ENVIRONMENTAL IMPACT ASSESSMENT FOR THE PROPOSED MEOB BAY TOURISM DEVELOPMENT, NAMIBIA

MARINE BIODIVERSITY SPECIALIST STUDY

Prepared for

Namibian Affirmative Management and Businesses (NAMAB) (Pty) Ltd

On behalf of
Knight Piésold Consulting (Pty) Ltd

Prepared by

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ABBREVIATIONS, UNITS AND GLOSSARY

Abbreviations

BCC	Benguela Current Commission
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CSIR	Council for Scientific and Industrial Research
EIA	Environmental Impact Assessment
EBSA	Ecologically or Biologically Significant Area
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
HAB	Harmful Algal Blooms
IBA	Important Bird Area
IUCN	International Union for Conservation of Nature
LDV	Light Duty/Delivery Vehicles
MET	Ministry of Environment and Tourism
MFMR	Ministry of Fisheries and Marine Resources
MPA	Marine Protected Area
NDP	Namibian Dolphin Project
NIMPA	Namibian Islands Marine Protected Area
ORV	Off-Road Vehicle
PIM	Particulate Inorganic Matter
POM	Particulate Organic Matter
SACW	South Atlantic Central Water
SADCO	Southern Africa Data Centre for Oceanography
TSPM	Total Suspended Particulate Matter
UNESCO	United Nations Educational, Scientific and Cultural Organisation
VOS	Voluntary Observing Ship

Units used in the report

cm	centimetres
cm/s	centimetres per second
g/ℓ	grams per litre
g/m^2	grams per square metre
$g\ C/\ m^2/\ day$	grams Carbon per square metre per day
h	hours
ha	hectare
kg	kilogram
km	kilometres
km/h	kilometres per hour
km^2	square kilometres
m	metres
m^2	square metres

mm	millimetres
m/s	metres per second
mg C/ m^2/ day	milligrams Carbon per square metre per day
mg/ℓ	milligrams per litre
ml/ℓ	millilitres per litre
s	seconds
%	percentage
‰	parts per thousand
~	approximately
<	less than
>	greater than
°C	degrees centigrade

Glossary

Barotropic	a fluid whose density is a function of only pressure
Bathymetry	measurements of the depths of the ocean relative to mean sea level.
Benthic	Referring to organisms living in or on the sediments of aquatic habitats (lakes, rivers, ponds, etc.).
Benthos	The sum total of organisms living in, or on, the sediments of aquatic habitats.
Benthic organisms	Organisms living in or on sediments of aquatic habitats.
Biodiversity	The variety of life forms, including the plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
Biomass	The living weight of a plant or animal population, usually expressed on a unit area basis.
Biota	The sum total of the living organisms of any designated area.
Bivalve	A mollusk with a hinged double shell.
Community structure	All the types of taxa present in a community and their relative abundance.
Community	An assemblage of organisms characterized by a distinctive combination of species occupying a common environment and interacting with one another.
Ecosystem	A community of plants, animals and organisms interacting with each other and with the non-living (physical and chemical) components of their environment.
Epifauna	Organisms, which live at or on the sediment surface being either attached (sessile) or capable of movement.
Environmental impact	A positive or negative environmental change (biophysical, social and/or economic) caused by human action.

Habitat	The place where a population (e.g. animal, plant, micro-organism) lives and its surroundings, both living and non-living.
Infauna	Animals of any size living within the sediment. They move freely through interstitial spaces between sedimentary particles or they build burrows or tubes.
Intertidal	the area of a seashore which is covered at high tide and uncovered at low tide
Macrofauna	Animals >1 mm.
Macrophyte	A member of the macroscopic plant life of an area, especially of a body of water; large aquatic plant.
Meiofauna	Animals <1 mm.
Mariculture	Cultivation of marine plants and animals in natural and artificial environments.
Marine environment	Marine environment includes estuaries, coastal marine and near-shore zones, and open-ocean-deep-sea regions.
Population	Population is defined as the total number of individuals of the species or taxon.
Recruitment	The replenishment or addition of individuals of an animal or plant population through reproduction, dispersion and migration.
Sediment	Unconsolidated mineral and organic particulate material that settles to the bottom of aquatic environment.
Sessile	attached directly by its base to the substratum without a stalk or peduncle
Species	A group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not produce viable offspring if bred with members of another group.
Subtidal	The zone below the low-tide level, *i.e.* it is never exposed at low tide.
Supralittoral	The supralittoral zone is situated above the high water spring tide level.
Surf zone	Also referred to as the 'breaker zone' where water depths are less than half the wavelength of the incoming waves with the result that the orbital pattern of the waves collapses and breakers are formed.
Suspended material	Total mass of material suspended in a given volume of water, measured in mg/ℓ.
Suspended matter	Suspended material.
Suspended sediment	Unconsolidated mineral and organic particulate material that is suspended in a given volume of water, measured in mg/ℓ.
Taxon (Taxa)	Any group of organisms considered to be sufficiently distinct from other such groups to be treated as a separate unit (e.g. species, genera, families).

Turbidity	Measure of the light-scattering properties of a volume of water, usually measured in nephelometric turbidity units.
Vulnerable	A taxon is vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

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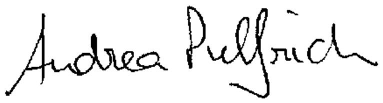
EXPERTISE AND DECLARATION OF INDEPENDENCE

This report was prepared by Dr Andrea Pulfrich of Pisces Environmental Services (Pty) Ltd. Andrea has 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 Programme Reports relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents. She is a member of the South African Council for Natural Scientific Professions (Pr.Sci.Nat. No: 400327/06), South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist assessment report was compiled for Knight Piésold Consulting (Pty) Ltd for their use in preparing an Environmental Impact Assessment (EIA) for the proposed Meob Bay Tourism Development Project (NAMAB (Pty) Ltd) off the Central Coast of Namibia.

I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of Knight Piésold and Namibian Affirmative Management and Businesses (NAMAB) (Pty) Ltd, and has no vested interests in the proposed project or the study area.



Dr Andrea Pulfrich

1. GENERAL INTRODUCTION

The NAMAB concession area covers approximately 25 000 km^2 of pristine Namib Dessert. It incorporates the coastline from Sylvia Hill to Conception Bay, and inland towards Solitaire in the north to the Kanaan gate in the south. The entire concession area is located within the Namib Naukluft National Park and overlaps with the UNESCO Namib Sand Sea World Heritage site. Since granting off the concession in 2009, NAMAB has offered exclusive eco-adventures *via* three different access routes and constructed a semi-permanent eco-tented camp near Meob Bay, approximately 190 km south of Walvis Bay and 220 km north of Lüderitz (Figure 1a). Due to the success of the tourism activities, and to cater for clients requiring more up-market accommodation, NAMAB is proposing to upgrade their facilities near Meob Bay.

The proposed tourism development project includes the construction and operation of a lodge and staff quarters approximately 5 km from the operational eco-tented camp, as well as upgrades to the existing facilities to accommodate pilots and tour guides (Figure 1b). An alternative site situated within the dunes some 650 m south of the temporary tented camp has been proposed so as to avoid potential impacts to shell middens located immediately adjacent to the proposed northern Lodge site. The southern Lodge site is the preferred alternative. Although access to the lodge can be gained from Lüderitz, Kanaan, Elim or Walvis Bay, it is expected that most guests will fly in to the airstrip at Fischersbrunn and be transported to the lodge in 4x4 vehicles along already established tracks. The combined footprint of the development infrastructure will be approximately 2 ha.

The duration of the construction phase will be in the order of six to ten months, and will entail the building of an eating and reception area, 10 chalets and services. Construction personnel will be accommodated at a temporary construction camp, which has been used as a camp site by travellers between Lüderitz and Walvis Bay for over ten years (Figure 1b). Transportation of construction materials to site will be undertaken by Light Duty Vehicles (LDVs) along existing 4x4 tracks. Two to three trips per week are anticipated during the construction phase.

The lifespan of the lodge is expected to be 20+ years, during which time the lodge and tented camp will be operated by ~20 permanent staff members who will reside at the staff quarters on site. Periodic maintenance activities of the lodge and associated facilities will be undertaken. Lodge guests will be offered recreational activities such as mining town-, dune- and shipwreck excursions. Transportation of raw materials to the lodge during the operational phase will entail one trip per week with LDVs on the existing 4x4 tracks.

Decommissioning of the lodge and associated facilities will take no more than 40 days. All structures will be demolished and materials removed off-site for re-use and/or safe disposal thereby returning the project-area to its natural / wilderness state. Two trips per week on existing 4x4 tracks are anticipated when removing disassembled buildings and materials during the decommissioning phase.

2. DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

This environmental description encompasses the coastal zone and shallow nearshore waters (< 40 m depth) of the general project area. Some of the data presented are, however, more regional in nature, e.g. the wave climate, nearshore currents, etc. The purpose of this environmental description is to provide the marine and coastal baseline environmental context within which the proposed development will take place. The summaries presented below are based on information gleaned from Penney *et al.* (2007), supplemented by more recent data available in peer-reviewed scientific publications and reports produced by governmental institutes.

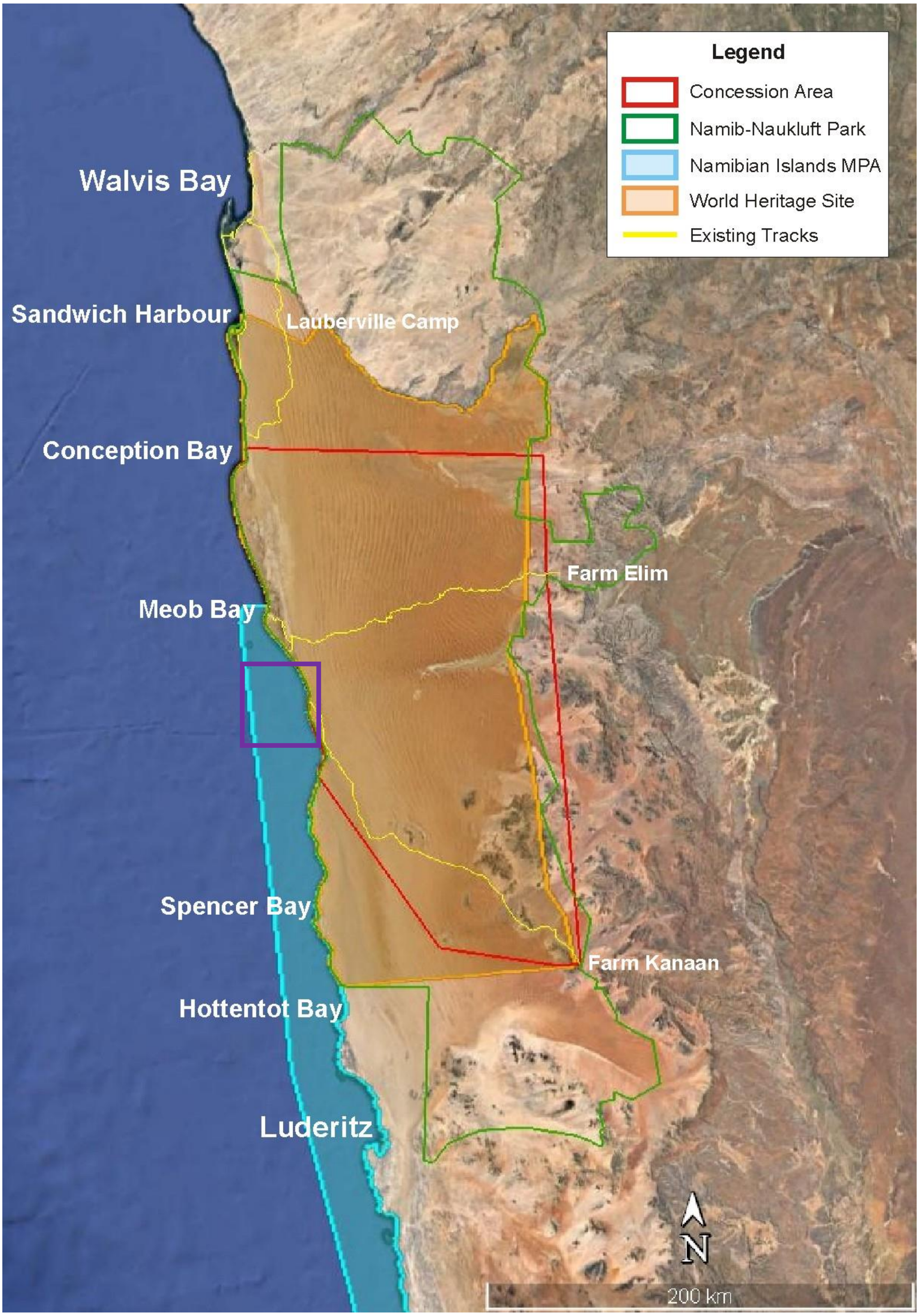


Figure 1a: GoogleEarth image of the broader project area illustrating the concession area (red polygon) within the Namib-Naukluft National Park (green polygon), its overlap with the Namib Sand Sea World Heritage Site(orange polygon), access points and existing tracks (yellow lines). The area in the purple square is detailed in Figure 1b.

Figure 1b: GoogleEarth image of the project area illustrating the alternative locations of the proposed lodge relative to existing camps and wells, the airstrip and existing tracks.

2.1 Geophysical Characteristics

2.1.1 Bathymetry

The continental shelf off Namibia is variable in width. Off the Orange River the shelf is wide (230 km) and characterised by well-defined shelf breaks, a shallow outer shelf and the aerofoil-shaped submarine Recent River Delta on the inner shelf. It narrows to the north reaching its narrowest point (90 km) off Chameis Bay, before widening again to 130 km off Lüderitz and Walvis Bay (Rogers 1977). Off Terrace Bay the shelf gives rise to the Walvis Ridge, an underwater plateau which extends from the African coast at around 18°S more than 3 000 km south-westwards to Tristan da Cunha, the Gough Islands and the Mid-Atlantic Ridge. To the north of the ridge, the shelf narrows again towards Cape Frio. Between Meob Bay and Palgrave Point there is a double shelf break, with the inner and outer breaks beginning at depths of around 140 m and 400 m, respectively (Shannon & O'Toole 1998) (Figure 2a).

The salient topographic features of the shelf include the relatively steep descent to about 100 m, the gentle decline to about 180 m, and the undulating depths to about 200 m. The most prominent topographic feature in the study area is the Walvis Ridge. The variable topography of the shelf is of significance for near shore circulation and for fisheries (Shannon & O'Toole 1998).

Off the Meob Bay area, the shelf break lies approximately 50 km offshore, with the -30 m depth contour located approximately 7 km offshore (Figure 2a).

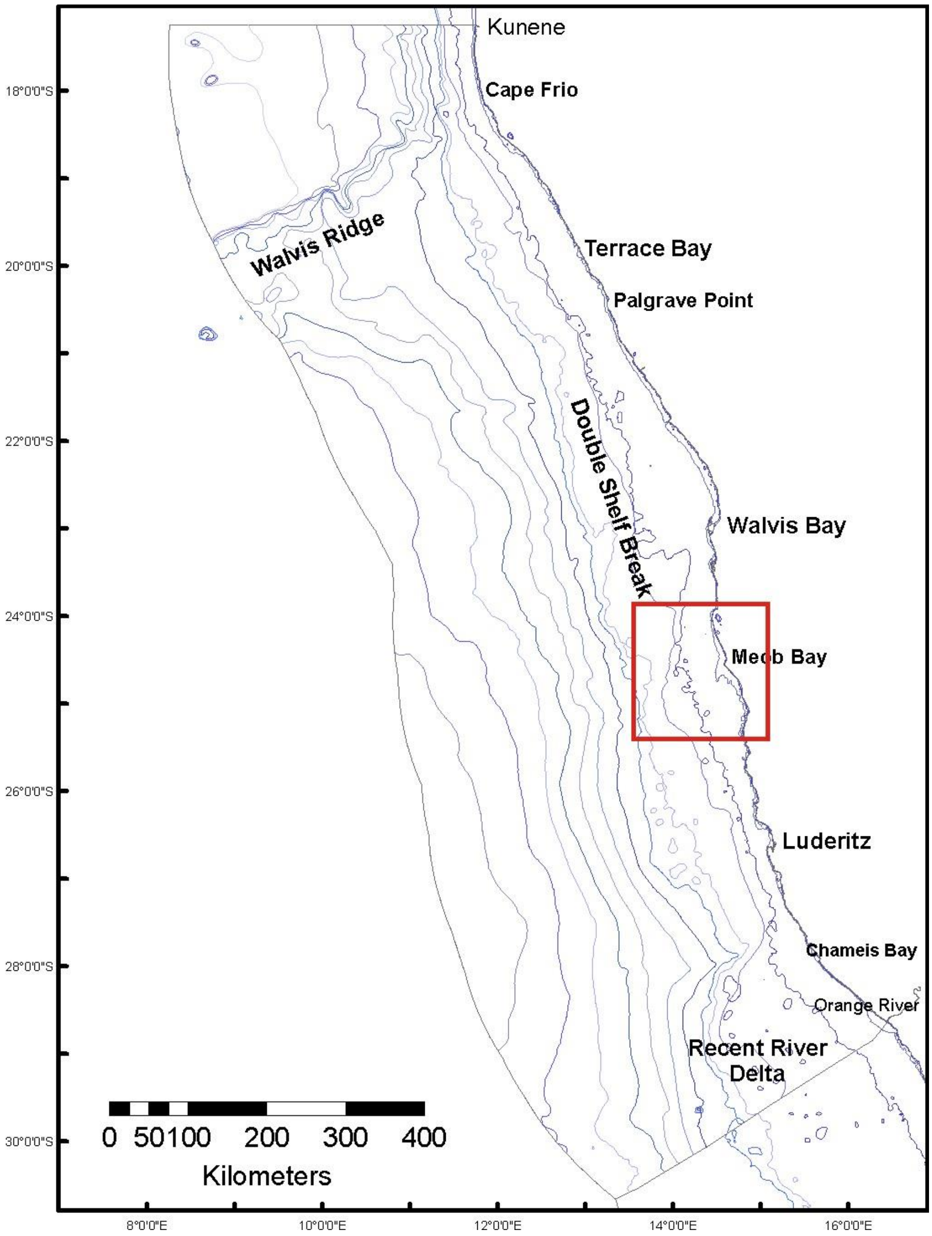


Figure 2a: Bathymetry of the Namibian Exclusive Economic Zone illustrating features mentioned in the text. The area in the red square is detailed in Figure 2b.

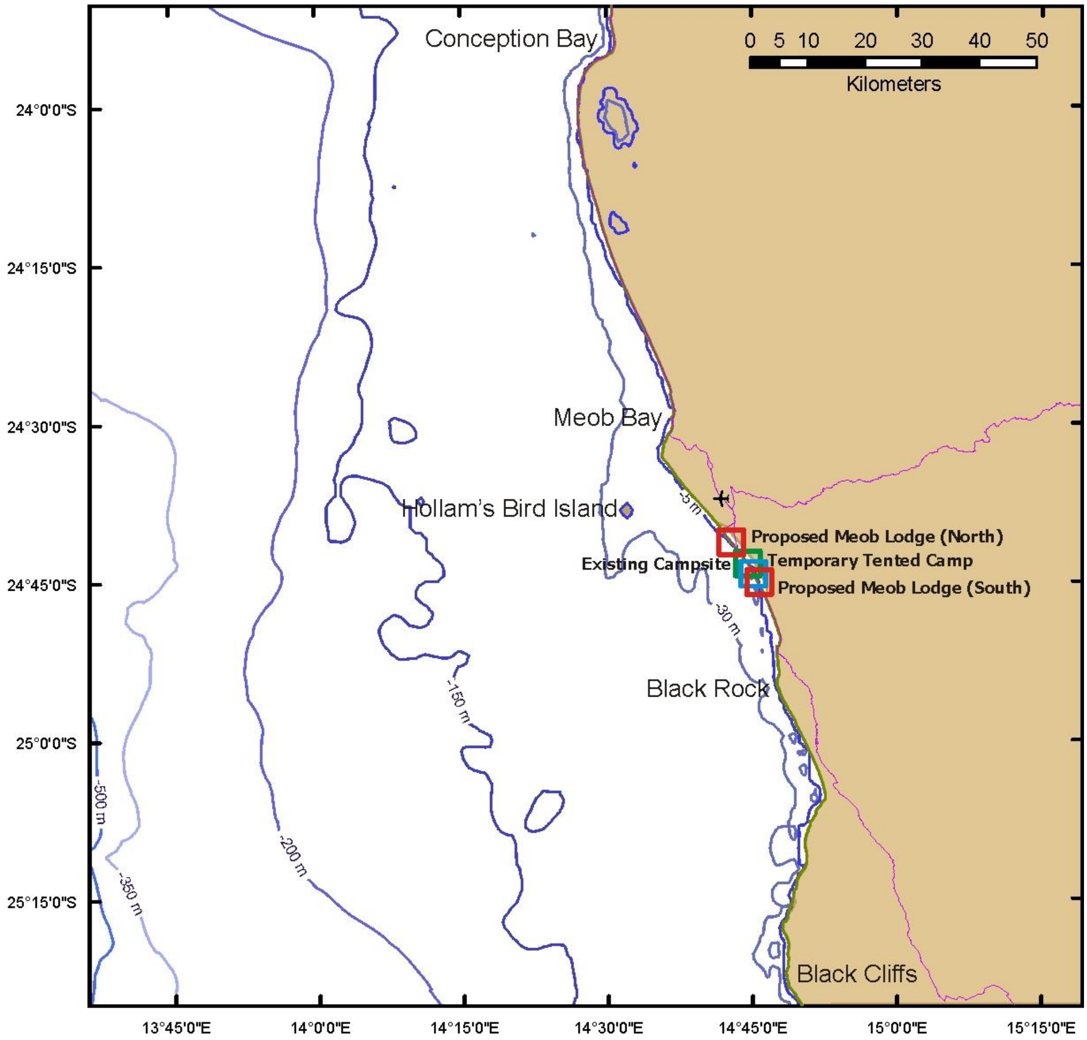


Figure 2b: Bathymetry off the project area. Existing tracks and the alternative locations of the proposed Lodge, existing camp and temporary camp are shown.

2.1.2 Coastal and Inner-shelf Geology and Seabed Geomorphology

As part of the recent Marine Spatial Planning (MSP) process in Namibia, the marine geology of the Namibian continental shelf and geomorphic seafloor features within the Exclusive Economic Zone (EEZ) were mapped (MFMR 2021). The inner shelf is underlain by Precambrian bedrock (also referred to as Pre-Mesozoic basement), whilst the middle and outer shelf areas are composed of Cretaceous and Tertiary sediments (Dingle 1973; Birch *et al*. 1976; Rogers 1977; Rogers & Bremner 1991). The shelf off the project areas comprises primarily medium shelf, with high shelf features occurring further offshore (Figure 3). As a result of erosion on the continental shelf, the unconsolidated sediment cover is generally thin, often less than 1 m. Sediments are finer seawards, changing from sand on the inner and outer shelves to muddy sand and sandy mud in deeper water. However, this general pattern has been modified considerably by biological deposition (large areas of shelf sediments contain high levels of calcium carbonate) and localised river input. Off Meob Bay, the sandy inshore area gives way to a tongue of organic-rich muddy sand, which extends from south of Conception Bay to Black Cliffs (Figure 4). South of Black Rock to as far as Black Cliffs a tongue of gravelly sand and sandy gravels extends offshore. The biogenic muds are the main determinants of the formation of low-oxygen waters and sulphur eruptions off central Namibia (see Sections 2.9 & 2.10).

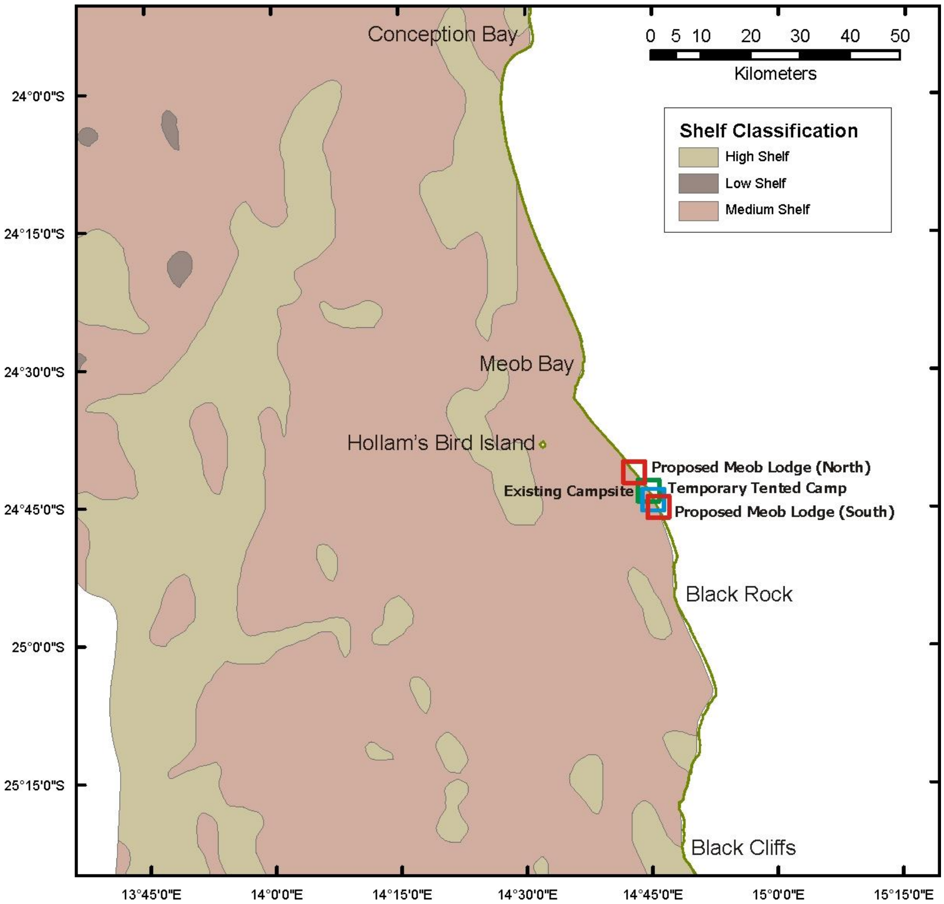


Figure 3: Project developments in relation to seabed geomorphic features off central Namibia (Adapted from MFMR 2021).

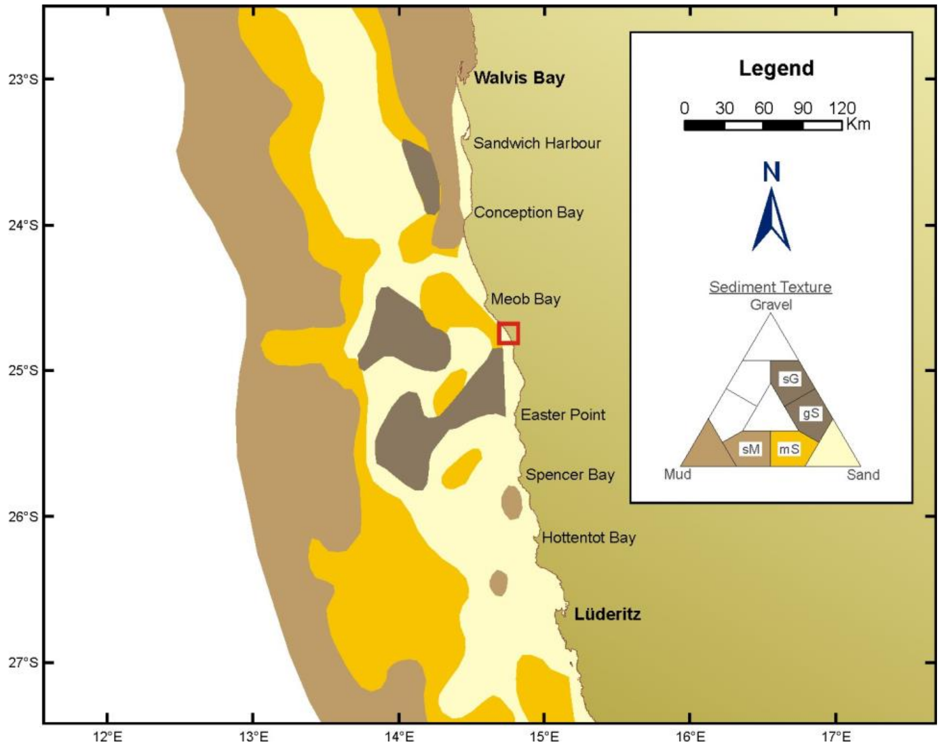


Figure 4: Location of the proposed project (red square) in relation to the offshore seabed sediments in the region (adapted from Rogers & Bremner 1991).

Onshore, the Central Namib Desert consists of a bedrock peneplain that rises from sea level at the coast to 800-1 000 m at its eastern edge. Bedrock outcrops occur sporadically along the coast, with the largest coastal outcrop area being the one between Conception Bay and Meob Bay. The nature of the coast between Lüderitz and Sandwich Harbour is highly variable. The coast is rocky in places with occasional small cliffs, or exposed basement rock of varying width separating sandy beaches from the inland dunes (e.g. south of Douglas Point to Hottentots Bay, Reutersbrunn to Conception Bay, south of Sandwich Harbour) (Seely 2012). North of Spencer Bay, rocky outcrops become less frequent and the coastline is characterised by mixed rock and sand (Currie *et al.* 2009). In some areas, aeollian sand sheets with small barchan dunes or vegetated hummock rise gradually from the shore. In contrast, other places boast high dunes the bases of which are eroded by the sea during high tides occurring directly on the shoreline (Seely 2012).

2.2 Biophysical Characteristics

2.2.1 Climate

The climate of the Namibian coastline is classified as hyper-arid with typically low, unpredictable winter rains and strong predominantly southerly or south-westerly winds. North of Lüderitz summer rains dominate. Further out to sea, a south-easterly component is more prominent. Winds reach a peak in the late afternoon and subside between midnight and sunrise.

The Namibian coastline is characterised by the frequent occurrence of fog, which occurs on average between 50-75 days per year, being most frequent during the months of February through May. The fog lies close to the coast extending about 20 nautical miles (~35 km) seawards (Olivier 1992, 1995). This fog, which is usually quite dense, appears as a thick bank hugging the shore and may reduce visibility to <300 m.

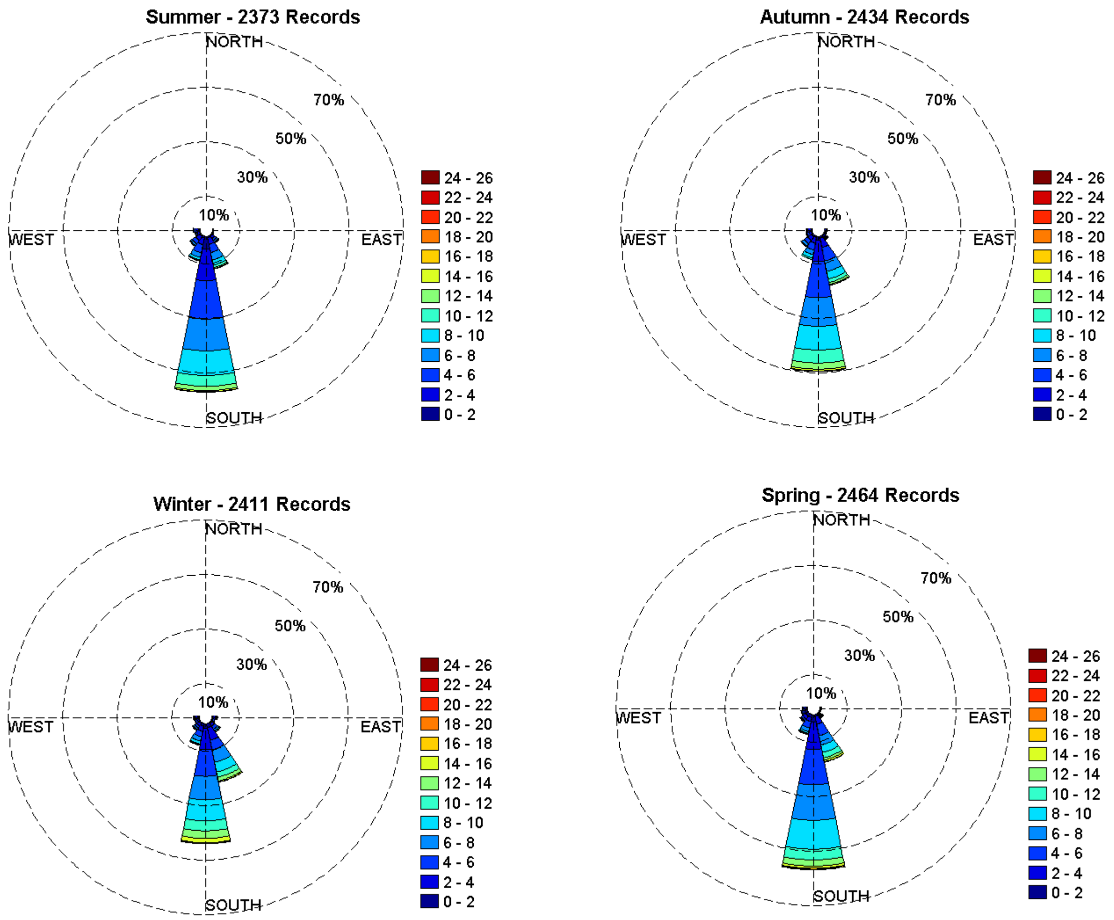
Average precipitation per annum along the coastal region between Lüderitz and Walvis Bay is <15 mm. Due to the combination of wind and cool ocean water, temperatures are mild throughout the year. Coastal temperatures average around 16°C, gradually increasing inland (Barnard 1998). In winter, maximum diurnal shifts in temperature can occur caused by the hot easterly 'Berg' winds which blow off the desert. During such occasions temperatures up to 30°C are not uncommon.

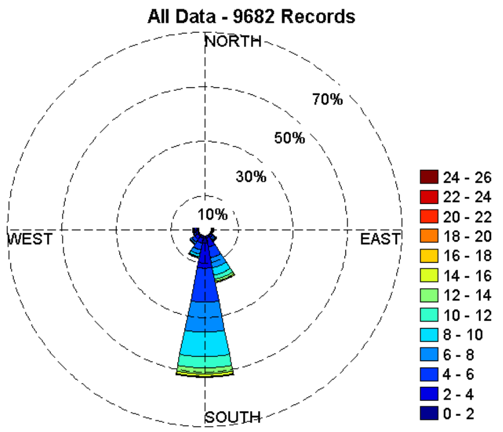
2.2.2 Wind Patterns

The atmospheric features and processes active on the West Coast of southern Africa have been described by Nelson & Hutchings (1983), Kamstra (1985), Shannon (1985), Shannon & Nelson (1996) and Shannon & O'Toole (1998). The description below is summarised from these authors.

Winds at the sea surface are seasonally modulated and significantly influence the oceanography of the Benguela region. The winds in the system are vigorous with gale force winds occurring in all seasons, but being most frequent in spring. The prevailing winds are controlled by the south Atlantic subtropical anticyclone, the seasonal atmospheric pressure field over the subcontinent, and the eastward moving mid-latitude cyclones south of the southern African subcontinent. The south Atlantic anticyclone is a perennial feature that forms part of the discontinuous belt of high-pressure systems, which encircle the subtropical southern hemisphere. It undergoes seasonal variations in that it is strongest in the austral summer when it also attains its southernmost extension lying southwest and south of the subcontinent. In contrast, the mid-latitude cyclones passing south of the subcontinent result in a short-term cyclicity of wind events. Gale force and strong wind events extend typically over 2-3 days for both south-southeast and north-northwest winds. Five-day strong wind events are rare.

Seasonal wind roses for the Walvis Bay area are illustrated in Figure 5.





u	1960-01-07 to 2010-07-23
Station	VOS data
Position	22.0 - 23.9°S and 13.0 - 14.7°E
Sensor Height	0 m
Records	9682

Figure 5: Seasonal wind roses for the offshore Walvis Bay area (Source: Voluntary Observing Ship (VOS) data from the Southern Africa Data Centre for Oceanography (SADCO)).

The arid coastal plain of the southern African West Coast acts as a thermal barrier to cross-flow thereby topographically steering the winds along the coast. This induces the characteristically moderate to strong southerly winds in the region, with wind speeds often exceeding 10 m/s. These winds bring cool, moist air into the coastal region. The winds produce coastal upwelling and play an important role in the loss of sediment from beaches. These strong equatorwards winds are interrupted by the passing of coastal lows with which are associated periods of calm or north or northwest wind conditions. These northerlies occur throughout the year, but are more frequent in spring and summer.

During autumn and winter, the south Atlantic anticyclone weakens and migrates north-westwards causing catabatic, or easterly 'berg' winds. These powerful offshore winds can exceed 50 km/h, producing sandstorms that considerably reduce visibility at sea and on land. Although they occur intermittently for about a week at a time, they have a strong effect on the coastal temperatures, which often exceed 30°C during 'berg' wind periods (Shannon & O'Toole 1998). The winds also play a significant role in sediment input into the coastal marine environment with transport of the sediments up to 150 km offshore (Figure 6).

Figure 6: Satellite image showing aerosol plumes of sand and dust being blown out to sea during a northeast 'berg' wind event along the central Namibian coast (Image source: www.intute.ac.uk). The project area is indicated by the red square.

2.2.3 Large-Scale Circulation and Coastal Currents

The Namibian coastline is strongly influenced by the Benguela Current. Current velocities in continental shelf areas generally range between 10–30 cm/s (Boyd & Oberholster 1994). The flows are predominantly wind-forced, barotropic and fluctuate between poleward and equatorward flow (Shillington *et al*. 1990; Nelson & Hutchings 1983). Fluctuation periods of these flows are 3 - 10 days, although the long-term mean current residual is in an approximate northwest (alongshore) direction. Near bottom shelf flow is mainly poleward (Nelson 1989) with low velocities of typically 5 cm/s. The poleward flow becomes more consistent in the southern Benguela.

In the nearshore zone, strong wave activity from the south and southwest (generated by winds and waves in the South Atlantic and Southern Ocean) drives a predominantly northward long-shore current (Shillington *et al*. 1990). Surface currents appear to be topographically steered, following the major topographic features (Nelson & Hutchings 1983). Current velocities vary accordingly (~10-35 cm/s), with increased speeds in areas of steep topography and reduced velocities in areas of regular topography. Typically wave-driven flows dominate in the surf zone (characteristically 150 m to 250 m wide), with the influence of waves on currents extending out to the base of the wave effect (~40 m; Rogers 1979). The influence of wave-driven flows extends beyond the surf zone in the form of rip currents. Longshore currents are driven by the momentum flux of shoaling waves approaching the shoreline at an angle, while cross-shelf currents are driven by the shoaling waves. The magnitude of these currents is determined primarily by wave height, wave period, angle of incidence of the wave at the coast and bathymetry. Surf zone currents have the ability to transport unconsolidated sediments along the coast in the northward littoral drift.

Nearshore velocities have not been reported for the Meob Bay area and are difficult to estimate because of acceleration features such as surf zone rips and sandbanks. However, computational model estimates using nearshore profiles and wave conditions representative of this central Namibian coastal region suggest time-averaged northerly longshore flows with a cross-shore mean of between 0.2 to 0.5 m/s. Instantaneous measurements of cross-shore averaged longshore velocities are often much larger. Surf zone-averaged longshore velocities in other exposed coastal regions commonly peak at between 1.0 m/s to 1.5 m/s, with extremes exceeding 2 m/s for high wave conditions (CSIR 2002). The southerly longshore flows are considered to remain below 0.5 m/s.

2.2.4 Waves and Tides

The Namibian Coast is classified as exposed, experiencing strong wave action rating between 13-17 on the 20-point exposure scale (McLachlan 1980). The coastline is influenced by major swells generated in the roaring forties, as well as significant sea waves generated locally by the persistent southerly winds.

The central Namibian coastline is influenced by major swells generated in the Roaring Forties, as well as significant sea waves generated locally by the persistent southerly winds. Apart from Walvis Bay and Sandwich Harbour, wave shelter in the form of west to north-facing embayments, and coast lying in the lee of headlands are extremely limited.

The wave regime along the southern African West Coast shows no strong seasonal variation except for slight increases in swell from WSW-W direction in winter (Figure 7). The median significant wave height is 2.4 m with a dominant peak energy period of ~12 seconds. Longer period swells (11 to 15 seconds), generated by mid-latitude cyclones occur about 25-30 times a year. These originate from the S-SW sectors, with the largest waves recorded along the southern African West Coast attaining 4-7 m. Wind-induced waves, on the other hand, have shorter wave periods (~8 seconds), are generally steeper than swell waves, and tend to come from a more south-easterly direction (CSIR 1996). Waves are concentrated in a fairly narrow directional band with 73% of the deep-sea waves originate from the SSE (165°) to SW (225°) sector. Generally, wave heights decrease with water depth and distance longshore. On occasion, the prevailing south-westerly winds can reach gale force velocities in excess of 70 km/hr, producing swells up to a maximum height of 10 m.

In common with the rest of the southern African coast, tides in the study area are regular and semi-diurnal. The maximum tidal variation is approximately 2 m, with a typical tidal variation of ~1 m. Variations of the absolute water level as a result of meteorological conditions such as wind and waves can however occur adjacent to the shoreline and differences of up to 0.5 m in level from the tidal predictions are not uncommon. Tidal currents are minimal with measurements of 0.1 m/s reported at Walvis Bay.

Table 1 lists mean tidal levels for Walvis Bay.

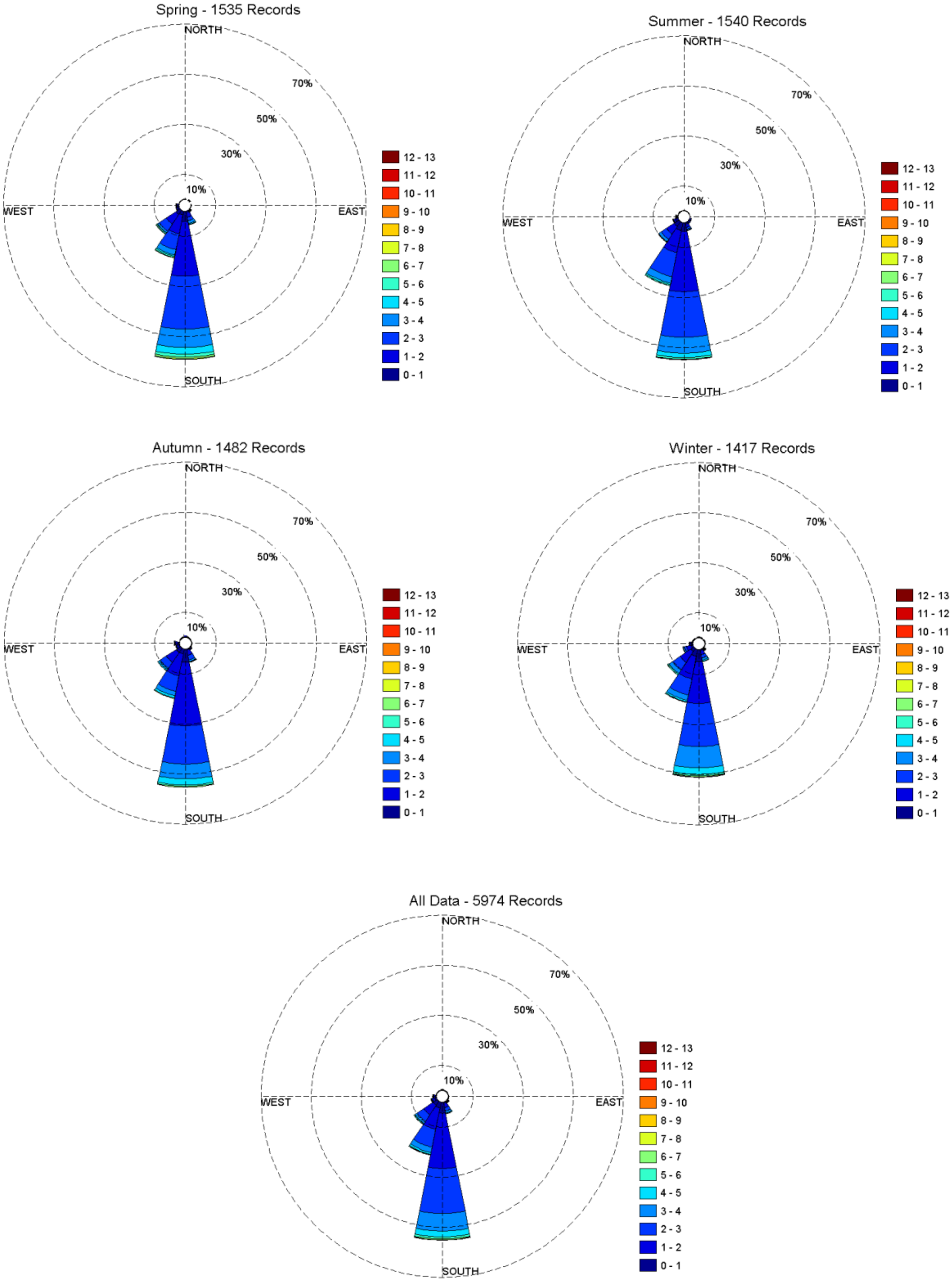


Figure 7: Seasonal swell data for the offshore Walvis Bay Area (22°-24°S; 13°-15°E). (Source: Voluntary Observing Ship (VOS) data from the Southern Africa Data Centre for Oceanography (SADCO)).

Table 1: Tide statistics for Walvis Bay from the SA Tide Tables (SAN 2020). All levels are referenced to Chart Datum.

Description		Level in m
Highest Astronomical Tide	HAT	+1.97
Mean High Water of Spring Tide	MHWS	+1.69
Mean High Water of Neap Tide	MHWN	+1.29
Mean Level	ML	+0.98
Mean Sea Level	MSL	+0.97
Mean Low Water of Neap Tide	MLWN	+0.67
Mean Low Water of Spring Tide	MLWS	+0.27
Lowest Astronomical Tide	LAT	0.00

2.2.5 Upwelling

The major feature of the Benguela Current Coastal is upwelling and the consequent high nutrient supply to surface waters leads to high biological production and large fish stocks. The prevailing longshore, equatorward winds move nearshore surface water northwards and offshore. To balance the displaced water, cold, deeper water wells up inshore. Although the rate and intensity of upwelling fluctuates with seasonal variations in wind patterns, the most intense upwelling tends to occur where the shelf is narrowest and the wind strongest. Consequently, it is a semi-permanent feature at Lüderitz and upwelling can occur there throughout the year and areas to the north due to perennial southerly winds (Figure 8; Shannon 1985). The Lüderitz upwelling cell is the most intense upwelling cell in the system (Figure 8), with the seaward extent reaching nearly 300 km, and the upwelling water is derived from 300-400 m depth (Longhurst 2006). Agenbag & Shannon (1988) suggested that the combined effect of changes in circulation and turbulence/stratification off Meob Bay resulted in an 'environmental barrier' that prevented interchange of biota between the northern and southern Benguela sub-systems. A subsequent detailed analysis of water mass characteristics confirmed a discontinuity in the central and intermediate water layers along the shelf north and south of Lüderitz (Duncombe Rae 2005; Ekau & Verheye 2005). Off northern and central Namibia, several secondary upwelling cells occur. Upwelling in these cells is perennial, with a late winter maximum (Shannon 1985).

2.2.6 Water Masses and Temperature

South Atlantic Central Water (SACW) comprises the bulk of the seawater in the study area, either in its pure form in the deeper regions, or mixed with previously upwelled water of the same origin on the continental shelf (Nelson & Hutchings 1983). Salinities range between 34.5‰ and 35.5‰ (Shannon 1985). Data recorded over a ten year period at Swakopmund (1988 – 1998) to the north of the project area show that seawater temperatures vary between 10°C and 23°C, averaging 14.9°C. They show a strong seasonality with lowest temperatures occurring during winter when upwelling is at a maximum. Temperatures for Meob Bay are reported to range between 9.5°C and 19.5°C (Kensley 1977; Currie *et al*. 2009).

During the non-upwelling season in summer, daily seawater temperature fluctuations of several degrees are common along the central Namibian nearshore coast. It appears that the thermal regime of the surf zone is controlled by the locally-forced Ekman offshore transport, which leads the associated temperature fluctuations by one day (Bartholomae & Hagen 2007). This time-lag suggests the existence of a persistent recirculation cell in nearshore waters in this region.

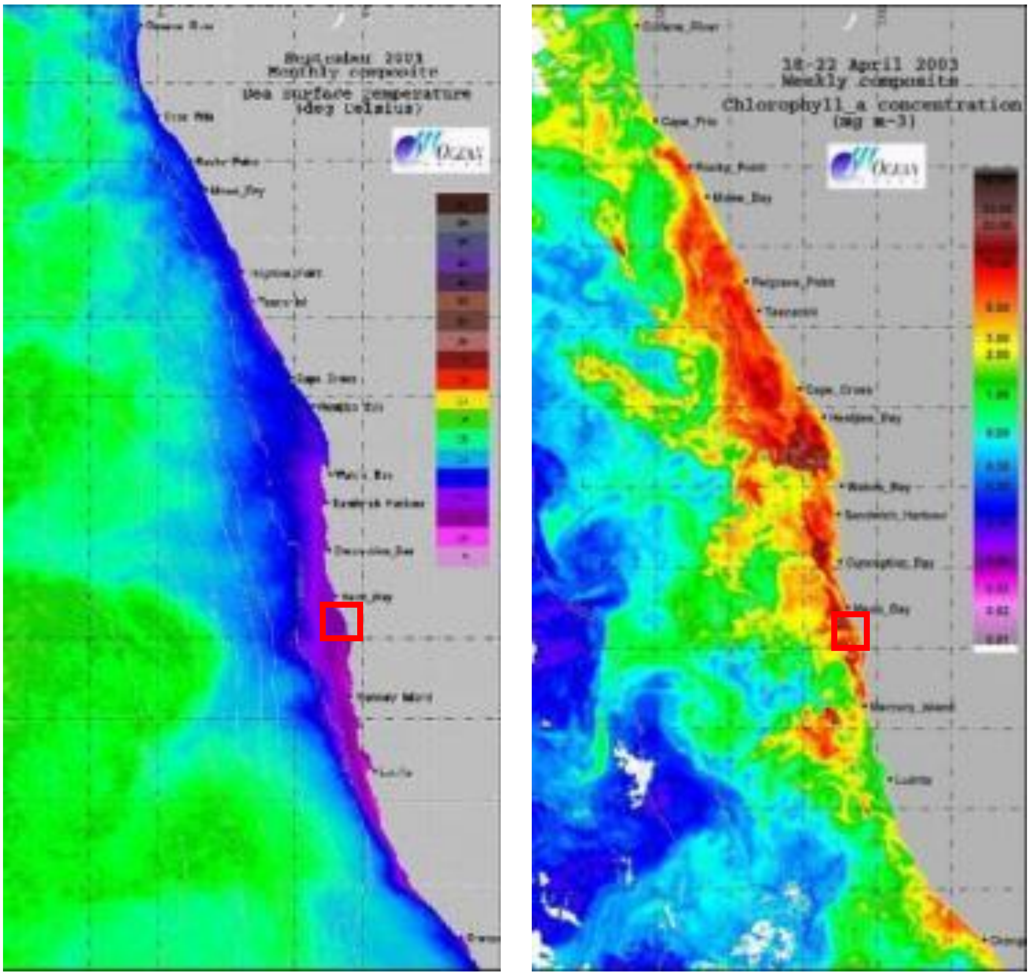


Figure 8: Location of the proposed project (red square) in relation to the upwelling centres (left) and Chlorophyll a concentrations on the central and northern coast of Namibia (Adapted from Currie 2010).

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations, especially on the bottom. SACW itself has depressed oxygen concentrations (~80% saturation value), but lower oxygen concentrations (<40% saturation) frequently occur (Visser 1969; Bailey *et al*. 1985; Chapman & Shannon 1985).

Nutrient concentrations of upwelled water of the Benguela system attain 20 µM nitrate-nitrogen, 1.5 µM phosphate and 15-20 µM silicate, indicating nutrient enrichment (Chapman & Shannon 1985). This is mediated by nutrient regeneration from biogenic material in the sediments (Bailey *et al*. 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.

2.2.7 Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulate matter. Total Suspended Particulate Matter (TSPM) is typically divided into Particulate Organic Matter (POM) and Particulate Inorganic Matter (PIM), the ratios between them varying considerably. The POM usually consists of detritus, bacteria, phytoplankton and zooplankton, and serves as a source of food for filter-feeders. Seasonal microphyte production associated with upwelling events will play an important role in determining the concentrations of POM in coastal waters. PIM, on the other hand, is primarily of geological origin consisting of fine sands, silts and clays. PIM loading in nearshore waters is strongly related to natural inputs from rivers or from 'berg' wind events, or through resuspension of material on the seabed.

Concentrations of suspended particulate matter in shallow coastal waters can vary both spatially and temporally, typically ranging from a few mg/ℓ to several tens of mg/ℓ (Bricelj & Malouf 1984; Berg & Newell 1986; Fegley *et al.* 1992). Field measurements of TSPM and PIM concentrations in the Benguela current system have indicated that outside of major flood events, background concentrations of coastal and continental shelf suspended sediments are generally <12 mg/ℓ, showing significant long-shore variation (Zoutendyk 1992, 1995). Considerably higher concentrations of PIM have, however, been reported from southern African west coast waters under stronger wave conditions associated with high tides and storms, or under flood conditions.

The major source of turbidity in the swell-influenced nearshore areas off Namibia is the redistribution of fine inner shelf sediments by long-period Southern Ocean swells. The current velocities typical of the Benguela (10-30 cm/s) are capable of resuspending and transporting considerable quantities of sediment equatorwards. Under relatively calm wind conditions, however, much of the suspended fraction (silt and clay) that remains in suspension for longer periods becomes entrained in the slow poleward undercurrent (Shillington *et al.* 1990; Rogers & Bremner 1991).

Superimposed on the suspended fine fraction, is the northward littoral drift of coarser bedload sediments, parallel to the coastline. This northward, nearshore transport is generated by the predominantly south-westerly swell and wind-induced waves. Longshore sediment transport, however, varies considerably in the shore-perpendicular dimension. Sediment transport in the surf zone is much higher than at depth, due to high turbulence and convective flows associated with breaking waves, which suspend and mobilise sediment (Smith & Mocke 2002).

On the inner and middle continental shelf, the ambient currents are insufficient to transport coarse sediments, and resuspension and shoreward movement of these by wave-induced currents occur primarily under storm conditions (see also Drake *et al.* 1985; Ward 1985).

The powerful easterly 'berg' winds occurring along the Namibian coastline in autumn and winter also play a significant role in sediment input into the coastal marine environment (Figure 6), potentially contributing the same order of magnitude of sediment input as the annual estimated input of sediment by the Orange River (Zoutendyk 1992; Shannon & O'Toole 1998; Lane & Carter 1999). For example, for a single 'berg'-wind event it was estimated that 50 million tons of dust were blown into the sea by extensive sandstorms along much of the coast from Cape Frio, Namibia in the north to Kleinzee, South Africa in the south (Shannon & Anderson 1982) with transport of the sediments up to 150 km offshore.

2.2.8 Organic Inputs

The Benguela upwelling region is an area of particularly high natural productivity, with extremely high seasonal production of phytoplankton and zooplankton. These plankton blooms in turn serve as the basis for a rich food chain up through pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (snoek), mammals (primarily seals and dolphins) and seabirds (African penguins, gannets, cormorants, terns and others). All of these species 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.

Balanced multispecies ecosystem models have estimated that during the 1990s the Benguela region supported biomasses of 76.9 tons/km^2 of phytoplankton and 31.5 tons/km^2 of zooplankton alone (Shannon *et al.* 2003). Thirty six percent of the phytoplankton and 5% of the zooplankton are estimated to be lost to the seabed annually. This natural annual input of millions of tons of organic material onto the seabed off the southern African west coast has a substantial effect on the ecosystems of the Benguela region. It provides most of the food requirements of the particulate and filter-feeding benthic communities that inhabit the sandy-muds of this area, and results in the high organic content of the muds in the region. As most of the organic detritus is not directly consumed, it enters the seabed decomposition cycle, resulting in subsequent depletion of oxygen in deeper waters overlying these muds and the generation of hydrogen sulphide and sulphur eruptions along the coast.

An associated phenomenon ubiquitous to the Benguela system are red tides (dinoflagellate and/or ciliate blooms) (see Shannon & Pillar 1985; Pitcher 1998). Also referred to as Harmful Algal Blooms (HABs), these red tides can reach very large proportions, with sometimes spectacular effects. Toxic dinoflagellate species can cause extensive mortalities of fish and shellfish through direct poisoning, while degradation of organic-rich material derived from both toxic and non-toxic blooms results in oxygen depletion of subsurface water. Periodic low oxygen events associated with massive algal blooms in the nearshore can have catastrophic effects on the biota (see below).

2.2.9 Low Oxygen Events

The low oxygen concentrations are attributed to nutrient remineralisation in the bottom waters of the system (Chapman & Shannon 1985). The absolute rate of this is dependent upon the net organic material build-up in the sediments, with the carbon rich mud deposits playing an important role. As the mud on the shelf is distributed in discrete patches, there are corresponding preferential areas for the formation of oxygen-poor water, the main one being off central Namibia (Chapman & Shannon 1985). The distribution of oxygen-poor water is subject to short (daily) and medium term (seasonal) variability in the volumes of oxygen depleted water that develops (De Decker 1970; Bailey & Chapman 1991). Subsequent upwelling processes can move this low-oxygen water up onto the inner shelf, and into nearshore waters, often with devastating effects on marine communities.

Oxygen deficient water can affect the marine biota at two levels. It can have sub-lethal effects, such as reduced growth and feeding, and increased intermoult period in the rock-lobster population (Beyers *et al.* 1994). The oxygen-depleted subsurface waters characteristic of the southern and central Namibian shelf are an important factor determining the distribution of rock lobster in the area. During the summer months of upwelling, lobsters show a seasonal inshore migration (Pollock & Shannon 1987), and during periods of low oxygen become concentrated in shallower, better-oxygenated nearshore waters.

On a larger scale, periodic low oxygen events in the nearshore region can have catastrophic effects on the marine communities. Low-oxygen events associated with massive algal blooms can lead to large-scale stranding of rock lobsters, and mass mortalities of other marine biota and fish (Newman & Pollock 1974; Matthews & Pitcher 1996; Pitcher 1998; Cockroft *et al.* 2000). In March 2008, a series of red tide or algal blooms dominated by the (non-toxic) dinoflagellate *Ceratium furca* occurred along the central

Namibian coast (MFMR 2008). These bloom formations ended in disaster for many coastal marine species and resulted in what was possibly the largest rock lobster walkout in recent memory (Figure 9). Other fish mortalities included those of rock suckers, rock fish, sole, eels, shy sharks, and other animals such as octopuses and red bait, which were trapped in the low oxygen area below the surf zone (Louw 2008). The main cause for these mortalities and walkouts is oxygen starvation that results from the decomposition of huge amounts of organic matter. The blooms developed during a time where high temperatures combined with a lack of wind. These anoxic conditions were further exacerbated by the release of hydrogen sulphide - which is highly toxic to most marine organisms. Algal blooms usually occur during summer-autumn (February to April) but can also develop in winter during the 'bergwind' periods, when similar warm windless conditions occur for extended periods.

Figure 9: 'Walk-outs' and mass mortalities of rock lobsters at the central Namibian coast (Image source: Louw 2008).

2.2.10 Sulphur Eruptions

Closely associated with seafloor hypoxia, particularly off central Namibia, is the generation of toxic hydrogen sulphide and methane within the organically-rich, anoxic muds following decay of expansive algal blooms. Under conditions of severe oxygen depletion, hydrogen sulphide (H_2S) gas is formed by anaerobic bacteria in anoxic seabed muds (Brüchert *et al*. 2003). This is periodically released from the muds as 'sulphur eruptions', causing upwelling of anoxic water and formation of surface slicks of sulphur discoloured water (Emeis *et al*. 2004), and even the temporary formation of floating mud islands (Waldron 1901). Such eruptions are accompanied by a characteristic pungent smell along the coast and the sea takes on a lime green colour (Figure 10). These eruptions strip dissolved oxygen from the surrounding water column. Such complex chemical and biological processes are often associated with the occurrence of harmful algal blooms, causing large-scale mortalities to fish and crustaceans (see above).

Sulphur eruptions have been known to occur off the Namibian coast for centuries (Waldron 1901), and the biota in the area are likely to be naturally adapted to such pulsed events, and to subsequent hypoxia. However, satellite remote sensing has shown that eruptions occur more frequently, are more extensive and of longer duration than previously suspected, and that resultant hypoxic conditions last longer than thought (Weeks *et al*. 2002, 2004).

The role of micro-organisms in the detoxification of sulphidic water was investigated by a collaborative group of German and Namibian scientists. During a research cruise in January 2004, a sulphidic water mass covering 7 000 km^2 of coastal seafloor was encountered off the coast off Namibia. The surface waters, however, were well oxygenated. In the presence of oxygen, sulphide is oxidized and transformed into non-toxic forms of sulphur. An intermediate layer in the water column was discovered, which contained neither hydrogen sulphide nor oxygen. It was ascertained that sulphide diffusing upwards from the anoxic bottom water is consumed by autotrophic denitrifying bacteria below the oxic zone. The intermediate water layer is the habitat of detoxifying microorganisms, which by using nitrate transform sulphide into finely dispersed particles of sulphur that are non-toxic. Thus, the microorganisms create a buffer zone between the toxic deep water and the oxygenated surface waters. These results, however, also suggest that animals living on or near the seafloor in coastal waters may be affected by sulphur eruptions more often than previously thought, and that satellite imagery may underestimate the occurrence of sulphidic events as the hydrogen sulphide is consumed by bacteria before it reaches the sea surface.

It is suspected that a sulphur eruption was likely the cause of a mass mortality of sand mussels (*Donax serra*) observed on the beach at Conception Bay during a coastal trip between Lüderitz and Walvis Bay in August 2019.

Figure 10: Satellite image showing the project area (red square) in relation to discoloured water offshore of the Namib Desert resulting from a nearshore sulphur eruption (satellite image source: www.intute.ac.uk). Inset shows a photograph taken from shore at Sylvia Hill, north of Lüderitz, during such an event in March 2002 (photograph J. Kemper)

2.3 Biological Environment

Biogeographically the central Namibian coastline falls into the warm-temperate Namib Province, which extends northwards from Lüderitz into southern Angola (Emanuel *et al*. 1992). The project area is located in the nearshore Kuiseb Biozone (De Cauwer 2007), which extends from the shore to the -30 m depth contour (Figure 11). The coastal, wind-induced upwelling characterising the Namibian coastline, is the principle physical process which shapes the marine ecology of the central Benguela region. The Benguela system is characterised by the presence of cold surface water, high biological productivity, and highly variable physical, chemical and biological conditions (Barnard 1998). During periods of less intense winds off the northern Nambian coast (*Benguela Niños*), upwelling weakens and the warmer, more saline waters of the Angola Current intrude southwards along the coast introducing organisms normally associated with the subtropical conditions typical off Angola (Barnard 1998). As these events are typically temporary, the species of tropical west African origin associated with them will not be discussed here.

The distribution of benthic and coastal habitats off Namibia were mapped by Holness *et al.* (2014). The coastline of the project area comprises Kuiseb Intermediate Sandy Beach habitat, with isolated mixed shores being present at Meob Bay to the north and Black Rock to the south (Figure 12).

These habitats were subsequently assigned an ecosystem threat status (Figure 13, left) based on their level of protection and mapped (Figure 13, right). The beach habitats along the coast of the project area have been assigned a threat status of ‘Least Concern’ and are considered ‘Well Protected’. Only the isolated mixed shores on the headlands at Meob Bay and Black Rock are considered ‘Endangered’.

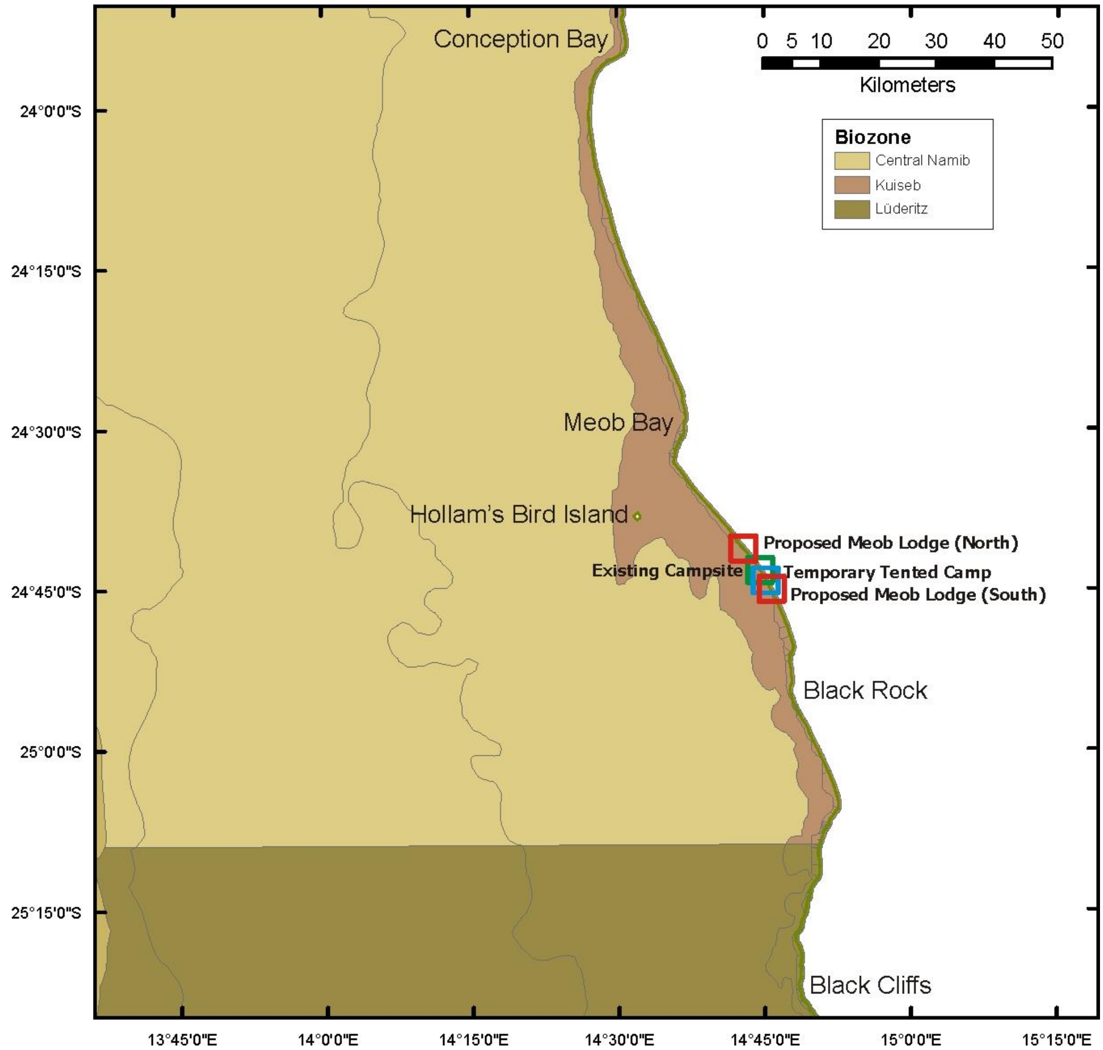


Figure 11: The project area in relation to the Namibian biozones (De Cauwer 2007; MFMR 2021).

The coastline of central Namibia is dominated by sandy beaches, with rocky habitats being represented only by occasional small rocky outcrops. Consequently, marine ecosystems along the coast comprise a limited range of habitats that include:

- sandy intertidal and subtidal substrates,
- intertidal rocky shores and subtidal reefs,
- mixed shores, and
- the water body.

The benthic communities within these habitats are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone. They consist of many hundreds of species, often displaying considerable temporal and spatial variability. The biological communities 'typical' of each 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 proposed project.

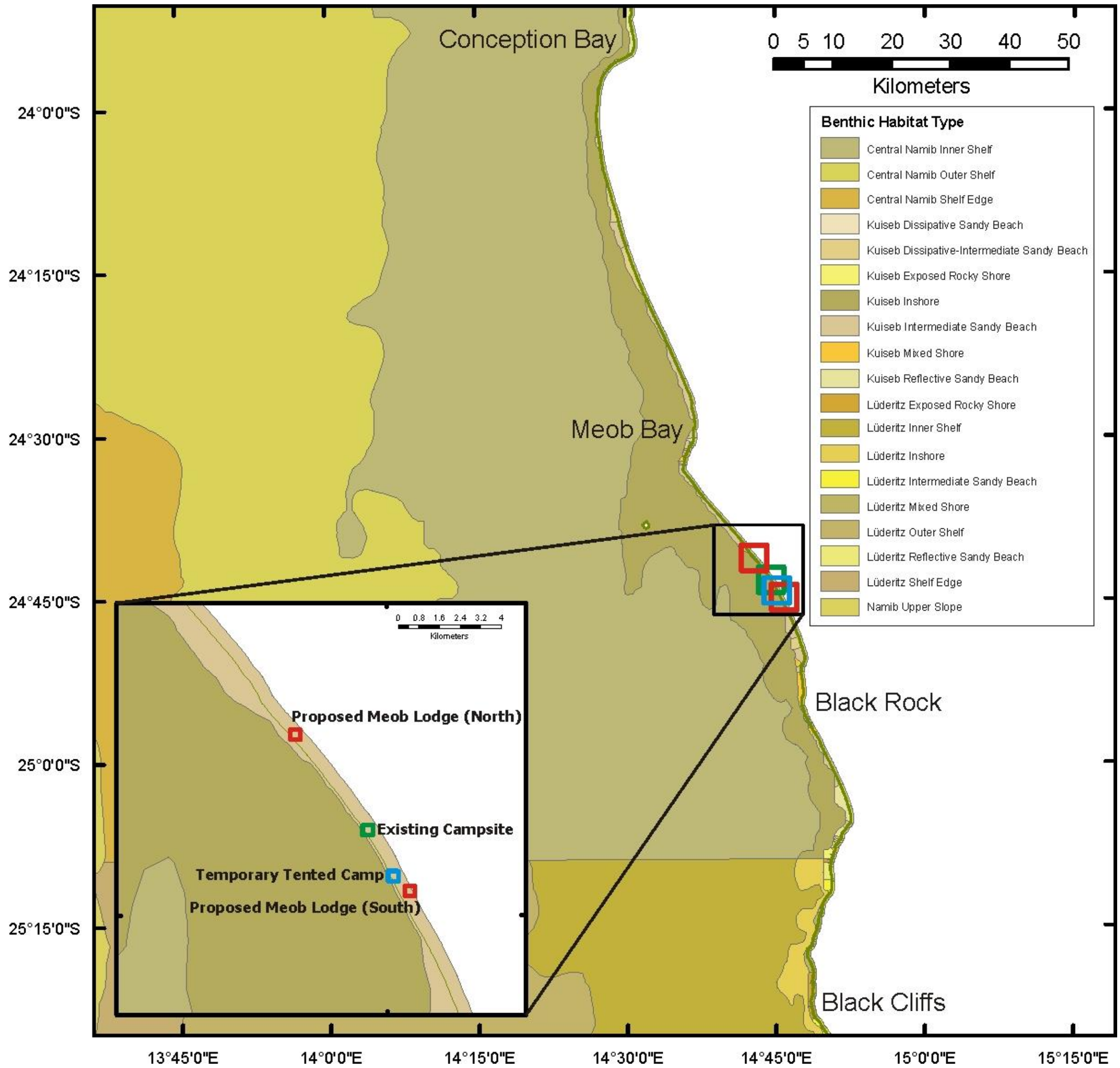


Figure 12: The project area in relation to the Namibian benthic and coastal habitats. Insert shows details of the coastal and nearshore habitats opposite the existing and proposed development (adapted from Holness *et al.* 2014).

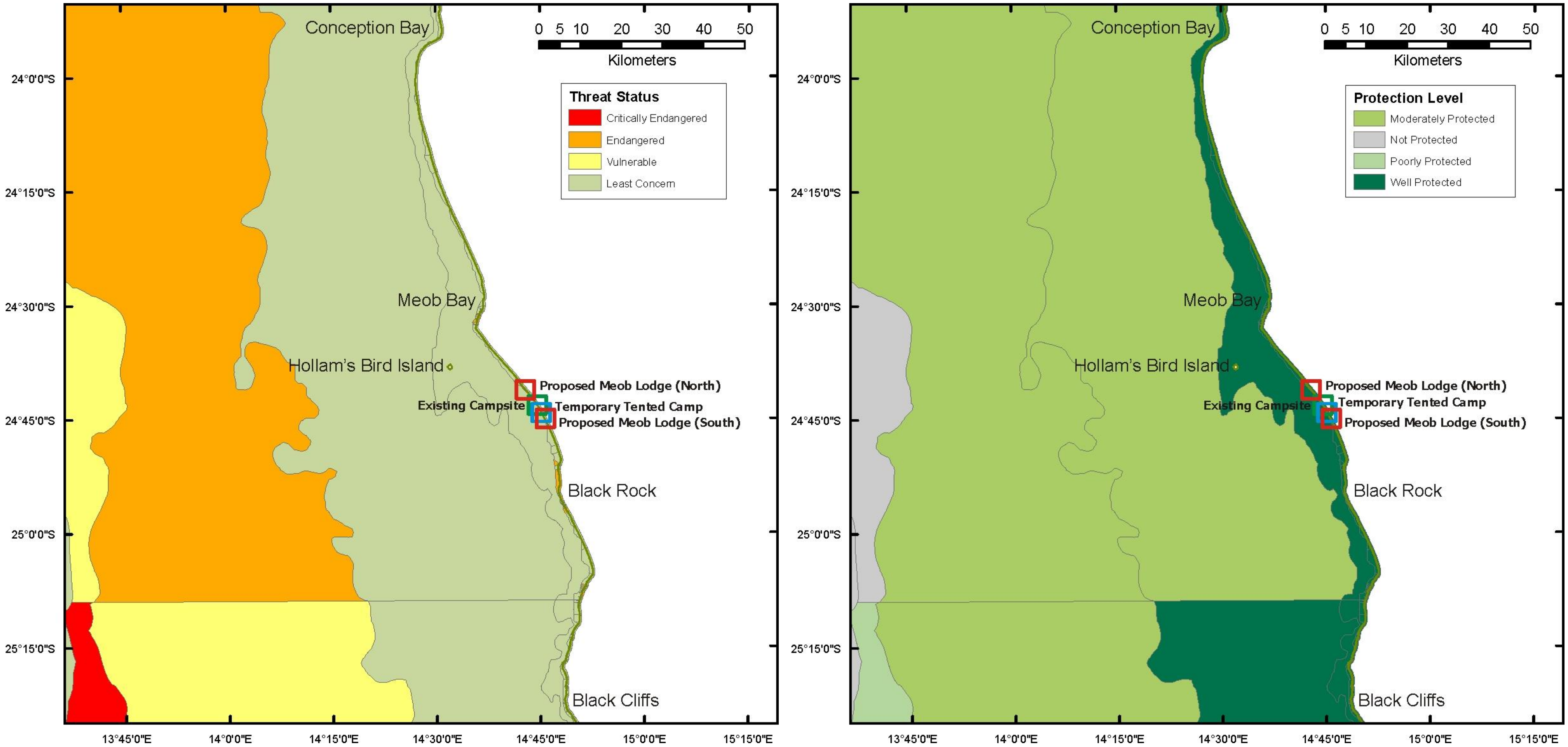


Figure 13: The project area in relation to ecosystem threat status (left) and protection levels (right) for coastal and offshore benthic habitat types off central Namibia (adapted from Holness *et al*. 2014).

2.3.1 Sandy Substrate Habitats and Biota

The benthic biota of soft bottom substrates constitutes invertebrates that live on (epifauna), or burrow within (infauna), the sediments, and are generally divided into megafauna (animals >10 mm), macrofauna (>1 mm) and meiofauna (<1 mm).

Intertidal Sandy Beaches

Sandy beaches are one of the most dynamic coastal environments. The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope and sand particle size, which is called beach morphodynamics.

Exposed sandy shores consist of coupled surf-zone, beach and dune systems, which together form the active littoral sand transport zone (Short & Hesp 1985). The nature of this zone is primarily dependent on two parameters that influence the rate of sand transport: wave energy and sediment particle size (Short & Wright 1983). Using a combination of these parameters, beaches can be classified into low, moderate and high wave energy environments, each with specific beach face characteristics. Wright *et al.* (1982) have combined these wave parameters and sediment characteristics into an index, the "dimensionless fall velocity", Ω (also referred to as Dean's parameter), which incorporates wave height and period, as well as sand grain size, to distinguish between different beach morphodynamic types. Microtidal beaches (beaches with a tidal range of 2 m or less) can be classified as either dissipative, intermediate or reflective beaches (McLachlan *et al.* 1993, Defeo & McLachlan 2005). Dissipative beaches (Ω>6) are characterised by fine sand, high waves and flat intertidal beach gradients. Wave energy is generally dissipated in the surf zone, so that the conditions experienced in the intertidal area are fairly calm. This generates slow swashes with long periods, resulting in less turbulent conditions on the gently sloping beach face. Such beaches harbour the richest intertidal faunal communities (McArdle & McLachlan 1991, 1992; McLachlan *et al.* 1993; Borzone *et al.* 1996). Reflective beaches (Ω<2), at the other extreme, are coarse grained (>500 µm sand) with narrow and steep intertidal beach faces. The shortened surf-zone results in most of the wave energy being dissipated in the intertidal area, and the waves break directly on the shore. This causes a high turnover of sand and a harsh intertidal climate, with resultant poor faunal communities. Intermediate beach conditions occur between Ω = 2 and 6 and have a very variable species composition (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 on beaches lacking a drift-line (Branch & Griffiths 1988; Field & Griffiths 1991). Although no direct measurements were made in the project area, the beaches to the north and south of Meob Bay would be classified as intermediate, with gently sloping beach gradients. However, as there is considerable small-scale spatial and temporal variability in wave energy, beach slope and sand particle size, beach macrofaunal communities are expected to be extremely dynamic, changing in community composition with natural alterations of physical state.

A number of studies have been conducted on sandy beaches in central Namibia, including Sandwich Harbour (Stuart 1975; Kensley & Penrith 1977), the Paaltjies (McLachlan 1985) and Langstrand (McLachlan 1985, 1986; Donn & Cockcroft 1989), beaches near Walvis Bay and Cape Cross (Donn & Cockcroft 1989), around the Areva Desalination plant near Wlotzkasbaken (Pulfrich 2007), between Mile 9 and Wlotzkasbaken (Pulfrich 2015) and south of Langstrand (Laird *et al.* 2018) and the recent surveys undertaken between Lüderitz and Walvis Bay as part of the Benguela Current Commission's (BCC) Project "Improving Ocean Governance in the Benguela Current Large Marine Ecosystem" (Kreiner *et al.* 2019). A further study by Tarr *et al.* (1985) investigated the ecology of three beaches further north on the Skeleton Coast. The results of these studies are summarised below.

Most beaches on the central Namibian coastline are open ocean beaches receiving continuous wave action. They are classified as exposed to very exposed on the 20-point exposure rating scale (McLachlan 1980), and intermediate to reflective and composed of well-sorted medium to coarse sands. The beaches tend to be characterised by well-developed berms, and are well-drained and oxygenated.

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, supplemented by data from central Namibian beach studies (Stuart 1975; Kensley & Penrith 1977; McLachlan 1985, 1986; Donn 1986; Donn & Cockcroft 1989; Pulfrich 2007, 2015; Laird *et al*. 2018; Kreiner *et al*. 2019) (Figure 14).

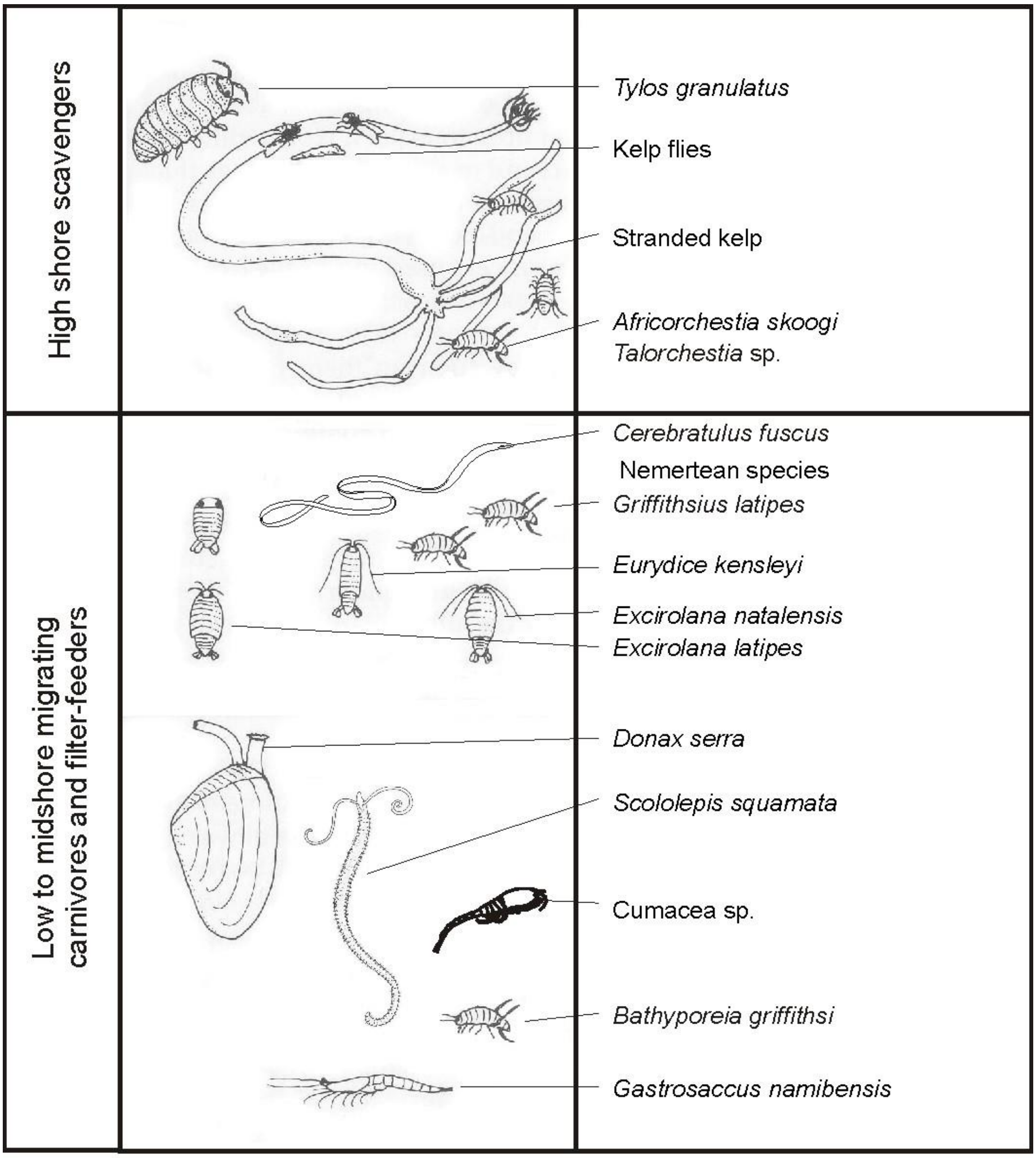


Figure 14: Schematic representation of the Central Namibian intertidal beach zonation (adapted from Branch & Branch 1981). Species commonly occurring on the central Namibian beaches and recorded at Spencer Bay and Conception Bay are listed.

The **supralittoral zone** is situated above the high water spring tide level, and receives water input only from large waves at spring high tides or through sea spray. The supralittoral is characterised by a mixture of air breathing terrestrial and semi-terrestrial fauna, often associated with and feeding on algal wrack 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*, the talitrid amphipods *Africorchestia quadrispinosa, A. skoogi* and *Talorchestia* sp., and the gamarrid amphipod *Bathyporeia griffithsi*. Community composition depends on the nature and extent of wrack, in addition to the physical factors structuring beach communities, as described above. Evidence of substantial populations of *Tylos granulatus* were observed at Meob Bay and along the sandy shoreline to and beyond Conception Bay, suggesting that this species contributes significantly to the macrofaunal biomass on the high shore.

The **intertidal zone**, also termed the mid-littoral zone, has a vertical range of about 2 m. This mid-shore region is characterised by the cirolanid isopods *Eurydice* (*longicornis*=) *kensleyi*, *Excirolana latipes* and *Excirolana natalensis*, the deposit-feeding polychaetes *Scolelepis squamata* and the amphipod *Griffithsius latipes*. In some areas, juvenile and adult sand mussels *Donax serra* (Bivalvia, Mollusca) may also be present in considerable numbers. Donn & Cockcroft (1989) reported that at Cape Cross this bivalve contributed 75% to the total macrofaunal biomass. A mass mortality of *D. serra* were recorded on the beach at Conception Bay in August 2019, suggesting that here too they contribute significantly to the biomass.

The surf zone in the study area is rich in phytoplankton (primarily dinoflagellates and diatoms) and zooplankton. Particulate organic matter is commonly deposited on the beaches as foam and scum. The organic matter, both in suspension and deposited on the sand, is thought to represent the main food input into these beaches, thereby accounting for the dominance of filter-feeders in the macrofaunal biomass (McLachlan 1985).

Most of the macrofaunal species recorded from beaches in central Namibia are ubiquitous throughout the biogeographic province, and no rare or endangered species are known. The invertebrate communities are similar to those recorded from beaches in southern Namibia (McLachlan & De Ruyck 1993; Nel *et al.* 1997; Meyer *et al.* 1998; Clark & Nel 2002; Clark *et al.* 2004; Pulfrich 2004a; Clark *et al.* 2005, 2006; Pulfrich & Atkinson 2007; Pulfrich *et al.* 2014, 2015; Pulfrich & Hutchings 2019, 2021). The mean abundance and biomass reported by Laird *et al.* (2018) for the Langstrand beach was 756 individuals/m^2 and 9.3 g/m^2 (dry weight), respectively. For Mile 9, north of Swakopmund Pulfrich (2015) reported much lower mean abundance and biomass values of 67 individuals/m^2 and 0.2 g/m^2 (dry weight), respectively, indicating the spatial variability of these parameters. The central Namibian beaches are all characterised by a relatively depauparate invertebrate fauna, both with regard to species diversity and biomass, which is typical of high-energy west coast beaches. Biomass values for Spencer Bay and Conception Bay were 1.4 g/m^2 (dry weight) and 2.8 g/m^2 (dry weight), respectively.

<u>Subtidal Sandy Habitats</u>

The intertidal zones described above, extend below the spring low water mark into the subtidal regions.

The **inner turbulent zone** extends from the low water spring tide level to about 2 m depth, and is characterised by highly motile specie. The bentho-planktic mysid *Gastrosaccus namibensis*, and Nemertean worms are typical of this zone, although they generally extend partially into the midlittoral above.

The **transition zone** spans approximately 2-3 m depth and marks the area to which the break point might move during storms. Extreme turbulence is experienced in this zone, and as a consequence this zone typically harbours the lowest diversity on sandy beaches. Typical fauna of this zone include the polychaetes *Nephtys hombergi* and *Glycera convoluta*, nemertean worms, various amphipod species including *Urothoe grimaldi*, and the isopods *Cirolana hirtipes* and *Eurydice (longicornis=) kensleyi*.

Below 3 m depth extends the **outer turbulent zone**, where turbulence is significantly decreased and which is marked by a sudden increase in species diversity and biomass. The abundance of polychaete and nemertean worms increases significantly from that in the transition zone. The three spot swimming crab *Ovalipes punctatus*, as well as the gastropods *Bullia laevissima* and *Natica forata* may be present.

In the subtidal region, the structure and composition of benthic soft bottom communities is primarily a function of water depth and sediment grain size, but other factors such as current velocity, organic content, and food abundance also play a role (Snelgrove & Butman 1994; Flach & Thomsen 1998; Ellingsen 2002).

With the exception of numerous studies on the benthic fauna of Walvis Bay lagoon (Kensley 1978; CSIR 1989, 1992; COWI 2003; Tjipute & Skuuluka 2006; Laird *et al.* 2018), there is a noticeable scarcity of published information on the subtidal soft sediment biota along the rest of the central Namibian coast. The only reference sourced was that of Donn & Cockcroft (1989) who investigated macrofauna to 5 m depth at Langstrand (see description for outer-turbulent zone above). In general, almost no scientific work on subtidal benthic communities has been done in the vicinity of the study area, or within the general region (J. Basson, MFMR, pers. comm.) and no further information could be obtained.

In the Meob Bay area, Kensley (1977) reported on the occurrence of drifts of *Panopea glycymeris* shells on a 10 km stretch of beach south of the rocky headland to the south of Meob Bay. The collected material suggested that the molluscs had recently died. Although no subtidal sampling was undertaken at the time (or since), Kensley (1977) concluded that there must be a relatively large population of *Panopea* living in the outer surf zone in the immediate vicinity of the Bay – a possible remnant population from times when warmer water occurred inshore along the northern and central Namibian coastline (Seely 2012). The closest neighbouring population occurs at Baia dos Tigres in Angola, more than 1 000 km to the north. Its presence in the northern portion of the Lüderitz upwelling cell has been attributed to a localised pocket of warm water, which is reported to accumulate periodically in Meob Bay (Kensley 1977; Currie *et al.* 2009; Seely 2012). It has been suggested that this may be through the seepage of warm (fresh?) water up through the subtidal sands (Seely 2012). Whether this population still exists today is not known, but considering the semi-permanent nature of the upwelling in the area and the increase in occurrence of sulphur eruptions, it seems unlikely.

Beyond the outer turbulent zone to 80 m depth, species diversity, abundance and biomass generally increases with communities being characterised equally by polychaetes, crustaceans and molluscs. The midshelf mudbelt is a particularly rich benthic habitat where biomass can attain 60 g/m^2 dry weight (Christie 1974; see also Steffani 2007b). The comparatively high benthic biomass in this mudbelt region represents an important food source to carnivores such as the mantis shrimp, cephalopods and demersal fish species (Lane & Carter 1999). In deeper water beyond this rich zone biomass declines to 4.9 g/m^2 at 200 m depth and then is consistently low (<3 g/m^2) on the outer shelf (Christie 1974).

Typical species occurring at depths of up to 60 m included the snail *Nassarius* spp., the polychaetes *Orbinia angrapequensis*, *Nepthys sphaerocirrata*, several members of the spionid genera *Prionospio*, and the amphipods *Urothoe grimaldi* and *Ampelisca brevicornis*. The bivalves *Tellina gilchristi* and *Dosinia lupinus orbignyi* are also common in certain areas. All these species are typical of the southern African West Coast (Christie 1974; 1976; McLachlan 1986; Parkins & Field 1998; Pulfrich & Penney 1999; Goosen *et al.* 2000; Savage *et al.* 2001; Steffani & Pulfrich 2004, 2007; Steffani 2007a;

2007b; Atkinson 2009; Steffani 2009a, 2009b, 2009c, 2010a, 2010b, 2010c; Atkinson *et al.* 2011; Steffani 2012a, 2012b, 2014; Karenyi 2014; Steffani *et al.* 2015; Biccard & Clark 2016; Biccard *et al.* 2016; Duna *et al.* 2016; Karenyi *et al.* 2016; Biccard *et al.* 2017, 2018; Gihwala *et al.* 2018; Biccard *et al.*2019; Giwhala *et al.* 2019) (Figure 15).

Whilst many empirical studies related community structure to sediment composition (e.g. Christie 1974; Warwick *et al.* 1991; Yates *et al.* 1993; Desprez 2000; van Dalfsen *et al.* 2000), other studies have illustrated the high natural variability of soft-bottom communities, both in space and time, on scales of hundreds of metres to metres (e.g. Kenny *et al.* 1998; Kendall & Widdicombe 1999; van Dalfsen *et al.* 2000; Zajac *et al.* 2000; Parry *et al.* 2003), with evidence of mass mortalities and substantial recruitments (Steffani & Pulfrich 2004a). It is likely that the distribution of marine communities in the mixed deposits of the coastal zone is controlled by complex interactions between physical and biological factors at the sediment–water interface, rather than by the granulometric properties of the sediments alone (Snelgrove & Butman 1994; Seiderer & Newell 1999). For example, off central Namibia it is likely that periodic intrusion of low oxygen water masses is a major cause of this variability (Monteiro & van der Plas 2006; Pulfrich *et al.* 2006). Although there is a poor understanding of the responses of local continental shelf macrofauna to low oxygen conditions, it is safe to assume that in areas of frequent oxygen deficiency the communities will be characterised by species able to survive chronic low oxygen conditions, or colonising and fast-growing species able to rapidly recruit into areas that have suffered complete oxygen depletion. Local hydrodynamic conditions, and patchy settlement of larvae, will also contribute to small-scale variability of benthic community structure.

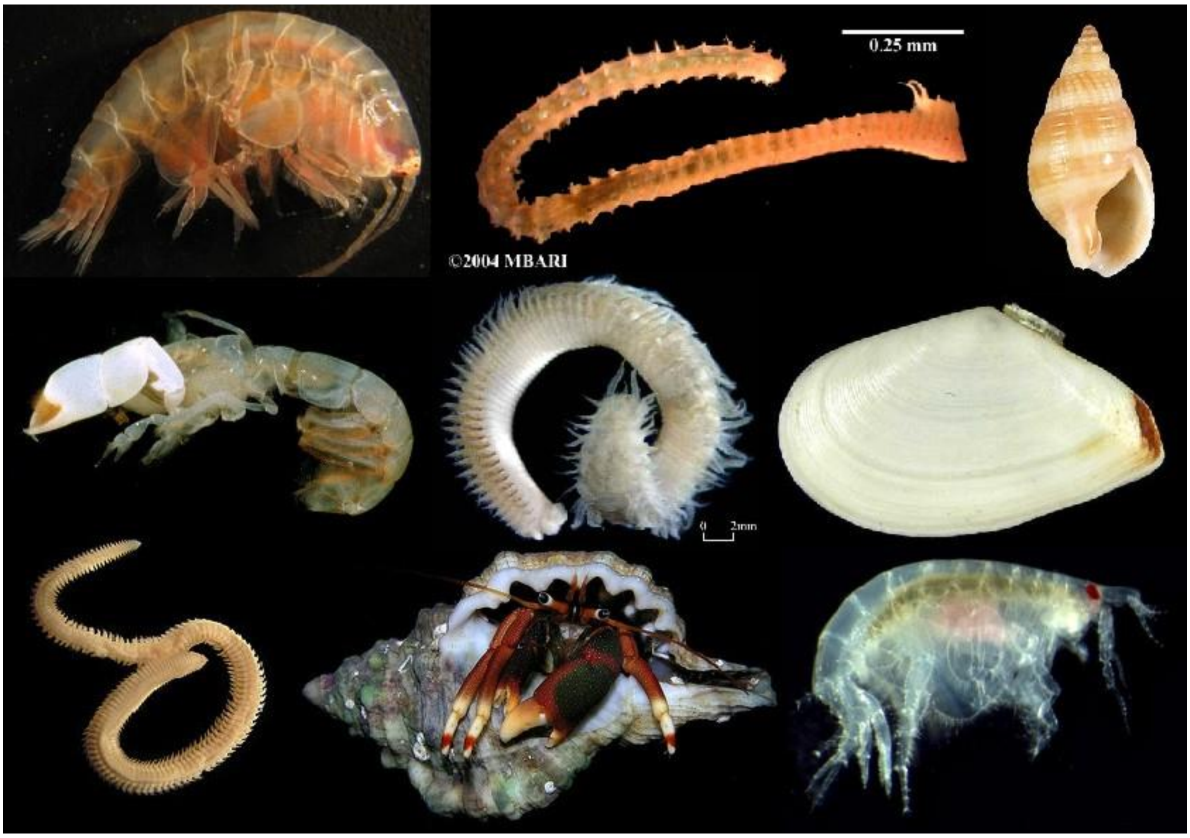


Figure 15: Benthic macrofaunal genera commonly found in nearshore sediments include: (top: left to right) *Ampelisca*, *Prionospio*, *Nassarius*; (middle: left to right) *Callianassa*, *Orbinia*, *Tellina*; (bottom: left to right) *Nephtys*, hermit crab, *Bathyporeia*.

It is evident that an array of environmental factors and their complex interplay is ultimately responsible for the structure of benthic communities. Yet the relative importance of each of these factors is difficult to determine as these factors interact and combine to define a distinct habitat in which the animals occur. However, it is clear that water depth and sediment composition are two of the major components of the physical environment determining the macrofauna community structure off southern Namibia (Steffani & Pulfrich 2004, 2007; Steffani 2007a, 2007b, 2009a, 2009b, 2009c, 2010a, 2010b, 2010c, 2011, 2012a, 2012b, 2014; Steffani *et al.* 2015.). However, in the deepwater shelf areas off central Namibia, it is likely that occurrence of oxygen minimum zones (OMZs) and the periodic intrusion of low oxygen water masses will play a major role in determining variability in community structure (Monteiro & van der Plas 2006).

Specialised benthic assemblages (protozoans and metazoans) can thrive in OMZs (Levin 2003), and many organisms have adapted to low oxygen conditions by developing highly efficient ways to extract oxygen from depleted water. Within OMZs, benthic foraminiferans, meiofauna and macrofauna typically exhibit high dominance and relatively low species richness. In the OMZ core, where oxygen concentration is lowest, macrofauna and megafauna (>10 cm) often have depressed densities and low diversity, despite being able to form dense aggregations at OMZ edges (Levin 2003, Levin *et al.* 2009). Taxa most tolerant of severe oxygen depletion (~0.2 ml/ℓ) include calcareous foraminiferans, nematodes, and polychaetes, with agglutinated protozoans, harpacticoid copepods, and calcified invertebrates typically being less tolerant. Small-bodied animals, with greater surface area for O_2 adsorption, are thought to be more prevalent than large-bodied taxa under conditions of permanent hypoxia as they are better able to cover their metabolic demands and often able to metabolise anaerobically (Levin 2003). Meiofauna may thus increase in dominance in relation to macro- and megafauna. This was not the case, however, within the lower OMZs of the Oman (Levin *et al.* 2000) and Pakistan margins (Levin *et al.* 2009), where the abundant food supply in the lower or edge OMZs is thought to be responsible for promoting larger macrofaunal body size.

There is a poor understanding of the responses of local continental shelf macrofauna to low oxygen conditions, as very little is known about the benthic fauna specific to the Namibian OMZ. It is safe to assume that in areas of frequent oxygen deficiency the communities will be characterised by species able to survive chronic low oxygen conditions, or colonising and fast-growing species able to rapidly recruit into areas that have suffered complete oxygen depletion. Local hydrodynamic conditions, and patchy settlement of larvae, will also contribute to small-scale variability of benthic community structure.

Data collected from between 150 m and 300 m depth offshore of the area between Meob Bay and Conception Bay showed that overall species richness of benthic macrofauna assemblages was relatively low and strongly dominated by polychaetes, particularly the spionid polychaete *Paraprionospio pinnata*. This species is dominant in oxygen-constrained environments worldwide. Crustaceans were poorly represented, both in terms of abundance and biomass (Steffani 2011). The phyla distribution is generally in common with other OMZs around the world.

Demersal Invertebrate and Fish Species

Also associated with soft-bottom substrates are demersal communities that comprise bottom-dwelling invertebrate and vertebrate species, most of which are dependent on the invertebrate benthic macrofauna as a food source.

As many as 110 species of bony and cartilaginous fish have been identified in the demersal communities on the continental shelf of the southern African West Coast (Roel 1987). Changes in fish communities occur with increasing depth (Roel 1987; Smale *et al.* 1993; Macpherson & Gordoa 1992; Bianchi *et al.* 2001; Atkinson 2009), with the most substantial change in species composition occurring in the shelf break region between 300 m and 400 m depth (Roel 1987; Atkinson 2009). Common commercial demersal species found mostly on the continental shelf include both the shallow-water hake, *Merluccuis capensis* and the deep-water hake (*Merluccius paradoxus*), monkfish (*Lophius vomerinus*), and kingklip (*Genypterus capensis*). There are also many other demersal "bycatch" species that include jacopever (*Helicolenus dactylopterus*), angelfish/pomfret (*Brama brama*), kingklip (*Genypterus capensis*) and gurnard (*Chelidonichtyes* sp), as well as several cephalopod species (such as squid and cuttlefishes) and many elasmobranch (sharks and rays) species (Compagno *et al*. 1991). Roel (1987) showed seasonal variations in the distribution ranges shelf communities, with species such as the pelagic goby *Sufflogobius bibarbatus*, and West Coast sole *Austroglossus microlepis* occurring in shallow water during summer only. Atkinson (2009) identified two long-term community shifts in demersal fish communities; the first (early to mid-1990s) being associated with an overall increase in density of many species, whilst many species decreased in density during the second shift (mid-2000s). These community shifts correspond temporally with regime shifts detected in environmental forcing variables (Sea Surface Temperatures and upwelling anomalies) (Howard *et al*. 2007).

2.3.2 Rocky Habitats and Biota

Intertidal Rocky Shores

The central coast of Namibia is bounded to the east by the Namib Desert and is characterised primarily by shifting dunes. In common with most semi-exposed to exposed coastlines on the southern African west coast, the rocky shores that occur in the region are strongly influenced by sediments, and 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 only 6.3% to the total Namibian shoreline habitats (Holness *et al*. 2014). In the study area, mixed shores are limited to the headlands at Meob Bay and Black Rock.

Typically, the intertidal area of rocky shores can be divided into different zones according to height on the shore. Each zone is distinguishable by its different biological communities, which is largely a result of the different exposure times to air. The level of wave action is particularly important on the low shore. Generally, biomass is greater on exposed shores, which are dominated by filter-feeders. Sheltered shores support lower biomass, and algae form a large portion of this biomass (McQuaid & Branch 1984; McQuaid *et al*. 1985).

Mixed shores incorporate elements of the trophic structures of both rocky and sandy shores. As fluctuations in the degree of sand coverage are common (often adopting a seasonal affect), the fauna and flora of mixed shores are generally impoverished when compared to more homogenous shores. The macrobenthos is characterized by sand-tolerant species whose lower limits on the shore are determined by their abilities to withstand physical smothering by sand (Daly & Mathieson 1977; Dethier 1984; van Tamelen 1996). The rocky shores along the coastline around Meob Bay are heavily influenced by mobile sediments. Patchy dominance in the mid- and low-shore by ephemeral green algae (*Ulva* spp., *Cladophora* spp.) also suggest that these shores are periodically smothered by sands, as these algae proliferate as soon as sediments are eroded away.

During the BCC Coastal Biodiversity survey undertaken in August 2019 (Kreiner *et al*. 2019b), four zones were identified at the rocky shore at Meob Bay (Figure 16, left): "Porphyra", "Barnacle", "Mussel" and "Algal mix". The "Porphyra" zone was dominated by diatoms with 28% coverage, followed by *Porphyra sp*. covering 4.5% (10% canopy cover). Typical species in this high shore zone included the tiny snail *Afrolittorina knysnaensis*, the false limpet *Siphonaria capensis*, the limpet *Scutellastra granularis*, and dense stands of the invasive alien barnacle *Balanus glandula*. The "Barnacle" zone was covered 71% by *Balanus glandula* followed by *Scutellastra granularis* with 4.4% and *Siphonaria capensis* with 4%. Algae were represented by the ephemeral green alga *Cladophora* sp. and the red alga *Caulacanthus ustulatus*. The "Mussel" zone was dominated by the invasive alien mussel *Semimytilus algosus*, covering 92% (Figure 16, right), with 4.2% cover from *Balanus glandula,* as well as minor representation by the sand tolerant anemone *Bunodactis reynaudi* and reef-buidling polychaete *Gunnarea gaimardi*, which depends on sand particles to construct its tubes. Grazers were represented by the limpet *Scutellastra granularis*. Algae were represented by the ephemeral green alga *Cladophora* sp. and the red algae *Caulacanthus ustulatus* and *Callithamnion collabens*. The "Algal mix" zone was also dominated by *Semimytilus algosus*, covering 82%, followed by *Polyopes constrictus* with 6%. Other algae present in the low shore included *Ulva*, spp., *Pachymenia orbitosa*, *Mazella capensis* and *Ceramium* sp.. Of interest was the complete lack of predatory gastropods (e.g. *Nucella* spp., *Burnupena* spp.) at the Meob Bay rocky shore. The predatory gastropod *Burnupena* sp., which is common on rocky shores, is also found on mixed shores due to its adaptive ability of both moving over sand as well as burrowing into it. Absence of these species at Meob Bay is likely due to the dense stands of *Semimytilus* dominating most of the mid- and low shore.

Many of the more sand-tolerant and opportunistic foliose algal genera (e.g. *Ulva* spp., *Polyopes constrictus*, *Pachymenia orbitosa*, *Mazella capensis*) have mechanisms of growth, reproduction and perennation that contribute to their persistence on sand-influenced shores (Daly & Matheison 1977; Airoldi *et al*. 1995; Anderson *et al*. 2008). Of the intertidal limpets, only *Siphonaria capensis* extends its distribution into regions where sand deposition is a regular occurrence (Marshall & McQuaid 1989). The mixed-shore habitat also provides important refuges for opportunistic species capable of sequestering, but susceptible to elimination by competition in more uniform intertidal environments.

Figure 16: Typical sand-influenced intertidal rocky shores at Meob Bay.

Also of interest is the prevalence of two alien invasive species, the acorn barnacle *Balanus glandula* and the bisexual mussel *Semimytilus algosus*. The acorn barnacle 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). It has now spread north into southern and central Namibia, having been recorded along the coastline of the Tsau//Khaeb (Sperrgebiet) National Park (A. Pulfrich pers. obs.) and northward into the Namib-Naukluft National Park (Kreiner *et al*. 2019a). Although native to the Pacific (west) coast of South America, *Semimytilus algosus* has been known to be present in central Namibia since the 1930s. On rocky shores north of Swakopmund, it has become the dominant filter feeder in the low shore at many localities (A. Pulfrich unpublished data; Ma *et al*. 2020a, 2020b). In South Africa (de Greef *et al*. 2013), the species has become the numerically dominant filter feeder, accounting for 73% of all mussels sampled and reaching densities exceeding 190 000 individuals m^{-2} in areas of high spat settlement.

Although not directly harbouring any rare faunal or floral species, rocky intertidal shores are food-rich habitats for seabirds and wetland birds, attracting higher numbers of birds than the surrounding sandy beaches. Rocky intertidal fauna most sensitive to disturbance are the large limpet species. They tend to be the first ones eliminated by disturbance and the last to recover because of possible narrow tolerance limits to changes in environmental conditions. They act as keystone species on rocky shore, controlling the abundance of foliose algae and hence many other species (Branch & Branch 1981).

Rocky shore sampling at Spencer Bay to the south of the project area, revealed similar zonation and species representation than that recorded at Meob Bay, although the diversity was higher (Kreiner *et al*. 2019b). This was likely due to the more exposed nature of the shores in Spencer Bay and the significantly lower cover by *Semimytilus*. At Spencer Bay, the dominant filter feeder was the alien mussel *Mytilus galloprovincialis*, which has become the primary space occupier on more exposed shores. First recorded in 1979 (although it is likely to have arrived in the late 1960s), it is now the most abundant and widespread invasive marine species spreading along the entire West 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, 2003b, 2005). None of the species found during the various surveys undertaken of rocky intertidal or mixed shores are vulnerable locally or regionally.

Nearshore Subtidal Reefs

The biological 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

Reports on the benthic biota of nearshore reefs in Namibia are restricted primarily to research undertaken in the vicinity of Lüderitz (Beyers 1979; Tomalin 1995; Pulfrich 1998; Pulfrich & Penney 1998, 1999b, 2001), and off Swakopmund (Pulfrich & Steffani 2008; B-4 Engineering & Diving 2014). No scientific surveys have been undertaken of rocky subtidal habitats in the study area.

Around Lüderitz Bay and northwards towards Sylvia Hill, rocky subtidal habitats are dominated by kelp beds *(Laminaria pallida* and *Ecklonia maxima*). As wave exposure in the region is very high, kelp beds play a major role in absorbing and dissipating much of the wave energy reaching the shore, thereby providing important semi-exposed and sheltered habitats for a wide diversity of both marine flora and fauna. The community structure of the subtidal benthos in the bays around Lüderitz is typical of the southern African West Coast kelp bed environment. In the inshore zone, the benthos is largely dominated by algae, in particular the kelp *L. pallida*, which forms a canopy to a height of about 2 m in the immediate subtidal region to a depth of ~10 m. *Ecklonia maxima*, which is the dominant species along the southern South African coastline is poorly represented in southern Namibia. 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. These plants and animals all have specialised habitat and niche requirements, and together form complex communities with highly inter-related food webs.

The sublittoral invertebrate fauna is dominated by suspension and filter feeders, such as the ribbed mussel *Aulacomya ater* and Cape Reef worm *Gunnarea capensis*, a variety of sponges and echinoderms. Grazers are less common with most herbivory being restricted to grazing of juvenile algae or debris feeding of detached macrophytes. The dominant grazer is the sea urchin *Parechinus angulosus*, with lesser pressure from limpets, and a variety of isopods and amphipods. Key predators in the sublittoral include the commercially important rock lobster *Jasus lalandii*. Due to their preference for reef habitats, the abundance of rock lobster **decreases** sharply to the north of 25°S (Pollock & Beyers 1981). Although their distribution is reported to extend as far as Walvis Bay (Heydorn 1969), abundances in the Meob Bay area are thus expected to be low due to the dominance of sandy coastline and sparseness of nearshore reefs. Nearshore reefs in the project area are reported to comprise underlying reefs in the surf zone along the otherwise sandy beach (Currie *et al.* 2009).

2.3.4 Pelagic Communities

The pelagic communities are typically divided into plankton and fish, and their main predators, marine mammals (seals, dolphins and whales), seabirds and turtles.

<u>Plankton</u>

Plankton is particularly abundant in the shelf waters off Namibia, being associated with the upwelling characteristic of the area. Plankton range from single-celled bacteria to jellyfish of 2-m diameter, and include bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton.

Off the Namibian coastline, phytoplankton are the principle primary producers with mean annual productivity being comparatively high at 2 g C/m^2/day. The phytoplankton is dominated by diatoms, which are adapted to the turbulent sea conditions. Diatom blooms occur after upwelling events, whereas dinoflagellates are more common in blooms that occur during quiescent periods, since they can grow rapidly at low nutrient concentrations (Barnard 1998). A study on phytoplankton in the surf zone off two beaches in the Walvis Bay and Cape Cross area showed relatively low primary production values of only 10-20 mg C/m^2/day compared to those from oceanic waters. This was attributed to the high turbidity in this environment (McLachlan 1986). In the surf zone, diatoms and dinoflagellates are nearly equally important members of the phytoplankton, and some silicoflagellates are also present. Charateristic species belong to the genus *Gymnodinium*, *Peridinium*, *Navicula*, and *Thalassiosira* (McLachlan 1986).

Namibian zooplankton reaches maximum abundance in a belt parallel to the coastline and offshore of the maximum phytoplankton abundance. Samples collected over a full seasonal cycle (February to

December) along a 10 to 90-nautical-miles transect offshore Walvis Bay showed that the mesozooplankton (<2 mm body width) community included egg, larval, juvenile and adult stages of copepods, cladocerans, euphausiids, decapods, chaetognaths, hydromedusae and salps, as well as protozoans and meroplankton larvae (Hansen *et al.* 2005). Copepods are the most dominant group making up 70–85% of the zooplankton. The four dominant calanoid copepod species, in order of abundance, are *M. lucens*, *C. carinatus*, *R. nasutus* and *Centropages* spp. During the period of intense upwelling, the two herbivorous species, *C. carinatus* and *R. nasutus*, increase in abundance inshore, leading to a shift in dominance from *C. carinatus* to *M. lucens* with increasing distance offshore. Seasonal patterns in copepod abundance, with low numbers during autumn (March–June) and increasing considerably during winter/early summer (July–December), appear to be linked to the period of strongest coastal upwelling in the northern Benguela (May–December), allowing a time lag of about 3–8 weeks, which is required for copepods to respond and build up large populations (Hansen *et al.* 2005). This suggest close coupling between hydrography, phytoplankton and zooplankton. Timonin *et al.* (1992) described three phases of the upwelling cycle (quiescent, active and relaxed upwelling) in the northern Benguela, each one characterised by specific patterns of zooplankton abundance, taxonomic composition and inshore-offshore distribution. It seems that zooplankton biomass closely follows the changes in upwelling intensity and phytoplankton standing crop. Consistently higher biomass of zooplankton occurs offshore to the west and northwest of Walvis Bay (Barnard 1998).

Ichthyoplankton constitutes the eggs and larvae of fish. As the preferred spawning grounds of numerous commercially exploited fish species are located off central and northern Namibia (Figure 17), their eggs and larvae form an important contribution to the ichthyoplankton in the region. Phytoplankton, zooplankton and ichthyoplankton abundances in the project area will be seasonally high, with diversity increasing in the vicinity of the confluence between the Angola and Benguela currents and west of the oceanic front and shelf-break. In particular, the Meob Bay area has been identified as a spawning area for small pelagic species, cob and hake (see Figure 17).

Pelagic Fish

The surf zone and outer turbulent zone habitats of sandy beaches are considered to be important nursery habitats for marine fishes (Modde 1980; Lasiak 1981; Clark *et al.* 1994). However, the composition and abundance of the individual assemblages seems to be heavily dependent on wave exposure (Blaber & Blaber 1980; Potter *et al.* 1990; Clark 1997a, 1997b). Although no studies have been undertaken in the project area, surf zone fish communities off the coast of central Namibia have been studied at Langstrand (McLachlan 1986; Romer 1988), between Mile 9 and Wlotzkasbaken (Pulfrich 2015) and south of Langstrand to the Walvis Bay Naval Base (Laird *et al.* 2018). Species from the surf zone off Langstrand beach and further south included galjoen (*Dichistius capensis*), West Coast steenbras (*Lithognathus aureti*), flathead mullet (*Mugil cephalus*), southern mullet (*Chelon richardsonii*) and Cape silverside (*Atherina breviceps*) (McLachlan 1986; Romer 1988; Laird *et al.* 2018). The Cape silverside is a small shoaling fish and an important prey species for piscivorous birds and fish. The size composition of the catches confirmed that most of these species utilize the surf zone in the area as a nursery. The presence of abundant suitable prey items for juvenile fish (principally beach mysids, amphipods and bivalves) and predator avoidance were considered important factors in the suitability of Namibian surf zones as fish nursery habitats (Romer 1988). Laird *et al.* (2018) concluded that the value of the surf-zone habitat for juvenile fish improves northwards as wave exposure increases and a surf-zone develops. The surf-zone and increased habitat heterogeneity due to the presence of rocky shore and reefs provides both shelter from predation and increased food availability for fish.

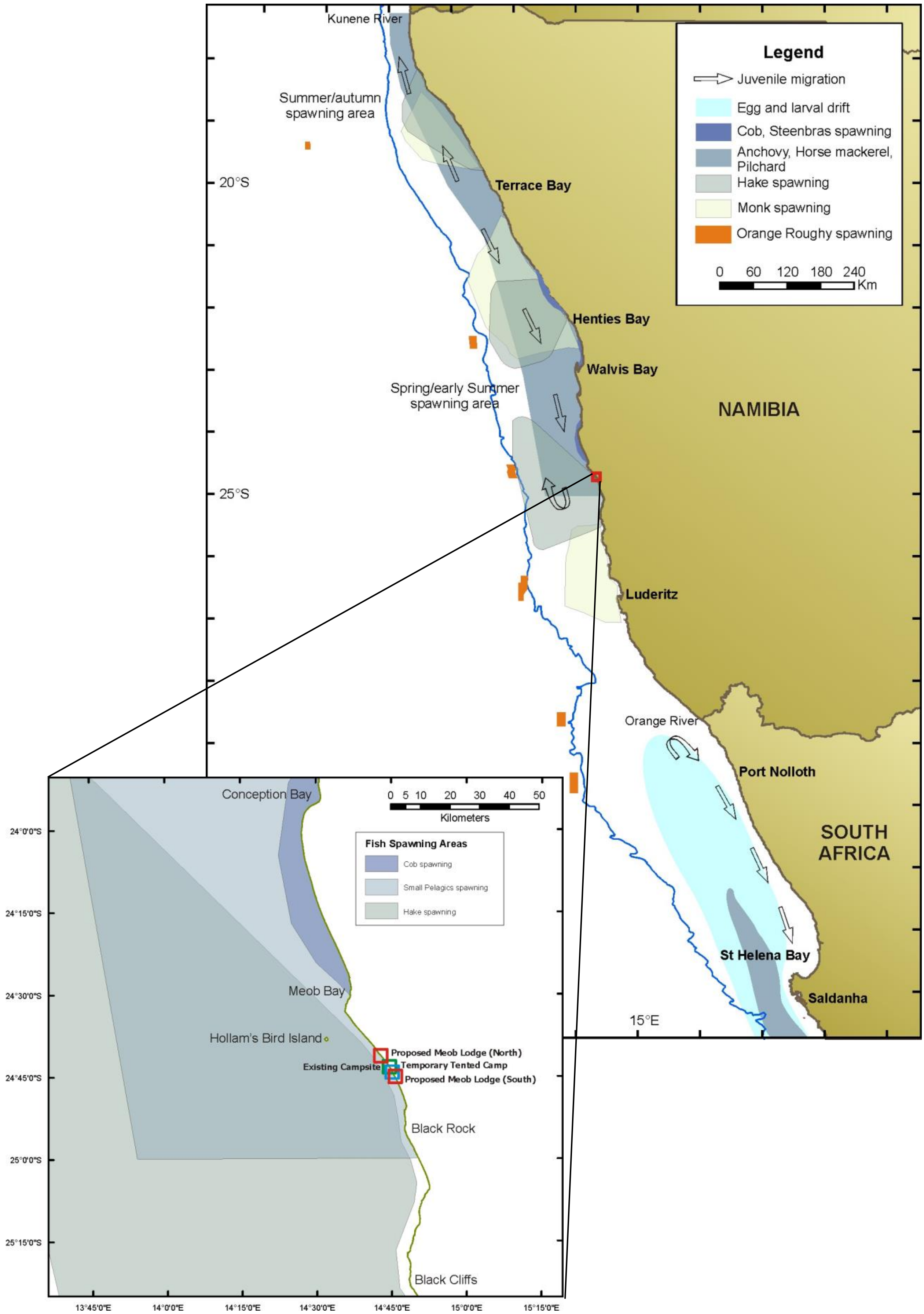


Figure 17: The project location (red square) in relation to major spawning areas in the Benguela region (adapted from Cruikshank 1990; Hampton 1992; MFMR 2021). Insert shows details in the Meob Bay area (adapted from MFMR 2021).

North of Mile 9 the surf zone fish catches were more diverse with silver kob (*Argyrosomus inodorus*), Blacktail (*Diplodus capensis*), elf (*Pomatomus saltatrix*), bluntnose guitarfish (*Rhinobatos blochii*) and maned blennie (*Scartella emarginata*) also being reported (Pulfrich 2015). Off Cape Cross only two species were recorded, these being sandsharks (*Rhinobatos annulatus*) and West Coast steenbras. Many of these species are important in the catches of recreational and/commercial net fisheries and linefisheries in Namibia (Kirchner *et al*. 2000; Holtzhausen *et al*. 2001, Stage & Kirchner 2005).

Available data suggest that that there have not been major changes in the fish community composition utilizing the nearshore surf zone nursery areas in the Walvis Bay-Swakopmund area. However, ongoing overexploitation of fish stocks could have played a role in reducing the spawner biomass and reproductive output of inshore Namibian fish stocks (Holtzhausen *et al*. 2001, Kirchner 2001). Sulphur eruptions/low oxygen events (e.g. February and March 2018) also result in large fish kills in the study area and may have contributed to reduced catches during some surveys. If such events occur after the spring summer spawning season, the abundance of juvenile fish in the nearshore habitats would be substantially reduced.

A number of the nearshore teleost and chondrichthyan species are considered 'Near Threatened' or 'Vulnerable' (are resident in the surf zone. Larvae are thought to drift north with the current to the nursery and juvenile area off the Dorob National Park.

Table 2).

The biological, behavioural and life-history characteristics of the three most important linefish species in Namibian coastal waters are summarised below.

Silver kob *Argyrosomus inodorus* are distributed from northern Namibia to the warm temperate / subtropical transition zone on South Africa's east coast (Griffiths & Heemstra 1995). Four stocks have been identified, one in Namibia, with its core distribution from Cape Frio in the north to Meob Bay in the south (Kirchner 2001). Spawning occurs throughout the year but mostly in the warmer months from October to March when water temperatures are above 15°C and large adult fish occur in the nearshore, particularly in the identified spawning areas of Sandwich Harbour and Meob Bay. Adults are migratory whereas juveniles are resident in the surf zone. Larvae are thought to drift north with the current to the nursery and juvenile area off the Dorob National Park.

Table 2: Some of the more important linefish species likely to occur off Central Namibia. The Global IUCN Conservation Status is also provided.

Common Name	Species	IUCN Conservation Status
Teleosts		
Silver kob	*Argyrosomus inodorus*	Vulnerable
Elf	*Pomatomus saltatrix*	Vulnerable
Galjoen	*Dichistius capensis*	Not Assessed*
West Coast steenbras	*Lithognathus aureti*	Near threatened
West coast dusky kob	*Argyrosomus coronus*	Data deficient
Chondrichthyans		
Bronze whaler	*Carcharhinus brachyurus*	Near threatened
Six gill shark	*Hexanchus griseus*	Near threatened
Spotted gullyshark	*Triakis megalopterus*	Near threatened
Smooth houndshark	*Mustelus mustelus*	Vulnerable

Common Name	Species	IUCN Conservation Status
Broadnose seven-gill cow shark	*Heptranchias perlo*	Near threatened

*assessed as 'Near Threatened' in the RSA National Assessment

West coast dusky kob *Argyrosomus coronus* are distributed from northern Namibia to northern Angola (Griffiths & Heemstra 1995), but do occur as far south as St Helena Bay in South Africa (Lamberth *et al*. 2008). Early juveniles frequent muddy sediments in 50-100 m depth, moving inshore once they reach 300 mm total length. These juveniles and adolescents are resident in the nearshore, and are especially abundant in the turbid plume off the Cunene River Mouth and in selected surf zones of northern and central Namibia (Potts *et al*. 2010). The adults are migratory according to the movement of the Angola-Benguela frontal zone, moving northwards as far as Gabon in winter and returning to southern Angola in spring where spawning occurs in the offshore (Potts *et al*. 2010).

West Coast steenbras *Lithognathus aureti* are endemic to the west coast of southern Africa, but rarely found outside Namibia's territorial waters (Holtzhausen 2000). Tagging studies have indicated that *L. aureti* comprise two separate closed populations; one in the vicinity of Meob Bay and one from central Namibia northwards (Holtzhauzen *et al*. 2001). The Meob Bay population shows distinct differences in growth rates, otolith morphology, size at maturity, sex ratios and length-at-age to the more northern population (Currie *et al*. 2009) and significant genotypic differentiation between the two populations has been demonstrated (van der Bank & Holzhausen 1999). Spawning localities are as yet unknown but tagging evidence suggests that males migrate considerable distances in search of gravid females (Holtzhausen 2000). The Meob Bay population of West Coast Steenbras is considered unique and requiring protection (Currie *et al*. 2009).

The spawning habitat of West coast steenbras is thought to also be limited. The bulk of the population exists in the nearshore at <10 m depth, with juveniles occurring in the intertidal surf zone (McLachlan 1986). By inference, spawning occurs in the surf zone and eggs and larvae from both populations drift northwards (Holtzhausen 2000). Whereas juveniles occur in the surf zone throughout its range, spawning habitat may be extremely limited and has yet to be clearly identified.

Small pelagic species include the sardine/pilchard (*Sardinops sagax ocellatus*) (Figure 18, left), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) (Figure 18, right) and round herring (*Etrumeus whiteheadi*). These species typically occur in mixed shoals of various sizes (Crawford *et al*. 1987), and generally occur within the 200 m contour, although they may often be found very close inshore, just beyond the surf zone. They spawn downstream of major upwelling centres in spring and summer, and their eggs and larvae are subsequently carried up the coast in northward flowing waters. Historically, two seasonal spawning peaks for pilchard occurred; the first from October to December in an inshore area between Walvis Bay and Palgrave Point and the second from February to March near the 200 m isobath between Palgrave Point and Cape Frio. However, since the collapse of the pilchard stock, spawning in the south has decreased (Crawford *et al*. 1987). 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 pelagic fish is highly variable both within and between species. The Namibian pelagic stock is currently considered to be in a critical condition due to a combination of over-fishing and unfavourable environmental conditions as a result of Benguela Niños.

Since the collapse of the pelagic fisheries, jellyfish biomass has increased and the structure of the Benguelan fish community has shifted, making the bearded goby (*Sufflogobius bibarbatus*) the new predominant prey species. Gobies have a high tolerance for low oxygen and high H_2S levels, which enables them to feed on benthic fauna within hypoxic waters during the day, and then move to oxygen-richer pelagic waters at night, when predation pressure is lower, to feed on live jellyfish (Utne-Palm *et al*. 2010; van der Bank *et al*. 2011).

Two species that migrate along the southern African West Coast following the shoals of anchovy and pilchards are snoek *Thyrsites atun* and chub mackerel *Scomber japonicus*. Their appearance along the Namibian coast is highly seasonal. Snoek are voracious predators occurring throughout the water column, feeding on both demersal and pelagic invertebrates and fish. The abundance and seasonal migrations of chub mackerel are thought to be related to the availability of their shoaling prey species (Payne & Crawford 1989).

Figure 18: Cape fur seal preying on a shoal of pilchards (left). School of horse mackerel (right) (photos: www.underwatervideo.co.za; www.delivery.superstock.com).

Turtles

Five of the eight species of turtle worldwide occur off Namibia (Bianchi *et al*. 1999). Turtles that are occasionally sighted off central Namibia, include the Leatherback Turtle (*Dermochelys coriacea*) (Figure 19, left), the largest living marine reptile. Limited information is available on marine turtles in Namibian waters, although leatherback turtles, which are known to frequent the cold southern ocean, are the most commonly-sighted turtle species in the region. Observations of Green (*Chelonia mydas*), Loggerhead (*Caretta caretta*) (Figure 19, right), Hawksbill (*Eretmochelys imbricata*) and Olive Ridley (*Lepidochelys olivacea*) turtles in the area are rare.

Figure 19: Leatherback (left) and loggerhead turtles (right) occur along the coast of Central Namibia (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

Leatherbacks turtles inhabit deeper waters and are considered a pelagic species, travelling the ocean currents in search of their prey (primarily jellyfish). Their large size allows them to maintain a constant core body temperature and consequently they can penetrate colder temperate waters.

The South Atlantic population of leatherback turtles is the largest in the world, with as many as 40,000 females thought to nest in an area centred on Gabon, yet the trajectory of this population is currently unknown (Witt *et al*. 2011). Namibia is gaining recognition as a feeding area for leatherback turtles that are either migrating through the area or undertaking feeding excursions into Namibian waters. The turtles are thought to be attracted by the large amount of gelatinous plankton in the Benguela ecosystem (Lynam *et al*. 2006). Based on tag returns from animals found dead in Namibia, these turtles are thought to come mainly from Gabonese and Brazilian nesting grounds (R. Braby, pers. comm., Namibia Coast Conservation and Management Project – NACOMA, 25 August 2010).

Although they tend to avoid nearshore areas, they may be encountered in the area around Walvis Bay between October and April when prevailing north wind conditions result in elevated seawater temperatures (Figure 20). Leatherback turtles have washed up in significant numbers on the central Namibian coast. Since 2009, at least 200 dead turtles have been found (Namibian Dolphin Project, pers. comm.). Paterson (2020) reported on a recent mass mortality of leatherback turtles along the coast from Lüderitz to Möwe Bay, stating that such mortalities have also been recorded in previous years. The cause of the mortalities is unknown as the carcasses were too decomposed by the time they were discovered.

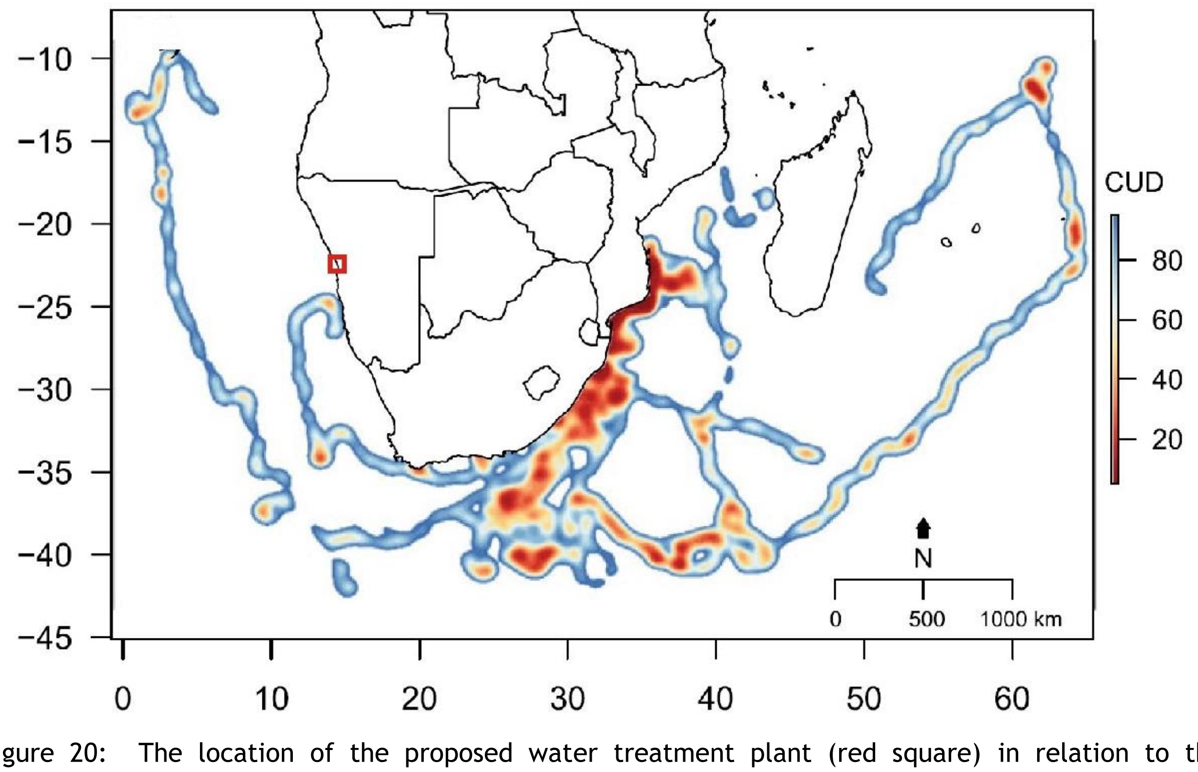


Figure 20: The location of the proposed water treatment plant (red square) in relation to the migration corridors of leatherback turtles in the south-western Indian Ocean. Relative use (CUD, cumulative utilization distribution) of corridors is shown through intensity of shading: light, low use; dark, high use (adapted from Harris *et al*. 2018).

Several anthropogenic factors threaten sea turtle populations including entanglement in fishing gear, incidental catches in fisheries, vessel strikes, ingestion of marine debris, pollution, decline of habitat along the Western Atlantic coast and loss of nesting habitat (Carr 1987; National Research Council

(NRC) 1990; Lutz & Alfaro-Shulman 1991; Lutcavage *et al.* 1997; Witzell 1999; Witherington & Martin 2000; Dwyer *et al.* 2003; James *et al.* 2005).

Leatherback Turtles are listed as 'Vulnerable' worldwide by the IUCN and are in the highest categories in terms of need for conservation in CITES (Convention on International Trade in Endangered Species), and CMS (Convention on Migratory Species).

Loggerhead and Olive Ridley turtles are globally listed as 'Vulnerable' whereas Hawksbill are globally listed as 'Critically Endangered', and Green turtles as 'Endangered'. The most recent conservation status, which assessed the species on a scale of Regional Management Units (RMU), is provided in Table 3. From this it is evident that leatherback and loggerhead turtles, the two species most likely to be encountered in the licence area, are rated as 'Critically Endangered' and 'Near Threatened', respectively in the Southwest Indian RMU[1]. Although not a signatory of CMS, Namibia has endorsed and signed a CMS International Memorandum of Understanding specific to the conservation of marine turtles. Namibia is thus committed to conserve these species at an international level.

Table 3: Global and Regional Conservation Status of the turtles occurring off the southern African coastline showing variation depending on the listing used.

Listing	Leatherback	Loggerhead	Green	Hawksbill	Olive Ridley
IUCN Red List:					
Species (date)	V (2013)	V (2017)	E (2004)	CR (2008)	V (2008)
Population (RMU)	CR (2013)	NT (2017)	*	*	*
Sub-Regional/National (RSA)					
NEMBA TOPS (2007)	CR	CR	E	CR	E
Hughes & Nel (2014)	E	V	NT	NT	DD

NT - Near Threatened V - Vulnerable E - Endangered CR - Critically Endangered

DD - Data Deficient * Not yet assessed

NEMBA TOPS: South African National Environmental Management: Biodiversity Act - List of Threatened Or Protected Species (TOPS)

Coastal birds

The Namibian coastline sustains large populations of breeding and foraging seabird and shorebird species, which require suitable foraging and breeding habitats for their survival. In terms of global populations Namibia supports >90% of the world's chestnut-banded plovers (*Charadrius pallidus*) and 26% of African black oystercatchers (*Haematopus moquini*). In terms of African endemics it supports >90% of the black-necked grebe (*Podiceps nigricollis gurneyi*) and in terms of southern African sub-continental population's it supports 13.7% of greater flamingos (*Phoenicopterus roseus*) and 10.3% of lesser flamingos (*Phoenicopterus minor*) (Williams & Simmons 2008).

In total, 11 species of seabirds are known to breed along the central Namibian coast (Table 4). Most seabirds breeding in Namibia are restricted to areas where they are safe from land predators, although some species are able to breed on the mainland coast, either cryptically on the open ground (e.g. Damara Tern) (Figure 21, left) or in inaccessible places. In general most breed on the islands off the southern Namibian coast, or on the man-made guano platforms in Walvis Bay, Swakopmund and Cape Cross. The southern Namibian islands and guano platforms therefore provide a vital breeding habitat

[1] Regional Management Units (RMUs) organise marine turtles that might be on independent evolutionary trajectories within regional entities into units of protection above the level of nesting populations, but below the level of species.

to most species of seabirds that breed in Namibia. However, the number of successfully breeding birds at the particular breeding sites varies with local food abundance (J. Kemper, pers. comm.). With the exception of the Greater Crested (Swift) Tern, Kelp Gull and White-breasted Cormorants all the breeding species are listed Red Data species in Namibia.

Most of the seabird species breeding in Namibia feed relatively close inshore (10-30 km), although exceptions occur (Ludynia *et al.* 2012), particularly when birds are forced to alter their dispersal patterns in response to environmental change (Sherley *et al.* 2017). Cape Gannets, however, are known to forage up to 140 km offshore (Dundee 2006; Ludynia 2007), and African Penguins have also been recorded as far as 60 km offshore (Ludynia *et al.* 2012). The closest Cape Gannet and African Penguin colonies to the project area are at Ichaboe and Mercury Islands to the south of the concession area. In Hottentots Bay, Neglectus Islet and the disused jetty provide important breeding areas. The jetty presently has the largest breeding colony of White-breasted cormorants along the southern Namibian coast (Currie *et al.* 2009).

Figure 21: Damara tern *Sternula balaenarum* and chick (left) (Photo: J. Kemper) and White-fronted Plovers *Charadrius marginatus* (right) (Photo: Jessica Kemper) breed primarily on gravel plains and beaches.

Other Red-listed species found foraging, or roosting along the coastline of southern Namibia are listed in (Table 4). Pelagic seabirds potentially encountered in the offshore portions of the project area are provided in (Table 5).

The near-endemic Damara Tern is considered a flagship species in Namibia. Its conservation importance has been flagged by the Ministry of Environment, Forestry and Tourism (MEFT); a Damara Tern Species Action Plan specifically aims to improve monitoring and research efforts to improve its conservation status (MEFT 2020). Gravel and gypsum plains, and salt pans are also favoured breeding sites for Damara terns (Braby 2011). There are two known Damara Tern breeding colonies in the broader project area; one is at Meob Bay, and the second to the north at Conception Bay. However, the area has been poorly studied and information on the exact location and extent of these two colonies – or the existence of additional colonies – is scant and largely outdated. It is estimated that there are at least 14 pairs nesting at each locality (Braby 2011), and up to 100 pairs, making this one of the five most important Damara Tern breeding colonies in Namibia - out of altogether 55 known, extant colonies in Namibia (MEFT 2020). It is generally assumed that the Damara Tern migrates north along the coast to West Africa during the non-breeding season in winter. However, recent Damara

Tern monitoring efforts in the greater Lüderitz area and at Hottentot's Bay, where the largest breeding colony of the species is situated, have shown that not all Damara Terns migrate to West Africa in winter, and that substantial numbers remain in southern Namibia and even continue to breed throughout winter (J-P. Roux unpubl. data). Based on observations of up to 70 Damara Terns, as well as record of suspected nests at Meob Bay in mid-winter (Braby 2011, R. Braby unpubl. data), it is likely that Meob Bay too constitutes an important winter roost site and possibly supports a winter-breeding colony. Figure 22 shows the rough location of Damara Tern colonies along the central Namibian coast.

Table 4: Namibian breeding seabird species with their Namibian and global IUCN Red-listing classification (from Kemper *et al*. 2007; Simmons *et al*. 2015; IUCN 2022). * denotes the species is endemic to southern Africa.

Species	Namibian	Global IUCN
*African Penguin *Spheniscus demersus*	Endangered	Endangered
*Bank Cormorant *Phalacrocorax neglectus*	Endangered	Endangered
*Cape Cormorant *Phalacrocorax capensis*	Endangered	Endangered
*Cape Gannet *Morus capensis*	Critically Endangered	Endangered
*Crowned Cormorant *Microcarbo coronatus*	Near Threatened	Near Threatened
*African Black Oystercatcher *Haematopus moquini*	Near Threatened	Near Threatened
White-breasted cormorant *Phalacrocorax lucidus*	Least Concern	Least Concern
Kelp Gull *Larus dominicanus*	Least Concern	Least Concern
*Hartlaub's Gull *Chroicocephalus hartlaubii*	Vulnerable	Least Concern
Caspian Tern *Hydroprogne caspia*	Vulnerable	Least Concern
*Greater Crested (Swift) Tern *Thalasseus bergii bergii*	Least concern	Least Concern
*Damara Tern *Sternula balaenarum*	Near Threatened	Vulnerable

Notes:
In the IUCN scheme 'Endangered' is a more extinction-prone class than 'Vulnerable', and differences between Namibia and global classifications are the result of local population size, and the extent and duration of declines locally.

Table 5: Other Namibian Red-listed bird species with their Namibian and global IUCN Red-listing classification (from Kemper *et al*. 2007; Simmons *et al*. 2015).

Species	Namibian	Global IUCN
Great white pelican *Pelecanus onocrotalus*	Vulnerable	Least Concern
Greater Flamingo *Phoenicopterus roseus*	Vulnerable	Near Threatened
Lesser Flamingo *Phoenicopterus minor*	Vulnerable	Near Threatened
Chestnut-banded Plover *Charadrius pallidus*	Near Threatened	Least Concern
Northern Giant-Petrel *Macronectes halli*	Near Threatened	Least Concern
Black-necked Grebe *Podioceps nigricollis*	Near Threatened	Least Concern
Eurasian Curlew *Numenius arquata*	Near Threatened	Near Threatened
Red Knot *Calidris canutus*	Least Concern	Near Threatened
Curlew Sandpiper *Calidris ferruginea*	Least Concern	Near Threatened

The mosaic of open sandy beaches and exposed rocky shore, backed by vegetated hummocks provides important roosting and foraging habitat for a number of shorebirds, including for birds that migrate, often in large numbers, along the west coast of Africa along the East Atlantic Flyway such as Sandwich Terns (*Thalasseus sandvicensis*), Common Terns (*Sterna hirundo*), Ruddy Turnstones (*Arenaria interpres*), Curlew Sandpipers (*Calidris ferruginea*), Sanderlings (*C. alba*), Little Stints (*C. minuta*), Common Ringed Plovers (*C. hiaticula*), Red Knots (*C. canutus*) and Grey Plovers (*Pluvialis squatarola*). Although the densities of shorebirds in the broader project area are unlikely to match those recorded at key wetlands such as Walvis Bay, Sandwich Harbour, the Orange River mouth and Langebaan Lagoon in South Africa (Simmons *et al.* 1999; Molloy & Reinikainen 2003; Wearne & Underhill 2005; http://www.ramsar.org/profile/profiles_namibia .htm), various resident and migratory shorebird species are expected to forage and/or roost on the shoreline between these wetlands, including at Meob Bay. These habitats also provide roosting habitat to a number of seabirds, such as various terns, cormorants, gulls and Greater Flamingo. The extensive salt pans in the Meob-Conception Bay area provide a valuable stopover for migrating Palaearctic birds with counts in the Conception Bay area reported to reach 17 000 birds (25 species) and often including large numbers of terns (Swart *et al.* 2012). Temporary pans that may form at the back of beaches during strong swell or spring tide events provide additional and relatively sheltered foraging and roosting habitat to shorebirds and flamingos.

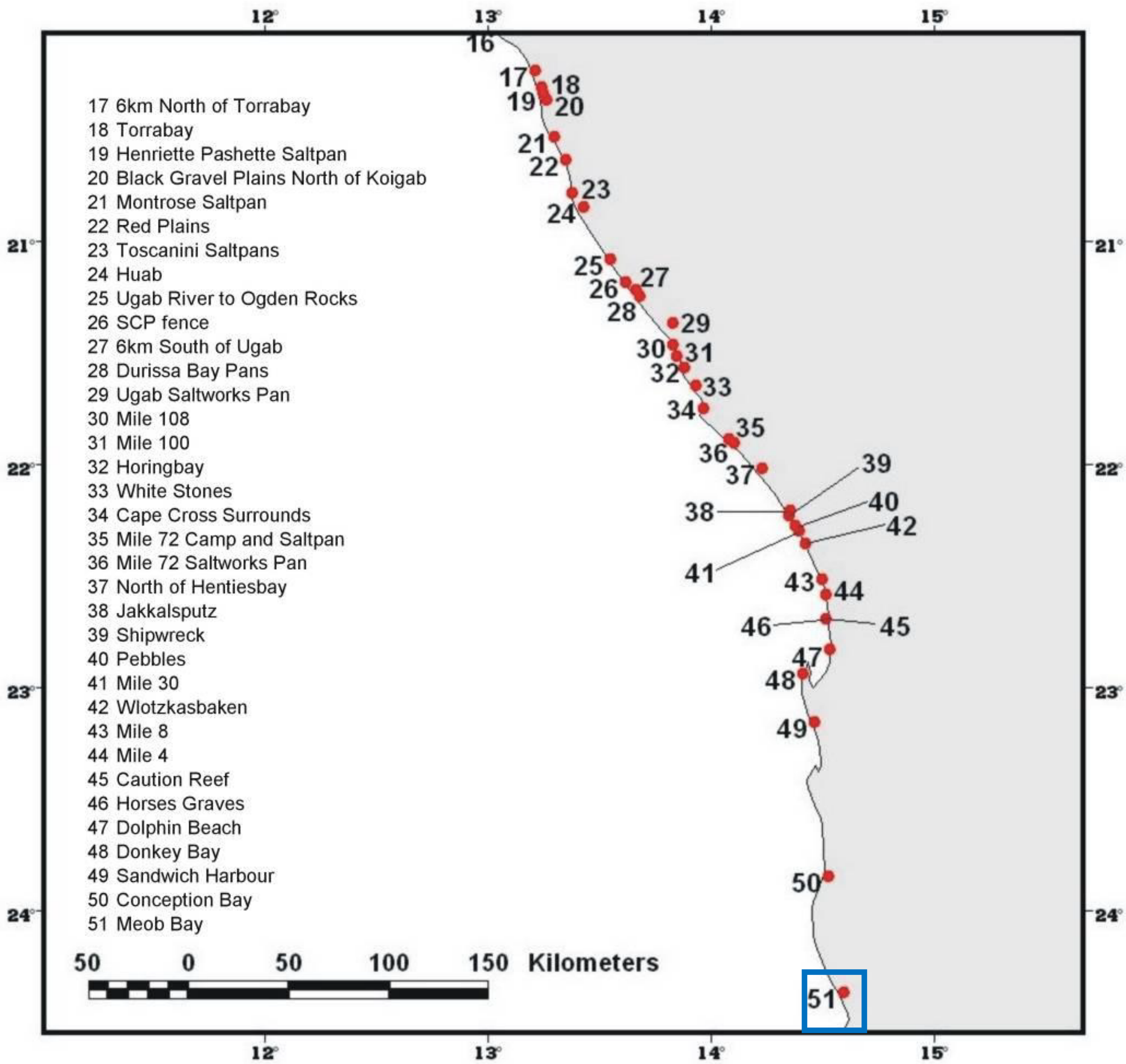


Figure 22: Distribution and location of all known Damara Tern breeding colonies in the southern part of the Skeleton Coast Park, the Dorob National Park, and the Namib Naukluft Park. The location of the project area is indicated (adapted from Braby 2011).

Marine Mammals

Marine mammals occurring off the central Benguela ecosystem include cetaceans (whales and dolphins) and seals. The cetacean fauna of southern and central Namibia comprises between 22 and 33 species of whales and dolphins known (historic sightings or strandings) or likely (habitat projections based on known species parameters) to occur here (

Table 6) (Findlay *et al.* 1992; Findlay 1996; Best 2007). The diversity reflects both species recorded from the waters of Namibia (Williams *et al.* 1990; Rose & Payne 1991; Findlay *et al.* 1992; Griffin & Coetzee 2005) and species expected to be found in the region based on their distributions elsewhere along the southern African West coast (Best 2007; Elwen *et al.* 2011). The majority of the species occur in offshore waters and are unlikely to be sighted in the project area and so will not be dealt with further here.

The most abundant of the migratory mysticete (baleen) whales are the southern right whales (Figure 23, right) and humpback whales. In the last decade, both species have been increasingly observed to remain on the west coast of South Africa well after the 'traditional' southern African whale season (June - November) into spring and summer (October - February) where they have been observed feeding in upwelling zones, especially off Saldanha and St Helena Bays in South Africa (Barendse *et al.* 2011; Mate *et al.* 2011). Increasing numbers of summer records of both species in Namibia, suggest that animals may also be feeding in the southern half of the country near the Lüderitz upwelling cell (NDP unpubl. data) and may therefore occur in or pass through the Walvis Bay area. Right whales have been recorded in Namibian waters in all months of the year (J-P Roux pers. comm.) but with numbers peaking in winter (June - August). A secondary peak in summer (November - January) also occurs, probably associated with animals feeding off the west coast of South Africa performing exploratory trips into southern Namibia (NDP unpubl. data). Notably, all available records have been very close to shore. In recent years a number of the sheltered bays between Chameis Bay (27°56'S) and Conception Bay (23°55'S) have become popular calving sites for Southern Right whales, including Meob Bay (Roux *et al.* 2010).

Figure 23: The endemic Heaviside's dolphin *Cephalorhynchus heavisidii* (left) (Photo: De Beers Marine Namibia), and Southern Right whale *Eubalaena australis* (right) (Photo: www.divephotoguide.com; Namibian Dolphin Project).

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). Although migrating through the Benguela, there is no existing evidence of a clear 'corridor' and humpback 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*. 2014). Regular sightings of humpback whales in spring and summer months in Namibia, suggest that summer feeding is occurring in Namibian waters as well (or at least that animals foraging off West South Africa range up into southern Namibia). Humpback whales are likely to be the most frequently encountered baleen whale in the project area, ranging from the coast out beyond the shelf, with year round presence but numbers peaking in June – July (northern migration) and a smaller peak with the southern breeding migration around September – October but with regular encounters until February associated with subsequent feeding in the Benguela ecosystem.

Meob Bay was historically a whaling station targeted by American and Liberian whalers, and whale bones are still evident on the beach to the south of the bay.

The Odontoceti (toothed whales) are a varied group of animals including the dolphins, porpoises, beaked whales and sperm whales. Species occurring within Namibian waters display a diversity of features, for example their ranging patterns vary from extremely coastal and highly site specific to oceanic and wide ranging.

Table 6: List of cetacean species known (from historic sightings or strandings) or likely (habitat projections based on known species parameters) to occur in Namibian shelf waters. IUCN Conservation Status is based on the RSA Red List Assessment (2014) (Child *et al*. 2016).

Common Name	Species	IUCN Conservation Status
Delphinids		
Dusky dolphin	*Lagenorhynchus obscurus*	Data Deficient
Heaviside's dolphin	*Cephalorhynchus heavisidii*	Least Concern
Common bottlenose dolphin	*Tursiops truncatus*	Least Concern
Common (short beaked) dolphin	*Delphinus delphis*	Least Concern
Southern right whale dolphin	*Lissodelphis peronii*	Least Concern
Pantropical spotted dolphin	*Stenella attenuata*	Least Concern
Long-finned pilot whale	*Globicephala melas*	Least Concern
Killer whale	*Orcinus orca*	Data Deficient
Risso's dolphin	*Grampus griseus*	Least Concern
Sperm whales		
Dwarf sperm whale	*Kogia sima*	Data Deficient
Baleen whales		
Antarctic minke whale	*Balaenoptera bonaerensis*	Least Concern
Dwarf minke whale	*B. acutorostrata*	Least Concern
Fin whale	*B. physalus*	Endangered
Sei whale	*B. borealis*	Endangered
Bryde's whale (inshore)	*B brydei (subspp)*	Vulnerable
Bryde's whale (offshore)	*B. brydei*	Not assessed
Pygmy right whale	*Caperea marginata*	Data Deficient
Humpback whale	*Megaptera novaeangliae*	Least Concern

Common Name	Species	IUCN Conservation Status
Humpback whale B2 population	*Megaptera novaeangliae*	Vulnerable
Southern right whale	*Eubalaena australis*	Least Concern

Heaviside's dolphins (Figure 23, left) are resident year-round and are relatively abundant in both the southern and northern Benguela ecosystem (Elwen *et al*. 2009a, 2009b). Although there are no population estimates for Heaviside's dolphins as a whole, the size of the population utilising Walvis Bay in 2009 was estimated at 505 (Elwen & Leeney 2011), and a degree of site fidelity of the species to Pelican Point was confirmed from images taken in 2008 and 2009. Sightings of this species in Walvis Bay occur mostly at Pelican Point; the few sightings in other parts of the bay occur more commonly in summer (January to March), when sightings at Pelican Point decrease, suggesting that these animals have a different primary habitat during those months. Although the range of the Heaviside's dolphins off Namibia is unknown, aerial surveys have revealed that they utilises nearshore habitat to at least 200 m depth (Elwen *et al*. 2006; Best 2007; Elwen *et al*. 2010) along much of the Namibian coastline including south of Walvis Bay, with a hotspot of abundance just south of Sandwich Harbour.

The bottlenose dolphin (*Tursiops truncatus*) is found in the extreme nearshore region between Lüderitz and Cape Cross (Elwen *et al*. 2011b) (including the Sandwich Harbour lagoon), as well as offshore of the 200 m isobath along the Namibian coastline. The population in 2008 was estimated at 77 individuals, with a 6-8% annual reduction in the number of animals identified in Walvis Bay since then (Elwen *et al*. 2011b), suggesting that the species is under pressure in at least part of its range. Roughly twice as many individuals occur in Walvis Bay in winter than during the summer months. A number of mother-calf pairs have been observed in Walvis Bay between 2008 and 2011. The reef north of Bird Island has been identified as an area used by these animals primarily for resting (Elwen & Leeney 2010; Elwen *et al*. 2011b), and has informally been designated as a 'no-go' zone for tour boats.

Common bottlenose dolphins (*Tursiops truncatus*) are widely distributed in tropical and temperate waters throughout the world, but frequently occur in small (10s to low 100s) isolated coastal populations. Within Nambian waters two populations of bottlenose dolphins occur; a small population inhabits the very near shore coastal waters (mostly <15 m deep) off the central Namibian coastline from approximately Lüderitz in the south to at least Cape Cross in the north, and is considered a conservation concern. The population is thought to number less than 100 individuals (Elwen *et al*. 2011a). An offshore 'form' of common bottlenose dolphins occurs around the coast of southern Africa including Namibia and Angola (Best 2007) with sightings restricted to the continental shelf edge and deeper.

Dusky dolphins (*Lagenorhynchus obscurus*) are boat friendly and will often approach boats to bowride. This 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 off South Africa and Lüderitz, with most records coming from beyond 5 nautical miles from the coast (Elwen *et al*. 2010; NDP unpubl. data). The dusky dolphin is also an occasional visitor to Walvis Bay, where they may strand (e.g. Elwen *et al*. 2011).

All whales and dolphins are given protection under the Namibian Law.

Seals

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 24) is the only species of seal resident along the west coast of Africa, occurring at numerous breeding and non-breeding sites on the mainland and on nearshore islands and reefs (see Figure 29). 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).

Currently the largest breeding site in Namibia is at Cape Cross north of Walvis Bay where about 51 000 pups are born annually (MFMR unpubl. Data). The colony supports an estimated 157 000 adults (Hampton 2003), with unpublished data from Marine and Coastal Management (South Africa) suggesting a number of 187 000 (Mecenero *et al*. 2006). A further colony of ~9 600 individuals exists on Hollam's Bird Island north-west of Meob Bay. Other colonies in the broader project area occur at Sylvia Hill and on the beaches at Meob Bay and Conception Bay, as well as at Ilheo Point at Sandwich Harbour (Seely 2012). The colony at Pelican Point in Walvis Bay is primarily a haul-out site. The mainland seal colonies present a focal point of carnivore and scavenger activity in the area, as jackals and hyena are drawn to this important food source. Population estimates fluctuate widely between years in terms of pup production, particularly since the mid-1990s (MFMR unpubl. Data; Kirkman *et al*. 2007).

The Cape fur seal population in the Benguela is regularly monitored by the South African and Namibian governments (e.g. Kirkman *et al*. 2012). Surveys of the full species range are periodically undertaken providing data on seal pup production (which can be translated to adult population size), thereby allowing for the generation of data on the population dynamics of this species. The population is considered to be healthy and stable in size although there has been a northward shift in the distribution of the breeding population (Kirkman *et al*. 2007; Skern-Mauritzen *et al*. 2009; Kirkman *et al*. 2012).

Figure 24: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: J. Kemper).

Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles (~220 km) offshore (Shaughnessy 1979), with bulls ranging further out to sea than females. The foraging area of tracked seals from Namibian colonies and the South African West Coast colonies was provided in Skern-Mauritzen *et al*. (2009) (Figure 25). The project area falls within the foraging range of seals from the Atlas Bay, Sylvia Hill, Hollam's Bird Island and Conception Bay colonies and seals are likely to be frequently encountered on the beaches in the project area. 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).

There is a controlled annual quota, determined by government policy, for the harvesting of Cape fur seals on the Namibian coastline. The Total Allowable Catch (TAC) for 2020 and 2021 stands at 60 000 pups and 8 000 bulls, distributed among seven licence holders at Cape Cross and a further three in Lüderitz. The annual quotas are seldom filled with concessionaires typically only harvesting 50% of the bulls and 30% of the pups. The seals are exploited mainly for their pelts (pups), blubber and genitalia (bulls). The pups are clubbed and the adults shot. These harvesting practices have raised concern among environmental and animal welfare organisations (Molloy & Reinikainen 2003).

In South Africa, an unprecedented mortality event was recorded between September and December 2021 at colonies around the West Coast Peninsula and north to Lambert's Bay and Elands Bay. Primarily pups and juveniles were affected. Post-mortem investigations revealed that seals died in a poor condition with reduced blubber reserves, and protein energy malnutrition was detected for aborted foetuses, for juveniles and subadults. Although no unusual environmental conditions were identified that may have triggered the die-off, or caused it indirectly (e.g. HABs), 2021 was a year of below average recruitment of anchovy and sardine, the main food source for seals. While a lack of food, as a result of possibly climate change and/or overfishing, has been predicted to be the cause of this mass mortality, the underlying causes of the mortality event remain uncertain (Seakamela *et al*. 2022). In Namibia, similar mortality events typically related to prey shortage occur periodically, the most recent being a large-scale abortion event in 2020, especially at the colonies in central Namibia (J.-P. Roux, pers.comm.).

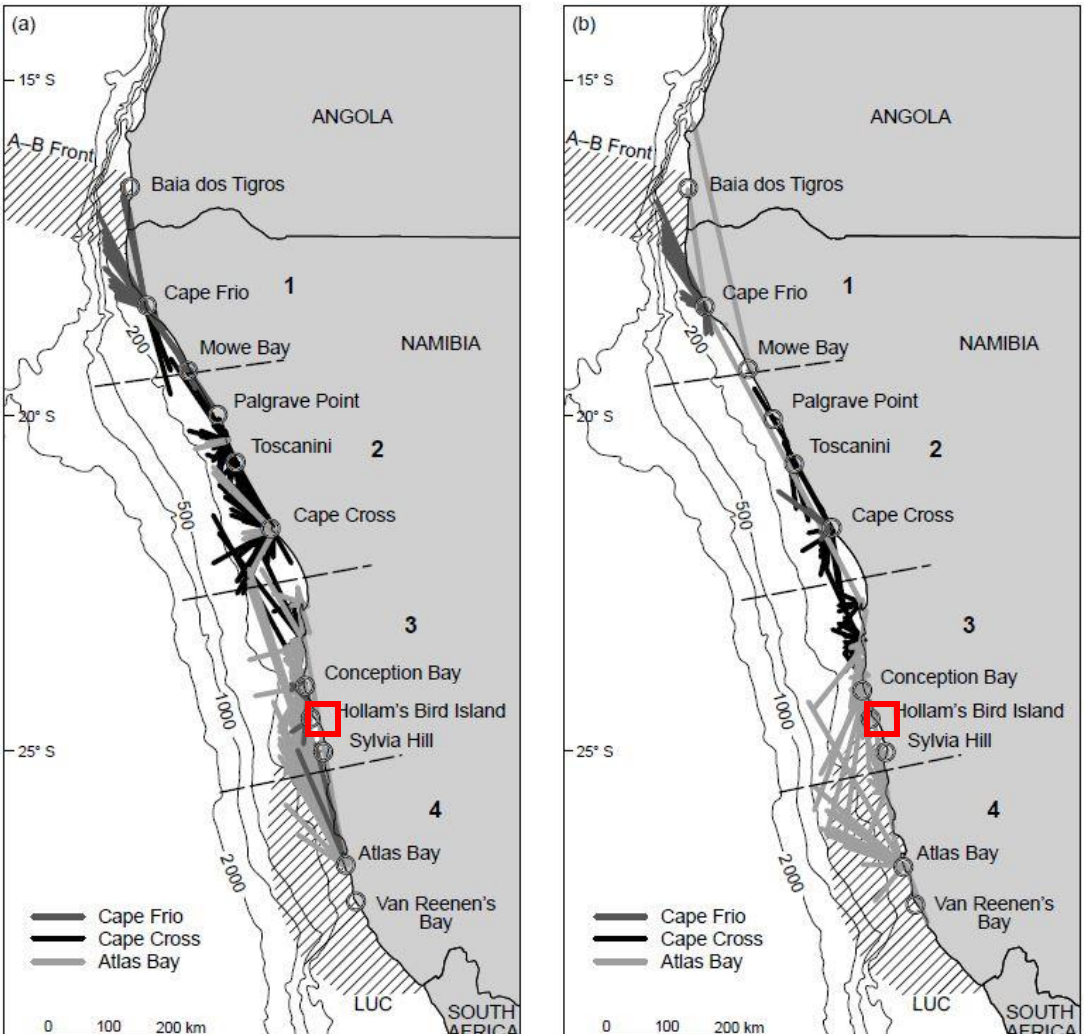


Figure 25: The project area (red square) in relation to foraging trips of (a) females and (b) males of Cape fur seals at the Cape Frio, Cape Cross and Atlas Bay colonies. Trips are depicted as straight lines between the start location and the location where the seals spent most time during a trip (adapted from Skern-Mauritzen *et al*. 2009).

2.3.5 Other Uses of the Area

<u>Commercial and Recreational Fisheries</u>

In Namibia various restrictions apply to areas permitable to commercial fisheries. No trawling or long-lining is permitted inshore of the 200 m depth contour, and south of 25°S, no freezer trawlers or hake trawlers are permitted inshore of the 350 m depth contour (Figure 26). In addition to the linefish sanctuary as part of the Namibian Islands Marine Protected Area (NIMPA) (see section 2.3.6), which lies offshore of the project area, there is no recreational fishing permitted along the coastline fishing between Sandwich Harbour and a beacon at 26° 34.167′S. Meob Bay and the surrounding coastline is therefore closed to shore angling and recreational fishing.

The Meob Bay research angling area lies between Langewand (24°46'S, 14°46'E) and Witklip (24°27'S, 14°36'E), with the Fischersbrunn fishing camp situated centrally (Currie *et al*. 2009). Some of the concession holders operational in the area hold 'catch and release' permits from the MFMR to undertake periodic, controlled shore angling. The MFMR is informed prior to each fishing venture during which biological information on the species caught is recorded before the fish are released back into the ocean. Catch data are reported back to the MFMR after each catch and release trip. While this is the only fishing permitted in the concession area, it will not form part of the activities offered to guests visiting the proposed lodge.

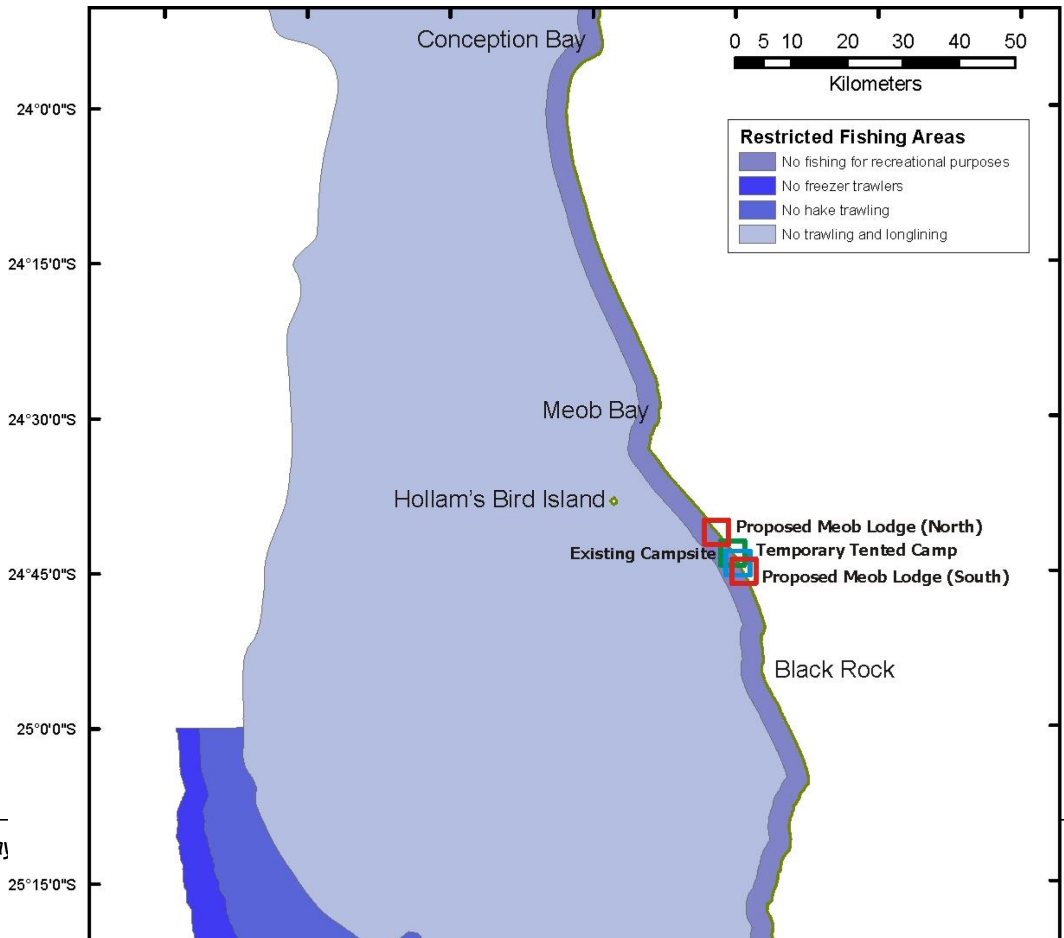


Figure 26: the project location in relation to restricted areas for trawling, long lining or recreational fishing along the southern Namibian coastline (adapted from MFMR 2021).

Mariculture Activities

As a matter of policy, and as outlined in Vision 2030 and the Third National Development Plan, the Namibian government has been promoting the development of aquaculture and mariculture. In Lüderitz, NamPort have allocated 20 plots covering a total area 280.6 ha to mariculture. Mariculture production comprises predominantly oysters (mainly *Crassostrea gigas*), abalone (*Haliotis midae*), rock lobster (*Jasus lalandii*), mussels (*Mytilus galloprovincialis*) and seaweed (*Gracilaria verrucosa* and experimental *Macrocystis* cultivation) (Oellermann 2010). Mariculture methods vary but include rafts, suspended long-lines, racks in the lagoon, onshore flow-through tanks and abalone ranching.

A Strategic Environmental Assessment developed for the Erongo Region, indicated that suitable locations for sea-based and land-based aquaculture were limited and would primarily be associated with Walvis Bay and Swakopmund (Skov *et al*. 2008). An ~1 200 ha Aqua Park under the jurisdiction of Namport has been proposed for oyster farming in the shallow areas in the lee of Pelican Point (Skov *et al*. 2008).

These operations should in no way be affected by the proposed development.

Ecotourism

Several concessions for adventure tourism using off-road vehicles to travel through the dunes and along the coast have been granted by the MEFT for the area between Lüderitz and Sandwich Harbour. In addition to the dune driving, destinations for these trips include the inselbergs and remains of the historical diamond mining and whaling in the area. There are five existing concessionaires, one of which is NAMAB who use the camp at Meob Bay, spending 6-10 days in the area. Permit conditions under which these concessionaires operate allow two trips per month per permit with up to a total of 6 000 tourists per year. To minimise the impact of off-road vehicles on the coastal environment, each concession holder is granted a different traffic corridor along which they may travel. The need to develop monitoring mechanisms to evaluate the effects of off-road driving has been identified (Seely 2012). Although the concessionaires are reported to jointly oversee their own compliance with MEFT regulations, both operators and visitors need to be further sensitised as to the impact of unrestricted off-road driving on the beaches (Figure 27).

Figure 27: Aerial evidence of indiscriminate beach driving in the Meob Bay area.

To the north of the project area, Swakopmund is described as the coastal playground of Namibia, and is increasingly attracting international tourism. Although its environment is its greatest economic asset (Skov *et al*. 2008), the area has now also become world-famous for adventure seekers who visit the area for quad-biking, sand boarding, tandem skydiving, camel and horse trails, paragliding, hot air ballooning etc. Further north, the old West Coast Recreation Area, now part of the Dorob National Park, is renowned for its excellent angling, and is visited annually by thousands of fishermen. Several skiboat operators from Swakopmund and Walvis Bay also offer guided angling tours. Specifically shark angling tours targeting bronze whalers, have become increasingly popular over the last decade and have become an established part of the local coastal tourist industry (Holtzhausen & Camarada 2007).

In recent years Walvis Bay has also begun successfully marketing its natural marine and desert attractions - the Bay itself and the Lagoon, the Kuiseb Delta and the Namib Desert, and the Dunebelt north of it. Specifically marine ecotourism has become increasingly important, with ten whale-watching operators currently offering general nature trips that include sightings of dolphins and whales, as well as other marine life (e.g. fur seals, turtles and sunfish) out of both Walvis Bay and Swakopmund.

Various operators in Walvis Bay also offer 4x4 excursions to the Sandwich Harbour area, which include the Walvis Bay Lagoon, the Saltpans, the Kuiseb River Delta, and - if weather and tides allow for it - the Sandwich Harbour.

As most of the area surrounding Lüderitz forms part of the restricted diamond area and the Tsau//Khaeb (Sperrgebiet) National Park, land-based recreational activities along this stretch of coast are limited to the Lüderitz Peninsula and to Agate Beach to the north-east of the town. A few tourism concessions have, however, been issued for the area by MEFT, including to the north of Lüderitz. Vessel-based recreational and tourism-related activities include motorised catamaran sight-seeing cruises that visit points of interest in the Bay and at Halifax Island. Fishing trips that target snoek and other linefish are also occasionally offered.

2.3.6 Conservation Areas and Marine Protected Areas

RAMSAR Sites and Important Bird Areas (IBAs)

The coastline of Namibia is part of a continuum of protected areas that stretches from Southern Angola into Namaqualand in South Africa, namely the Skeleton Coast National Park, the Dorob National Park, the Namib-Naukluft National Park and the Tsau //Khaeb (Sperrgebiet) National Park.

Sandwich Harbour, located 55 km south of Walvis Bay, is one of Namibia's four proclaimed RAMSAR sites and one of southern Africa's richest coastal wetlands. The area consists of two distinct parts: a northern, saltmarsh and adjoining intertidal sand flat area, which supports typical emergent vegetation, and a southern area of mudflats and raised shingle bars under tidal influence. The area supports an extremely rich avifauna including eight endangered species among the large numbers of waders, terns, pelicans and flamingos. The area hosts upwards of 70 000 birds, mostly seasonal migrants from the northern hemisphere (Kolberg 2015). Bird numbers are reported to reach 175 000, with Palearctic waders reaching densities of 7 000 birds per km^2. Several archaeological sites dating back 1 000 years also exist within the area (Barnard 1998). It was proclaimed a Ramsar site in December 1995.

Another Ramsar site, the **Walvis Bay wetland,** is one of the most important coastal wetlands in Southern Africa. As the largest single area of shallow sheltered water along the Namibian coastline, it encompasses the lagoon and mudflats, Paaltjies beach on the Pelican Point peninsula, the salt works, and sand dunes and gravel fields extending to the boundary of the Namib-Naukluft Park (Barnard 1998; www.nacoma.org.na). It was proclaimed a Ramsar site in December 1995, supporting up to 156 000 birds at peak times during the summer season and about 82 000 birds during winter (Wearne & Underhill 2005). The wetland serves primarily as a dry-season and drought refuge for intra-African migrants and as a non-breeding area for Palaearctic migrants. Key species are Greater and Lesser Flamingos, Chestnut-banded Plover, Black-necked Grebe and the African Black Oystercatcher (www.nnf.org.na/CTEN). Eleven threatened bird species are regularly observed (http://www.ramsar.org/ profile/ profiles_namibia. htm).

Of the 19 Important Bird Areas (IBAs) designated by BirdLife International in Namibia, those located along the Namibian coastline are listed in Table 7. The proposed project is located within the Namib-Naukluft Park IBA.

Table 7: List of Important Bird Areas (IBAs) and their criteria listings.

Site Name	IBA Criteria
Cape Cross Lagoon	A1, A4i, A4iii
Namib-Naukluft Park	A1, A2, A3, A4i
Mile 4 Saltworks	A1, A4i, A4iii
30-Kilometre Beach: WalvisSwakopmund	A1, A4i
Walvis Bay	A1, A4i, A4iii
Sandwich Harbour	A1, A4i, A4iii
Ichaboe Island	A1, A4i, A4ii, A4iii
Lüderitz Bay Islands	A1, A4i, A4iii
Possession Island	A1, A4i, A4ii, A4iii
Sperrgebiet	A1, A2, A3, A4i

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. modeled 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.

Various marine IBAs have also been proposed in Namibian territorial waters (Figure 28). The project area falls within the proposed Namib-Naukluft Marine IBA. A candidate trans-boundary marine IBA has been suggested off the Orange River mouth well to the south of the project area.

Marine Protected Areas

The first (and to date only) Namibian MPA was launched on 2 July 2009 under the Namibian Marine Resources Act (No. 27 of 2000), with the purpose of protecting sensitive ecosystems and breeding and foraging areas for seabirds and marine mammals, as well as protecting important spawning and nursery grounds for fish and other marine resources (such as rock lobster). The MPA comprises a coastal strip extending from Hollam's Bird Island (24°38´S) in the north, to Chamais Bay (27°57´S) in the south, spanning approximately three degrees of latitude and an average width of 30 km, including 16 specified offshore islands, islets and rocks (Currie *et al*. 2009). The MPA spans an area of 9 555 km^2, and includes a linefish sanctuary constituting 1 003 km^2 between Meob Bay and St Francis Bay, and a rock-lobster sanctuary constituting 478 km^2 between Chameis Bay and Prince of Wales Bay. The offshore islands, whose combined surface area amounts to only 2.35 km^2 have been given priority conservation and highest protection status (Currie *et al*. 2009). The area has been zoned into four degrees of incremental protection. These are detailed in Currie *et al*. (2009).

The project area is located on the shores of this MPA.

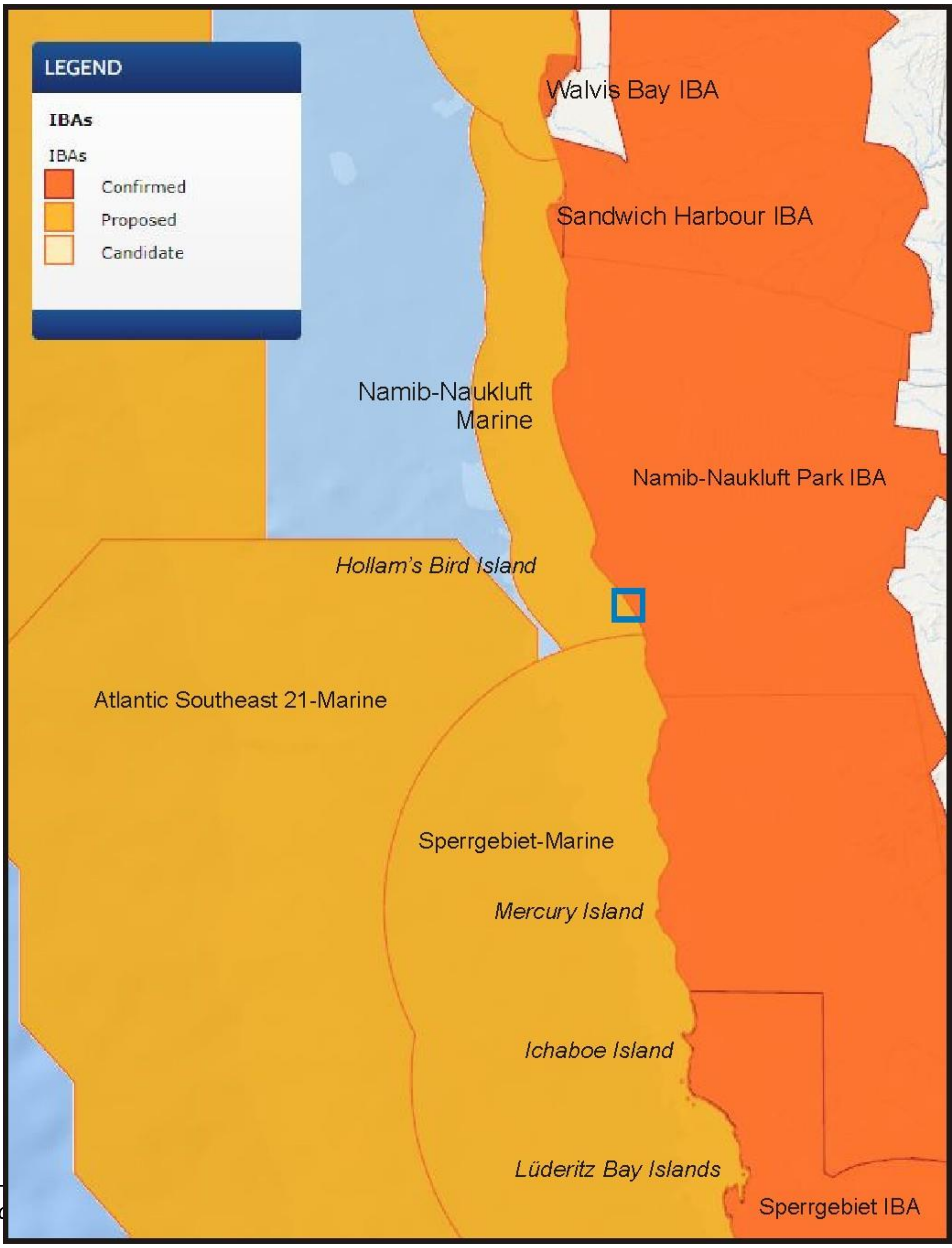


Figure 28: The project location (red square) in relation to coastal and marine IBAs in Namibia (Source: https://maps.birdlife.org/marineIBAs).

Ecologically or Biologically Significant Areas

Ecologically or Biologically Significant marine Areas (EBSAs) are areas that provide important services to an ecosystem or to one or more species / populations within an ecosystem. These areas require targeted conservation and management measures to limit marine biodiversity declines. An inventory of EBSAs aids marine spatial planning by advising which activities would be (in)compatible with areas of high ecological value (Dunn *et al*. 2014). Currently 279 EBSAs have been identified across the world; of these, 11 EBSAs that fall into the Benguela Current Large Marine Ecosystem (BCLME) have been recognized by the Convention of Biological Diversity (CBD).

In the spatial marine biodiversity assessment undertaken for Namibia (Holness *et al*. 2014), a number of offshore and coastal area were identified as being of high priority for place-based conservation measures. To this end, EBSA spanning the coastline between Angola and South Africa were proposed and successfully submitted for international recognition to in March 2020. The EBSAs are delineated to minimise conflict and avoid negative impacts with industries. In line with Namibia's National Development Plan 5, the EBSAs will be used to inform and enhance Marine Spatial Planning in the country's EEZ.

Although no specific management actions have as yet been formulated for the EBSAs, two biodiversity zones have recently been defined within each EBSA as part of the marine spatial planning process (Figure 29) (https://cmr.mandela.ac.za/EBSA-Portal/Namibia/Namibian-EBSA-Status-Assessment-Management). The management objective in the zones marked for 'Conservation' is "*strict place-based biodiversity protection aimed at securing key biodiversity features in a natural or semi-natural state, or as near to this state as possible*". The management objective in the zones marked for 'Impact Management' is "*management of impacts on key biodiversity features in a mixed-use area to keep key biodiversity features in at least a functional state*". Other than the associated sea-use guidelines, no specific management actions have been formulated for the EBSAs at this stage and they carry no legal status. Regulated nature-based and strictly-controlled ecotourism is the primary recommended compatibility for the Namibian Islands EBSA for both Conservation and Impact Management zones. Any future decisions in relation to management of the areas and possible restrictions of human activities are within the mandate of the responsible authorities.

Of the eight identified EBSAs off Namibia, two fall solely within Namibian national jurisdiction (Namib Flyway and Namibian Islands), while one is shared with Angola (Namibe) and two are shared with South Africa (Orange Shelf Edge and Orange Cone). The Benguela Upwelling System transboundary EBSA extends along the entire southern African West Coast from Cape Point to the Kunene River and includes a portion of the high seas beyond the Angolan EEZ (Figure 29).

The **Benguela Upwelling System** is a transboundary EBSA is globally unique as the only cold-water upwelling system to be bounded in the north and south by warm-water current systems, and is characterized by very high primary production (>1 000 mg $C.m^{-2}.day^{-1}$). It includes important spawning and nursery areas for fish as well as foraging areas for threatened vertebrates, such as sea- and shorebirds, turtles, sharks, and marine mammals. Another key characteristic feature is the diatomaceous mud-belt in the Northern Benguela, which supports regionally unique low-oxygen benthic communities that depend on sulphide oxidising bacteria.

The **Namib Flyways EBSA** extends from 18 km north of Cape Cross to 30 km south of Conception Bay, spanning about 380 km of coastline bordering the Dorob National Park, Cape Cross Seal Reserve and the Namib-Naukluft Park. The weak upwelling cell off Walvis Bay and the sheltered bays (Walvis Bay and Sandwich Harbour) and shallow waters featured in this EBSA (Cape Cross lagoons, Swakop River Mouth Lagoon, Walvis Bay Lagoon and Mile 4 salt works) lead to warmer waters and higher productivity. Two of Namibia's five Ramsar sites (Walvis Bay and Sandwich Harbour) are included, both of which are of international importance for resident bird species as well as resident and transient marine mammals, and constitute key refueling and roosting habitats for many species of migrating waterbirds. The EBSA includes six terrestrial IBAs (Table 7), and two proposed marine IBAs (Figure 28). The coastline includes mixed rocky and sandy shoreline, which together with the adjacent marine inshore environment supports resident, Palearctic, Oceanic and intra-African migrant bird species. The area also encompasses key spawning and nursery areas of various fish species, including sardine and anchovy - important forage fish for a range of marine predators. The area is highly relevant in terms of its importance for life-history stages of species, threatened, endangered or declining species and/or habitats, and biological productivity.

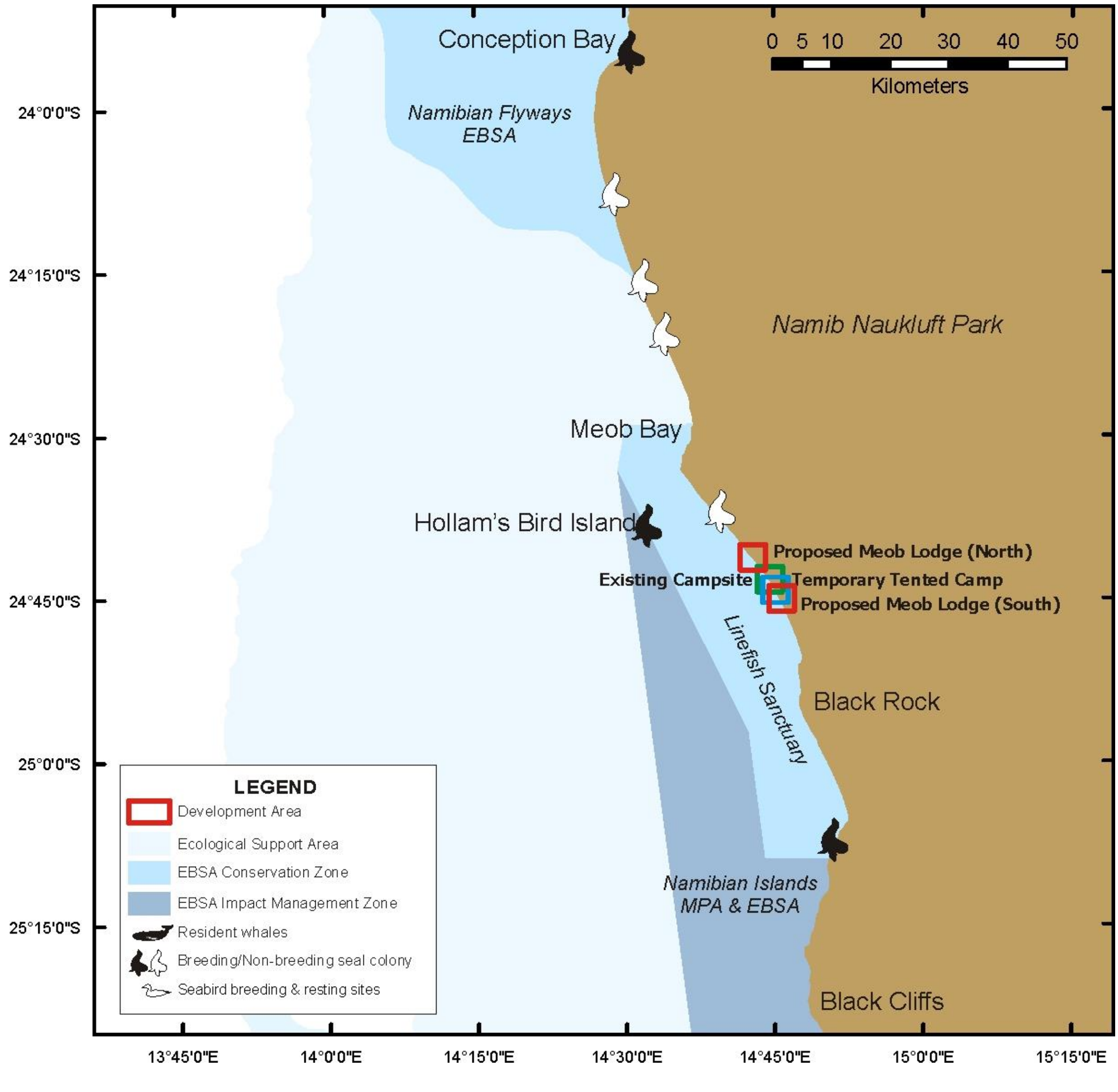


Figure 29: The project location in relation to the Namibian Islands Marine Protected Area, Ecologically and Biologically Significant Areas (EBSAs) and the marine spatial planning zones within these. Ecological support areas (ESAs) mapped by MFMR (2021) and the location of seal colonies are also shown.

The **Namibian Islands** are located offshore of the central Namibian coastline and within the intensive Lüderitz upwelling cell. These islands and their surrounding waters are significant for life history stages of threatened seabird species as they serve as crucial seabird breeding sites within the existing Namibian Islands Marine Protected Area (NIMPA). The surrounding waters are also key foraging grounds for both seabirds and for 'Critically Endangered' leatherback turtles that nest along the north-eastern coast of South Africa. The project area falls within the Namibian Islands EBSA.

Biodiversity Priority Areas and Marine Spatial Planning

In addition to EBSAs, Ecological Support Areas (ESAs) have been identified. Although these areas do not meet the EBSA criteria they reflect secondary priority conservation areas with special attributes that support a healthy and functioning marine ecosystem (Figure 29).

Namibia recently embarked on a Marine Spatial Planning (MSP) process implemented as a development planning approach to organize the use of the country's marine territory in such way that comprehensive, integrated and complementary planning and management across sectors and for all ocean uses is enabled. MSP in Namibia is highly precautionary and forward-looking given the relatively low intensity of current uses, has a strong ecosystem-based perspective due to the fairly pristine environment, is driven by a social equity and distributive justice agenda, and features a strong collaborative process governance (Finke *et al*. 2020a, 2020b). Although at this stage MSP lacks legislation and has only weak links to broader ocean governance, the MSP process has resulted in a clear framework for the development of the first marine plan (MFMR 2019), as it was linked to a systematic conservation planning process from the outset.

The objectives and principles for MSP, as well as the steps each planning process is expected to follow, is set out in the National MSP Framework (MFMR 2019). The Framework provides high-level direction to ensure consistent and coherent plan development, implementation and review across Namibia's marine space and its three proposed planning areas: a northern, central and southern area.. It also describes the background to MSP and its overarching objectives in Namibia and identifies relevant institutional structures, roles and responsibilities (MFMR 2022). The first MSP for Namibia is being developed for the central area, followed by the northern and the southern areas. Although all three areas have sites of high ecological sensitivity and importance, growing economic interests and increasingly overlapping human uses, particularly in the central and southern MSP areas call for improved management.

The Marine Spatial Plans in each of the three planning areas will translate the National Framework for MSP into integrated and strategic sustainable development plans that guide users, developers and regulators in their decision-making, setting out which activities should take place where, when and under what conditions. Any future licensing decisions would need to be in line with the provisions set out in the respective plans.

3. IMPACT ASSESSMENT METHODOLOGY

The purpose of impact assessment is to identify and evaluate the likely significance of the potential impacts on identified receptors and resources according to defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise, reduce or compensate for any potential adverse environmental effects, and to report the significance of the residual impacts that remain following mitigation.

3.1 Defining the nature of the impact

The following terminology used to define the nature of an impact:

Term	Definition
Positive (+)	An impact that is considered to represent an improvement on the baseline or introduces a positive change.
Negative (-)	An impact that is considered to represent an adverse change from the baseline or introduces a new undesirable factor.
Direct impact (D)	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors (e.g. between occupation of a site and the pre-existing habitats or between an effluent discharge and receiving water quality).
Indirect impact (I)	Impacts that result from other activities that are encouraged to happen as a consequence of the Project (e.g. in-migration for employment placing a demand on resources).
Cumulative impact (C)	Impacts that act together with other impacts (including those from concurrent or planned future third party activities) to affect the same resources and/or receptors as the Project.

3.2 Assessing Significance

The Knight Piésold impact significance rating system is based on the following equation:

Significance of Environmental / Social Impact = Consequence x Probability

The consequence of an impact can be derived from the following factors:

Severity / Magnitude – the degree of change brought about in the environment

Reversibility - the ability of the receptor to recover after an impact has occurred

Duration - how long the impact may be prevalent

Spatial Extent - the physical area which could be affected by an impact.

The **severity, reversibility, duration, and spatial extent** are ranked using the ranking criteria indicated in the Table below. The overall consequence is determined by adding up the individual scores and multiplying it by the **overall probability**. Once a score has been determined, this is checked against the **significance** descriptions.

Table 8: Ranking Criteria

Severity / magnitude (M)	Reversibility (R)	Duration (D)	Spatial extent (S)	Probability (P)
5 - Very high – The impact causes the characteristics of the receiving environment/ social receptor to be altered by a factor of 80 – 100 %	**5 - Irreversible** – *Environmental* - where natural functions or ecological processes are altered to the extent that it will permanently cease. *Social* - Those affected will not be able to adapt to changes and continue to maintain-pre impact livelihoods.	**5 - Permanent** - Impacts that cause a permanent change in the affected receptor or resource (e.g. removal or destruction of ecological habitat) that endures substantially beyond the Project lifetime.	**5 - International** - Impacts that affect internationally important resources such as areas protected by international conventions, international waters etc.	**5 - Definite** - The impact will occur.
4 - High – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 60 – 80 %		**4 - Long term** - impacts that will continue for the life of the Project, but ceases when the Project stops operating.	**4 - National** - Impacts that affect nationally important environmental resources or affect an area that is nationally important/ or have macro-economic consequences.	**4 - High probability** – 80% likelihood that the impact will occur
3 - Moderate – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 40 – 60 %	**3 - Recoverable** *Environmental* - where the affected environment is altered but natural functions and ecological processes may continue or recover with human input. *Social* - Able to adapt with some difficulty and maintain pre-impact livelihoods but only with a degree of support or intervention.	**3 - Medium term** - Impacts are predicted to be of medium duration (5 – 15 years)	**3 - Regional** - Impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries, habitat type/ecosystem.	**3 - Medium probability** – 60% likelihood that the impact will occur u

Severity / magnitude (M)	**Reversibility (R)**	**Duration (D)**	**Spatial extent (S)**	**Probability (P)**
2 - Low – The impact alters the characteristics of the receiving environment/ social receptor by a factor of 20 – 40 %		**2 - Short term** - Impacts are predicted to be of short duration (0 – 5 years)	**2 - Local** - Impacts that affect an area in a radius of 2 km around the site.	**2 - Low probability** - 40% likelihood that the impact will occur
1 - Minor – The impact causes very little change to the characteristics of the receiving environment/ social receptor and the alteration is less than 20 %	**1 - Reversible** The impact affects the environment in such a way that natural functions and ecological processes are able to regenerate naturally.	**1 - Temporary -** Impacts are predicted to intermittent/ occasional over a short period.	**1 - Site only** - Impacts that are limited to the site boundaries.	**1 - Improbable** - 20% likelihood that the impact will occur

Significance Definitions

Score According to Impact Assessment Matrix	Significance Definitions	Colour Scale Ratings	
		Negative Ratings	Positive Ratings
Between 0 and 29 significance points indicate **Low Significance**	An impact of low significance is one where an effect will be experienced, but the impact magnitude is sufficiently small and well within accepted standards, and/or the receptor is of low sensitivity/value.	Low	Low
Between 30 and 59 significance points indicate **Moderate Significance**	An impact of moderate significance is one within accepted limits and standards. The impact on the receptor will be noticeable and the normal functioning is altered, but the baseline condition prevail, albeit in a modified state. The emphasis for moderate impacts is on demonstrating that the impact has been reduced to a level that is As Low As Reasonably Practicable (ALARP). This does not necessarily mean that "moderate" impacts have to be reduced to "low" impacts, but that moderate impacts are being managed effectively and efficiently to not exceed accepted standards.	Moderate	Moderate
60 to 100 significance points indicate **High Significance**	An impact of high significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. An impact with high significance will completely modify the baseline conditions. A goal of the ESIA process is to get to a position where the Project does not have any high negative residual impacts, certainly not ones that would endure into the long term or extend over a large area. However, for some aspects there may be high residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). It is then the function of regulators and stakeholders to weigh such negative factors against the positive factors, such as employment, in coming to a decision on the Project.	High	High

4. ASSESSMENT OF IMPACTS

The proposed lodge will be constructed a set-back distance (~150 m) from the high water mark. Direct impacts on the marine environment resulting from the construction, operation and decommissioning of the lodge are therefore not expected as these will all be confined to the terrestrial environment. Indirect and cumulative impacts are, however, likely as a result of the recreational activities offered to visitors to the lodge.

The proposed development is located within the linefish sanctuary as part of the NIMPA, and consequently all regulations regarding exploitation of marine resources as outlined under the Marine Resources Act relating to the Namibian Islands' Marine Protected Area (No. 316 of 2012) will apply. As recreational activities offered to visitors will not be focused on the marine environment, but rather on mining town-, dune- and shipwreck excursions, potential indirect impacts of the development on exploitation of marine resources (e.g. rock lobster fishing, bait collection, shore angling) will not be dealt with further here. Mitigation measures will, however, need to be included as part of the Environmental Management Plan for the proposed lodge to ensure that visitors do not partake in the recreational exploitation of marine resources whilst on site. These will be detailed in Section 5 below.

The assessment of impacts provided below will therefore focus on the use of off-road vehicles[2] (ORV) in the coastal zone and the potential impacts of indiscriminate off-road driving.

4.1 Off-Road Driving

Driving ORV in coastal habitats has long been recognised as being environmentally highly destructive (Anon 1977; Palmer & Leatherman 1979; Godfrey & Godfrey 1980; Schlacher *et al*. 2007; Defeo *et al*. 2009; Kindermann & Gormally 2010), as demonstrated in the plethora of international literature investigating the use of vehicles in natural beach systems. Whilst all human activities (including walking) undertaken on beaches potentially have an impact on the natural beach systems, the potential impact of vehicles compared to pedestrians on the beach geomorphological and ecological systems is far greater due to the weight of the vehicle, the engine power transferred to the wheels, the speed and potential range, and the noise generated. In fact Schooler *et al*. (2017) recently demonstrated that local scale processes (such as beach driving) exerted a stronger influence on intertidal biodiversity on beaches than regional processes thereby highlighting the role of human impacts for local spatial scales.

There are three key impacts of ORV on beaches:

Physical impacts: the direct effect of the weight of the vehicle, the engine power transferred to the wheels, and the speed at which the vehicle is driving;

Indirect effects related to loss of vegetation, microfauna, displacement of sand and changes in microclimate (wind speed and temperature).

Biodiversity impacts: loss and change of composition of vegetation, disturbance to wildlife, introduction of exotic species, erosion, litter and increased exploitation of marine animals.

Social impacts: vehicle use that conflicts with other beach and coastal users.

[2] The term off-road vehicle refers collectively to four-wheel-drives, trail bikes, and all-terrain vehicles such as quad bikes and dune buggies.

4.1.1 Physical Impacts

The physical impact of vehicles on dunes and beaches relates primarily to the compaction and rutting of the beach sediments. Rutting of the beach surface by ORV and was shown to significantly reduce the aeolian transport of sand from the beach to the dunes (Austin, undated; Houser *et al.* 2013). Such changes are significant for beaches and dunes as they affect conditions that enable coastal vegetation to grow and regenerate. Further studies indicated that once the initial damage to dune vegetation has been done, effects are perpetuated by other ORV users who perceive the tracks as legitimate, thereby leading to cumulative impacts (Lindberg & Crook 1979; Priskin 2004). Direct displacement experiments, however, showed that while ORV traffic compacts beach sand at depth, sand at the beach surface is loosened thus rendering it more susceptible to aeolian and/or swash activity (Anders & Leatherman 1981). Hylgaard & Liddle (1981) demonstrated that tracks used more frequently wear down faster, but that the intervals between use are also of importance in that repeated use over a short time period can be more damaging than the same number of passes occurring over a longer time period.

Furthermore, the physical impacts caused by vehicle traffic on the beach are thought to be enhanced by the natural erosion and accretion processes active on open-coast shorelines. Although quantitative research is lacking, the tracks left by vehicles may influence physical characteristics such as seasonal changes in beach slope, sand compaction and particle size distribution and ultimately the beach morphodynamics (see for example Abdulla *et al.* 2015). Following heavy traffic some beach profiles exhibited erosion (Leatherman & Long 1977), indicating that small and continues modifications to the physical environment can be significant on an exponential basis, thereby rendering beaches more susceptible to storm erosion over the long term. Other beaches, however, exhibited more variable profiles over the long-term than did non-impacted beaches (Anders & Leatherman 1981). On highly dynamic beaches experiencing large natural changes, the effects of daily or weekly off-road traffic on the geomorphology is considered to be insignificant compared to storm generated beach erosion.

The creation of access tracks through vegetation and over dunes results in localised damage to dune vegetation through crushing of plants and breaking of rhizomes, which in turn leads to reduced root production and consequently decreases in the floral ground cover and its associated abundance and biodiversity (Luckenbach & Bury 1983; Rickard *et al.* 1994; Stephenson 1999; Kutiel *et al.* 1999, 2000; Groom *et al.* 2007; Thompson & Schlacher 2008; Kelly 2014; Dewidar *et al.* 2016). The loss of plant cover in dunes can impact soil structure directly through increased soil densities, reduction of soil moisture, reduced infiltration, extension of diurnal soil temperature ranges and reduction of organic carbon content (Wilshire *et al.* 1978; Dewidar *et al.* 2016). Vegetation loss in response to ORV driving has also been linked to alteration of localised atmospheric conditions and soil chemistry (McAtee & Drawe 1981) leading to alteration of natural foredune profiles and formation of embryonic foredunes, increased dune deflation rates, loss of sediments to the swash zone, destabilisation and increased vulnerability to wind and wave erosion (Brodhead & Godfrey 1977; Griggs & Walsh 1981; Anders & Leatherman 1987a, 1987b; van der Merwe 1988; Priskin 2003; Thompson & Schlacher 2008; Spence 2014, but see also Houser *et al.* 2013).

Changes in the geomorphology of the beach in response to ORV traffic associated with the proposed development would be considered an indirect impact potentially of LOW to MODERATE magnitude (depending on traffic density and height on the beach). The impact would extend REGIONALLY across the shoreline of the concession area. Considering the highly dynamic nature of the coastline along the project area, impacts within the intertidal zone are predicted to be TEMPORARY only, with recovery of the beach's physical characteristics occurring within a few tidal cycles. Impacts would therefore be fully reversible. Where changes have occurred on the upper beach, in the dunes or on pans, out of the tidal influence, recovery would likely extend over the SHORT- to MEDIUM-TERM, respectively. The probability of geomorphological effects occurring as a result of indiscriminate beach driving is considered LOW.

The overall significance of the impact is therefore rated as **LOW.**

1	*Impacts of off-road driving on beach geomorphology*	
Project Phase:	**Construction, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	Moderate	Low
Reversibility	Recoverable	Reversible
Duration	Short to Medium	Short
Extent	Regional	Local
Probability	Low	Low
Significance	LOW (24)	LOW (9)
Confidence	High	
Loss of Resources	Low	
Mitigation Potential	High	
Cumulative potential	Unlikely if mitigation measures are implemented	

4.1.2 Impacts on Biodiversity

Coastal Birds

Vehicle use on the high shore and in the dunes has been linked to decreases in productivity of shorebirds that feed, roost and nest there (Burger 1991, 1994; Lord *et al*. 2001; Verhulst *et al*. 2001; Schlacher *et al*. 2013a). Impacts relate to modification of key behavioural traits that are crucial to their survival and reproduction, namely (1) changes to foraging behaviour, shifts in feeding times and decreased food intake (Stolen 2003; Thomas *et al*. 2003; Weston & Elgar 2005a, 2005b; Schlacher *et al*. 2013a); (2) decreased parental care when disturbed birds spend less time attending the nest, thus increasing exposure and vulnerability of eggs and chicks to predators; (3) decreased nesting densities in disturbed areas through crushing of nests and eggs; and (4) declines in fledgling numbers, direct collision and disturbance whilst feeding or roosting resulting in population shifts to less disturbed sites (Buick & Paton 1989; Hubbard & Dugan 2003; Williams *et al*. 2004; Cherry 2005; Tarr *et al*. 2010; Meager *et at*. 2012). Incidental crushing of beach invertebrate macrofauna by ORVs (see later) would also decrease food availability to foraging littoral birds (Schlacher *et al*. 2013b).

Damara Terns breed primarily on barren gravel or sandy plains, or on salt pans up to about 11 km inland (Frost & Shaughnnessy 1976; Braby *et al*. 2001), usually in loose colonies (Braby *et al*. 2009). When breeding, they commute between their nest and the sea, where they tend to feed in or just behind the surf zone (Braby 2011). Resting and preening between feeding bouts, as well as courtship rituals, mating, feeding of recently fledged chicks and other social interactions typically take place on open beaches near their nesting and/or foraging grounds (Braby 2011; J-P. Roux and J. Kemper pers. obs.). Previous studies have shown that ORV activity not only resulted in the direct loss of nest contents from nest being run over, but that the disturbance caused by ORVs also decreases breeding success (Frost & Shaughnessy 1976; Braby *et al*. 2009). Frequent and or regular ORV activity along beaches that are relatively close to their breeding colonies and foraging areas are therefore likely to cause disturbance and, at worst, reduced breeding success or permanent displacement of Damara Terns.

Resident and migratory shorebirds, especially those that forage predominantly on sandy beaches in the broader project area, such as Sanderlings, Curlew Sandpipers, White-fronted Plovers, Grey Plovers, Red Knots and Little Stints, but also Greater Flamingos and Lesser Flamingos feeding or roosting in temporary water-filled pans, may have their foraging and resting times significantly affected by ORV presence (e.g. Williams *et al*. 2004; Forgues 2010). Various resident and migratory coastal seabirds that may roost on mainland beaches in large numbers, such as Cape Cormorants, African Oystercatchers, Greater Crested Terns, Sandwich Terns, Common Terns and Kelp Gulls may also have their resting times curtailed by ORV presence, including at key juvenile nursery areas and migration staging areas (e.g. Pfister *et al*. 1992; Underhill 2014). White-fronted Plovers, which breed opportunistically throughout the year, often at the back of beaches just above the high water line, as well as on sandy or gravelly sparsely vegetated coastal plains, are particularly at risk of getting run over or having their nest contents destroyed by ORV activities. African Oystercatchers, which only infrequently breed on mainland beaches in Namibia, may be similarly affected.

Impacts on the abundance, breeding productivity and biodiversity on coastal sea- and shorebirds in response to ORV traffic associated with the proposed development would largely consist of an indirect impact (disturbance) and a small likelihood of a direct impact (bird mortalities), potentially of MODERATE magnitude (depending on traffic density, frequency and routes used). The impact would extend REGIONALLY across the shoreline of the concession area. Impacts are likely to be SHORT-TERM, but could have LONG-TERM implications, if ORV activities result in a reduction or loss of Damara Tern breeding colonies in the Meob Bay area, or the loss of a juvenile nursery or migration staging site. Impacts are likely to be recoverable and the probability of coastal bird biodiversity effects occurring as the result of indiscriminate, high density and/or frequent beach driving is considered to be MEDIUM.

The overall significance of the impact is therefore rated as **MODERATE.**

1	***Impacts of off-road driving on coastal birds***	
Project Phase:	**Construction, Operation and Decommissioning**	
Type of Impact	**Indirect (Disturbance) and Direct (Mortality)**	
Nature of Impact	**Negative**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	Moderate	Low
Reversibility	Recoverable	Reversible
Duration	Short (Long)	Short
Extent	Regional	Regional
Probability	Medium	Low
Significance	MODERATE (33/44)	LOW (14)
Confidence	High	
Loss of Resources	High	
Mitigation Potential	High	
Cumulative potential	Unlikely if mitigation measures are implemented	

Macroinvertebrates

Macrobenthic invertebrates (e.g. worms, molluscs, crustaceans) play a key role in the trophic structure of sandy beaches (McLachlan & Brown 2006), supporting higher-order consumers such as shorebirds and surf-zone fishes, and contributing to nutrient recycling on beaches (Soares *et al.* 1997). These macrofauna typically occupy the sand matrix of the intertidal zone (high- and mid-shore) where most vehicle traffic is concentrated (Schlachter & Thompson 2007) and are thus potentially vulnerable to impacts by ORVs through direct crushing of organisms (Wolcott & Wolcott 1984; van der Merwe & van der Merwe 1991; Barros 2001; Moss & McPhee 2006; Schlachter *et al.* 2007; Taylor 2013; Davies *et al.* 2016, amongst others), destruction or loss of habitat through compaction of sand (Dewidar *et al.* 2016) or crushing of alga wrack, leaf litter and drift wood on and above the driftline where organisms feed and live (Steinback & Ginsberg 2003). As the shear stress of ORVs can penetrate up to 30 cm into the sand (Atkinson & Clark 2003; but see also Davies *et al.* 2016) any invertebrates living in the upper layers of the beach would be expected to be negatively impacted by vehicle passes (Taylor *et al.* 2012; Taylor 2013).

Numerous studies have shown that macrobenthic assemblages on ORV-impacted beaches had significantly lower species diversity and reduced abundance, resulting in substantial changes in community structure and composition, particularly on the middle and upper shore where vehicle traffic was concentrated (Schlacher *et al.* 2008a; Schooler *et al.* 2017). On beaches with high ORV traffic, the high shore areas may be completely devoid of macroinvertebrates. Schlacher & Thompson (2007) reported negligible impacts of species whose distribution is centred below the effluent line, suggesting they occupy a “spatial refuge” from ORV traffic. In contrast, Davies *et al.* (2016) recently reported that even lowshore communities were affected, particularly on narrow beaches where drivers were forced to traverse a greater percentage of the beach face. Species occurring of the swash zone may also be more susceptible to vehicle traffic (van der Merwe & van der Merwe, 1991), implying that even occasional vehicle passes could inflict mortality to sensitive species.

Vehicle impacts would be expected to differ substantially between species depending on their burrowing depth, intertidal position, robustness of the exoskeleton and the compactness of the sediments (Wolcott & Wolcott 1984; van der Merwe & van der Merwe 1991; Schlacher *et al.* 2007a; Taylor 2013). In South Africa, van der Merwe & van der Merwe (1991) showed that surf clams[3] (*Donax serra* and *D. sordidus*) and whelks (*Bullia rhodostoma*) are less vulnerable to ORV impacts if buried in compact sand (see also Stephenson 1999), with individual whelks being robust enough to withstand being run over by vehicles even when placed on the beach surface. However, if surf clams and soft-bodies crustaceans such as the mysid *Gastrosaccus psammodytes* were exposed on or near the surface of the sand, damage increased significantly. Macroinvertebrates on the upper shore (in particular the isopod *Tylos granularis*) are highly susceptible to traffic impacts because of the softer sand and the tendency for ORV drivers to follow in the same tracks. As with turtle hatchlings, *Tylos* become trapped in the tracks thereby increasing their susceptibility to being crushed by passing vehicles.

Numerous studies undertaken on specific indicator species have likewise demonstrated both the sub-lethal and lethal impacts of ORVs. For example, both ghost crabs (*Ocypode* species) and surf clams (*Donax deltoids*) had lower densities and decreased body sizes at beaches with ORV traffic (Moss & McPhee 2006; Steiner & Leatherman 1981; Schlacher *et al.* 2007; Schlacher *et al.* 2008b; Thompson & Schlacher 2008, see also Taylor 2013). Sheppard *et al.* (2009) reported that ORVs significantly impaired the burrowing performance and some aspects of the body condition of surf clams thereby potentially increasing mortality by causing displacement to less favourable habitats by swash, and intensifying the

[3] Also known as white mussels, and frequently collected as bait by shore anglers.

risk of predation and desiccation. ORV-effects on ghost crabs include decreased home ranges, changed burrowing behaviour and burrow architecture, reduced densities, altered population structures and a shift in burrows distribution across the shore (Moss & McPhee 2006; Maccarone & Mathews 2007; Hobbs *et al*. 2008; Lucrezi & Schlacher 2010; Schlacher & Lucrezi 2010; Lucrezi *et al*. 2014, amongst others).

In many of the studies mentioned above, the magnitude of the impacts could be directly related to the type of vehicles involved, traffic volume, vehicle speed and driver behaviour. For example, the impacts from slow speed access along the foreshore in a straight path differ from vehicles travelling at high speed in dune areas, or turning across the beach face. Different beaches will have different capacities to withstand the impacts of vehicles. Nonetheless, a recent study identified that even low-level vehicle traffic negatively impacts the physical environment of the beach, and the ability of macroinvertebrates to survive in this habitat in the face of the disturbance (Davies *et al*. 2016). Such changes to these communities can have knock-on effects on higher-order consumers such as shore birds and surf-zone fish.

Studies investigating the recovery of beach macrofaunal communities following large-scale coastal diamond mining in southern Namibia, however, indicated that on cessation of the mining disturbance macrofauna recovered to functional similarity within three to five years (Pulfrich & Branch 2014; Pulfrich *et al*. 2014, 2015; but see also Nel *et al*. 2003).

Impacts on the biodiversity of beach macrobenthic invertebrates in response to ORV traffic associated with the proposed development would be considered an indirect impact potentially of LOW to MODERATE magnitude (depending on traffic density and height on the beach). The impact would extend REGIONALLY across the shoreline of the concession area. Impacts within the intertidal zone are predicted to be SHORT-TERM only, with recovery of the beach macrofaunal communities occurring within two to five years. Impacts would therefore be fully reversible. The probability of biodiversity effects occurring as a result of indiscriminate beach driving is considered MEDIUM.

The overall significance of the impact is therefore rated as **LOW.**

2	***Impacts of off-road driving on macrofaunal biodiversity***	
Project Phase:	**Construction, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	Moderate	Low
Reversibility	Fully Reversible	Fully Reversible
Duration	Short	Short
Extent	Regional	Local
Probability	Medium	Low
Significance	LOW (27)	LOW (14)
Confidence	High	
Loss of Resources	Low	
Mitigation Potential	High	
Cumulative potential	Unlikely if mitigation measures are implemented	

Two macroinvertebrate species are singled out for further discussion and assessment of impacts from ORVs, namely the giant isopod *Tylos granulatus* and the surf clam (white mussel) *Donax serra*.

The giant isopod, *Tylos granulatus,* is one of two semi-terrestrial isopod species that occur on sandy beaches in southern Africa. It is commonly referred to as the 'Pill bug' due to its propensity to curl up into a ball when disturbed. Historically, *T. granulatus* is known to have a natural distribution range extending from Swakopmund in Namibia to Cape Point in South Africa (Kensley 1974), being restricted to the west coast of southern Africa.

Tylos granulatus is strictly nocturnal and exhibits lunar and semi-lunar behavioural rhythmicity (Kensley 1972, 1974). *T. granulatus* remains buried up to 40 cm under the sand above the Spring High Water Mark during the day. During periods of burial, its metabolic rate drops dramatically, conserving energy (Marsh & Branch 1979). It emerges *en masse*, at least one hour after sunset, to scavenge on kelp wrack and other organic flotsam on sandy beaches (Figure 30). *T. granulatus* will infrequently emerge on high (but ebbing) tides during neaps, but most foraging activity takes place in a couple of hours during low tides each night (Kensley 1972, 1974). *T. granulatus* appears strongly photophobic. Kensley (1974) noted that on Blouberg beach near Cape Town, *T. granulatus* seldom emerges during full moons, and Odendaal *et al.* (1999) state that the species is inactive during full moon. It has strong rhythms of activity, emerging progressively later each night as the tide get later and later (Kensley 1972; Marsh & Branch 1979). Odendaal *et al.* (1999) studied *T. granulatus* populations in Namaqualand and found evidence that *T. granulatus* is preyed on by yellow mongoose *Cynictis pencillata.* They postulated that predation may be an important factor regulating activity (resulting in inactivity during daytime and full moon nights).

Figure 30: Abundance of *Tylos* feeding on washed up kelp (top) and a seal carcass (bottom).

The population status of *T. granulatus*, remains mostly unknown, but there is circumstantial evidence suggesting that certain populations may be severely threatened and others have completely disappeared. Species whose continued existence is threatened are classified into different categories of perceived risk and listed in an appropriate Red Data Book. It has been suggested that *T. granulatus* should be assigned a Red Data Book status of perhaps 'Vulnerable' (Brown 2000). The range of *T. granulatus* once extended across the whole southern African west coast, stretching far north into Namibia, but has now been reduced to probably less than half that. Human-induced disturbance (in the form of pollution, vehicles, construction and development) in the coastal zone is hypothesised to be responsible for the reduction in *T. granulatus* abundance and distribution (Brown & Odendaal 1994). A recent ecological survey between Lüderitz and Walvis Bay, however, found abundant evidence of *T. granulatus* populations on nearly all beaches along this relatively undisturbed coastal stretch (A. Pulfrich personal observation).

Recent genetic research has uncovered high levels of population structure in southern African *T. granulatus* populations with two distinct lineages present on the west coast, to the north and south of a Hondeklip/Kleinzee break (Mbongwa *et al.* 2019). The Namibian populations sampled from Elizabeth Bay and Mining Area 1 were not significantly differentiated from others in the northern section of its distribution, but they were found to be genetically distinct from other *T. granulatus* population sampled to the south of the Hondeklip/Kleinzee break (Mbongwa *et al.* 2019). With the exception of the populations occurring along the coastline of the Namib-Naukluft Park, nearly the entire northern *T. granulatus* lineage exists in areas impacted by coastal diamond mining. Considering the wide-scale decrease in abundance and distribution of this species, it remains an environmental concern with respect to coastal diamond mining and other developments.

The sandy beach bivalve *Donax serra* occurs abundantly on most wave-exposed beaches along the southern African West Coast (Figure 31). Juveniles inhabit the upper intertidal area for a period of three months (Laudien *et al.* 2001), whereas adults are found year-round at or below the spring low water mark (Donn 1990). Starvation, hydrodynamic processes, chemical parameters and different release times during the spawning period are thought to cause the differences in settlement time and recruitment strength between locations (Laudien *et al.* 2001). Studies on the burrowing times of individuals in sediments of different grain size (Nel *et al.* 2001; Serrano *et al.* 2002) suggests that adults are less able to withstand the more reflective morphodynamic conditions occurring on coarse-grained beaches. This would explain the absence of the species on southern Namibian beaches impacted by coastal diamond mining

D. serra is unusual among intertidal dwelling *Donax* species in that it does not undergo tidal migrations, but exhibit a semilunar pattern of movement corresponding to the spring-neap tidal cycle. These migrations keep the adults in the zone of water-saturated sand close to the water table (Donn *et al.* 1986).

It lives to up to 5 years of age and is extensively exploited for bait and eating both today (Branch *et al.* 2016) and over the past 4 000 years during which there was a heavy reliance on this food source by coastal hunter-gatherers (Kinahan 2022). Its fast growth rate makes the species fairly resilient to high fishing pressure. White mussels are harvested by hand or foot along the low water mark. As this fishing method is highly selective, there is little to no bycatch. Genetic research has revealed substantial subdivision of the two Namibian populations studied (Meob Bay and Langstrand) (Laudien *et al.* 2003), supporting the existence of a potential biotic barrier in the vicinity of Meob Bay (Agenbag & Shannon 1988). This, however, implies that separate analyses of population dynamics between the two populations would be required.

Figure 31: The white mussel or surf clam *Donax serra* (photo: https://uk.inaturalist.org).

Impacts on the abundance of white mussel and pillbugs in response to ORV traffic associated with the proposed development would be considered an indirect impact potentially of LOW (*Donax*) to MODERATE (*Tylos*) magnitude (depending on time of day and height on the beach). The impact would extend REGIONALLY across the shoreline of the concession area. Impacts within the intertidal zone are predicted to be SHORT-TERM only, with recovery of the affected species occurring within two to five years. Impacts would therefore be fully reversible. The probability of indiscriminate off-road driving resulting in decreased abundances of these species is considered MEDIUM to HIGH.

The overall significance of the impact is therefore rated **LOW** (*Donax*) to **MEDIUM (***Tylos***).**

3	***Impacts of off-road driving on* Tylos *and* Donax**	
Project Phase:	**Construction, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	Low (*Donax*) to Moderate (*Tylos*)	Minor
Reversibility	Fully Reversible	Fully Reversible
Duration	Short	Short
Extent	Regional	Regional
Probability	High	Improbable
Significance	MODERATE (24-36)	LOW (6)
Confidence	High	
Loss of Resources	Low	
Mitigation Potential	High	
Cumulative potential	Unlikely if mitigation measures are implemented	

Other Faunal and Floral species

Marked declines in herbaceous and perennial plants, arthropods, reptiles (particularly slow-moving species such as adders, chameleons and ground geckos) and mammals in ORV-used areas have also been reported, with heavily-used areas having virtually no native plants or wildlife remaining (Hosier & Eaton 1980; Luckenbach & Bury 1983; van Dam & Van Dam 2008). Negative effects were even measurable in areas experiencing relatively low levels of ORV activities (Luckenbach & Bury 1983). Wheel ruts (even as shallow as 5 cm) left by ORVs have also been shown to be detrimental to the dispersal of turtle hatchlings (van der Merwe *et al.* 2012), as they spend considerable time navigating through these, thereby increased exposure to predation, dehydration and energy expenditure during this initial stage of dispersal (Hosier *et al.* 1981;). Lights from night-driving ORVs have also been shown to affect the occurrence of loggerhead turtle nests, incubation periods and emergence success of turtle hatchlings in North Carolina (Nester 2006). More direct impacts of ORV on turtles include direct collisions with adults, hatchlings and live stranded turtles and crushing of or damage to nests. In turtle rookeries, high ORV usage can also result in deterrence to nesting and decreased nesting success due to compaction of beach sediments (US Fish and Wildlife Service 2016).

Other impacts of ORV driving on the biodiversity of sandy beaches and dune systems include habitat fragmentation from vehicle-induced dune breaches resulting in disruption of vegetation and accelerated sea or wind erosion. Extensive vehicle tracks through the dunes can result in previously contiguous areas of beach/dune habitat being converted into isolated patches of vegetation, which in turn can lead to an increased ecological vulnerability (Jalava 2004). There is also the potential for vehicles to act as vectors that spread alien or invasive pest plant species. This can occur by the physical transportation of seeds or plant material into new areas or by disrupting the existing indigenous vegetation cover to such an extent that new or invasive species can become established where they previously may not have survived (Sargent 2012).

Impacts on the abundance and diversity of other coastal species by ORV traffic associated with the proposed development would be considered an indirect impact potentially of LOW magnitude (depending on species, time of day and height on the beach). The impact would extend REGIONALLY across the shoreline of the concession area. Impacts within the intertidal zone are predicted to be SHORT-TERM only, with recovery of the affected species occurring within two to five years. Impacts would therefore be fully reversible. The probability of indiscriminate off-road driving resulting in decreased abundances of these species is considered MEDIUM to HIGH.

The overall significance of the impact is therefore rated **LOW.**

4	*Impacts of off-road driving on other fauna and flora*	
Project Phase:	**Construction, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	Low	Low
Reversibility	Fully Reversible	Fully Reversible
Duration	Short	Short
Extent	Regional	Local
Probability	Low	Low
Significance	LOW (16)	LOW (6)
Confidence	High	
Loss of Resources	Low	
Mitigation Potential	High	
Cumulative potential	Unlikely if mitigation measures are implemented	

4.3 Social and cultural Impacts

The use of ORV on beaches can be detrimental to both the enjoyment and safety of all beach users (Maguire *et al*. 2011; Steven & Salmon 2015; Kirk *et al*. 2020). Studies have shown that people who treat the beach as a place to explicitly drive 4x4 vehicles for enjoyment drove much faster than other people who drove on beaches (Steven & Salmon 2015; Petch *et al*. 2018), thereby disrupted over 70% of the area the vehicles drove on. A study by Maguire *et al*. (2011) conducted at south-eastern Australian beaches revealed that 67% of coastal residents would prefer vehicles to be banned from the beach, due to compromised safety of other beach users, loss of the overall beach experience and environmental concerns (see also Lindberg & Crook 1979). Similarly, in South Africa, De Ruyck *et al*. (1995) found that 81% of survey respondents wanted vehicles banned from the three beaches studied, with the primary reasons again being the safety of other users.

Indiscriminate driving of ORV can also cause physical damage to palaeontological and archaeological sites, as drivers are frequently unaware of their existence (Anon 1977). Potential impacts to archaeological sites at Meob Bay is dealt with in the specialist study on archaeology (Kinahan 2022).

Impacts of off-road driving associated with the proposed development on other beach users along the coastline of the Namib-Naukluft Park would be considered an indirect impact potentially of MINOR magnitude due to the low visitor numbers in the area. Should it occur, the impact would be highly LOCALISED, and TEMPORARY only. Impacts would therefore be fully reversible. The probability of indiscriminate off-road driving associated with the proposed development on other beach users is therefore considered IMPROBABLE.

The overall significance of the impact is therefore rated **LOW.**

5	*Impacts of off-road driving on other beach users*	
Project Phase:	**Construction, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	Minor	Minor
Reversibility	Fully Reversible	Fully Reversible
Duration	Temporary	Temporary
Extent	Local	Site
Probability	Improbable	Improbable
Significance	LOW (5)	LOW (5)
Confidence	High	
Loss of Resources	Low	
Mitigation Potential	High	
Cumulative potential	Unlikely if mitigation measures are implemented	

5. RECOMMENDATIONS AND CONCLUSION

5.1 Mitigation Measures and Management Recommendations

Should the application be authorised, the following mitigation measures and management actions are proposed:

- Conduct a comprehensive environmental awareness programme regarding the impacts of off-road driving on the environment amongst contracted construction and lodge personnel;
- Schedule the beach driving trips to coincide with the receding tide, i.e. driving should occur only 2-3 hours either side of the low tide;
- Access to the beach must be *via* established and fixed access points only;
- Strict track discipline must be maintained at all times, both by guides and visitors;
- When undertaking trips to the south and north of the lodge, keep to the designated existing tracks only;
- Once on the beach, restrict traffic on the upper shore to the minimum required, i.e. drive below the driftline, in the mid- to lower beach zones only;
- No driving at night;
- Maintain a buffer of at least 25 m and a vehicle speed slower than 30 km/h around roosting or feeding shorebirds (Schlacher *et al.* 2013b);
- If necessary, stop to allow large groups of roosting or foraging birds to move away from approaching vehicles and to take flight without causing a mass stampede;
- Maintain a buffer of at least 100 m and a vehicle speed of slower than 30 km/h around seal colonies or haul-out sites, allowing seals to move away from approaching vehicles towards the ocean without causing a mass stampede;
- Consider imposing a seasonal closure during periods critical to the life cycle of vulnerable coastal bird species. This would concurrently provide opportunity to allow impacted macroinvertebrates to recover;
- When observing Damara Terns or shorebirds displaying behaviour that indicates the presence of a nest nearby (e.g. mobbing or alarm call behaviour by parent birds, birds acting injured to distract attention from their nest), avoid the nest and a 100 m radius until nesting has clearly been concluded;
- Lodge guests may not undertake any recreational fishing or bait collection whilst in the area;
- Adhere to NIMPA regulations, including access restrictions to sensitive seabird breeding areas.
- Have good house-keeping practices in place at all times (e.g. remove all solid waste generated during beach trips and dispose of this in suitable containers at the lodge for subsequent transport to a licenced landfill site);
- Consider conducting regular collection and removal of refuse and litter from intertidal and coastal areas;
- Only equipment and vehicles actively involved in coastal tours should be permitted on the beach. When not in use, and overnight, all vehicles and equipment must be withdrawn to designated parking areas;
- No refuelling of vehicles on the beach. Refuelling of vehicles from a bowser should take place on higher ground in a designated refuelling station at the lodge facilities;
- Maintain all vehicles and equipment used on the beach to ensure that no oils, diesel, fuel or hydraulic fluids are spilled;
- Vehicles should have a spill kit (peatsorb/ drip trays) onboard in the event of a spill.

5.2 Environmental Acceptability and Conclusions

From an environmental perspective the proposed coastal and beach routes have all been subjected to past anthropogenic disturbance; there are established tracks along the coast and inland towards the airstrip, wells and existing campsites and the beaches receive comparatively low and irregular pressures from pedestrian and ORV traffic. Although the current application is perhaps benign in isolation, it will contribute to a cumulative negative impact upon the coastal environment, the beach macrofauna and coastal birds. Nonetheless, if the appropriate mitigation measures and management recommendations advanced in this report, and for the proposed project as a whole, are implemented, there is no reason why the proposed development should not go ahead.

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