditions exist between these extremes and have a very variable species composition (McArdle & McLachlan 1991; McLachlan *et al.* 1993; Jaramillo *et al.* 1995). This variability is mainly attributable to the amount and quality of food available. Beaches with a high input of e.g. kelp wrack have a rich and diverse drift-line fauna, which is sparse or absent at beaches lacking a drift-line (Branch and Griffiths 1988, Field and Griffiths 1991). The beach on Robben Island is likely to be an intermediate beach.

Numerous methods of classifying beach zonation have been proposed, based either on physical or biological criteria. The general scheme proposed by Branch & Griffiths (1988) is used below (Figure 8), supplemented by data from various publications on West Coast sandy beach biota (e.g. Bally 1987, Brown *et al.* 1989, Soares *et al.* 1996, 1997, Nel 2001, Nel *et al*. 2003, Soares 2003, Branch *et al.* 2010, Harris 2012). The upper beach dry zone (supralittoral) is situated above the high water spring (HWS) tide level, and receives water input only from large waves at spring high tides or through sea spray. This zone is characterised by a mixture of air breathing terrestrial and semi-terrestrial fauna, often associated with and feeding on kelp deposited near or on the driftline. Terrestrial species include a diverse array of beetles and arachnids and some oligochaetes, while semi-terrestrial fauna include the oniscid isopod *Tylos granulatus*, and amphipods of the genus Africhorchestia (=*Talorchestia*). The mid-beach retention zone and low-beach saturation zone (intertidal zone or mid-littoral zone) has a vertical range of about 2 m. This mid-shore region is characterised by the cirolanid isopods *Pontogeloides latipes*, *Eurydice* (*longicornis*=) *kensleyi*, and *Excirolana natalensis*, the polychaetes *Scolelepis squamata*, *Orbinia angrapequensis*, *Nepthys hombergii* and *Lumbrineris tetraura*, and amphipods of the families Haustoridae and Phoxocephalidae. In some areas (e.g. Blouberg), juvenile and adult sand mussels *Donax serra* may also be present in considerable numbers (Figure 9).

3.3.1.2 Subtidal Sandy Habitats

The benthic biota of soft bottom substrates constitutes invertebrates that live on, or burrow within, the sediments, and are generally divided into macrofauna (animals >1 mm) and meiofauna (<1 mm). The zonation described for intertidal beaches continues into the subtidal regions, where the structure and composition of benthic soft-bottom communities is primarily determined by water depth and sediment grain size. Other factors such as current velocity, organic content, and food abundance, however, also play a role (Snelgrove & Butman 1994; Flach & Thomsen 1998; Ellingsen 2002). This array of environmental factors and their complex interplay is ultimately responsible for the structure of benthic communities in unconsolidated substrates by defining a distinct habitat in which the animals occur.

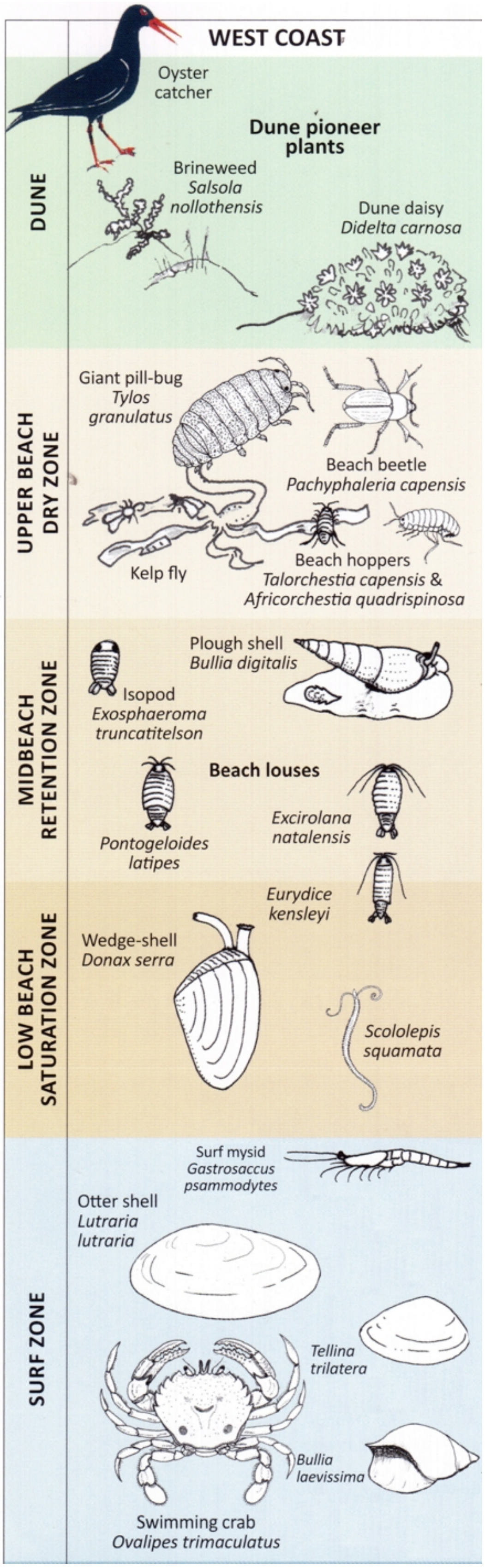

Figure 8: Schematic representation of the typical West Coast intertidal beach zonation (adapted from Branch & Branch 2018). Species commonly occurring on the Cape beaches are listed.

The surf zone (inner turbulent and transition zones) extends from the Low Water Spring mark to about -2 m depth. The mysid *Gastrosaccus psammodytes* (Mysidacea, Crustacea), the ribbon worm *Cerebratulus fuscus* (Nemertea), the cumacean *Cumopsis robusta* (Cumacea) and a variety of polychaetes including *Scolelepis squamata* and *Lumbrineris tetraura*, are typical of this zone, although they generally extend partially into the midlittoral above. In areas where a suitable swash climate exists, the gastropod *Bullia digitalis* (Gastropoda, Mollusca) may also be present in considerable numbers, surfing up and down the beach in search of carrion. The **transition zone** spans approximately 2 - 5 m depth beyond the inner turbulent zone. Extreme turbulence is experienced in this zone, and as a consequence this zone typically harbours the lowest diversity on sandy beaches. Typical fauna include amphipods such as *Cunicus profundus* and burrowing polychaetes such as *Cirriformia tentaculata* and *Lumbrineris tetraura.* In the **outer turbulent zone**, which extends below 5 m depth, turbulence is significantly decreased and species diversity is again much higher. In addition to the polychaetes found in the transition zone, other polychaetes in this zone include *Pectinaria capensis*, and *Sabellides ludertizii*. The sea pen V*irgularia schultzi* (Pennatulacea, Cnidaria) is also common as is a host of amphipod species and the three spot swimming crab *Ovalipes punctatus* (Brachyura, Crustacea).

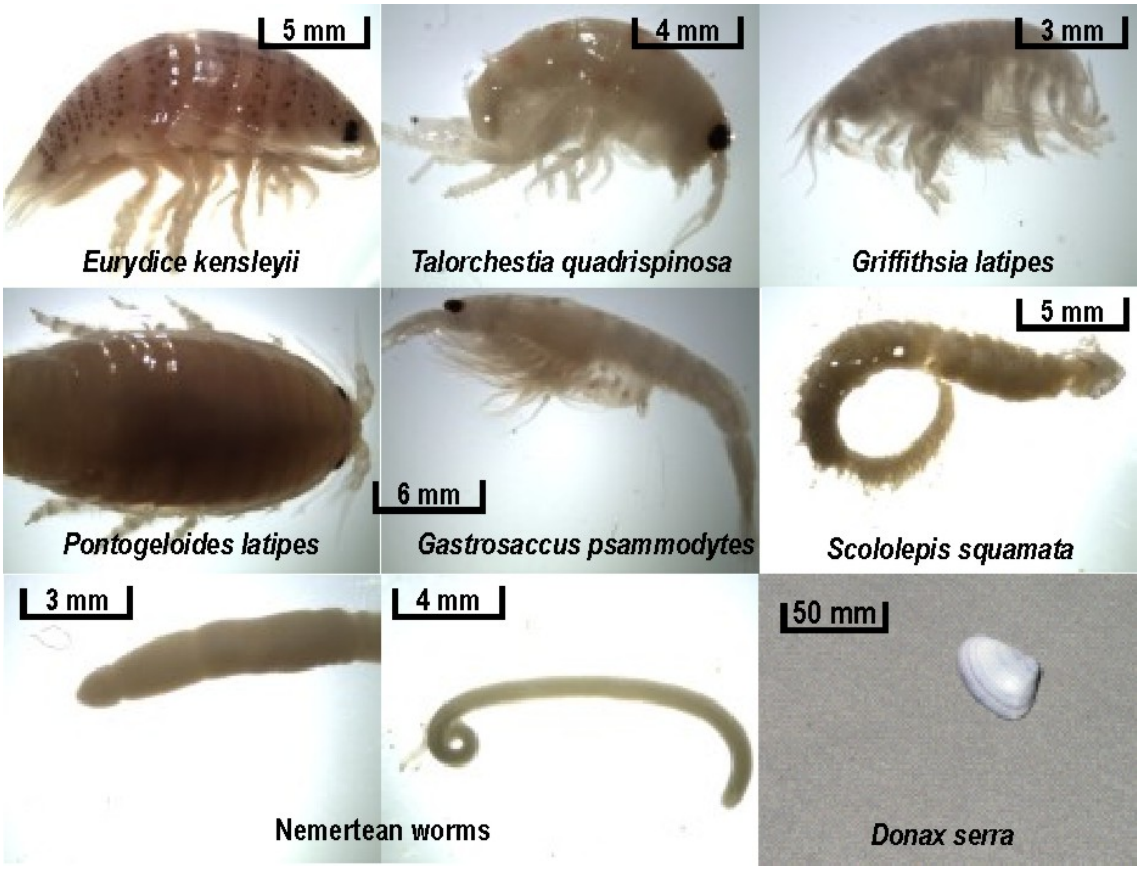

Figure 9: Common beach macrofaunal species occurring on West Coast beaches.

3.3.2 Rocky Habitats and Biota

3.3.2.1 Intertidal Rocky Shores

The benthic communities of rocky intertidal shores are in essence ubiquitous throughout the biogeographic province, differing only with exposure to wave action. Specifically, wave action enhances filter-feeders (McQuaid & Branch 1985) by increasing the concentration and turnover of particulate food (Bustamante & Branch 1996), leading to an elevation of overall biomass despite a low species diversity (Bustamante *et al*. 1995). Conversely, sheltered shores are diverse with a relatively low biomass, and only in relatively sheltered embayments does drift kelp accumulate and provide a vital support for very high densities of kelp-trapping limpets, for example *Cymbula granatina* that occur exclusively there (Bustamante *et al*. 1995). In the subtidal, these differences diminish as wave exposure is moderated with depth.

Like sandy beaches, rocky intertidal shores on the southern African West Coast can be divided into zones on the basis of their characteristic biological communities. Tolerance to the physical stresses associated with life on the intertidal, as well as biological interactions such as herbivory, competition and predation interact to produce five zones. The biological zones, however, also correspond roughly to zones based on tidal heights (Figure 10 and Figure 11).

The **Littorina zone**, is the uppermost part of the shore most exposed to air, thus perhaps having more in common with the terrestrial environment. The supralittoral is characterised by low species diversity, with the tiny gastropod *Afrolittorina (=Littorina) knysnaensis*, and the red alga *Porphyra capensis* (Rhodophyta) constituting the most common macroscopic life. The **upper midlittoral/balanod** is characterised by the limpets *Scutellastra granularis* and *Siphonaria capensis* (Gastropoda, Mollusca), which are present on almost all shores. The gastropods *Oxystele variegata*, *Nucella dubia*, and *Helcion pectunculus* are variably present, as are low densities of the barnacles *Chthalamus dentatus*, *Tetraclita serrata* and *Octomeris angulosa* (Cirripedia, Crustacea). Flora is best represented by the leafy green alga *Ulva* spp. (Chlorophyta), with *Hildenbrandia rubra* (Rhodophyta) present in damp depressions.

Toward the lower shore, biological communities in the l**ower midlittoral/lower Balanoid zone** are determined by exposure to wave action. Sheltered shores are dominated by grazers, principally the limpets *S. granularis*, *Cymbula granatina* and a diversity of foliose algae. The algae diversity abounds with a variable representation of: green algae - *Codium* and *Cladophora* spp., brown algae (Phaeophyta) - *Splachnidium rugosum, Chordariopsis capensis*, and red algae *Nothogenia erinacea*, *Aeodes orbitosa*, *Mazzaella (=Iridaea) capensis*, *Gigartina polycarpa* (=*radula*), *Sarcothalia* (=*Gigartina*) *stiriata*, *Champia lumbricalis* (often epiphytized by *Aristothamnion collabens*) and some *Polysiphonia,* and articulated and crustose corallines. The gastropods *Burnupena* spp. and the starfish *Parvulastra exigua* (Asteroidea) are also common. Filter-feeder biomass, however, is low on sheltered shores and represented primarily by the Cape reef worm *Gunnarea capensis* in sediment influenced area.

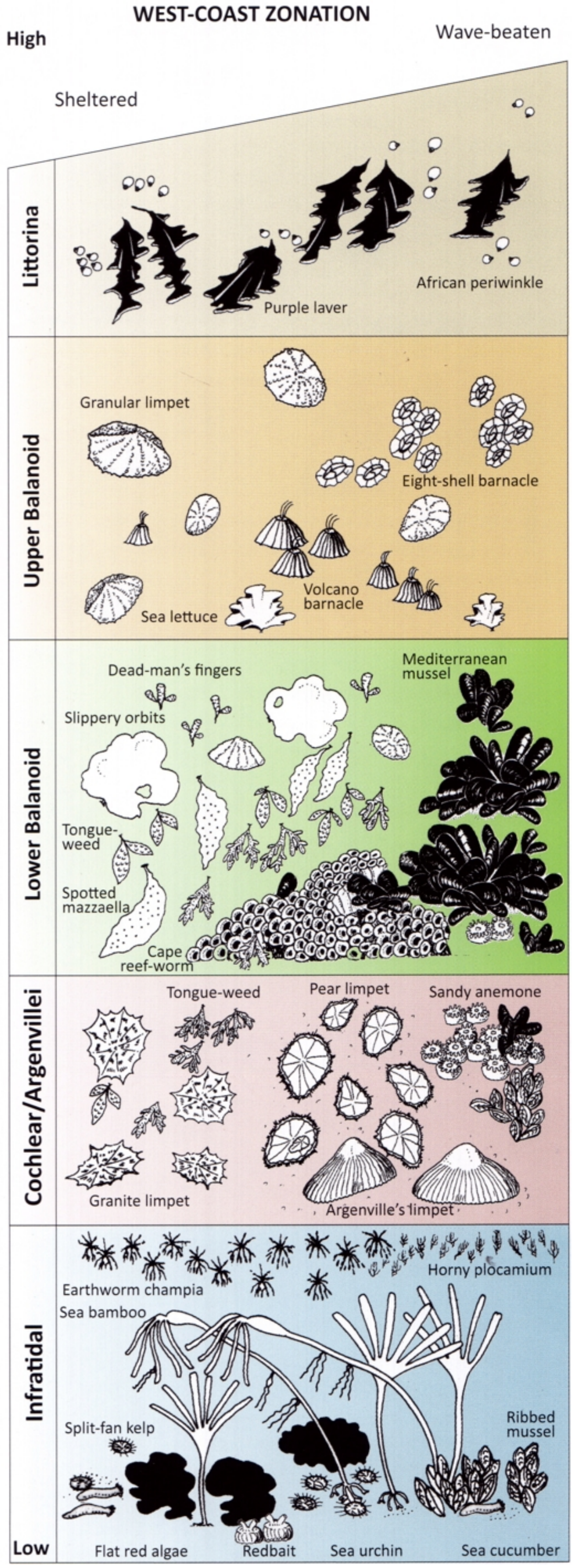

Figure 10: Schematic representation of the West Coast intertidal rocky shore zonation (adapted from Branch & Branch 2018).

Figure 11: Typical rocky intertidal zonation on the southern African west coast.

In contrast, on more exposed shores wave action enhances filter-feeders (McQuaid & Branch 1985) by increasing the concentration and turnover of particulate food (Engledow & Bolton 1994; Bustamante & Branch 1996), leading to an elevation of overall biomass (Bustamante *et al.* 1995). The communities are dominated by foliose algae, particularly by the red algae *Plocamium cornutum*, which occurs prolifically as a secondary canopy on the mussel beds. Several algal species are associated with the *Gunnarea* reefs, notably *Ceramium* sp., *Leathesia difformis*, *Caulacanthus ustulatus* and *Cladophora.* On more exposed shores, almost all of the primary space can be occupied by the dominant alien invasive mussel *Mytilus galloprovincialis*. First recorded in 1979 (although it is likely to have arrived in the late 1960's), it is now the most abundant and widespread invasive marine species along the entire West Coast and parts of the South Coast (Robinson *et al.* 2005). *M. galloprovincialis* has partially displaced the local mussels *Choromytilus meridionalis* and *Aulacomya ater* (Hockey & Van Erkom Schurink 1992), and competes with several indigenous limpet species (Griffiths *et al.* 1992, Steffani & Branch 2003a, b). Recently, another alien invasive has been recorded, the acorn barnacle *Balanus glandula*, which is native to the west coast of North America where it is the most common intertidal barnacle. The presence of *B. glandula* in South Africa was only noticed a few years ago as it had always been confused with the native barnacle *Cthamalus dentatus* (Simon-Blecher *et al.* 2008). There is, however, evidence that it has been in South Africa since at least 1992 (Laird & Griffith 2008). At the time of its discovery, the barnacle was recorded from 400 km of coastline from Elands Bay to Misty Cliffs near Cape Point (Laird & Griffith 2008) and is thus likely to also occur on Robben Island. When present, the barnacle is typically abundant at the mid zones of semi-exposed shores.

Along the well-marked **infratidal fringe** or **Argenvillei zone** on semi-exposed and exposed shores, the limpet *Scutellastra argenvillei* dominates except where it has been displaced by

M. galloprovincialis. The kelps *Laminaria pallida* and *Ecklonia maxima* dominate the algal diversity in this zone, and where limpet densities are lower, there is variable representation of the flora and fauna described for the lower midlittoral above. This includes the anemone *Aulactinia reynaudi* (Actiniaria, Cnidaria), other patellid limpets (*S. granularis*, *S. barbara*, *Cymbula granatina*, C. *miniata*), numerous whelk species (*Nucella* spp. and *Burnupena* spp.) and the sea urchin *Parechinus angulosus* (Echinoidea, Echinodermata). On more exposed shores, the mussels *Aulacomya ater* or the tunicate *Pyura stolonifera* (Ascidiacea) may also occur. Most of these species extend into the subtidal below.

The invasion of west coast rocky shores by another mytilid, the small *Semimytilus algosus*, was recently noted (de Greef *et al.* 2013). It is hypothesized that this species has established itself in the last ten years. Its current range extends from the Groen River mouth in the north to Bloubergstrand in the south. Where present, it completely dominates primary rock space in the lower intertidal zone, while *M. galloprovincialis* dominates higher up the shore. Many shores on the West Coast have thus now been effectively partitioned by the three introduced species, with *B. glandula* colonizing the upper intertidal, *M. galloprovincialis* dominating the mid-shore, and now *S. algosus* smothering the low-shore (de Greef *et al.* 2013).

Most semi-exposed to exposed rocky shores on the Southern African West coast are strongly influenced by sediments, and may include considerable amounts of sand intermixed with the benthic biota. This intertidal mixture of rock and sand is referred to as a mixed shore, and constitutes a substantial proportion of the rocky intertidal regions along the Southwestern Cape coastline.

3.3.2.2 Subtidal Reefs

For the current project, the biological communities of the sublittoral habitat would be those most affected by the discharges from the WWTW. Communities of the sublittoral habitat can be broadly grouped into an inshore zone (from the supralittoral fringe to a depth of ~10 m), and an offshore zone (below 10 m depth). The shift in communities from the flora-dominated inshore zone to the fauna-dominated offshore zone is not knife-edge, however, representing instead a continuum of species distributions, merely with changing abundances. As wave exposure is moderated with depth, wave action is less significant in structuring the communities than in the intertidal, with prevailing currents, and the vertical distribution of oxygen and nutrients playing more important roles.

From the sublittoral fringe to a depth of between 5 m and 10 m, the benthos is largely dominated by algae, in particular two species of kelp. The canopy forming kelp *Ecklonia maxima* extends seawards to a depth of about 10 m. The smaller *Laminaria pallida* forms a sub-canopy to a height of about 2 m underneath *Ecklonia*, but continues its seaward extent to about 30 m depth, although further north increasing turbidity limits growth to shallower waters (10 - 20 m) (Velimirov *et al*. 1977; Jarman & Carter 1981). *Ecklonia maxima* is the dominant species in the south forming extensive beds from west of Cape Agulhas to north of Cape Columbine (Stegenga *et al.* 1997; Rand 2006) (Figure 11).

Kelp beds absorb and dissipate much of the high wave energy reaching the shore, thereby providing important partially-sheltered habitats for a high diversity of marine flora and fauna, resulting in diverse and typical kelp-forest communities being established. Through a combination of shelter and provision of food, kelp beds support recruitment and complex trophic food webs of numerous species, including commercially important rock lobster and abalone stocks.

Growing beneath the kelp canopy, and epiphytically on the kelps themselves, are a diversity of understorey algae, which provide both food and shelter for predators, grazers and filter-feeders associated with the kelp bed ecosystem. Representative under-storey algae include *Botryocarpa prolifera*, *Neuroglossum binderianum*, *Botryoglossum platycarpum*, *Hymenena venosa* and *Epymenia obtusa*, various coralline algae, as well as subtidal extensions of some algae occurring primarily in the intertidal zones (Bolton 1986). Epiphytic species include *Carradoria virgata*, *Suhria vittata* and *Carpoblepharis flaccida*.

The sublittoral invertebrate fauna is dominated by suspension and filter-feeders, such as the ribbed mussel *Aulacomya ater* and Cape reef worm *Gunnarea capensis*, and a variety of sponges and sea cucumbers. Grazers are less common, with most herbivory being restricted to grazing of juvenile algae or debris-feeding on detached macrophytes. The dominant herbivore is the sea urchin *Parechinus angulosus*, with lesser grazing pressure from limpets. Key predators in the sub-littoral include the commercially important West Coast rock lobster *Jasus lalandii* and the octopus *Octopus vulgaris*. The rock lobster acts as a keystone species as it influences community structure via predation on a wide range of benthic organisms (Mayfield *et al*. 2000). Of lesser importance as predators, although numerically significant, are various starfish, feather and brittle stars, and gastropods, including the whelks *Nucella* spp. and *Burnupena* spp.

Figure 12: The canopy-forming kelp *Ecklonia maxima* provides an important habitat for a diversity of marine biota (Photo: Geoff Spiby).

3.3.3 Pelagic Communities in Table Bay

The pelagic communities are typically divided into plankton (phytoplankton, zooplankton and ichthyoplankton) and fish, and their main predators marine mammals (seals, dolphins and whales). Table Bay forms part of the southern Benguela ecosystem and, as there are few barriers to water exchange, pelagic communities are typical of those of the region.

3.3.3.1 Plankton and Ichthyoplankton

The phytoplankton is typically dominated by large-celled diatoms and dinoflagellates (Figure 12). The most common diatom genera are *Chaetoceros*, *Nitschia*, *Thalassiosira*, *Skeletonema*, *Rhizoselenia*, *Coscinodiscus* and *Asterionella* whilst common dinoflagellates are *Prorocentrum*, *Ceratium* and *Peridinium* (Shannon & Pillar 1985) Some of the dinoflagellate species which are known to cause harmful algal blooms (HAB) (e.g. *Ceratium furca*, *C. lineatum*, *Promocentrum micans*, *Dinophysis* sp, *Noctiluca scintillans*, *Gonyaulax tamarensis*, *G polygramma*, *Alexandrium catanella*, *Mesodinium rubrum*) also occur episodically and dense HABs have been observed in Table Bay (Pitcher & Calder 2000). Mean phytoplankton biomass ranges between 3 and 4 µg chl *a*/l but varies considerably with phases in the upwelling cycle and in HABs (Brown *et al*. 1991).

Zooplankton comprises predominantly copepods (*Centropages, Calanoides, Metridia, Nannocalanus, Paracalanus, Ctenocalanus* and *Oithona*) and euphausiids (*Euphausia lucens* and *Nyctiphanes capensis*) (Hutchings *et al*. 1991, Shannon & Pillar 1986) (Figure 13). The zooplankton generally graze phytoplankton and therefore biomass and biomass distributions depend upon this component of the plankton.

Ichthyoplankton in the southern Benguela area comprises mostly fish eggs and larvae, mainly from anchovy and pilchard, and to a lesser extent from hake and mackerel (Shannon & Pillar 1986). As Table Bay falls within the main recruitment areas for these commercially and ecologically important species, it is likely that relatively high densities of fish eggs and larvae could be present in the plankton (Crawford *et al*. 1989).

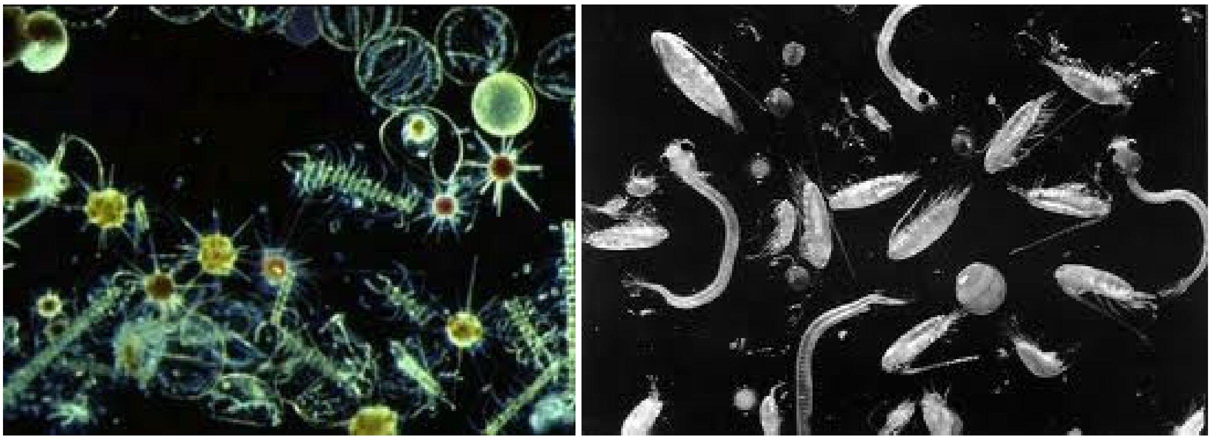

Figure 13: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

3.3.3.2 Pelagic Fish

Small pelagic shoaling species include the sardine/pilchard (*Sadinops ocellatus*) (Figure 14, left), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) (Figure 14, right) and round herring (*Etrumeus whiteheadi*). These species typically occur in mixed shoals of various sizes (Crawford *et al*. 1987) within the 200 m contour and would thus be expected in Table Bay and around Robben Island. Most of the pelagic species exhibit similar life history patterns involving seasonal migrations between the west and south coasts. The spawning areas are distributed on the continental shelf south of St Helena Bay (Shannon & Pillar 1986). The eggs and larvae of those that spawn on the Agulhas Bank in spring and summer, are subsequently carried around Cape Point and up the coast in northward flowing surface waters. At the start of winter every year, juveniles of most small pelagic species recruit back into coastal waters south of the Orange River to utilise the shallow shelf region as nursery grounds before gradually migrating southwards, towards the major spawning grounds east of Cape Point. Recruitment success relies on the interaction of oceanographic events, and is thus subject to spatial and temporal variability. Consequently, the abundance of adults and juveniles of these small, short-lived (1-3 years) pelagic fish is highly variable both within and between species.

Two species that migrate along the West Coast following the shoals of anchovy and pilchards are snoek *Thyrsites atun* and chub mackerel *Scomber japonicas*. Their appearance along the West coast is highly seasonal, with snoek reaching the area between St Helena Bay and the Cape Peninsula between May and August. They spawn in these waters between July and October before moving offshore and commencing their return northward migration (Payne & Crawford 1989). They are voracious predators occurring throughout the water column, feeding on both demersal and pelagic invertebrates and fish. Chub mackerel similarly migrate along the southern African West Coast reaching South-Western Cape waters between April and August. They move inshore in June and July to spawn before starting the return northwards offshore migration later in the year. Their abundance and seasonal migrations are thought to be related to the availability of their shoaling prey species (Payne & Crawford 1989).

Figure 14: Cape fur seal preying on a shoal of pilchards (left). School of horse mackerel (right) (photos: www.underwatervideo.co.za; www.delivery.superstock.com).

The structure of the nearshore and surf zone fish community varies greatly with the degree of wave exposure. Species richness and abundance is generally high in sheltered and semi-exposed areas but typically very low off the more exposed beaches (Clark 1997a, 1997b).

The surf-zone and outer turbulent zone habitats of sandy beaches are important nursery habitats for marine fishes (Modde 1980; Lasiak 1981; Clark *et al.* 1994). However, the composition and abundance of the individual assemblages is heavily dependent on wave exposure (Clark 1997a, b). Surf-zone fish communities off the South African West Coast have relatively high biomass, but low species diversity. Typical surf-zone fish include harders (*Liza richardsonii*), white stumpnose (*Rhabdosargus globiceps*), Cape sole (*Heteromycteris capensis*), Cape gurnard (*Chelidonichthys capensis*), False Bay klipfish (*Clinus latipennis*), sandsharks (*Rhinobatos annulatus*), eagle ray (*Myliobatis aquila*), and smooth-hound (*Mustelus mustelus*) (Clark 1997b).

Fish species commonly found in kelp beds off the West Coast include hottentot *Pachymetopon blochii* (Figure 15, left), twotone fingerfin *Chirodactylus brachydactylus* (Figure 15, right), red fingers *Cheilodactylus fasciatus*, galjoen *Dichistius capensis*, rock suckers *Chorisochismus dentex,* maned blennies *Scartella emarginata* and the catshark *Haploblepharus pictus* (Sauer *et al.* 1997; Brouwer *et al*. 1997; Branch *et al*. 2010).

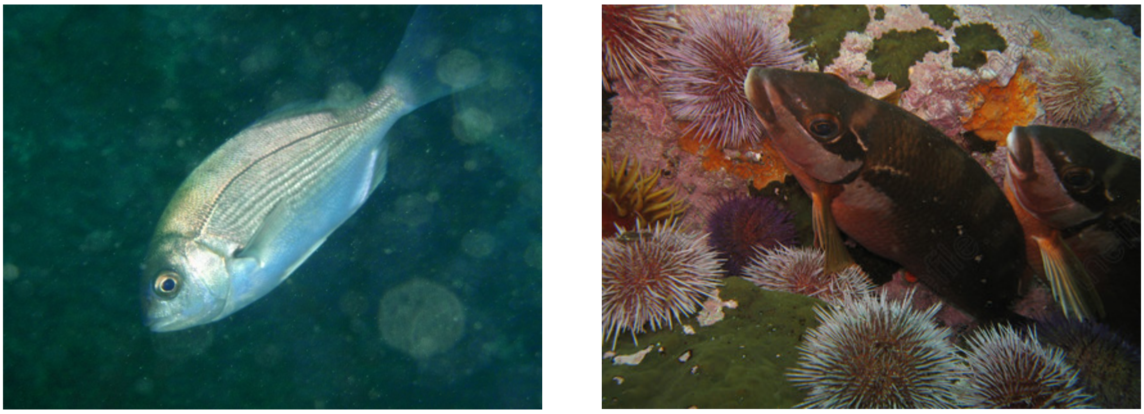

Figure 15: Common fish found in kelp beds include the Hottentot fish (left, photo: commons. wikimedia.org) and the twotone fingerfin (right, photo: www.parrphotographic.com).

3.3.4 Seabirds

Of the fifteen species of seabirds that breed in southern Africa (Table 2), nine are known to breed on Robben Island.

Important seabirds in the Table Bay area include the African penguin *Spheniscus demersus* (Figure 16, left), Cape Cormorant *Phalacrocorax capensis* and the Bank cormorant *P. neglectus*. All three species are endemic to southern Africa and are classified as 'Endangered' under the International Union for the Conservation of Nature (IUCN) criteria as well as the South African National Assessment (Sink *et al.* 2018). African Penguins re-colonised Robben Island in 1983 after an absence of about 180 years. Numbers of penguins have increased from nine pairs in 1983 to over 4,000 pairs in 1996. The island is one of only seven remaining penguin colonies (Dassen Island, Robben Island, Boulders, Stoney Point, Dyer Island and Bird and St. Croix

Islands), with the breeding population in 2000 comprising 5,705 pairs (Crawford *et al.* 2000). Numbers of breeding pairs peaked in 2004 at 8,524, but have declined again to 2,600 in 2010 (Crawford *et al.* 2011; Sherley *et al*. 2014), 1,216 in 2019 (Miller 2020) and only 1,009 in 2021 (DFFE, unpublished data) reflecting the global decline of the species. Despite increased chick survival following the experimental three-year fisheries closure around Robben Island (Sherley *et al*. 2015; Sherley *et al*. 2018), poor prey availability due to depletion of fish stocks by commercial fisheries (Crawford *et al*. 2006), and a shift in prey biomass eastwards in response to climatic changes has lead to high adult mortality and continued population declines (Sherley *et al.* 2017).

Figure 16: The African Penguin (Left, photo: Klaus Jost) and African Black Oystercatcher (Right, photo: patrickspilsbury.blogspot.com) nest on Robben Island.

Table 2: Breeding resident seabirds present along the West Coast (adapted from CCA & CMS 2001). IUCN Red List and National Assessment status are provided (Sink *et al*. 2019). Species reported breeding on Robben Island are highlighted in bold text.

Common Name	Species Name	National	Global Assessment
African Penguin	***Spheniscus demersus***	**Endangered**	**Endangered**
African Black Oystercatcher	***Haematopus moquini***	**Least Concern**	**Near Threatened**
White-breasted Cormorant	***Phalacrocorax carbo***	**Least Concern**	**Least Concern**
Cape Cormorant	***Phalacrocorax capensis***	**Endangered**	**Endangered**
Bank Cormorant	***Phalacrocorax neglectus***	**Endangered**	**Endangered**
Crowned Cormorant	***Phalacrocorax coronatus***	**Near Threatened**	**Near Threatened**
White Pelican	*Pelecanus onocrotalus*	Vulnerable	Least Concern
Cape Gannet	*Morus capensis*	Endangered	Endangered
Kelp Gull	***Larus dominicanus***	**Least Concern**	**Least Concern**
Greyheaded Gull	*Larus cirrocephalus*	Least Concern	Least Concern
Hartlaub's Gull	***Larus hartlaubii***	**Least Concern**	**Least Concern**
Caspian Tern	***Hydroprogne caspia***	**Vulnerable**	**Least Concern**
Swift Tern	***Sterna bergii***	**Least Concern**	**Least Concern**
Roseate Tern	*Sterna dougallii*	Endangered	Least Concern
Damara Tern	*Sterna balaenarum*	Vulnerable	Vulnerable

The location of the breeding colonies in 2013 is shown in Figure 17. While decreasing in numbers, penguins continue to increase the areas of the island where they breed, now also breeding along the south of the island from Alpha One to the light house. Recent GPS tracking research has shown that penguins forage mainly to the north and south of the island making them particularly vulnerable to oil spill associated with vessel traffic in and out of the Port of Cape Town (http://penguin-tracks.blogspot.com) (Figure 18).

Figure 17: Current African Penguin nesting sites on Robben Island from DEA 2013 Census Data. Penguin highways and seabird breeding sites in the vicinity of the proposed sewage package plant (red) and existing discharge pipeline (white) are also shown (source: P. Barham, pers. comms; Sherley *et al*. 2011, 2014).

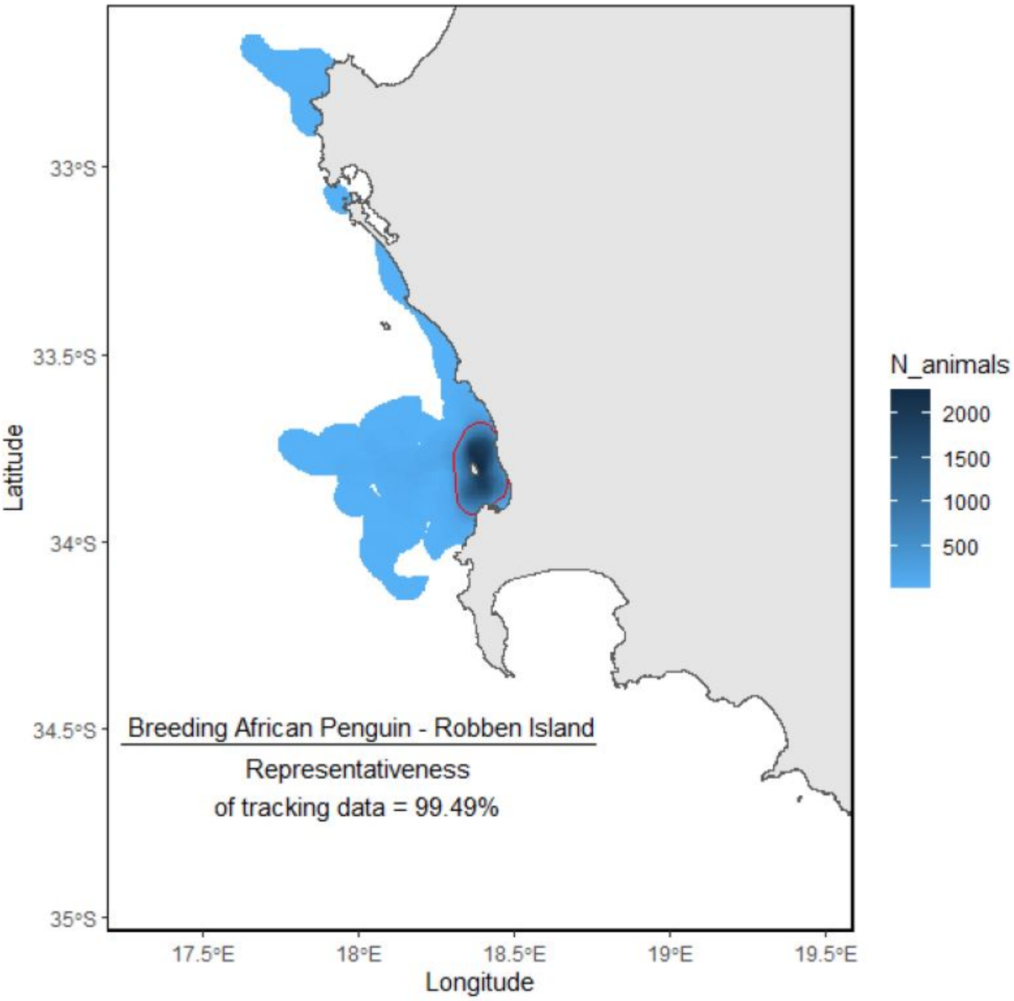

Figure 18: Important core usage area (red polygon) and general distribution (blue shaded area) of breeding African Penguins from Robben Island (Source: BirdLife South Africa 2021.

The island also holds the largest numbers of breeding Bank Cormorant *Phalacrocorax neglectus* in the Western Cape (120 pairs in 2000, but only 20 pairs today) (Crawford *et al.* 2000; P. Barham, pers. comm.), which breed on the short arm of the breakwater of Murray's Harbour (Figure 19) (Sherley *et al.* 2011). A significant populations of Cape Cormorants *Phalacrocorax capensis* (6,000 breeding pairs in 2020) also breed on the harbour wall as well as along the north-western side of the island, with small breeding clusters of Crowned Cormorant *Phalacrocorax coronatus* occurring in alien vegetation. African Black Oystercatcher *Haematopus moquini* (~250 breeding pairs in 2009) (Figure 16, right), Kelp Gull *Larus dominicanus* (>2,000 breeding pairs in 2020), Hartlaub's Gull *Larus hartlaubii* and Swift Tern *Sterna bergii*. Swift Terns and Hartlaub's Gulls have been recorded breeding on the Faure Jetty and about 600 m south of Sobukwe House, but these species tend to move to new breeding locations each year. In recent years, however, Robben Island has been host to the majority of the Western Cape's breeding population of Swift Terns, with the bulk of the pairs nesting close to the western shoreline. In 2021 a large colony developed to the south Sobukwe House. Since 2007 the colony of Hartlaub's Gulls has been located within the settlement at the southeast of the island (Sherley *et al*. 2011). Sandwich terns *Sterna sandvicensis* and Caspian Terns *Sterna caspia* have also been reported to occasionally breed on the island in small numbers.

Figure 19: Cape cormorants nesting on the Murray's Harbour breakwater.

Historically, Robben Island supported huge numbers of seabirds. The high level of human-induced disturbance and activity has, however, resulted in several species abandoning breeding there. Nonetheless, the island still remains an extremely important conservation area for seabirds. If management measures are successful in directing tourism activities away from sensitive seabird areas, it is expected that many breeding seabirds will return.

3.3.5 Marine Mammals

Thirty three species of cetaceans (dolphins and whales) are known (based on historic sightings or strandings records) or likely (based on habitat projections of known species parameters) to occur in the waters off the southwestern Cape. Apart from the resident species such as the endemic Heaviside's dolphin and dusky dolphin, the southern Benguela also hosts species that migrate between Antarctic feeding grounds and warmer breeding ground waters, as well as species with a global distribution. Table 3 lists those resident, semi-resident and migrant cetaceans likely to be sighted in Table Bay and around Robben Island (Best 1981; Findlay *et al.* 1992). A brief review of the distribution and seasonality of the key cetacean species likely to be found within the project area is provided below.

Two genetically and morphologically distinct populations of Bryde's whales live off the coast of southern Africa; and "offshore population" and an "inshore population" (Best 2001; Penry 2010). The "offshore population" lives beyond the shelf (>200 m depth) off west Africa and is unlikely to occur in Table Bay. The "inshore population" occurs on the continental shelf and Agulhas Bank ranging from ~Durban in the east to at least St Helena Bay off the west coast. This species is unique amongst baleen whales in the region by being non-migratory.

Table 3: Common whales and dolphins found in inshore waters of the Southern African West Coast and their South African (Child *et al.* 2016) and Global IUCN Red List conservation status.

Common Name	**Scientific Name**	**RSA Regional Assessment**	**IUCN Conservation Status**
RESIDENT			
Heaviside's dolphin	*Cephalorhynchus heavisidii*	Least Concern	Near Threatened
Dusky dolphin	*Lagenorhynchus obscurus*	Least Concern	Least Concern
Common dolphin	*Delphinus delphis*	Least Concern	Least Concern
Killer whale	*Orcinus orca*	Least Concern	Data Deficient
Bryde's whale	*Balaenoptera brydei*	Vulnerable	Least Concern
SEMI-RESIDENT/MIGRANT			
Humpback whale B2 population	*Megaptera novaeangliae*	Vulnerable	Not Assessed
Humpback whale	*Megaptera novaeangliae*	Least Concern	Least Concern
Southern Right whale	*Eubalaena australis*	Least Concern	Least Concern

The most abundant baleen whales in the Benguela are southern right whales and humpback whales (Figure 20). In the last decade, both species have been increasingly observed to remain in the Cape Columbine – Yzerfontein area well after the 'traditional' South African whale season (June – November) into spring and early summer (October – February) where they have been observed feeding in upwelling zones, especially off Saldanha and St Helena Bays (Barendse *et al.* 2010, 2011; Mate *et al.* 2011). It was previously thought that whales feed only rarely while migrating (Best *et al.* 1995), but these localised summer concentrations suggest that these whales may in fact have more flexible foraging habits.

The majority of humpback whales passing through the Benguela are migrating to breeding grounds off tropical west Africa, between Angola and the Gulf of Guinea (Rosenbaum *et al.* 2009; Barendse *et al.* 2010). Animals migrating north strike the coast at varying places mostly north of St Helena Bay (South Africa) resulting in increasing whale density on shelf waters as one moves northwards. On the southward migration, many humpback whales follow the Walvis Ridge offshore then head directly to high latitude feeding grounds, while others follow a more coastal route (including the majority of mother-calf pairs) possibly lingering in the feeding grounds off west South Africa in summer (Elwen *et al.* 2013, Rosenbaum *et al.* in press). Therefore, although humpbacks migrate through the Benguela, there is no evidence of a clear 'corridor' and whales appear to be spread out widely across the shelf and into deeper pelagic waters, especially during the southward migration (Barendse *et al.* 2010; Best & Allison 2010; Elwen *et al*. 2013). Abundance estimates in 2005 put the number of animals in the west African breeding population to be in excess of 9,000 individuals (IWC 2012) and it is likely to have increased by about 5% per annum since this time at (IWC 2012). Humpback whales are thus likely to be frequently encountered in Table Bay, with numbers peaking in July – February associated with the breeding migration and subsequent feeding in the Benguela.

Figure 20: The Humpback whale (left) and the Southern Right whale (right) are the most abundant large cetaceans occurring along the southern African West Coast (Photos: www.dive-photoguide.com; www.aad.gov.au).

The southern African population of southern right whales historically extended from southern Mozambique (Maputo Bay) to southern Angola (Baie dos Tigres) and is considered to be a single population within this range (Roux *et al.* 2011). The most recent abundance estimate (2008) estimated the population at ~4,600 individuals including all age and sex classes, which is at least 23% of the original population size (Brandaõ *et al.* 2011). As the population is continuing to grow at ~7% per year (Brandaõ *et al.* 2011), the population size in 2013 would number more than 6,000 individuals. When the population numbers crashed, the range contracted down to just the south coast of South Africa, but as the population recovers, it is repopulating its historic grounds including Namibia (Roux *et al.* 2001) and Mozambique (Banks *et al.* 2011). Southern right whales are seen regularly in the nearshore waters of the West Coast (<3 km from shore), extending north into southern Namibia (Roux *et al.* 2001, 2011). Right whales have been recorded off the West Coast in all months of the year, but with numbers peaking in winter (June - September).

Killer whales have a circum-global distribution being found in all oceans from the equator to the ice edge (Best 2007). They occur year round in low densities off western South Africa (Best *et al.* 2010). Killer whales are found from the coast to deep open ocean environments and may thus occasionally be encountered at low levels in Table Bay.

The common dolphin is known to occur offshore in West Coast waters (Findlay *et al.* 1992; Best 2007), but the extent to which they will be encountered is likely to be low. Group sizes of common dolphins can be large, averaging 267 (± *SD* 287) for the South Africa region (Findlay *et al.* 1992). They are more frequently seen in the warmer waters offshore; seasonality is unknown.

Dusky dolphins (Figure 21, right) are likely to be the most frequently encountered small cetacean in Table Bay as they are very "boat friendly" and often approach vessels to bowride. The species is resident year round throughout the Benguela ecosystem in waters from the coast to at least 500 m deep (Findlay *et al.* 1992). Although no information is available on the size of the population, they are regularly encountered in near shore waters between Cape Town and Lamberts Bay (Elwen *et al.* 2010a; NDP unpubl. data) with group sizes of up to 800 having been reported (Findlay *et al.* 1992). Dusky dolphins are resident year round in the Benguela.

Figure 21: The endemic Heaviside's Dolphin C*ephalorhynchus heavisidii* (left) (Photo: De Beers Marine Namibia), and Dusky dolphin *Lagenorhynchus obscurus* (right) (Photo: scottelowitzphotography.com).

Heaviside's dolphins (Figure 21, left) are relatively abundant in the Benguela ecosystem with in the region of 10,000 animals estimated to live in the 400 km of coast between Cape Town and Lamberts Bay (Elwen *et al.* 2009). Individuals show high site fidelity to small home ranges, 50 - 80 km along shore (Elwen *et al*. 2006). This species occupies waters from the coast to at least 200 m depth, (Elwen *et al.* 2006; Best 2007), and may show a diurnal onshore-offshore movement pattern (Elwen *et al*. 2010b), although this varies throughout the species range. Heaviside's dolphins are resident year round.

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 22) is the only species of seal resident along the west coast of Africa, and is common in Table Bay. Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* subantarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989). A non-breeding population has established itself in the Port of Cape Town, and the northern shores of Robben Island are occasionally used as a haul-out site. The nearest breeding colonies are at Seal Island in False Bay and at Robbensteen between Koeberg and Bok Punt just to the north of Table Bay (Wickens 1994).

Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles offshore (Shaughnessy 1979), with bulls ranging further out to sea than females. The timing of the annual breeding cycle is very regular occurring between November and January. Breeding success is highly dependent on the local abundance of food, territorial bulls and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen 1991).

Figure 22: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich).

3.4. Resources, and Commercial and Recreational Fisheries

Robben Island is located within the West Coast Rock Lobster Sanctuary which extends from Melkbos Point to “Die Josie” near Chapmans Peak and extend 12 nautical miles seawards of the high water mark. Furthermore, the marine environment around Robben Island is protected within a one nautical mile buffer zone around the island. It is legally protected as a National Heritage Site through the National Environmental Management Act (Act No 107 of 1998); National Environmental Management: Biodiversity Act (Act No 10 of 2004); and the National Environmental Management: Protected Areas Act (Act No 57 of 2003) (amongst others). Protection in terms of the latter implies that mining or prospecting will be completely prohibited from taking place within the buffer zone.

Despite the one nautical mile exclusion zone around the island, and its inclusion in the West Coast Rock Lobster Sanctuary, the waters around the island have for many years been targeted by rock lobster and abalone poachers, and consequently these populations have been severely depleted. Nonetheless an annual Total Allowable Catch (TAC) of 20 tons is currently still allocated to the commercial harvest of abalone in Zone F around Robben Island (Rob Tarr, DAFF, pers. comm.), with Zone E (Cape Point to Table Bay) and Zone G (Blouberg to St Helena) set at 12 tons and 18 tons, respectively. The total TAC for all areas for the 2012/13 season was 150 tons.

Several other fisheries operate in the adjacent waters of Table Bay and some important resources occur in Table Bay. The Bay supports a small commercial linefishery for hottentot (*Pachymetopon blochii*) (Pulfrich and Griffiths 1988) and large numbers of snoek (*Thyrsites atun*) are also sometimes caught in the bay (M. Griffiths, Linefish Section, MCM, pers. comm).

A large white mussel (*Donax serra*) population occurs at Big Bay just north of the rocky shores at Blouberg (Farquhar 1995), and on the northern end of Milnerton Beach (P. Nel, Marine Biology Research Unit, UCT, pers. comm.). The white mussel is harvested recreationally for bait and represents an important resource in the area. Along the West Coast, the mussel has a typical distribution pattern according to size, from small to large down the beach from the mid-water to the low-water mark and below. A large portion of the adult stock is usually located subtidally (De Villiers 1975, Donn 1990, Farquhar 1995). It was estimated that on a stretch of 900 m along Bloubergstrand 15.8 tons of white mussel were collected annually (Farquhar 1995).

3.5. Conservation Areas and Marine Protected Areas

Marine Protected Areas

'No-take' MPAs offering protection of the offshore biozones (sub-photic, deep-photic and shallow-photic) were until recently absent around the South African coast. This resulted in substantial portions of the shelf-edge marine biodiversity in the area being assigned a threat status of 'Critically endangered', 'Endangered' or 'Vulnerable' (Lombard *et al.* 2004; Sink *et al.* 2012). Using biodiversity data mapped for the 2004 and 2011 National Biodiversity Assessments a systematic biodiversity plan was developed for the Southwest Coast (Majiedt *et al.* 2013) with the objective of identifying both coastal and offshore priority areas for MPA expansion. The biodiversity data were used to identify numerous focus areas for protection. These focus areas were carried forward during Operation Phakisa, which identified potential offshore MPAs. A network of 20 MPAs was gazetted on 23 May 2019, thereby increasing the ocean protection within the South African Exclusive Economic Zone (EEZ) to 5%. Robben Island is located within one of these approved MPAs. The following description is drawn from https://www.marineprotectedareas.org.za/.

The 612 km^2 **Robben Island MPA** was proclaimed in 2019 to protect the surrounding kelp forests - one of the few areas that still supports viable stocks of abalone. The island harbours the 3rd largest penguin colony, with the breeding population peaking in 2004 at 8,524, but declining since. The island also holds the largest numbers of breeding Bank Cormorant in the Western Cape (120 pairs in 2000) and significant populations of Crowned Cormorant, African Black Oystercatcher (35 breeding pairs in 2000), Hartlaub's Gull and Swift Tern. The MPA consists of four distinct zones – a Restricted Zone (RIRZ) and three controlled zones - Offshore Controlled Zone (RIOCZ), a Middle Controlled Zone (RIMCZ) and an Inner Controlled Zone (RIICZ). The proposed marine outfall would fall within the RIICZ (Figure 23).

Sensitive Areas

Despite the development of the offshore MPA network a number of 'Vulnerable' and 'Endangered' ecosystem types are currently 'poorly protected' or 'not protected' at all and further effort is needed to improve protection of these threatened ecosystem types (Sink *et al.* 2019). Around Robben Island, the Cape Kelp Forest ecosystem type is considered 'vulnerable' whereas the Cape Island and Cape Bay ecosystem types have been rated as 'endangered'. Ideally, all highly threatened ('Critically Endangered' and 'Endangered') ecosystem types should be well protected. Currently, however, most of the habitats within Table Bay are moderately protected receiving between 10% -20% protection within the protected areas network but with the 'near threatened' intermediate sandy shores south of Melkbos considered poorly protected (Sink *et al.* 2019) (Figure 24).

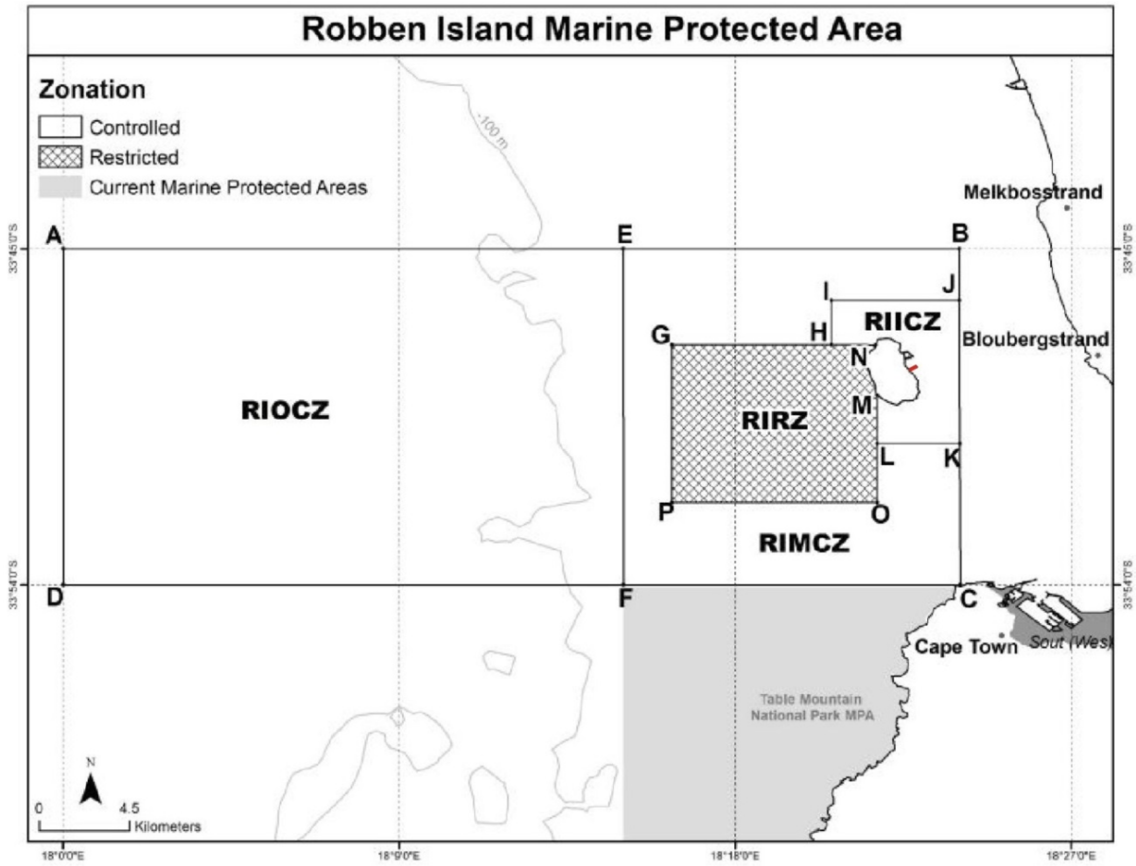

Figure 23: The Robben Island Marine Protected Area showing the zonation and the location of the proposed waste water discharge pipeline (red line) (adapted from Government Gazette 2019).

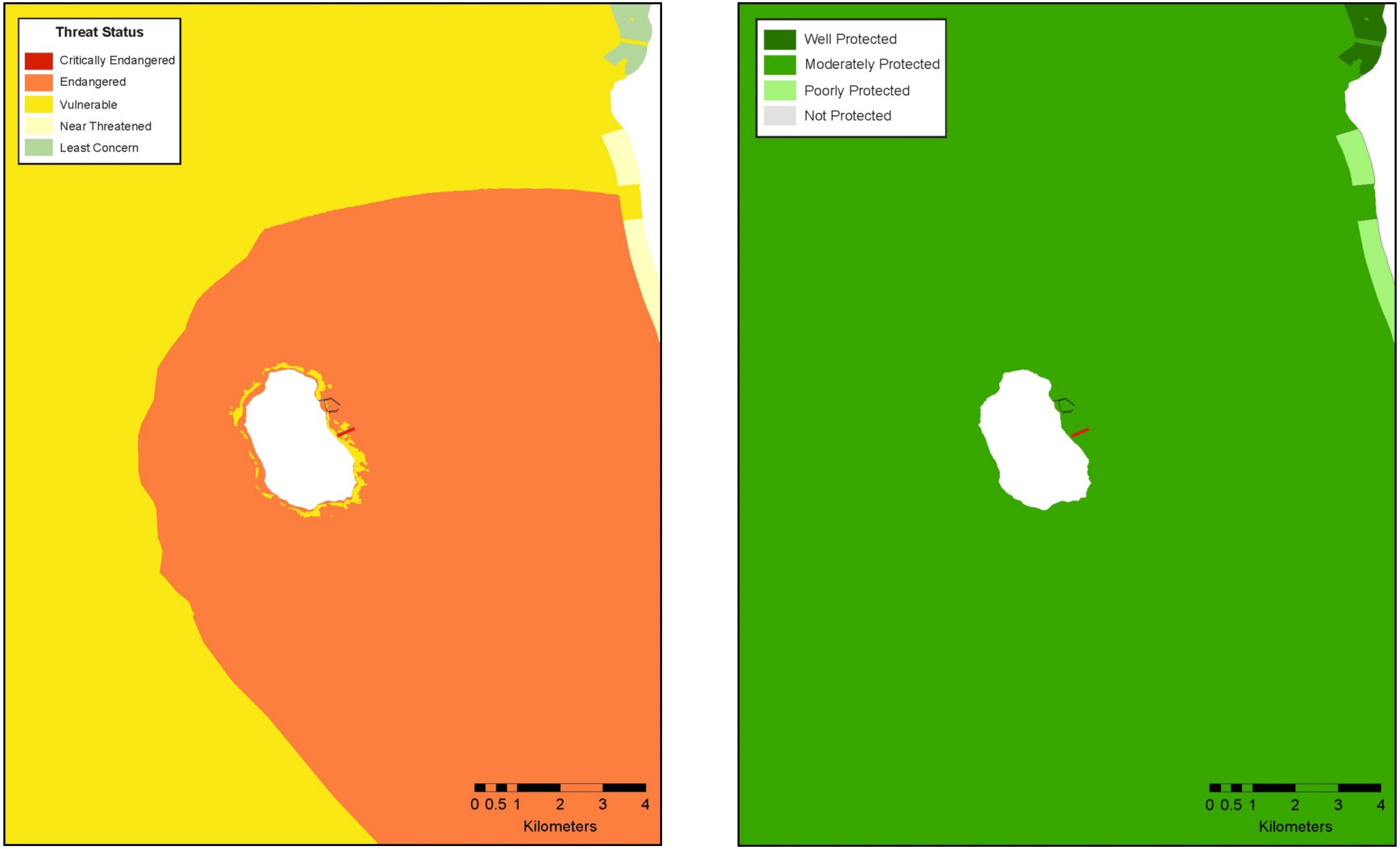

Figure 24: Threat Status (left) and Protection Levels (right) of marine ecosystem types as assessed by Sink *et al.* (2019) (see Figure 5) in relation to the proposed waste water discharge pipeline (red line).

Ecologically or Biologically Significant Areas (EBSAs)

As part of a regional Marine Spatial Management and Governance Programme (MARISMA 2014-2020) the Benguela Current Commission (BCC) and its member states have identified a number of Ecologically or Biologically Significant Areas (EBSAs) both spanning the border between Namibia and South Africa and along the South African West, South and East Coasts, with the intention of implementing improved conservation and protection measures within these sites. South Africa currently has 12 EBSAs solely within its national jurisdiction with a further three having been proposed. It also shares eight trans-boundary EBSAs with other countries (Namibia (3) and Mozambique (2)) and high seas (3). The principal objective of these EBSAs is identification of features of higher ecological value that may require enhanced conservation and management measures. They currently carry no legal status. The impact management and conservation zones within the EBSAs are currently being reviewed and additional zones may be proposed.

Robben Island falls within the Cape Canyon and Associated Islands EBSA, which includes the Benguela Muds MPA, the Cape Canyon MPA, the West Coast National Park MPA and the Robben Island MPA. The area is considered important for pelagic fish, foraging marine mammals and several threatened seabird species and serves to protect nine 'Endangered' and 12 'Vulnerable' ecosystem types, and two that are 'Near Threatened'. There are also several small coastal MPAs within the EBSA.

Biodiversity Priority Areas

The National Coastal and Marine Spatial Biodiversity Plan[1] comprises a map of Critical Biodiversity Areas (CBAs), Ecological Support Area (ESAs) and accompanying sea-use guidelines. The CBA Map presents a spatial plan for the marine environment, designed to inform planning and decision-making in support of sustainable development. The sea-use guidelines enhance the use of the CBA Map in a range of planning and decision-making processes by indicating the compatibility of various activities with the different biodiversity priority areas so that the broad management objective of each can be maintained. The intention is that the CBA Map (CBAs and ESAs) and sea-use guidelines inform the MSP Conservation Zones and management regulations, respectively.

As Robben Island falls within an MPA, with Critical Biodiversity Area 1 (CBA 1), Critical Biodiversity Area 2 (CBA 2), and Ecological Support Area (ESA) lying adjacent to the boundary of the MPA on the east and north (see Figure 25). CBA 1 indicates irreplaceable or near-irreplaceable sites that are required to meet biodiversity targets with limited, if any, option to meet targets elsewhere, whereas CBA 2 indicates optimal sites that generally can be adjusted to meet targets in other areas. ESAs represent EBSAs outside of MPAs and not already selected as CBAs.

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[1] The latest version of National Coastal and Marine Spatial Biodiversity Plan (v1.1 was released in June 2021) (Harris *et al.* 2020). The Plan is intended to be used by managers and decision-makers in those national government departments whose activities occur in the coastal and marine space, e.g., environment, fishing, transport (shipping), petroleum, mining, and others. It is relevant for the Marine Spatial Planning Working Group where many of these departments are participating in developing South Africa's emerging marine spatial plans. It is also intended for use by relevant managers and decision-makers in the coastal provinces and coastal municipalities, EIA practitioners, organisations working in the coast and ocean, civil society, and the private sector.

Activities within these management zones are classified into those that are compatible, those that are incompatible, and those that may be compatible subject to certain conditions.

These zones have been incorporated into the most recent iteration of the national Coastal and Marine CBA Map (v1.1 released June 2021) (Harris *et al.* 2020).

Figure 25: The Robben Island marine outfall in relation to Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) (Version 1.1) (Harris *et al.* 2020).

Important Bird Areas (IBAs)

There are numerous coastal Important Bird Areas (IBAs) in the general project area (Table 13) (https://maps.birdlife.org/marineIBAs).

Various marine IBAs have also been proposed in South African territorial waters, with Robben Island falling within the proposed Bird Island / Dassen Island / Heuningnes river and estuary system / Lower Berg river wetlands marine IBA.

Table 4: Coastal Important Bird Areas (IBAs) and their criteria listings (www.BirdLife.org.za).

Site Name	IBA Criteria
West Coast National Park and Saldanha Bay Islands (ZA 084)	A1, A4i, A4ii, A4iii
Dassen Island (ZA088)	A1, A4i, A4ii, A4iii
Robben Island (ZA089)	A1, A4i, A4ii, A4iii
Rietvlei Wetland: Table Bay Nature Reserve (ZA090)	A1, A4i
Boulders Beach (ZA096)	A1
False Bay Nature Reserve (ZA095)	A1, A4i, A4iii

A1. Globally threatened species
A2. Restricted-range species
A3. Biome-restricted species
A4. Congregations
  i. Applies to 'waterbird' species
  ii. This includes those seabird species not covered under i.
  iii. Modelled on criterion 5 of the Ramsar Convention for identifying wetlands of international importance. The use of this criterion is discouraged where quantitative data are good enough to permit the application of A4i and A4ii.

3.6. Unique Biodiversity Resources

The benthic communities in Table Bay and around Robben Island are typical for the West Coast, and cannot therefore be classified as locally, regionally or internationally unique biodiversity resources. This similarly applies to the pelagic fish and marine mammals occurring in Table Bay, as these are widespread throughout the South African west (and south) coast. Table Bay itself also does not appear to be critically important as either a foraging or breeding area for these fauna.

The resident seabird community on Robben Island is a strong exception to this, especially the endemic African penguin and Bank cormorant. It is estimated that approximately 36% of the global population of penguins forage in continental shelf waters adjacent to Table Bay. These birds come from the breeding sites at Dassen and Robben Islands and, to a lesser extent, Boulders Beach in False Bay. Robben Island is an important breeding site for Bank Cormorants as it represents the third largest breeding colony for this species. Both of these species have undergone severe declines in population size over the last century and are currently classified as ‘endangered’ under the IUCN criteria (Crawford *et al*. 1998). Both species are seriously at risk from oil spills, and due to their population size, endemism and conservation classification represent internationally significant biodiversity resources.

4. EXISTING ENVIRONMENTAL IMPACTS

Because of its physical isolation, Robben Island has been used as a place of punishment and segregation for over 300 years (Hart 2002). Furthermore, at least 72 shipwrecks from thirteen flag states, dating from the early 17th century to date, are reported in the water around the island (Werz 1993). The environment on and around the island is thus not pristine and the existing environmental impacts in the marine environment must be taken into consideration when assessing the potential impacts of the marine outfall. Some of these are discussed briefly below.

4.1. Faure Jetty and Murray's Bay Harbour

The area where the harbour is today was originally a sheltered bay and landing area, used by the Dutch East India Company when establishing its first structures on the island in *circa* 1654. The abandoned buildings were later used by John Murray as a base for his whaling operation. During the 19th and early 20th centuries the human habitation became concentrated primarily on the southeast end of the island, where it was serviced by a series of jetties. The Faure Jetty, which was built in 1896 survives to this day (Figure 26, left). Although, it has become too unstable for safe human use, it is used as a roosting area by a variety of birds. It also supports the brine discharge pipeline from the island's desalination plant.

Construction of the Murray's Bay harbour commenced in 1940 and involved substantial reclamation of a large portion of Murray Bay and the building of two breakwaters to create a sheltered harbour, the basis of that which exists today (Figure 26, right). The breakwaters serve as an important roosting and nesting site for Bank Cormorants and Cape Cormorants, amongst others (http://the-conservationist.blogspot.com).

Figure 26: The old Faure Jetty (Left, photo: www.culturalheritagevalues.com) and the new Murray's Harbour and breakwaters (right, photo: www.commons.wikimedia.org).

4.2. Sewage Plant and Marine Outfalls

Prior to the visitor upgrades initiated in 1998, the waste water handling system on the island consisted of a collection system, septic tanks and outfall sewers. With the exception of one which disposed directly into Murray's Bay Harbour, the outfalls were constructed to discharge into the sea at depth along the eastern coast of the island. However, as a result of storm damage, all of these 'deep water' outfalls, bar the one in the penguin area to the north of the harbour, drained into intertidal rock pools and onto the beach at low tide (Figure 27). Furthermore, excessive sludge build-up and corrosion of the septic tanks were resulting in blockages and bypassing, with uncontrolled outflows frequently occurring leading not only to human health risks but localised pollution of the marine environment (Eco-Africa 1998).

Figure 27: Some of the old sewage discharge pipelines discharging into the intertidal area on the eastern shore of Robben Island.

To address these issues and cater for higher visitor numbers, the island's waste water handling facilities were upgraded in 2001 and the current marine outfall was constructed. The marine outfall was initially designed to discharge an effluent comprising ***untreated sewerage*** (Table 1), as well as a brine effluent from a desalination plant (see below). To ensure adequate dilution the outfall was designed with a 10-m long diffuser discharging at a depth of 7.0 – 7.5 m, ~460 m offshore and ~250 m beyond the seaward edge of the kelp bed (WamTech & Roussouw 1999). Discharges were anticipated to be intermittent and in the order of 25 l/s, with peak discharges of 50 l/s. The maximum expected velocity of effluent exiting the diffuser ports was 1.09 m/s. The seaward section of the pipeline traverses mostly rocky seabed, with the last 300 m of the pipe crossing the intertidal being buried in patches of shelly sand, gravel and boulders. The diffuser is located on rocky substratum overlaid with sand. The pipeline is held in position by concrete collars and is encased in a concrete blanket over its entire length (Prochazka 2003).

At the time of its design, it was predicted that compliance of the effluent with water quality guidelines for direct contact recreation would be achieved within 1 km of the discharge location, and that suspended solids would be reduced to 5 mg/l above ambient within 200 m of the discharge (WamTech & Roussouw 1999). In 2004, however, the impacts of the marine sewer outfall were recognised as one of the threats to the Robben Island World Heritage site, which if not adequately managed or controlled could adversely impact on the integrity of the area (http://whc.unesco.org/en/soc/1432). Although improvement in the management of water-borne sewage by the Department of Public Works (DPW), were noted in 2009 (http://whc.unesco.org/en/soc/659), monitoring of the effluent indicated that values of ammonia (as nitrogen), chemical oxygen demand (COD) and suspended solids were significantly above DWAF requirements within 100 m from the outlet. Furthermore, values for various trace metals (copper and zinc) were also well in excess of General Waste Water Limits (GWWLs) as well as DWAF and international water quality guidelines. When compared with the GWWLs the effluent was significantly non-compliant particularly with regards to faecal coliform bacteria and chlorine. For chlorine in particular, values were several orders of magnitude above limits as far as 100 m from the outfall. It can therefore be expected that marine communities in the vicinity of the outfall have been impacted to at least some degree by the effluent discharged since 2001.

4.3. Desalination Plant

Fresh water on the island was initially supplied by springs, but with increased water demand at the turn of the century, boreholes were drilled to exploit groundwater resources. However, due to individual boreholes being pumped at too high a rate, seawater intrusion of the underlying aquifer system occurred. To overcome the problem of gradually deteriorating groundwater quality, a groundwater treatment plant was installed in the mid-1980s to treat the brackish water by reverse osmosis. A new seawater reverse osmosis desalination plant was installed in 1998 to replace the dysfunctional groundwater treatment plant. The feedwater intake pipe for the plant is located near Ladies' Rock on the southeast side of the island. With implementation of the sewage outfall, the intention was to discharge the brine through the waste water effluent outfall. Although available waste water quality analyses (2010 – 2012) suggest that the brine (containing significant concentrations of chlorine) was discharged with the sewage effluent at that stage, this has been discontinued. The discharges of the past are, however, expected to have had some degree of impact on marine communities in the vicinity of the discharge. The brine is currently being discharged through a pipeline routed along the old Faure Jetty, with the only co-pollutants in the brine being an organic, and readily biodegradable, scale inhibitor (M. Gildenhuys, pers. comm.). The discharge is located above the sea surface to enable mixing and dispersion.

4.4. Current Pollution Status of Table Bay

Table Bay serves as a safe anchorage for tankers and container vessels waiting to enter the Port of Cape Town. The shores of Robben Island are thus prone to the accumulation of marine litter disposed of through the emptying of ships' bilges, material discarded into the sea along the coastline of Table Bay and from fishing boats. The Island is also vulnerable to operational spills from nearby anchored or passing vessels, as well as vessels that may become wrecked within the Bay

Table Bay receives effluents and contaminants from a number of point source outfalls (Figure 1). These range from sewage and industrial pipelines, through point and diffuse stormwater outfalls, spillages and discharges from shipping associated with the Port of Cape Town, to atmospheric deposition (Henry *et al*. 1989; Bartlett *et al*. 1988; Monteiro 1997). In 1993 it was reported that ~30,000 m^3 of domestic sewage effluent was discharged daily from the Green Point outfall (Quick & Roberts 1993). Volumes are likely to have increased since then. In addition, there are minor outflows from the Salt and Diep Rivers, and from shipping. Monteiro (1997) tracked deposition of sewage derived organic matter in Table Bay sediments on the basis of organic carbon and stable isotope ratios of carbon and nitrogen. Results showed that organic carbon content in sediments were low (<0.1% in bulk sediments), with areas of highest concentrations characterised by marine rather than terrestrial (=plant plus sewage) derived carbon and nitrogen. Terrestrial derived organic matter was restricted to nearshore areas adjacent to the Salt and Diep river mouths where sediment organic carbon concentrations were particularly low due to continuous advection out of the system by wave driven currents.

The low organic enrichment concurs with the absence of any significant depositional area characterised by fine sediments (< 63 µm silts and clays) in Table Bay, the general paucity of sediment in the system (Woodborne 1983), and the apparent short residence time of surficial sediment in Table Bay (2-3 years, Monteiro 1997). There was thus little biogeochemical evidence to support the contention that Table Bay was, or is, being negatively impacted by sewage discharged from the Green Point outfall. However, there are indications that the bay is more exposed to water quality problems emanating from the Salt and Diep rivers.

Table Bay currently hosts one industrial outfall located on the eastern side of the bay, which discharges 2,625 m^3/day from the Chevron refinery (Quick & Roberts 1993). The outfall discharges trace metals into Table Bay, and occasionally also releases relatively large amounts of oil and grease (~ 9.5 tons/year). Recent upgrades to the waste water treatment plant has, however, greatly improved the quality of the outfall. A second outfall, which had discharged 1,300 m^3/day from the Kynoch fertilizer plant was discontinued in the early 2000s due to closure of the plant. Other sources of trace metals are the Salt and Diep Rivers, the Green Point sewage outfall, and the Port of Cape Town. Bartlett et al. (1985) calculated the supply of the trace metals copper, cadmium and lead to be 16,000, 1,000 and 7,000 kg/year, respectively. Despite these large inputs there was no convincing evidence of trace metal accumulation in Table Bay sediments (Monteiro 1997), and in most cases values were well below ANZECC (2000) sediment quality guideline trigger values for the protection of benthos. The biological communities would thus unlikely be negatively impacted by these contaminants. It appears that trace metal contaminants are transported out of Table Bay more or less at the same rate they are supplied. Only limited data exist on water column trace metal concentrations (Bartlett *et al*. 1985), which suggest that, on the whole, the water mass in Table Bay does not contain significantly elevated trace metal concentrations from discharged industrial effluents.

Trace metal distribution maps did, however, indicate areas of elevated concentrations, notably high copper concentrations at the Green Point outfall, peaks in cadmium associated with the Chevron and Green Point outfalls, and two areas of elevated concentrations of lead. Water column trace metal concentration data for Table Bay are limited (Bartlett *et al.* 1985), but distribution maps indicated that highest concentrations were generally distributed nearshore particularly around the Green Point – Harbour – Salt and Diep River and towards Blouberg, probably as a result of the outfalls in the area. With few exceptions (mercury at the Green Point outfall), concentrations were all below target values for the beneficial use of the maintenance of marine ecosystems (DWAF 1995).

Over the period August 1991 to October 1999, 11 spills or discharges of oils from shipping were recorded in Table Bay (MCM, unpublished data). The estimated total volume discharged into the sea was 135 tonnes with an average spill size of 12.3 tonnes and an average occurrence of 1.4 spills/year. These spill data are, however, probably an underestimate of the actual frequency of discharges of oil by shipping as the observations are limited in time and space and are solely conducted during daylight. Deliberate 'illegal' discharges of oils made at night would thus go undetected. Unfortunately more recent spill data could not be sourced. Further sources of hydrocarbons to the Bay were from storm water runoff (Mason 1988). Such minor spills and discharges are relatively small when compared with larger spills associated with sinking of vessels immediately outside of Table Bay such as the 'Apollo Sea' (June 1994, ~2,600 tonnes) and ‘MV Treasure' (June 2000, ~1,260 tonnes). Nonetheless, they contribute to chronic oiling of the coastline, and specifically African penguins.

Marine pollution can be traced by investigating pollution impacts on specific species or species groups. For example, trace metal and hydrocarbon burdens in mussels collected from sites distributed around Table Bay have been measured regularly since 1985 by DFFE as part of their 'mussel watch' programme. Due to differential uptake and elimination rates mussels can bioaccumulate inorganic (trace metals) and organic (hydrocarbons) contaminants, and body burdens represent a time-integrated estimate of environmental contaminant levels. The mussel flesh trace metal concentrations throughout Table Bay are indicative of trace metal pollution in the system when compared to non-industrialised areas in South Africa, and internationally (Widdows & Donkin 1992; Fowler 1990). Whereas levels of lead in mussel tissue have declined since 1985, zinc and cadmium levels appear to be increasing.

Another species, which is well researched and reported on in terms of oil pollution, is the African penguin (Crawford *et al*. 2000, amongst others). The effect of oiling on penguins (and seabirds in general) primarily results in the death of adults through hypothermia during foraging, decreased breeding success due to oiling of one or both parents during egg incubation and/or chick rearing, and mortalities of fledged juveniles during first excursions to the sea around breeding sites. Oiled penguins can be cleaned and rehabilitated, but their breeding success may be reduced by 30% compared to unoiled birds (Avian Demography Unit, University of Cape Town, unpublished data).

5. SOURCES OF RISK TO THE MARINE ENVIRONMENT FROM SEWAGE DISCHARGES

The waste water handling facilities on Robben Island were upgraded in 2001. The outfall design included a diffuser to ensure adequate dilution of the effluent. Not long afterwards, however, the marine sewer outfall and its associated marine impacts was recognised as a major threat to the integrity of the Robben Island World Heritage site. The current proposed upgrade to the waste water treatment plant will alleviate many of the issues previously surrounding the disposal of untreated sewage to the marine environment. However, for the sake of completeness the impacts associated with the discharge of raw sewage are discussed briefly below.

Disposal of primary treated (screening, de-gritting, removal of floatables and primary sedimentation) sewage into the marine environment through deepwater outfalls is a relatively common practice, particularly for larger coastal cities (Port Said: UNEP 1991; Hong Kong: Smith-Evans & Dawes 1996; Durban: Bailey 2000; Boston: Signell *et al*. 2000; Cubatão: Braga *et al.* 2000; Athens: Siokou-Frangou *et al*. 2009; amongst others). The discharge of domestic waste water and consequent deterioration of water quality is one of the most significant threats to coastal environments worldwide (GPA 2001), with adverse effects on public health, socio-economics, food quality and security, aesthetics and marine ecology being well documented (Luker & Brown 1999; Danulat *et al*. 2002; WHO 2003).

The potential deleterious effects of pollutants in sewage effluents on the receiving water quality are diverse, and depend on the discharge volume, the nature of the discharge and its chemical composition. Untreated sewage typically comprises water, nutrients (nitrogen and phosphorus), suspended solids (including organic matter), and pathogens (e.g. bacteria, viruses and protozoa). Other constituents that may be present include intestinal worms and parasites, oils and greases. Discharges from mainland WWTW would also include runoff from streets, parking lots and roofs, heavy metals (including mercury, cadmium, lead, chromium, copper), and toxic chemicals (e.g. PCBs, PAHs, pesticides, phenols and chlorinated organics), but due to the limited infrastructure on the island these are unlikely in discharges from the island.

Effects of sewage pollution on marine biota occur at the cellular, individual, population and community levels of organisation, with the majority of studies documenting effects at the community level (Underwood & Peterson 1988). Pearson and Rosenberg (1978) developed a conceptual framework on how benthic communities respond to organic enrichment. Different assemblages of benthic macroinvertebrates develop along an organic enrichment gradient, according to distance, or time, from the source of organic input or enrichment. Sediments close to the source are virtually devoid of macrofauna. Moving further away from the discharge point, the establishment of numerous small opportunistic, pollution-tolerant species results in an increase in abundance and biomass. Beyond the highly enriched areas, abundance of opportunistic species decreases in favour of a higher diversity of species, which form a second biomass peak. In areas unaffected by the discharge, species numbers and biomass decline to normal levels for unpolluted waters. Spatially, impacts may be restricted to the immediate vicinity around the outfall (May 1985; Fairweather 1990; Underwood *et al*. 1990, 1992; Koop & Hutchings 1996), but in other cases may extend for several kilometres (Gray 1996; Raimondi & Reed 1996; Costanzo *et al*. 2001; Savage *et al*. 2002). Impacts may, however, also have temporal components, which may be short-lived ‘pulses’, or prolonged events.

5.1. Nutrients

The abnormally high inputs of dissolved inorganic nutrients (e.g. phosphorus and nitrogen) typical of sewage effluents, usually lead to eutrophication. The excessive algal growth can take the form of phytoplankton blooms, which can limit the sunlight available to other primary producers (Pastorok & Bilyard 1985; Mitchell 1998; see also Warwick 1993 for review). However, since silica does not increase simultaneously, the ratio of nutrients is altered, thereby influencing phytoplankton species composition and succession (Meyer-Reil & Köster 2000). Species of algae that do not require silica dominate, and diatoms requiring silica are discriminated against. Such alterations in the ratio of macronutrients are thought to be responsible for the occurrence of toxic algal blooms in nutrient enriched environments (Meyer-Reil & Köster 2000). Certain dinoflagellate and diatom species can be either directly toxic to fish, or can accumulate in filter-feeders, which if eaten, can cause gastrointestinal disorders or paralytic shellfish poisoning in man (O’Sullivan 1971). When the blooms decay the increased oxygen demand can result in the development of anoxic conditions, with potentially devastating effects on other marine life (Matthiessen & Law 2002).

Similarly, the increased nutrients can cause a decline in cover of large foliose macro-algae and an increase in cover of ephemeral green and blue-green algae (Littler & Murray 1975, 1978; Kindig & Littler 1985; May 1985; Fairweather 1988; Lopez-Gappa *et al.* 1990; Soltan *et al*. 2001), which in turn can result in a reduction in algal biodiversity due to dominance by certain species (Borowitzka 1972; Pastorok & Bilyard 1985; Smith 1996; Bishop *et al*. 2002; Terlizzi *et al*. 2002). Increased cover of ephemeral algae in turn can lead to increased abundances of invertebrate grazers (Bishop *et al*. 2002). Roberts (1996) and Roberts *et al.* (1998) reported significant reductions in foliose and crustose algae and sponges around a sewage outfall, where despite no significant decline in overall cover of total fauna, the community changed from one where algae and sponges dominated to one dominated by silt and ascidians. Similar sewage-induced shifts have been described for kelp holdfast communities, which changed from a community dominated by omnivorous biota, to one dominated by bivalve and ascidian suspension feeders (Smith 1996; Smith & Simpson 1992, 1993; Roach *et al*. 1995; but see also Littler & Murray 1978; Fairweather 1990; Chapman *et al.* 1995). In contrast, Fairweather (1988) and Lopez-Gappa *et al*. (1990) reported a decline in the abundances of ascidians and mussels, respectively, in polluted intertidal areas. Changes in the variability of impacted communities, however, appear to depend on the spatial scale investigated (Fairweather 1990; Chapman *et al*. 1995).

In some case, however, high availability of dissolved organic carbon and nutrients close to the sewage outfalls favour bacterial production rather than primary production as well as the abundance of ciliates preying upon bacteria (Saridou *et al*. 2009; Zeri *et al*. 2009). Particularly in the Eastern Mediterranean, areas affected by the effluents tend to be dominated by microbial food webs.

Point-source sewage outfalls can result in the development of a dynamic and diverse fish community in the vicinity of the discharge (Bailey 2000; Guidetti *et al*. 2002, 2003). Whereas in some cases increases in diversity and abundance were reported (Russo 1982; Grigg 1994; Hall *et al*. 1997; Guidetti *et al*. 2002), in others a significant decline in species richness occurred (Smith *et al*. 1999). These apparently contradictory results can be explained by differences in effluent volumes, the type of pre-treatment of the product, the nature of pollutants discharged, and concentrations of dissolved and particulate organic matter in the effluent. In the Mediterranean, sewage effluent was found to affect the total abundance and density of several ecological categories of shallow-water reef fishes, as well as altering the aggregation patterns and spatio-temporal structures of the fish assemblages (Guidetti *et al*. 2002). Sewage can also affect the mortality, fecundity and size of fish, lead to toxic effects and alter behavioural responses (Gray 1989; Adams *et al*. 1993; EPA 1993a).

Sewage plumes from point-source outfalls can also cause significant degradation of larval habitat. The early life stages of fishes are particularly vulnerable to nutrient enrichment and pollutants, with potential effects ranging from changes in the species composition and abundance of larval fish, susceptibility to infections and deformities, to mortality (Arfi et al. 1981; Gray 1996; Gray *et al.* 1996; Kingsford & Gray 1996). As larvae can be swept into sewage plumes by longshore currents from great distances, a significant proportion of offspring from local populations may be affected. Any pollution-related impacts on survivorship of larvae could in turn affect subsequent year-class strength, particularly if the species is of commercial or recreational importance (Gray *et al*. 1996; Kingsford *et al*. 1996).

5.2. Organic Matter

The disposal of raw sewage typically also results in objectionable floating matter, an increase in suspended solids and a concomitant increase in turbidity. Increased turbidity in turn can negatively effect primary productivity. Furthermore, the decomposition of high organic loads require a high oxygen demand thereby influencing the dissolved oxygen concentration in near-bottom waters and in the sediments themselves (Matthiessen & Law 2002).

Sublittoral soft-bottom habitats are especially vulnerable to sewage input, principally in relation to three main sedimentological factors: organic matter, silt content, and degree of oxygenation (Cardell *et al*. 1999). As their associated communities respond well to anthropogenic disturbances, most of the studies undertaken to date on sewage effects on marine environments concern soft-bottom benthic assemblages (e.g. Pearson & Rosenberg 1978; Diener *et al*. 1995; Estacio *et al*. 1997; Cardell *et al*. 1999). Organic enrichment of unconsolidated habitats by sewage discharges may result in changes in the abundance, biomass and diversity of benthic macrofauna (Pearson & Rosenberg 1978), bioaccumulation of organic and inorganic compounds (Phillips 1977, 1978) and alteration of trophic interactions among species, with potential cascade effects on higher order consumers (Otway 1995; Otway *et al*. 1996 and references therein). In cases of extreme pollution (and hypoxic or anoxic conditions), low diversity pollutant tolerant communities will replace more sensitive communities (Cardell et al. 1999; Savage et al. 2002; Siokou-Frangou *et al*. 2009; Trevor et al. 2010). These communities are often dominated by surface and sub-surface deposit feeders (Cardell *et al*. 1999).

5.3. Pathogens

Pathogenic bacteria can survive in the sea from a few days to several weeks; viruses can survive in water, fish or shellfish for several months while the hepatitis virus can remain viable in the sea for over a year (GESAMP 2001). The discharge of sewage polluted by human and animal pathogens is of particular concern in coastal area used for the cultivation of bivalves, as pathogens in the seawater can be taken up by the filter-feeders, concentrate in their tissues and thus present a potential health hazard. Where sewage is discharged near bathing beaches, the contaminated waste water can be responsible for swimming-related illnesses (Cabelli 1979).

5.4. Heavy Metals

Heavy metals associated with waste water outfalls (particularly Cd, Pb, Zn, Cr, Hg) tend to enrich in suspended material and finally in seabed sediments. Areas of restricted water exchange and unconsolidated habitats impacted by the discharge could thus be affected by heavy metal accumulation (Mitchell 1998; Nergis *et al*. 2012). Many benthic invertebrates feed on this suspended or deposited material, with the risk that metals are enriched in their bodies and passed on to higher trophic levels. Such bioassimilation and bioaccumulation of metals in aquatic organisms can have potential long-term negative implications for human and ecosystem health. Furthermore, the movement of these persistent organic pollutants within environmental compartments, and the potential for long-range transport can result in serious threats not only at the point of release, but also to organisms distant to the pollution source (Nergis *et al*. 2012).

5.5. Xenobiotic Substances

Xenobiotic substances are foreign chemicals (e.g. dioxins, organochlorides and polychlorinated biphenyls) or natural compounds (e.g. human hormones) found within organisms that are not normally naturally produced by or expected to be present within those organisms.

Treated domestic sewage discharges have been identified as a major cause of oestrogenic effects in both freshwater and marine environments (Routledge *et al*. 1998; Allen *et al*. 1999, and references therein; Atkinson *et al*. 2003). Many of the effects can be attributed to natural and synthetic oestrogenic hormones derived from glucuronide-conjugated material excreted by women and livestock. De-conjugation is thought to occur in sewage treatment works, leading to the reappearance of fully potent hormones in the environment. Generally these dilute rapidly around the discharge (Allen *et al*. 1999; Atkinson *et al*. 2003), although in some cases (e.g. alkylphenol ethoxylate surfactants and their degradation products) the substances become adsorbed to and persist in bottom sediments, thereby acting as a slow release source of oestrogenic activity and causing feminisation (vitellogenesis) in affected organisms.

As oestrogens are pervasive in the environment and resistant to bacterial degradation (Katzenellenbogen 1995), oestrogens discharged to coastal marine systems in sewage effluents could have potential physiologic or ecologic effects on marine organisms. Oestrogen-mimicking compounds in the coastal marine environment are increasingly considered environmental pollutants that disrupt basic physiologic functions in organisms. Effects (often from the picomolar range of concentrations) include blocked embryonic development (Hathaway & Black 1969; Shoemakers *et al.* 1981), altered enzymatic activities (Ghosh & Ray 1993a, 1993b), cellular damage or apoptosis (Wiens *et al*. 1999; Viarengo *et al*. 2000), reduced testicular size or spermatogenesis and production of vitellogenin in males (Richmond 1993; Harries *et al*. 1997; Robinson *et al*. 2003), skewed sex determination, poor development, and overall reduction in reproduction and recruitment (Sumpter & Jobling 1995; MacLatchy *et al.* 1997; Peters *et al*. 1997; Shurin & Dodson 1997).

Vitellogenesis in male and immature female fish is thought to cause significant metabolic stress due to the drain on energy reserves, and can also lead to kidney and liver damage and necrosis (Herman & Kincaid 1988, cited in Allen *et al*. 1999). In reality, organisms are exposed to a complex mixture of natural and synthetic compounds, which could have additive or interactive effects. Considering that many invertebrates are at the base of aquatic food chains, human-derived oestrogens in marine ecosystems could greatly affect ecosystem functioning.

5.6. Biocides (chlorine)

Chlorination is the most common form of sterilisation for secondary and tertiary treated waste waters. Chlorine is either applied in gaseous form or as hypochlorite salts, but as free and combined chloride residues are highly toxic to aquatic life, the effluent must be neutralised before it is discharged to remove all or part of the total combined chloride residues.

The chemistry associated with seawater chlorination when using chlorine-based products is complex. The reader is referred to ANZECC (2000), Lattemann & Höpner (2003) and UNEP (2008) for more details. Chlorine does not persist for extended periods in water but is very reactive. However, the chlorinated compounds, which constitute the combined chlorine, are far more persistent than the free chlorine. A major disadvantage of chlorination is the formation of organohalogen compounds. However, as only a few percent of the total added chlorine is recovered as halogenated by-products, and as by-product diversity is high, the environmental concentration of each substance can be expected to be relatively low. Dechlorination will further considerably reduce the potential for by-product formation. Nonetheless, there is some evidence that chlorinated-dechlorinated seawater increased mortality of test species and chronic effects of dechlorinated seawater were observed, which were assumed to be due to the presence of halogenated organics formed during chlorination (see UNEP 2008 for references).

Marine organisms are extremely sensitive to residual chlorine, making it a prime choice as a biocide to prevent the fouling of marine water intakes. Many of the chlorinated and halogenated by-products that are formed during chlorination are also carcinogenic or otherwise harmful to aquatic life (Lattemann & Höpner 2003). Values listed in the South African Marine Water Quality Guideline (DWAF 1995) show that 1,500 µg/ℓ is lethal to some phytoplankton species, 820 µg/ℓ induced 50% mortality for a copepod and 50% mortality rates are observed for some fish and crustacean species at values exceeding 100 µg/ℓ (see also ANZECC 2000). The lowest values at which lethal effects are reported are 10 – 180 µg/ℓ for the larvae of a rotifer, followed by 23 µg/ℓ for oyster larvae (*Crassostrea virginica*). Sublethal effects include valve closure of mussels at values <300 µg/ℓ and inhibition of fertilisation of some urchins, echiuroids, and annelids at 50 µg/ℓ. Eppley *et al.* (1976) showed irreversible reductions in phytoplankton production, but no change in either plankton biomass or species structure at chlorine concentrations greater than 10 µg/ℓ. Bolsch & Hallegraeff (1993) showed that chlorine at 50 µg/ℓ decreased germination rates in the dinoflaggelate *Gymnodinium catenatum* by 50% whereas there was no discernable effect at 10 µg/ℓ. This indicated that particularly the larval stages of some species may be vulnerable to chlorine pollution. The minimum impact concentrations reported in the South African Water Quality Guidelines are in the range 2 to 20 µg/ℓ at which fertilisation success in echinoderm (e.g. sea urchin) eggs is reduced by approximately 50% after 5 minute exposures.

5.7. Depressed Salinities

By far the greatest proportion by volume of a sewage discharge comprises fresh or brackish water, which, depending on the volume discharged, may result in a short-term decrease in salinity in the immediate vicinity of the outfall. The physical factors (salinity, light and nutrients) associated with inflow of freshwater into the marine environment affect primary productivity. Primary production and phytoplankton biomass are generally elevated near riverine plumes relative to the open-ocean waters (Dustan & Pinckney 1989; Grimes & Finucane 1991; Grimes & Kingsford 1996), with production typically increasing with the size of the plume (Grimes & Kingsford 1996). In the case of a sewage effluent containing elevated nutrient levels, increased productivity can be expected. Salinity gradients are also reported to influence the structure of phytoplankton assemblages, with salinity levels determining which taxa dominate the community. Similarly, freshwater inflows can affect zooplankton assemblage both spatially, in terms of both horizontal and vertical distributions (Kaartvedt & Nordby 1992), and temporally (Nyan Taw & Ritz 1978).

Macroalgae are typically tolerant of a wide range of salinities, but information on the effects of alterations in freshwater inflow on macroalgae, particularly habitat-forming species, is limited. Species from estuarine environments that experience frequent fluctuations in freshwater inputs are likely to be more tolerant than those from the more stable intertidal or subtidal marine environments, making predictions of the effects of freshwater input on growth and survival of macroalgae complex (Gillanders & Kingsford 2002). The effect of reduced salinities on subtidal macroalgal species will depend on the volume of inflow and the depth of the low salinity wedge (Kennelly & Underwood 1992).

Freshwater input is known to greatly influence recruitment, growth, movement, mortality and fecundity of marine invertebrates (Thomas & White 1969; Staples & Vance 1985; Roller & Stickle 1993; Jury *et al*. 1994; Rippengale & Kelly 1995; Richmond & Woodin 1996; Irlandi *et al*. 1997; Metaxas 1998; Witman & Grange 1998). Heavy mortalities of benthic invertebrates following strong pulses of freshwater inflow have been reported for starfish, molluscs, lobsters, and polychaetes (Thomas & White 1969) and sea urchins (Andrew 1991; see also Irlandi *et al*. 1997), with mortalities typically attributed to limited osmoregulatory capabilities of stenohaline organisms (Roller & Stickle 1993, Jury *et al*. 1994; see also Branch *et al.* 1990). Lobsters, however, are reportedly able to sense and avoid areas of reduced salinity by moving away from the impacted area (Roller & Stickle 1993, Jury *et al*. 1994). The benthic and pelagic stages of jellyfishes are also vulnerable to changes in salinity, with growth, asexual reproduction, strobilation and mortality rates of polypoid forms, and biomass and mortality rates of medusae being affected by reduced salinities associated with river inflow (Lu *et al*. 1989; Purcell *et al*. 1999; Kingsford *et al*. 2000).

Variations in salinity also influence developmental patterns and mortality rates of many marine invertebrate larvae (reviewed by Roller & Stickle 1993 and Richmond & Woodin 1996), with reduced salinities negatively affecting growth rates. Similarly, decreasing salinity caused declines in abundance and diversity of meiofaunal assemblages, and changes in community structure of macrofauna living in the top 2-3 cm of sediment (Coull 1988; Gillanders & Kingsford 2002).

5.8. Potential for Recovery

Numerous studies have investigated the change in communities following either a cessation of inshore waste water discharges (Smith *et al.* 1981; Underwood & Chapman 1996; Wilson *et al.* 1998) or the upgrade of treatment plants following the introduction of primary, secondary and tertiary treatment process (Swartz *et al*. 1986; Savage *et al*. 2002). Responses vary widely. Typically the recovery processes in the intertidal involve the recolonization of sites where macroalgae had disappeared (Hardy *et al*. 1993), a significant increase in diversity (Bokn *et al*. 1996), an increase in algal cover and a greater complexity in community stratification (Gorostiaga & Diez 1996). In some cases the trends described by Pearson & Rosenberg (1978) for communities in unconsolidated sediments reversed; pollutant tolerant species declined or disappeared resulting in a decline in abundance and biomass. The pollutant-tolerant species were replaced by the more sensitive species, which with time moved closer to outfall (Swartz *et al*. 1986). Archambault *et al.* (2001) reported a clear increase in the number of species and a decline in the cover of ephemeral green algae in the lower intertidal around a decommissioned outfall, two years following cessation of effluent discharges (see also Smith *et al*. 1981). In contrast, Soulsby *et al*. (1985) found that ephemeral algae did not decrease in abundance following the closure of a sewage discharge, but attributed this to the ambient nutrient regimen of their study area. Similarly, Underwood & Chapman (1996) could not detect significant changes in community structure of subtidal reef communities above natural heterogeneity following cessation of inshore effluent discharges, concluding that communities were possibly not stressed due to continual removal and dilution of the effluents by wave action, currents and tides.

In cases where impacts of sewage discharge had been observed over larger spatial scales, recovery of communities following introduction of further treatment of sewage prior to discharge were still measureable up to 8 years later (Soltan *et al*. 2001; Savage *et al*. (2002).

5.9. Disturbance of Nesting Seabirds

The onshore activities required for the construction and installation of the proposed sewage package plant would result in some disturbance through excavations, air, noise and vibration pollution, generation of dust, and human activity. The construction time has been minimised through the installation of a modular (pre-assembled) unit. Disturbance resulting from the construction activities would be limited to a period of six months. Regardless of the localised nature and the relatively short duration of the construction activities, there is still a possibility that the proposed development may lead to disturbance of birdlife within 200 – 300 m of the construction site.

The construction area is separated from the high-shore area typically used by seabirds and shorebirds by dense bushes. Of the ~1,000 breeding pairs of penguins currently on the island, ~100 nest in the census areas falling within a 250 m radius of the proposed package plant site. Although this recent census data (DFFE, unpublished data) has revealed that the area is not among the most densely populated in terms of the African Penguin breeding populations, there is potential that the penguins or other sea-birds nesting within the area may be disturbed or displaced during construction. Despite there being no known nests in the construction development footprint, which has now been set further away from the high-shore, close monitoring and mitigation during establishment of the construction site are necessary to ensure that no nests are eliminated or damaged in the vicinity of the construction area.

The location of the two 'penguin highways' do not coincide directly with the development footprint of the construction area, but do pass close to the eastern boundary fence of the proposed plant site and to the north of Robert Sobukwe House (see Figure 17), and construction activities may therefore disturb commuting birds. These highways are primarily utilised by the penguins from about 90 minutes after sunrise when they head out to sea, and again 90 minutes before sunset when they return to their nests to feed the chicks. If disturbed during their return journey, they may not go to their nests, thereby depriving their chicks of food. Construction activities during the penguins’ morning and evening commute should therefore be avoided. Penguins may also accidentally become trapped within the construction site, resulting in injury or even death of the bird(s). The construction site should therefore be completely enclosed by appropriate fencing so that penguins cannot access the area.

Although no other seabirds are breeding within the possible zone of impact (200 – 300 m), species such as Swift Terns and Hartlaub’s Gulls are nomadic breeders establishing colonies in different locations each year. In 2021 a colony of Swift Terns established south of the Sobukwe House and within the possible zone of construction impacts. To prevent disturbance during their breeding season, the birds should be deterred from establishing their nests within the potential zone of impact around the construction site at the beginning of breeding season (late December/early January) (pers. comm. Prof. Peter Barnham) until they set up nests elsewhere on the island. This would require a Threatened or Protected Species (TOPS) permit from the Oceans and Coasts Branch of the Department of Forestry, Fisheries and the Environment (DFFE). Disturbance of adult birds or nesting areas during the breeding season could negatively affect reproductive success. Every effort should thus be made to ensure that species considered ‘endangered’ (African Penguin, Cape Cormorant, Bank Cormorant) or ‘near threatened’ (Crowned Cormorant) are not disturbed during nesting as this may have significant consequences to the population size.

5.10. The Robben Island Outfall in Perspective

The current marine outfall on Robben Island was designed to discharge an effluent comprising macerated sewerage, as well as a brine effluent from a desalination plant. Roberts (2002) predicted that 50 x dilution would be achieved within 50 m of the outfall under worse-case scenario calm conditions. Compliance of the effluent with water quality guidelines for direct contact recreation was predicted to be achieved within 1 km of the discharge location, with suspended solids reduce to 5 mg/l above ambient within 200 m of the discharge. At the time of its construction, an environmental monitoring programme was put in place to assess the impacts of the sewage discharge on the nearshore marine environment to the east of Robben Island. A baseline survey was conducted in January 2001 prior to the commencement of the discharge, with a further three monitoring surveys being conducted in May 2002, October 2002 and February 2003. Analyses undertaken included sediment particle size, heavy metal concentrations in sediments, meiofauna and epibenthic macrofauna (Prochazka 2001, 2003). The results indicated that 10 months after the start of sewage disposal:

- the proportion of sand in the sediments around the diffuser (<30 m radius) increased significantly;
- there was no marked increase in the organic content of the sediment around the diffuser;
- heavy metal concentrations in the sediments were below the maximum allowable effects range low (ERL) levels stipulated by the South African Sediment Quality Guidelines (see also Toefy 2010); and
- there was an increase in the abundance of filter-feeders, grazers and detritivors around the diffuser, but a decline of predators and scavengers.

The approach used in most defensible EMP studies undertaken to detect environmental impacts of ocean outfalls is based on comparisons using the before-after/control-impact (BACI) designs as recommended by Green (1979) and Underwood (1992, 1993, 1994). Although a before-after sampling approach was implemented for the Robben Island monitoring, unfortunately sampling was not concurrently conducted at suitable control sites, making it impossible to determine whether observed changes in community composition around the pipeline were in response to the sewage discharge or the result of natural variability. It was concluded that there was no substantial change in assemblage composition as a result of the discharge of sewage into the area. This conclusion should be treated with caution, however, firstly because of the inadequate sampling design and secondly because monitoring did not extend beyond 10 months following the start of discharges. The importance of long-term studies of sewage impacts was emphasised by Pastorok & Bilyard (1985). Although primary producers are known to respond rapidly to sewage enrichment, community level impacts over and above natural temporal variability are usually only detectable over a period of several years. In particular, accumulation of heavy metals in sediments and subsequent bioassimilation in organisms is usually only detectable in the medium- to long-term (Philip & Prichard 1996).

Although the impacts of the sewer outfall were recognised as a threat to the integrity of the Robben Island World Heritage site in 2004, the magnitude and extent of the impacts on marine biota over the past decade have not been quantified. As the effluent appears to have regularly exceeded the South African Marine Water Quality Guidelines as far as 100 m from the outfall for at least ten years, it is safe to assume that marine communities in the vicinity of the outfall have to some degree been affected by the sewage discharges.

It is anticipated that the diversity of subtidal communities has declined throughout the last decade and become dominated by pollution-tolerant suspension-feeding species. Judging by the high BOD of the effluent, the development of anoxic conditions in the sediments may also be expected, particularly during calm periods when wave conditions are insufficient to ensure adequate flushing rates and turn-over of the water column. This effect may, however, be naturally mitigated by the coarse nature of the sediments around the diffuser (Toefy 2010). The effects of the sewage may also have become apparent in rocky intertidal and sandy habitats inshore of the outfall (i.e. in the area between the outfall and the southern breakwater of Murray's Harbour), particularly during the summer months when wind-generated surface currents could transport suspended solids and floating organic matter onto the island. During a site visit in January 2014, it was noted that intertidal areas in the vicinity of the outfall were characterised by a proliferation of ephemeral green algae (primarily *Ulva* spp.) thus suggesting eutrophication of intertidal communities.

As part of the upgrade of the waste water handling system, the effluent will be treated to General Limit Values (GN 665 of 2013) before being discharged to sea. The quality of effluent will thus be significantly improved relative to the current discharge. The modelling study undertaken by WSP Water and Marine to assess the performance of the diffuser given the improved effluent (van Ballegooyen 2021) identified that a predicted minimum achievable dilution of 65 would be required within 10 m of the discharge location to achieve compliance with water quality guidelines. Results indicated that there will be compliance with the existing water quality guidelines for all effluents constituents other than Phosphate, which is predicted to comply within between 30 m and 100 m of the outfall diffuser, depending on the assumed phosphate concentration in the wastewater effluent. Non-compliances (Phosphate) or marginal compliances (free chlorine, suspended sediments and Nitrate/Nitrite) were predicted to occur primarily during stagnant conditions in the receiving water column, which is unlikely to be a common occurrence for the marine outfall location. In the case of Phosphate, non-compliance is considered non-substantive as it is generally not a limiting nutrient in the marine environment. Furthermore, the discharge of effluents would be intermittent, giving the effluent time to disperse during the "no-flow" periods. The modelling study further predicted that subsequent dispersion and diffusion would achieve dilutions exceeding 2,500 within 100 m of the outfall, even under stagnant conditions (Table 5).

As the impact footprint for discharges from the proposed WWTW would be considerably smaller and the effluent quality considerably improved over that of the current raw sewage discharge, a recovery of marine communities over the medium- to long-term can be expected.

Table 5: Predicted near and far-field dilutions for a representative range of environmental conditions (Source: van Ballegooyen 2021).

Model Type	**Near-field**	**Far-field**						
Distance from Diffuser	**<10 m**	**20 m**	**30 m**	**50 m**	**100 m**	**200 m**	**300 m**	**400 m**
Stagnant conditions	66	335	530	1,000	2,575	6,900	12,450	19,000
Average conditions	79	95	115	155	280	600	990	1,440
20% exceedance	250	270	30	370	595	1,140	1,800	2,540
5% exceedance	756	770	810	925	1,310	2,245	3,245	4,580

6. ASSESSMENT OF IMPACTS

6.1. Assessment Procedure

The potential environmental impacts were evaluated according to their severity, duration, extent and significance of the impact. Cumulative impacts were also taken into consideration. WSP's Risk Assessment Methodology was used for the ranking of the impacts.

This system derives environmental significance on the basis of the consequence of the impact on the environment and the likelihood of the impact occurring. Consequence is calculated as the average of the sum of the ratings of severity, duration and extent of the environmental impact. Likelihood considers the frequency of the activity together with the probability of an environmental impact occurring. Tables 3 - 10) describe the process in detail:

Consequence

Consequence is calculated as the average of the ratings for severity, duration and extent of the environmental impact.

Table 6: Assessment and Rating of Magnitude

Rating	Description
1	Very Low
2	Low
3	Medium
4	High
5	Very High

Table 7: Assessment and Rating of Extent

Rating	Description
1	Site: Within immediate area of activity
2	Local: within activity area
3	Regional: Outside activity area
4	National
5	International: across borders or boundaries

Table 8: Assessment and Rating of Reversibility

Rating	Description
1	Reversible: recovery without rehabilitation
2	
3	Recoverable: recovery with rehabilitation
4	
5	Irreversible: recovery not possible despite rehabilitation

Table 9: Assessment and Rating of Duration

Rating	Description
1	Immediate: On impact
2	Short-term: 0-5 years
3	Medium-term: 5-15 years
4	Long-term: project life
5	Permanent: Beyond life of project

Table 10: Assessment and Rating of Probability

Rating	Description
1	Improbable
2	Low: Low probability
3	Medium: Probable
4	High: Highly Probable
5	Definite

Environmental significance

Environmental significance is calculated by:
Environmental Significance = (Magnitude + Extent + Reversibility + Duration) X Probability

Table 11: Determination of Environmental Significance and key to colour coding

Environmental Significance (Impact) = C × L

Very Low (-ve) (4 - 15)	Very Low (+ve) (4 - 15)
Low (-ve) (16 – 30)	Low (+ve) (16 - 30)
Moderate (-ve) (31 - 60)	Moderate (+ve) (31 - 60)
High (-ve) (61 – 80)	High (+ve) (61 - 80)
Very High (-ve) (81 – 100)	Very High (+ve) (81 - 100)

6.2. Identification of Impacts

In their study of sewage outfalls discharging into shallow water in Sydney, Australia, Underwood *et al*. (1990, 1992) concluded that the discharge of secondarily treated sewage has only a marginal, if any, effect on shallow subtidal assemblages and no documented effect on intertidal assemblages. Nonetheless, the potential impacts to the marine environment as a result of the proposed discharge of treated sewage at Robben Island may include:

- modification of **primary productivity** due to changes in nutrient levels in the water column;
- changes in **diversity and benthic floral and faunal community structure** due to changes in nutrient levels;

- modification of **community structure of soft-sediment macrofauna** as a result of changes in organic content and/or oxygen levels in the sediments;
- alterations in **diversity, abundance and community structure of fish assemblages** around the outfall due to inputs of organic matter;
- potential **health hazard to humans** of pathogens discharged in the effluent;
- accumulation in the **sediments of heavy metals** discharged in the effluent;
- **bioassimilation and bioaccumulation** of heavy metals and xenobiotic substances in marine fauna;
- **toxic effects of biocides** discharged with the effluent on marine biota; and
- effects **on marine biota of depressed salinities** around the discharge.

Furthermore, construction of the waste water treatment plant and installation of the associated land-based infrastructure, may result in:

- disturbance of seabird nesting sites thereby resulting in reduction in breeding success, and/or
- obstruction of penguin highways in the vicinity of the proposed sewage treatment plant.

6.3. Assessment of Impacts associated with the Upgrade of the Waste Water Treatment Facility

Using information from the international literature, the potential impacts of sewage discharges were discussed in Section 5. The upgrade of the waste water treatment plant will result in significant ***improvement*** in the quality of the effluent relative to the current discharge, as the waste water will be treated prior to discharge and contaminant concentrations reduced. Relative to the current discharge, all associated impacts can therefore be rated as ***positive***. The assessment assumes that effluents from the new WWTW will be treated to the DWA General Limit Values (GLV) effluent quality standards, and that should sub-standard discharges occur, these will be immediately identified and remedied.

As the marine outfall pipeline is already in place and all construction associated with the WWTW will occur above the high water mark, construction impacts to the marine environment are not further assessed here. Potential construction impacts on seabirds are, however, covered.

Construction Phase

		Pre-Mitigation						Post-Mitigation					
Impact Description	Impact Status	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**
Construction of the sewage package plant may result in disturbance of penguin, cormorant and tern nesting sites in the immediate vicinity with implications for reproductive success.	-ve	3	1	3	1	4	Moderate (32)	2	1	3	1	3	Low (21)
Construction of the sewage package plant may obstruct movement along penguin highways	-ve	2	1	3	1	2	Very Low (14)	2	1	1	1	2	Very Low (10)

Operational Phase

		Pre-Mitigation						Post-Mitigation					
Impact Description	Impact Status	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**
Decrease in nutrient levels in the discharge from the proposed WWTW relative to those in the current raw sewage discharge would decrease the likelihood of plankton blooms and seabed hypoxia, improve turbidity and potentially reduce macroalgal growth on the outfall pipeline	+ve	4	1	1	5	5	Moderate (55)	No mitigation necessary (with the possible exception of phosphate) other than adherence to CWDP					
Decreased nutrient levels in the discharge from the proposed WWTW may result in recovery of biodiversity and community structure of subtidal benthic macrofauna and flora impacted by the current raw sewage discharge	+ve	4	1	1	5	5	Moderate (55)	No mitigation necessary other than adherence to CWDP					
Reduced levels of organic matter in the discharge from the WWTW relative to those in the current raw sewage discharge may result in recovery of the structure and diversity of soft-sediment macrofauna	+ve	4	1	1	5	5	Moderate (55)	No mitigation necessary other than adherence to CWDP					

		Pre-Mitigation						**Post-Mitigation**					
Impact Description	Impact Status	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**
Reduced levels of organic matter and heavy metals discharged from the WWTW relative to the current raw sewage discharge may improve sediment quality (e.g. oxygen levels, heavy metals)	+ve	4	1	1	4	4	Moderate (40)	No mitigation necessary other than adherence to CWDP					
Reduced levels of organic matter in the discharge from the WWTW relative to the current raw sewage discharge may modify the diversity, abundance and structure of fish assemblages	+ve	4	1	1	5	4	Moderate (44)	No mitigation necessary other than adherence to CWDP					
Reduced levels of colifom bacteria and other pathogens in the discharge from the WWTW relative to the current raw sewage discharge will improve environmental health and alleviate existing health hazards to humans	+ve	4	1	1	4	4	Moderate (40)	No mitigation necessary other than adherence to CWDP					
Xenobiotic substances in the discharge from the WWTW can bioaccumulate in higher order consumers	-ve	2	2	2	4	2	Low (20)	2	2	2	4	2	Low (20)
Biocides used to disinfect the effluent are highly toxic to marine biota	-ve	3	1	5	1	3	Low (30)	1	1	1	4	1	Very Low (7)

		Pre-Mitigation						Post-Mitigation					
Impact Description	Impact Status	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**
The fresh water in the discharge from the WWTW will reduce salinities around the outfall and affect the osmoregulatory abilities of marine organisms	-ve	3	1	1	4	3	Low (27)	3	1	1	4	3	Low (27)

Cumulative Impacts

		Pre-Mitigation						Post-Mitigation					
Impact Description	Impact Status	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**	Magnitude	Extent	Reversibility	Duration	Probability	**SIGNIFICANCE**
Disturbance of nesting seabirds during construction will be cumulative relative to current and future disturbance by island visitors and researchers.	-ve	3	1	3	4	3	Moderate (33)	2	1	3	2	3	Low (24)
Recovery of biodiversity and community structure of subtidal benthic macrofauna and flora over time in response to improved waste water quality	+ve	2	1	3	1	2	Moderate (40)	4	2	1	2	5	Moderate (45)

6.4. Mitigations

The above impact assessment has been completed against the existing baseline environmental conditions. As monitoring of the current discharge revealed a number of exceedances in marine water quality in the vicinity of the outfall, it is safe to assume that the marine environment in the area has been significantly degraded as a result of the disposal of raw sewage *via* the existing outfall over a significant period of time. In light of this, the proposed sewage package plant is expected to have a ***net positive benefit*** to the existing marine water quality and ecosystem health.

It must be noted, however, that both of these assertions rely on the assumption that:

- the upgraded treatment facility operates according to the required treatment limits and meets the specified general limit values; and
- the resulting impact on the marine water quality is in line with the dispersion modelling completed by van Ballegooyen (2021) for the proposed WWTW discharge.

A monitoring programme is included as the primary mechanism by which to ensure that these assertions are correct, as detailed in Section 7 below.

Should the impact assessment have been completed against a (theoretical) pristine environmental baseline, the discharge would in any case, only have resulted in impacts of **low significance**. This assessment was completed as part of this study but has not been included in this report since it does not accurately reflect the current baseline environment in which the outfall already exists.

The assessment of operational impacts undertaken above does not included pre- and post-mitigation assessments when the impact status was considered positive, as the correctly functioning treatment facility in itself can be seen as the primary mitigation measure for the current discharge, thereby preventing further adverse effects on and degradation of the marine environment in the vicinity of the outfall. Where negative impacts were identified, pre- and post-mitigation significance was determined.

The main mitigation measures associated with the upgrade of the Robben Island waste water treatment works relate to the construction of the plant itself. To keep construction disturbance of endangered seabirds occurring on the island to a minimum, the following mitigation measures should be implemented:

- If feasible, schedule construction activities so as to avoid the main seabird breeding periods (March to October), and penguin moulting periods (summer months);
- Prior to commencement of construction, ensure that there are no known nests in the development footprint;
- Construction should be limited to hours when the penguins are not moving around (~90 minutes after sunrise to 90 minutes before sunset) to minimise the impact on birds using the path along the coast.
- Ensure that a penguin-proof perimeter fence is installed around the site boundary prior to commencement of construction activities to prevent penguins accidentally becoming trapped within the construction site;

- Monitor establishment of potential Hartlaub's Gulls and Swift Terns breeding areas in the vicinity of the construction site during December/early January and if necessary deter them from starting to breed near the construction site by using the presence of people to scare them off at the start of the breeding season until they start to breed elsewhere on the island; and
- Ensure that settling tanks are suitably covered with screens to prevent birds getting into the tanks.

7. ENVIRONMENTAL STATEMENT AND CONCLUSIONS

7.1. Environmental Statement

Taking into consideration potential cumulative impacts in Table Bay, and that marine communities in the vicinity of the outfall are highly likely to have been negatively affected by the existing sewage discharges, the impacts resulting from the installation of the proposed WWTW were mostly rated as **positive** impacts of **moderate significance**. As the waste water from the proposed WWTW would be treated prior to discharge and contaminant concentrations reduced, the upgrade of the sewage handling facilities will result in significant improvement in the quality of the effluent relative to the current discharge. The few potentially negative impacts were all rated as being of very low to low significance. The impact footprint for discharges from the proposed WWTW would thus be considerably smaller than the existing sewage handling system, and a recovery of marine communities over the medium- to long-term can be expected.

7.2. Recommendations

I. To ensure that the WWTW continues to result in an improvement in marine ecosystem health relative to the current situation, it is recommended that routine monitoring of the constituent concentrations in the effluent be implemented **before** it is discharged through the marine outfall. This is particularly important as the achievable dilutions calculated by van Ballegooyen (2021) depend on the quality of the effluent being discharged.

   Requirements in terms of effluent quality monitoring are detailed in Point 1.2.1 of Table 12 of the Marine Specific EMP (Section 8).

II. This assessment of potential impacts of the upgraded discharge on marine communities is based on the results of the dilutions modelling study undertaken by van Ballegooyen (2021). The predictions of these models, whilst considered to be robust, need to be validated by field observations and subsequent monitoring. If monitoring fails to mirror predicted results, the forecasted impacts will need to be re-assessed. For this reason it is recommended that the quality of the receiving waters be monitored following commissioning of the WWTW, and at intervals thereafter, to ensure that model predictions are realised and that compliance with marine water quality guidelines are consistently achieved.

   Requirements in terms of water quality monitoring of the receiving environment are detailed in Point 1.2.2 of Table 12 of the Marine Specific EMP (Section 8).

7.3. Conclusions

If all environmental guidelines and appropriate mitigation measures and monitoring recommendations advanced in this report and detailed in the Marine-specific EMP in Section 8, are implemented, there is no reason why the proposed upgrade of the sewage handling system on Robben Island should not proceed. In fact, considering that many constituents of the current raw sewage discharge exceed Marine Water Quality Guidelines as well as GWWLs, and taking into account the potential impacts this may already have had on the marine biota on the eastern shores of the island, it is imperative that the upgrade to the sewage handling system are undertaken as soon as possible.

8. ENVIRONMENTAL MANAGEMENT PROGRAMME

Internationally, monitoring programmes for waste water discharges to the marine environment typically (as a minimum) include comprehensive analyses of both the waste water and the receiving waters, as well as the sediments in the vicinity of the outfall (see for example Philip & Pritchard 1996; Bailey 2000). Additional monitoring includes baseline studies conducted prior to the construction of the discharge pipeline, as well as ongoing analyses during discharge to determine and monitor biophysical changes to the marine environment. Analyses conducted as part of comprehensive monitoring programmes include regular measurement of physical parameters (waste water flow, solids content, turbidity (TSS) and temperature), chemical parameters (COD, BOD, dissolved oxygen, nutrients, heavy metals, organic carbon, salinity) and biological parameters (coliform bacteria and pathogens in water column and sediments, changes to plankton, fish, and benthic organisms in unconsolidated sediments and/or on rocky habitats, and toxicity testing in indicator species).

Considering the capacity of the proposed WWTW, and that the effluent would in future conform to General Limit Values **prior** to discharge to the marine environment, a comprehensive monitoring programme comprising all the elements outlined above is **not deemed necessary**. As a minimum, however, monitoring of the constituent concentrations in the effluent **before** it is discharged through the marine outfall is recommended. Furthermore, to validate the predictions of the achievable dilutions models, monitoring of the receiving waters following commissioning of the WWTW is recommended, to ensure that model predictions and the impacts forecasted in this assessment are realised, and that compliance with marine water quality guidelines are consistently achieved.

The marine-specific EMP provided below covers both generic environmental management procedures associated with the plant and its discharges as well as an environmental monitoring plan. The EMP **does not** provide details on managing general plant operations, and it is assumed that all operational performance parameters and maintenance procedures are meticulously adhered to, and that any sub-standard discharges that may occur are immediately identified and remedied.

Table 12: Marine Specific EMP Requirements

ACTIVITIES	OBJECTIVES (AIMS TO ACHIEVE) & REQUIRED MANAGEMENT ACTIONS (HOW THEY CAN BE ACHIEVED)	*PHASED TARGET DATES*	*RESPON-SIBLE PERSON*	*PERFOR-MANCE REPORT*
1. Environmental Management Procedures	**Environmental objectives are to:** • Employ the EMP process so that WWTW operations and discharges are conducted in an environmentally responsible manner. Increase understanding about potential impacts of discharges and environmental management			
1.1 Construction Activities				
1.1.1 Disturbance of breeding seabirds	• As far as practicable schedule construction activities to avoid peak seabird breeding periods (March – October) and penguin moulting periods (summer months). • Ensure that construction activities avoid known penguin nesting sites. Construction 'no-go' areas should be delineated in collaboration with SANCCOB's seabird ranger on the island. • During the peak penguin breeding season (March – October) limit construction activities from 90 minutes after sunrise to 90 minutes before sunset, when penguins are not using the highway to the east of the proposed plant site. • Ensure that a penguin-proof perimeter fence is installed around the site boundary prior to commencement of construction activities to prevent penguins accidentally becoming trapped within the construction site. • Monitor establishment of potential Hartlaub's Gulls and Swift Terns breeding areas in the vicinity of the construction site during December/early January and if necessary deter them from starting to breed near the construction site by using people to scare them off at the start of the breeding season until they start to breed elsewhere on the island. This will require a TOPS permit. • Ensure that sludge drying beds are suitably covered with screens to prevent birds getting into the sludge.			

ACTIVITIES	**OBJECTIVES (AIMS TO ACHIEVE)** **& REQUIRED MANAGEMENT ACTIONS (HOW THEY CAN BE ACHIEVED)**	***PHASED TARGET DATES***	***RESPONSIBLE PERSON***	***PERFORMANCE REPORT***
1.2 Environmental Monitoring				
1.2.1 Measurement of effluent	• Ensure that the sewage effluent conforms with the General Limit Values to discharge to the sea. • Monitor discharge water quality weekly until sufficient data have been collected to allow a statistically robust prediction that the levels will fall below the guideline levels 95% of the time. (The minimum measurement period would be 12 months, and the more the variations in the data collected over this period the longer the monitoring would need to continue). Thereafter monitor at bi-weekly (2 week) intervals. The following parameters should be measured: – Total suspended solids – Salinity – pH – Dissolved oxygen – Biological Oxygen Demand – Dissolved nutrients (nitrite, nitrate, ammonium, reactive phosphate and reactive silicate) – Faecal coliform bacteria – Chlorine • Ensure that the analyses are carried out by a laboratory certified (by the South African National Accreditation Service) to conduct the analyses. • Have the monitoring results scientifically evaluated by an appropriately qualified independent consultant on an annual basis. • Submit the monitoring results together with the evaluation to the DWS and DFFE on an annual basis.			

ACTIVITIES	OBJECTIVES (AIMS TO ACHIEVE) & REQUIRED MANAGEMENT ACTIONS (HOW THEY CAN BE ACHIEVED)	PHASED TARGET DATES	RESPON-SIBLE PERSON	PERFOR-MANCE REPORT
1.2.2 Measurement of receiving water body	• Ensure that the South African Marine Water Quality Guidelines DWAF 1995): Maintenance of the Ecosystem are achieved for ALL constituents of the effluent, within 100 m of the diffuser. • On commissioning of the Waste Water Treatment Works, monitor the quality of the receiving waters once every 2 weeks at distances of 10 m, 50 m and 100 m to the north, south, west and east of the diffuser to verify the predictions of the dilution model. Monitoring should continue until sufficient data have been collected to allow a statistically robust prediction that the levels will fall below the guideline levels 95% of the time. (The minimum measurement period would be 4 months, and the more the variations in the data collected over this period the longer the monitoring would need to continue). The following parameters should be measured within a predetermined grid around the diffuser: – Total suspended solids – Salinity – pH – Dissolved oxygen – Biological Oxygen Demand – Dissolved nutrients (nitrite, nitrate, ammonium, reactive phosphate and reactive silicate) – Faecal coliform bacteria • Monitoring should continue on a quarterly basis thereafter (every 3 months) for at least three years. • Ensure that the analyses are carried out by a laboratory certified (by the South African National Accreditation Service) to conduct the analyses. • Have the monitoring results scientifically evaluated by an appropriately qualified independent consultant on completion of the three-year monitoring programme. • Submit the monitoring results together with the evaluation to the DWS and DFFE on an annual basis.			

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