APPENDIX 8: MARINE ECOLOGY IMPACT ASSESSMENT

ENVIRONMENTAL IMPACT ASSESSMENT FOR PROPOSED EXPLORATION WELL-DRILLING IN BLOCK 2912 OFF THE COAST OF SOUTHERN NAMIBIA

Marine Ecology Impact Assessment

Prepared for:

SLR

On behalf of:

Total E and P Namibia B.V.

TotalEnergies

January 2023

ENVIRONMENTAL IMPACT ASSESSMENT FOR PROPOSED EXPLORATION WELL-DRILLING IN BLOCK 2912 OFF THE COAST OF SOUTHERN NAMIBIA

MARINE FAUNA IMPACT ASSESSMENT

Prepared for

SLR Environmental Consulting (Namibia) (Pty) Ltd

On behalf of:

Total E and P Namibia B.V.

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January 2023

PISCES Environmental Services (Pty) Ltd

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EXECUTIVE SUMMARY

Total Exploration & Production Namibia BV (TEEPNA) is planning undertake pre-drilling surveys (sonar, echo sounder, sub-bottom profiling and sediment sampling) and to drill up to 10 exploration wells in Block 2912 during the 2023/2024 season and possibly in the future. The Licence Block is located in the Deep Offshore and Ultra Deep Offshore of the Orange Basin, approximately 290 km west of Oranjemund in southern Namibia, in water depths of between approximately 3 000 m and 4 000 m.

Sediments in the licence area comprises muds, with benthic habitat types dominated by Namib Lower Slope and Namib Abyss, which are considered 'Least threatened'. Strong south-easterly winds predominate in the offshore regions. The oceanography of the project area is dominated by the Benguela Current. Waters in the offshore regions of the Licence Area will primarily be nutrient poor and clear, although seasonal upwelling can be expected on the coast, with the Lüderitz upwelling cell to the north of the project area being the most intense upwelling cell in the system.

Plankton abundance in offshore waters is generally low. Information on seabed communities specific to the area indicates that macrofaunal communities are dominated by polychaetes, with further representation by molluscs, crustaceans and echinoderms. The fish species likely to be encountered in the survey area comprise primarily the large pelagic species (e.g. tunas, billfish and pelagic sharks), which migrate throughout the southern oceans, between surface and deep waters (>300 m). Information on mesopleagic fish species is lacking. Migrating leatherback turtles are also likely to occur, as are a variety of pelagic seabirds. Marine mammals likely to be encountered include migrating humpback whales, sperm whales, and various baleen and toothed whales known to frequent offshore waters. Block 2912 lies well offshore of the Namibian Islands' Marine Protected Area, and the offshore Ecologically and Biologically Significant Areas (EBSAs), Ecological Support Areas (ESAs) and marine Important Bird Areas (IBAs).

The identified aspects and their potential impacts resulting from the proposed pre-drilling surveys are:

- Increase in underwater noise levels by geophysical surveys, and survey and support vessels
  - Disturbance / behavioural changes of marine fauna
  - Avoidance of key feeding areas
  - Effects on key breeding areas
- Physical disturbance of the seabed during piston-coring and box-coring surveys
  - Disturbance and loss of seabed habitat and associated benthic macrofauna

The identified aspects and their potential impacts resulting from the proposed drilling operations are:

- Physical disturbance of the seabed during ROV surveys, discharge of residual cement and well installation, or loss of equipment
  - Disturbance and loss of seabed habitat and associated benthic macrofauna
- Accumulation of excess cement (from cementing and disposed drill cuttings on the seabed
  - Smothering of seabed habitat and associated benthic fauna
  - Toxicity and bioaccumulation effects on marine fauna
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
- Discharge of drilling fluids and product water

  - Increased water turbidity and reduced light penetration
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
- Alteration of the seabed habitat through the physical presence of subsea structures (placement and abandonment of wellhead), solidified excess cement, or loss of equipment
  - Increase in benthic and demersal biodiversity and biomass
- Introduction of invasive alien species in the ballast water of the drilling units or as fouling organisms on the hulls/rig infrastructure
  - Threats to Benguela ecosystem biodiversity
- Increase in underwater and atmospheric noise levels by VSP surveys, drilling unit, support vessels and helicopters
  - Disturbance / behavioural changes of coastal and marine fauna
  - Avoidance of key feeding areas
  - Effects on key breeding areas (e.g. coastal birds and cetaceans)
  - Abandonment of nests (birds) and young (birds and seals)
- Discharge of waste to sea (e.g. deck and machinery space drainage, sewage and galley wastes) from drilling unit and support vessels, and local reduction in water quality
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
  - Increased food source for marine fauna
  - Fish aggregation and increased predator-prey interactions
- Increase in ambient lighting from drilling unit and support vessels
  - Disorientation and mortality of marine birds
  - Physiological and behavioural effects on marine fauna
  - Fish aggregation and increased predator-prey interactions
- Collision of vessel with marine fauna and entanglement in gear
  - Ship strikes by drill rig and/or support vessels
- Localised reduction in water quality due to accidental release of fuel into the sea, discharge of fuel during bunkering and discharge of hydraulic fluid due to pipe rupture
  - Toxic effects on marine biota and reduced faunal health
- Uncontrolled release of oil/gas from the well
  - Toxic effects on marine biota and reduced faunal health
  - Pollution and smothering of coastal habitats

The highest sensitivities to the proposed drilling activities are:

- Tripp Seamount, which is located ~140 km east of the licence block, that potentially supports vulnerable, long-lived benthic invertebrate species;
- Numerous vulnerable and endangered pelagic shark species;
- Leatherback turtles that migrate through the area;
- Globally endangered African Penguins, Cape Gannets, Bank Cormorants and Cape Cormorants, that breed within the Namibian Islands' Marine Protected Area (NIMPA);
- Sperm whales, which occur in the area year-round;
- Humpback and Fin whales, which migrate through the area between May and December; and
- The NIMPA and EBSA, and the Orange Seamount and Canyon Complex EBSA.

The residual impacts on marine habitats and communities associated with the proposed pre-drilling surveys and drilling activities are summarised below, and the main mitigation measures are listed.

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Biological component		
Reduction in water quality due to normal vessel discharges	• Implement a waste management system that addresses all wastes generated • Use drip trays to collect run-off from equipment that is not contained within a bunded area and route contents to the closed drainage system • Implement leak detection and repair programs for valves, flanges, fittings, seals, etc. • Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages • Prohibit operational discharges within the Namibian Islands MPA and EBSA and Orange Seamount and Canyon Complex EBSA (and up current when in close proximity) during surveying or transit to and from the drill site	Very Low
Risks to biodiversity due to discharge of ballast water	• Avoid the unnecessary discharge of ballast water. • Use filtration procedures during loading • Ensure that routine cleaning of ballast tanks • Ensure all infrastructure is thoroughly cleaned prior to deployment	Negligible
Disturbance of marine fauna due to helicopter noise	• Pre-plan flight paths to ensure that no flying occurs over the Atlas Bay, Wolf Bay and Long Island seal colonies or any of the Islands within the NIMPA. • Avoid extensive low-altitude coastal flights • Maintain a flight altitude >1 000 m at all times, except when taking off and landing or in a medical emergency. • Maintain an altitude of at least 1 000 m above the NIMPA islands within a radius of one nautical mile around islands' low water mark. • Over-flight restrictions of a minimum altitude of 3000 feet/1000 meters apply to seal colonies at Van Reenen Bay, Wolf and Atlas Bays and Bakers Bay on the mainland of the NIMPA, except for Diaz Point provided Diaz Point is only approached from the North by air. • Comply fully with aviation and authority guidelines and rules. • Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Disturbance of marine fauna due to vessel lighting and flaring	• Reduce lighting on the survey and support vessels, and drill rig, to a minimum compatible with safe operations • Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard boxes) in a quiet area for subsequent release during daylight hours. • Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring).	Very Low
Disturbance of Seabed Sediments and Associated Biota by ROV Surveys and Drilling	• Do not land ROVs on the seabed as part of normal operations. • Design of pre-drilling site surveys to ensure there is sufficient information on seabed habitats, including the mapping potentially vulnerable habitats thereby preventing potential conflict with the well site. • In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations.	Low
Impacts on benthic macrofauna through disturbance of sediments and increased seabed turbidity	• Do not land ROVs on the seabed as part of normal operations. • Limit the area directly affected by seabed sampling or physical contact with infrastructure to the smallest area required.	Negligible
Disturbance and smothering of soft-sediment biota from due to drilling solids discharge	• Meticulous design of pre-drilling site surveys to provide sufficient information on seabed habitats, and to map potentially vulnerable habitats thereby preventing potential conflict with the well site. • Pre-drilling site surveys (ROV or drop camera) should be undertaken over a 100 m[1] radius around potential drilling locations to ensure that vulnerable habitats (e.g. hard grounds), species (e.g. cold corals, sponges) or structural features (e.g. rocky outcrops) are avoided. Expert review of ROV footage of pre-drilling surveys to identify potential vulnerable habitats within 100 m of the drill site. • Ensure drill site is located more than 100 m from any identified vulnerable habitats.	Low

[1] A 500 m radius area for the ROV survey would be preferable. Because of the considerable depth in the area of interest, this would, however, not be technically feasible. Based on evidence from the baseline visual information gathered during a survey across the area of interest in Block 2912 in October 2022 (BSL, unpublished), the seabed at > 3 000 m depth is seen as homogenous unconsolidated sediment and the presence of vulnerable habitats unlikely. Considering this and the limited distance around the drill site that smothering of benthic fauna would be expected (maximum deposition layer up to 88 m from drill site), a minimum 100 m radius ROV survey would be deemed appropriate in this deepwater environment.

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Disturbance and/or Smothering of deep-water reef communities due to drilling solids discharge	• If vulnerable habitats are detected, adjust the well position accordingly or implement appropriate technologies, operational procedures and monitoring surveys to reduce the risks of, and assess the damage to, vulnerable seabed habitats and communities.	Medium
Biochemical Impacts of Residual Water-Based muds and NADFs on marine organisms in unconsolidated sediments	• Ensure only low-toxicity and partially biodegradable additives are used. • Use high efficiency solids control equipment.	Negligible
Biochemical Impacts of Residual Water-Based muds and NADFs on marine organisms in unconsolidated sediments	• Ensure regular maintenance of the onboard solids control equipment	Low
Biocemical impacts of cement additives	• Ensure regular maintenance of the onboard solids control equipment.	Negligible
Impacts of drill cuttings discharge on water column (turbidity & light) and seabed (turbidity)	None	Negligible
Impacts of Cuttings Discharges: development of anoxic sediments around the wellbore	None	Negligible
Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in seabirds, seals, turtles and cetaceans due to drilling and vessel noise	• Implement a maintenance plan to ensure all diesel motors and generators receive adequate maintenance to minimise noise emissions. • Ensure vessel transit speed between the survey / drill area and port is a maximum of 12 knots (22 km/hr), except within 25 km of the coast where it is reduced further to 10 knots (18 km/hr). • Apply marine mammal observation and monitoring procedures during VSP operations (visual surveillances by trained staff, soft start procedures, low visibility procedures).	Very Low
Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to pre-drilling geophysical surveys and VSP	• Appoint a minimum of two dedicated Marine Mammal Observer (MMO), with a recognised MMO training course, on board for marine fauna observation (360 degrees around survey vessel), distance estimation and reporting. One MMO should also have Passive Acoustic Monitoring (PAM) training. The MMO must ensure compliance with mitigation measures during seismic geophysical surveying. • Ensure survey vessel is fitted with PAM technology (one or more hydrophones), which detects animals through their vocalisations, should it be possible to safely deploy PAM equipment, particularly if surveying takes place between June and November.	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
	• Pre-survey scans should be limited to 15 minutes prior to the start of survey equipment. • "Soft starts" should be carried out for any equipment of source levels greater than 210 dB re 1 µPa at 1 m over a period of 20 minutes duration, allowing sensitive species to move out of the area and thus avoid potential physiological injury. • If several types of sonar equipment are to be started sequentially or interchanged during the operation, only one pre-shoot search is required prior to the start of acoustic output. A pre-shoot search will, however, be required for gaps in data acquisition of greater than 10 minutes. • Terminate the survey if any marine mammals show affected behaviour within 500 m of the survey vessel or equipment until the mammal has vacated the area. • Avoid planning geophysical surveys during the movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters (beginning of June to end of November). As no seasonal patterns of abundance are known for odontocetes occupying the area, a precautionary approach to avoiding impacts throughout the year is recommended.	
Impacts of petroleum infrastructure, lost equipment and residual cement on marine biodiversity	• The location of abandoned wellheads must be registered and distributed via "Notice to Mariners" and "Notice to Fishers". • In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations.	Very Low
Well testing	• Use high efficiency burners for flaring to optimise combustion of the hydrocarbons in order to minimise emissions and hydrocarbon 'drop-out' during well testing. • Maximise flare combustion efficiency by controlling and optimising flare fuel/air/stream flow rates. • Operational monitoring.	Very Low

The identified aspects and their potential impacts resulting from unplanned events are summarised below:

- Collision of vessel with marine fauna and entanglement in gear
  - Ship strikes by drill rig and/or support vessels

- Localised reduction in water quality due to accidental release of fuel into the sea, discharge of fuel during bunkering and discharge of hydraulic fluid due to pipe rupture
  - Toxic effects on marine biota and reduced faunal health
- Uncontrolled release of oil/gas from the well
  - Toxic effects on marine biota and reduced faunal health
  - Pollution and smothering of coastal habitats

The highest sensitivities to unplanned events are:

- Large migratory and resident cetaceans;
- Tripp Seamount that potentially supports vulnerable, long-lived benthic invertebrate species;
- Offshore MPAs and EBSAs in the broader project area;
- Coastal and estuarine habitats along the coast;
- Endangered, regionally endemic African Penguins, Cape Gannets, Bank Cormorants and Cape Cormorants that breed in the broader project area;
- Critically endangered, endangered and vulnerable pelagic seabirds (primarily albatrosses); and
- Leatherback turtles that migrate through the area.

The residual impacts on marine habitats and communities associated with the proposed drilling activities are summarised below, and the main mitigation measures are listed.

Impact	Significance (before mitigation)	Significance (after mitigation)
Plankton and ichthyoplankton	Negligible	Negligible
Marine invertebrates	Negligible	Negligible
Fish	Medium	Low
Seabirds	Low	Very Low
Turtles	Medium	Low
Seals	Low	Very Low
Whales and dolphins		
Baleen whales	Medium	Low
Toothed whales and dolphins	Medium	Low

Other impacts before and after mitigation on marine habitats and communities associated with the proposed project are summarised below:

Impact	Significance (before mitigation)	Significance (after mitigation)
Non-seismic noise - helicopter	Low	Low
Non-seismic noise - vessel	Very Low	Very Low
Vessel lighting	Very Low	Very Low
Hull fouling and ballast water discharge	Very Low	Negligible
Waste Discharges to sea	Very Low	Very Low

Impact	Significance (before mitigation)	Significance (after mitigation)
Ship strikes and entanglement in gear	Low	Low
Accidental loss of equipment	Very Low	Very Low
Operational spills and vessel collision	Medium	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Biological component		
Collision of Vessels with marine fauna and entanglement in gear	• Keep a constant watch from all vessels (Vessel Captain and crew) for cetaceans and turtles in the path of the vessel. Alter course and avoid animals when necessary. • Ensure vessel transit speed between the drill area and port is a maximum of 12 knots (22 km/hr), except within 25 km of the coast where it is reduced further to 10 knots (18 km/hr) as well as when sensitive marine fauna are present in the vicinity. • Report any collisions with large whales to the IWC database	Low
Accidental loss of equipment to seabed	• Ensure containers for hazardous substances are sealed / covered and loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system. • Minimise the lifting path between vessels. • Maintain an inventory of all equipment and undertake frequent checks to ensure these items are stored and secured safely on board each vessel. • Undertake a post drilling ROV survey to scan seafloor for any dropped equipment and other removable features (e.g. excess cement) around the well site. In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the licence area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval. • Notify Ministry of Works and Transport (Directorate of Maritime Affairs) and the SAN Hydrographer of any hazards left on the seabed or floating in the water column, and request that they send out a Notice to Mariners with this information.	Very Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Accidental oil release to the sea due to vessel collisions, bunkering accident and line / pipe rupture	• Ensure personnel are adequately trained in both accident prevention and immediate response, and resources are available on each vessel. • Use low toxicity dispersants cautiously and only with the permission of MFMR. • As far as possible, and whenever the sea state permits, attempt to control and contain the spill with suitable recovery techniques to reduce its spatial and temporal impacts. • Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station. • Contact the following cleaning stations to help coordinate the rescue: – MFMR Lüderitz (+264 63 202415) – SANCCOB Cape Town (+27 21 5576155) • Ensure offshore bunkering is not undertaken in the NIMPA or under the following circumstances: – Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; – During any workboat or mobilisation boat operations; – During helicopter operations; – During the transfer of in-sea equipment; and – At night or times of low visibility.	Low
Effects of blow-out on marinefauna	• As far as possible, all effort will be made to not schedule drilling operations during the Austral Winter when the likelihood of shoreline oiling following the unlikely event of a blow-out is highest. In the case of exploration wells drilled in a sequence covering this period, response needs to be enhanced. • Develop a well-specific response strategy and plans (OSCP and BOCP), aligned with the National OSCP, for each well location that identifies the resources and response required to minimise the risk and impact of oiling (shoreline and offshore). This response strategy and associated plans must take cognisance to the local oceanographic and meteorological seasonal conditions, local environmental receptors and local spill response resources. The development of the site-specific response strategy and plans must include the following: – Assessment of onshore and offshore response resources (equipment and people) and capabilities at time of drilling, location of such resources (in-country or international),	Very igh

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
	and associated mobilisation / response timeframes.	
Effects of blow-out on marinefauna (cont.)	– Selection of response strategies that reduce the mobilisation / response timeframes as far as is practicable. Use the best combination of local and international resources to facilitate the fastest response. – Should there be any significant changes in the modelling input data closer to the spud date of the well, these should be considered and the modelling report must be updated accordingly in order to guide the final response strategy – The sensitivity maps used for all future studies must be regularly updated and used to guide all activities and response. – Develop intervention plans for the most sensitive areas to minimise risks and impacts and integrate these into the well-specific response strategy and associated plans. – If modelling and intervention planning indicates that the well-specific response strategy and plans cannot reduce the response times to less than the time it would take oil to reach the shore, additional proactive measures must be committed to. • Schedule joint oil spill exercises including TEEPNA and local ministries / other authoritities and organisations to test the Tier 1, 2 & 3 responses. • Ensure contract arrangements and service agreements are in place to implement the OSCP, e.g. capping stack in Saldanha Bay and other international locations, SSDI kit, surface response equipment (e.g. booms, dispersant spraying system, skimmers, etc.), dispersants, response vessels, etc. • Use low toxicity dispersants that rapidly dilute to concentrations below most acute toxicity thresholds. Dispersants should be used cautiously and only with the permission of MFMR. • Ensure a standby vessel is within 30 minutes of the drilling unit, equipped for dispersant spraying and can be used for mechanical dispersion (using the propellers of the ship and/or firefighting equipment). It should have at least 5 m^3 of dispersant onboard for initial response.	Very High

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blow-out on marinefauna (cont.)	• As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill • In the event of a spill, use satellite-borne Synthetic Aperture Radar (SAR)-based oil pollution monitoring to track the behaviour and size of the spill and optimise available response resources • Ensure adequate resources are provided to OSCP (including to collect, stabilise and transport oiled birds to a cleaning station). • Ensure that the following aspects are included in insurance cover to financially manage the consequences of any unplanned pollution event on environmental and social aspects: – Damages and compensation to Third-Parties. Evidence to be provided to NAMCOR.	Very High

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ABBREVIATIONS and UNITS

A	Amperes
AAIW	Antarctic Intermediate Water
ALARP	As Low As Reasonably Practicable
BAR	Basic Assessment Report
BAT	Best Available Techniques
bbls/day	Barrels per day
BCC	Benguela Current Commission
BCLME	Benguela Current Large Marine Ecosystem
BOP	Blow-out Preventor
BOCP	Blow Out Contingency Plan
CBD	Convention of Biological Diversity
cm	centimetres
cm/s	centimetres per second
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CSIR	Council for Scientific and Industrial Research
dB	decibels
DNA	deoxyribonucleic acid
DWH	Deepwater Horizon
EBSA	Ecologically or Biologically Significant Area
EIA	Environmental Impact Assessment
EIF	Environmental Impact Factor
EMF	Electromagnetic Field
EMP	Environmental Management Programme
EPLs	Exclusive Prospecting Licences
ERP	Emergency Response Plan
ESIA	Environmental and Social Impact Assessment
g/m^2	grams per square metre
$g\ C/m^2$	grams Carbon per square metre
g/ℓ	Grams per litre
h	hour
ha	hectares
HAB	Harmful Algal Bloom
HF	High Frequency
H_2S	hydrogen sulphide
Hz	Herz
IBAs	Important Bird Areas
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ITOPF	International Tanker Owners Pollution Federation
IMMA	Important Marine Mammal Area
IMO	International Maritime Organisation
IUCN	International Union for the Conservation of Nature

IWC	International Whaling Commission
JNCC	Joint Nature Conservation Committee
KBA	Key Biodiversity Area
kHz	kiloHerz
km	kilometre
km^2	square kilometre
km/h	kilometres per hour
kts	knots
LCDW	Lower Circumpolar Deep Water
LF	Low Frequency
LUCORC	Lüderitz upwelling cell - Orange River Cone
Ma	million years
MEFT	Ministry of Environment, Forestry and Tourism
MFMR	Ministry of Fisheries and Marine Resources
ML	Mining Licence
MMO	Marine Mammal Observer
MPA	Marine Protected Area
MSP	Marine Spatial Planning
MWT	Ministry of Works and Transport
m	metres
m^2	square metres
mm	millimetres
m^3/s	cubic metre per second
m/sec	metres per second
MFO	Mixed-function oxygenase
mg $C/m^2/hr$	milligrams Carbon per square metre per hour
mg/ℓ	milligrams per litre
mg/m^3	milligrams per cubic metre
ml/l	millilitres per litre
NADW	North Atlantic Deep Water
NAMCOR	National Petroleum Corporation of Namibia
NBHF	narrow band, high frequency
NEMBA	National Environmental Management: Biodiversity Act
NDP	Namibian Dolphin Project
NIMPA	Namibian Islands Marine Protected Area
NMFS	National Marine Fisheries Service
NSF	National Science Foundation
NW	north-west
OMZs	Oxygen Minimum Zones
ONCS	Offshore Chemical Notification Scheme
OSCP	Oil Spill Contingency Plan
OSPAR	Oslo/Paris convention *(for the Protection of the Marine Environment of the North-East Atlantic)*
OSPL	Oil Spill Response Limited
PAH	Polycyclic aromatic hydrocarbons

PAM	Passive Acoustic Monitoring
PEL	Petroleum Exploration Licence
PIM	Particulate Inorganic Matter
POM	Particulate Organic Matter
ppm	parts per million
psi	pound-force per square inch
PTS	permanent threshold shifts
rms	root mean squared
RMU	Regional Management Unit
ROVs	Remote Operated Vehicles
SACW	South Atlantic Central Water
SADCO	Southern African Data Centre for Oceanography
SANBI	South African National Biodiversity Institute
SAR	Synthetic Aperture Radar
SAT	saturation
SD	**standard deviation**
S&EIR	Scoping and Environmental Impact Reporting
SEL	**sound exposure level**
SLR	SLR Consulting (Pty) Ltd
Sm^3/day	Standard cubic metre per day
SOPEP	Shipboard Oil Pollution Emergency Plan
SPL	sound pressure level
SPRFMO	South Pacific Regional Fisheries Management Organisation
SSDI	Subsea Dispersion Injection
SST	Sea Surface Temperature
SW	south-west
SWIO	South Western Indian Ocean
TAC	Total Allowable Catch
TEEPNA	Total Exploration and Production Namibia B.V.
TOC	Total Organic Carbon
TOPS	Threatened or Protected Species
TSPM	Total Suspended Particulate Matter
TSS	Total Suspended Solids
TTS	temporary threshold shifts
UCDW	Upper Circumpolar Deep Water
UK	United Kingdom
US	United States of America
VHF	Very High Frequency
VMEs	Vulnerable Marine Ecosystems
VOCs	volatile organic compounds
VOS	Voluntary Observing Ships
WHO	World Health Organisation
WWF	World Wildlife Fund
W-SW	west south-west

µg	micrograms
µm	micrometre
µg/ℓ	micrograms per litre
µM/ℓ	micro Mols per litre
µPa	micro Pascal
°C	degrees Centigrade
%	percent
‰	parts per thousand
~	approximately
<	less than
>	greater than

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 Plans/Programmes relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents. She is a registered 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 report was compiled for SLR Environmental Consulting (Namibia) (Pty) Ltd on behalf of Total E and P Namibia BV for their use in preparing an Environmental Impact Assessment for proposed exploration well drilling in Block 2912 off the coast of Southern Namibia.

I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of TEEPNA and SLR, and has no vested interests in the proposed project or the study area.

Dr Andrea Pulfrich

1 GENERAL INTRODUCTION

1.1 Background

Total E and P Namibia BV (TEEPNA) is the operator of Blocks 2912 and 2913B offshore of southern Namibia. Intensive geological and geophysical studies have been conducted in the blocks since 2017 to identify all possible leads and prospects. As a result, a clearance certificate was received to drill the first exploration well during 2020. Following further 3D seismic acquisition over the two blocks, TEEPNA is planning to drill up to 10 exploration wells within an Area of Interest within Block 2912. The Licence Block is situated offshore of the Orange River mouth at the edge of the Namibian Exclusive Ecolomic Zone (EEZ) in water depths between 3 000 m and 4 000 m.

Under Namibia's Environmental Management Act of 2007, the drilling of exploration wells is a listed activity (Government Notice No. 29) requiring an Environmental Impact Assessment (EIA) process in order to obtain an Environmental Clearance Certificate from the Ministry of Environment, Forestry and Tourism (MEFT).

SLR Environmental Consulting (Namibia) (Pty) Ltd (SLR) has been appointed by TEEPNA to undertake the necessary application process in terms of the Environmental Management Act, 2007 (No. 7 of 2007). SLR in turn has approached Pisces Environmental Services (Pty) Ltd to provide a specialist report on potential impacts of the proposed exploration well-drilling activities on marine fauna and ecological processes in the area.

1.2 Terms of Reference

The Terms of Reference for the Marine Faunal Specialist Study as provided by SLR are:

- Provide a general description of the marine fauna off the Southwest Coast of South Africa, based on current available literature, with specific relevance to Block 5/6/7 and the proposed and Project's area of influence, where possible;
- Describe the coastal and offshore habitats in the area of influence that are likely to be affected by the exploration drilling activities;
- Identify sensitive habitats and species that may be potentially affected by the proposed exploration activities;
- Describe seasonal and migratory occurrences of key marine fauna based on available data;
- Identify, describe and assess the significance of potential impacts of the proposed exploration programme on the local marine fauna, focussing particularly on the benthic environment, but including generic effects on cetaceans, turtles, seals, fish and pelagic invertebrates. These should include impacts of drilling on the benthic environment and those associated with normal drilling operations and upset conditions on marine fauna using information from the underwater noise, drill cutting and oil spill modelling studies conducted for the ESIA; and
- Identify practicable mitigation measures to reduce the significance of any negative impacts and indicate how these can be implemented during the execution of proposed exploration programme.

1.3 Approach to the Study

All identified marine and coastal impacts are summarised, categorised and ranked in an appropriate impact assessment table, to be incorporated in the overall ESIA.

NOTE: This report covers **exploration drilling** of up to ten wells only. The possible range of the future exploration and production activities that may arise cannot at this stage be reasonably defined as these may vary significantly in scope, location, extent, and duration depending on whether a resource(s) is discovered, its size, properties and location, etc. It is possible that the proposed exploration fails to identify an economic hydrocarbon resource, in which case the potential impacts associated with the production phase would not be realised. It is thus not possible to include an assessment of the potential environmental impacts associated with the production phase. Should the project proceed to the production phase, a new full ESIA process would need to be undertaken.

1.3.1 Assumptions, Limitations and Information Gaps

As determined by the terms of reference, this study has adopted a 'desktop' approach. Consequently, the description of the natural baseline environment in the study area is based on a review and collation of existing information and data from the scientific literature, internal reports and the Marine Mammal Observer (MMO) Reports (Benthic Solutions Ltd 2019b, 2019c) and the Environmental Baseline and Habitat Assessment Report compiled for the Venus 1X project (Benthic Solutions Ltd 2019a). Information had been updated where appropriate.

The information for the identification of potential impacts of the proposed exploration activities on the benthic marine environment was drawn from various scientific publications, the Generic EMPr (CCA and CMS 2001) and Benguela Current Large Marine Ecosystem (BCLME) Thematic Report (CSIR 1999), previous specialist reports (Atkinson 2010; Atkinson & Shipton 2010) and information sourced from the Internet. The sources consulted are listed in the Reference chapter.

Information gaps include:

- abundance, distribution and diversity of the benthic macrofaunal communities and potentially vulnerable species beyond the shelf break and in continental slope and abyssal habitats;
- abundance, distribution, diversity and seasonality of demersal fish communities beyond the shelf break and in continental slope and abyssal habitats;
- information specific to the marine communities of seamounts (Tripp Seamount) and submarine canyons; and
- current information on the distribution, population sizes and seasonal trends of pelagic seabird, turtle and cetacean species occurring in southern African waters and the project area in particular.

Keeping these information gaps in mind, the assessment of impacts has adopted a strongly precautionary approach and information gaps are thus not considered to have any negative implications in terms of the credibility of the results of the assessment.

1.3.2 Assessment Procedure

The assessment methodology applied to the impact assessment section is detailed in Appendix A.

2 DESCRIPTION OF THE PROPOSED PROJECT

Block 2912 off the coast of Southern Namibia has an area of approximately 9 955 km^2 and is located in the Deep Offshore of the Orange Basin, approximately 290 km off the Namibian coast (at closest point), in water depths of between approximately 2 940 m and 3 700 m (Figure 1).

The project description below is summarised from the Scoping Report. For a full project description please refer to the relevant section in the ESIA Report.

2.1 PRE-DRILLING SURVEYS

Pre-drilling surveys may be undertaken prior to drilling in order to confirm baseline conditions at the drill site and to identify and delineate any seabed and sub-seabed geo-hazards that may impact the proposed exploration drilling operations. Pre-drilling surveys may involve sonar surveys, sediment sampling, water sampling and ROV activities.

2.1.1 Sonar Surveys

Pre-drilling sonar surveys may involve multi- and single beam echo sounding and sub-bottom profiling. TEEPNA is proposing to undertake these surveys between the 2 900 m and 3 500 m depth ranges within Block 2912, resulting in a survey area of approximately 4 500 km^2. These surveys would take up to four weeks to complete. A description of the proposed techniques is provided below.

Echo Sounders

The majority of hydrographic depth/echo sounders are dual frequency, transmitting a low frequency pulse at the same time as a high frequency pulse. Dual frequency depth/echo sounding has the ability to identify a vegetation layer or a layer of soft mud on top of a layer of rock. TEEPNA is proposing to utilise a single beam echo-sounder with a frequency range of 38 to 200 kHz. In addition, it is proposed to also utilise multibeam echo sounders (70 - 100 kHz range and 200dB re 1µPa at 1m source level) that are capable of receiving many return “pings”. This system produces a digital terrain model of the seafloor.

Sub-bottom profilers

Sub-bottom profilers are powerful low frequency echo-sounders that provide a profile of the upper layers of the ocean floor. Bottom profilers emit an acoustic pulse at frequencies ranging between 2 and 16 kHz, typically producing sound levels in the order of 200-230 db re 1µPa at 1m.

2.1.2 Seabed Sediment Coring

Seabed sediment sampling may involve the collection of sediment samples in order to characterise the seafloor and for laboratory geochemical analyses in order to determine if there is any naturally occurring hydrocarbon seepage at the seabed or any other type of contamination prior to the commencement of drilling.

No specific target area has as yet been identified for the sediment sampling. It is currently anticipated that up to 20 samples could be taken across the entire area of interest. The sediment sampling process would take up to four weeks to complete.

Piston and box coring (or grab samples) techniques may be used to collect the seabed sediment samples. These techniques are further described below.

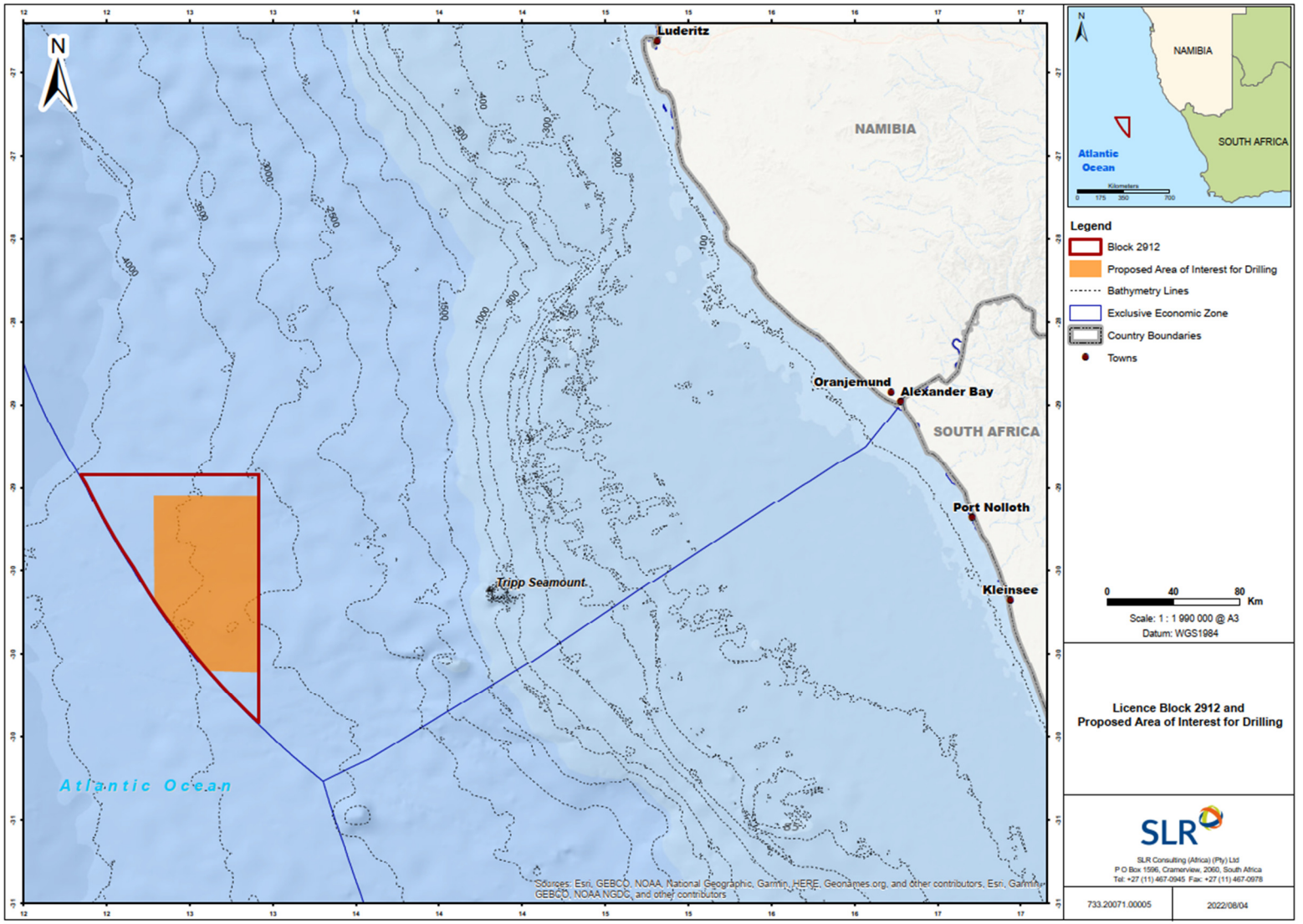


Figure 1: Location of Block 2912 (red polygon) and the area of interest for proposed exploration drilling (orange) in relation to bathymetric features off southern Namibia. Places mentioned in the text are also indicated.

Piston Coring

Piston coring (or drop coring) is one of the more common methods used to collect seabed geochemical samples. The piston coring rig is comprised of a trigger assembly, the coring weight assembly, core barrels, tip assembly and piston. The core barrels are 6 - 9 m in lengths with a diameter of 10 cm. Samples up to a depth of 6 m would be collected in Block 2912 using a Kullenberg type piston core.

The recovered cores are visually examined at the surface for indications of hydrocarbons (gas hydrate, gas parting or oil staining) and sub-samples retained for further geochemical analysis in an onshore laboratory.

Box Coring

Box corers are lowered vertically to the seabed from a survey vessel by. At the seabed the instrument is triggered to collect a sample of seabed sediment. The recovered sample is completely enclosed thereby reducing the loss of finer materials during recovery. On recovery, the sample can be processed directly through the large access doors or via complete removal of the box and its associated cutting blade. TEEPNA is proposing to take box core samples (50 cm x 50 cm) at a depth of less than 60 cm.

2.2 WELL LOCATION AND DRILLING PROGRAMME

TEEPNA is proposing to drill up to ten exploration wells within an Area of Interest within Block 2912. The Block covers an area of approximately 9 955 km^2 and is located 290 km offshore (at its closest point) roughly between Oranjemund in southern Namibia and Hondeklipbaai in South Africa. Water depths range from ~3 000 m to about 4 000 m. Within Block 2912, the Area of Interest for drilling is 5 206 km^2 in extent, approximately 350 km southwest of of Lüderitz and 340 km west-southwest of Oranjemund at its closest point, in water depths between 2 940 m and 3 700 m. The final well location would be based on a number of factors, including further detailed analysis of the seismic data, pre-drilling survey data, the geological target and seafloor obstacles.

The schedule for drilling the wells is not confirmed yet; however, the earliest anticipated date for commencement of drilling is between the second quarter of 2023 (Q2 2023) and second quarter of 2024 (Q2 2024). The expected target drilling depth is not confirmed yet and a notional well depth of 3 500 m is assumed at this stage. It is expected that it would take approximately three to four months to complete the physical drilling and testing of each well (excluding mobilisation and demobilisation). TEEPNA's strategy for future drilling is that drilling could be undertaken throughout the year (i.e. not limited to a specific seasonal window period).

2.3 MAIN PROJECT COMPONENTS

2.3.1 Drilling Unit Options

Various types of drilling technology can be used to drill an exploration well (e.g. barges, jack-up rigs, semi-submersible drilling units (rigs) and drill-ships) depending on, inter alia, the water depth and marine operating conditions experienced at the well site. Based on the anticipated sea conditions, TEEPNA is proposing to utilise a semi-submersible drilling unit or a drill-ship, both with

dynamic positioning system suitable for the deep-water harsh marine environment. The final rig selection will be made depending upon availability and final design specifications.

- A semi-submersible drilling unit (Figure 2, right) is essentially a drilling rig located on a floating structure of pontoons. When at the well location, the pontoons are partially flooded (or ballasted), with seawater, to submerge the pontoons to a pre-determined depth below the sea level where wave motion is minimised. This gives stability to the drilling vessel thereby facilitating drilling operations.
- A drill-ship (Figure 2, left) is a fit for purpose built drilling vessel designed to operate in deep water conditions. The drilling "rig" is normally located towards the centre of the ship with support operations from both sides of the ship using fixed cranes. The advantages of a drill-ship over the majority of semi-submersible units are that a drill-ship has much greater storage capacity and is independently mobile, not requiring any towing and reduced requirement of supply vessels.

Figure 2: Example of a drill rig, the Noble Globetrotter II (left) and of a semi-submersible, the Deepwater Nautilus, being transported on a heavy-lift ship.

2.3.2 Support Vessels

The drilling unit would be supported / serviced by up to three support vessels, which would facilitate equipment, material and waste transfer between the drilling unit and onshore logistics base. A supply vessel will always be on standby near the drilling unit to provide support for firefighting, oil containment / recovery, rescue in the unlikely event of an emergency and supply any additional equipment that may be required. Support vessels can also be used for medical evacuations or transfer of crew if needed.

2.3.3 Helicopters

Transportation of personnel to and from the drilling unit would be provided by helicopter from Lüderitz airport. It is estimated that there may be up to four return flights per week between the drilling unit and the helicopter support base at Lüderitz (i.e. 17 weeks (˜120 days) x 4 = 68 trips per well). The helicopters can also be used for medical evacuations from the drilling unit to shore (at day- or night-time), if required.

2.3.4 Onshore Logistics Base

The onshore logistics base would most likely be located in the Port of Lüderitz.

The shore base would provide for the storage of materials and equipment that would be shipped to the drilling unit and back to storage for onward international freight forwarding. The shore base would also be used for offices, waste management services, bunkering vessels, and stevedoring / customs clearance services.

2.4 MOBILISATION PHASE

The mobilisation phase will entail the required notifications, establishment of the onshore base, appointment of local service providers, procurement and transportation of equipment and materials from various ports and airports, accommodation arrangements and transit of the drilling unit and support vessels to the drilling area.

The drilling unit and supply vessels could sail directly to the well site from outside Namibian waters or from a Namibian port, depending on which drilling unit is selected, and where it was last used.

Core specialist and skilled personnel would arrive in Namibia onboard the drilling unit and the rest of the personnel will be flown to Lüderitz.

Drilling materials, such as casings, mud components, cement and other equipment and materials will be brought into the country on the drilling unit itself or imported *via* a container vessel directly to the onshore logistics base from where the supply vessels will transfer it to the drilling unit.

2.5 OPERATION PHASE

2.5.1 Final Site Selection and Seabed Survey

The selection of the specific well locations will be based on a number of factors, including further detailed analysis of the seismic and pre-drilling survey data and the geological target. A Remote Operating Vehicle (ROV) will be used to finalise the well position based on inter alia the presence of any seafloor obstacles or the presence of any sensitive features that may become evident.

2.5.2 Well drilling operation

The well will be created by drilling a hole into the seafloor with a drill bit attached to a rotating drill string, which crushes the rock into small particles, called “cuttings”. After the hole is drilled, casings (sections of steel pipe), each slightly smaller in diameter, are placed in the hole and permanently cemented in place (cementing operations are described below). The hole diameter decreases with increasing depth.

The casings provide structural integrity to the newly drilled wellbore, in addition to isolating potentially dangerous high-pressure zones from each other and from the surface. With these zones safely isolated, and the formation protected by the casing, the well will be drilled deeper with a smaller drill bit, and also cased with a smaller sized casing. For the current project, it is anticipated that there will be five sets of subsequently smaller hole sizes drilled inside one another, each cemented with casing, except the last phase that will remain an open hole.

Drilling is essentially undertaken in two stages, namely the riserless and risered drilling stages (Figure 3).

A typical well design is summarised in Table 1 below. The well design ultimately depends upon factors such as planned depths, expected pore pressures and anticipated hydrocarbon-bearing formations. Several types of drilling fluids with different compositions and densities would be used

for drilling operations. The composition of the muds is provided in Appendix I of the drillings discharge modelling Report (ProOceano 2023). This may vary slightly depending on the contractor's selection and may be modified to suit operational needs.

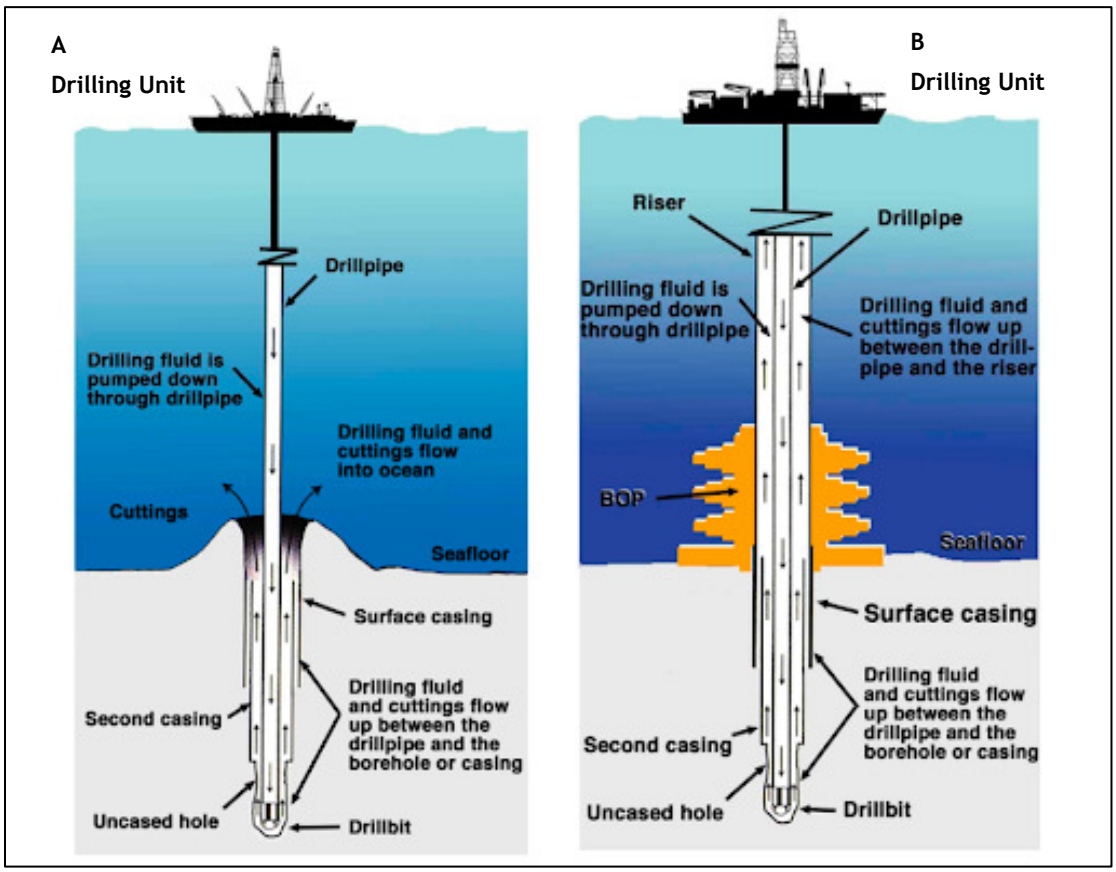


Figure 3: Drilling stages: (a) Riserless Drilling Stage; and (b) Risered Drilling Stage.

Table 1: Cuttings and mud volumes per phase for notional base case well design and estimated drilling discharges.

Drill Section	Hole diameter (inches)	Depth of section (m)	Type of drilling fluid used	Mass of drilling fluid discharged (tonnes)	Mass of cuttings released (tonnes)	Drilling fluid and cuttings discharge location
Riserless drilling stage						
1	42"	96	Seawater, viscous sweeps & WBM	324	209	At sea bottom
2	26"	773		540	877	
-	Suspension / Displacement before drilling Section 3	-	High Viscous Gel sweeps / KCl Polymer PAD mud	1 040	-	1 m above seabed
Risered drilling stage						
3	17.5"	731	NADF	51.9*	376	10 m below mean sea level
4	12.25"	1 265		44*	319	
5	8.5"	467		7.8*	57	
Totals	-	**3 332**	-	**2 007.7**	**1 838**	-

Note: * Total quantity of NABM mud discharged including Oil On Cuttings (OOC) @ 6% by weight of cuttings (metricT) + Other constituents.

Initial (riserless) drilling stage

The process of preparing the first section of a well is referred to as "spudding." Sediments just below the seafloor are often very soft and loose, thus to keep the well from caving in and to carry the weight of the wellhead, a 30- or 36 inch diameter structural conductor pipe is drilled and cemented into place or in some cases jetted.

For the proposed wells, the drill and cement option is preferred. It is usually implemented where the nature of the seafloor sediments (hard sediments) necessitate drilling. A hole of diameter 36 to 42 inches will be drilled and the conductor pipe will be run into the hole and cemented into place. The cement returns exit the bottom of the conductor and travel up the annular space between the conductor and the hole with some cement being deposited on the seabed around the conductor pipe.

When the conductor pipe and low-pressure wellhead are at the correct depth, approximately 70 m deep (depending upon substrate strength), a new drilling assembly will be run inside the structural conductor pipe and the next hole section will be drilled by rotating the drill string and drill bit.

Below the conductor pipe, a hole of approximately 26 inches in diameter will be drilled to a depth of approximately 1 070 m below the seabed. The rotating drill string causes the drill bit to crush rock into small particles, called "cuttings". While the wellbore is being drilled, drilling fluid is pumped from the surface down through the inside of the drill pipe, the drilling fluid passes through holes in the drill bit and travels back to the seafloor through the space between the drill string and the walls of the hole, thereby removing the cuttings from the hole. At a planned depth the drilling is stopped and the bit and drill string is pulled out of the hole. A surface casing of 20 inch diameter is then placed into the hole and secured into place by pumping cement through the casing at the bottom of the hole and back up the annulus (the space between the casing and the borehole). The 20-inch casing will have a high-pressure wellhead on top; which provides the entry point to the subsurface and it is the connection point to the Blow-out Preventor (BOP).

These initial hole sections will be drilled using seawater (with viscous sweeps) and WBM. All cuttings and WBM from this initial drilling stage will be discharged directly onto the seafloor adjacent to the wellbore.

Risered Drilling Stage

The risered drilling stage commences with the lowering of a BOP and installing it on the wellhead. The BOP is designed to seal the well and prevent any uncontrolled release of fluids from the well (a 'blow-out'). A lower marine riser package is installed on top of the BOP and the entire unit is lowered on riser joints. The riser isolates the drilling fluid and cuttings from the environment, thereby creating a "closed loop system".

Drilling is continued by lowering the drill string through the riser, BOP and casing, and rotating the drill string. During the risered drilling stage, should the WBMs not be able to provide the necessary characteristics, a low toxicity Non-aqueous Drilling Fluid (NADF) will be used. The drilling fluid emerges through nozzles in the drill bit and then rises (carrying the rock cuttings with it) up the annular space between the sides of the hole to the drilling unit.

The cuttings are removed from the returned drill mud and discharged overboard. In instances where NADFs are used, cuttings will be treated to reduce oil content and discharged overboard. Operational discharges are discussed further in Section 2.6.1.

The hole diameter decreases in steps with depth as progressively smaller diameter casings are inserted into the hole at various stages and cemented into place. The expected target drilling

depth is not yet confirmed but the notional well depth is 3 570 m below the seafloor with a final hole diameter between of 8.5 and 12 inches and a casing diameter of between 7 and 9.6 inches.

Cementing operation

Cementing is the process of pumping cement slurry through the drill pipe and / or cement stinger at the bottom of the hole and back up into the space between the casing and the borehole wall (annulus). Cement fills the annulus between the casing and the drilled hole to form an extremely strong, nearly impermeable seal, thereby permanently securing the casings in place. To separate the cement from the drilling fluid in order to minimise cement contamination a cementing plug and/or spacer fluids are used. The plug is pushed by the drilling fluid to ensure the cement is placed outside the casing filling the annular space between the casing and the hole wall.

Cementing has four general purposes: (i) it isolates and segregates the casing seat for subsequent drilling, (ii) it protects the casing from corrosion, (iii) it provides structural support for the casing, and (iv) it stabilises the formation.

To ensure effective cementing, an excess of cement is often used. Until the marine riser is set, excess cement from the first two casings emerges out of the top of the well onto the seafloor. This cement does not set and is slowly dissolved into the seawater.

Offshore drilling operations typically use Portland cements, defined as pulverised clinkers consisting of hydrated calcium silicates and usually containing one or more forms of calcium sulphate. The raw materials used are lime, silica, alumina and ferric oxide. The cement slurry used is specially designed for the exact well conditions encountered.

Additives can be used to adjust various properties in order to achieve the desired results. There are over 150 cementing additives available. The amount (concentrations) of these additives generally make up only a small portion (<10%) of the overall amount of cement used for a typical well. Usually, there are three main additives used: retarders, fluid loss control agents and friction reducers. These additives are polymers generally made of organic material and are considered non-toxic.

Once the cement has set, a short section of new hole is drilled, then a pressure test is performed to ensure that the cement and formation are able to withstand the higher pressures of fluids from deeper formations.

2.5.3 Well Logging and Testing

Once the target depth is reached, the well would be logged and tested.

Well logging involves the evaluation of the physical and chemical properties of the sub-surface rocks, and their component minerals, including water, oil and gas to confirm the presence of hydrocarbons and the petrophysical characteristics of rocks. It is undertaken during the drilling operation using Wireline Logging or Logging While Drilling (LWD) to log core data from the well. Information from engineering and production logs, as well as mud logging, may also be used.

Vertical Seismic Profiling (VSP) is an evaluation tool used to generate a high-resolution seismic image of the geology in the well's immediate vicinity. The VSP images are used for correlation with surface seismic images and for forward planning of the drill bit during drilling. VSP uses a small airgun array with a gun pressure of 2 000 per square inch (psi), which is operated from the drilling unit at a depth of between 7 m and 10 m. During VSP operations, four to five receivers are positioned in a section of the borehole and the airgun array is discharged approximately five times at 20 second intervals. The generated sound pulses are reflected through the seabed and are

recorded by the receivers to generate a profile along a 60 to 75 m section of the well. This process is repeated for different stations in the well and may take up to nine hours to complete approximately 250 shots, depending on the well's depth and number of stations being profiled.

Well or flow testing is undertaken to determine the economic potential of the discovery before the well is either abandoned or suspended. One test would be undertaken per exploration well should a resource be discovered and up to two tests per appraisal well. Each test would take up to 7 days to complete (5 days of build-up and 2 days of flowing and flaring). For well flow-testing, hydrocarbons would be burned at the well site. A high-efficiency flare is used to maximise combustion of the hydrocarbons. Burner heads which have a high burning efficiency under a wide range of conditions will be used.

The volume of hydrocarbons (to be burned) and possible associated produced water from the reservoir which could be generated during well testing cannot be reliably predicted due to variations in gas composition, flow rates and water content. Burners are manufactured to ensure emissions are kept to a minimum. The estimated volume of hydrocarbons to be burned cannot be predicted with much accuracy because the actual test requirements can only be established after the penetration of a hydrocarbon-bearing reservoir. However, an estimated 10 200 bbl oil could be flared per test, i.e. up to 20 400 bbl over the two tests associated with an appraisal well. If produced water is generated during well testing, it will be separated from the hydrocarbons.

2.5.4 Well Sealing and Plugging

The purpose of well sealing and plugging is to isolate permeable and hydrocarbon bearing formations. Well sealing and plugging aims to restore the integrity of the formation that was penetrated by the wellbore. The principal technique applied to prevent cross flow between permeable formations is plugging of the well with cement, thus creating an impermeable barrier between two zones.

Once drilling and logging have been completed, the exploration wells will be sealed with cement plugs, tested for integrity and abandoned according to international best practices. Cement plugs will be set to isolate hydrocarbon bearing and / or permeable zones and cementing of perforated intervals (e.g., from well logging activities) will be evaluated where there is the possibility of undesirable cross flow. These cement plugs are set in stages from the bottom up. Three cement plugs would be installed: i.e. one each for isolation of the deep reservoir and the main reservoir; and a third as a second barrier for the main reservoir.

The integrity of cement plugs can be tested by a number of methods. The cement plugs will be tag tested (to validate plug position) and weight tested, and if achievable then a positive pressure test (to validate seal) and/or a negative pressure test will be performed. Additionally, a flow check may be performed to ensure sealing by the plug. Once the well is plugged, seawater will be displaced before disconnecting the riser and the BOP.

2.6 DEMOBILISATION PHASE

After the exploration wells have been sealed, tested for integrity and abandoned, the intention is to abandon the wellheads on the seafloor if deemed safe to do so based on a risk assessment. The risk assessment criteria will consider factors such as the water depth and use of the area by other sectors (e.g., fishing). Due to the water depth and no trawl fishing taking place in the area, it is proposed to leave the wellhead in place without installing over trawlable protective equipment.

Monitoring gauges to monitor pressure and temperature through wireless communication with frequencies between the transmitter and the receiver in the 12.75 to 21.25 kHz range may be installed on wells where TEEPNA will return in the future for appraisal / production purposes. The gauges will be placed and remain on the wellhead. Monitoring gauges will not be installed on exploration wells which are earmarked for abandonment

With the exception of the abandoned wellheads and drilling discharges deposited on the seabed, no further physical remnants of the drilling operation will be left on the seafloor. A final clearance survey check will be undertaken using an ROV. The drilling unit and supply vessels will demobilise from the offshore licence area and either mobilise to the following drilling location or relocate into port or a regional base for maintenance, repair or resupply.

2.7 DISCHARGES, WASTES AND EMISSIONS

The prosed drilling operations (including mobilisation and demobilisation) will result in various discharges to water, the generation of waste and emissions. All vessels will have equipment, systems and protocols in place for prevention of pollution by oil, sewage and garbage in accordance with international MARPOL requirements. Any oil spill related discharges would be managed by an Oil Spill Contingency Plan (OSCP). Onshore licenced waste disposal sites and waste management facilities will be identified, verified and approved prior to commencement of drilling operations.

2.7.1 Discharges to Sea

Drilling Cuttings and Mud

Drill cuttings, which range in size from clay to coarse gravel and reflect the types of sedimentary rocks penetrated by the drill bit, are the primary discharge during well drilling. Drilling discharges would be disposed at sea in line with accepted drilling practices. This is in line with most countries (including South Africa) for early exploration development phases. The rationale for this is based on the low density of drilling operations in the vast offshore area and the high energy marine environment. As such, TEEPNA proposes to use the "offshore treatment and disposal" option for their drilling campaign in Block 2912. The same method was applied and approved for drilling of TEEPNA's other exploration well in the adjacent Block 2913B and TotalEnergies' exploration wells in Block 11B/12B (namely Brulpadda and Luiperd wells) off the South Coast of South Africa.

During the riserless drilling stage, all cuttings and WBM will be discharged directly onto the seafloor adjacent to the wellbore. An estimated volume of 1 838 t of cuttings and 2 008 t of drilling fluid will be discharged per well (based on notional depth of 3 570 m) (refer to Table 1).

Where NADFs are used (possibly during the risered drilling stage, if WBMs are not able to provide the necessary characteristics), these are sometimes treated onshore and disposed, treated to recover oil and disposed offshore and sometimes re-injected into wells. For the current project TEEPNA, in instances where NADFs are used, cuttings will be treated offshore to reduce oil content to <6.9% Oil On Cutting (OOC) and discharged overboard. An estimated volume of 752 t of cuttings and 104 t of drilling fluid will be discharged per well (based on notional depth of 3 570 m) (refer to Table 1). During this drilling stage the circulated drilling fluid will be cleaned and the cuttings discharged into the sea at least 10 m below sea level. The drill cuttings will be treated to reduce their mud content using shakers and a centrifuge.

Cuttings released from the drilling unit during the risered drilling stage will be dispersed by the current and settle to the seafloor. The rate of cuttings discharge decreases with increasing well

depth as the hole diameter becomes smaller and penetration rates decrease. Discharge is intermittent as actual drilling operations are not continuous while the drilling unit is on location.

Further drilling fluid totalling 1 040 tons will be released 1 m above the seafloor during well suspension and displacement (between drilling section 2 and 3). The mud used during these processes is a High Viscous Gel sweeps / KCl Polymer PAD mud.

The expected fall and spatial extent of the deposition of discharged cuttings have been investigated in the Drilling Discharges Modelling Study (ProOceano 2023), the results of which will inform the marine biodiversity assessment.

Cement and Cement Additives

Typically, cement and cement additives are not discharged during drilling. However, during the initial cementing operation (i.e. surface casing), excess cement emerges out of the top of the well and onto the seafloor in order to ensure that the conductor pipe is cemented all the way to the seafloor. During this operation a maximum of 150-200 % of the required cement volume may be pumped into the space between the casing and the borehole wall (annulus). In the worst-case scenario, approximately 100 m^3 of cement could be discharged onto the seafloor.

BOP Hydraulic Fluid

As part of routine opening and closing operations the subsea BOP stack elements will vent some hydraulic fluid into the sea at the seafloor. It is anticipated that between approximately 500 and 1 000 litres of oil-based hydraulic emulsion fluid could be vented per month during the drilling of a well. BOP fluids are completely biodegraded in seawater within 28 days.

Produced Water

If water from the reservoir arises during well flow testing, these would be separated from the oily components and treated onboard to reduce the remaining hydrocarbons from these produced waters. The hydrocarbon component will be burned off via the flare booms, while the water is temporarily collected in a slop tank. The water is then either directed to:

- a settling tank prior to transfer to supply vessel for onshore treatment and disposal; or
- a dedicated treatment unit where, after treatment, it is either:
  (i) if hydrocarbon content is < 30 mg/l, discharged overboard; or
  (ii) if hydrocarbon content is > 30 mg/l, subject to a 2nd treatment or directed to tank prior to transfer to supply vessel for onshore treatment and disposal.

Reinjection of the produced water may be considered if volumes are large and cannot be managed onboard the drilling unit.

Vessel Machinery Spaces (Bilge Water)

Vessels will occasionally discharge treated bilge water. Bilge water is drainage water that collects in a ship's bilge space (the bilge is the lowest compartment on a ship, below the waterline, where the two sides meet at the keel). In accordance with MARPOL Annex I, bilge water will be retained on board until it can be discharged to an approved reception facility, unless it is treated by an approved oily water separator to <15 ppm oil content and monitored before discharge. The residue from the onboard oil/water separator will be treated / disposed of onshore at a licenced hazardous landfill site.

Deck Drainage

Deck drainage consists of liquid waste resulting from rainfall, deck and equipment washing (using water and a water-based detergent). Deck drainage will be variable depending on the vessel characteristics, deck activities and rainfall amounts.

In areas of the drilling unit where oil contamination of rainwater is more likely (i.e. the rig floor), drainage is routed to an oil / water separator for treatment before discharge in accordance with MARPOL Annex I (i.e. 15 ppm oil and grease maximum). There will be no discharge of free oil that could cause either a film, sheen or discolouration of the surface water or a sludge or emulsion to be deposited below the water's surface. Only non-oily water (i.e. <15 ppm oil and grease, maximum instantaneous oil discharge monitor reading) will be discharged overboard. If separation facilities are not available (due to overload or maintenance) the drainage water will be retained on board until it can be discharged to an approved reception facility. The oily residue from the onboard oil / water separator will be treated / disposed of onshore at an approved hazardous landfill site.

Brine generated from onboard desalination plant

The waste stream from the desalination plant is brine (concentrated salt), which is produced in the reverse osmosis process. The brine stream contains high concentration of salts and other concentrated impurities that may be found in seawater. Water chemical agents will not be used in the treatment of seawater and therefore the brine reject portion would be in a natural concentrated state. Based on previous well drilling operations, freshwater production amounts to approximately 40 m3/day, which will result in approximately 35 g salt for each litre water produced (i.e. approx. 1 400 kg salt/brine per day).

Sewage and Grey Water

Discharges of sewage (or black water) and grey water (i.e. wastewater from the kitchen, washing and laundry activities and non-oily water used for cleaning) will occur from vessels intermittently throughout the project and will vary according to the number of persons on board, estimated at an average of 200 litres per person. All sewage discharges will comply with MARPOL Annex IV.

Sewage and grey water will be treated using a marine sanitation device to produce an effluent with:

- A Biological Oxygen Demand (BOD) of <25 mg/l (if the treatment plant was installed after 1/1/2010) or <50 mg/l (if installed before this date);
- Minimal residual chlorine concentration of 0.5 mg/l; and
- No visible floating solids or oil and grease.

Food (Galley) Wastes

The disposal into the sea of food waste is permitted, in terms of MARPOL Annex V, when it has been comminuted or ground to particle sizes smaller than 25 mm and the vessel is en route more than 3 nautical miles (approximately 5.5 km) from land. Disposal overboard without macerating is permitted for moving vessels greater than 12 nautical miles (approximately 22 km) from the coast. On the drilling unit, all food waste will be macerated to particles sizes <25 mm and the daily discharge is typically about seven tonnes per month.

Ballast Water

Ballast water is used during routine operations to maintain safe operating conditions onboard a ship by reducing stress on the hull, providing stability, improving propulsion and manoeuvrability, and compensating for weight lost due to fuel and water consumption.

Ballast water is discharged subject to the requirements of the 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments. The Convention stipulates that all ships are required to implement a Ballast Water Management Plan and that all ships using ballast water exchange will do so at least 200 nautical miles (nm) (± 370 km) from nearest land in waters of at least 200 m deep when arriving from a different marine region. Where this is not feasible, the exchange should be as far from the nearest land as possible, and in all cases a minimum of 50 nm (±93 km) from the nearest land and preferably in water at least 200 m in depth. Project vessels will be required to comply with this requirement.

Detergents

Detergents used for washing exposed marine deck spaces will be discharged overboard. The toxicity of detergents varies greatly depending on their composition. Water-based detergents are low in toxicity and are preferred for use. Preferentially biodegradable detergents should be used. Detergents used on work deck space will be collected with the deck drainage and treated as described under deck drainage above.

Noise Emissions

The key sources generating underwater noise are vessel propellers (and positioning thrusters), with a contribution from the pontoons (e.g. noise originating from within the pontoons and on-deck machinery), supply vessels and from drilling activities. This is expected to result in highly variable sound levels, being dependent on the operational mode of each vessel. The pre-drilling sonar surveys and VSP survey would generate a short-term noise, taking 4 weeks and less than nine hours to complete, respectively.

The main sources of noise from these activities are categorised below.

- Pre-drilling sonar surveys may involve multi- and single beam echo sounding and sub-bottom profiling. These surveys would be undertaken between the 2 900 m and 3 500 m depth ranges covering a survey area of approximately 4 500 km^2. These surveys would take up to four weeks to complete. A single beam echo-sounder operates within a frequency range of 38 to 200 kHz, whereas multibeam echo sounders operate in the 70 - 100 kHz range and have a 200dB re 1µPa at 1m source level. Sub-bottom profilers emit an acoustic pulse at frequencies ranging between 2 and 16 kHz, typically producing sound levels in the order of 200-230 db re 1µPa at 1m.
- Drilling noise: Drilling units generally produce underwater noise in the range of 10 Hz to 100 kHz (OSPAR commission, 2009) with major frequency components below 100 Hz and average source levels of up to 190 dB re 1 µPa at 1 m (rms) (the higher end of this range from use of bow thrusters). These noise levels will be assumed as indicative for the current project.
- Propeller and positioning thrusters: Noise from propellers and thrusters is predominately caused by cavitation around the blades whilst transiting at speed or operating thrusters under load in order to maintain a vessel's position. The noise produced by a drilling unit's dynamic positioning systems can be audible for many kilometres. Noise produced is typically broadband noise, with some low tonal peaks. The supply vessels will also contribute to an overall propeller noise generation.
- Machinery noise: Machinery noise is often of low frequency and can become dominant for vessels when stationary or moving at low speeds. The source of this type of noise is from large machinery, such as large power generation units (diesel engines or gas turbines),

compressors and fluid pumps. Sound is transmitted through different paths, i.e. structural (machine to hull/pontoons to water) and airborne (machine to air to hull to water) or a mixture of both. The nature of sound is dependent on a number of variables, such as the type and size of machinery operating; and the coupling between machinery and the vessel body. Machinery noise is typically tonal in nature. A ROV will be used to conduct a sweep of the drilling site to identify any debris; however, this is not expected to form a significant noise source.

- Well logging noise: If relevant, VSP will be undertaken in order to generate a high-resolution image of the geology in the well's immediate vicinity. It is expected to use a small dual airgun array, comprising a system of three 250 cubic inch airguns and three 150 cubic inch airguns with a total volume of 1 200 cubic inches of compressed nitrogen at about 2 000 psi. VSP source will generate a pulse noise level in the 5 to 1 000 Hz range. The volumes and the energy released into the marine environment are significantly smaller than what is required or generated during conventional seismic surveys. The airguns will be discharged approximately five times at 20 second intervals. This process is repeated, as required, for different sections of the well for a total of approximately 250 shots. A VSP is expected to take up to nine hours per well to complete, depending on the well's depth and number of stations being profiled.
- Well testing noise: Flaring would produce some air-borne noise above the sea level where flaring is implemented for up to two days of flowing and flaring.
- Equipment in water: Noise is produced from equipment such as the drill string. The noise produced will be low relative to the drilling noise and the dynamic positioning system.
- Helicopter noise: Helicopters will also form a source of noise, which can affect marine fauna both in terms of underwater noise beneath the helicopter and airborne noise.

The extent of project-related noise above the background noise level may vary considerably depending on the specific vessels used and the number of supply vessels operating. It will also depend on the variation in the background noise level with weather and with the proximity of other vessel traffic (not associated with the project).

An Underwater Noise Modelling Study has been undertaken to determine the underwater noise transmission loss with distance from well site and compare results with threshold values for marine fauna to determine zones of impact. These modelling results will be used in the assessment of impacts on marine fauna.

Light Emissions

Operational lighting will be required on the drilling unit and supply vessels for safe operations and navigation purposes during the hours of darkness. Where feasible, operational lights will be shielded in such a way as to minimise their spill out to sea.

Heat Emissions

Flaring during well testing generates heat emissions from the combustion of hydrocarbons at the burner head.

3. DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

The descriptions of the physical and biological environments along the southern and central Namibian coast primarily cover the offshore area from Lüderitz in the north to the Orange River mouth in the south, although where appropriate reference is made to the entire Namibian coastline. The purpose of this environmental description is to provide the marine baseline environmental context within which the proposed exploration drilling activities will take place. The summaries presented below are based on information gleaned from Lane and Carter (1999), Morant (2006), Penney *et al*. (2007) and the Marine Mammal Observer (MMO) Reports and the Environmental Baseline and Habitat Assessment Report compiled for the Venus 1X project (Benthic Solutions Ltd 2019a, 2019b, 2019c). The marine mammal section has been updated relative to the text originally compiled by Simon Elwin.

3.1 Geophysical Characteristics

3.1.1 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 (Rogers 1977) (see Figure 1).

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. In the south, the Orange Banks comprise three low mounds rising to about 160 m on the outer shelf. North of Chameis Bay, the shelf becomes a stepped feature, with a low step having an elevation between roughly 400 - 450 m below mean sea level, making it one of the deepest in the world. The variable topography of the shelf is of significance for near shore circulation and for fisheries (Shannon & O'Toole 1998).

Banks on the continental shelf in the broader project area include the Orange Bank (Shelf or Cone), a shallow (160 - 190 m) zone that reaches maximal widths (180 km) offshore of the Orange River, and Childs Bank, situated ~150 km offshore in South African waters at about 31°S. Tripp Seamount is a geological feature situated ~300 km offshore at about 29°S, which rises from the seabed at ~1 000 m to a depth of 150 m. Tripp Seamount is located approximately 85 km to the east and 250 km to the south-east of Blocks 2912 and 2913B, respectively.

Within Block 2913B, previous seismic and bathymetric datasets have revealed several bathymetric features where variability in seabed erosion has resulted in defined bathymetric boundaries, which in turn are likely to affect localised habitat types. Conspicuous features include mass gravitational flow features, escarpments, eroded plateaus and sedimentary basins (AECOM 2019).

3.1.2 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 EEZ were mapped (MFMR 2021) (Figure 4 and Figure 5). Figure 6 illustrates the distribution of seabed surface sediment types off the southern Namibian coast. 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). 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. An ~500-km long mud belt (up to 40 km wide, and of 15 m average thickness) is situated over the outer edge of the middle shelf between the Orange River and St Helena Bay in South Africa (Birch *et al*. 1976; Meadows *et al*. 1997, 2002; Herbert & Compton 2007) (Figure 6). These biogenic muds are the main determinants of the formation of low-oxygen waters and sulphur eruptions off central Namibia (see Sections 3.2.9 and 3.2.10). Further offshore these give way to muddy sands, sands and gravels before changing again into mud-dominated seabed beyond the 500-m contour. The continental slope, seaward of the shelf break, has a smooth seafloor, underlain by calcareous ooze.

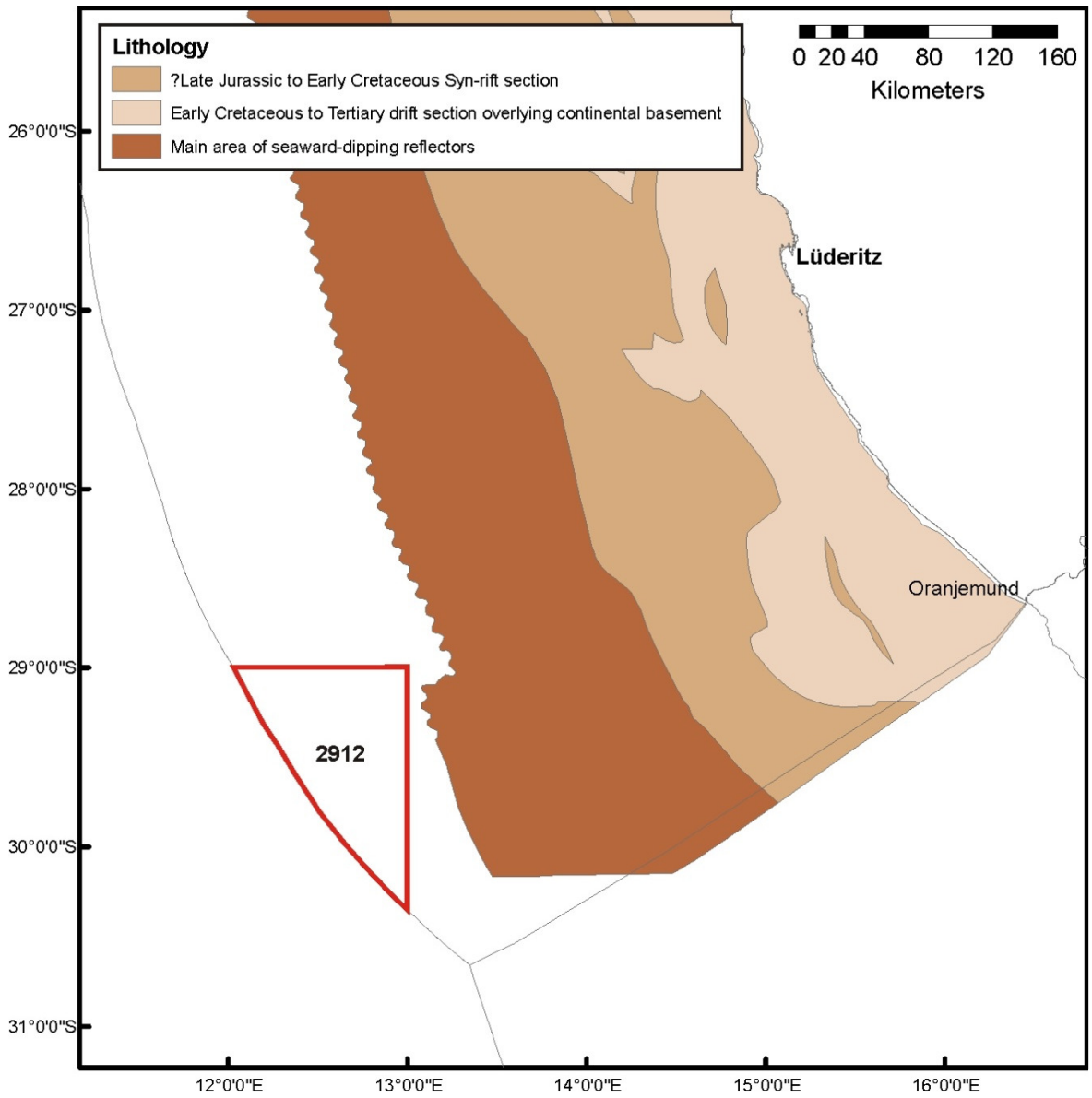


Figure 4: Block 2912 (red polygon) in relation to the marine geology of the southern Namibian continental shelf (Adapted from MFMR 2021).

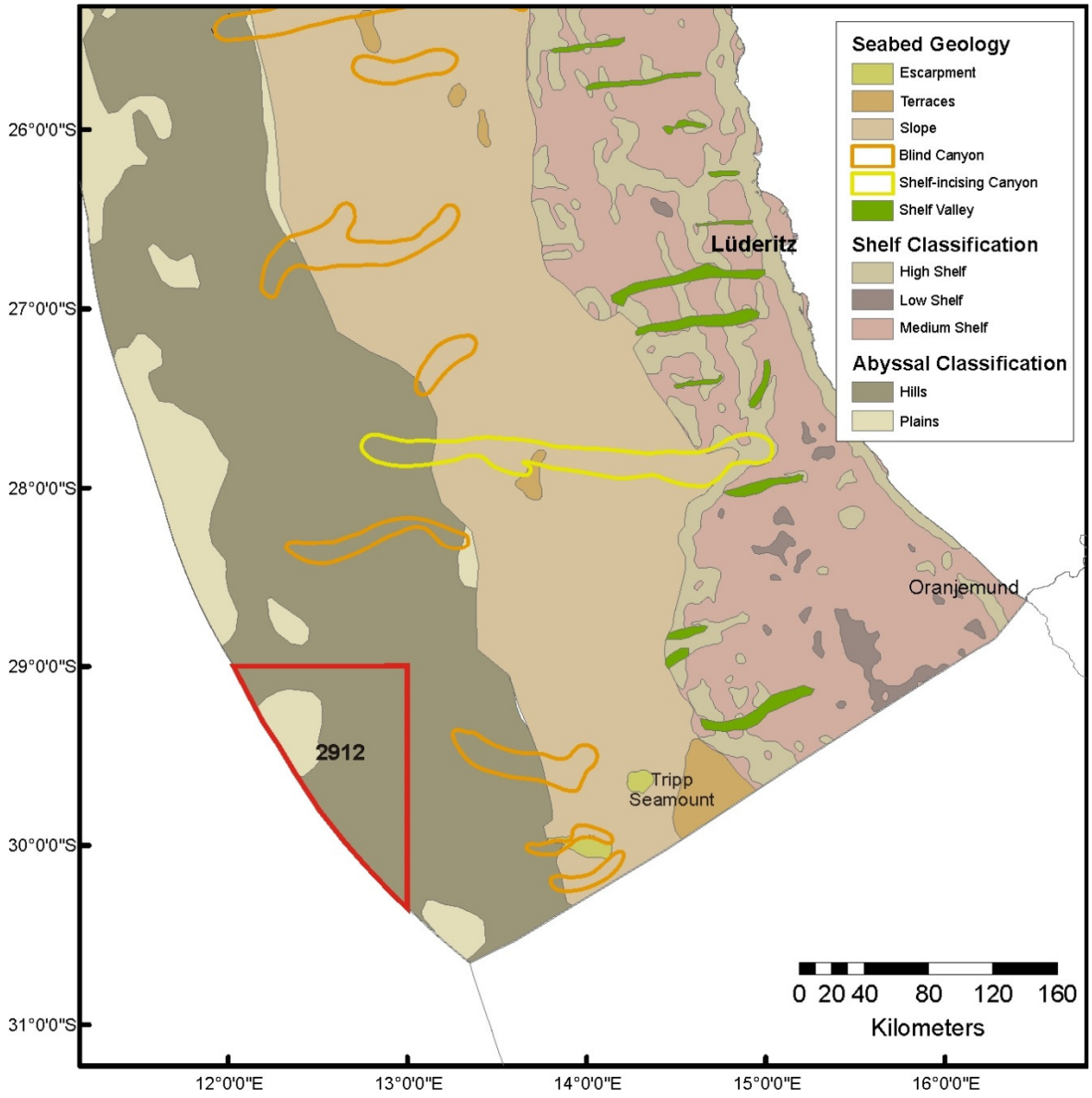


Figure 5: Block 2912 (red polygon) in relation to seabed geomorphic features off southern Namibia (Adapted from MFMR 2021).

The baseline survey undertaken in the adjacent Block 2913B (Benthic Solutions Ltd 2019) identified that the seabed is characterised by homogeneous poorly to very poorly sorted fine to medium silts (muddy sands), which comprised between 81.5% and 94.4% of the sediments. The remaining sediment is a coarser component (>500 µm) comprising predominantly relic biogenic materials from foraminifera. Gravels were absent. Video footage of the seabed throughout the area revealed evidence of bioturbation on the silt-dominated surface, although with no discernible species could be identified. The Total Organic Carbon (TOC) content of the sediments is comparatively low, suggesting that the carbon flux from near surface productivity is not strong. This would be expected from sediments in areas far offshore of the highly productive coastal upwelling.

Present day sedimentation is limited to inputs from the Orange River. This sediment is generally transported northward. In the southern portion of the study area, most of the sediment is therefore

considered to be relict deposits by now ephemeral rivers active during wetter climates in the past. The Orange River, when in flood, still contributes largely to the mud belt as suspended sediment is carried southward by poleward flow. In this context, the absence of large sediment bodies on the inner shelf reflects on the paucity of terrigenous sediment being introduced by the few rivers that presently drain the South African West Coast coastal plain.

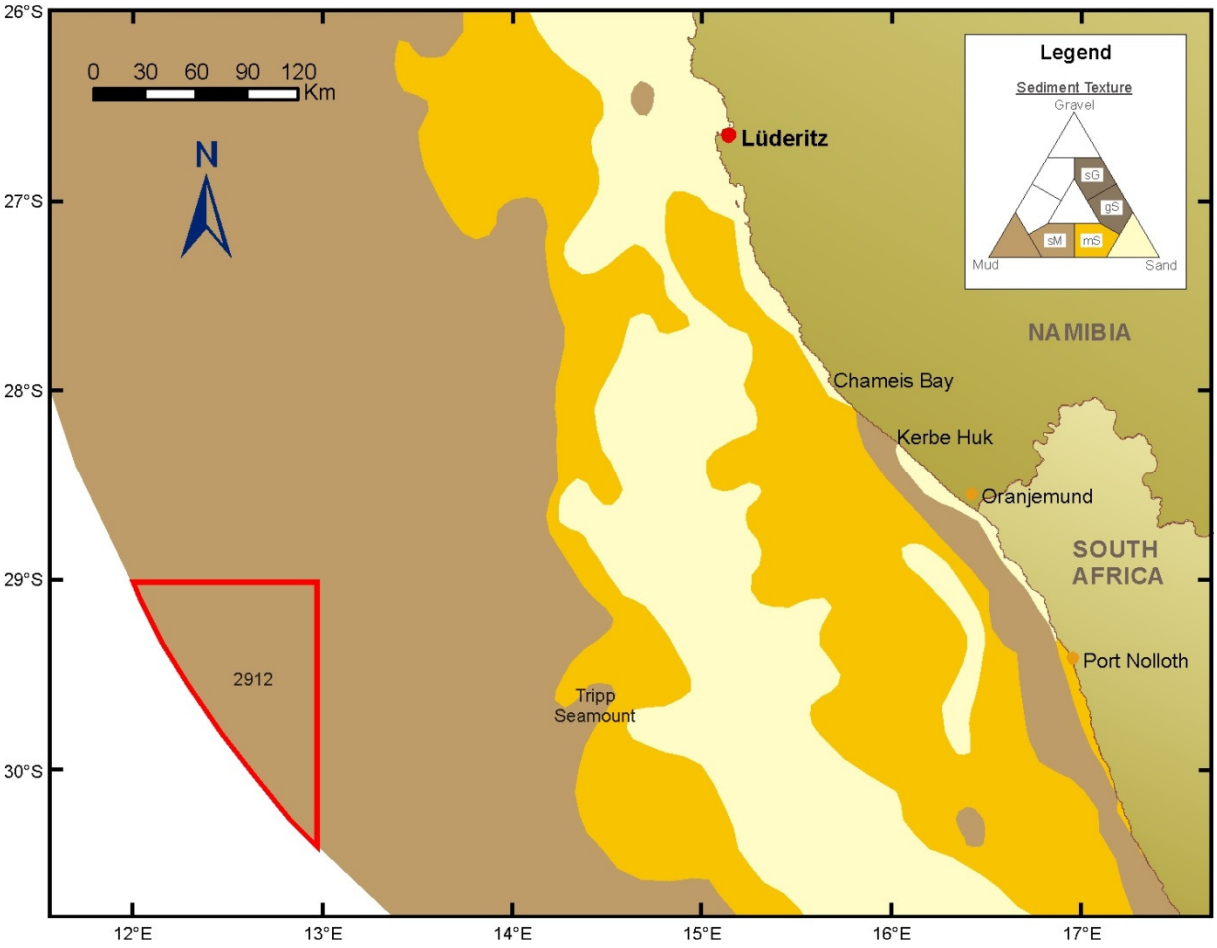


Figure 6: Block 2912 (red polygon) in relation to the sediment distribution on the continental shelf off southern Namibia (Adapted from Rogers 1977). Based on information in Holness *et al.* (2014), the mud/sandy mud sediments have been extended to the edge of the EEZ beyond that shown in Rogers (1977).

3.1.3 Sedimentary Phosphates

Phosphorite, or phosphate-rich rock, is defined as sedimentary rock typically containing between 5%-20% phosphate. In the marine environment, it occurs either as a nodular hard ground capping of a few metres thick or as layers of consolidated or unconsolidated sediments on continental shelves and in the upper part of continental slopes (Morant 2013). Such deposits provide a record of paleoceanographic changes in upwelling systems linked to climate. Being one of the most productive upwelling systems in the world, the Benguela Upwelling System is associated with major phosphorite deposits (of various type and grade) exposed over an area of 24 700 km^2 on the Namibian shelf (Compton & Bergh 2016).

The “open shelf” phosphorite deposits, originated from the precipitation of phosphate in the form of calcium phosphate. Intense upwelling resulted in a change in temperature and pressure of the phosphate-laden oceanic waters, thus lowering the solubility of the phosphate salts they contained, and consequently precipitating the phosphates (in the form of apatite) over the continental shelf to form phosphatic packstones and colitic pellets at the sediment-water interface. The precipitation is facilitated by the decay of siliceous phytoplankton. The precipitated phosphates subsequently combined with calcium, derived from the disaggregation of calcareous foraminiferal and coccolithophorid debris on the outer continental shelf, to form phosphatised lime-rich muds. These muds subsequently lithified or consolidated through their replacement by secondary calcium phosphate (francolite), to form a near-continuous hard capping of phosphate rock over the seafloor sediments (Birch 1990; Morant 2013).

Off Namibia, marine phosphates were first discovered and regionally mapped in the late 1960s and 1970s, with subsequent exploratory work undertaken in the 1990s and 2000s. Various types of phosphorite are known to exist on the Namibian continental shelf these being concretionary phosphorite, as well as pelletal and glauconitized pelletal phosphorite on the middle shelf to the south and north of Walvis Bay, respectively. ‘Rock phosphate’ occurs on the middle and inner shelves, predominantly north of Walvis Bay (Bremner 1980). On the middle to outer shelf (190 m and 350 m water depth) offshore of Lüderitz and Walvis Bay the deposit consists of coarsening-upward muddy to gravelly pelletal phosphorite sand, up to several meters thick (Baturin 2002; Compton & Bergh 2016). These deposits are characterized by their spatial continuity (especially in a SSW - NNE direction) and general uniformity in grade. The variations in thickness are generally the product of thicker accumulation of sediment in very shallow palaeo-topographic depressions in the underlying clay surface, which is locally burrowed, with these borings being filled with phosphate-rich sediment (NMP 2012). Less extensive and less continuous deposits occur offshore of Walvis Bay as far north as the Kunene River mouth on the inner to middle shelf (50 and 250 m water depth). Pelletal phosphorite sand and concretionary phosphorite pebbles are the dominant grain types consisting of up to 90 wt.% carbonate fluorapatite (francolite) cement and inclusions of organic matter, pyrite and terrigenous mud.

Phosphogenesis is predicted to have been initiated in the latest Miocene, with most phosphorite formed in the Plio/Pleistocene but ranging through to the Holocene. The early diagenetic phosphorite was extensively reworked by glacial to interglacial sea-level fluctuations, which correspond to Benguela coastal upwelling intensity and continental aridification. Repeated phosphorite formation and reworking over Pleistocene glacial to interglacial cycles resulted in the economic concentration of phosphorite on the Namibian shelf, with an estimated total resource of 7 800 million tons of phosphate rock at an average grade of 19 wt.% P_2O_5 (Compton & Bergh 2016).

Block 2912 lies well offshore of the known phosphate deposits (Figure 7).

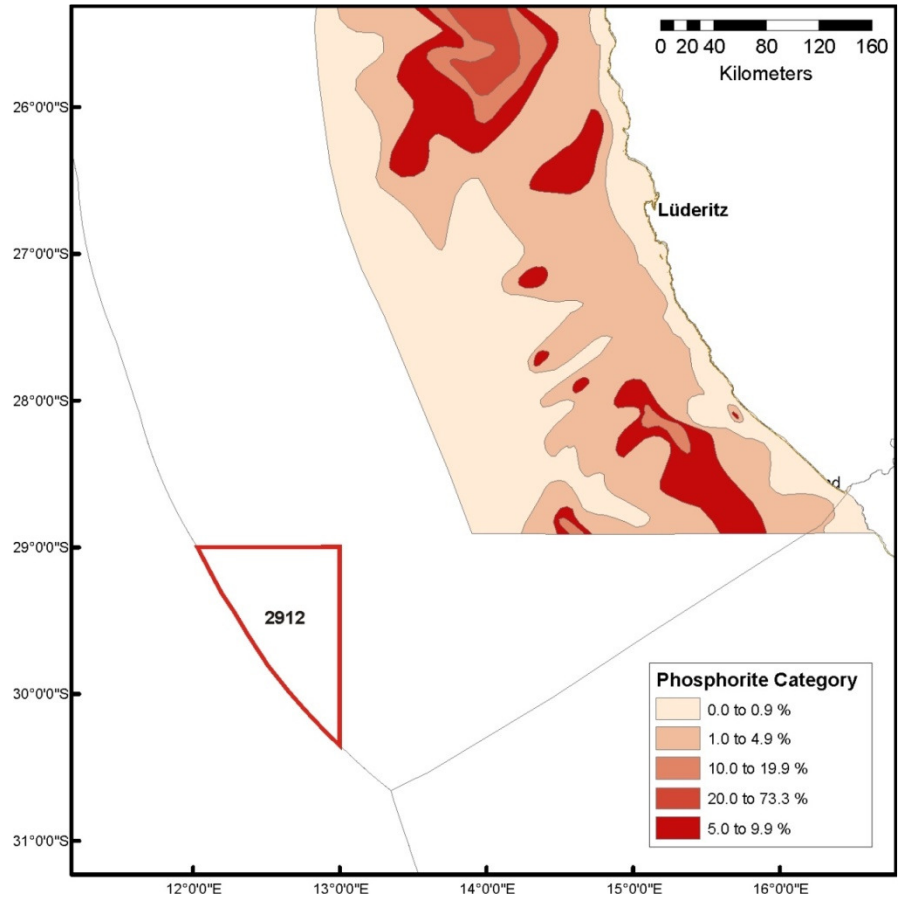


Figure 7: Block 2912 (red polygon) in relation to the known location of phosphate deposits on the southern Namibian continental shelf (Adapted from MFMR 2021).

3.2 Biophysical Characteristics

3.2.1 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 is usually quite dense, appears as a thick bank hugging the shore and visibility may be reduced to <300 m.

Average precipitation per annum along the coastal region between Walvis Bay and the Kunene River 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.

3.2.2 Wind Patterns

Winds are one of the main physical drivers of the near shore Benguela region, both on an oceanic scale, generating the heavy and consistent south-westerly swells that impact this coast, and locally, contributing to the northward-flowing longshore currents, and being the prime mover of sediments in the terrestrial environment. Consequently, physical processes are characterised by the average seasonal wind patterns, and substantial episodic changes in these wind patterns have strong effects on the entire Benguela region.

The prevailing winds in the Benguela region are controlled by the South Atlantic subtropical anticyclone, the eastward moving mid-latitude cyclones south of southern Africa, and the seasonal atmospheric pressure field over the subcontinent. The south Atlantic anticyclone is a perennial feature that forms part of a discontinuous belt of high-pressure systems that encircle the subtropical southern hemisphere. This undergoes seasonal variations, being strongest in the austral summer, when it also attains its southernmost extension, lying south west and south of the subcontinent. In winter, the south Atlantic anticyclone weakens and migrates north-westwards.

These seasonal changes result in substantial differences between the typical summer and winter wind patterns in the region, as the southern hemisphere anti-cyclonic high-pressure system, and the associated series of cold fronts, move northwards in winter, and southwards in summer. The strongest winds occur in summer, when winds blow 99% of the time. Virtually all Winds in summer are strongly dominated by southerlies, which occur over 40% of the time, averaging 20 – 30 kts and reaching speeds in excess of 60 kts. These southerly winds bring cool, moist air into the coastal region and drive the massive offshore movements of surface water, and the resultant strong upwelling of nutrient-rich bottom waters, which characterise this region in summer. The winds also 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 winter.

Winter remains dominated by southerly winds, but the closer proximity of the winter cold-front systems results in a significant north-westerly component. This 'reversal' from the summer condition results in cessation of upwelling, movement of warmer mid-Atlantic water shorewards and breakdown of the strong thermoclines which typically develop in summer. There are also more calms in winter, occurring about 3% of the time, and wind speeds generally do not reach the maximum speeds of summer. However, the westerlies winds blow in synchrony with the prevailing south-westerly swell direction, resulting in heavier swell conditions in winter.

Seasonal wind roses for the area offshore of Oranjemund, are illustrated in Figure 8. Further offshore and south in the project area, the winds have a stronger S-SE component (Total E and P Namibia, unpublished data).

During autumn and winter, catabatic, or easterly 'berg' winds can also occur. 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 9).

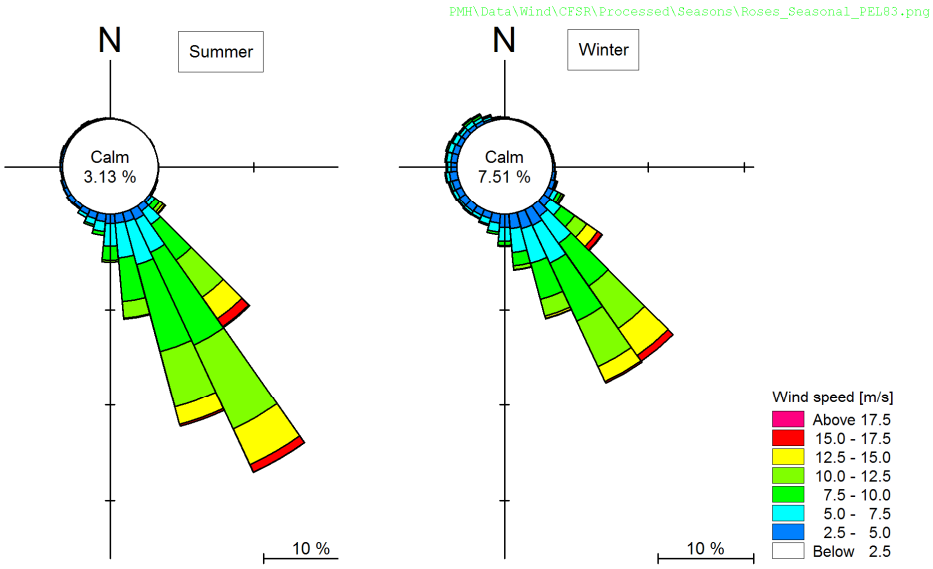


Figure 8: Seasonal wind roses at 14°E, 28°S in the vicinity of Block 2912 (Source PRDW 2019).

Figure 9: Satellite image showing Block 2912 in relation to an aerosol plumes of sand and dust being blown out to sea during a northeast 'berg' wind event along the southern Namibian coast (Image source: www.earthdata.nasa.gov/worldview/worldview-image-archive/dust-blows-off-coast-namibia-south-africa).

3.2.3 Large-Scale Circulation and 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). In the south the Benguela current has a width of 200 km, widening rapidly northwards to 750 km. The flows are predominantly wind-forced, barotropic and fluctuate between poleward and equatorward flow (Shillington *et al*. 1990; Nelson & Hutchings 1983) (Figure 10). 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.

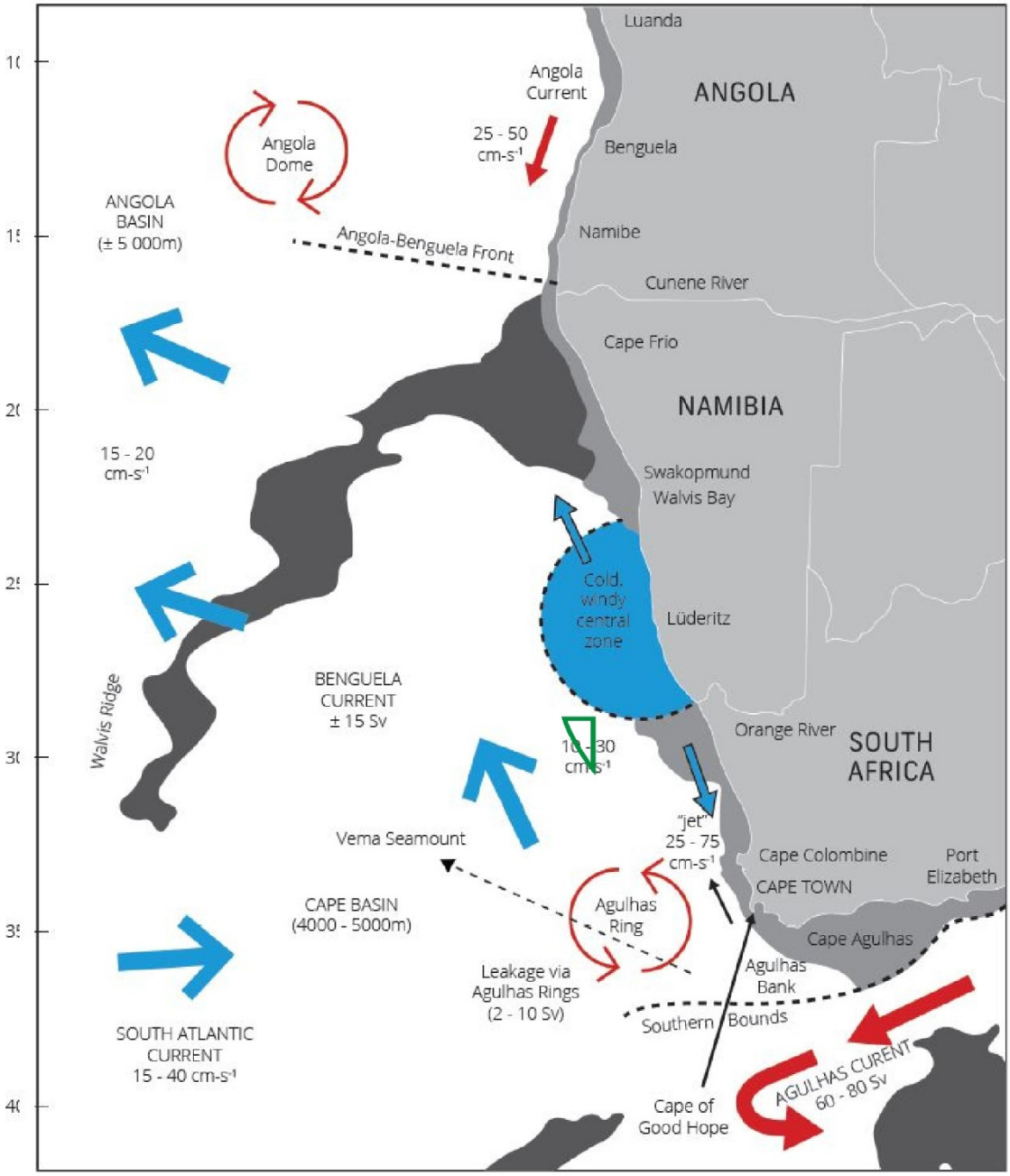


Figure 10: Block 2912 (green polygon) in relation to major features of the predominant circulation patterns and volume flows in the Benguela System (adapted from Shannon *et al*. 2006).

Near-surface currents in the project area are primarily from the south-southeast (Figure 11), with maximum speeds exceeding 60 cm/s occurring primarily during summer months (November to March). Current speeds decrease with depth to <20 cm/s near the seabed (Total E and P Namibia, unpublished data).

The major feature of the Benguela Current is coastal 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 areas to the north due to perennial southerly winds (Shannon 1985). The Lüderitz upwelling cell is the most intense upwelling cell in the system, with the seaward extent reaching nearly 300 km, and the upwelling water is derived from 300-400 m depth (Longhurst 2006). A detailed analysis of water mass characteristics revealed a discontinuity in the central and intermediate water layers along the shelf north and south of Lüderitz (Duncombe Rae 2005). The Lüderitz / Orange River region thus forms a major environmental barrier between the northern and southern Benguela sub-systems (Ekau & Verheye 2005) (see Figure 12). Off central and northern Namibia, several secondary upwelling cells occur. Upwelling in these cells is perennial, with a late winter maximum (Shannon 1985).

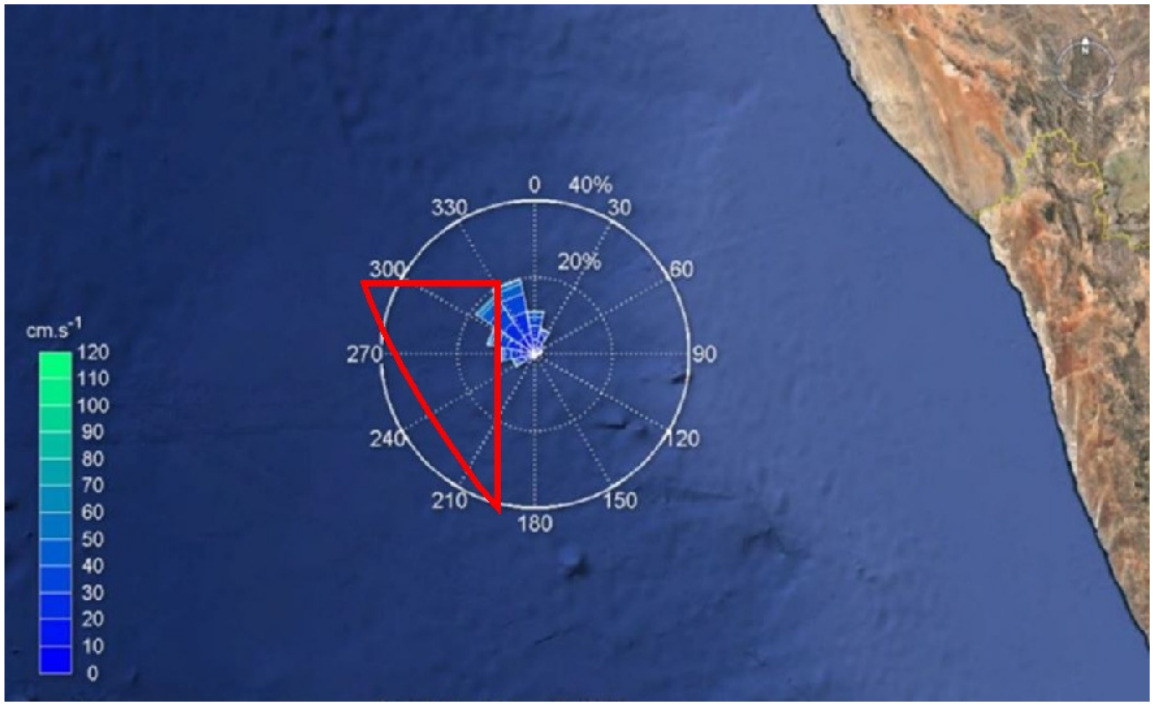


Figure 11: Near-surface (~2 m depth) current rose for Block 2912 (Source: Total E and P Namibia).

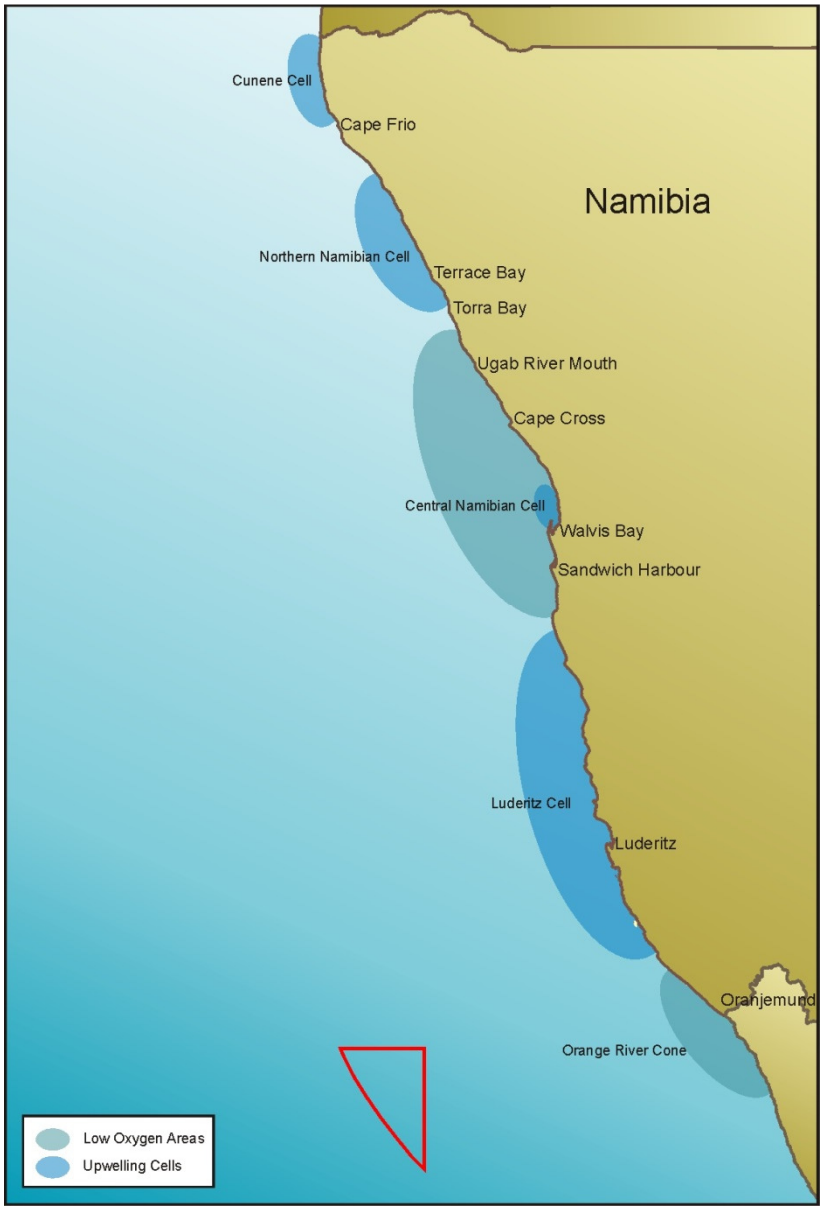


Figure 12: Block 2912 (red polygon) in relation to upwelling centres and low oxygen areas off the West Coast of Namibia (adapted from Shannon 1995).

3.2.4 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.

Typical seasonal swell-height rose-plots, compiled from Voluntary Observing Ship (VOS) data off Oranjemund are shown in Figure 13 (supplied by CSIR). The wave regime along the southern African west coast shows only moderate seasonal variation in direction, with virtually all swells throughout the year coming from the SW - S direction. In winter there is a slight increase in swell from SW-S direction. 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. With wind speeds capable of reaching 100 km/h during heavy winter south-westerly storms, winter swell heights can exceed 10 m. Generally, wave heights decrease with water depth and distance longshore.

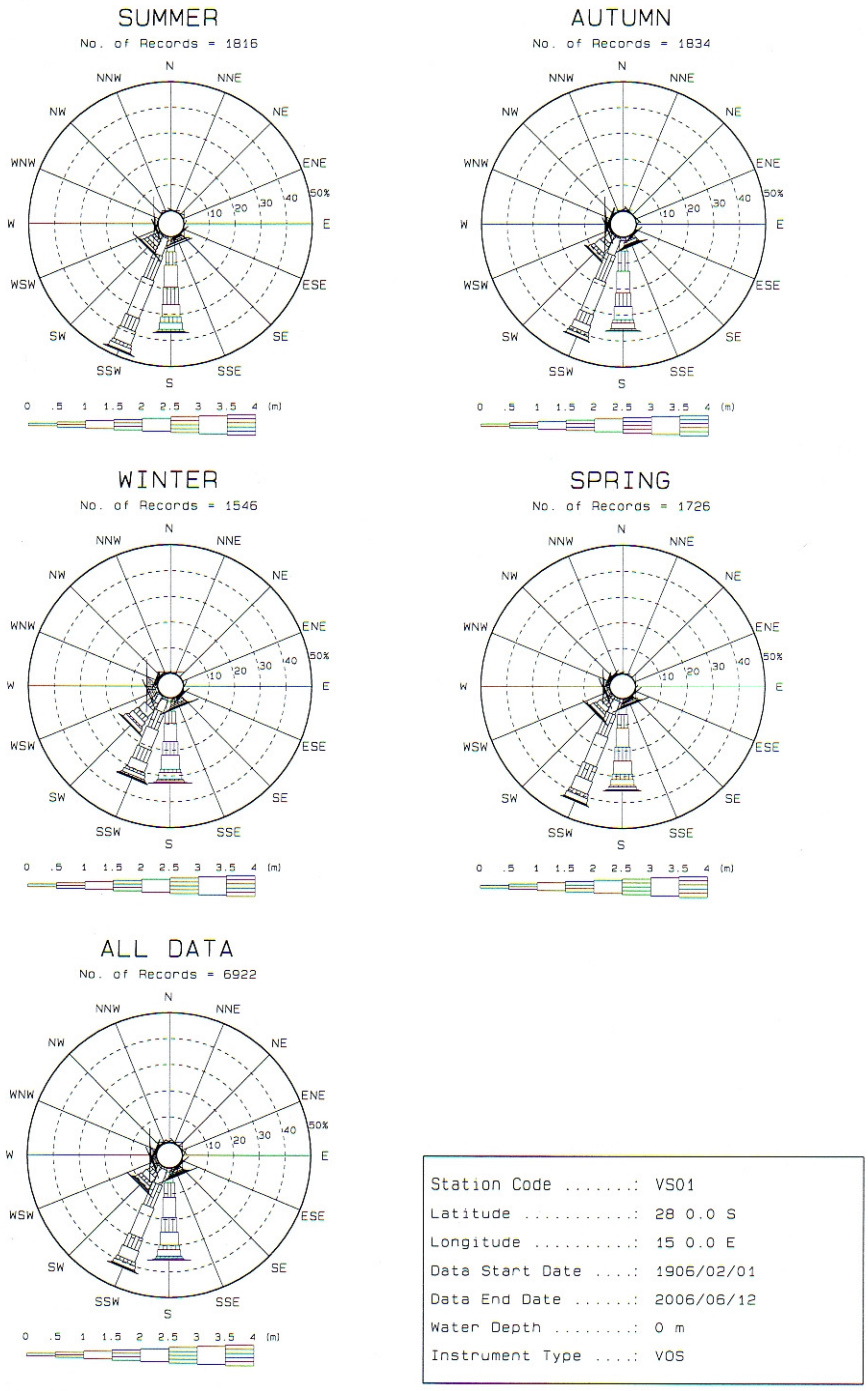


Figure 13: VOS Wave Height vs. Wave Direction data for the offshore area (28°-29°S; 15°-16°E recorded during the period 1 February 1906 and 12 June 2006)) (Source: Voluntary Observing Ship (VOS) data from the Southern African Data Centre for Oceanography (SADCO)).

In comparison, spring and summer swells tend to be smaller on average, typically around 2 m, not reaching the maximum swell heights of winter. There is also a more pronounced southerly swell component in summer. These southerly swells tend to be wind-induced, with shorter wave periods (~8 seconds), and are generally steeper than swell waves (CSIR 1996). These wind-induced southerly waves are relatively local and, although less powerful, tend to work together with the strong southerly winds of summer to cause the northward-flowing nearshore surface currents, and result in substantial nearshore sediment mobilisation, and northwards transport, by the combined action of currents, wind and waves.

Further offshore in the project area the majority of waves come from the S to S-SW direction, with maximum swell height of over 0.6 m occurring in winter (June and July) (Total E and P Namibia, unpublished data).

In common with the rest of the southern African coast, tides are semi-diurnal, with a total range of some 1.5 m at spring tide, but only 0.6 m during neap tide periods.

3.2.5 Water

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). Seawater profilers deployed at two stations in Block 2913B recorded salinities around 36‰ at the sea surface, dropping to a minimum of 34.4‰ between 500-700 m depth and increasing again to ~34.9‰ near the seabed (Benthic Solutions Ltd 2019a).

Seawater temperatures on the continental shelf of the southern Benguela typically vary between 6°C and 16°C. Seawater profilers deployed at two stations in Block 2913B recorded a maximum temperature of 17.5°C at the surface, declining steadily with depth to 2.3°C at the seabed (Benthic Solutions Ltd 2019a). Although not recorded at the time of the survey in Block 2913B, well-developed thermal fronts do exist, demarcating the seaward boundary of the upwelled water. Upwelling filaments are characteristic of these offshore thermal fronts, occurring as surface streamers of cold water, typically 50 km wide and extending beyond the normal offshore extent of the upwelling cell. Such fronts typically have a lifespan of a few days to a few weeks, with the filamentous mixing area extending up to 625 km offshore (Figure 14).

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 (Bailey *et al*. 1985; Chapman & Shannon 1985). Oxygen minima recorded in adjacent Block 2913B ranged from 34.3% to 43.1% (Benthic Solutions Ltd 2019a). 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. As Block 2912 is located well offshore of the upwelling cells, nutrient concentrations are expected to be low. This was confirmed from water samples collected in the adjacent Block 2913B, which found that Phosphate as P and Orthophosphate (PO_4) ranged from 0.04

to 0.07 mg/l and 0.12 to 0.21 mg/l, respectively, with the highest concentrations recorded near the seabed. Nitrate and Nitrite were both below the limits of detection and ammoniacal nitrogen ranged from 0.41 to 0.44 mg/l, whilst total nitrogen remained below 2 mg/l (Benthic Solutions Ltd 2019a).

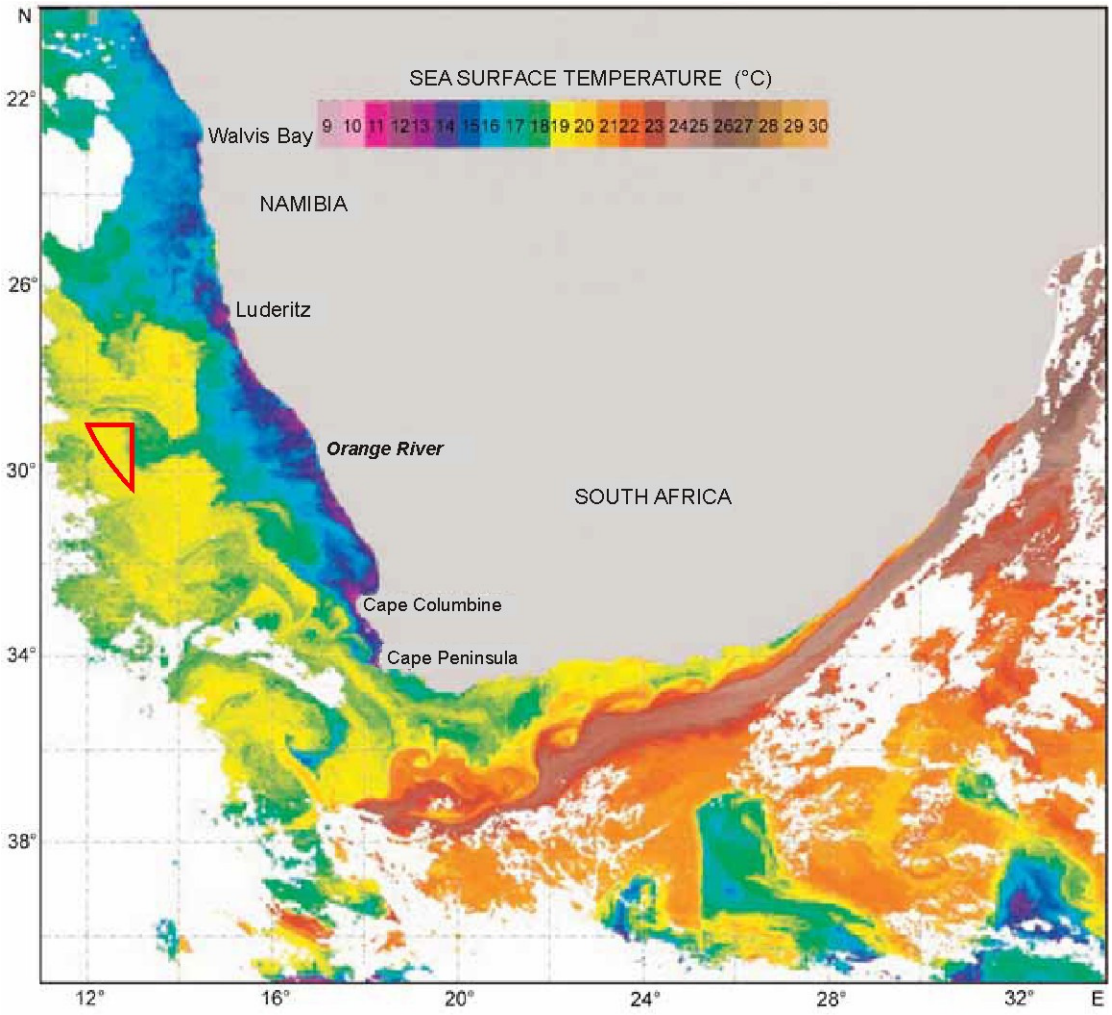


Figure 14: Sea Surface Temperature image for 15 May 2003 showing Block 2912 (red polygon) in relation to coastal upwelling events (Adapted from Weeks *et al*. 2006).

3.2.6 Upwelling and Plankton Production

The cold, upwelled water is rich in inorganic nutrients, the major contributors being various forms of nitrates, phosphates and silicates (Chapman and Shannon 1985). During upwelling the comparatively nutrient-poor surface waters are displaced by enriched deep water, supporting substantial seasonal primary phytoplankton production. This, in turn, serves as the basis for a rich food chain up through zooplankton, pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (hake and snoek), mammals (primarily seals and dolphins) and seabirds (penguins, cormorants, pelicans, terns and others). High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters. This results in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays.

3.2.7 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) can be 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. Off the southern African West Coast, the PIM loading in nearshore waters is strongly related to natural riverine inputs. 'Berg' wind events can potentially contribute the same order of magnitude of sediment input as the annual estimated input of sediment by the Orange River (Shannon & Anderson 1982; Zoutendyk 1992, 1995; Shannon & O'Toole 1998; Lane & Carter 1999).

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 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. In the offshore waters of Blocks 2912 and 2913B total suspended solids (TSS) remained below 5 mg/l being highest near the surface (~2.9 mg/l) declining to around 2.6 mg/l near the seabed (Benthic Solutions Ltd 2019a).

The major source of turbidity in the swell-influenced nearshore areas off the West Coast 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 varies considerably in the shore-perpendicular dimension, being substantially higher in the surf-zone 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).

3.2.8 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 (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.

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. 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. Being associated primarily with upwelling cells, HABs would not be expected in the offshore waters of Block 2912.

3.2.9 Low Oxygen Events

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations with <40% saturation occurring frequently (e.g. Visser 1969; Bailey *et al*. 1985). 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 (see Figure 6), there are corresponding preferential areas for the formation of oxygen-poor water. The two main areas of low-oxygen water formation in the central Benguela region are in the Orange River Bight and off Walvis Bay (Chapman & Shannon 1985; Bailey 1991; Shannon & O'Toole 1998; Bailey 1999; Fossing *et al*. 2000). The spatial distribution of oxygen-poor water in each of the areas is subject to short- and medium-term variability in the volume of hypoxic water that develops. De Decker (1970) showed that off Lambert's Bay in South Africa, the occurrence of low oxygen water is seasonal, with highest development in summer/autumn. Bailey and Chapman (1991), on the other hand, demonstrated that in the St Helena Bay area in South Africa, daily variability exists as a result of downward flux of oxygen through thermoclines and short-term variations in upwelling intensity. 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.

Periodic low oxygen events in the nearshore region can have catastrophic effects on the marine communities leading to large-scale stranding of rock lobsters, and mass mortalities of marine biota and fish (Newman & Pollock 1974; Matthews & Pitcher 1996; Pitcher 1998; Cockcroft *et al*. 2000). The development of anoxic conditions as a result of the decomposition of huge amounts of organic matter generated by algal blooms is the main cause for these mortalities and walkouts. The blooms

develop over a period of unusually calm wind conditions when sea surface temperatures where high. Algal blooms usually occur during summer-autumn (February to April) but can also develop in winter during the 'berg' wind periods, when similar warm windless conditions occur for extended periods.

3.2.10 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 15). These eruptions strip dissolved oxygen from the surrounding water column, resulting in mass mortalities of marine life. 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 recently 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). Such events, however, typically occur to the north and well inshore of Block 2912.

Recently the role of micro-organisms in the detoxification of sulphidic water was investigated during the occurrence of a sulphidic water mass covering 7 000 km^2 of seafloor off the coast of Namibia (http://www.mpi-bremen.de/Projekte_9.html; http://idw-online.de/ pages/de/ news292832), when surface waters, however, remained well oxygenated. In the presence of oxygen, sulphide is oxidized and transformed into non-toxic forms of sulphur. An intermediate layer was discovered in the water column, which contained neither hydrogen sulphide nor oxygen. It was established that sulphide diffusing upwards from the anoxic bottom water is consumed by autotrophic denitrifying bacteria that inhabit the intermediate water layer. By using nitrate, the detoxifying microorganisms transform sulphide into finely dispersed particles of sulphur that are non-toxic, thereby creating a buffer zone between the toxic deep water and the oxygenated surface waters. These results, however, also suggest that benthic and demersal animals in coastal waters may be affected by sulphur eruptions more often than previously thought, and that many of these sulphidic events may go unnoticed on satellite imagery as the bacteria consume the hydrogen sulphide before it reaches the surface.

Figure 15: Satellite image showing discoloured water offshore 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 by J. Kemper).

3.2.11 Natural Hydrocarbon Seeps

Petroleum discharges, both from natural seeps at the seabed and discharges occurring during the production and transport of petroleum are a common source of toxic substances in marine ecosystems (NRC 2003a). Satellite imagery analysis was used by TEEPNA (in 2021) in an oil slicks detection study of the western offshore part of South Africa. The large radar dataset covering 12 years included medium and high resolution 864 ENVISAT (2002 - 2012) and 1 864 SENTINEL (2015 - 2021) radar images, respectively.

The following was concluded from the oil slicks detection study:

- No oil seep anomaly was detected.
- Potential oil slicks detected were identified off the West Coast:
    - oil spills (pollution) from boats were identified orientated mainly NNW-SSE, and thus in agreement with the orientation of the shipping lanes
    - potential oil seeps corresponding to light oil associated with gas, but they are not recurrent.

3.3 The Biological Environment

Biogeographically, the study area falls into the cold temperate Namaqua Bioregion, which extends from Sylvia Hill, north of Lüderitz in Namibia to Cape Columbine (Emanuel *et al*. 1992; Lombard *et al*. 2004). Block 2912 is located in the offshore Namib Biozone (De Cauwer 2007), which extends beyond the shelf break onto the continental slope and into abyssal depths (Figure 16). The coastal, wind-induced upwelling characterising the Namibian coastline, is the principle physical process that shapes the marine ecology of the 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. During periods of less intense winds off the northern Namibian 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.

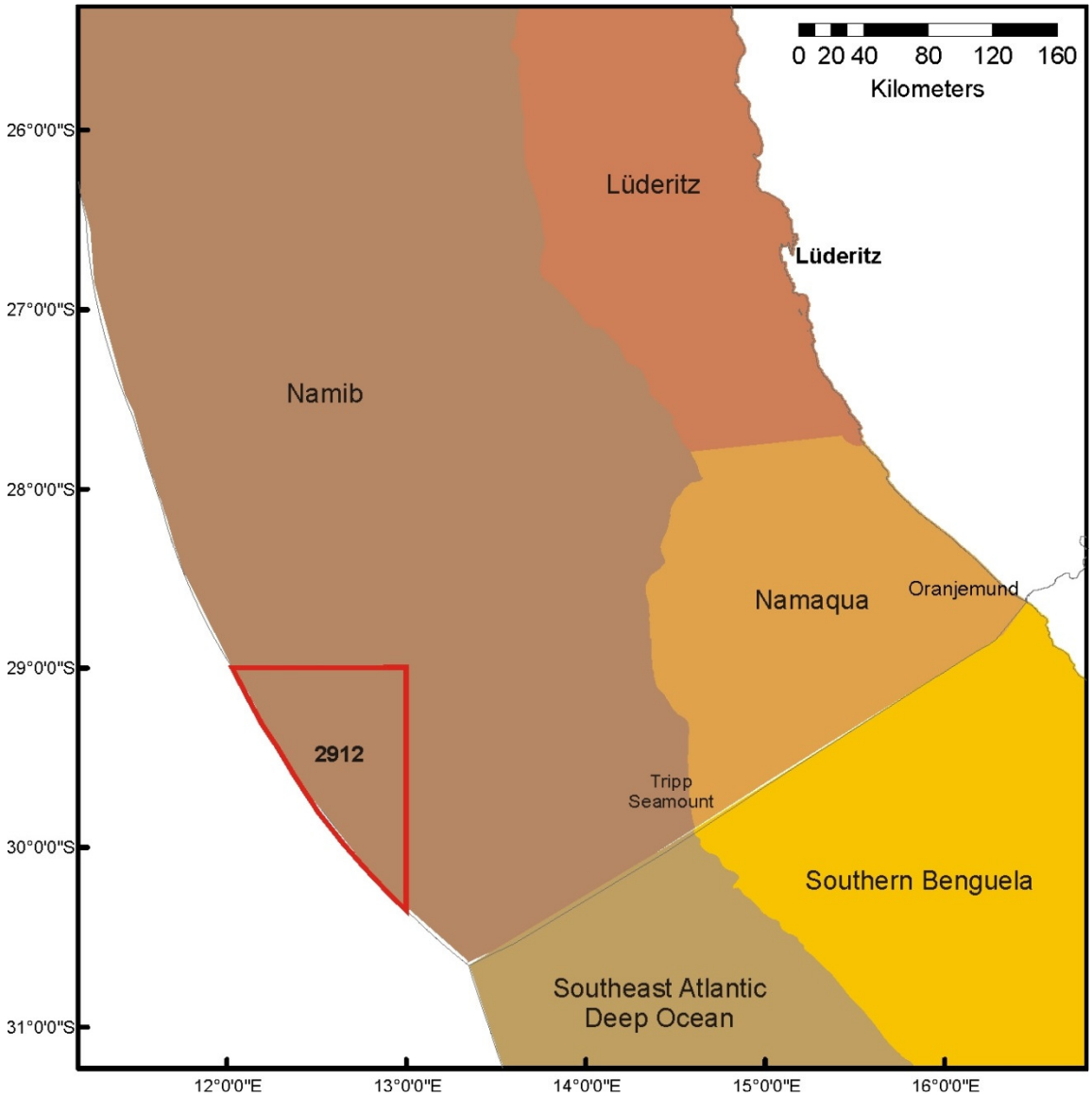


Figure 16: Block 2912 in relation to the Namibian biozones (De Cauwer 2007; MFMR 2021). The adjacent South African ecoregions (Sink *et al*. 2019) are also shown.

Communities within marine habitats are largely ubiquitous throughout the southern African West Coast region, being particular only to substrate type or depth zone. These biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability (even at small scales). Block 2912 is located beyond the 1 000 m depth contour, the closest point to shore being ~285 km off the coast from Baker's Bay. The offshore marine ecosystems comprise a limited range of habitats, namely unconsolidated seabed sediments and the water column. The biological communities 'typical' of these habitats are described briefly below, focussing both on dominant, commercially important and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the proposed exploration well-dilling.

3.3.1 Demersal Communities

3.3.1.1 Benthic Invertebrate Macrofauna

The seabed communities in Block 2912 lie within the Namib sub-photic and continental slope biozone, which extends from the shelf edge into the abyss. The benthic and coastal habitats of Namibia were mapped as part of the Benguela Current Commission's Spatial Biodiversity Assessment (BCC-SBA) (Holness *et al*. 2014) to develop assessments of the ecosystem threat status and ecosystem protection level. Submarine canyons were also mapped as biodiversity features, although descriptions of their geographical situations were not sufficiently accurate to include them in the benthic habitat map[2] (Figure 17). The benthic habitats were subsequently assigned an ecosystem threat status based on their level of protection (Table 2) and mapped (see Figure 18).

The benthic biota of unconsolidated marine sediments constitute invertebrates that live on (epifauna) or burrow within (infauna) the sediments, and are generally divided into macrofauna (animals >1 mm) and meiofauna (<1 mm). Numerous studies have been conducted on southern African West Coast continental shelf benthos, mostly focused on mining, pollution or demersal trawling impacts (Christie & Moldan 1977; Moldan 1978; Jackson & McGibbon 1991; Field *et al*. 1996; Field & Parkins 1997; Parkins & Field 1997, 1998; Pulfrich & Penney 1999; Goosen *et al*. 2000; Savage *et al*. 2001; Steffani & Pulfrich 2004; 2007; Steffani 2007a; 2007b; Atkinson 2009; Steffani 2009a, 2009b, 2010a, 2010b, 2010c; Atkinson *et al*. 2011; Steffani 2011, 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). The description below is drawn from the various baseline and monitoring surveys conducted by diamond mining companies (Bickerton & Carter 1995; Steffani & Pulfrich 2007; Steffani 2007a; 2007b).

Polychaetes, crustaceans and molluscs make up the largest proportion of individuals, biomass and species on the west coast. The distribution of species within these communities are inherently patchy reflecting the high natural spatial and temporal variability associated with macro-infauna of unconsolidated sediments (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 recorded on the South African West Coast (Steffani & Pulfrich 2004a). Generally species richness increases from the inner shelf across the mid shelf and is influenced by sediment type (Karenyi unpublished data). The highest total abundance and species diversity was measured in sandy sediments of the mid-shelf. Biomass is highest in the inshore (± 50 g/m^2 wet weight) and

[2] Possible marine canyons identified by the international Deep Ocean project mapped them as lines. The lines were buffered by 5 km to ensure that both the canyon and its associated adjacent ecosystems were included.

decreases across the mid-shelf averaging around 30 g/m^2 wet weight. The midshelf mudbelt, however, 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).

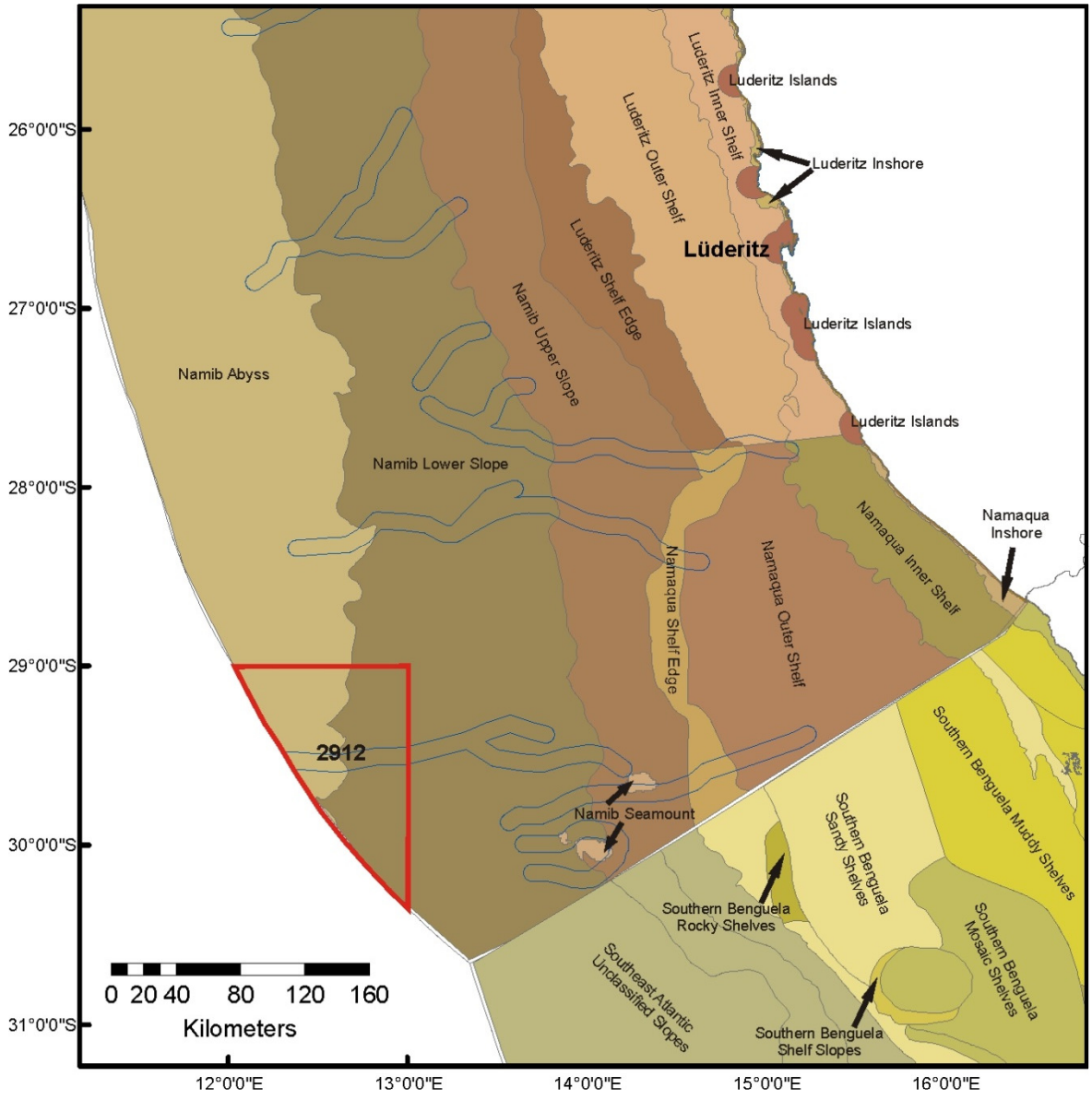


Figure 17: Block 2912 (red polygon) in relation to the Namibian benthic and coastal habitats. The positions of potential submarine canyons are also shown (blue lines) (adapted from Holness *et al*. 2014). The adjacent South African substratum types (Sink *et al*. 2019) are also shown.

Table 2: Ecosystem threat status for marine habitat types on the Namibian Coast (adapted from Holness *et al*. 2014).

Key	Habitat Type	Threat Status	Area (km^2)
1	Namib Abyss	Least Threatened	800.93
2	Namib Lower Slope	Least Threatened	1 380.13
3	Namib Upper Slope	Least Threatened	590.66
4	Namib Seamount	Least Threatened	26.83
5	Namaqua Shelf Edge	Endangered	44.40
6	Namaqua Outer Shelf	Least Threatened	175.29
7	Namaqua Inner Shelf	Least Threatened	69.48
8	Namaqua Inshore	Vulnerable	4.45
9	Lüderitz Shelf Edge	Critically Endangered	87.55
10	Lüderitz Outer Shelf	Vulnerable	184.70
11	Lüderitz Inner Shelf	Least Threatened	62.91
12	Lüderitz Islands	Least Threatened	13.32
13	Lüderitz Inshore	Least Threatened	3.56

Note: Those habitats potentially affected by the proposed exploration drilling are shaded.

The benthic fauna of the abyss, lower and upper continental slope and outer shelf (beyond ~450 m depth) are very poorly known largely due to limited opportunities for sampling as well as the lack of access to Remotely Operated Vehicles (ROVs) for visual sampling of hard substrata. To date very few areas of the continental slope off the southern African West Coast have been biologically surveyed. Benthic habitats along the 500 m depth contour have been assigned a threat status of 'Endangered' by the Benguela Current Commission (BCC) Spatial Biodiversity Assessment (Holness *et al*. 2014) but further offshore in Blocks 2912 the benthic habitat type is considered 'Least Threatened' (Figure 18).

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.

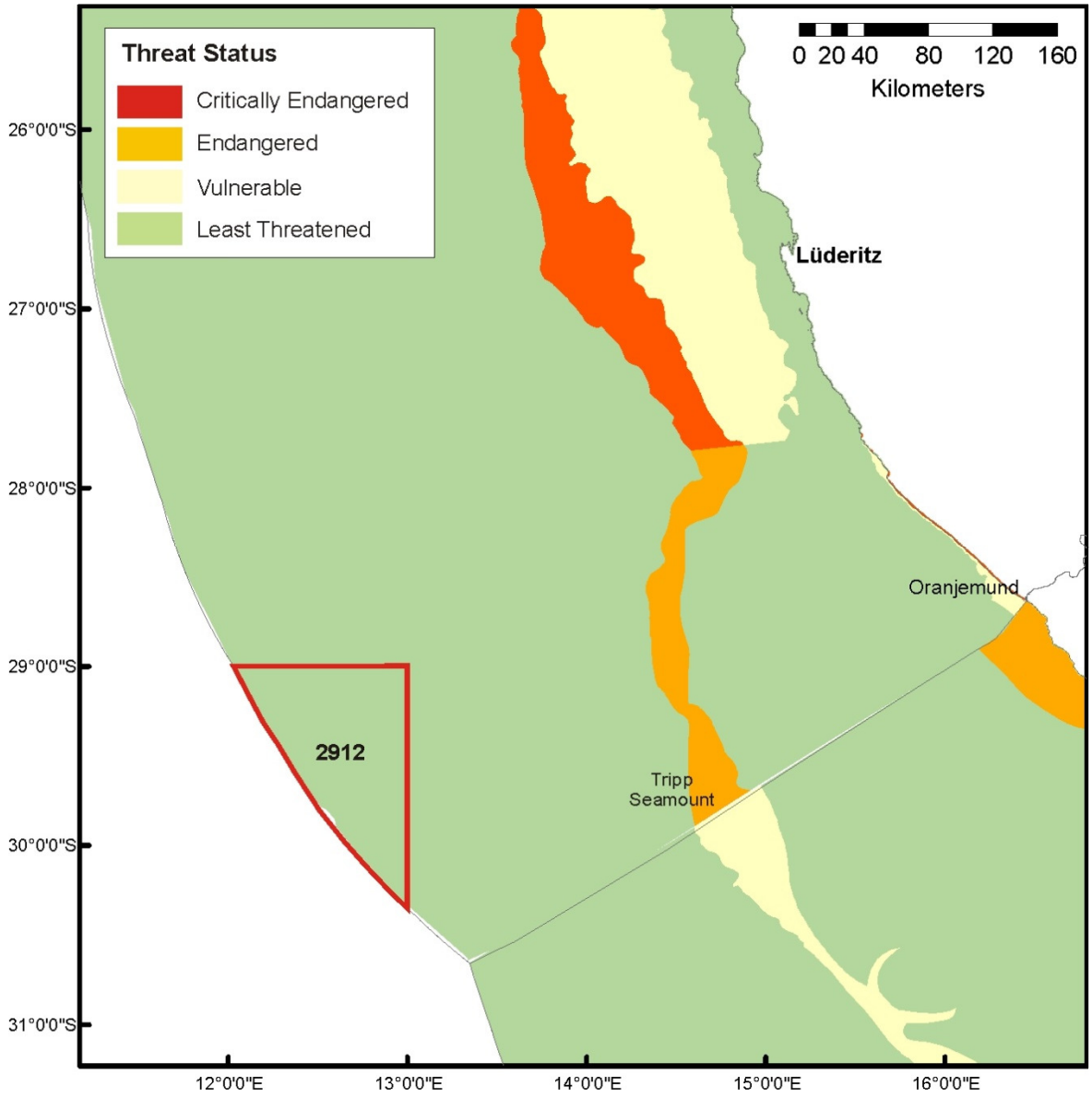


Figure 18: Block 2912 (red polygon) in relation to ecosystem threat status for offshore benthic habitat types off southern Namibia (adapted from Holness *et al*. 2014). The threat status of adjacent South African substratum types (Sink *et al*. 2019) are also shown.

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 the west coast of southern Africa (Steffani & Pulfrich 2004a, 2004b, 2007; Steffani 2007a, 2007b, 2009a, 2009b, 2009c, 2010, 2011, 2015).

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.

Information on the benthic fauna of the lower continental slope and abyss (beyond 1 800 m depth) is largely lacking due to limited opportunities for sampling. As part of the Environmental Baseline Survey for Block 2913B, however, deepwater benthic sampling was undertaken using a box corer (Benthic Solutions Ltd 2019a) thereby providing valuable information on the benthic infaunal communities in the project area.

The macrofauna throughout the survey area are generally impoverished but fairly consistent, which is typical for deep water sediments. The 105 species recorded, were dominated by polychaetes, which accounted for 64.1% of the total individuals. Molluscs were represented by 11 species (19.6% of total individuals), whilst 20 species of crustaceans were recorded (contributing to only 9.8% of total individuals). Echinoderms were represented by only 3 species (5.8% of total individuals), whilst all other groups (Actiniaria, Nemertea, Nematoda, Ascidiacea and Priapulida) accounted for the remaining 5.9% of individuals. The deposit-feeding polychaete *Spiophanes* sp. was the most abundant species recorded. This small bristleworm can either be a passive suspension feeder or a surface deposit feeder, living off sediment particles, planktonic organisms and meiobenthic organisms. The bivalve mollusc *Microgloma mirmidina* was the second most common species, with the polychaete tentatively identified as a *Leiocapitellide* being the third most abundant. With the exception of the carnivorous polychaete *Glycera capitata*, most species were suspension or deposit feeders typical of soft unconsolidated sediments.

Examples of the macroinvertebrate infauna of the project area are illustrated in Figure 19.

3.3.1.2 Deep-water coral communities

There has been increasing interest in deep-water corals in recent years because of their likely sensitivity to disturbance and their long generation times. These benthic filter-feeders generally occur at depths exceeding 150 m. Some species form reefs while others are smaller and remain solitary. Corals add structural complexity to otherwise uniform seabed habitats thereby creating areas of high biological diversity (Breeze *et al*. 1997; MacIssac *et al*. 2001). Deep water corals establish themselves below the thermocline where there is a continuous and regular supply of concentrated particulate organic matter, caused by the flow of a relatively strong current over special topographical formations which cause eddies to form. Nutrient seepage from the substratum might also promote a location for settlement (Hovland *et al*. 2002). Substantial shelf areas in the productive Benguela region should thus potentially be capable of supporting rich, cold water, benthic, filter-feeding communities. Such communities would also be expected with

topographic features such as Tripp Seamount and Child's Bank, some 125 km to the east and 280 km to the southeast of Block 2912, respectively.

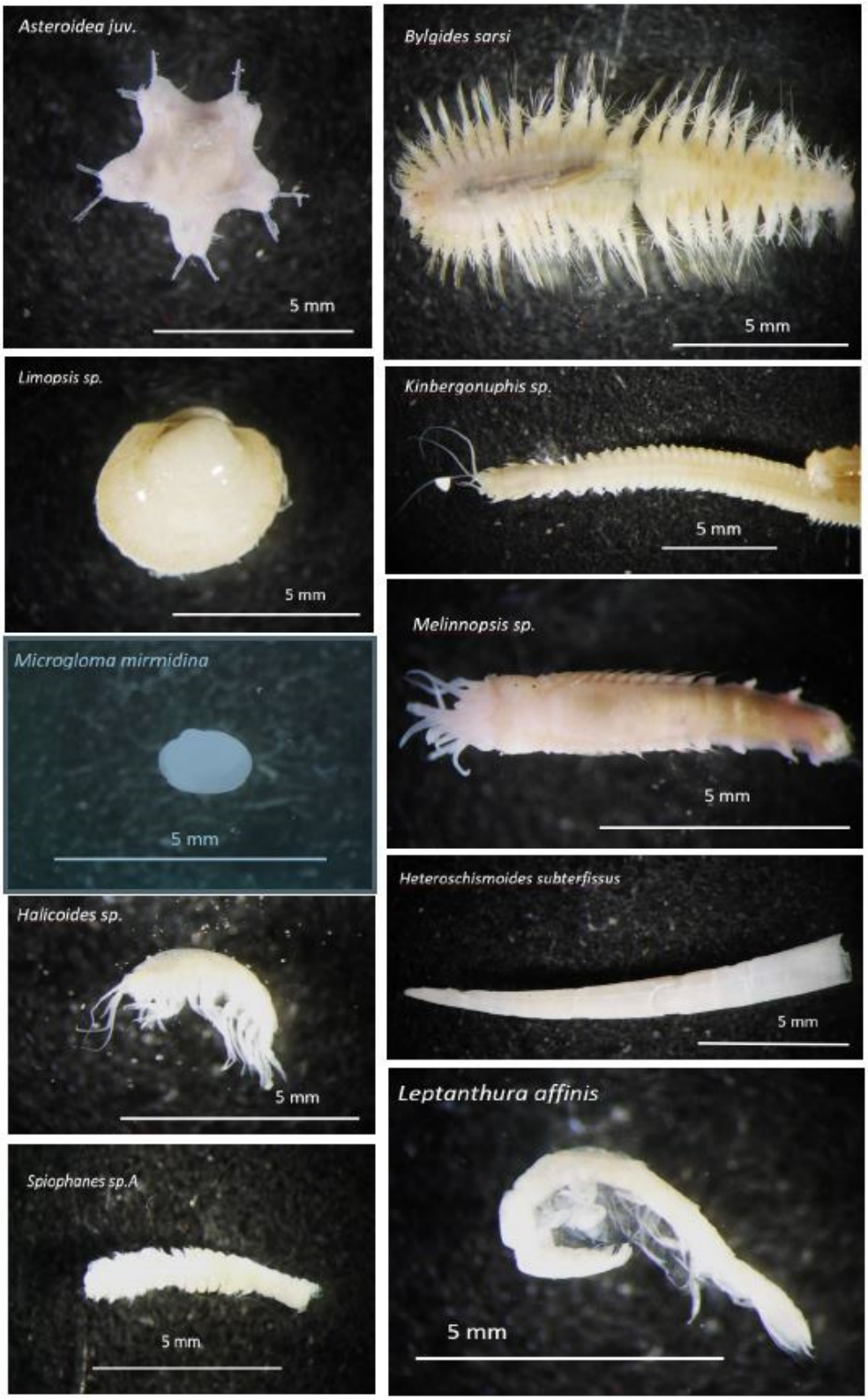


Figure 19: Examples of macroinvertebrates recorded in the adjacent Block 2913B (Source Benthic Solutions Ltd 2019a).

3.3.1.3 Demersal Fish Species

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 but also extending beyond 500 m water depth 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. The deep-sea community was found to be homogenous both spatially and temporally. In a more recent study, however, 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) and with the eastward shifts observed in small pelagic fish species and rock lobster populations (Coetzee *et al*. 2008, Cockcroft *et al*. 2000).

The diversity and distribution of demersal cartilagenous fishes on the southern African west coast was discussed by Compagno *et al*. (1991). The species that may occur in the Area of Interest and on the continental shelf inshore thereof, and their approximate depth range, are listed in Table 3. The distribution of some of these species on the South African coast was provided in Harris *et al*. (2022) (Figure 20), and although not illustrated extending across the border, their continued distribution ranges into Namibian waters can be inferred. Block 2912 lies well offshore of most of the distribution ranges of these species.

Information on demersal and cartilageonous fish species beyond the shelf break is lacking.

3.3.2 Seamount Communities

Features such as banks, knolls and seamounts (referred to collectively here as "seamounts"), which protrude into the water column, are subject to, and interact with, the water currents surrounding them. The effects of such seabed features on the surrounding water masses can include the up-welling of relatively cool, nutrient-rich water into nutrient-poor surface water thereby resulting in higher productivity (Clark *et al*. 1999), which can in turn strongly influences the distribution of organisms on and around seamounts. Evidence of enrichment of bottom-associated communities and high abundances of demersal fishes has been regularly reported over such seabed features.

Table 3: Demersal cartilaginous species found on the continental shelf along the southern African west coast, with approximate depth range at which the species occur (Compagno *et al.* 1991) and their IUCN conservation status.

Common Name	Scientific name	Depth Range (m)	IUCN Conservation Status
Frilled shark	*Chlamydoselachus anguineus*	200-1 000	LC
Six gill cowshark	*Hexanchus griseus*	150-600	NT
Gulper shark	*Centrophorus granulosus*	480	EN
Leafscale gulper shark	*Centrophorus squamosus*	370-800	EN
Bramble shark	*Echinorhinus brucus*	55-285	EN
Black dogfish	*Centroscyllium fabricii*	>700	LC
Portuguese shark	*Centroscymnus coelolepis*	>700	NT
Longnose velvet dogfish	*Centroscymnus crepidater*	400-700	NT
Birdbeak dogfish	*Deania calcea*	400-800	NT
Arrowhead dogfish	*Deania profundorum*	200-500	NT
Longsnout dogfish	*Deania quadrispinosa*	200-650	VU
Sculpted lanternshark	*Etmopterus brachyurus*	450-900	DD
Brown lanternshark	*Etmopterus compagnoi*	450-925	LC
Giant lanternshark	*Etmopterus granulosus*	>700	LC
Smooth lanternshark	*Etmopterus pusillus*	400-500	LC
Spotted spiny dogfish	*Squalus acanthias*	100-400	VU
Shortnose spiny dogfish	*Squalus megalops*	75-460	LC
Shortspine spiny dogfish	*Squalus mitsukurii*	150-600	EN
Sixgill sawshark	*Pliotrema warreni*	60-500	LC
Goblin shark	*Mitsukurina owstoni*	270-960	LC
Smalleye catshark	*Apristurus microps*	700-1 000	LC
Saldanha catshark	*Apristurus saldanha*	450-765	LC
“grey/black wonder” catsharks	*Apristurus* spp.	670-1 005	LC
Tiger catshark	*Halaelurus natalensis*	50-100	VU
Izak catshark	*Holohalaelurus regani*	100-500	LC
Yellowspotted catshark	*Scyliorhinus capensis*	150-500	NT
Soupfin shark/Vaalhaai	*Galeorhinus galeus*	<10-300	CR
Common smoothhound/Houndshark	*Mustelus mustelus*	<100	EN
Whitespot smoothhoundshark	*Mustelus palumbes*	>350	LC
Lesser guitarfish	*Acroteriobatus annulatus*	>100	VU
Atlantic electric ray	*Torpedo nobiliana*	120-450	LC
African softnose skate	*Bathyraja smithii*	400-1 020	LC
Smoothnose legskate	*Cruriraja durbanensis*	>1 000	DD
Roughnose/triangular legskate	*Cruriraja parcomaculata*	150-620	LC
African dwarf skate	*Neoraja stehmanni*	290-1 025	LC
Thorny skate	*Raja radiata*	50-600	VU
Bigmouth skate	*Raja robertsi*	>1 000	LC
Slime skate	*Dipturus pullopunctatus*	15-460	LC

Common Name	Scientific name	Depth Range (m)	IUCN Conservation Status
Rough-belly skate	*Raja springeri*	85-500	LC
Yellowspot skate	*Raja wallacei*	70-500	VU
Roughskin skate	*Dipturus trachydermus*	1 000-1 350	EN
Biscuit skate	*Raja clavata*	25-500	NT
Munchkin skate	*Rajella caudaspinosa*	300-520	LC
Bigthorn skate	*Raja confundens*	100-800	LC
Ghost skate	*Rajella dissimilis*	420-1 005	LC
Leopard skate	*Rajella leopardus*	300-1 000	LC
Smoothback skate	*Rajella ravidula*	500-1 000	LC
Spearnose skate	*Rostroraja alba*	75-260	EN
St Joseph	*Callorhinchus capensis*	30-380	LC
Cape chimaera	*Chimaera notafricana*	680-1 000	LC
Brown chimaera	*Chimaera carophila*	420-850	LC
Spearnose chimaera	*Rhinochimaera atlantica*	650-960	LC

LC – Least Concern VU – Vulnerable NT – Near Threatened
EN – Endangered CR – Critically Endangered DD – Data Deficient

The enhanced fluxes of detritus and plankton that develop in response to the complex current regimes lead to the development of detritivore-based food-webs, which in turn lead to the presence of seamount scavengers and predators. Seamounts provide an important habitat for commercial deepwater fish stocks such as orange roughy, oreos, alfonsino and Patagonian toothfish, which aggregate around these features for either spawning or feeding (Koslow 1996).

Such complex benthic ecosystems in turn enhance foraging opportunities for many other predators, serving as mid-ocean focal points for a variety of pelagic species with large ranges (turtles, tunas and billfish, pelagic sharks, cetaceans and pelagic seabirds) that may migrate large distances in search of food or may only congregate on seamounts at certain times (Hui 1985; Haney *et al*. 1995). Seamounts thus serve as feeding grounds, spawning and nursery grounds and possibly navigational markers for a large number of species (SPRFMA 2007).

Enhanced currents, steep slopes and volcanic rocky substrata, in combination with locally generated detritus, favour the development of suspension feeders in the benthic communities characterising seamounts (Rogers 1994). Deep- and cold-water corals (including stony corals, black corals and soft corals) are a prominent component of the suspension-feeding fauna of many seamounts, accompanied by barnacles, bryozoans, polychaetes, molluscs, sponges, sea squirts, basket stars, brittle stars and crinoids (reviewed in Rogers 2004). There is also associated mobile benthic fauna that includes echinoderms (sea urchins and sea cucumbers) and crustaceans (crabs and lobsters) (reviewed by Rogers 1994). Some of the smaller cnidarians species remain solitary while others form reefs thereby adding structural complexity to otherwise uniform seabed habitats. The coral frameworks offer refugia for a great variety of invertebrates and fish (including commercially important species) within, or in association with, the living and dead coral framework thereby creating spatially fragmented areas of high biological diversity. Compared to the surrounding deep-

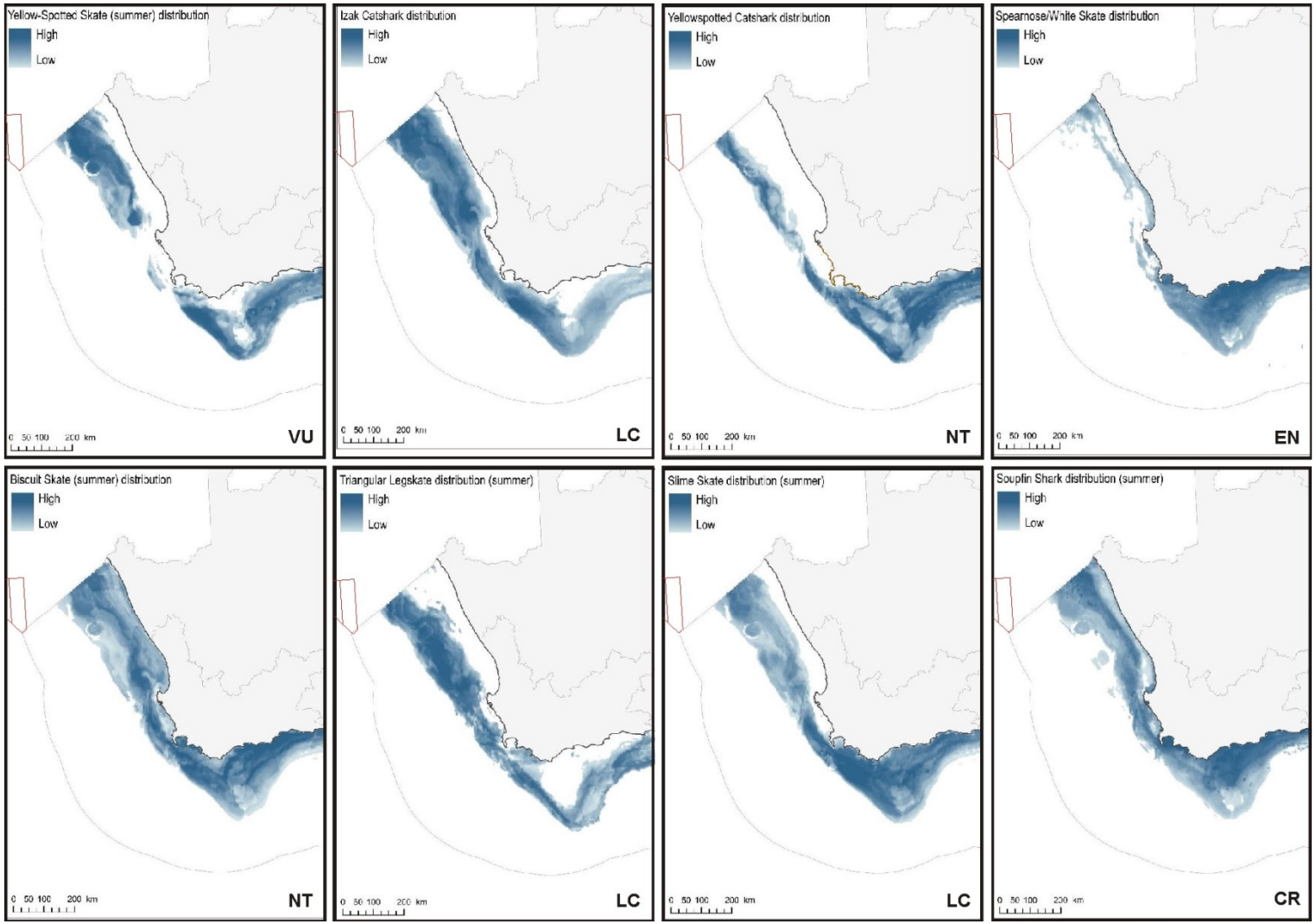


Figure 20: The distribution south of Namibia's border with South Africa of various cartilaginous species mentioned in Table 3 in relation to Block 2912 and 2913B (red polygons) (adapted from Harris *et al*. 2022). The IUCN conservation status is provided.

sea environment, seamounts typically form biological hotspots with a distinct, abundant and diverse fauna, many species of which remain unidentified. Consequently, the fauna of seamounts is usually highly unique and may have a limited distribution restricted to a single geographic region, a seamount chain or even a single seamount location (Rogers *et al*. 2008). Levels of endemism on seamounts are also relatively high compared to the deep sea. As a result of conservative life histories (*i.e*. very slow growing, slow to mature, high longevity, low levels of recruitment) and sensitivity to changes in environmental conditions, such biological communities have been identified as Vulnerable Marine Ecosystems (VMEs). They are recognised as being particularly sensitive to anthropogenic disturbance (primarily deep-water trawl fisheries and mining), and once damaged are very slow to recover, or may never recover (FAO 2008).

It is not always the case that seamount habitats are VMEs, as some seamounts may not host communities of fragile animals or be associated with high levels of endemism. Evidence from video footage taken on hard-substrate habitats in 100 - 120 m depth off southern Namibia (Figure 21) suggest that vulnerable communities including gorgonians, octocorals and reef-building sponges occur on the continental shelf, and similar communities may thus be expected on Tripp Seamount, some 125 km to the east of Block 2912.

Figure 21: Gorgonians and bryozoans communities recorded on deep-water reefs (100-120 m) off the southern African West Coast (Photos: De Beers Marine).

3.3.3 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.

As with seabed habitats, pelagic habitat types have been defined as 'Vulnerable', 'Endangered' or 'Critically Endangered' depending on their level of protection (Holness *et al*. 2014). Pelagic ecosystems south of Walvis Bay have all been assigned a threat status of 'Least Threatened' (Figure 35 in Holness *et al*. 2014).

3.3.3.1 Plankton

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 (Figure 22).

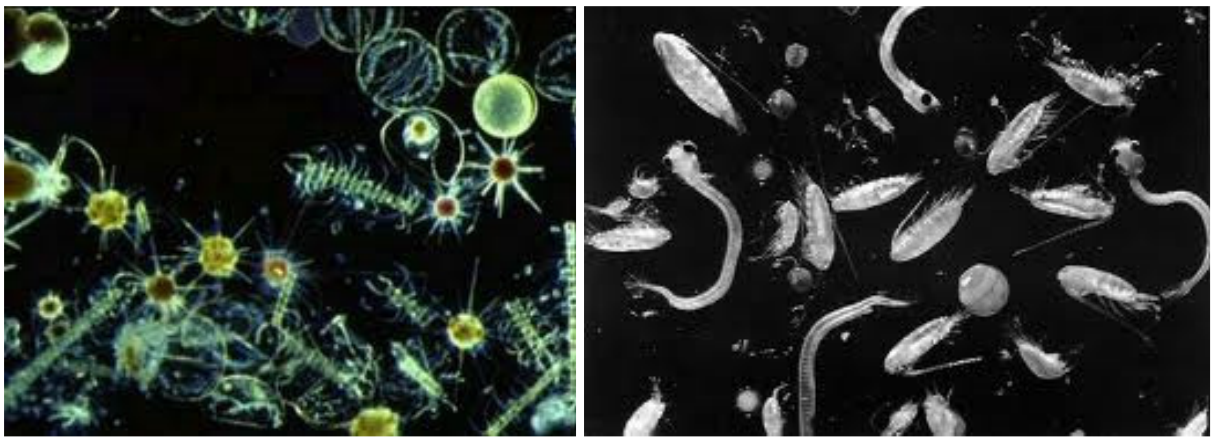


Figure 22: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

Off the Namibian coastline, phytoplankton are the principal primary producers with mean annual productivity being comparatively high at 2 g C/m^2/day (Barnard 1998). 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. In the surf zone, diatoms and dinoflagellates are nearly equally important members of the phytoplankton, and some silicoflagellates are also present.

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 (Maartens 2003; Hansen *et al*. 2005). Copepods are the most dominant group making up 70–85% of the zooplankton. 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 23), their eggs and larvae form an important contribution to the ichthyoplankton in the region. The Lüderitz upwelling cell - Orange River Cone (LUCORC) area, south of the Lüderitz upwelling cell between approximately 29°S – 31°S, is considered to be an environmental barrier to the transport of ichthyoplankton from the southern to the northern Benguela upwelling ecosystems. Areas of powerful upwelling are considered unfavourable spawning habitats, with pelagic fish species, such

as anchovy, redeye round herring, horse mackerel and shallow-water hake, reported as spawning on either side of the LUCORC area, but not within it (Figure 23). The area is characterised by diminished phytoplankton biomass due to high turbulence and deep mixing in the water column. A deficiency of phytoplankton results in poor feeding conditions for micro-, meso- and macrozooplankton and for ichthyoplankton, and successful survival and recruitment of these species in the area is considered unlikely (Lett *et al*. 2007). Due to its location far offshore and beyond the influence of upwelling, the abundance of phytoplankton, zooplankton and ichthyoplankton in Block 2912, is thus expected to be comparatively low.

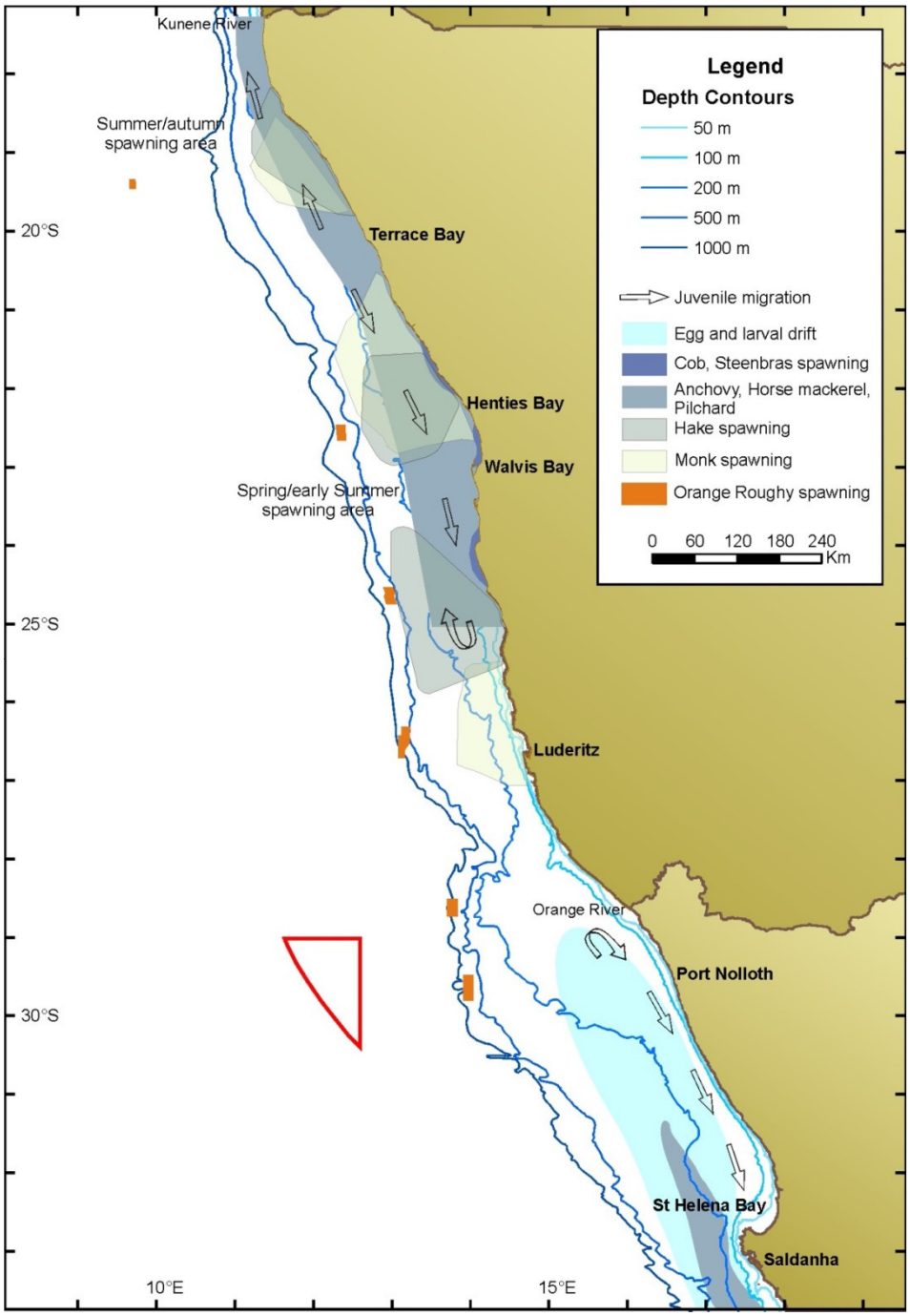


Figure 23: Block 2912 (red polygon) in relation to major spawning areas in the Benguela region (adapted from Cruikshank 1990; Hampton 1992; MFMR 2021).

Vertical plankton hauls undertaken in the adjacent Block 2913B, however, identified that a wide diversity of copepods (39 different species) dominated the zooplankton, contributing 88.5% to the zooplankton captured, followed by Ostracods (2.6%) and Amphipods (2.3%). Chaetognathes (1.84%), Ophiuroid larvae (1.24%) and Cnidera (0.31%) were also present with decapods, mysids, euphausids, ctenopores, molluscs, polychaetes and chordates also represented (Benthic Solutions Ltd 2019a).

3.3.3.2 Pelagic Invertebrates

Pelagic invertebrates that may be encountered in the project area are the colossal squid *Mesonychoteuthis hamiltoni* and the giant squid *Architeuthis* sp. Both are deep dwelling species, with the colossal squid's distribution confined to the entire circum-antarctic Southern Ocean (Figure 24, top) while the giant squid is usually found near continental and island slopes all around the world's oceans (Figure 24, bottom). Both species could thus potentially occur in the pelagic habitats of the project area, although the likelihood of encounter is extremely low.

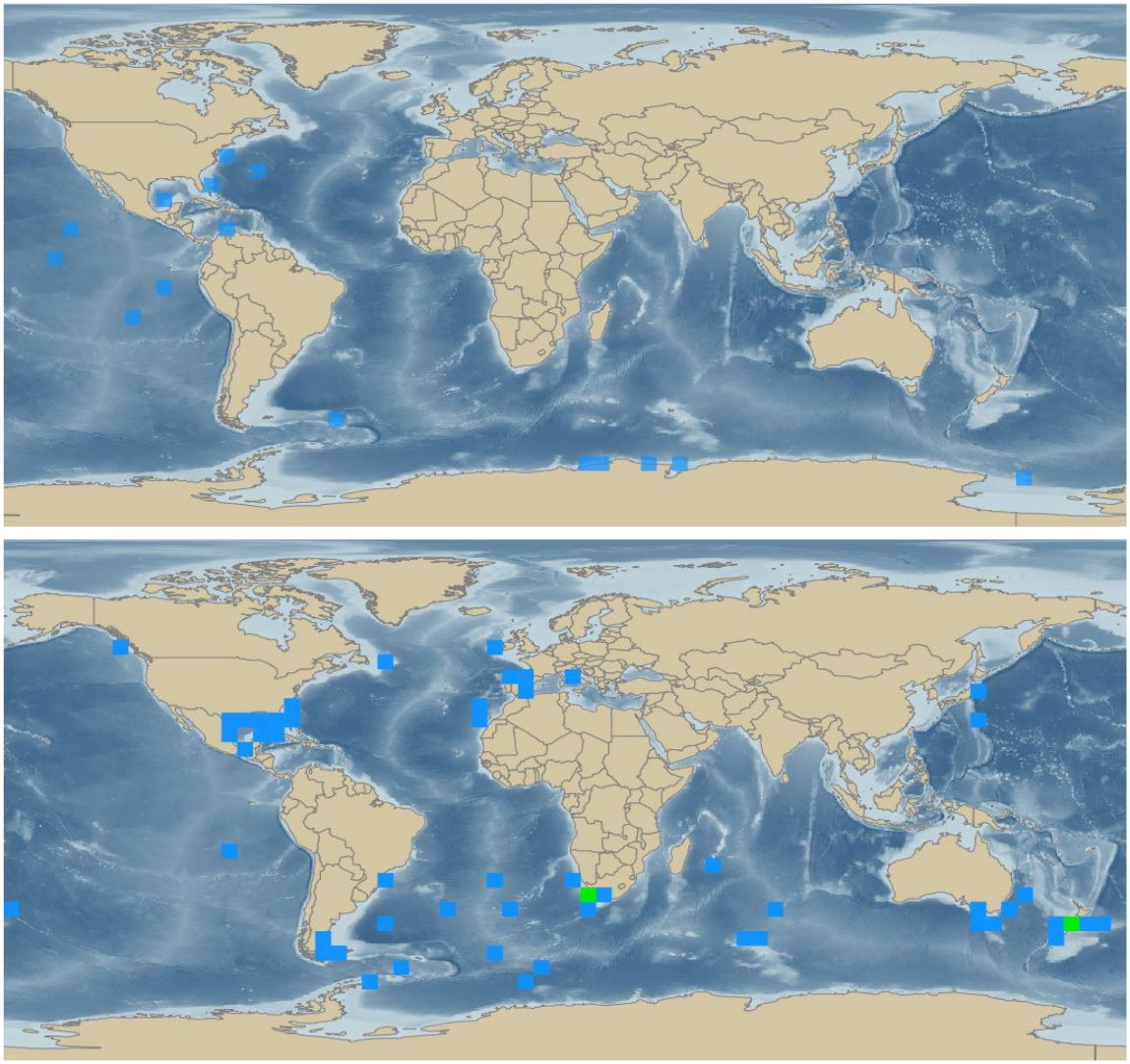


Figure 24: Distribution of the colossal squid (top) and the giant squid (bottom). Blue squares <5 records, green squares 5-10 records (Source: http://iobis.org).

Growing to in excess of 10 m in length, they are the principal prey of the sperm whale, and are also taken by beaked whales, pilot whales, elephant seals and sleeper sharks. Nothing is known of their vertical distribution, but data from trawled specimens and sperm whale diving behaviour suggest they may span a depth range of 300 – 1 000 m. They lack gas-filled swim bladders and maintain neutral buoyancy through an ammonium chloride solution occurring throughout their bodies.

3.3.3.3 Fish

Small pelagic species include the sardine/pilchard (*Sardinops sagax ocellatus*) (Figure 25, left), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) (Figure 25, 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*.

Figure 25: Cape fur seal preying on a shoal of pilchards (left). School of horse mackerel (right) (photos: www.underwatervideo.co.za; www.delivery.superstock.com).

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 japonicas*. Both these species have been rated as 'Least concern' on the national assessment (Sink *et al*. 2019). 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).

The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of Block 2912 are the large migratory pelagic species, including various tunas, billfish and sharks, many of which are considered threatened by the International Union for the Conservation of Nature (IUCN), primarily due to overfishing (

Table 4). Tuna and swordfish are targeted by high seas fishing fleets (Figure 26) and illegal overfishing has severely damaged the stocks of many of these species. Off the southern African west coast, fishers typically follow the movement of longfin tuna from the Southern Benguela waters northwards into southern Namibia and the southern part of the Northern Benguela. This movement occurs from mid to late summer (January to March) at which time aggregations may occur around or near oceanic features, in particular Vema and Tripp seamounts. Other species movements (e.g. yellowfin and bigeye tuna), which occur spatially and temporally throughout the south east Atlantic have not been clearly defined, although their availability to the fisheries is believed to increase from later summer into winter (March through to July) (Lehodeya *et al*. 2006; Lan *et al*. 2011). Similarly, pelagic sharks, are either caught as bycatch in the pelagic tuna longline fisheries (Figure 26), or are specifically targeted for their fins, where the fins are removed and the remainder of the body discarded.

Table 4: Some of the more important large migratory pelagic fish likely to occur in the offshore regions of the West Coast and their Global IUCN Conservation Status.

Common Name	Species	IUCN Conservation Status
Tunas		
Southern Bluefin Tuna	*Thunnus maccoyii*	Endangered
Bigeye Tuna	*Thunnus obesus*	Vulnerable
Longfin Tuna/Albacore	*Thunnus alalunga*	Least concern
Yellowfin Tuna	*Thunnus albacares*	Least concern
Frigate Tuna	*Auxis thazard*	Least concern
Eastern Little Tuna	*Euthynnus affinis*	Least concern
Skipjack Tuna	*Katsuwonus pelamis*	Least concern
Billfish		
Black Marlin	*Istiompax indica*	Data deficient
Blue Marlin	*Makaira nigricans*	Vulnerable
Striped Marlin	*Kajikia audax*	Least Concern
Sailfish	*Istiophorus platypterus*	Vulnerable
Swordfish	*Xiphias gladius*	Near Threatened
Pelagic Sharks		
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Critically Endangered
Dusky Shark	*Carcharhinus obscurus*	Endangered
Great White Shark	*Carcharodon carcharias*	Vulnerable
Shortfin Mako	*Isurus oxyrinchus*	Endangered
Longfin Mako	*Isurus paucus*	Endangered
Whale Shark	*Rhincodon typus*	Endangered
Blue Shark	*Prionace glauca*	Near Threatened

*Until recently Southern Bluefin Tuna was globally assessed as 'Critically Endangered' by the IUCN. Although globally the stock remains at a low state, it is not considered overfished as there have been improvements since previous stock

assessments. Consequently, the list of species changing IUCN Red List Status for 2020-2021 now list Southern Bluefin Tuna is globally 'Endangered'. In South Africa the stock is considered collapsed (Sink *et al.* 2019).

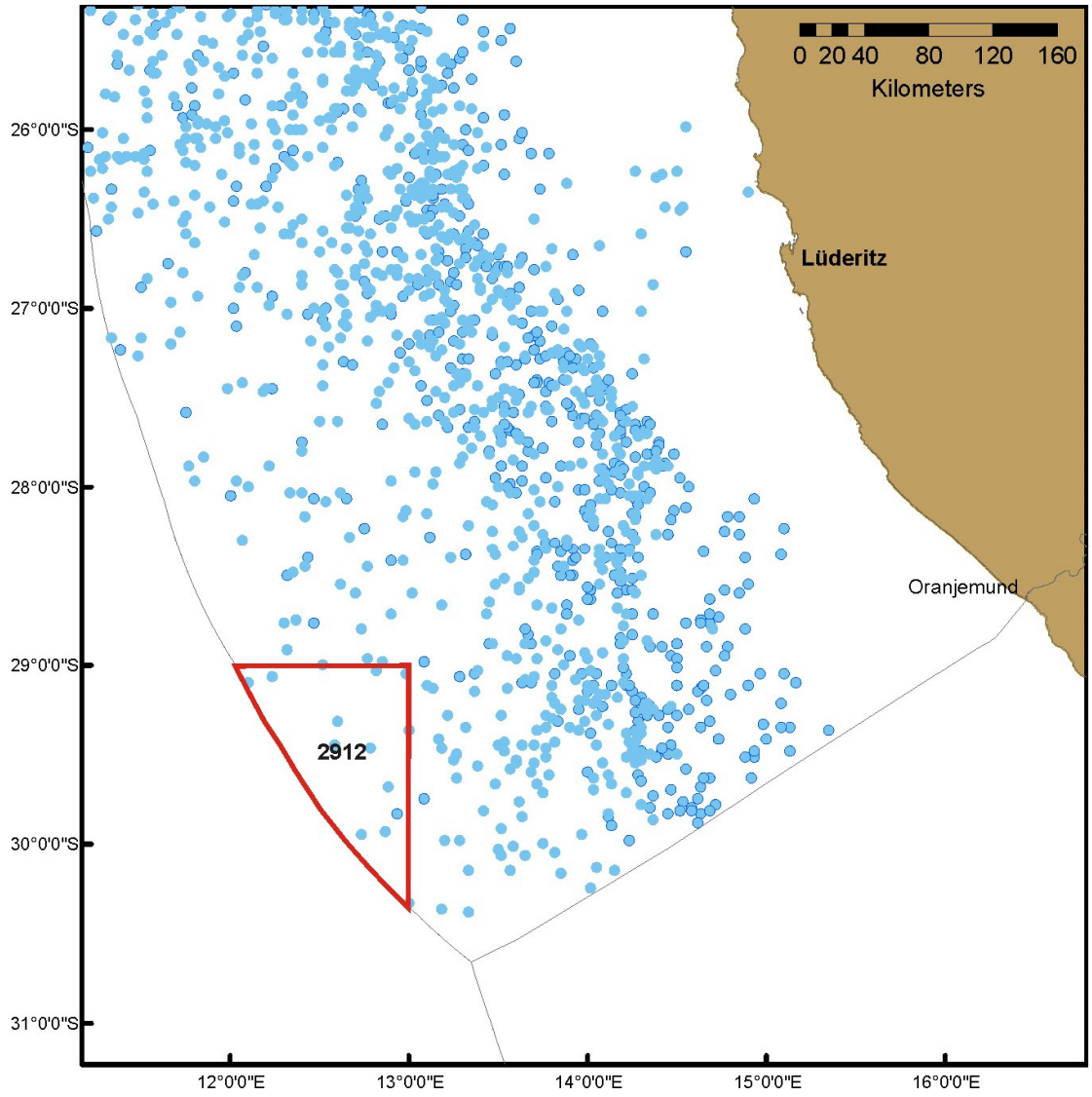


Figure 26: Block 2912 in relation to the catch positions of swordfish, blue sharks and shortfin mako sharks, three migratory large pelagic species occurring in offshore waters (adapted from MFMR 2021).

Species occurring off Namibia include the albacore/longfin tuna *Thunnus alalunga* (Figure 27, right), yellowfin *T. albacares*, bigeye *T. obesus*, and skipjack *Katsuwonus pelamis tunas*, as well as the Atlantic blue marlin *Makaira nigricans* (Figure 27, left), the white marlin *Tetrapturus albidus* and the broadbill swordfish *Xiphias gladius* (Payne & Crawford 1989). Large pelagic species migrate throughout the southern oceans, between surface and deep waters (>300 m) and have a highly seasonal abundance in the Benguela. The distributions of these species are dependent on food availability in the mixed boundary layer between the Benguela and warm central Atlantic waters. Concentrations of large pelagic species are also known to occur associated with underwater feature

such as canyons and seamounts as well as meteorologically induced oceanic fronts (Penney *et al*. 1992).

A number of species of pelagic sharks are also known to occur off the southern African West Coast, including blue *Prionace glauca*, short-fin mako *Isurus oxyrinchus* and oceanic whitetip sharks *Carcharhinus longimanus*. Occurring throughout the world in warm temperate waters, these species are usually found further offshore. The recapture of a juvenile blue shark off Uruguay, which had been tagged off the Cape of Good Hope, supports the hypothesis of a single blue shark stock in the South Atlantic (Hazin 2000; Montealegre-Quijano & Vooren 2010) and Indian Oceans (da Silva *et al*. 2010). Using the Benguela drift in a north-westerly direction, it is likely that juveniles from the parturition off the south-western Cape would migrate through the project area en route to South America (da Silva *et al*. 2010). Of the species that occur off the southern African West Coast the blue shark is listed as 'Near threatened', and the short-fin mako, whitetip, and great white as 'Vulnerable' on the IUCN.

Figure 27: Large migratory pelagic fish such as blue marlin (left) and longfin tuna (right) occur in offshore waters (photos: www.samathatours.com; www.osfimages.com).

3.3.3.4 Turtles

Five of the eight species of turtle worldwide occur off Namibia (Bianchi *et al*. 1999). The Leatherback (*Dermochelys coriacea*) turtle (Figure 28, left) is occasionally encountered in the offshore waters off Namibia. Observations of Green (*Chelonia mydas*), Loggerhead (*Caretta caretta*), Hawksbill (*Eretmochelys imbricata*) and Olive Ridley (*Lepidochelys olivacea*) turtles in the area are rare. Although not reported in the Marine Mammal Observer (MMOs) reports for Block 2913B (Benthic Solutions Ltd 2019b, 2019c), loggerhead turtles have been reported by MMOs during seismic operations in the adjacent PEL 83. The leatherback turtle may also be encountered in the offshore waters of southern Namibia, although abundance in the study area is expected to be low.

The Benguela ecosystem is increasingly being recognized as a potentially important feeding area for leatherback turtles from several globally significant nesting populations in the south Atlantic (Gabon, Brazil) and south-east Indian Ocean (South Africa) (Lambardi *et al*. 2008, Elwen & Leeney 2011). Leatherback turtles from the east South Africa population have been satellite tracked swimming around the west coast of South Africa and remaining in the warmer waters west of the Benguela ecosystem (Lambardi *et al*. 2008).

Leatherback turtles inhabit deeper waters and are considered a pelagic species, travelling the ocean currents in search of their prey. While hunting they may dive to over 600 m and remain submerged for up to 54 minutes (Hays *et al*. 2004). Their abundance in the study area is unknown but expected to be low. Although they tend to avoid nearshore areas, they may be encountered in Walvis Bay and off Swakopmund between October and April when prevailing north wind conditions result in elevated seawater temperatures (Figure 29). Entanglement and drowning of Leatherback turtles in mariculture rafts in Lüderitz Lagoon have been reported (J. Kemper pers. obs.).

Figure 28: Leatherback (left) and loggerhead turtles (right) occur along the coast of Central Namibia (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

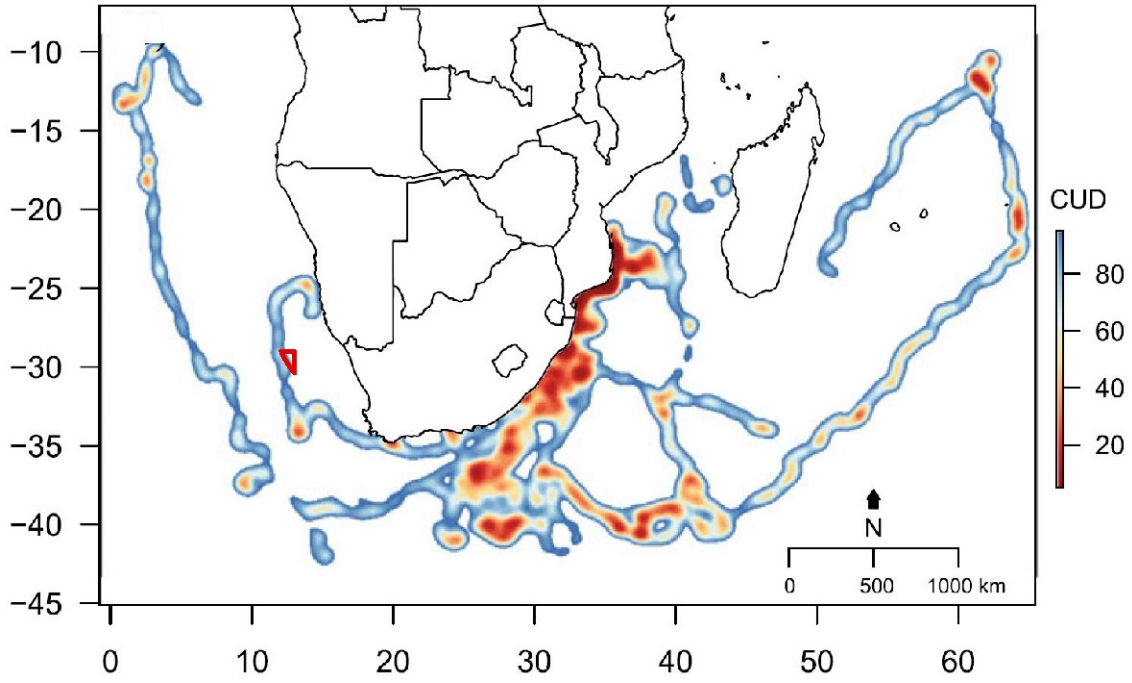


Figure 29: Block 2912 (red polygon) in relation to the migration corridors of leatherback turtles in the south-western Indian Ocean. Relative use (CUD, cumulative utilization distribution) of corridors is shown through intensity of shading: light, low use; dark, high use (adapted from Harris *et al*. 2018).

Leatherback turtles have recently washed up in significant numbers on the central Namibian shore. During the past five years 200 to 300 dead turtles were found (www.nacoma.org.na). Leatherbacks

feed on jellyfish and are known to have mistaken plastic bags, raw plastic pellets, plastic and styrofoam, tar balls and balloons for their natural food. Ingesting this debris can obstruct the gut, lead to absorption of toxins and reduce the absorption of nutrients from their real food. The turtles also get entangled in fishing gear and drown. 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)[3], is provided in Table 5. 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. 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 5: 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)

3.3.3.5 Seabirds

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 total, 12 species of seabirds are known to breed along the southern Namibian coast (Table 6). 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) or in inaccessible places. In general most breed on the islands off the southern Namibian coast, inshore and in excess of 250 km to the east-northeast of Blocks 2912 and 2913B, or on the man-made guano platforms in Walvis Bay, Swakopmund and Cape Cross, well to the north of Block

[3] 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.

2912. The southern Namibian islands and guano platforms therefore provide a vital breeding habitat 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. With the exception of Kelp Gulls and White-breasted Cormorants all the breeding species are listed Red Data species in Namibia.

Table 6: 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 *Thallaseus 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.

Species recorded by MMOs en route to Block 2913B are highlighted (Benthic Solutions, 2019b, 2019c).

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 (Figure 30, left), however, are known to forage up to 140 km offshore (Dundee 2006; Ludynia 2007) (Figure 31), and African Penguins (Figure 30, right) have also been recorded as far as 60 km offshore (Ludynia *et al*. 2012). The closest Cape Gannet colony to the Area of Interest for drilling is at Possession Island some 310 km to the northeast, with the closest African Penguin colony at Sinclair, Plumpudding and Possession Islands, which lie some 288 km, 290 km and 310 km to the northeast, respectively. As the project area is over 280 km offshore at its closest point and south of the southern-most islands (Sinclair and Plumpudding Islands in Baker's Bay), encounters with these species during exploration drilling operations in Block 2912 is highly unlikely.

Among the other species present off Namibia's southern coast there are at least nine species of albatrosses, petrels or giant-petrels recorded (Boyer & Boyer 2015, Benthic Solutions Ltd 2019b, 2019c). However, none of these species breed in Namibia, and the numbers foraging in Namibian waters are poorly known, although some tracking data are available (Figure 32). Forty-nine species of pelagic seabirds have been recorded in the broader project area, of which 14 are resident. Highest pelagic seabird densities occur offshore of the shelf-break in winter. Pelagic seabirds

potentially encountered in Block 2912, and encountered *en route* and within adjacent Block 2913B (Benthic Solutions Ltd, 2019b, 2019c) are provided in

Table 7.

Figure 30: Cape Gannets *Morus capensis* (left) (Photo: J. Kemper) and African Penguins *Spheniscus demersus* (right) (Photo: Klaus Jost) breed primarily on the offshore islands.

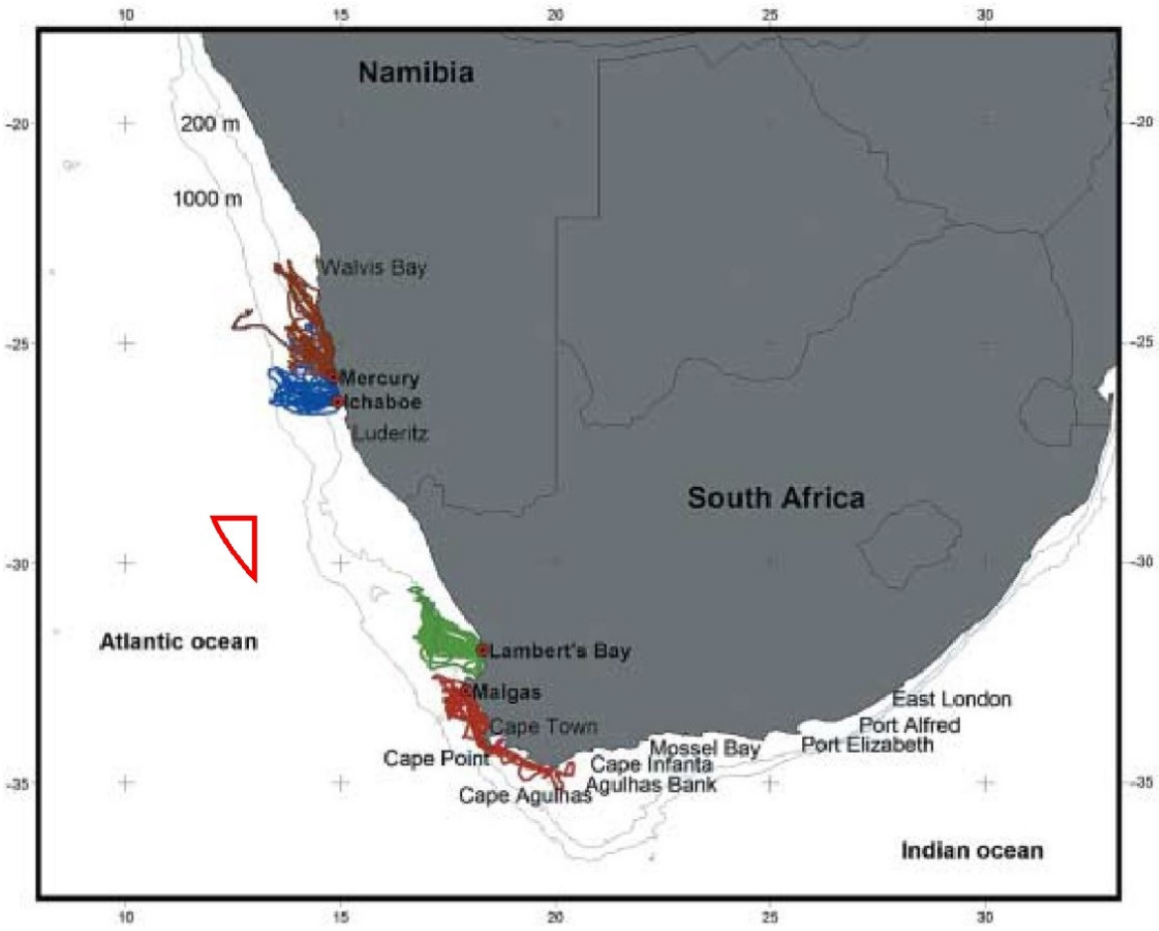


Figure 31: Block 2912 (red polygon) in relation to GPS tracks recorded for 93 Cape Gannets foraging off four breeding colonies in South Africa and Namibia (adapted from Grémillet *et al*. 2008).

Table 7: Other Red-listed bird species that occur in Namibia, with their Namibian and global IUCN Red-listing classification (from Kemper *et al.* 2007; Simmons *et al.* 2015; IUCN 2022).

Species	Namibian	Global IUCN
Tristan Albatross *Diomedea dabbenena*	Critically Endangered	Critically Endangered
Atlantic Yellow-nosed Albatross *Thalassarche chlororhynchos*	Endangered	Endangered
Black-browed Albatross *Thalassarche melanophrys*	Endangered	Least Concern
Wandering Albatross *Diomedea exulans*	Vulnerable	Vulnerable
Shy Albatross *Thalassarche cauta*	Near Threatened	Near Threatened
White-capped Albatross *Thalassarche sneadi*	Near Threatened	Near Threatened
Spectacled Petrel *Procellaria conspicillata*	Vulnerable	Vulnerable
Northern Giant-Petrel *Macronectes halli*	Near Threatened	Least Concern
Southern Giant-Petrel *Macronectes giganteus*	Not listed	Least Concern
Cape (Pintado) Petrel *Daption capense*	Not listed	Least Concern
Kerguelen Petrel *Aphrodroma brevirostris*	Not listed	Least Concern
Great-winged Petrel *Pterodroma macroptera*	Not listed	Least Concern
Soft-plumaged Petrel *Pterodroma mollis*	Not listed	Least Concern
White-chinned Petrel *Procellaria aequinoctialis*	Vulnerable	Vulnerable
Leach's Storm-Petrel *Oceanodroma leucorhoa*	Not listed	Vulnerable
Wilson's Storm-Petrel *Oceanites oceanicus*	Not listed	Least Concern
European Storm-Petrel *Hydrobates pelagicus*	Not listed	Least Concern
Sabine's Gull *Xema sabini*	Not listed	Least Concern
Arctic Tern *Sterna paradisaea*	Not listed	Least Concern
Red Phalarope *Phalaropus fulicarius*	Not listed	Least Concern
Brown (Sub-Antarctic) Skua *Catharacta antarctica*	Not listed	Least Concern
Pomarine Jaeger (Skua) *Stercorarius pomarinus*	Not listed	Least Concern
Antarctic Prion *Pachyptila desolata*	Not listed	Least Concern
Long-Tailed Jaeger (Skua) *Stercorarius longicaudus*	Not listed	Least Concern
Sooty Shearwater *Ardenna grisea*	Near Threatened	Near Threatened
Cory's Shearwater *Calonectris borealis*	Not listed	Least Concern
Scopoli's Shearwater *Calonectris diomedea*	Not listed	Least Concern
Manx Shearwater *Puffinus puffinus*	Not listed	Least Concern
Great Shearwater *Ardenna gravis*	Not listed	Least Concern

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 importance, and the extent and duration of declines locally / globally.
Species recorded by MMOs en route to Block 2913B are highlighted (Benthic Solutions, 2019b, 2019c).

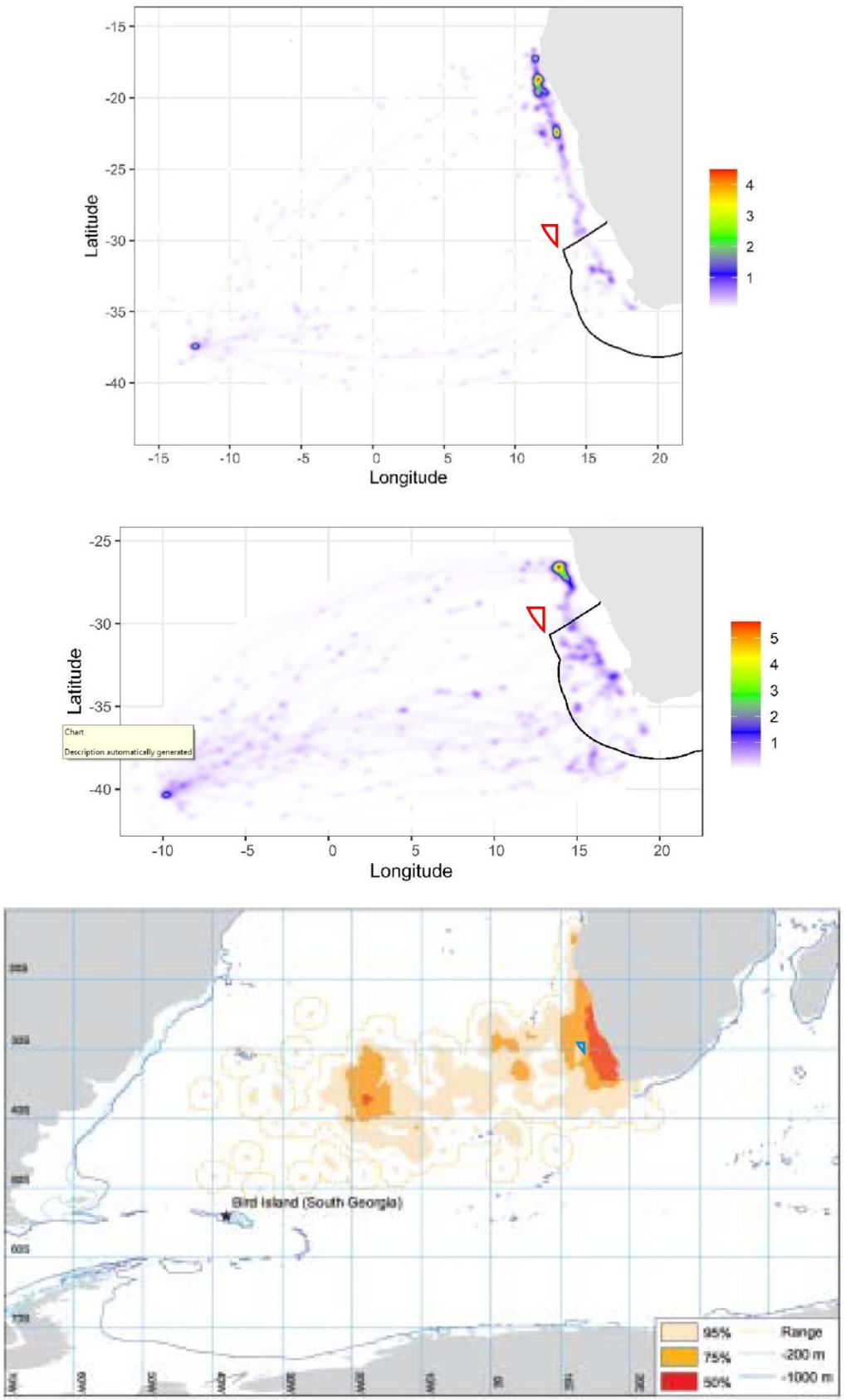


Figure 32: Block 2912 in relation to the utilization distribution of incubating Atlantic Yellow-Nosed Albatrosses from Gough Island (top), and Nightingale Island (bottom) Southern Ocean, and Black-browed Albatross from Bird Island, South Georgia (Adapted from BirdLife Africa 2004, 2022).

3.3.3.6 Marine Mammals

Marine mammals occurring off the central Benguela ecosystem include cetaceans (whales and dolphins) and seals. The cetacean fauna of southern Namibia comprises 33 species of whales and dolphins known (historic sightings or strandings) or likely (habitat projections based on known species parameters) to occur here (Table **8**), and their known seasonality (Table 9). Apart from the resident species such as the endemic Heaviside's dolphin, bottlenose and dusky dolphins, Namibia's waters also host species that migrate between Antarctic feeding grounds and warmer low latitude breeding grounds, as well as species with a circum-global distribution. The Namibian shelf and deeper waters has been poorly studied with most available information in deeper waters (>200 m) arising from historic whaling records, although data from marine mammal observers and passive acoustic monitoring is improving knowledge in recent years. Current information on the distribution, population sizes and trends of most cetacean species occurring in Namibian waters is lacking. Information on smaller cetaceans in deeper waters (>100 m) is particularly poor and the precautionary principal must be used when considering possible encounters with cetaceans in this area.

Although the location of Block 2912 can be considered to be truly within the Benguela Ecosystem, the warmer waters that occur more than ~100 km offshore provide an entirely different habitat, that despite the relatively high latitude may host some species associated with the more tropical and temperate parts of the Atlantic such as rough toothed dolphins, striped dolphins, Pan-tropical spotted dolphins and short finned pilot whales.

The distribution of cetaceans in Namibian waters can largely be split into those associated with the continental shelf and those that occur in deep, oceanic water. Importantly, species from both environments may be found in the shelf edge area (200-1 000 m) making this the most species-rich area for cetaceans. Cetacean density on the continental shelf is usually higher than in pelagic waters as species associated with the pelagic environment tend to be wide ranging across 1 000s of kilometers. The most common species within the broader project area (in terms of likely encounter rate not total population sizes) are likely to be the humpback whale and pilot whale.

Cetaceans comprise two basic taxonomic groups, the mysticetes (filter feeding whales with baleen) and the odontocetes (predatory whales and dolphins with teeth). The term 'whale' is used to describe cetaceans larger than approximately 4 m in length, in both these groups and is taxonomically meaningless (e.g. the killer whale and pilot whale are members of the Odontocetes and the family Delphinidae and are thus dolphins, not whales). Due to large differences in their size, sociality, communication abilities, ranging behaviour and principally, acoustic behaviour, these two groups are considered separately.

Table **8** lists the cetaceans likely to be found within the licence area based on data sourced from: Findlay *et al*. (1992), Best (2007), Weir (2011), Dr J-P Roux, (MFMR pers comm) and unpublished records held by the Namibian Dolphin Project, which includes sightings from fisheries observers and Marine Mammal Observers (MMOs) working on seismic surveys in the area (de Rock *et al*. 2019). The predicted distribution of some of these species on the South African coast was provided in Harris *et al*. (2022) (Figure 33), and although not illustrated extending across the border, their continued distribution ranges into Namibian waters can be inferred. Block 2912 lies well offshore of most of the predicted distribution ranges of these species. From Marine Mammal Observer (MMO) sightings (Figure 34a – 34c) it is evident that many species do occur as far offshore as Block 2912, particularly sei, fin, pilot and humpback whales.

The South African red list of cetacean fauna was updated in 2016 and global reviews are underway. As the Namibian list has not been updated recently the South African red list ratings are used as the most up to date. Of the 33 species listed, one is 'critically endangered', two are 'endangered' and one is considered 'vulnerable'. Altogether 11 species are listed as 'data deficient', underlining how little is known about cetaceans, their distributions and population trends in Namibian waters. A review of the distribution and seasonality of the key cetacean species likely to be found within the broader project area is provided below, based on information provided by the Sea Search - Namibian Dolphin Project (NDP), which has been conducting research in Namibian waters since 2008. The NDP holds the most up-to-date data of cetacean occurrence and distribution since whaling times, with the records including a total database of over 7 000 records with more than 1 000 sightings made by MMOs on seismic or mining vessels and fisheries observers operating in shelf or pelagic waters.

Mysticete (Baleen) whales

The majority of mysticetes whales fall into the family Balaenidae. Those occurring in the study area include the blue, fin, sei, Antarctic minke, dwarf minke, humpback and Bryde's whale (see Table 8 for scientific names). The majority of these species occur in pelagic waters with only the occasional visit to shelf waters. All of these species show some degree of migration either to, or through the latitudes of Block 2912 when *en route* between higher latitude (Antarctic or Sub Antarctic) feeding grounds and lower latitude breeding grounds. Depending on the ultimate location of these feeding and breeding grounds, seasonality in Namibian waters can be either unimodal, usually in winter months, or bimodal (e.g. May-July and October-November) reflecting a northward and southward migration through the area. Northward and southward migrations may take place at different distances from the coast due to whales following geographic or oceanographic features, thereby influencing the seasonality of occurrence at different locations. Due to the complexities of the migration patterns, each species is discussed in further detail below.

There is very little information on **sei whales** in Namibian waters and most information on the species from the southern African sub-region originates from whaling data from 1958-1963. Sei whales spend time at high altitudes (40-50˚S) during summer months and migrate north through South African waters (where they were historically hunted in relatively high numbers) to unknown breeding grounds further north (Best 2007). As whaling catches were confirmed off both Congo and Angola, it is likely that they migrate through Namibian waters. Due to their migration pattern, densities in the project area are likely to show a bimodal peak with numbers predicted to be highest in May and June, and again in August, September, and October. All whales were historically caught in waters deeper than 200 m with most catches from deeper than 1 000 m (Best & Lockyer 2002). There is no current information on the abundance or distribution of this species in the region, but a recent sighting of a mother and calf in March 2012 (NDP unpublished data) and a stranding in Walvis Bay in July 2013 (NDP unpublished data) confirms their contemporary and probably year round occurrence on the Namibian continental shelf and beyond. Encounters in the project area are likely to occur.

Two genetically and morphologically distinct populations of **Bryde's whales** live off the west coast of southern Africa (Best 2001; Penry 2010). The "offshore population" lives beyond the shelf (>200 m depth) off west Africa and migrates between wintering grounds off equatorial west Africa (Gabon) and summering grounds off western South Africa. Its seasonality on the west coast is thus opposite to the majority of the balaenopterids with abundance likely to be highest in the project

Table 8: Cetaceans occurrence off the southern Namibian Coast, their seasonality, likely encounter frequency with proposed exploration activities and South African (Child *et al*. 2016) and Global IUCN Red List conservation status.

Common Name	Species	Hearing Frequency	Shelf (<200 m)	Offshore (>200 m)	Seasonality	RSA Regional Assessment	IUCN Global Assessment
Delphinids							
Dusky dolphin	*Lagenorhynchus obscurus*	HF	Yes (0- 800 m)	No	Year round	Least Concern	Least Concern
Heaviside's dolphin	*Cephalorhynchus heavisidii*	VHF	Yes (0-200 m)	No	Year round	Least Concern	Near Threatened
Common bottlenose dolphin	*Tursiops truncatus*	HF	Yes	Yes	Year round	Least Concern	Least Concern
Common dolphin	*Delphinus delphis*	HF	Yes	Yes	Year round	Least Concern	Least Concern
Southern right whale dolphin	*Lissodelphis peronii*	HF	Yes	Yes	Year round	Least Concern	Least Concern
Striped dolphin	*Stenella coeruleoalba*	HF	No	Yes	Year round	Least Concern	Least Concern
Pantropical spotted dolphin	*Stenella attenuata*	HF	Edge	Yes	Year round	Least Concern	Least Concern
Long-finned pilot whale	*Globicephala melas*	HF	Edge	Yes	Year round	Least Concern	Least Concern
Short-finned pilot whale	*Globicephala macrorhynchus*	HF	Edge	Yes	Year round	Least Concern	Least Concern
Rough-toothed dolphin	*Steno bredanensis*	HF	No	Yes	Year round	Not Assessed	Least Concern
Killer whale	*Orcinus orca*	HF	Occasional	Yes	Year round	Least Concern	Data deficient
False killer whale	*Pseudorca crassidens*	HF	Occasional	Yes	Year round	Least Concern	Near Threatened
Pygmy killer whale	*Feresa attenuata*	HF	No	Yes	Year round	Least Concern	Least Concern
Risso's dolphin	*Grampus griseus*	HF	Yes (edge)	Yes	Year round	Data Deficient	Least Concern
Sperm whales							
Pygmy sperm whale	*Kogia breviceps*	VHF	Edge	Yes	Year round	Data Deficient	Least Concern
Dwarf sperm whale	*Kogia sima*	VHF	Edge	Yes	Year round	Data Deficient	Least Concern
Sperm whale	*Physeter macrocephalus*	HF	Edge	Yes	Year round	Vulnerable	Vulnerable

Common Name	Species	Hearing Frequency	Shelf (<200 m)	Offshore (>200 m)	Seasonality	RSA Regional Assessment	IUCN Global Assessment
Beaked whales							
Cuvier's	*Ziphius cavirostris*	HF	No	Yes	Year round	Data Deficient	Least Concern
Arnoux's	*Berardius arnuxii*	HF	No	Yes	Year round	Data Deficient	Least Concern
Southern bottlenose	*Hyperoodon planifrons*	HF	No	Yes	Year round	Least Concern	Least Concern
Layard's	*Mesoplodon layardii*	HF	No	Yes	Year round	Data Deficient	Least Concern
True's	*Mesoplodon mirus*	HF	No	Yes	Year round	Data Deficient	Least Concern
Gray's	*Mesoplodon grayi*	HF	No	Yes	Year round	Data Deficient	Least Concern
Blainville's	*Mesoplodon densirostris*	HF	No	Yes	Year round	Data Deficient	Least Concern
Baleen whales							
Antarctic Minke	*Balaenoptera bonaerensis*	LF	Yes	Yes	>Winter	Least Concern	Near Threatened
Dwarf minke	*B. acutorostrata*	LF	Yes	Yes	Year round	Least Concern	Least Concern
Fin whale	*B. physalus*	LF	Yes	Yes	MJJ & ON	Endangered	Vulnerable
Blue whale (Antarctic)	*B. musculus intermedia*	LF	No	Yes	Winter peak	Critically Endangered	Critically Endangered
Sei whale	*B. borealis*	LF	Yes	Yes	MJ & ASO	Endangered	Endangered
Bryde's (inshore)	*B. edeni (subspp)*	LF	Yes	Edge	Year round	Vulnerable	Least Concern
Bryde's (offshore)	*B. edeni*	LF	Edge	Yes	Summer (JFM)	Data Deficient	Least Concern
Pygmy right	*Caperea marginata*	LF	Yes	?	Year round	Least Concern	Least Concern
Humpback sp.	*Megaptera novaeangliae*	LF	Yes	Yes	Year round, SONDJF	Least Concern	Least Concern
Humpback B2 population	*Megaptera novaeangliae*	LF	Yes	Yes	Spring/Summer peak ONDJF	Vulnerable	Not Assessed
Southern Right	*Eubalaena australis*	LF	Yes	No	Year round, ONDJFMA	Least Concern	Least Concern

- Marine animals do not hear equally well at all frequencies within their functional hearing range. Based on the hearing range and sensitivities, Southall *et al*. (2019) have categorised noise sensitive marine mammal species into six underwater hearing groups: low-frequency (LF), high-frequency (HF) and very high-frequency (VHF) cetaceans, Sirenians (SI), Phocid carnivores in water (PCW) and other marine carnivores in water (OCW).

Table 9: Seasonality of baleen whales in the broader project area based on data from multiple sources, predominantly commercial catches (Best 2007 and other sources) and data from stranding events (NDP unpubl data). Values of high (H), Medium (M) and Low (L) are relative within each row (species) and not comparable between species. For abundance / likely encounter rate within the broader project area, see Table **8**.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bryde's Inshore	L	L	L	L	L	L	L	L	L	L	L	L
Bryde's Offshore	**H**	**H**	**H**	L	L	L	L	L	L	L	L	L
Sei	L	L	L	L	**H**	**H**	L	**H**	**H**	**H**	L	L
Fin	M	M	M	**H**	**H**	**H**	M	**H**	**H**	**H**	M	M
Blue	L	L	L	L	L	**H**	**H**	**H**	L	M	L	L
Minke	M	M	M	**H**	**H**	**H**	M	**H**	**H**	**H**	M	M
Humpback	M	M	L	L	L	**H**	**H**	M	M	L	M	**H**
Southern Right	**H**	M	L	**L**	L	**H**	**H**	**H**	**M**	**M**	**H**	**H**
Pygmy right	**H**	**H**	**H**	M	L	L	L	L	L	L	M	M

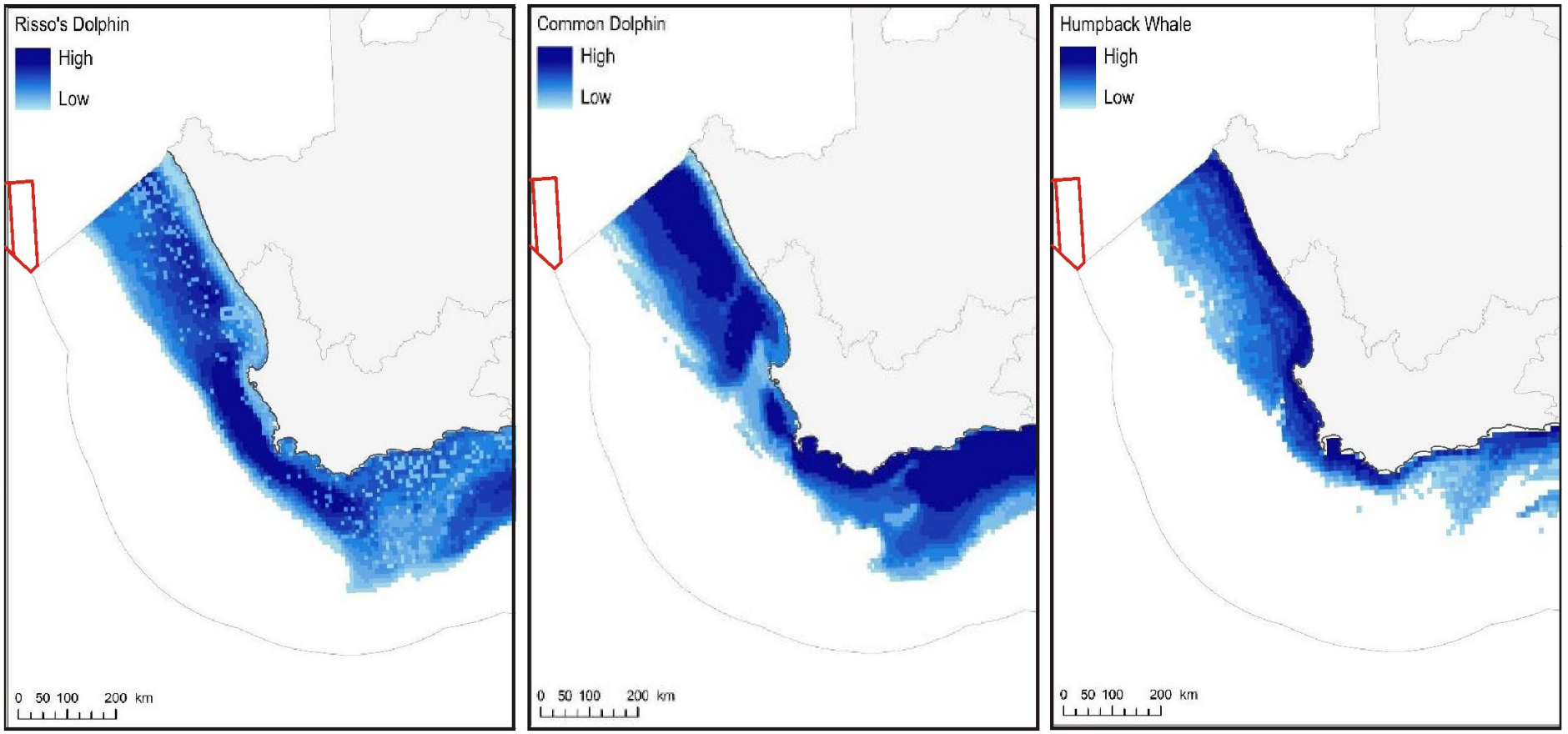


Figure 33: The predicted distribution of Risso's dolphin, common dolphin and humpback whale south of Namibia's border in relation to Block 2912 and 2913B (red polygons) (adapted from Harris *et al*. 2022).

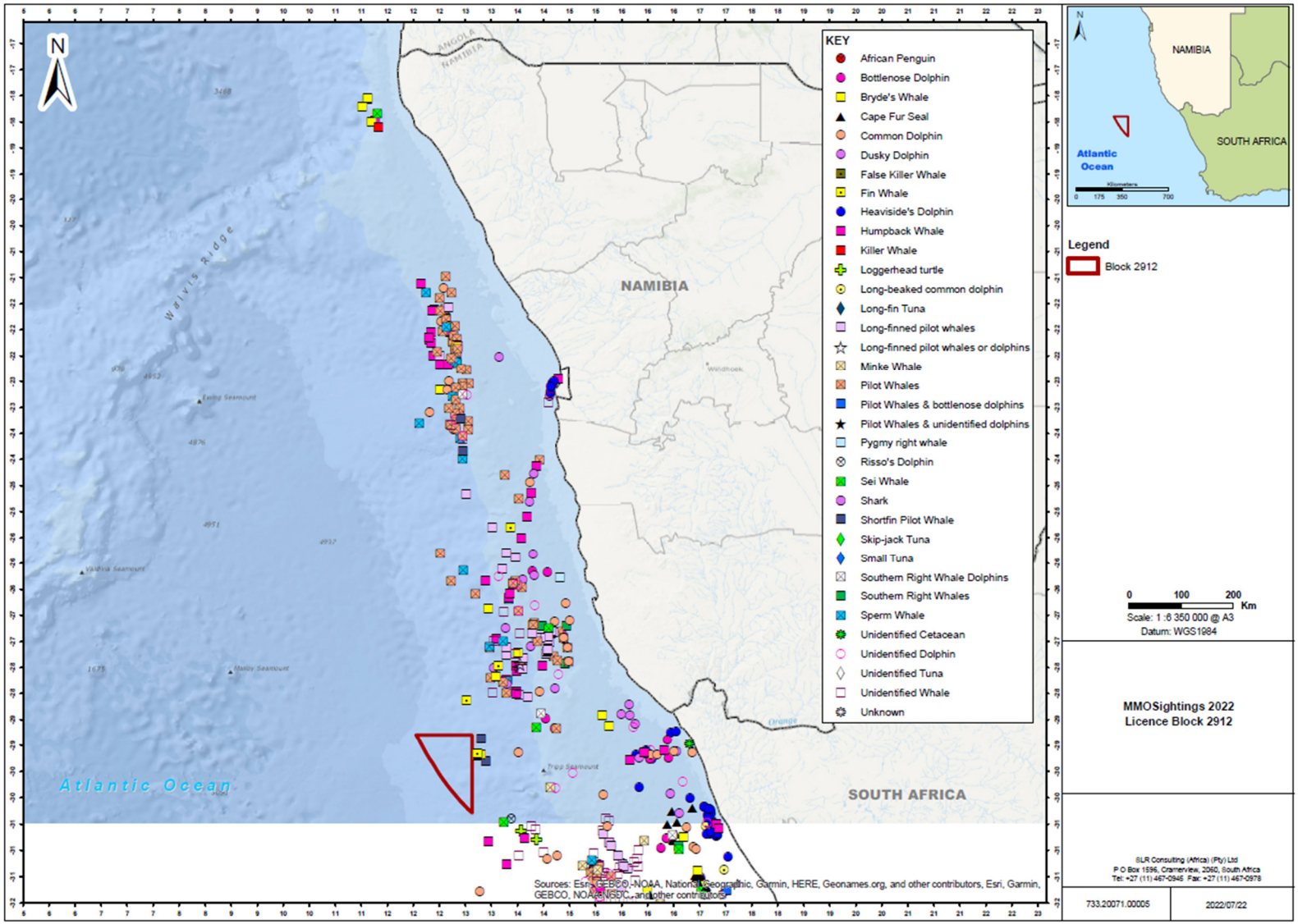


Figure 34a: Block 2912 (red polygon) in relation to the distribution and movement of cetaceans sighted by MMOs within the Namibian EEZ, collated between 2001 and 2022 (SLR MMO database).

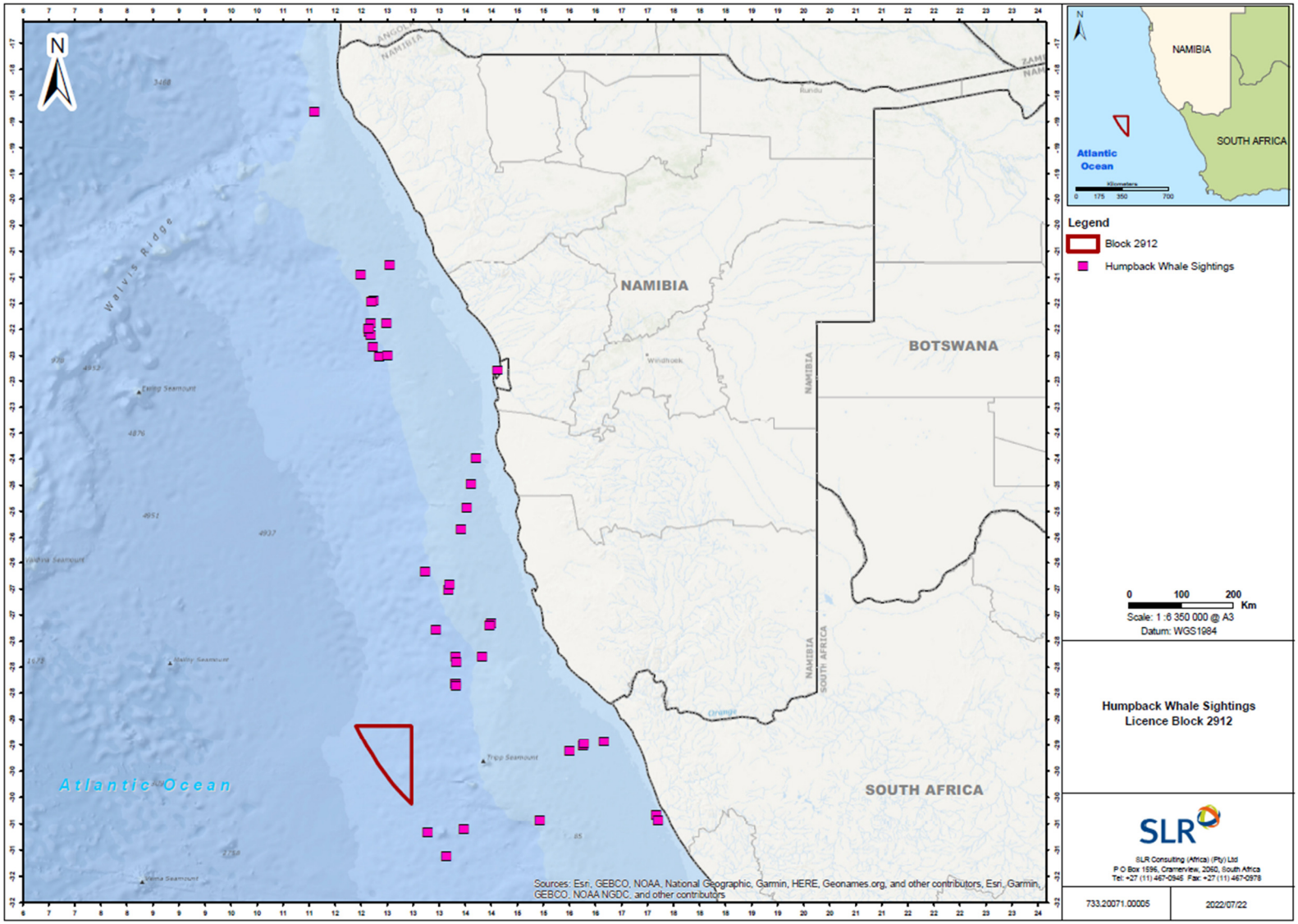


Figure 34b: Block 2912 (red polygon) in relation to the distribution and movement of humpback whales sighted by MMOs within the Namibian EEZ, collated between 2001 and 2022 (SLR MMO database).

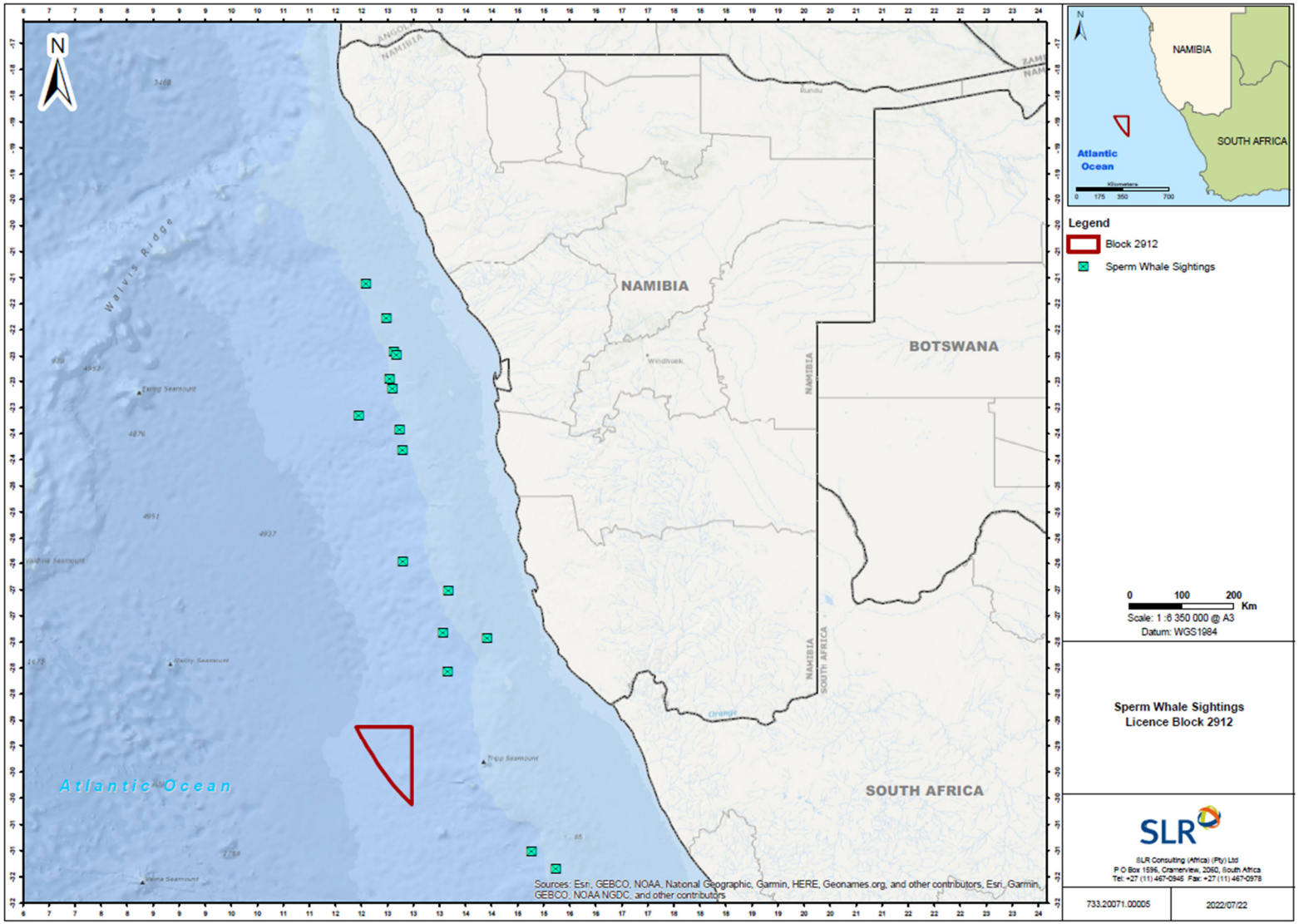


Figure 34c: Block 2912 (red polygon) in relation to the distribution and movement of sperm whales sighted by MMOs within the Namibian EEZ, collated between 2001 and 2022 (SLR MMO database).

area in January - March. Several strandings of adult offshore Bryde's whales have occurred in central Namibia including in January 2012 and November 2017 near Walvis Bay, Namibia. The "inshore population" of Bryde's whales is unique amongst baleen whales in the region by being non-migratory. The published range of the population is the continental shelf and Agulhas Bank of South Africa ranging from Durban in the east to at least St Helena Bay off the west coast with possible movements further north into the winter months (Best 2007). A live stranding of a calf of this population (population assigned genetically – G Penry pers. comm.) in Walvis Bay, Namibia confirms the current occurrence of this population in Namibian waters. An additional live sighting in the Namibian Islands Marine Protected Area (NIMPA) and a third stranding of a Bryde's whale adult in April 2013 have not been assigned to population but supports regular, year-round occurrence of both populations of the species in the central Benguela ecosystem. Three sightings of Bryde's whales were made *en route* to and within Block 2913B in early 2019 (Benthic Solutions Ltd 2019c). Encounters in the project area are thus likely to occur.

Fin whales were historically caught off the west coast of South Africa and Namibia. A bimodal peak in the catch data from South African shore based stations suggests animals were migrating further north to breed (during May-June) before returning to Antarctic feeding grounds (during August-October). However, the location of the breeding ground (if any) and how far north it is remains a mystery (Best 2007). Some juvenile animals may feed year round in deeper waters off the shelf (Best 2007). Four strandings have occurred between Walvis Bay and the Kunene River, Namibia in the last decade during January, April (2) and October (NDP unpubl. data). Groups of 5-8 animals have been seen on multiple occasions on the coast either side of Lüderitz in April, May of 2014 and January 2015 (NDP unpubl. data) confirming their contemporary occurrence in Namibian waters and potential use of the upwelling areas for feeding. To date, most sightings or strandings have occurred in late summer (April-May), supporting evidence from whaling data that this is a peak time of occurrence in southern Namibia. Five sightings of Bryde's whales were made *en route* to and within Block 2913B in late 2018 and early 2019 (Benthic Solutions Ltd 2019b, 2019c). Encounters in the project area are thus likely to occur.

Antarctic **blue whales** were historically caught in high numbers during commercial whaling activities, with a single peak in catch rates during July in Walvis Bay, Namibia and Namibe, Angola suggesting that in the eastern South Atlantic these latitudes are close to the northern migration limit for the species (Best 2007). Evidence of blue whale presence off Namibia is rapidly increasing. Recent acoustic detections of blue whales in the Antarctic peak between December and January (Tomisch *et al*. 2016) and in northern Namibia between May and July (Thomisch 2017) supporting observed timing from whaling records. Several recent (2014-2015) sightings of blue whales have occurred during seismic surveys off the southern part of Namibia in water >1 000 m deep confirming their current existence in the area and occurrence in Autumn months. Encounters in the project area may occur.

Two forms of **minke whale** occur in the southern Hemisphere, the Antarctic minke whale and the dwarf minke whale; both species occur in the Benguela (Best 2007; NDP unpubl. data). Antarctic minke whales range from the pack ice of Antarctica to tropical waters and are usually seen more than ~50 km offshore. Although adults of the species do migrate from the Southern Ocean (summer) to tropical/temperate waters (winter) where they are thought to breed, some animals, especially juveniles, are known to stay in tropical/temperate waters year round. Regular sightings of semi-resident Antarctic minke whales in Lüderitz Bay, especially in summer months (December - March) and a stranding of a single animal in Walvis Bay (in February 2014) confirm the contemporary occurrence of the species in Namibia (NDP unpubl. data). Recent data available from passive acoustic monitoring over a two-year period off the Walvis Ridge shows acoustic presence in June - August and November - December (Thomisch *et al*. 2016), supporting observations from whaling records. The dwarf minke

whale has a more temperate distribution than the Antarctic minke and they do not range further south than 60-65°S. Dwarf minke whales have a similar migration pattern to Antarctic minkes with at least some animals migrating to the Southern Ocean in summer months. Around southern Africa, dwarf minke whales occur closer to shore than Antarctic minkes and have been seen <2 km from shore on several occasions around South Africa. Both species are generally solitary and densities are likely to be low in the licence area, but encounters may occur.

The **pygmy right whale** is the smallest of the baleen whales reaching only 6 m total length as an adult (Best 2007). The species is typically associated with cool temperate waters between 30°S and 55°S and records in Namibia there are the northern most for the species with no confirmed records north of Walvis Bay (Leeney *et al*. 2013).

The most abundant baleen whales in the Benguela are southern right whales and humpback whales (Figure 35). In the last decade, both species have been increasingly observed to remain on the west coast of South Africa well after the 'traditional' South 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 (Barendse *et al*. 2011; Mate *et al*. 2011). Increasing numbers of summer records of both species, suggest that animals may also be feeding in upwelling areas off Namibia, especially the southern half of the country near the Lüderitz upwelling cell (NDP unpubl. data) and will therefore occur in or pass through the project area.

Figure 35: The Southern Right whale *Eubalaena australis* (left) and the humpback whale *Megaptera novaeangliae* (right) migrate along the coastal and shelf waters of southern Africa, including Namibia (Photos: www.NamibianDolphinProject.com).

The southern African population of **southern right whales** historically extended from southern Mozambique (Maputo Bay) to southern Angola (Baie dos Tigres) and is considered to be a single population within this range (Roux *et al*. 2015). The most recent abundance estimate for this population is available for 2017 which estimated the population at ~6 100 individuals including all age and sex classes, and still growing at ~6.5% per annum (Brandaõ *et al*. 2017). When the population numbers crashed, the range contracted down to just the south coast of South Africa, but as the population recovers, it is repopulating its historic grounds including Namibia (Roux *et al*. 2001, 2015; de Rock *et al*. 2019) and Mozambique (Banks *et al*. 2011).

Southern right whales are seen regularly in Namibian coastal waters (<3 km from shore), especially in the southern half of the Namibian coastline (Roux *et al*. 2001, 2011) 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 with only a few out to 100 m depth, so they are unlikely to be encountered in Block 2912.

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). A recent synthesis of available humpback whale data from Namibia (Elwen *et al*. 2014) shows that in coastal waters, the northward migration stream is larger than the southward peak supporting earlier observations from whale catches (Best & Allison 2010). This supports previous suggestions that animals migrating north strike the coast at varying places mostly north of St Helena Bay (South Africa) resulting in increasing whale density on shelf waters as one moves north towards Angola, but no clear migration 'corridor'. On the southward migration, there is evidence from satellite tagged animals and the smaller secondary peak in numbers in Walvis Bay, that many humpback whales follow the Walvis Ridge offshore then head directly to high latitude feeding grounds, while others follow a more coastal route (including the majority of mother-calf pairs), possibly lingering in the feeding grounds off west South Africa in summer (Elwen *et al*. 2013, Rosenbaum *et al*. 2014) (Figure 36). 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, especially in the Lüderitz area, 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). The most recent abundance estimates available put the number of animals in the west African breeding population to be in excess of 9 000 individuals in 2005 (IWC 2012) and it is likely to have increased since this time at about 5% per annum (IWC 2012). Humpback whales are thus likely to be the most frequently encountered baleen whale in Block 2912, 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.

In the first half of 2017 (when numbers are expected to be at their lowest) more than 10 humpback whales were reported stranded along the Namibian and west South African coasts. A similar event was recorded in late 2021-early 2022 when numerous strandings of young humpbacks were reported along the Western Cape Coast and in Namibia (Simon Elwen, Sea Search, pers. comm.). The cause of these deaths is not known, but a similar event off Brazil in 2010 was linked to possible infectious disease or malnutrition (Siciliano *et al*. 2013), which suggests the West African population may be undergoing similar stresses and caution should be taken in increasing stress through human activities. Unusual mortality events of humpback whales between 2016 and 2022 have similarly been reported along the US Atlantic Coast from Maine to Florida (https://www.fisheries.noaa.gov/national/marine-life-distress/2016-2022-humpback-whale-unusual-mortality-event-along-atlantic-coast). The West African population may be undergoing similar stresses in response to changes in their ecosystem (see for example Kershaw *et al*. 2021). It is not yet understood what may be driving these ecosystem changes and what the long-term effects to populations could potentially be.

Figure 36: Block 2912 (red polygon) in relation to 'blue corridors' or 'whale superhighways' showing tracks of Humpback whales (orange) and Southern Right whales (green) between southern Africa and the Southern Ocean feeding grounds (adapted from Johnson *et al*. 2022).

Odontocete (toothed) whales

The Odontoceti are a varied group of animals including the dolphins, porpoises, beaked whales and sperm whales. Species occurring within the broader project area display a diversity of features, for example their ranging patterns vary from extremely coastal and highly site specific to oceanic and wide ranging. Those in the region can range in size from 1.6 m long (Heaviside's dolphin) to 17 m (bull sperm whale).

All information about **sperm whales** in the southern African subregion stems from data collected during commercial whaling activities, *i.e*. pre 1985 (Best 2007). Sperm whales are the largest of the toothed whales and have a complex, structured social system with adult males behaving differently to younger males and female groups. They live in deep ocean waters, usually greater than 1 000 m depth, although they occasionally come into waters 500-200 m deep on the shelf (Best 2007). They are relatively abundant globally (Whitehead 2002), although no estimates are available for the southern African subregion. Seasonality of catches off west South Africa suggests that medium and large sized males are more abundant in winter months, while female groups are more abundant in autumn (March-April), although animals occur year round (Best 2007). Sperm whales were one of the most frequently seen cetacean species from offshore seismic survey vessels operating between Angola and the Gulf of

Guinea. All sightings were made in water deeper than 780 m, and numbers peaked during April – June (Weir 2011). Multiple sightings of sperm whales have been recorded by MMOs operating around Tripp Sea Mount in the last decade (NDP Unpublished data, De Rock *et al*. 2019). Sperm whales feed at great depths during dives in excess of 30 minutes making them difficult to detect visually. The regular echolocation clicks made by the species when diving, however, make them relatively easy to detect acoustically using Passive Acoustic Monitoring (PAM). Sperm whales in the project area are likely to be encountered in deeper waters (>500 m), predominantly in the winter months (April - October). This is confirmed by the sighting / detection of two sperm whales *en route* to Block 2913B in April 2019 (Benthic Solutions 2019c).

There are almost no data available on the abundance, distribution, or seasonality of the smaller odontocetes (including the beaked whales and dolphins) known to occur in oceanic waters (greater than 200 m) off the Namibian continental shelf (see Table **8**). **Beaked whales** are all considered to be true deep-water species, usually recorded in waters in excess of 1 000 – 2 000 m (see various species accounts in Best 2007) and thus may be encountered in the project area.

Beaked whales seem to be particularly susceptible to man-made sounds and several strandings and deaths at sea, often *en masse,* have been recorded in association with naval mid-frequency sonar (Cox *et al*. 2006; MacLeod & D'Amico 2006) and a seismic survey for hydrocarbons also running a multi-beam echo-sounder and sub bottom profiler (Cox *et al*. 2006). Although the exact reason that beaked whales seem particularly vulnerable to man-made noise is not yet fully understood, the existing evidence clearly shows that animals change their dive behaviour in response to acoustic disturbance (Tyack *et al*. 2011), and all possible precautions should be taken to avoid causing any harm. Sightings of beaked whales in the project area are expected to be very low.

The genus *Kogia* currently contains two recognised species, the **dwarf (*K. sima*) and pygmy (*K. breviceps*) sperm whales**, both of which occur worldwide in pelagic and shelf edge waters, with with few sighting records of live animals in their natural habitat (McAlpine 2018). Both species are deep water specialists living primarily off the shelf. There is preliminary evidence of species level genetic differentiation between *K. sima* populations in the Indian and Atlantic Oceans (Chivers *et al*. 2004). Due to their small body size, cryptic behaviour and small school sizes, these whales are difficult to observe at sea, and morphological similarities make field identification to species level problematic, although their narrow-band high frequency echolocation clicks make them detectable and identifiable (at least to the genus) using passive acoustic monitoring equipment. The majority of what is known about Kogiid whales in the southern African subregion results from studies of stranded specimens (e.g. Ross 1979; Findlay *et al*. 1992; Plön 2004; Elwen *et al*. 2013, but see also Moura *et al*. 2016). There are >30 records of *K. breviceps* collected along the Namibian coastline with a peak in strandings in June and August. A single account of *K. sima* collected in Walvis Bay in 2010, demonstrates that this species also occurs in Namibian waters (Elwen *et al*. 2014). *Kogia* species are most frequently occur in pelagic and shelf edge waters, are thus likely to occur in the project area at low levels; seasonality is unknown. Dwarf sperm whales are associated with warmer tropical and warm-temperate waters, being recorded from both the Benguela and Agulhas ecosystem (Best 2007) in waters deeper than ~1 000 m.

Killer whales have a circum-global distribution being found in all oceans from the equator to the ice edge (Best 2007). Killer whales occur year round in low densities off western South Africa (Best *et al*. 2010), Namibia (Elwen & Leeney 2011) and in the Eastern Tropical Atlantic (Weir *et al*. 2010). Killer whales are found in all depths from the coast to deep open ocean environments and may thus be encountered in the licence area at low levels.

False killer whales are recognized as a single species globally, although clear differences in morphological and genetic characteristics between different study sites show that there is substantial difference between populations and a revision of the species taxonomy may be needed (Best 2007). The species has a tropical to temperate distribution and most sightings off southern Africa have occurred in water deeper than 1000 m but with a few close to shore as well (Findlay *et al*. 1992; NDP Unpubl. data). False killer whales usually occur in groups ranging in size from 1-100 animals (mean 20.2) (Best 2007), and are thus likely to be fairly easily seen in most weather conditions. However, the strong bonds and matrilineal social structure of this species makes it vulnerable to mass stranding (8 instances of 4 or more animals stranding together have occurred in the western Cape, South Africa, all between St Helena Bay and Cape Agulhas (Kirkman *et al*. 2010)), which may aggrandize the consequences of any injury or disturbance by seismic airguns or associated activities. There is no information on population numbers of conservation status and no evidence of seasonality in the region (Best 2007).

Long- and short-finned pilot whales (*Globicephala melas and G.macrorhynchus*) display a preference for temperate waters and are usually associated with the continental shelf or deep water adjacent to it (Mate *et al*. 2005; Findlay *et al*. 1992; Weir 2011; Seakamela *et al*. 2022). They are regularly seen associated with the shelf edge by MMOs, fisheries observers and researchers operating in Namibian waters (NDP unpubl. data; De Rock *et al*. 2019). The distinction between long-finned and short finned (*G. macrorhynchus*) pilot whales is difficult to make at sea. Short finned pilot whales are regarded as a more tropical species (Best 2007), and most sightings within the Benguela Ecosystem are thought to be long-finned pilot whales, however, due to the low latitude and offshore nature of the project, it is likely that either could be encountered. This is confirmed by the sighting of two short-finned pilot whales *en route* to Block 2913B in late 2018 (Benthic Solutions Ltd 2019b). There are many confirmed sighting of pilot whales along the shelf edge of South Africa and Namibia including within the survey area since 2010 (de Rock *et al*. 2019; Sea Search unpublished data, SLR data). Observed group sizes range from 8-100 individuals (Seakamela *et al*. 2022). Pilot whales are commonly sighting by MMOs and detected by PAM during a seismic surveys.

Dusky dolphins (*Lagenorhynchus obscurus*) (Figure 37, left) are likely to be the most frequently encountered small cetacean in water less than 500 m deep. The species is very 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, although encounters near-shore are rare along the central Namibian coast (Walvis Bay area), with most records coming from beyond 5 nautical miles from the coast (Elwen *et al*. 2010a; NDP unpubl. data). In a recent survey of the Namibian Islands Marine Protected Area (between latitudes of 24˚29' S and 27˚57' S and depths of 30-200 m) dusky dolphin were the most commonly detected cetacean species with group sizes ranging from 1 to 70 individuals (NDP unpubl. data), although group sizes up to 800 have been reported in southern African waters (Findlay *et al*. 1992). Four sightings of dusky dolphins were made during the two trips to Block 2913B in late 2018 and early 2019 (Benthis Solutions Ltd 2019a, 2019b). However, due to the offshore location of Block 2012, encounters within the project area are unlikely.

Heaviside's dolphins (Figure 37, right) are relatively abundant in both the southern and northern Benguela ecosystem within the region of 10 000 animals estimated to live in the 400 km of coast between Cape Town and Lamberts Bay (Elwen *et al*. 2009a) and several hundred animals living in the areas around Walvis Bay and Lüderitz. Heaviside's dolphins are resident year-round. This species

occupies waters from the coast to at least 200 m depth (Elwen *et al*. 2006; Best 2007), and may show a diurnal onshore-offshore movement pattern feeding offshore at night, although this varies throughout the range (Elwen *et al*. 2009b). This species occupies waters from the coast to at least 200 m depth (Elwen *et al*. 2006; Best 2007; Elwen *et al*. 2010). All sightings made during the two trips to Block 2913B in late 2018 and early 2019 (Benthis Solutions Ltd 2019a, 2019b) occurred closer inshore suggesting they are unlikely to be encountered in the project area.

Figure 37: The dusky dolphin *Lagenorhynchus obscurus* (left) and endemic Heaviside's dolphin *Cephalorhynchus heavisidii* (right) (Photos: www.NamibianDolphinProject.com)).

The **common dolphin** (*Delphinus delphis*) is known to occur offshore in Namibian waters (Findlay *et al*. 1992). Two forms of common dolphins occur around southern Africa, a long-beaked and short-beaked form (Findlay *et al*. 1992; Best 2007), although they are currently considered part of a single global species (Cunha *et al*. 2015). The long-beaked common dolphin lives on the continental shelf of South Africa rarely being observed north of St Helena Bay on the west coast or in waters more 500 m deep (Best 2007), although more recent sightings, including those from MMOs, suggest sightings regularly out to 1 000 m or more (SLR data, Sea Search data). A stranding in Lüderitz (May 2012, NDP unpublished data) and MMO reports have confirmed their occurrence in the region. Although group sizes can be large, averaging 267 (± *SD* 287) for the southern African region (Findlay *et al*. 1992), average sizes of 37 (± *SD* 31) have been reported for the Namibian region (NDP unpublished data). They are more frequently seen in the warmer waters offshore and to the north of the country, and all sightings to date have been in water deeper than 500 m. There is no evidence of seasonality. Although not reported in the MMOs reports for Block 2913B (Benthic Solutions, 2019b, 2019c), common dolphin have been reported by MMOs during seismic operations in the adjacent PEL 83. Thus, encounters in the licence area may occur. Far less is known about the short-beaked form, which is challenging to differentiate at sea from the long-beaked form. Group sizes are also typically large. It is likely that common dolphins encountered deeper than 2 000 m are of the short-beaked form.

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) of 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*. 2011), but its nearshore habitat makes it unlikely to be impacted by the proposed seismic activities. 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.

Offshore bottlenose dolphins frequently form mixed species groups, often with pilot whales or Risso's dolphins.

The cold waters of the Benguela provide a northwards extension of the normally sub Antarctic habitat of **Southern right whale dolphins** (*Lissodelphis peronii*) (Best 2007). Most records in the region originate in a relatively restricted region between 26°S and 30°S roughly between Lüderitz and Tripp Seamount in water 100-2 000 m deep (Rose & Payne 1991; Best 2007; NDP Unpublished data). There has been a recent live stranding of two individuals in Lüderitz Bay in December 2013. They are often seen in mixed species groups with other dolphins such as dusky dolphins. This small area where they are regularly seen overlaps almost entirely with the proposed Licence area. It is possible that the Namibian sightings represent a regionally unique and resident population (Findlay *et al*. 1992) and as such caution is needed to minimize negative effects of hydrocarbon exploration. Any encounters in the project area are likely at low levels.

Several other species of toothed whales that might occur in the deeper waters of licence area at low levels include the pygmy killer whale, Risso's, and Striped dolphins, and Cuvier's and Layard's beaked whales. Nothing is known about the population size or density of these species in the project area but it is likely that encounters would be rare (Findlay *et al*. 1992; Best 2007).

Beaked whales were never targeted commercially and their pelagic distribution makes them largely inaccessible to most researchers making them the most poorly studied group of cetaceans. With recorded dives of well over an hour and in excess of 2 km deep, beaked whales are amongst the most extreme divers of any air breathing animals (Tyack *et al*. 2011), but they also appear to be particularly vulnerable to certain types of anthropogenic noise. Several species of beaked whale (mainly Cuvier's but also Blainville's and Gervais' beaked whales) have been recorded to strand or die at sea, often *en masse,* in response to man-made sounds, particularly mid frequency naval sonar and potentially multi-beam echo-sounders (Cox *et al*. 2006, MacLeod & D'Amico, 2006). Although the exact reason for this vulnerability is not yet fully understood, the existing evidence clearly shows that these animals are susceptible to man-made noise and precautions should be taken to avoid causing any harm. All the beaked whales that may be encountered in the project area are pelagic species that tend to occur in small groups usually less than five, although larger aggregations of some species are known (MacLeod & D'Amico 2006; Best 2007). The long, deep dives of beaked whales make them difficult to detect visually, but PAM will increase the probability of detection as animals frequently echo-locate when on foraging dives.

In summary, there is very little current data on the presence, density or conservation status of any cetaceans within the project area. All information provided above is based on at least some level of projection of information from studies elsewhere in the region, at some time in the past (often decades ago) or extrapolated from knowledge of habitat choice of the species. The large whale species for which there are current data available are the humpback and southern right whale, although with almost all data being limited to the continental shelf. Both these species are known to use feeding grounds around Cape Columbine in South Africa, with numbers there highest between September and February, and not during winter as is common on the South Coast breeding grounds. Whaling data indicates that several other large whale species are also most abundant on the West Coast during this period: fin whales peak in May-July and October-November; sei whale numbers peak in May-June and again in August-October and offshore Bryde's whale numbers are likely to be highest in January-March. Whale numbers on the shelf and in offshore waters are thus likely to be highest between October and February.

Of the migratory cetaceans, the Blue whale is considered 'Critically Endangered', and Sei and Fin whales are listed as 'Endangered' in the IUCN Red Data book. All whales and dolphins are given protection under the Namibian Law. The regulations under the Namibian Marine Resources Act, 2000 (No. 27 of 2000) states that no whales or dolphins may be harassed, killed or fished. Although not legislated in Namibia, no vessel or aircraft should approach closer than 300 m to any whale and a vessel or aircraft should move to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft.

Seals

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 38) 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 43). Vagrant records from four other species of seal more usually associated with the sub Antarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* sub Antarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989).

Figure 38: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: J. Kemper).

The southern colonies (Spencer Bay to Baker's Bay) historically contributed ~62% to the overall seal population in Namibia. With the distributional shift of the seal population northwards in response to environmental change and altered prey distributions, the southern colonies currently comprise just less than a third of the total Namibian seal population (J-P Roux pers comm.). Population estimates fluctuate widely between years in terms of pup production, particularly since the mid-1990s (MFMR unpubl. Data; Kirkman *et al*. 2007). The colonies closest to Block 2912 are at van Reenen Bay and Baker's Bay approximately 290 km inshore and to the northeast of the northeastern corner of the Block, in the Tsau//Khaeb (Sperrgebiet) National Park. These southern Namibian colonies have important conservation value since they are largely undisturbed at present, as public access to the southern Namibian coast is restricted. Further colonies occur at Kleinzee (incorporating Robeiland), at Bucchu Twins near Alexander Bay, and Strandfontein Point (south of Hondeklipbaai) in South Africa. The colony at Kleinzee has the highest seal population and produces the highest seal pup numbers on the South African coast (Wickens 1994). The colony at Buchu Twins, formerly a non-breeding colony, has also attained breeding status (M. Meÿer, SFRI, pers. comm.). These colonies are all located over 300 km east of Block 2912.

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).

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 39) and Harris *et al*. (2022), respectively (Figure 40). Block 2912 lies well offshore of the foraging ranges from these colonies. Seals were, however, regularly sighted by MMOs during seismic surveying in PEL 83, inshore and adjacent to Block 2912, but no seals were reported from Block 2913B (Benthic Solutions Ltd 2019b, 2019c), although they were encountered *en route*. 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.).

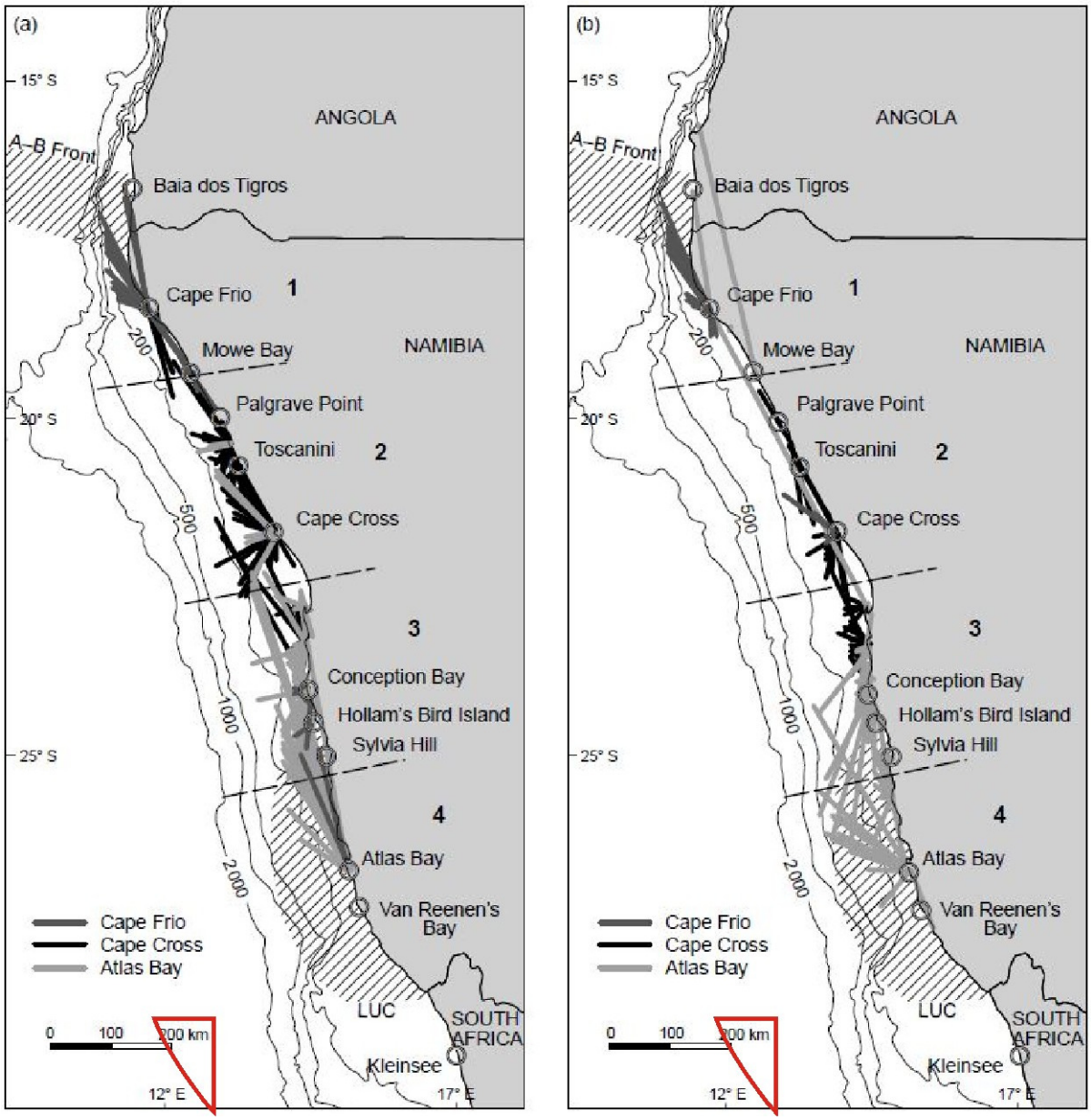


Figure 39: Blocks 2912 (red polygon) in relation to foraging trips of (a) females and (b) males of Cape fur seals at the Cape Frio, Cape Cross and Atlas Bay colonies. Trips are depicted as straight lines between the start location and the location where the seals spent most time during a trip (adapted from Skern-Mauritzen *et al*. 2009).

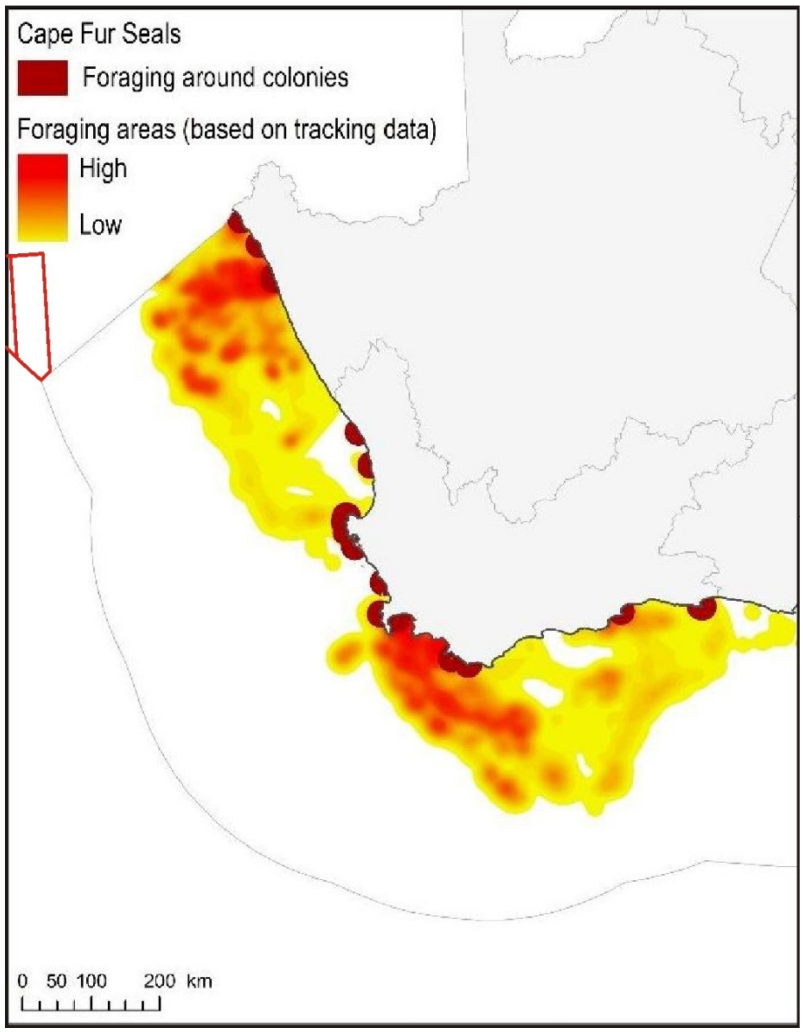


Figure 40: Blocks 2912 and 2913B (red polygon) in relation to seal foraging areas on the South African West Coast. Brown areas are generalised foraging areas around colonies, and areas in shades of red are foraging areas based on tracking data. Darker shades of red indicate areas of higher use (Adapted from Harris *et al*. 2022).

3.4 Other Uses of the Licence Area

3.4.1 Beneficial Uses

The licence area is located well offshore at depths beyond 3 000 m. Other users of the offshore areas include the commercial pelagic long-line fishery (see Specialist Report on Fisheries), and oil and gas licence holders. In Namibia various restrictions apply to areas permittable 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 41). The coastal area south of Lüderitz falls within the diamond mining area (Sperrgebiet) and as public access is restricted, recreational activities along the coastline are limited to mining-based tourism by concessionaires operating between Lüderitz and Bogenfels.

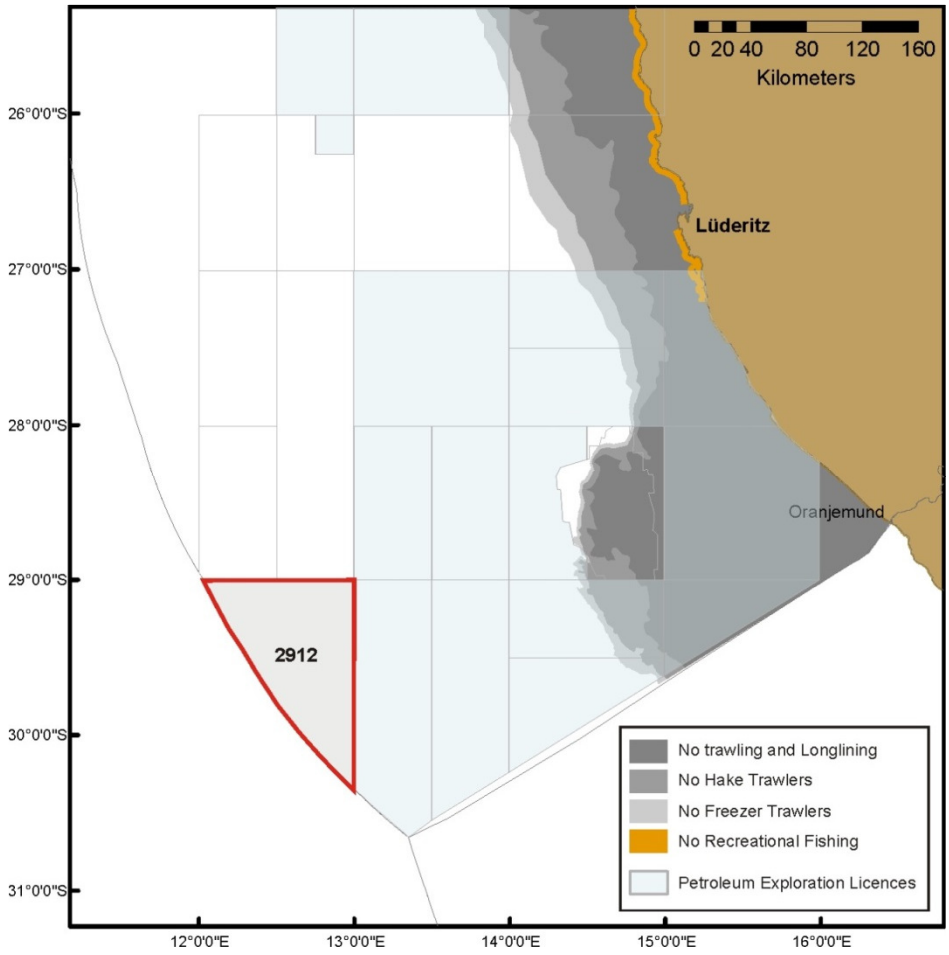


Figure 41: Block 2912 in relation to restricted areas for trawling, long lining or recreational fishing along the southern Namibian coastline and Petroleum Exploration Licence Blocks (adapted from MFMR 2021).

Block 2912 lies well offshore of the Exclusive Prospecting Licences (EPLs) and Mining Licences (MLs) for minerals (Figure 42). Current activities in the EPLs is minimal to non-existent, the only active operations being diamond mining in ML-47 (Atlantic 1) held by De Beers Marine Namibia off Oranjemund. Deep-water diamond mining operations in the Atlantic 1 Mining Licence Area are typically conducted to depths of 150 m from fully self-contained mining vessels with on board processing facilities, using either large-diameter drill or seabed crawler technology. These vessels operate as semi-mobile mining platforms, anchored by a dynamic positioning system, commonly on a three to four anchor spread. Computer-controlled positioning winches enable the vessels to locate themselves precisely over a mining block of up to 400 m x 400 m. These mining vessels thus have limited manoeuvrability and other vessels should remain at a safe distance.

Other current and proposed industrial uses of the marine environment include the intake of cooling water for power plants, intake of feed-water for desalination plants, and seawater intakes for fish processing, or mariculture operations. These, however, are all located around Lüderitz and Walvis Bay, well to the north and inshore of Block 2912 and should in no way be affected by the drilling of exploration wells beyond the 3 000 m depth contour.

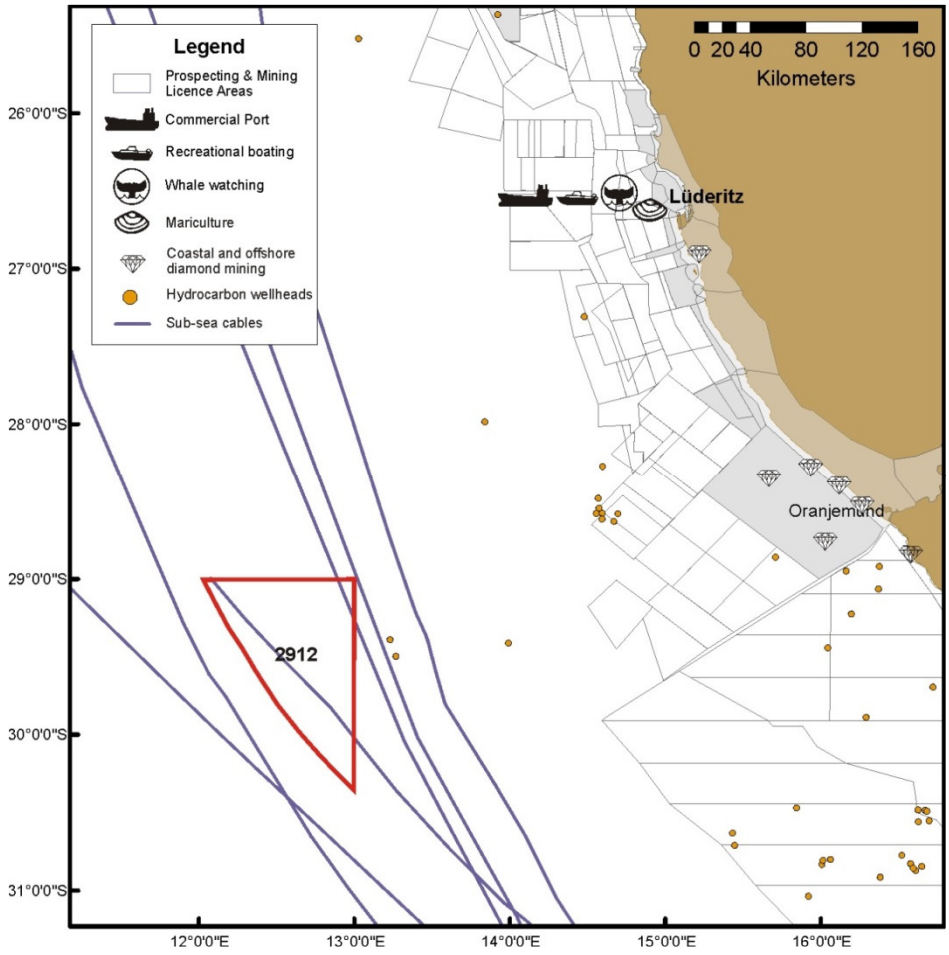


Figure 42: Block 2912 in relation to project - environment interaction points on the Namibian coast, illustrating the active marine diamond mining concessions (shaded) and Exclusive Prospecting Licences, hydrocarbon wellheads, telecommunications cables and other users of the marine environment.

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. The cold, nutrient-rich waters around Lüderitz are ideal for mariculture operations, and NamPort have allocated 20 plots covering a total area 280.6 ha to mariculture. The plots are primarily located in the area between Lüderitz Harbour and Second Lagoon. 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 2007). Mariculture methods vary but include rafts, suspended long-lines, racks in the lagoon, onshore flow-through tanks and abalone ranching. These various mariculture activities should likewise not be affected in any way by the drilling of exploration wells beyond the 3 000 m depth contour.

3.4.2 Sanctuaries, Marine Protected Areas and other Sensitive Areas

Numerous conservation areas and a coastal marine protected area (MPA) exist along the southern Namibian coastline, although none overlap with Block 2912.

Sanctuaries

Sanctuaries are considered a type of management area within Namibia's multi-purpose National Park and MPA network in which access and/or resource use is prohibited.

The **Lüderitz Bay and Ichaboe Island Rock-Lobster Sanctuaries** were proclaimed by South Africa in 1939 and 1951, respectively (Matthews & Smit 1979), and subsequently maintained as reserves by MFMR after Namibian independence. There is no restriction on other activities within these reserves.

National Parks

Inshore of Block 2912, the coastline of Namibia is part of a continuum of protected areas that stretch along the entire Namibian coastline, a distance of about 1 570 km, from Southern Angola into Namaqualand in South Africa. From north to south these comprise the Skeleton Coast National Park, the Dorob National Park, the Namib-Naukluft National Park and the Tsau//Khaeb (Sperrgebiet) National Park (Figure 43). In the south across the Orange River it borders on the Richtersveld in South Africa, which comprises a protected area of about 1 600 km^2 within a multiple-use buffer zone of about 3 984 km^2. This whole area forms the Ai-Ais/Richtersveld Transfrontier Conservation Area under a formal co-operative agreement between the governments of Namibia and South Africa.

The southern components of the Namib-Skeleton Coast National Park are described briefly below:

The Sperrgebiet was proclaimed in 1908 to prevent public access to the rich surface diamond deposits occurring in the area, and has largely remained closed off to general public access since then. It extends between latitude 26° in the north and the Orange River in the south, extending inland from the coast for 100 km, covering an area of approximately 22 000 km^2. As diamond mining has remained confined to the narrow coastal strip and along the banks of the Orange River and around Elizabeth Bay, most the area has effectively been preserved as a pristine wilderness. Large parts of the Sperrgebiet have since been de-proclaimed from exclusive prospecting and mining licences, and reverted to unproclaimed State land. Consequently, the **Tsau//Khaeb (Sperrgebiet) National Park** was proclaimed in 2008. The park has been zoned in accordance with IUCN guidelines for Protected Area Management Categories. Management plans for the park for the period 2020/21 to 2029/30 were published in late 2021.

Marine Protected Areas

The first (and to date only) Namibian MPA was launched on 2 July 2009 under the Namibian Marine Resources Act (No. 29 of 1992 and 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 Hollamsbird 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 **Namibian Islands' Marine Protected Area** (NIMPA) spans an area of 9 555 km^2, and includes 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).

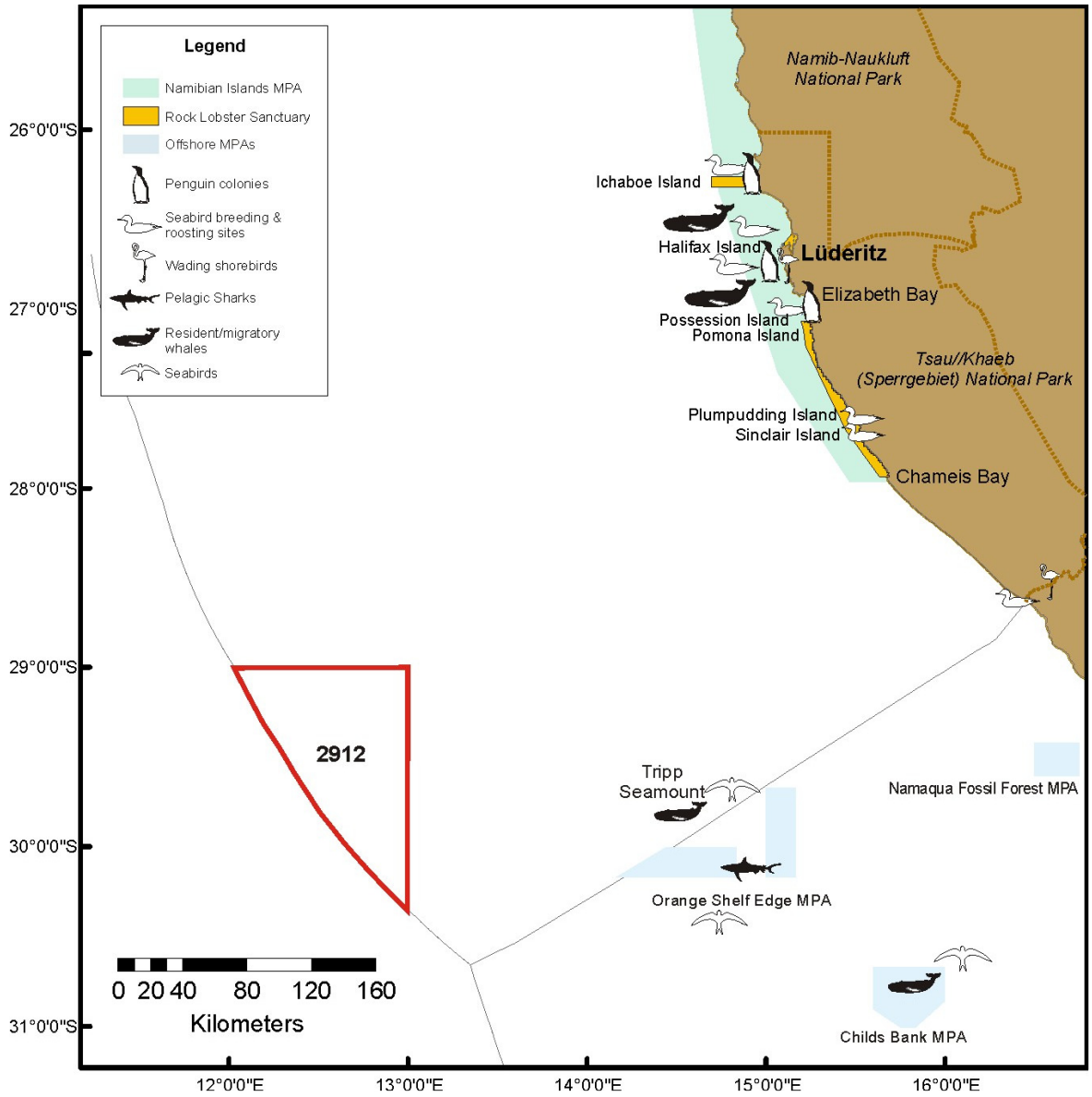


Figure 43: Block 2912 (red polygon) in relation to project - environment interaction points on the Namibian coast, illustrating sanctuaries, conservation areas and marine protected areas (MPAs).

Sensitive Areas

Despite the current lack of knowledge of the community structure and endemicity of southern African macro-infauna off the edge of the continental shelf, the spatial marine biodiversity assessment (Holness *et al*. 2014), rated the Namib bathyal and abyssal unconsolidated habitat types that characterise depths beyond 500 m, as being of 'Least concern' (Figure 18), reflecting the great extent of these habitats in the Namibian Exclusive Economic Zone (EEZ). However, those ecosystem types occurring along the shelf edge (-350 to -500 m) in the Namaqua biozone are considered 'Endangered', with those in the Lüderitz biozone rated as 'Critically Endangered'. In the Namaqua biozone the habitats betweem -30 m and -350 m have been rated as 'Least Concern' with only the shallow habitats <30 m rated as 'Vulnerable'. In contrast, those between -150 m and -350 m in the Lüderitz biozone are considered

'Vulnerable and those at <150 m as 'Least concern'. The Area of Interest for drilling is located beyond -3 000 m depth in habitat considered as 'Least Concern'.

Despite the development of the offshore EBSAs a number of 'Vulnerable' ecosystem types in the broader project area are currently considered 'not well protected' or 'poorly protected' and further effort is needed to improve protection of these threatened ecosystem types (Holness *et al*. 2014) (Figure 44). Ideally, all highly threatened ('Critically Endangered' and 'Endangered') ecosystem types should be well protected. Currently, however, most of the upper and lower slope and abyss of the Namib biozone receives no protection at all, with the 'Endangered' and 'Critically Endangered' Namaqua Shelf Edge and Lüderitz Shelf edge being 'poorly protected' and 'moderately protected', respectively. Block 2912 lies within an area receiving no protection.

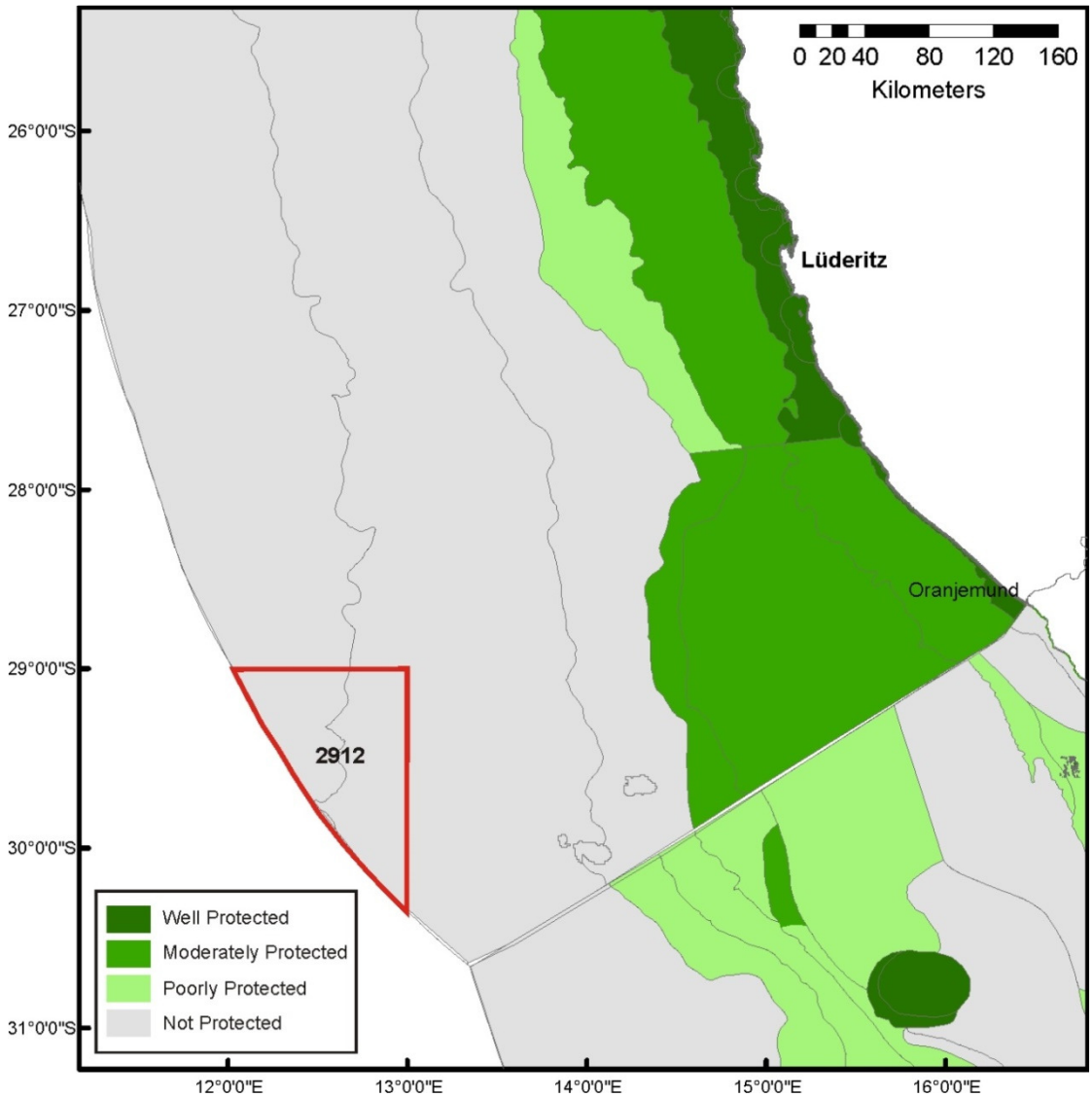


Figure 44: Block 2912 (red polygon) in relation to the protection levels of benthic habitat types as assessed by Holness *et al*. (2014). The threat status of adjacent South African substratum types (Sink *et al*. 2019) are also shown.

Ecologically or Biologically Significant Areas

In the spatial marine biodiversity assessment undertaken for Namibia (Holness *et al*. 2014), a number of offshore and coastal areas were identified as being of high priority for place-based conservation measures. To this end, Ecologically or Biologically Significant Areas (EBSA) spanning the coastline between Angola and South Africa were proposed and successfully submitted for international recognition to the Convention of Biological Diversity (CBD) in March 2020. The principal objective of the EBSAs is identification of features of higher ecological value that may require enhanced conservation and management measures. 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.

No specific management actions have been formulated for the EBSAs at this stage and they carry no legal status. 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. The following summaries are adapted from the MARISMA EBSA Workstream (2020).

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 northeastern coast of South Africa.

The **Orange Seamount and Canyon Complex** occur at the western continental margin of southern Africa, spanning the border between South Africa and Namibia. On the Namibian side, it includes Tripp Seamount and a shelf-indenting canyon. The EBSA comprises shelf and shelf-edge habitat with hard and unconsolidated substrates, including at least eleven offshore benthic habitat types of which four habitat types are 'Threatened', one is 'Critically Endangered' and one 'Endangered'. The Orange Shelf Edge EBSA is one of few places where these threatened habitat types are in relatively natural/pristine condition. The local habitat heterogeneity is also thought to contribute to the Orange Shelf Edge being a persistent hotspot of species richness for demersal fish species. Although focussed primarily on the conservation of benthic biodiversity and threatened benthic habitats, the EBSA also considers the pelagic habitat, which is characterized by medium productivity, cold to moderate Atlantic temperatures (SST mean = 18.3°C) and moderate chlorophyll levels related to the eastern limit of the Benguela upwelling on the outer shelf.

The **Orange Cone** is a transboundary EBSA that spans the mouth of the Orange River. The estuary is biodiversity-rich but modified, and the coastal area includes many Critically Endangered, Endangered, and Vulnerable habitat types (with the area being particularly important for the Critically Endangered Namaqua Sandy Inshore, Namaqua Inshore Reef and Hard Grounds and Namaqua Intermediate and Reflective Sandy Beach habitat types). The marine environment experiences slow, but variable currents and weaker winds, making it potentially favourable for reproduction of pelagic species. An ecological dependence for of river outflow for fish recruitment on the inshore Orange Cone is also likely. The Orange River Mouth is a transboundary Ramsar site and falls within the Tsau//Khaeb

(Sperrgebiet) National Park. It is also under consideration as a protected area by South Africa, and is an Important Bird and Biodiversity Area. This area is thus highly relevant in terms of: 'Uniqueness or rarity', 'Importance for threatened, endangered or declining species and/or habitats' and 'Special importance for life history stages of species'.

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 **Namaqua Fossil Forest** EBSA, which lies inshore of the Deep Western Orange Basin block, is a small seabed outcrop composed of fossilized yellowwood trees at 136-140 m depth, approximately 30 km offshore on the west coast of South Africa. A portion of the EBSA comprised the Namaqua Fossil Forest MPA. The fossilized tree trunks form outcrops of laterally extensive slabs of rock have been colonized by fragile, habitat-forming scleractinian corals and a newly described habitat-forming sponge species. The EBSA thus encompasses a unique feature with substantial structural complexity that is highly vulnerable to benthic impacts.

The **Childs Bank and Shelf Edge** EBSA, which lies to the east of the Deep Western Orange Basin block, is a unique submarine bank feature rising from 400 m to -180 m on the western continental margin on South Africa. This area includes five benthic habitat types, including the bank itself, the outer shelf and the shelf edge, supporting hard and unconsolidated habitat types. Childs Bank and associated habitats are known to support structurally complex cold-water corals, hydrocorals, gorgonians and glass sponges; species that are particularly fragile, sensitive and vulnerable to disturbance, and recover slowly.

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 45)(https://cmr.mandela.ac.za/EBSA-Portal/Namibia/Namibian-EBSA-Status-Assessment-Management). Although the proposed zonation of the EBSAs is still under discussion, 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*". In the list of sea-use activities provided for this EBSA, the marine spatial planning zone for petroleum activities recommends that non-destructive exploration (e.g. seismic acquisition) and localised destructive exploration (e.g. exploration drilling) is conditionally permissible within the biodiversity conservation zone (or Critical Biodiversity Area, CBA). Conditional activities are defined as activities that "*are recommended to be managed as Consent activities, which are those that can continue in the zone subject to specific regulations and controls, e.g. to avoid unacceptable impacts on biodiversity features, or to avoid intensification or expansion of impact footprints of uses that are already occurring and where there are no realistic prospects of excluding these activities*" (MARISMA Project 2019). The Orange Seamount and Canyon Complex transboundary EBSA lies 46 km east of the eastern boundary of Block 2912.

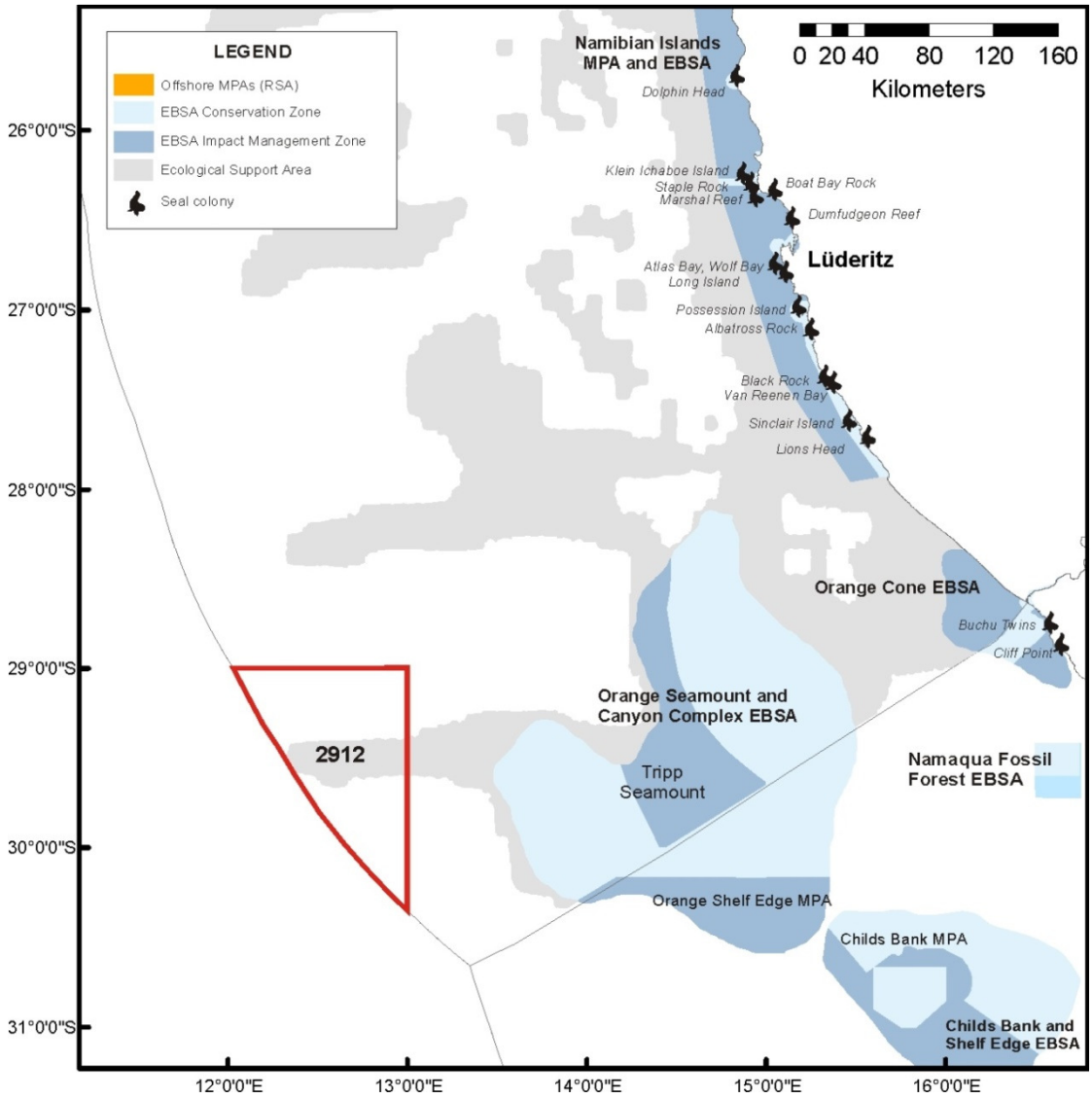


Figure 45: Block 2912 (red polygon) in relation to Ecologically and Biologically Significant Areas (EBSAs) and the marine spatial planning zones within these. Ecological support areas (ESAs) mapped by MFMR (2021) and the location of seal colonies are also shown.

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 45).

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.

RAMSAR Sites and Important Bird Areas (IBAs)

Namibia's southern-most designated coastal Ramsar site falls within the broader project area and is described briefly below. The **Orange River Mouth** is an important staging area for Palaearctic migrants, the next nearest coastal wetland being the Olifants River mouth, some 400 km to the south in South Africa, and Sandwich Harbour, 500 km to the north. The exact boundaries of the Ramsar site are somewhat unclear, however, the South African section of the wetland covers approximately 20 km^2 while the remaining 5 km^2 falls within Namibia. On the South African side the Orange River Mouth received its Ramsar status on 28 June 1991. The Namibian side was declared a Ramsar wetland on 23 August 1995. Processes are underway to declare a jointly-managed transboundary Ramsar reserve. The Orange River Mouth can be described as a delta type river mouth, comprising a distributor channel system between sand banks covered with pioneer vegetation, a tidal basin, the river mouth and the saltmarsh on the south bank of the river mouth. It is regarded as one of the most important coastal wetlands in southern Africa in terms of the number of birds supported, at times supporting more than 20 000 waterbirds of between 50 and 57 species. It is consequentially also recognized as an Important Bird Area (SA030).

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).

Sandwich Harbour, a natural tidal lagoon, is located approximately 50 km south of Walvis Bay in the Namib-Naukluft National Park. The area hosts upwards of 70 000 birds, mostly seasonal migrants from the northern hemisphere (Kolberg 2015). It was proclaimed a Ramsar site in December 1995.

These coastal Ramsar sites all lie more than 300 km to the east and north of Block 2912.

Table 10: List of coastal RAMSAR sites in the area of influence of Block 2912.

Name	Size (ha)	Description
Walvis Bay Wetlands	10 550	Ramsar site no. 742. A tidal lagoon consisting of adjacent intertidal areas, Pelican Point, mudflats exposed at low tide, and sandbars serving as roosting sites. The site supports varying numbers of wetland birds (37,000 to 79,000 individuals); some species such as flamingos occur in impressive numbers. Eleven endangered bird species are regularly observed. Human activities consist of recreation and salt production. Residential development exists along the lagoon, and natural siltation may eventually lead to the infilling.
Sandwich Harbour	13 825	Ramsar site no. 743. Two distinct wetlands and associated mudflats. One is aquifer-fed and supports typical emergent vegetation, but is slowly disappearing due to natural causes. The second, under tidal influence, consists of mudflats and raised shingle bars. One of Namibia's most important coastal wetlands, supporting eight endangered species among the large numbers of wading birds. Several archaeological sites dating back 1 000 years exist within the site. The site is used for scientific research, with surrounding areas used for tourism, recreation, and angling.
Orange River Mouth	2 000	Ramsar site no. 526. Transboundary area of extensive saltmarshes, freshwater lagoons and marshes, sand banks, and reedbeds shared by South Africa and Namibia. Important for resident birds and for staging locally migrant waterbirds. Following the collapse of the saltmarsh component of the estuary, the site was placed on the Montreux Record in 1995.

Of the 19 Important Bird Areas (IBAs) designated by BirdLife International in Namibia, those located along the southern Namibian coastline are listed in Table 11. Block 2912 lies well offshore of these coastal IBAs.

Various marine IBAs have also been proposed in Namibian territorial waters, with a candidate trans-boundary marine IBA suggested off the Orange River mouth (Figure 46). The Atlantic Southeast 21 IBA specifically targets the protection of Atlantic Yellow-nosed Albatross, Black-browed Albatross and White-chinned Petrels. Blocks 2912 and 2913B lie offshore of these proposed marine IBAs.

Table 11: List of Important Bird Areas (IBAs) and their criteria listings.

Site Name	IBA Criteria
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.

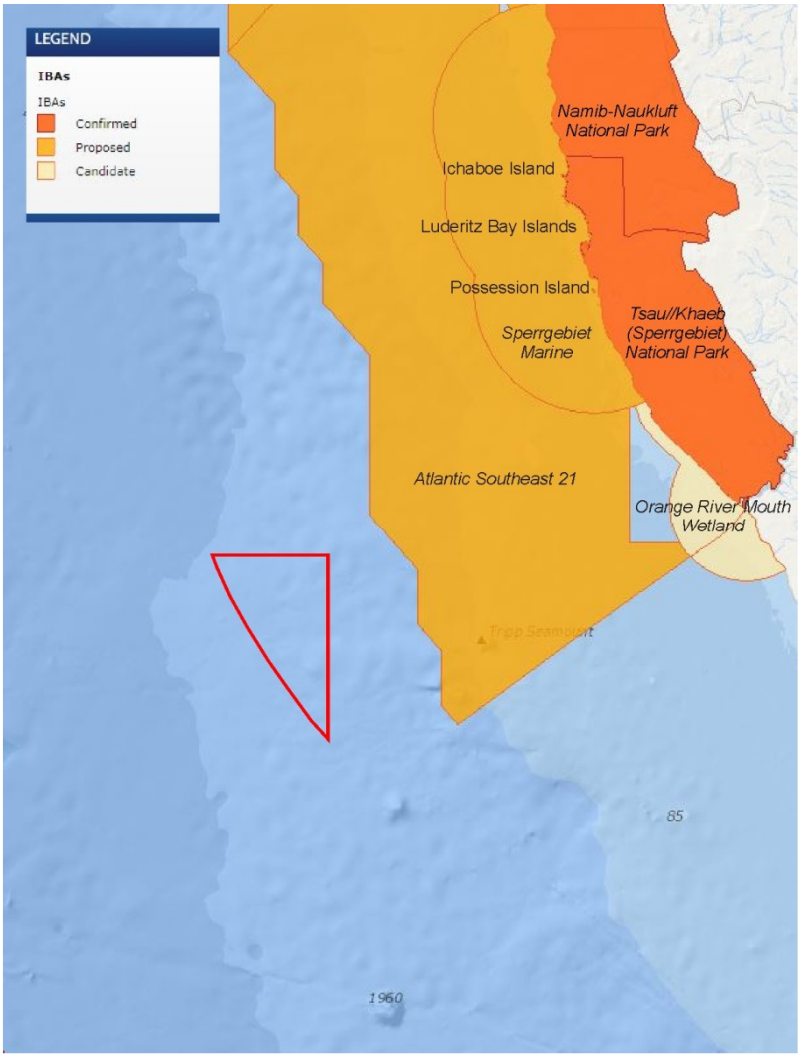


Figure 46: Block 2912 in relation to coastal and marine IBAs in Namibia (Source: https://maps.birdlife.org/marineIBAs).

Important Marine Mammal Areas (IMMAs)

Important Marine Mammal Areas (IMMAs) were introduced in 2016 by the IUCN Marine Mammal Protected Areas Task Force to support marine mammal and marine biodiversity conservation. Complementing other marine spatial assessment tools, including the EBSAs and Key Biodiversity Areas (KBAs), IMMAs are identified on the basis of four main scientific criteria, namely species or population vulnerability, distribution and abundance, key life cycle activities and special attributes. Designed to capture critical aspects of marine mammal biology, ecology and population structure, they are devised through a biocentric expert process that is independent of any political and socio-economic pressure or concern. IMMAs are not prescriptive but comprise an advisory, expert-based classification of areas that merit monitoring and place-based protection for marine mammals and broader biodiversity.

Modelled on the BirdLife International process for determining IBAs, IMMAs are assessed against a number of criteria and sub-criteria, which are designed to capture critical aspects of marine mammal biology, ecology and population structure. These criteria are:

Criterion A – Species or Population Vulnerability

Areas containing habitat important for the survival and recovery of threatened and declining species.

Criterion B – Distribution and Abundance

Sub-criterion B1 – Small and Resident Populations: Areas supporting at least one resident population, containing an important proportion of that species or population, that are occupied consistently.

Sub-criterion B2 – Aggregations: Areas with underlying qualities that support important concentrations of a species or population.

Criterion C – Key Life Cycle Activities

Sub-criterion C1 – Reproductive Areas: Areas that are important for a species or population to mate, give birth, and/or care for young until weaning.

Sub-criterion C2 – Feeding Areas: Areas and conditions that provide an important nutritional base on which a species or population depends.

Sub-criterion C3 – Migration Routes: Areas used for important migration or other movements, often connecting distinct life-cycle areas or the different parts of the year-round range of a non-migratory population.

Criterion D – Special Attributes

Sub-criterion D1 – Distinctiveness: Areas which sustain populations with important genetic, behavioural or ecologically distinctive characteristics.

Sub-criterion D2 – Diversity: Areas containing habitat that supports an important diversity of marine mammal species

Although much of the west coast of southern Africa has not yet been assessed with respect to its relevance as an IMMA, the coastline from the Olifants River mouth on the West Coast to the Mozambiquan border overlaps with three declared IMMAs (Figure 47) namely the

- Southern Coastal and Shelf Waters of South Africa IMMA (166 700 km^2),
- Cape Coastal Waters IMMA (6 359 km^2), and
- South East African Coastal Migration Corridor IMMA (47 060 km^2).

These all lie well to the south of Block 2912.

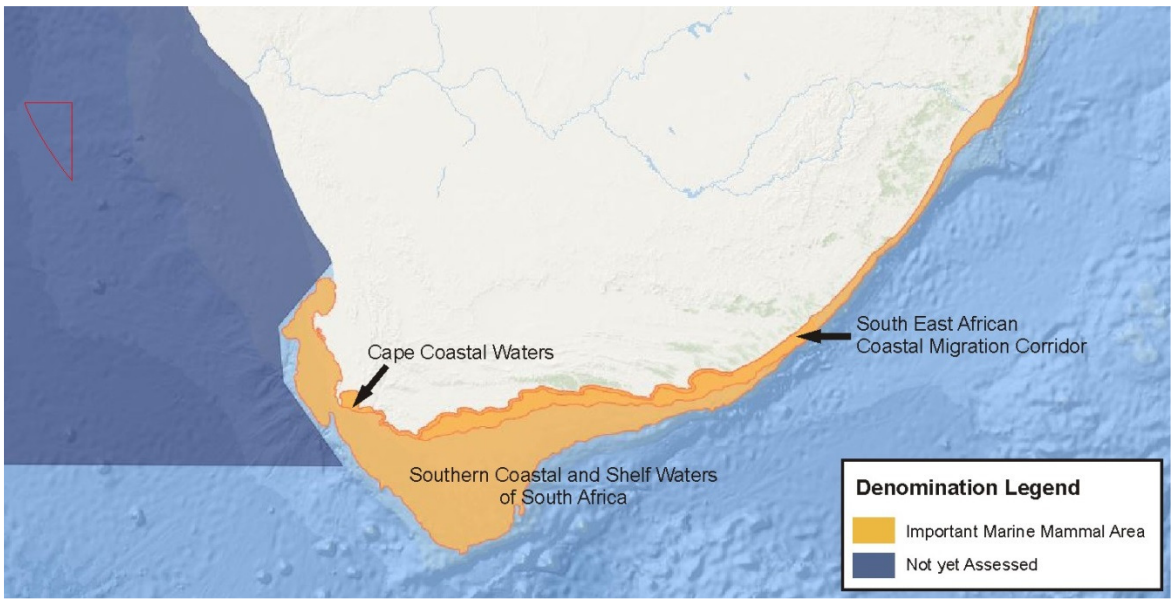


Figure 47: Block 2912 (red polygon) in relation to coastal and marine IMMAs (Source: www.marinemammalhabitat.org/imma-eatlas/).

3 ASSESSMENT OF IMPACTS

In the Strategic Environmental Assessment (SEA) for the coastal areas of the Erongo and Kunene Regions (Skov *et al*. 2007) it was identified that the offshore areas of the Kunene Region showed potential for oil and gas exploration. The subsequent SEA for the Benguela Current Large Marine Ecosystem (Tarr 2013) noted that Namibia had commenced with the exploration for both oil and gas, with expansion of the industry expected over the medium term in response to rising energy prices. While it recognised that the exploitation of an oil and gas resource can act as an important catalyst for economic growth and development, the threat of marine pollution associated with oil and gas exploration and production was acknowledged and the potential impacts associated with exploration, construction, production and decommissioning were listed.

For this project, the identification and assessment of impacts relating specifically to the marine ecology cover the four main activity phases (see **Error! Reference source not found.** for an outline of the activities in these phases) of the proposed seismic acquisition project, namely:

- Mobilisation Phase
- Operational Phase
- Demobilisation Phase
- Unplanned Activities

4.1 Identification of Impacts

Interaction of these activities with the receiving environment gives rise to a number of environmental aspects, which in turn may result in a single or a number of potential impacts. The identified aspects and their potential impacts are summarised in Table 12 below.

4.2 Application of the Mitigation Hierarchy

A key component of this ESIA process is to explore practical ways of avoiding and where not possible to reducing potentially significant impacts of the proposed well drilling activities. The mitigation measures put forward are aimed at preventing, minimising or managing significant negative impacts to as low as reasonably practicable (ALARP). The mitigation measures are established through the consideration of legal requirements, project standards, best practice industry standards and specialist inputs.

The mitigation hierarchy, as specified in International Finance Corporation (IFC) Performance Standard 1, is based on a hierarchy of decisions and measures aimed at ensuring that wherever possible potential impacts are mitigated at source rather than mitigated through restoration after the impact has occurred. Any remaining significant residual impacts are then highlighted and additional actions are proposed. With few exceptions, however, identified impacts were of low to negligible significance with very low or zero potential for further mitigation. In such cases the appropriate project Standards will be used and additional best management practices are proposed.

Table 12: Aspects and Impacts Register for marine ecological impacts (adapted from SLR Scoping Report).

Activity Phase	Activity	Aspect	Potential Impact
1. Mobilisation Phase	Transit of survey vessel, drilling unit and supply vessels to drill site	Increased underwater noise levels from vessel transit	Disturbance of behaviour (foraging and anti-predator) and physiology of marine fauna
		Light emissions in marine environment	Disorientation and mortality of seabirds
		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality	Physiological effect on marine fauna
			Increased food source for marine fauna
			Increased predator - prey interactions
	Discharge / exchange of ballast water	Introduction / spread of invasive alien species	Loss of biodiversity
2 Pre-drilling Surveys	Sonar surveys	Increased underwater noise levels from multibeam echo sounders and sub-bottom profilers	Disturbance / behavioural changes to marine fauna (cetaceans, turtles, etc)
			Physiological effect on marine fauna
			Masking or interfering with other biologically important sounds
	Seabed sediment coring	Disturbance of sediment due to piston and box coring	Disturbance of seabed and benthos
3. Operation Phase	Presence and operation of drill unit and support vessels (including waste management, water intake, air emissions and discharges to sea)	Increase in underwater noise levels	Disturbance / behavioural changes to marine fauna (cetaceans, turtles, etc)
		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality	Physiological effect on marine fauna
			Increased food source for marine fauna
			Fish aggregation and increased predator - prey interactions
	Lighting from drill unit	Light emissions in marine environment	Disorientation and mortality of seabirds
			Attraction of plankton and increased risk to fish, turtles and cetaceans
	Operation of helicopters	Increase in ambient noise levels	Disturbance of coastal and marine fauna in sensitive and protected areas
			Faunal avoidance of key breeding areas (e.g. coastal birds and cetaceans)
			Abandonment of nests (birds) and young (birds and seals)

Activity Phase	Activity	Aspect	Potential Impact
3. Operation Phase (cont.)	Well drilling (including ROV site selection, installation of conductor pipes; well head, BOP and riser system, well logging, and plugging)	Disturbance of sediment due to equipment installation	Disturbance of seabed and benthos
		Increased underwater noise levels	Disturbance / behavioural changes to marine fauna
	Discharge of cuttings and drilling fluid, and residual cement	Accumulation of cuttings and cement on seafloor and sediment disturbance	Smothering disturbance and mortality of benthic biota
			Toxicity and bioaccumulation or other physiological effects on marine fauna
			Reduced physiological functioning of marine organisms
		Sediment plume and water column disturbance	Increased water turbidity, reduced light penetration and physiological effects on marine fauna
	Vertical Seismic profiling	Increase in underwater noise levels	Disturbance / behavioural changes to marine fauna
			Physiological effect on marine fauna
			Masking or interfering with other biologically important sounds
	Well (flow) testing	Flaring of gas and liquid hydrocarbons	Disturbance, disorientation and mortality of marine faunal due to flare lighting
			Effect on faunal health (toxic effects) due to hydrocarbon 'drop-out' during flaring
		Discharge of treated produced water	Effect on marine biota health (e.g. physiological injury) or mortality (e.g. suffocation and poisoning)
4. Demobilisation Phase	Abandonment of well	Increased hard substrate on seafloor	Increased and modification of benthic biodiversity and biomass
	Demobilisation of drilling unit and support vessels from drill site	Increased underwater noise levels during transit	Disturbance to marine fauna
		Routine discharges to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality during transit	Physiological effect on marine fauna
			Increased food source for marine fauna
			Increased predator - prey interactions
		Light emissions in marine environment	Disorientation and mortality of seabirds

Activity Phase	Activity	Aspect	Potential Impact
5. Unplanned Activities	Faunal strikes	Collision with marine fauna	Physiological effect on marine fauna
	Accidental hydrocarbon spills / releases (minor) (e.g. vessel accident, bunkering and pipe rupture)	Loss of hydrocarbons to sea	Effect on faunal health (e.g. respiratory damage) or mortality (e.g. suffocation and poisoning)
	Dropped objects / Lost equipment	Increased hard substrate on seafloor on seafloor or obstruction in water column	Physical damage to and mortality of benthic species / habitats
	Loss of well control / well blow-out	Uncontrolled release of oil / gas from well	Effect on health of marine fauna (e.g. respiratory damage) or mortality (e.g. suffocation and poisoning)
			Oiling of coastal habitats

4.3 Potential Impacts related to Operation of Drill Unit, Vessels and Helicopters

4.3.1 Routine Operational Discharges to Sea

4.3.1.1 Impacts on Marine Ecology/Environment

Source of Impact

The project activities that will result in a reduction of water quality from routine discharges to the sea from vessels are listed below.

Project phase	Activity
Mobilisation	Transit of drilling unit and project vessels to the drilling/survey site
Operation	Operation of survey vessels and drilling unit and transit of support vessels between the drill area and Lüderitz
Demobilisation	Survey vessels, drilling unit and support vessels leave drill/survey area and transit to port or next destination
* Note: drilling discharges do not fall under the normal vessel operation, but under drilling operations (see Section 4.4.2).	

These activities and their associated aspects are described further below:

- **Deck drainage**: Contaminated or hazardous deck drainage is collected and piped into sump tanks on board the vessels to ensure MARPOL compliance (15 ppm oil in water). The fluid would be analysed and any hydrocarbons skimmed off the top prior to discharge. The oily substances would be added to the waste (oil) lubricants and disposed of at a suitable facility onshore.
- **Grey Water and Sewage**: sewage discharges will be comminuted, disinfected and discharged intermittently. Treated sanitary effluents discharged into the sea are estimated at an average of 200 litres per person per day.
- **Vessel machinery spaces or bilge water drainage**: Machinery space or bilge water drainage will be occasionally discharged after treatment. Bilge water is drainage water that collects in a ship's bilge space (the bilge is the lowest compartment on a ship, below the waterline, where the two sides meet at the keel). If the vessel intends to discharge bilge or ballast water at sea, this is achieved through use of an oily-water separation system. Oily waste substances will be shipped to land for treatment and disposal.
- **Food (galley) wastes**: Galley wastes, comprising mostly of biodegradable food waste, generated on board the project vessels may be discharged overboard. The daily volume of discharge from a standard seismic vessel is expected to be <0.2 m^3.
- **Cooling Water and freshwater surplus:** The cooling water and surplus generated by the fresh water supply system (including brine) are likely to contain a residual concentration of chlorine (generally less than 0.5 mg/ℓ for fresh water supply systems).

Impact Description

The routine liquid and solid discharges to sea could create local reductions in water quality, both during transit to and within the Area of Interest for drilling. Deck and machinery space drainage may result in small volumes of oils, detergents, lubricants and grease, the toxicity of which varies depending on their

composition, being introduced into the marine environment. Sewage and galley waste will place a small organic and bacterial loading on the marine environment, resulting in an increased biological oxygen demand.

These discharges will result in a local reduction in water quality, which could impact marine fauna (indirect impact) in a number of different ways:

- Physiological effects: Ingestion of hydrocarbons, detergents and other waste could have adverse effects on marine fauna, which could ultimately result in mortality.
- Increased food source: The discharge of galley waste and sewage will result in an additional food source for opportunistic feeders, speciality pelagic fish species.
- Increased predator - prey interactions: Predatory species, such as sharks and pelagic seabirds, may be attracted to the aggregation of pelagic fish attracted by the increased food source.

Project Controls

Contractors will ensure that the proposed exploration campaign is undertaken in compliance with the applicable requirements in MARPOL 73/78, as summarised below.

- The discharge of biodegradable food wastes (excluding cooking oils and grease) from vessels is regulated by MARPOL 73/78 Annex V, which stipulates that:
  - No disposal to occur within 3 nm (± 5.5 km) of the coast.
  - Disposal between 3 nm (± 5.5 km) and 12 nm (± 22 km) needs to be comminuted to particle sizes smaller than 25 mm.
  - Disposal overboard without macerating can occur greater than 12 nm from the coast. As the drilling unit will be stationary, food waste will need to be comminuted prior to discharge at the drilling site.
- Discharges of oily water (deck drainage, bilge and mud pit wash residue) to the marine environment are regulated by MARPOL 73/78 Annex I, which stipulates that vessels must have:
  - A Shipboard Oil Pollution Emergency Plan (SOPEP).
  - A valid International Oil Pollution Prevention Certificate, as required by vessel class.
  - Equipment for the control of oil discharge from machinery space bilges and oil fuel tanks, e.g. oil separating/filtering equipment and oil content meter. Oil in water concentration must be less than 15 ppm prior to discharge overboard.
  - Oil residue holding tanks.
  - Oil discharge monitoring and control system. The system will ensure that any discharge of oily mixtures is stopped when the oil content of the effluent exceeds 15 ppm.
- Sewage and grey water discharges from vessels are regulated by MARPOL 73/78 Annex IV, which specifies the following:
  - Vessels must have a valid International Sewage Pollution Prevention Certificate (ISPPC).
  - Vessels must have an onboard sewage treatment plant providing primary settling, chlorination and dechlorination before discharge of treated effluent.
  - The discharge depth is variable, depending upon the draught of the seismic vessel / support vessel at the time, but will be in accordance with MARPOL 73/78 Annex IV.
  - Discharge of sewage beyond 12 nm requires no treatment. However, sewage effluent must not produce visible floating solids in, nor cause the discolouration of, the surrounding water.

  - Sewage must be comminuted and disinfected for discharges between 3 nm (± 6 km) and 12 nm (± 22 km) from the coast. This will require an onboard sewage treatment plant or a sewage comminuting and disinfecting system.
  - Disposal of sewage originating from holding tanks must be discharged at a moderate rate while the ship is proceeding on route at a speed not less than 4 knots.
- Sewage will be treated using a marine sanitation device to produce an effluent with:
  - A biological oxygen demand (BOD) of <25 mg/ℓ (if the treatment plant was installed after 1/1/2010) or <50 mg/ℓ (if installed before this date).
  - Minimal residual chlorine concentration of 0.5 mg/ℓ.
  - No visible floating solids or oil and grease.
- Cooling water and freshwater surplus would be tested prior to discharge and would comply with relevant South African Water Quality Guidelines for residual chlorine, salinity and temperature relative to the receiving environment.

Contractors will be required to develop a Waste and Discharge Management Plan for all wastes generated at the various sites and a Chemical Management Plan detailing the storage and handling of chemicals, as well as measures to minimise potential pollution. These plans will include / address the following:

- Environmental awareness to ensure wastes are reduced and managed as far as possible.
- Avoidance of waste generation, adopting the Waste Management Hierarchy (reduce, reuse, recycle, recover, residue disposal), and use of BAT.
- Treatment of wastes at source (including maceration of food wastes, compaction, incineration, treatment of sewage and oily water separation).
- Development of a waste inventory that classifies (hazardous, non-hazardous or inert) and quantifies waste, and identifies treatment and disposal methods.
- Waste collection and temporary storage, which is designed to minimise the risk of escape to the environment (for example by particulates, infiltration, runoff or odours).
- On-site waste storage, which is limited in time and volume.
- Provision of dedicated, clearly labelled, containers (bins, skips, etc.) in quantities adequate to handle anticipated waste streams and removal frequency.
- Chemicals will be appropriately stored onboard the project vessels (segregation, temperature, ventilation, retention, etc.).

Sensitivity of Receptors

The operational waste discharges from the activities described above would primarily take place at the drill site(s) and along the route taken by the support vessels between the drill site(s) and Lüderitz. The Area of Interest for drilling is located 290 km offshore at its nearest point and far removed from coastal MPAs and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks). There is also no overlap of the Area of Interest with proposed EBSAs and ESAs. The NIMPA is located over 250 km north-east of the Area of Interest, whereas the Orange Shelf Edge offshore MPA is located ~125 km east at its closest point, in South African waters. Discharges could also directly affect migratory pelagic species transiting through the drill area. Vessel discharges *en route* to the onshore supply base in Lüderitz could result in discharges closer to shore, thereby potentially having an environmental effect on the sensitive coastal environment.

The taxa most vulnerable to routine operational discharges are pelagic seabirds, turtles, and large migratory pelagic fish and marine mammals. Some of the species potentially occurring in the drill area,

are considered regionally or globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles and blue whales), 'Endangered' (e.g. Black-Browed and Yellow-Nosed Albatross, whale shark, shortfin mako shark, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, loggerhead turtles, oceanic whitetip shark, dusky shark, great white shark, longfin mako and sperm, Bryde's and humpback whales) or 'Near Threatened' (e.g. striped marlin, blue shark, longfin tuna/albacore and yellowfin tuna).

Although species listed as 'Critically Endangered' or 'Endangered' may potentially occur in the drill area, compliance with MARPOL will ensure reduced discharges and reduced sensitivity of marine fauna to these discharges. In addition, the drill area is located within the main marine traffic route around southern Africa and thus is in an area already experiencing increased vessel operational discharges. Thus, the overall sensitivity is considered to be **MEDIUM**.

Impact Magnitude

The contracted vessels and drilling unit will have the necessary sewage treatment systems in place, and will have oil/water separators and food waste macerators to ensure compliance with MARPOL 73/78 standards. Compliance with MARPOL means that intermittent operational discharges introduce relatively small amounts of nutrients and organic material to oxygenated surface waters, which will result in a minor contribution to local marine productivity and possibly of attracting opportunistic feeders. The intermittent discharge of sewage is likely to contain a low level of residual chlorine following treatment, but given the relatively low total discharge and rapid dilution in surface waters this is expected to have a minimal effect on seawater quality.

Furthermore, the drill area is suitably far removed from sensitive coastal receptors (>250 km) and the dominant wind and current direction will ensure that any discharges are rapidly dispersed north-westwards and away from the coast. The transit route to the new drill area does overlap with the NIMPA; however, the habitat and biota are unlikely to be impacted by intermittent surface discharges, which rapidly disperse to very low concentrations. There is no potential for accumulation of substances discharged leading to any detectable long-term impact.

Due to the distance offshore, it is only pelagic fish, birds, turtles and cetaceans that may be affected by the discharges, and these are unlikely to respond to the minor changes in water quality resulting from vessel discharges. The most likely animal to be attracted to project vessels / drilling unit will be large pelagic fish species, such as the highly migratory tuna and billfish, as well as sharks and odontocetes (toothed whales). Pelagic seabirds that feed primarily by scavenging would also be attracted.

Other types of wastes generated during the exploration activities will not be discharged at sea, but will be transported to shore for disposal at a licensed waste management facility approved by TEEPNA. The disposal of all waste onshore will be fully traceable.

Based on the relatively small discharge volumes and compliance with MARPOL 73/78 standards, offshore location and high energy sea conditions, the potential impact of normal discharges from the project vessels / drilling unit will be of VERY LOW intensity, SHORT-TERM duration and REGIONAL (although localised at any one time around the project vessels). The impact magnitude is therefore considered **VERY LOW**.

Impact Significance

The impacts associated with routine operational discharges from project vessels / drilling unit are deemed to be of **VERY LOW** significance, due to the medium sensitivity of the offshore receptors and the very low magnitude.

Identification of Mitigation Measures

In addition to compliance with MARPOL 73/78 standard, the other project controls and their monitoring, the following measures will be implemented to reduce wastes at the source:

No.	Mitigation measure	Classification
1	Prohibit operational discharges when transiting through the NIMPA and Namibian Islands and Orange Seamount and Canyon Complex EBSAs during transit to and from the drill site.	Avoid/reduce at source
2	Implement an awareness programme that addresses reduced water usage and waste generation at the various sites, shore-based and marine.	Reduce at Source
3	Use drip trays to collect run-off from equipment that is not contained within a bunded area and route contents to the closed drainage system.	Avoid / Reduce at Source
4	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
5	Use a low-toxicity biodegradable detergent for the cleaning of the deck and any spillages.	Reduce at Source

Residual Impact Assessment

This potential impact cannot be eliminated because project vessels / drilling unit are needed to undertake the exploration activities and will generate routine discharges during operations. With the implementation of the project controls and mitigation measures, the residual impact will remain of **VERY LOW** significance.

1	***Impacts of normal vessel discharges on marine fauna***	
Project Phase:	**Mobilisation, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**MEDIUM**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	VERY LOW	VERY LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Significance	**VERY LOW**	**VERY LOW**
Probability	**LIKELY**	**LIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.3.2 Discharge of Ballast Water from Vessels

4.3.2.1 Impact on Marine Biodiversity

Source of Impact

The project activities that will result in the discharge of ballast water and potential introduction of alien invasive species are listed below.

Project phase	Activity
Mobilisation	Transit of drilling unit and support vessels to drilling area
	Discharge of ballast water by drilling unit (and possibly support vessels)
Operation	n/a
Demobilisation	n/a

These activities and their associated aspects are described further below:

- The drilling unit (and possibly other project vessels) and the use of subsea equipment from other regions (excluding local or national translocations) may provide for the potential translocation of introduced or alien species that are attached to hulls and infrastructure that have been at sea for any length of time.
- Depending on where the ballast water is loaded, de-ballasting of project vessels / drilling unit *en route* or once at the drill area could introduce non-native species into the area, especially if the drilling unit (or possibly the support vessels) is arriving from another country abroad.

Impact Description

Artificial structures deployed at sea serve as a substrate for a wide variety of larvae, cysts, eggs and adult marine organisms. The transportation of vessels and equipment from other regions would therefore facilitate the transfer of the associated marine organisms. Similarly, depending on where the ballast water is loaded, it may contain larvae, cysts, eggs and adult marine organisms from other regions. Thus, ballasting and de-ballasting of these vessels / drilling unit may lead to the introduction of exotic species and harmful aquatic pathogens to the marine ecosystems (Bax *et al*. 2003). This would be an indirect, negative impact.

The marine invertebrates that colonize the surface of vessels or those in discharged ballast water can easily be introduced to a new region, where they may become invasive by outcompeting and displacing native species. Marine invasive species are considered primary drivers of ecological change in that they create and modify habitat, consume and outcompete native fauna, act as disease agents or vectors, and threaten biodiversity and ecosystem function (indirect negative impact). Once established, an invasive species is likely to remain in perpetuity (Bax *et al*. 2003).

Project Controls

Ballast water discharged will follow the requirements of the International Maritime Organisation's (IMO) 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments. By establishing standards and procedures for the management and control of ships' ballast water and sediments, the Convention aims to prevent the spread of harmful aquatic organisms from one region to

another. The Convention stipulates that all ships are required to implement a Ballast Water Management Plan, which includes a detailed description of the actions to be taken to implement the Ballast Water Management requirements. All ships using ballast water exchange should, wherever possible, do so at least 200 nautical miles (± 370 km) from nearest land in waters of at least 200 m deep. Where this is not feasible, the exchange should be as far from the nearest land as possible, and in all cases a minimum of 50 nm (± 93 km) from the nearest land and preferably in water at least 200 m in depth. Ships will also have a Ballast Water Record Book to record when ballast water is taken on board; circulated or treated for Ballast Water Management purposes; and discharged into the sea. Project vessels would be required to comply with this requirement.

Sensitivity of Receptors

The discharge of ballast water from the drill rig and possible support vessels would take place in the vicinity of the drill area, but at least 93 km (so more than 200 m water depth) from the coast as per the IMO requirements, far removed from any sensitive coastal receptors (e.g. sessile benthic invertebrates, endemic neritic and demersal fish species). In addition, due to the water depths in the Area of Interest (2 950 m and 3 400 m), colonisation by invasive species on the seabed is considered unlikely. Thus, the sensitivity of benthic receptors in the offshore waters of Block 2912 is considered **VERY LOW**.

Impact Magnitude

The most important pathways in the transfer of marine alien species have always been related to shipping (Hewitt *et al*. 1999; Ruiz *et al*. 2000; Ruiz & Carlton 2003), with primary introduction events arising mainly from ships moving between major international ports and secondary local spread occurring *via* regional vessels (Wasson *et al*. 2001; Lacoursière-Roussel *et al*. 2012).

The principal vectors responsible for transfer of alien invasive species are ballast water and external hull fouling (Carlton 1987, 1999; Hewitt *et al*. 2009). Following the prohibition of harmful organotins, such as tributyltin (TBT), in anti-fouling paints (IMO 2001), hull fouling remains responsible for a large proportion of current alien introductions. More than half of the recognised marine alien species in the United Kingdom have been associated with shipping, with the main vector being fouling (Eno 1996), with Australia demonstrating a similar pattern (Thresher 1999).

In South Africa the first review of marine alien species was published in 1992 and listed 15 introduced species (Griffiths *et al*. 1992). This number has grown rapidly since, with the National Biodiversity Assessment (Sink *et al*. 2019) reporting 96 introduced marine species including 55 that are considered to be invasive. Invasive species were more prevalent on rocky shores than in other broad ecosystem groups, and in the Southern Benguela than in other ecoregions. Shipping activity has been responsible for 86% of these marine introductions, 48% of which are due to fouling (Mead *et al*. 2011).

Alien species have the potential to displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food web properties and ecosystem processes, impede the provision of ecosystem services, impact human health and cause substantial economic losses (Katsanevakis *et al*. 2014).

The drilling unit, and possibly the other project vessels, will more than likely have spent time outside of Namibia's EEZ prior to commencing drilling activities. This exposure to foreign water bodies and possible loading of ballast water increases the risk of introducing invasive or non-indigenous species into Namibian waters. The risk of this impact is, however, significantly reduced due by the implementation of ballast water management measures in accordance with the IMO guidelines. The risk is further

reduced due to the far offshore location of the drill area, and the dominant wind and current direction will ensure that any invasive species drift mainly in a north-westerly away from the coast. In addition, the water depths in the Area of Interest (2 940 m and 3 700 m) will ensure that colonisation of invasive species on the seabed is unlikely. De-ballasting in the drill area, complying with IMO requirements, will thus not pose an additional risk to the introduction of invasive species.

In terms of hull fouling, the drill area is located in the main traffic routes that pass around southern Africa. Thus, the introduction of invasive species into Namibian waters due to hull fouling of project vessels is unlikely to add to the current risk that exists due to the numerous vessels that operate in or pass through Namibian coastal waters on a daily basis.

Considering the remote location of the drill area and compliance with the IMO guidelines for ballast water, the impact related to the introduction of alien invasive marine species is considered to be of MEDIUM intensity (due to it having a minimal effect on receptors) in the SHORT-TERM (due to invasive species not being able to establish) and of REGIONAL extent. The magnitude (or consequence) is, therefore, considered to be **LOW**.

Impact Significance

The potential for introductions of non-native marine species through hull fouling or ballast water discharge is deemed to be of **VERY LOW significance**, due to the very low sensitivity of the offshore receptors and the low magnitude.

Identification of Mitigation Measures

In addition to compliance with the requirements of the IMO 2004 Ballast Water Management Convention, recommendations for mitigation will be implemented to reduce and manage the potential introduction of alien species in ballast water and hull or equipment fouling:

No.	Mitigation measure	Classification
1	Avoid the unnecessary discharge of ballast water.	Reduce at source
2	Use filtration procedures during loading in order to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms	Avoid/reduce at source
3	Ensure that routine cleaning of ballast tanks is carried out, where practicable, in mid-ocean or under controlled arrangements in port or dry dock, in accordance with the provisions of the ship's Ballast Water Management Plan	Avoid/reduce at source
4	Ensure all equipment (e.g. drill string, wellhead, BOP etc.) that has been used in other regions is thoroughly cleaned prior to deployment	Avoid/Reduce at Source

Residual Impact Assessment

This potential impact cannot be eliminated due to the necessity of bringing the drilling unit and drilling equipment to the drill area from other parts of the world, and the need for de-ballasting once on site. With the implementation of the mitigation measures above, the residual impact would reduce to **very low magnitude** and be of **NEGLIGIBLE significance**.

2	*Impacts of marine biodiversity through the introduction of non-native species in ballast water and on ship hulls*	
Project Phase:	**Mobilisation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**VERY LOW**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**LOW**	**VERY LOW**
Intensity	MEDIUM	LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT TERM	SHORT TERM
Significance	**VERY LOW**	**NEGLIGIBLE**
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**MEDIUM**	**MEDIUM**
Reversibility	**IRREVERSIBLE**	**IRREVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.3.3 Noise from Helicopters

4.3.3.1 Impact on Coastal and Marine Fauna

Source of Impact

The project activities that will result in an increase in noise impacts on marine fauna are listed below.

Project phase	Activity
Mobilisation	n/a
Operation	Operation of helicopters between drill area and Lüderitz
Demobilisation	n/a

Possible crew transfers by helicopter from Lüderitz to the drilling unit will generate noise in the atmosphere that may disturb coastal species such as seabirds and seals. It is estimated that there could be up to four trips per week between the drilling unit and the helicopter support base at Lüderitz (i.e. up to 68 trips per well over a 4 month period). Noise source levels from helicopters flying at an altitude of 150 m or more above sea level are expected to be around 109 dB re 1µPa at the most noise-affected point (SLR Consulting Canada 2023).

Impact Description

Elevated aerial noise levels from helicopters may disturb faunal species resulting in behavioural changes or displacement from important feeding or breeding areas (direct negative impact).

Project Controls

The drilling contractor will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT).

All whales and dolphins are given protection under the Namibian Law. The regulations under the Namibian Marine Resources Act, 2000 (No. 27 of 2000) states that no whales or dolphins may be harassed, killed or fished. Although not legislated in Namibia, no vessel or aircraft should approach closer than 300 m to any whale and a vessel or aircraft should move to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft.

The operation of helicopters aircraft is governed by the Civil Aviation Act (No. 6 of 2016) and associated regulations.

Sensitivity of Receptors

The aircraft noise described above would primarily take place in the drilling area and along the route taken by the helicopters between the drilling area and Lüderitz. Although the Area of Interest is located approximately 350 km southwest of Lüderitz at its closest point, the flight path between the Area of Interest and Lüderitz would cross over the NIMPA, and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks). In addition, migratory pelagic species transiting through the drill area may also be directly affected.

The taxa most vulnerable to disturbance by helicopter noise are pelagic and coastal seabirds, turtles, and large migratory pelagic fish and marine mammals. Some of the species potentially occurring in the drill area, are considered regionally or globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles and blue whales), 'Endangered' (e.g. Black-Browed and Yellow-Nosed Albatross, whale shark, shortfin mako shark, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, loggerhead turtles, oceanic whitetip shark, dusky shark, great white shark, longfin mako and sperm whale, Bryde's and humpback whales) or 'Near Threatened' (e.g. striped marlin, blue shark, longfin tuna/albacore and yellowfin tuna). Although species listed as 'Critically Endangered' or 'Endangered' may potentially occur in the proposed drill area, due to their extensive distributions their numbers are expected to be low. Furthermore, various coastal birds occurring in the NIMPA are considered regionally

In addition, seabirds and seals in breeding colonies and roosts along the coast could be impacted where the flight path crosses the coastal zone. Some of the seabirds roosting and nesting along the coast are listed by the IUCN as 'Endangered' (e.g. African Penguin, Bank Cormorant, Cape Cormorant and Cape Gannet), 'Near threatened' (e.g. African Black Oystercatcher and Crowned Cormorant) or 'Vulnerable' (e.g. Damara Tern). The Cape Gannet is also considered as 'Critically Endangered' nationally. The overall sensitivity is considered to be **HIGH**.

Impact Magnitude

The ocean is a naturally noisy place and marine animals are continually subjected to both physically produced sounds from sources such as wind, rainfall, breaking waves and natural seismic noise, or biologically produced sounds generated during reproductive displays, territorial defence, feeding, or in echolocation (see references in McCauley 1994). Such acoustic cues are thought to be important to many marine animals in the perception of their environment as well as for navigation purposes, predator avoidance, and in mediating social and reproductive behaviour. Anthropogenic sound sources

in the ocean can thus be expected to interfere directly or indirectly with such activities thereby affecting the physiology and behaviour of marine organisms (NRC 2003). Natural ambient noise will vary considerably with weather and sea state, ranging from about 80 to 120 dB re 1 µPa for the frequency range 10 – 10k Hz (Croft & Li 2017).

Noise propagation represents energy travelling either as a wave or a pressure pulse through a gas or a liquid. Due to the physical differences between air and water (density and the speed at which sound travels), the decibel units used to describe noise underwater are different from those describing noise in air. Furthermore, hearing sensitivities vary between species and taxonomic groups. Underwater noise generated in the air is therefore treated separately from noise generated by drilling activities (see Section 4.4.6). The dominant low-frequency components of aircraft engine noise (10-550 Hz) penetrate the water only in a narrow (26° for a smooth water surface) sound cone directly beneath the aircraft, with the angle of the cone increasing in Beaufort wind force >2 (Richardson *et al*. 1995). The peak sound level received underwater is inversely related to the altitude of the aircraft. More recently, Erbe *et al*. (2018) established that commercial passenger airplanes in a coastal underwater soundscape exhibited broadband received levels of 84–132 dB re 1 µPa rms, detectable at between 12 Hz and 10 kHz and exceeding underwater ambient levels by up to 36 dB. Planes were on flight paths approaching (400-800 m altitude) and leaving (400-800 m altitude) airports. Underwater noise from commercial airplanes would thus be audible to a variety of marine fauna, including seals and dolphins.

Available data indicate that the expected frequency range and dominant tones of sound produced by smaller, fixed-wing aircraft and helicopters also overlap with the hearing capabilities of most odontocetes and mysticetes (Richardson *et al*. 1995; Ketten 1998; Erbe *et al*. 2017). Determining the reactions of cetaceans to over flights is difficult, however, since most observations are made from either the disturbing aircraft itself (Richardson & Würsig 1997), or from a small nearby vessel. Reactions to aircraft flyovers vary both within and between species, and range from no or minimal observable behavioural response (Belugas: Stewart *et al*. 1982; Richardson *et al*. 1991; Sperm: Clarke 1956; Gambell 1968; Green *et al*. 1992), to avoidance by diving, changes in direction or increased speed of movement away from the noise source (Gray: Withrow 1983; Belugas: Richardson *et al*. 1991, Patenaude *et al*. 2002; Sperm: Clarke 1956; Fritts *et al*. 1983; Mullin *et al*. 1991; Würsig *et al*. 1998; Minke: Leatherwood *et al*. 1982; Bowhead: Patenaude *et al*. 2002; Humpbacks: Smultea *et al*. 1995), separation of cow-calf pairs (Gray: Withrow 1983), increased surface intervals (Belugas: Awbrey & Stewart 1983; Stewart *et al*. 1982; Patenaude *et al*. 2002), changes in vocalisation (Sperm whales: Watkins & Schevill 1977; Richter *et al*. 2003, 2006) and dramatic behavioural changes including breaching and lobtailing (Minke: Leatherwood *et al*. 1982; Sperm: Fritts *et al*. 1983; Bowhead: Patenaude *et al*. 2002; Beluga: Patenaude *et al*. 2002), and active and tight clustering behaviour at the surface (Sperm: Smultea *et al*. 2008).

Most authors established that the reactions resulted from the animals presumably receiving both acoustic and visual cues (the aircraft and/or its shadow). As would be expected, sensitivity of whales to disturbance by an aircraft generally lessened with increasing distance, or if the flight path was off to the side and downwind, and if its shadow did not pass directly over the animals (Watkins 1981; Smultea *et al*. 2008). Smultea *et al*. (2008) concluded that the observed reactions of whales to brief over flights were short-term and isolated occurrences were probably of no long-term biological significance and Stewart *et al*. (1982) suggested that disturbance could be largely eliminated or minimised by avoiding flying directly over whales and by maintaining a flight altitude of at least 300 m. However, repeated or prolonged exposures to aircraft over flights have the potential to result in significant disturbance of biological functions, especially in important nursery, breeding or feeding areas (Richardson *et al*. 1995).

The reactions of pinnipeds to aircraft noise were reviewed by Richardson *et al*. (1995). As the frequency of aircraft engine noise overlaps with the hearing ranges of seals, these will likely similarly receive both acoustic and visual cues from aircraft flyovers. Richardson *et al*. (1995), however, point out that in very few cases was it determined that responses were specifically to aircraft noise as opposed to visual cues. Furthermore, most reported observations relate to pinnipeds on land or ice, with few data specifically on the reactions of pinnipeds in water to either airborne or waterborne sounds from aircraft. Reactions to flyovers vary between species, ranging from stampeding into the water, through temporary abandonment of pupping beaches to alertness at passing aircraft. When in the water, seals have been observed diving when the aircraft passes overhead. Pinnipeds thus exhibit varying intensities of a startle response to airborne noise, most appearing moderately tolerant to flyovers and habituating over time (Richardson *et al*. 1995; Laws 2009). The rates of habituation also vary with species, populations, and demographics (age, sex). Any reactions to over flights would thus be short-term and, except for cases where commercial airports are located close to the coast and overflights are frequent (Erbe *et al*. 2018), isolated occurrences around the drill site(s) would unlikely be of any long-term biological significance or have population-level effects.

The hazards of aircraft activity to birds include direct strikes as well as disturbance, the degree of which varies greatly. The negative effects of disturbance of birds by aircraft were reviewed by Drewitt (1999) and include loss of usable habitat, increased energy expenditure, reduced food intake and resting time and consequently impaired body condition, decreased breeding success and physiological changes. Nesting birds may also take flight and leave eggs and chicks unattended, thus affecting hatching success and recruitment success (Zonfrillo 1992). Differences in response to different types of aircraft have also been identified, with the disturbance effect of helicopters typically being higher than for fixed-wing aeroplanes. Results from a study of small aircraft flying over wader roosts in the German Wadden Sea showed that helicopters disturbed most often (in 100% of all potentially disturbing situations), followed by jets (84 %), small civil aircraft (56 %) and motor-gliders (50 %) (Drewitt 1999).

Sensitivity of birds to aircraft disturbance are not only species specific, but generally lessened with increasing distance, or if the flight path was off to the side and downwind. However, the vertical and lateral distances that invoke a disturbance response vary widely, with habituation to the frequent loud noises of landing and departing aircraft without ill effects being reported for species such as gulls, lapwings, ospreys and starlings, amongst others (reviewed in Drewitt 1999). Further work is needed to examine the combined effects of visual and acoustic stimuli, as evidence suggests that in situations where background noise from natural sources (e.g. wind and surf) is continually high, the visual stimulus may have the greater effect.

Southern right whales were completely displaced from Namibian waters during historical whaling activities and have only recently returned to the Namibian coast to calve. Calving and nursing activities are known to occur in Hottentot Bay (approximately 60 km north of Lüderitz, well to the north of any potential flight paths) and Elizabeth Bay (approximately 10 km east of a direct flight path to the south-eastern corner of the area of operation) (Currie *et al*. 2009) (Figure 48), and will not be impacted by helicopter flights between Lüderitz and the drill area. The months of main calving and nursing activities include June to September. The level of disturbance would also depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions.

Noise generated by helicopters undertaking crew transfers between Lüderitz and the drill rig could affect seabirds and seals in breeding colonies and roosts on the mainland coast. The nearest seabird colonies to Lüderitz airport are at Lüderitz lagoon, Halifax and Possession Islands, all of which are

important bird areas and provide a vital breeding habitat. The Lüderitz lagoon and Halifax colonies fall 6 km and 13 km north of the potential flight paths between the airport and the northwestern corner of the licence area, and are unlikely to be impacted by helicopter flights. North and South Long Islands and the Atlas and Wolf Bay seal colonies, however, fall within the direct flight path between Lüderitz and the project area and flight paths would need to be planned to avoid these colonies.

The seal colonies at Atlas Bay, Wolf Bay and Long Islands ~320 km to the northeast of Block 2912 represent the largest colonies in southern Namibia, with smaller colonies at Van Reenen Bay and Baker's Bay, about 290 km inshore of the eastern boundary of the project area. If the Lüderitz airport is used as the logistics base for rotary-wing operations as part of the proposed exploration drilling, flight paths would need to be planned to avoid these colonies, particularly the one at Atlas Bay, Wolf Bay and Long Islands, which falls into the direct flight path from the airport to the area of operation (Figure 48).

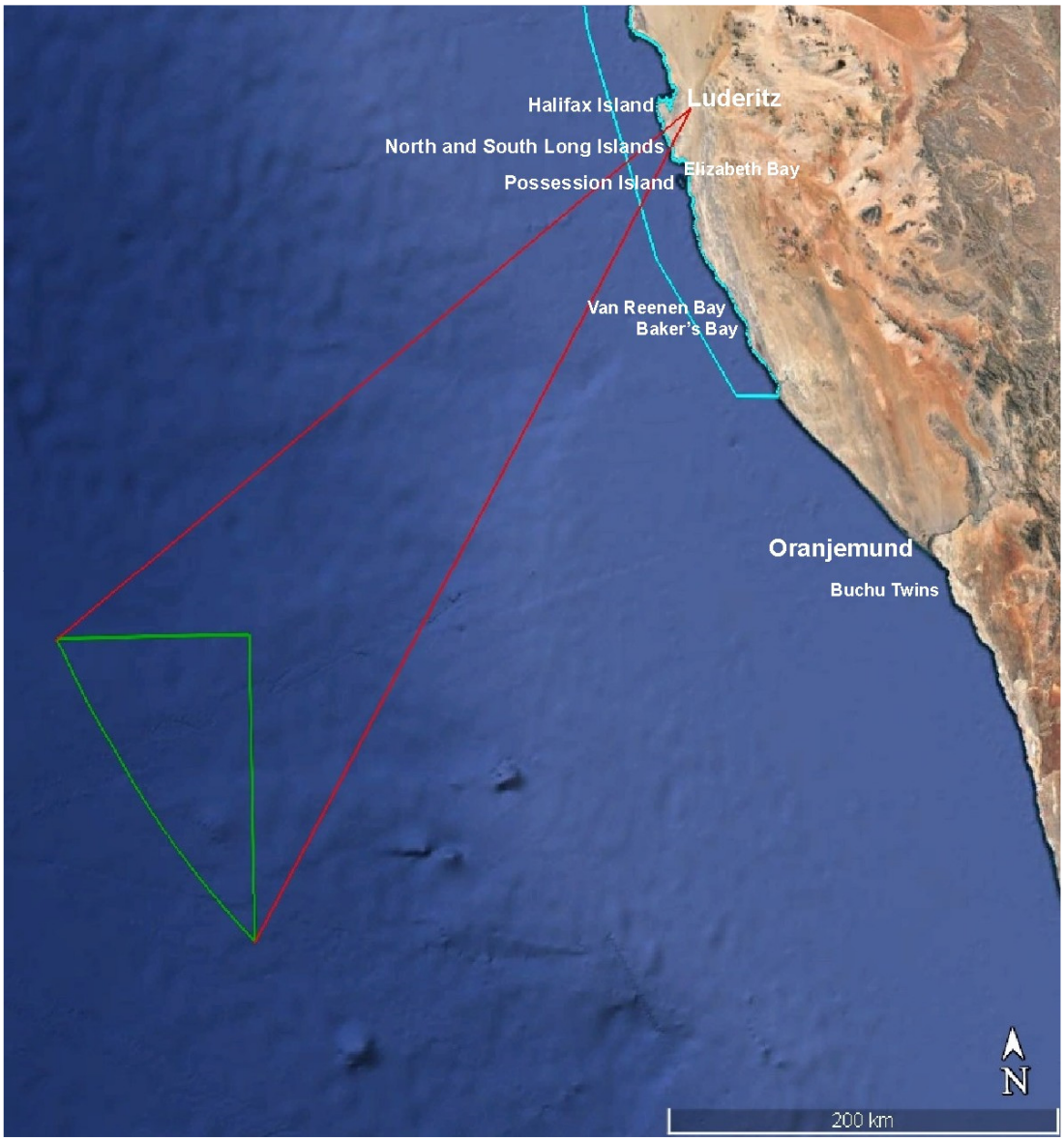


Figure 48: Area of potential flight paths (within red lines) from Lüderitz airport to the north-western and south-eastern extremes of Block 2912.

Indiscriminate low altitude flights over whales, seals, seabird colonies and turtles by helicopters used to support the drilling unit could thus have an impact on behaviour and breeding success. The intensity of disturbance would depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions and could range from low to high intensity for individuals but of LOW intensity for the populations as a whole. As such impacts would be REGIONAL (although temporary in nature a few minutes in every week while the helicopter passes overhead) and SHORT TERM (4 months per well), impacts would be of **VERY LOW** magnitude.

Impact Significance

The potential impact of aircraft noise causing physiological injury to, or behavioural avoidance by, pelagic and coastal sensitive species, is deemed to be of **LOW** significance considering their high sensitivity and very low magnitude. Aircraft noise would, however, likely contribute to the growing suite of cumulative acoustic impacts to marine fauna in the area, but assessing the population level consequences of multiple smaller and more localised stressors (see for example Booth *et al*. 2020; Derous *et al*. 2020) is difficult to determine.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over the Atlas Bay, Wolf Bay and Long Island seal colonies or any of the Islands within the NIMPA.	Avoid / abate on site
2	Avoid extensive low-altitude coastal flights	Avoid/ abate on site
3	Maintain a flight altitude >1 000 m to be maintained at all times, except when taking off and landing or in a medical emergency	Avoid/ abate on site
4	Maintain an altitude of at least 1 000 m above the NIMPA islands within a radius of one nautical mile around islands' low water mark	Avoid/ abate on site
5	Over-flight restrictions of a minimum altitude of 3 000 feet/1 000 meters apply to seal colonies at Van Reenen Bay, Wolf and Atlas Bays and Baker's Bay on the mainland of the NIMPA, except for Diaz Point provided Diaz Point is only approached from the North by air.	Avoid/ abate on site
6	Comply fully with aviation and authority guidelines and rules.	Avoid/ abate on site
7	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Avoid

Residual Impact Assessment

The generation of noise from helicopters cannot be eliminated if helicopters are required for crew changes. With the implementation of the mitigation measures above, the residual impact would remain of **very low magnitude** and **LOW significance**.

3	*Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to the noise of support aircraft*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Significance	**LOW**	**LOW**
Probability	**POSSIBLE**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**POSSIBLE**	**POSSIBLE**

4.3.4 Lighting from Drill Unit and Vessels

4.3.4.1 Impact on Marine Fauna

Source of Impact

The project activities that will result in potential impacts on marine fauna due to an increase in ambient lighting are listed below.

Project phase	Activity
Mobilisation	Transit of drill rig and support vessels to drilling area
Operation	Operation of drill rig at the drill site, operation of survey vessels and support vessels between the drilling unit and port
Demobilisation	Drill rig and survey and support vessels leave drilling area and transit to port or next destination

The operational lighting of support vessels during transit and well-drilling can be a significant source of artificial light in the offshore environment increasing the ambient lighting in offshore areas.

Impact Description

The strong operational lighting used to illuminate the project vessels and especially the drill rig at night increase ambient lighting in offshore areas. Increased ambient lighting may disturb and disorientate pelagic seabirds feeding in the area (direct negative impact). Operational lights may also result in physiological and behavioural effects of fish and cephalopods (direct negative impact), as these may be drawn to the lights at night where they may be more easily preyed upon by other fish and seabirds.

Project Controls

Contractors will ensure that the proposed exploration campaign is undertaken in a manner consistent with good international industry practice and BAT.

Sensitivity of Receptors

The drilling activities would be undertaken in the offshore marine environment, 290 km from the shore at its closest point and thus far removed from any sensitive coastal receptors (e.g. bird or seal colonies) and range of most coastal seabirds (10-30 km), but could still directly affect some migratory pelagic species (pelagic seabirds, marine mammals and fish) transiting through the licence / drill area, as well as coastal species during vessel transit to port. Thus the taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans transiting through the drilling area may also be attracted by the lights.

Some of the species potentially occurring in the drilling area, are considered regionally or globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles and blue whales), 'Endangered' (e.g. Black-Browed and Yellow-Nosed Albatross, whale shark, shortfin mako shark, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, loggerhead turtles, oceanic whitetip shark, dusky shark, great white shark, longfin mako and sperm, Bryde's and humpback whales) or 'Near Threatened' (e.g. striped marlin, blue shark, longfin tuna/albacore and yellowfin tuna). Although species listed as 'Critically Endangered' or 'Endangered' may potentially occur in the drill area, the Area of Interest is located in a main marine traffic route and thus is in an area already experiencing increased operational lighting above ambient. Thus, the overall sensitivity is considered to be MEDIUM.

Impact Magnitude

The strong operational lighting used to illuminate the drilling unit or vessels at night may disturb and disorientate pelagic seabirds feeding in the area. Potential attraction may increase during fog when greater illumination is caused by refraction of light by moisture droplets. It is expected, however, that seabirds and marine mammals in the area would become accustomed to the presence of the project vessels and drill rig within a few days. Since the drilling area is located within the main traffic routes that pass around southern Africa, which experience high vessel traffic, animals in the area should be accustomed to vessel traffic and associated lighting.

Although little can be done on the project vessels and drill rig to prevent seabird collisions, reports of collisions or death of seabirds on vessels are rare. Should they occur, the light impacts would primarily take place in the drilling area and along the route taken by the support vessels between the drilling area and Lüderitz.

Operational lights may also result in physiological and behavioural effects on fish and cephalopods, as these may be drawn to the lights at night where they may be more easily preyed upon by other fish, marine mammals and seabirds. This would be more of an issue for a stationary drilling unit than for a support vessel, which would be constantly moving. Although seals are known to forage up to 120 nautical miles (~220 km) offshore, the proposed Area of Interest falls beyond the foraging range of seals from the southern Namibian and Northern Cape colonies. Odontocetes, however, are also highly mobile, supporting the notion that various species are likely to occur in the Area of Interest and could thus potentially be attracted to the area.

Due to the proximity of drilling area to the main traffic routes, the increase in ambient lighting in the offshore environment would be of LOW intensity and limited to the area in the immediate vicinity of the vessel / drilling unit (SITE SPECIFIC for drilling unit to REGIONAL for project vessels) within the drill area (LOCAL) over the short-term (3-4 months for drilling). For support vessels travelling from Lüderitz increase in ambient lighting would likewise be restricted to the immediate vicinity of the vessel over the short-term. The potential for behavioural disturbance as a result of vessel lighting would thus be of **VERY LOW** magnitude.

Impact Significance

The potential for behavioural disturbance by vessel lighting is deemed to be of **VERY LOW** significance, due to the medium sensitivity of the receptors and the low magnitude.

Identification of Mitigation Measures

The use of lighting on the project vessels and drill rig cannot be eliminated due to safety, navigational and operational requirements. Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	The lighting on the support vessels, and drill rig, should be reduced to a minimum compatible with safe operations whenever and wherever possible.	Avoid/Reduce at Source
2	Light sources should, if possible and consistent with safe working practices, be positioned in places where emissions to the surrounding environment can be minimised	Avoid/Reduce at Source
3	Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard boxes) for subsequent release during daylight hours.	Repair or Restore
4	Report ringed/banded birds to the appropriate ringing/banding scheme (details are provided on the ring).	Repair or restore

Residual Impact Assessment

With the implementation of the mitigation measures above, the residual impact would remain **VERY LOW**.

4	*Disturbance and behavioural changes in pelagic fauna due to vessel and drill rig lighting and flaring*	
Project Phase:	**Mobilisation, Operation & Demobilisation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	MEDIUM	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Significance	**VERY LOW**	**VERY LOW**
	Pre-Mitigation Impact	**Residual Impact**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**VERY LOW**
Cumulative potential	**POSSIBLE**	**POSSIBLE**

4.4 Potential Impacts related to Drilling and Associated Activities

Apart from Sink *et al.* (2010), who reported significant differences in benthic infaunal assemblages at distances up to 250 m from a well head in ~120 m depth off Mossel Bay in South Africa, there are few studies that have examined the impacts of hydrocarbon infrastructure and well drilling on deepwater benthic communities in Southern Africa. In their assessment of impacts associated with hydrocarbon exploration, Biccard *et al.* (2018) concluded that the direct and indirect risks associated with drilling discharges during exploration well drilling were mostly very low or low, with only the disturbance and/or destruction of hard-bottom communities being high. Due to limited opportunities for sampling, the benthic biota of the outer shelf, continental slope and beyond into the abyss are very poorly known, and quantitative data on the biota from depths beyond the shelf break are largely lacking.

Although not directly comparable to Southern Africa, several studies have been conducted in other parts of the world (USA, Mexico, North Sea) where there has been full oil and gas field production since the 1970s (Neff 2005; IOGP 2003; Trefry *et al.* 2013; IOGP 2016, to name a few). These studies provide a good indication of possible impacts to benthic habitats that might be expected in future petroleum exploration and production activities in southern Namibia. The identified environmental aspects and the related potential impacts are discussed and assessed below using information from the international literature.

4.4.1 Drilling and Placement of Infrastructure on the Seafloor

4.4.1.1 Impact of Physical Seabed Disturbance on Benthic biota

Source of Impact

The project activities that will result in impacts to benthic biota as a consequence of the disturbance of seabed sediments are listed below.

Project phase	Activity
Mobilisation	n/a
Operation	Sediment coring survey
	Pre-drilling ROV seabed survey
	Spud and start of drilling - Installation of the conductor pipe, wellhead and BOP
	Plug well with cement
	Removal of BOP
Demobilisation	Abandonment of wellhead

These activities and their associated aspects are described further below.

- During pre-drilling surveys, piston coring and box coring will be undertaken to obtain samples of the seabed sediments. The recovered piston cores will be visually examined for indications of hydrocarbons (gas hydrate, gas parting or oil staining) and sub-samples retained for further geochemical analysis onshore. Box core samples will be subsampled and analysed for sediment size distribution and invertebrate macrofauna. Such sampling will remove seabed sediments in the sampling footprint and the drop-weight of the piston corer can crush benthic biota as it hits the seabed.
- During pre-drilling surveys, a ROV will be deployed to obtain video footage of the seabed at the proposed well location. Although the standard operating procedure is not to land or rest the ROV on the seabed, the ROVs thrusters can stir up the soft or silty sediments when operating close to the seabed. This resuspension of fine sediments would temporarily disturb seabed communities and result in localised increased turbidity.
- The current well-design parameter is to have a wellbore diameter of 42 inches (107 cm) during spudding. The penetration of the seabed by the drill bit would physically disturb a maximum surface area of 0.9 m^2 per well (i.e. 9 m^2 cumulatively for 10 wells), and displace deeper sediments into a conical cuttings pile around the wellhead. Casing of the hole and installation of the wellhead and BOP would potentially also result in localised direct disturbance of an area of about 3 m^2 around the well site (i.e. 30 m^2 cumulatively for 10 wells).
- Before demobilisation, the BOPs would be removed and the well(s) would be plugged, tested for integrity and abandoned, irrespective of whether hydrocarbons have been discovered in the reserve sections. Cement plugs would be set inside the well bore and across any reserve sections. Excess cement used during plugging is similarly discarded on the seabed. Removal of the BOP (which will include the use of a ROV) and plugging would result in localised direct disturbance of the seabed around the well site.

Impact Description

Any benthic biota in the footprint of the ROV skids or equipment lost to the seabed, would either be disturbed or crushed (ROV, lost equipment) or would be completely eliminated (drilling, installation of casing, wellhead and over trawlable cap) (direct negative impact). Drilling of exploration wells in the Area of Interest in Block 2912 would result in the direct physical disturbance and removal of sediments, with potential changes in sediment characteristics and condition. Casing of the hole and installation of the wellhead may further disturb or crush benthic biota present on the seabed and in the sediments.

Physical disturbance of the seabed, through the resuspension of sediments by ROV thrusters may also occur during ROV surveys, resulting in increased turbidity near the seabed, potentially with physiological effects on benthic communities (indirect negative impact). Disturbance of seabed sediments during pre-drilling ROV surveys could potentially increase turbidity of the near-bottom water layers thereby placing transient stress on sessile and mobile benthic organisms, by negatively affecting filter-feeding efficiency of suspension feeders or through disorientation of mobile species due to reduced visibility (reviewed by Clarke and Wilber 2000).

Project Controls

Based on pre-drilling ROV survey(s), the well(s) will specifically be sited to avoid sensitive hardgrounds, as the preference will be to have a level surface area to facilitate spudding and installation of the wellhead.

Contactors will also ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT.

Sensitive Receptors

The drilling activities would be undertaken in the offshore marine environment (290 km from the coastline at its nearest points) where the Namib Lower Slope and Namib Abyss habitats have been rated as 'Least Threatened' due to the expansive areas they occupy.

The benthic biota inhabiting unconsolidated sediments of the continental slope and abyss are very poorly known, but at the depths of the proposed well drilling are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise urchins, holothurians, sea stars, brittle stars, burrowing anemones, molluscs, seapens, crabs and shrimps, and sponges, many of which are longer lived and therefore more sensitive to disturbance. No rare or endangered species have been reported or are known from the continental slope and abyssal unconsolidated sediments. The sensitivity of the benthic communities of unconsolidated sediments is therefore considered **LOW**.

In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. Should they occur in the Area of Interest, the sensitivity of such deep water reef communities to physical disturbance is considered **HIGH**.

Impact Magnitude

Disturbance of sediments due to ROV Surveys

Any disturbance of benthic biota through increased turbidity and elevated suspended sediment concentrations in near-bottom waters would be of VERY LOW intensity, and limited to the turbidity plume generated by the ROV thrusters (SITE SPECIFIC) (a few metres around the ROV and/or ROV flight track). However, in most cases sub-lethal or lethal responses would occur only at concentrations well in excess of those anticipated due to resuspension of sediments by ROV thrusters. Marine communities of continental shelf waters along the southern Namibian coast can be expected to have behavioural and physiological mechanisms for coping with increased turbidity in their near bottom habitats. Any turbidity effects would be transient only as sediments would redeposit after the ROV has departed the area. Any impacts would thus persist over the SHORT-TERM (hours) only resulting in the impact being of **VERY LOW** magnitude.

Loss or disturbance of the benthos due to smothering under the spoil mounds generated by disposal of drilling muds and cuttings are discussed further under Section 4.4.2.

Disturbance of sediments due to coring and drilling (spudding and associated works)

The immediate effect of the physical disturbance and removal of seabed sediments on the benthos during coring and well spudding depends on their degree of mobility, with sedentary and relatively immobile species likely to be physically removed, damaged or destroyed during the disturbances associated with seabed sampling and well drilling. Considering the available area of similar habitat on and off the edge of the continental shelf off southern Namibia and the 'Least Threatened' status, and avoidance of possible hardgrounds through the ROV survey (project control), this disturbance of and reduction in benthic biodiversity can be considered of LOW intensity, and limited to the immediate vicinity of the well site (SITE SPECIFIC). As the wellhead would become colonised by succession communities after abandonment, any impacts to benthic communities would persist over the SHORT-TERM only, resulting in the impact being of **VERY LOW** magnitude.

As siting of the well(s) will specifically avoid hardgrounds this is not assessed further here. Further loss or disturbance of the benthos in unconsolidated sediments due to smothering under the spoil mounds generated by disposal of drilling muds and cuttings are discussed further under Section 4.4.2.

Impact Significance

Due to the low sensitivity of the receptors and the very low magnitude for each of the impacts considered above, the disturbance of sediments and potential loss of associated benthic communities is deemed to be of **NEGLIGIBLE** significance.

Identification of Mitigation Measures

In addition to the project controls, specifically avoiding spudding on any potential hardgrounds (using ROV footage), the following measures will be implemented to mitigate the seabed disturbance impact:

No.	Mitigation measure	Classification
1	Implement procedures for ROVs that stipulate that the ROV does not land or rest on the seabed as part of normal operations.	Abate on site
2	Design of pre-drilling site surveys to ensure there is sufficient information on seabed habitats, including the mapping of sensitive and potentially vulnerable habitats within 100 m of a proposed well site.	Avoid
3	If sensitive and potentially vulnerable habitats are detected, adjust the well position accordingly to beyond 100 m or implement appropriate technologies, operational procedures and monitoring surveys to reduce the risks of, and assess the damage to, vulnerable seabed habitats and communities.	Avoid/ reduce at source
4	Limit the area directly affected by physical contact with infrastructure to the smallest area required.	Avoid/ reduce at source

Residual Impact Assessment

This potential impact cannot be eliminated due to the necessity for pre-drilling ROV seabed surveys, and spudding. The impact thus remains **NEGLIGIBLE** for increased seabed turbidity from ROV surveys.

5	***Impacts of drilling activities on benthic macrofauna due to seabed disturbance***	
Project Phase:	**Operation and Demobilisation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	LOW	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	SITE	SITE
Duration	SHORT	SHORT
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Probability	**HIGHLY LIKELY**	**HIGHLY LIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.4.2 Discharge of Cement, Cuttings and Drilling Fluids

Source of Impact

The project activities that will result in impacts to benthic biota as a consequence of sediment disturbance and smothering by accumulation of cement, drill cuttings and drilling fluids are listed below.

Project phase	Activity
Mobilisation	n/a
Operation	Discharge of drilling cuttings and muds (WBM) during the initial riserless drilling phase
	Discharge of residual cement during casing installation at the end of the riserless stage
	Discharge of drill cuttings and NADFs below sea surface during the risered drilling phase
	Discharge of excess fluids and residual cement during plugging of well
Demobilisation	n/a

These activities and their associated aspects are described further below.

- The cuttings from the initial (riserless) top-hole sections of the well (drilled with WBMs) are discharged onto the seafloor where they would accumulate in a conical cuttings pile around the wellhead. In the order of 1 086 tons of cuttings would be generated at the wellbore. In addition to the cuttings, approximately 864 tons of WBM will be discharged onto the seafloor over a period of 7 days (55 hrs in 2 batches plus lagtime between operations) (see Table 1). Further muds are released from the drilling unit during the displacement phase, at the end of the 26˝ section. The mud used during these processes is a High Viscous Gel sweeps / KCl Polymer PAD mud, of which releases totalling 1 040 tons would occur over a period of 6 hours.

- After the surface casing string is set in a well, specially designed cement slurries are pumped into the annular space between the outside of the casing and the borehole wall. To ensure effective cementing, an excess of cement is usually used. This excess (100 m^3 in the worst case) emerges out of the top of the well onto the cuttings pile, where (depending on its mix) it either does not set and dissolves slowly into the surrounding seawater, or if it remains in a pile, may act as an artificial reef, be colonised by epifauna and attract fish and other mobile predators (Buchanan *et al*. 2003).

- During the risered drilling stage, the primary discharge from the drilling unit would be the drill cuttings. The chemistry and mineralogy of the rock particles reflects the types of sedimentary rocks penetrated by the bit. Cuttings from lower hole sections (drilled with NADFs) are lifted up the marine riser to the drilling unit and separated from the drilling fluid by the on-board solid control systems. The solids waste stream is discharged overboard through the cutting chute, which would be located 10 m below the sea surface. Cuttings released from the drilling unit would be dispersed more widely around the drill site by prevailing currents. In the order of 752 tons of cuttings and 104 tons of or NADFs will be discharged from the drill unit (see Table 1).

Cuttings and mud released during the risered stage would be discharged over a period of ~14 days (180 hrs in 3 batches plus lagtime between operations).

- Before demobilisation, the well(s) would be plugged, tested for integrity and abandoned, irrespective of whether hydrocarbons have been discovered in the reserve sections. Cement plugs would be set inside the well bore and across any reserve sections.

4.4.2.1 Impact of Cuttings, Drilling Fluid and Cement Discharge on Marine Biota

4.4.2.1.1 Smothering of benthic biota/habitats by cuttings, drilling fluid and cement on seabed

Impact Description

The discharge of cuttings and WBM onto the seabed from the top-hole section of the well and the discharge of treated cuttings with NADF from the drill rig during the risered drilling stage would have both direct and indirect effects (assessed in section 4.4.3) on benthic communities in the vicinity of the wellhead and within the fall-out footprint of the cuttings plume discharged from the drill rig.

The cuttings and WBMs from the top-hole sections of the well are discharged onto the seafloor at the wellbore where they would accumulate in a conical cuttings pile around the wellbore thereby smothering or crushing invertebrate benthic communities living on the seabed or within the sediments (direct negative impact). Cuttings and associated NADF drilling muds discharged from the drill rig would disperse and settle over a wider area around the wellhead resulting in changes in sediment structure and community composition within the fall-out footprint of the cuttings plume.

The discharge of residual cement during cementing of the first string (surface casing) and plugging of the well on demobilisation would result in accumulation of cement on the seabed and on the cuttings pile, respectively. Any benthic biota present on the seabed may potentially be smothered (direct impact) by the residual cement or suffer indirect toxicity and bioaccumulation effects due to leaching of potentially toxic cement additives (see section 4.4.3).

Project Controls

The operator will also ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT. The following controls will be implemented:

- Based on pre-drilling ROV survey(s), the well(s) will specifically be sited to avoid sensitive or potentially vulnerable hardground habitats as the preference will be to have a level surface area to facilitate spudding and installation of the wellhead.
- Should WBMs not be able to provide the necessary characteristics for drilling during the risered stage, a low toxicity Group III NADF will be used. In this instance, an "offshore treatment and disposal" strategy will be implemented (i.e. cuttings will be treated offshore to reduce oil content to <6% Oil On Cutting (OOC) and discharged overboard).
- Discharge of risered cuttings *via* a caisson at greater than 10 m below surface to reduce dispersion of the cuttings in surface currents.

Sensitive Receptors

The drilling activities would be undertaken in the offshore marine environment, more than 290 km offshore where the Namib Lower Slope and Namib Abyss habitats have been rated as of 'Least Threatened' due to the expansive areas they occupy. See section 4.4.1.1 for details on sensitivities. The overall sensitivity of these receptors is considered **LOW**.

In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. No deep canyons, valleys or hard grounds have been reported for the area. However, should they occur, the sensitivity of such deep water reef communities to physical disturbance is considered **HIGH**.

Impact Magnitude

Disturbance and/or Smothering of the Seabed due to discharge of Drilling Muds and Cuttings

The effects of drilling mud and cuttings discharges on the benthic environment are related to the total mass of drilling solids discharged, whether these are discharged at the seabed or off the drilling unit, and the relative energy of the water column and benthic boundary layer at the discharge site. The total volume of cuttings discharged during the drilling of a well would be dependent upon the well depth and the drilling conditions encountered. With increasing well depth and concomitant decrease in both penetration rate and wellbore diameter, the rate of cuttings discharged decreases.

The cuttings discharged at the seabed during the spudding of a well would form a highly localised spoil mound around the wellbore, thinning outwards. In contrast, the cuttings discharged from the drilling unit form two plumes as they are discharged. The larger particles and flocculated solids, which constitute ~90% of the discharge, settle to the seabed nearest the wellbore while the fine-grained unflocculated solids and soluble components of the mud (10% of the discharge) are rapidly diluted in the receiving waters and dispersed in the water column at increasing distances from the drill unit (Figure 49) (Neff 2005). The dispersion pattern and degree of accumulation depends on water depth, current strength and the frequency of storm surges (Buchanan *et al*. 2003).

In high energy environments, where surface currents are strong and highly variable directionally but bottom currents are weaker with less directional variability, accumulation of drilling discharges on the seabed is minimal as the drilling solids are rapidly dispersed and redistributed. Under such conditions adverse effects of the discharges on benthic community composition are difficult to detect above the natural variability (Lees & Houghton 1980; Houghton *et al*. 1980; Bothner *et al*. 1985; Neff *et al*. 1989; Daan & Mulder 1993, 1996). Where changes in abundance and diversity of macrofaunal communities were detected in other studies, these were typically restricted to within about 100 m of the discharge, but did not persist much beyond six months after drilling operations had ceased (Chapman *et al*. 1991; Carr *et al*. 1996; Currie & Isaacs 2005).

However, in low-energy, deep-water environments, such as those in Block 2912, the effects of drilling discharges on benthic ecosystems are more severe and long-lasting. Typically, the coarse cuttings accumulate within 200 m of the drilling unit, although depending on the strength of prevailing current, some may disperse as far as 800 m from the drilling unit. Some authors report that cuttings piles near a rig can be 1-2 m high (Hinwood *et al*. 1994; Hartley *et al*. 2003; Neff 2005), but these were usually associated either with the disposal of NADF cuttings, which tend to aggregate once discharged and thus disperse less readily resulting in a smaller area but thicker deposition on the seabed, or with cuttings shunted to and discharged near the seabed. The results of international modelling studies and physical

sampling exercises have indicated that the majority of discharges would have a maximum accumulated height of less than 8 cm around the well bore during and immediately after drilling, with fine-sediment cover of less than 2 mm thickness likely to extend to ~0.5 km from the discharge point (Perry 2005).

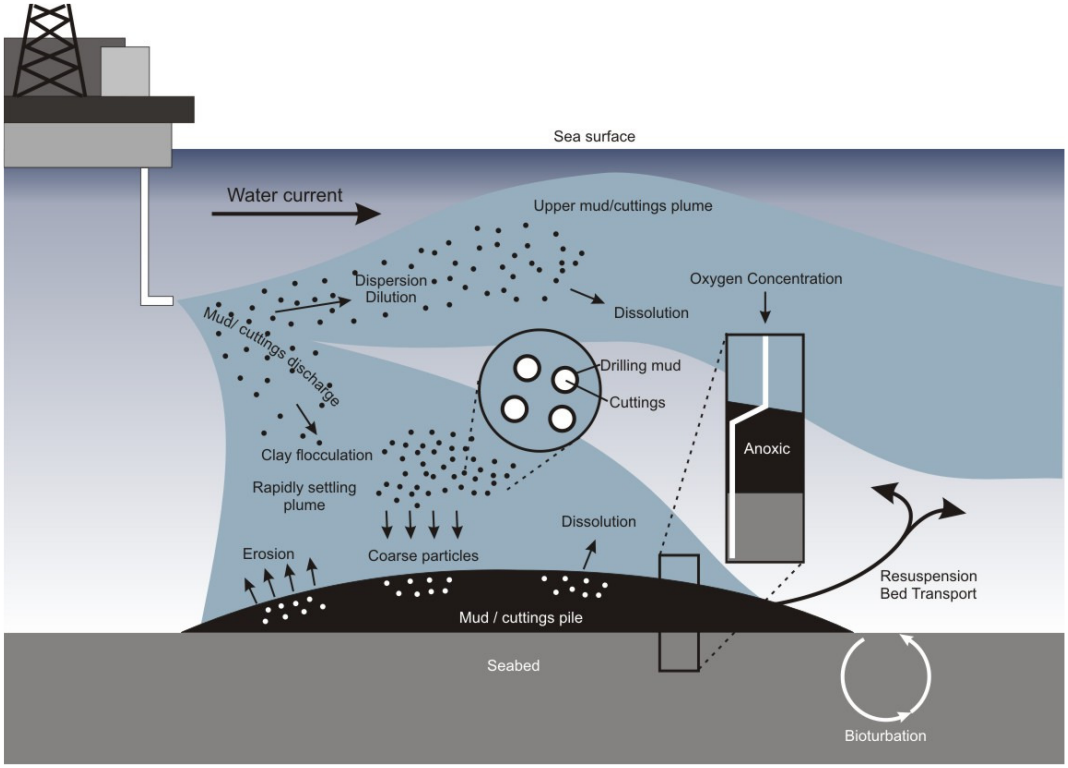


Figure 49: Hypothetical dispersion and fates of cuttings following discharge to the ocean, from a drilling unit. The solids undergo dispersion, dilution, dissolution, flocculation, and settling in the water column. If the discharge contains a high concentration of organic matter, the cuttings pile may become anaerobic near the surface, before being altered by redox cycling, bioturbation, and bed transport (adapted from Neff 2005).

Ecological impacts in response to cuttings disposal are typically characterised by reduced species diversity, enrichment of opportunistic and/or pollution-tolerant fauna and a loss of more sensitive species (Ellis *et al*. 2012; Paine *et al*. 2014). A recent study by Jones *et al*. (2012), however, reported significant increases in densities and richness of motile megabenthic epifauna immediately after drilling, presumably attracted to available carcasses of sessile organisms killed by drilling disturbance (see also Jones *et al*. 2007; Hughes *et al*. 2010). Sessile megafaunal densities and richness increased significantly with increasing distance from drilling, with partial megabenthic recovery between 3 and 10 years post-disturbance (Gates & Jones 2012; Jones *et al*. 2012). Such community changes are, however, rarely measurable beyond 500 m of the drilled area (Neff *et al*. 1992; Ranger 1993; Montagna & Harper 1996; Schaanning *et al*. 2008; Sink *et al*. 2010), with recovery of the benthos observed to take from several months to several years after drilling operations had ceased (Husky 2000, 2001a, 2001b; Buchanan *et al*. 2003; Neff 2005; Currie & Isaacs 2005; Netto *et al*. 2010; Gates & Jones 2012; Jones *et al*. 2012). Exceptions to this have, however, been reported especially for sensitive species (reviewed by Ellis *et al*. 2012; Cordes *et al*. 2016). The potential environmental effects (both smothering and toxicity) of drilling solids discharges have been discussed in several studies (Morant 1999; Husky 2000, 2001a; CAPP 2001; Hurley & Ellis 2004), all of which concluded that exploratory drilling with WBMs has no enduring ecological impacts on the marine environment.

The main impacts associated with the disposal of drilling solids would be smothering of sessile benthic biota, physical alteration of the benthic habitat (changes in sediment properties) in the immediate vicinity (<200 m) of the well. The effects of smothering on the receiving benthic macrofauna are determined by 1) the depth of burial; 2) the nature of the depositing sediments; 3) the tolerance of species (life habitats, escape potential, tolerance to hypoxia etc.) and 4) duration of burial (which is linked to the species tolerance) (Kranz 1974; Maurer *et al*. 1981a, 1981b, 1982, 1986; Bijkerk 1988; Hall 1994; Baan *et al*. 1998; Harvey *et al*. 1998; Essink 1999; Schratzberger *et al*. 2000b; Baptist *et al*. 2009).

Many benthic infaunal species are able to burrow or move through the sediment matrix, and some infaunal species are able to actively migrate vertically through overlying deposited sediment thereby significantly affecting the recolonisation and subsequent recovery of impacted areas (Maurer *et al*. 1979, 1981a, 1981b, 1982, 1986; Ellis 2000; Schratzberger *et al*. 2000a; Harvey *et al*. 1998; Blanchard & Feder 2003). Maurer *et al*. (1979) reported that some animals are capable of migrating upwards through 30 cm of deposited sediment. In contrast, consistent faunal declines were noted during deposition of mine tailings from a copper mine in British Columbia when the thickness of tailings exceeded 15-20 cm (Burd 2002), and Schaffner (1993) recorded a major reduction in benthic macrofaunal densities, biomass, and species richness in shallow areas in lower Chesapeake Bay subjected to heavy disposal (>15 cm) of dredged sediments. Similarly, Roberts *et al*. (1998) and Smith and Rule (2001) found differences in species composition detectable only if the layer of instantaneous applied overburden exceeded 15 cm (see also Bakke *et al*. 1986; Trannum *et al*. 2011). In general, mortality tends to increase with increasing depth of deposited sediments, and with speed and frequency of burial.

The survival potential of benthic infauna, however, also depends on the nature of the deposited non-native sediments (Turk & Risk 1981; Chandrasekara & Frid 1998; Schratzberger *et al*. 2000a). Although there is considerable variability in species response to specific sediment characteristics (Smit *et al*. 2006), higher mortalities were typically recorded when the deposited sediments have a different grain-size composition from that of the receiving environment (Cantelmo *et al*. 1979; Maurer *et al*. 1981a, 1981b, 1982, 1986; Smit *et al*. 2006; Smit *et al*. 2008), which would be the case in the discharge of drill cuttings. Migration ability and survival rates of organisms are generally lower in silty sediments than in coarser sediments (Hylleberg *et al*. 1985; Ellis & Heim 1985; Maurer *et al*. 1986; Romey & Leiseboer 1989, cited in Schratzberger *et al*. 2000a; Schratzberger *et al*. 2000b). Some studies indicate that changes to the geomorphology and sediment characteristics may in fact have a greater influence on the recovery rate of invertebrates than direct burial or mortality (USDOI/FWS 2000). The availability of food in the depositional sediment is, however, also influential.

The duration of burial would also determine the effects on the benthos. Here a distinction must be made between incidental deposition, where species are buried by deposited material within a short period of time (as would occur during drilling solids disposal), and continuous deposition, where species are exposed to an elevated sedimentation rate over a long period of time (e.g. in the vicinity of river mouths). Provided the sedimentation rate of incidental deposition is not higher than the velocity at which the organisms can move or grow upwards, such deposition need not necessarily have negative effects. The sensitivity to short-term incidental deposition is species dependent and also dependent on the sediment type, with deposition of silt being more lethal than a deposition of sand.

The nature of the receiving community is also of importance. In areas where sedimentation is naturally high (e.g. wave-disturbed shallow waters) the ability of taxa to migrate through layers of deposited sediment is likely to be well developed (Roberts *et al*. 1998). In the case of sedentary and relatively

immobile species that occur in waters beyond the influence of aeolian and riverine inputs (such as offshore waters in the area of interest), they will be more susceptible to smothering. However, deep-water fauna inhabiting unconsolidated sediments usually comprise fast-growing species that are able to rapidly recruit into disturbed areas. In contrast, the benthos associated with hard substrata is typically vulnerable to disturbance due to their long generation times.

There has recently been increasing focus on the potential impacts of drilling solids disposal on vulnerable deep-water coral communities in the Northeast Atlantic (Rogers 1999; Colman *et al*. 2005; www.coralreef.noaa.gov/deepseacorals/threats). As deep-water corals tend to occur in areas with low sedimentation rates (Mortensen *et al*. 2001), these benthic suspension-feeders and their associated faunal communities are likely to show particular sensitivity to increased turbidity and sediment deposition associated with cuttings discharges. Exposure of corals to drilling solids can result in mortality of the colony due to smothering, alteration of feeding behaviour and consequently growth rate, disruption of polyp expansion and retraction, physiological and morphological changes, and disruption of calcification (Dodge & Szmant-Froelich 1985; Roberts *et al*. 2006; Larsson & Purser 2011; Larsson *et al*. 2013. While tolerances to increased suspended sediment concentrations will be species specific, drilling mud concentrations as low as 100 mg/ℓ have been shown to have noticeable effects on coral function (Roger 1999). Lepland and Mortensen (2008) identified that deep-water corals on the Norwegian shelf, downcurrent of a test well discharge, did not show clear differences in health status, although barite crystals derived from the drilling mud were present among trapped sediments in the skeleton cavities of dead coral polyps older than six years, with highest barite concentration found in a polyp older than 13 years. The impacts of drilling discharges on more fragile ecosystems such as cold-water corals are thought to persist for longer than recorded for soft-sediment communities (Fisher *et al*. 2014; Cordes *et al*. 2016). Such sensitive deep-water ecosystems have not been reported for Block 2912. International best practice recommends that pre-drilling site surveys be carefully designed to provide sufficient information on seabed habitats on and in the vicinity of the proposed drill sites, and appropriate technologies and monitoring surveys implemented to reduce the risks of, and assess the damage to, vulnerable seabed habitats and communities should they occur in the target area (Jødestøl & Furuholt 2010; Purser & Thomsen 2012; Purser 2015). In this regard, a set-back distance of 610 m (2 000 ft) for sea surface discharge of drilling discharges from sensitive deep-water communities is mandated in US territorial waters.

The life-strategies of organisms are a further aspect influencing the susceptibility of the fauna to mortality. Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat (e.g. hake, kingklip; all of which spawn inshore of the Area of Interest for drilling and potential depositional footprints of discharges, which extend to a maximum of 1.8 km from the discharge point in a WNW direction) may be negatively affected by the smothering effects of drill cuttings. Studies on the burrowing habits of 30 species of bivalves showed that mucous-tube feeders and labial palp deposit-feeders were most susceptible to sediment deposition, followed by epifaunal suspension feeders, boring species and deep-burrowing siphonate suspension-feeders, none of which could cope with more than 1 cm of sediment overburden. Infaunal non-siphonate suspension feeders were able to escape 5 cm of burial by their native sediment, but normally no more than 10 cm (Kranz 1972, cited in Hall 1994). The most resistant species were deep-burrowing siphonate suspension-feeders, which could escape from up to 50 cm of overburden. Meiofaunal species appear to be less susceptible to burial than macrofauna (Menn 2002).

Cuttings dispersion modelling:

The results of the cuttings dispersion modelling studies undertaken as part of this project (ProOceano 2023) largely confirm the reports of international studies that predicted that the effects of discharged cuttings are localised (see Perry 2005). A single discharge location was selected for the purposes of the modelling study; located on the eastern boundary of the licence block, ~310 km from the coast in 3 200 m depth. For the current project, ~1 838 tons of cuttings would be generated, of which 1 086 tons would be discharged directly at the seafloor (59% of the total volume of cuttings generated), with the remaining 752 tons discharged off the drill unit, after treatment to reduce oil content to <6% Oil On Cutting, into the water column. In addition, approximately 1 904 tons of WBM (riserless: 864 t; displacement: 1 040 t) will be discharged onto the seafloor at the wellbore with an additional 104 tons of NADFs discharged from the drilling unit. These discharges are pulsed throughout the drilling campaign (Base case: 34 days), reflecting the five periods corresponding to the different wellbore diameters. Four scenarios, representing the four seasons (Season 1: December – February; Season 2: March – May; Season 3: June – August; Season 4: September – November) were modelled for each discharge to account for metocean data variability. Only the most conservative (worst-case) results from these scenarios are highlighted below.

The cuttings discharged at the seabed during the riserless drilling stage typically create a cone close to the wellbore, thinning outwards. The spatial extent of the cuttings pile depends on the volume of cuttings discharged and the local hydrodynamic regime: in areas with strong currents, the cuttings piles often have an elliptical footprint with the long axis of the ellipse aligned with the predominant current direction (Breuer *et al*. 2004).

Thickness Deposits

- For the current project the cuttings mound at the wellbore at the modelled discharge point at the end of drilling operations (i.e. at the end of both the riserless and risered drilling stages) will amount to a maximum depositional thickness of 338 mm (0.338 m) extending up to 67 m south of the discharge point (Season 4), progressively thinning out in a WNW direction to 0.1 mm at a maximum distance of 1.566 km from the discharge (Figure 50, top). The maximum distance reached by a threshold depositional thickness of >6.5 mm was 88 m (Season 1), whereas the maximum distance reached for thickness >0.1 mm was 1 834 m (Season 3) in a SW direction. For Seasons 1, 2 and 4, the maximum distance reached for a depositional thickness of >0.1 mm was less extensive than for the Season 3 (Season 1: 1 264 m; Season 2: 880 m and Season 4: 1 566 m).
- Most of the deposit (60%) is attributable to the riserless discharges at the seabed from drilling of the top hole sections (42″ and 26″), remaining close to the discharge points due to the low current speeds at the seabed.
- The cuttings deposit thickness does not show recovery with time, showing negligible decrease in thickness 10 years after the operations. This can primarily be attributed to weak bottom currents at the well locations. The environmental risks[4] associated with the riserless drilling stage are primarily physical, induced by the thickness deposit at the discharge point.

[4] The environmental risk assessment used in the drillings discharge modelling uses the conventional PEC (Predicted Environmental Concentration) / PNEC (Predicted No Effect Concentration) ratio approach. This ratio gives an indication of the likelihood of adverse environmental effects occurring as a result of exposure to the contaminants and is based on the comparison of the ecosystem exposure to a compound (or deposition thickness) with the ecosystem sensitivity for this compound (or deposition thickness). A significant risk corresponds to a calculated concentration (or thickness) in the environment (exceeding the predicted no effect concentration to a level likely to potentially impact 5% of species in a typical ecosystem.

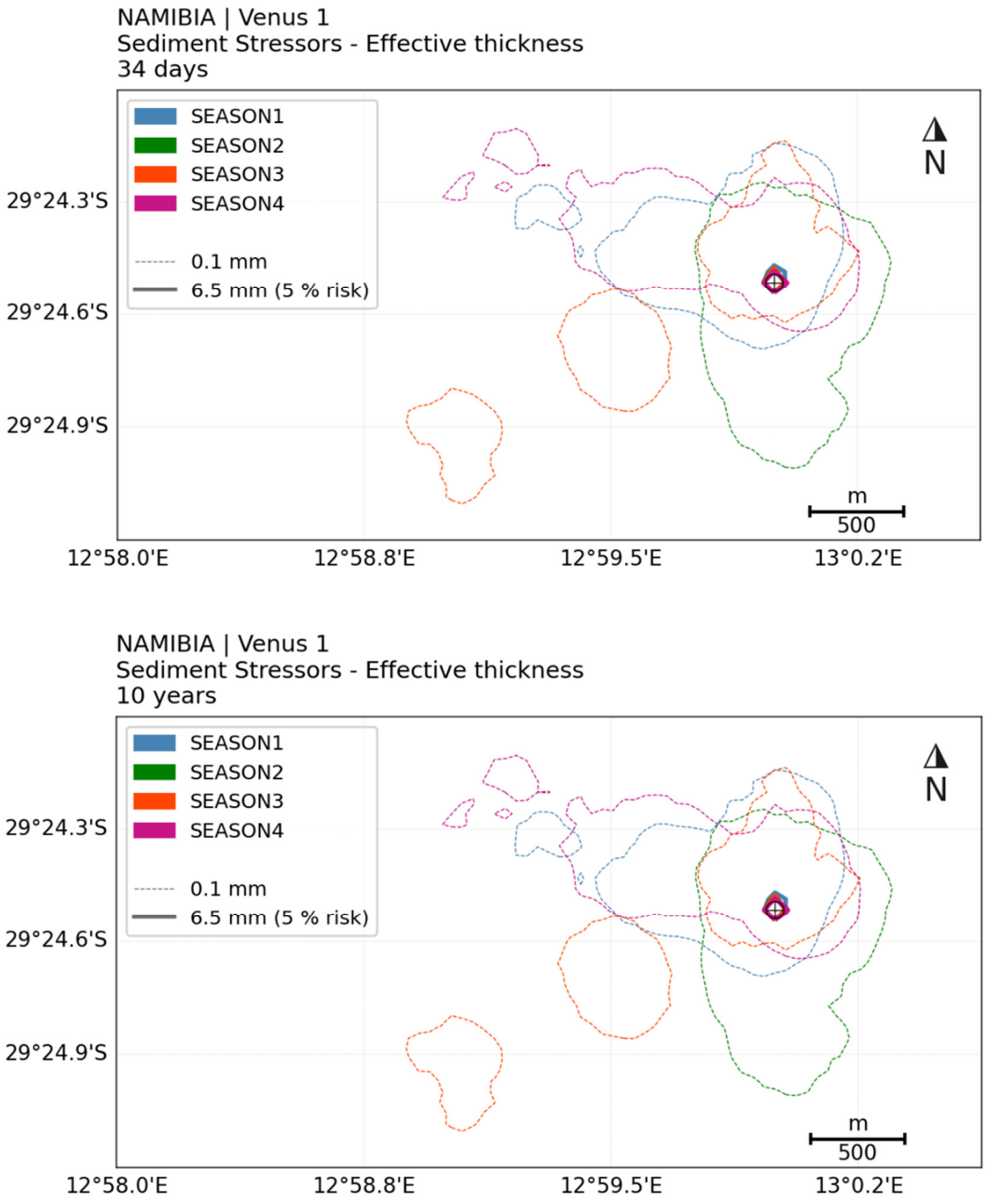


Figure 50: Effective cuttings thickness deposit on the seabed at the end of drilling operations (34 days) (top), and after 10 years (bottom) (Source ProOceano 2023).

Grain-size Variation

- As would be expected, the riserless discharges resulted in the greatest variation in grain size in surficial sediments to those originally present, with the maximum variation recorded at the end of operations being 13 089% (compared to a natural median grain size of 7 µm) (Worst case: Season 1), but confined to a maximum distance from the wellbore of no more than 19 m.
- Change in grain size around the wellbore associated with the riserless drilling stage are primarily physical, accounting for a maximum of 5.1% (Season 4) to the total Environmental Impact Factor.

Although information on benthic communities beyond the shelf break is lacking, those on the shelf in the region show a high natural variability (Steffanie *et al*. 2015; Biccard *et al*. 2019; Gihwala *et al*. 2019), mainly determined by sediment structure. Similarly, the structure of the community developing after an impact depends on (1) the nature of the impacted substrate, (2) environmental factors such as bedload transport, near-bottom dissolved oxygen concentrations etc., and (3) differential re-settlement of larvae into the area, migration of mobile species into the area and from burrowing species migrating upwards back to the surface. The structure of the recovering communities beyond the shelf will thus likely be highly spatially and temporally variable. Where grain size variation relative to the original sediment structure is low, relatively rapid recolonisation of benthic infauna can thus be expected (see for example Kingston 1987, 1992; Trefry *et al*. 2013), with subsequent bioturbation playing an important role in the physical recovery of the seabed (Munro *et al*. 1997). However, near the wellbore where cumulative deposition thickness and grain size variability are high, and the original fauna was severely disturbed or eliminated through smothering, the benthos would take longer to recover to functional similarity as re-establishment of benthic communities depends on recolonisation (Trannum *et al*. 2011).

Magnitude of smothering of unconsolidated sediments: in assessing this impact, it is important to note, that the depositional footprints on the seabed of the drilling discharges are located in lower slope and abyssal habitats rated as 'Least Threatened'. Similarly, the sediment plume may overlap with the proposed ESAs in the Area of Interest depending on the location of the well(s). The depositional footprints are also highly localised, and overlap of concentrations of total discharge in the superficial layers of seabed sediments with these sensitive ecosystem types would be negligible. Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat may be negatively affected by smothering effects. However, the major fish spawning areas for commercial species such as hake and kingklip, occur further inshore on the shelf to the east of the Area of Interest and beyond the chemical footprint (see Figure 23). The smothering effects resulting from the discharge of drilling solids at the wellbore is assessed to have an impact of MEDIUM intensity on the benthic macrofauna of unconsolidated sediments in the cuttings footprint due to the higher deposit thickness and grain size variation associated with riserless discharges. Mortality of most fauna can be expected if deposit thickness of drilling solids at the well bore is >30 mm; this would, however, be expected only within a few metres around the well bore. Discharges from the drilling unit would have a LOW intensity impact as the depositional footprint would have a considerably lower deposit thickness, but be spread over a larger area (although outside of key spawning areas). Some biota will be smothered, but many will be capable of burying up through the deposited drilling solids. For the discharge of drilling solids at the wellbore the impact is highly localised (SITE SPECIFIC deposition of >6.5 mm confined to within <100 m of the well bore per well), whereas discharges from the drilling unit would have LOCAL impacts (up to 1.8 km to the WNW from the drilling unit per well). Since the model predicts that physical changes to the sediment structure within the deposition footprint would persist for over 10 years, recovery of benthic communities to functional similarity is expected to occur within the LONG TERM. The impact from riserless and risered drilling is assessed to be of **MEDIUM** magnitude for all 10 wells regardless of season.

Magnitude of smothering of sensitive hard substrata: Considering the avoidance of possible hardgrounds through the ROV survey (project control) the wells would be sited in unconsolidated sediments beyond the shelf edge. Modelling shows that the largest deposition footprints extend primarily in a WNW (Season 1 and 4) and SW (Season 3) direction away from a drill site, and the sensitive ecosystem types along the shelf edge and within the Orange Seamount and Canyon Complex EBSA. The cuttings footprint does, however, overlap with an ESA located within the Area of Interest and may overlap with

as yet unmapped vulnerable communities on hard ground. The riserless drilling stage, which results in the majority of the deposit (95%), is unlikely to affect sensitive hardgrounds. Should the cuttings footprint (from discharge at the surface) overlap with unknown vulnerable communities on hard substrates the smothering effects would potentially have a LOCALISED impact (limited to a maximum distance of 1.8 km to the NW of the well site) of HIGH intensity due to the sensitivity of these long-lived, slow-growing biota to physical disturbance. Recovery would only be expected over the LONG-TERM due to the long generation times of vulnerable hard-ground communities. Should the impact occur, it can be considered to be of **HIGH** magnitude for up to 10 wells regardless of season.

Disturbance and/or Smothering of the Seabed due to Cement Release

The disturbance of and reduction in benthic biodiversity due to smothering following cementing would result in no additional impact as the cement will be discharged in an area already affected by drill cuttings in the near vicinity of the wellbore.

Impact Significance

For biota inhabiting unconsolidated sediments on the continental slope and in the abyss, the smothering effects resulting from the discharge of cuttings both at the wellbore and from the drilling unit are deemed to be of **LOW** significance due to the low sensitivity of the receptors and the medium magnitude for the impacts of smothering. However, the potential smothering effects of drilling discharges on deep-water reef communities (should they occur) are considered of **HIGH** significance due to the high sensitivity of the biota and the high magnitude of the impact.

Identification of Mitigation Measures

No.	Mitigation measure	Classification
1	Ensure there is meticulous design of pre-drilling site surveys to provide sufficient information on seabed habitats, and to map sensitive and potentially vulnerable habitats thereby preventing potential conflict with the well site. Undertake pre-drilling site surveys (with ROV) to ensure there is sufficient information on seabed habitats, including the mapping sensitive and potentially vulnerable habitats within 100 m of a proposed well site.	Avoid / reduce at source
2	Ensure that, based on the pre-drilling site survey and expert review of ROV footage, drilling locations are not located within a 100 m radius of any sensitive and potentially vulnerable habitats (e.g. hard grounds), species (e.g. cold corals, sponges) or sensitive structural features (e.g. rocky outcrops).	Avoid / reduce at source
3	If sensitive and potentially vulnerable habitats are detected, adjust the well position accordingly or implement appropriate technologies, operational procedures and monitoring surveys to reduce the risks of, and assess the damage to, vulnerable seabed habitats and communities.	Avoid / reduce at source
4	Monitor (using ROV) cement returns and if significant discharges are observed on the seafloor terminate cement pumping.	Reduce at source

Residual Impact Assessment

This potential impact cannot be eliminated due to the nature of the drilling approach and the need for and nature of the cuttings discharge. As no mitigation is proposed for communities in unconsolidated sediments (except for monitoring and the minimising discharge of cement), the significance of residual impacts would not change. For vulnerable seabed communities, however, the implementation of the

above-mentioned mitigation measures, would lower the intensity and duration (although still long term) of the impacts, and the residual impact would drop to **MEDIUM** significance.

As pre-drilling ROV surveys would reveal the presence of vulnerable habitats (e.g. hard grounds) and TEEPNA will actively avoid known sensitive seabed communities by >100 m, the likelihood of such occurring in the Area of Interest for drilling is low.

6	***Disturbance and/or Smothering of soft-sediment benthic communities due to drilling solids discharge***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	LOW	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**MEDIUM**	**MEDIUM**
Intensity	MEDIUM	MEDIUM
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
	LOW	**LOW**
Probability	**DEFINITE**	**DEFINITE**
Confidence	**HIGH**	**HIGH**
Reversibility	**PARTIALLY REVERSIBLE**	**PARTIALLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

7	***Disturbance and/or Smothering of vulnerable habitats (e.g. hardgrounds / deep-water reef communities) due to drilling solids discharge***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**HIGH**	**MEDIUM**
Intensity	HIGH	MEDIUM
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
Significance	**HIGH**	**MEDIUM**

	Pre-Mitigation Impact	Residual Impact
Probability	POSSIBLE	UNLIKELY
Confidence	HIGH	HIGH
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Loss of Resources	HIGH	LOW
Mitigation Potential	-	HIGH
Cumulative potential	UNLIKELY	UNLIKELY

4.4.2.1.2 Seabed and Water Column Toxicity and Bioaccumulation Effects on Marine Biota

Impact Description

Cement: Various chemical additives are used in the cementing programme to control its properties, including setting retarders and accelerators, surfactants, stabilisers and defoamers. The formulations are adapted to meet the requirements of a particular well. Their concentrations, however, typically make up <10% of the overall cement used. There is potential for the leaching of the additives into the surrounding water column, where they would potentially have toxic effects on benthic communities, or the potential for bioaccumulation.

Drilling fluids and cuttings: The disposal of cuttings and muds at the wellbore and from the drilling unit would have various direct and indirect biochemical effects on the receiving environment (seabed sediments and water column). The direct effects are associated with the contaminants contained in the drilling muds used during drilling operations (direct negative impact). The indirect effects result from changes to water and sediment quality. Although the cuttings themselves are generally considered to be relatively inert, the drilling muds are a specially formulated mixture of natural clays, polymers, weighting agents and/or other materials suspended in a fluid medium. The constituents and additives of the discharged muds may potentially have ecotoxicological effects on the water column and sediments. The effects may be of significance in terms of:

- Chronic accumulation of persistent contaminants in the marine environment;
- Acute or chronic effects on biota, including effects on productivity; and
- Acute or chronic effects on other biota (i.e. indirect effects on biodiversity).

Project Controls

The operator will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT. In this regard TEEPNA has various project controls in place for the proposed drilling operations. These include:

- TEEPNA has indicated it plans to use WBMs (riserless sections) and low toxicity Group III NADFs for the risered sections. For the risered sections, an "offshore treatment and disposal" strategy will be implemented (i.e. cuttings will be treated offshore to reduce oil content to <6% Oil On Cutting (OOC) and discharged overboard).
- Cuttings will be discharge 10 m below surface during risered drilling.

Sensitive Receptors

The drilling activities would be undertaken in the marine environment, more than 290 km offshore where the Namib Lower Slope and Namib Abyss habitats have been rated as of 'Least Threatened. See

description of sensitive receptors under section 4.4.2.1.1. The receptors in unconsolidated sediments are considered of LOW sensitivity. In contrast, the sensitivity of deep water reef communities is considered HIGH, however, the Area of Interest for drilling has specifically been planned to avoid such known sensitive habitats.

Impact Magnitude

Toxicity and Bioaccumulation effects of Cements

Although various chemical additives are used in the cementing programme, the additives typically have a low toxicity to marine life (Ranger 1993; Chevron 1994) and the organic additives are partially biodegradable. The additives may leach into the surrounding water column, where they may have potential toxic or bioaccumulation effects on benthic communities, but dilution in the surrounding water column would be rapid.

Toxicity and Bioaccumulation effects of Water-Based Muds (WBMs) and Non-Aqueous Drilling Fluids (NADFs)

WBMs would be used to drill the first ~870 m riserless section of each well. This drilling fluid would be discharged at the seabed together with the drill cuttings. For the current project, it is estimated that 1 086 tons of cuttings and 864 tons of WBMs will be discharged at the seabed during the riserless stage, with an additional 1 040 tons of High Viscous Gel sweeps / KCl Polymer PAD mud released during well suspension and displacement. The cuttings themselves are generally considered to be relatively inert, but may contribute small amounts of trace metals and/or hydrocarbons to receiving waters (Neff *et al*. 1987). However, most of the metals associated with cuttings are in immobile mineral forms from the geologic strata, and their composition will thus resemble that of natural marine sediments.

For the risered sections of the well, NADFs containing primarily barite (~71%) and a suite of chemicals (see Appendix 1) may be used that provide properties such as shale inhibition (reducing the hydration, swelling and disintegration of clays and shales) and degree of lubrication. Although mostly biodegradable, a number of these chemicals (e.g. EDC-99 DW, GELTON E, INVERMUL NT and EZ MUL NT) have a log K_{ow} >3, and are considered potentially hazardous to the marine environment due to their low PNEC. During the risered stage, 752 tons of cuttings and 104 tons (5% of total drilling fluid discharge) of NADFs may be discharged 10 m below the sea surface at the drilling unit.

Cuttings containing WBMs do not clump when discharged, but disperse and settle over a wide area, preventing development of significant cuttings mounds and speeding biodegradation (Getliff *et al*. 1997). In contrast, NADF cuttings tend to aggregate once discharged and thus disperse less readily resulting in a smaller area but thicker deposition on the seabed. The heavier cuttings and particles settle near the wellbore where a localised smothering effect can be expected (see previous Section). The fines generate a plume in the upper water column, which is dispersed away from the drilling unit by prevailing currents, diluting rapidly to background levels at increasing distances from the drill unit. Despite the widespread dispersion of the cuttings, toxicity effects may occur in the seabed sediments and in the water column from the potential solution of the constituents and additives of the discharged WBMs and NADFs muds. These are discussed further below.

WBMs are generally assumed to be less toxic than NADFs causing only marginal effects on the benthos resulting mainly from sedimentation (Ellis *et al*. 2012). The zone of biological effects on benthic community diversity and abundance ranged from 0.1 to 1 km for both water and synthetic fluids. Typically, the major ingredients that make up over 90% of the total mass of the WBFs are fresh or sea water, the barium sulphate (barite) (weighting agents), bentonite clay (viscosifier), lignite,

lignosulphonate, and caustic soda (pH control). Low concentrations of other typically biodegradable organic compounds are added to gain the desired density and drilling properties. Effects on the benthos is thus primarily physical, through accumulation of fine particles (disruption of filter feeding) or burial of epi- and in-faunal benthic organisms (Paine *et al*. 2014) as discussed in Section 4.4.2 above. However, some WBMs, particularly those containing glycols or organic long chain screen blinding polymers, have been found to cause temporary organic enrichment of sediments, resulting in a reduction in abundance, biomass and diversity of sensitive macrofaunal species (Schaanning *et al*. 2008; Trannum *et al*. 2010, 2011), although enrichment effects on tolerant species have also been reported (Paine *et al*. 2014). Other sub-lethal effects of metals contained in barite (Edge *et al*. 2016) may play an additional role (see below), with lagged responses three to five years after drilling started suggesting chronic or indirect effects (Paine *et al*. 2014).

Cuttings dispersion modelling:

Environmental Risk due to Contaminant Concentrations in the Sediments

- The risk related to the sections drilled with the riser is much higher than the potential risk induced by the riserless sections (which has a negligible impact and is physical rather than chemical). The sediment environmental risk of the sections drilled with a riser is more chemical than physical, due to EZ MUL NT (mostly fatty acid component of the product), INVERMUL NT (mostly the fatty acid component) and EDC-99 DW (base oil) and GELTON E (viscosifier).
- The risered sections of the well represent a significant risk above the threshold at which 5% of the species in the ecosystem are likely to be affected. This risk is primarily associated with the chemicals from the drilling muds remaining in the sediments. There is no trace of chemical risk due to the riserless section discharges. The drill cuttings discharge model determined that a significant risk of concentration of chemicals in the sediments was only observed for Season 1 extending up to 176 m from the discharge at the end of operations (34 days). Results for the maximum summary for the same point emphasise the slow recovery of seabed impacts at such depths under low current conditions. However, this risk remains highly localised (Figure 51).
- The maximum distance from the discharge point at which a significant cumulative risk was calculated at the end of the drilling operations was 760 m to the WSW of the discharge site (Season 3) (Figure 51). As would be expected, the risk is not centralised around the discharge point, but is orientated towards the direction of the prevailing current, illustrating the strong influence of surface currents on drill cuttings dispersion and redeposition on the seabed.

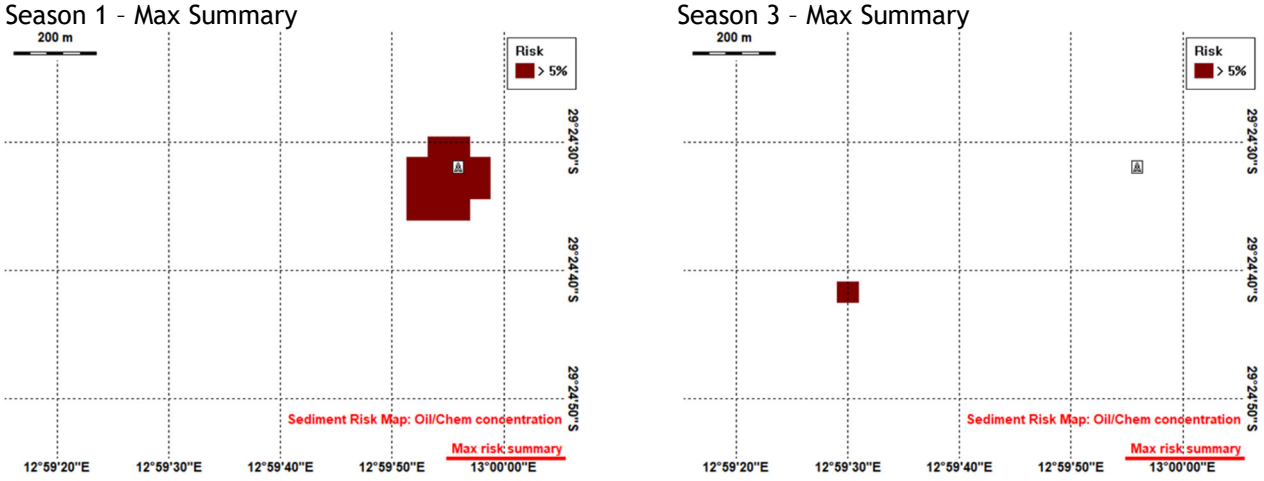


Figure 51: Maximum Summary of the risk of total concentration of chemicals in the sediments from the risered section (Source ProOceano 2023).

Contaminant Concentrations [5]in the Sediments

- Contaminant concentrations in the sediment as a result of drilling the riserless sections with WBMs will be negligible and the plumes will be in the direction of the prevailing northerly bottom currents. Cuttings are released in two pulses and comprise primarily bentonite (~95%) and caustic soda (~3.5%). No concentrations are provided for the caustic soda and other chemical components, but these are expected to dilute rapidly.
- Once the marine riser has been set (risered drilling stage), cuttings and NADFs would be released in three pulses near the sea surface from the drilling unit. The stronger surface currents prevailing during the drilling of the risered sections would result in the discharges experiencing greater dispersion as they settle through the water column resulting in an elongated, patchy deposit that extends from the well bore in the direction of the prevailing currents. Risered cuttings discharges would therefore affect the entire water column (see Section 4.4.2.1.3 below). However, once the cuttings have settled, the concentrations of contaminants released in the muds would contribute to environmental risk in the surficial sediments around the well bore. Contaminant concentrations in the sediment as a result of risered drilling are thus more substantial than for the riserless stages, despite contributing only a maximum of 1.8% to the Environmental Impact Factor (EIF).
- The maximum concentrations of the particulate matter at the end of operations are high but remain localised to within <50 m of the discharge point. Depositional footprints for the weighting agents and particulate matter of >500 ppm extend up to a maximum of 2 km from the well bore in the direction of the prevailing currents.
- In the case of the chemical constituents of the non-aqueous drilling muds used during drilling of the risered sections, the highest risk to the sediments is posed by the fatty acid in the EZ MUL NT and in the INVERMUL NT, and the base oils in the EDC-99 DW. For the chemical component of total discharges during the risered sections, the maximum distance at risk in the sediments with concentrations of >50 ppm extend to a maximum distance of 2 km from the well bore (worst-case Season 3) in the direction of the prevailing currents (Figure 52). Although concentrations are lower than for the weighting agents, their high PNEC[6] values results in these constituting a far greater risk to the environment than the weighting agents.
- A further two pulses in environmental risk occur due to the discharge of KCl-WBMs during well logging and plugging. Although these discharges do constitute a risk to the water column, in most cases the risk falls well below the threshold at which 5% of the species in the ecosystem are likely to be affected. Risks to the seabed are not attained during these discharges due to the rapid dilution and dispersion of the chemicals and particulates in the prevailing currents.
- During drilling of the risered sections with NADFs, the main contributors to the ecological risk in the sediments are therefore chemical rather than physical as was the case with the riserless section using WBMs. The modelling report identified that the chemical risks in the sediments were low (<2%) reaching a maximum distance of 760 m for a single grid point.

[5] This differs from the environmental risk as it provides the actual predicted concentrations of various constituents in the sediments.

[6] PNEC represents the ecosystem sensitivity to the exposure. For toxic risk, its value is usually derived from standardized eco-toxicity tests on species. For the physical risk factors, it is obtained by field surveys coupled with the statistical analysis of the variation in species sensitivity (Species Sensitivity Distributions).

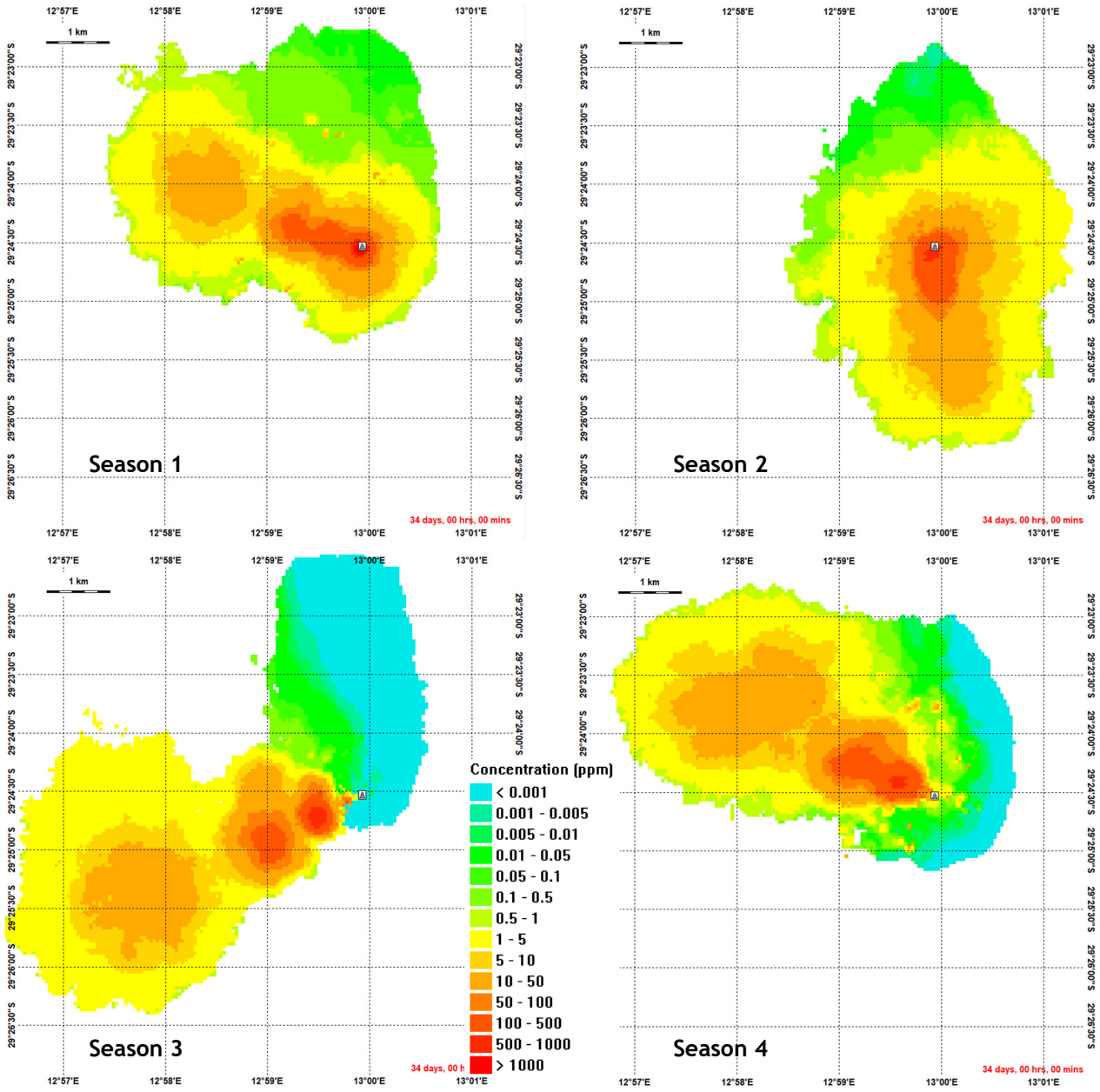


Figure 52: Concentrations of the chemical component of the total discharges for the four seasons in the superficial layer of seabed sediments at the end of risered drilling operations (Source ProOceano 2023).

Environmental Risk due to Contaminant Concentrations in the Water Column for riserless sections

- The cuttings modelling studies for the current project (ProOceano 2023) identified that concentrations of contaminants in the water column that may pose a risk to benthic biota released during the riserless drilling stages are restricted to depths of ~3 000 m. Additives released into the water column above the seabed during the riserless drilling stages will therefore remain near the seabed and spreading in the direction of the prevailing currents. The maximum

distances from the discharge with a significant environmental risk[7] was up to 7.7 km in a northerly direction, thereby clearly showing the effect of water column currents near the seabed on the dispersion of drill cuttings and drilling muds (Figure 53). Current speeds near the seabed are higher during Season 3 (up to 0.09 m/s) and more frequent in a northerly direction leading to a calculated risk spreading further from the discharge point.

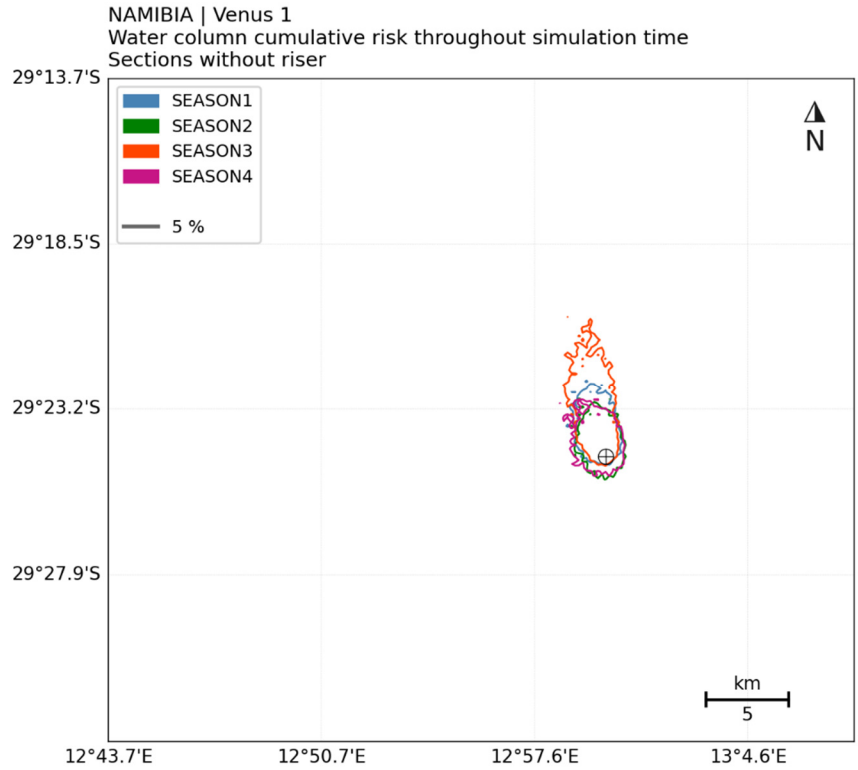


Figure 53: Cumulative significant environmental risk >5% in the water column near the seabed during drilling of the riserless sections at the modelled discharge point for all the seasons (ProOceano 2023).

- The cumulative risks[8] in the water column above the seabed illustrated in Figure 53 are short-term, however, being concentrated around the discharge point and decreasing rapidly with distance as the plume dilutes.
  - The worst case scenario for the percentage of time with a significant risk above 5% was for Season 3 where a maximum risk with a duration exceeding 24 hours extended up to 2.9 km from the wellbore. At greater distances from the well, the percentage of time with risk above 5% did not exceed 10%, which is equivalent to approximately 1 day.
- The main contributors to the environmental risk in the water column during the riserless drilling stages are bentonite with a total contribution of ~95%. Bentonite is a naturally occurring, insoluble, non-toxic and non-biodegradable clay. It is thus essentially inert toxicologically to marine organisms having primarily a physical effect. The other main contributor is caustic soda used during the riserless stage, which has chemical effects and which contribute ~3.5% to the risk in the water column near the seabed.

[7] A significant risk corresponds to a calculated concentration in the environment (exceeding the predicted no effect concentration to a level likely to potentially impact 5% of species in a typical ecosystem.

[8] The cumulative risk is based on an environmental risk of >5% being achieved at any time during the calculation by the model.

Contaminant concentrations in the water column for the risered sections

With implementation of NADFs at the start of the 17.5˝ section during the risered stages, the contaminant contributions in the muds increase significantly, producing a footprint throughout the entire water column due to dispersion and dilution of the drilling fluid additives following release of drilling cuttings from the drill rig. The cumulative significant environmental risks in the water column for the risered discharges at the modelled discharge point are shown in Figure 54.

- Maximum distance of the plume with significant risk from the discharge during risered drilling is 20.5 km (Worst case: Season 3) in a WSW direction. The maximum distances at risk around the discharge point varies depending on variability in water column currents with season.
- Modelling results indicate that during risered drilling surface currents ensure that plumes are rapidly diluted and dispersed (few hours) and are not detectable beyond the cessation of drilling operations. Chemical footprints are therefore ephemeral only. As was the case near the seabed, the area at risk in the water column is not centred around the discharge point but extends in the direction of the prevailing currents.
  - The longest period with risk above 5% in the same grid point was a maximum duration of 16 days (90%) to a distance of 820 m (Season 3). For the riserless sections, the maximum duration in the same grid point was for 6 days (47%), up to a distance of 400 m (Season 2).
- The main contributors to the environmental risk to the water column during the risered stages constitute the particulate compounds (barite: 8-10%) as well as the chemical constituents (Invermul NT and EZMUL NT: 4.3%, and the base oil EDC 99 DW: 82.5%-85.2%). Weighting agents and chemicals released into the water column at the surface, result in an environmental risk plume that extends throughout the entire water column, with a maximum calculated risk of 100% close to the release point at the sea surface during the drilling of the risered sections.

Bioaccessibility of Metals

Several metals (Ba, Cr, Cu, Ni, Pb, and Zn) typically occur in significantly higher concentrations in discharged drilling muds than background concentrations in uncontaminated marine sediments (Breuer *et al*. 2004). Barium (from drilling mud barite) is usually the most abundant metal in WBMs and NADF, and is thus used most frequently as an indicator of drilling muds in sediments (Neff 2005). Increased levels of barium in the sediments surrounding wells have been recorded up to 65 km from drill sites (Neff *et al*. 1989), and persisting in the sediments at lethal levels for up to 1.5 years post-drilling (Steinhauer *et al*. 1994). Other metals (most of them associated with barite) often present at substantially higher concentrations in drilling muds than in natural marine sediments are chromium, lead, and zinc (Neff *et al*. 1989; Neff 2005 and references therein), with elevated concentrations of cadmium, arsenic, copper and mercury in near-field sediments (<500 m) also being recorded in some cases (Buchanan *et al*. 2003; Breuer et al 2004). However, due to the low solubility of barite in seawater and in anoxic marine sediments, a considerable proportion of the associated contaminants are likely to remain within the cuttings pile unless they are disturbed (Breuer et al 2004). These metals are thus typically not bioavailable to benthic biota and do not bioaccumulate in the marine food chain (Neff 2005 and references therein), and thus essentially inert toxicologically to marine organisms. If, however, they do become bioavailable, toxic effects in high concentrations can be expected (Neff 2008; see also Edge *et al*. 2016). Lead appears to be the only metal that is bioavailable in some cuttings piles.

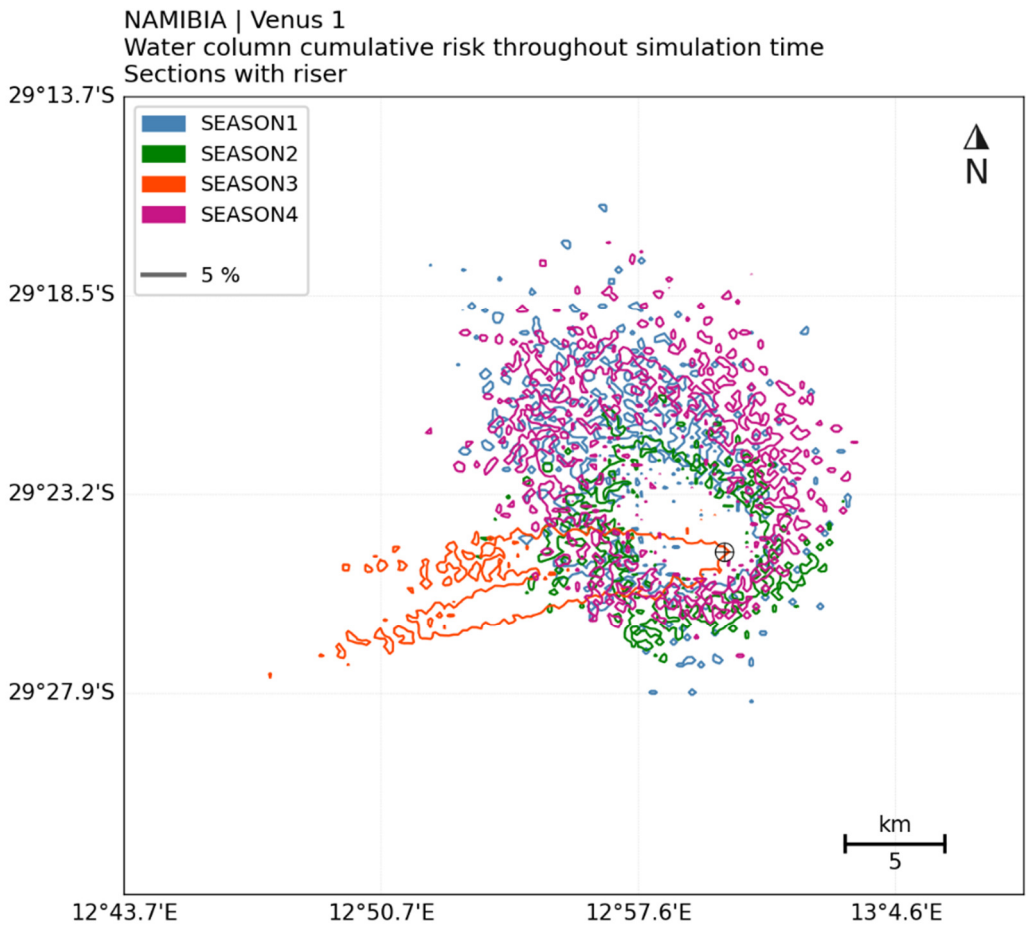


Figure 54 Cumulative significant environmental risk >5% in the water column during drilling of the risered sections at the modelled discharge point for all the seasons (Source: ProOceano 2023).

Bioaccessibility of Drilling Mud Ingredients

The overall conclusion drawn from toxicity tests around the world is that the majority of the components of WBMs currently used in offshore drilling operations constitute a low risk of chemical toxicity to marine communities. NADFs, however, constitute a higher risk of chemical toxicity due to components such as fatty acids.

As the most abundant solid ingredient in both WBMs and NADF is particulate barite which is almost insoluble and non-biodegradable, and thus essentially inert toxicologically to marine organisms. In chronic exposure studies with benthic shrimp *Palaemonetes pugio* barite accumulated in the exoskeleton, hepatopancreas, and muscle tissue, with ingestion damaging the epithelial tissue of the gut (Neff 2005). Tagatz and Tobia (1978) reported that although barite-rich sediments did not prevent recruitment of several planktonic larvae of polychaetes and mussels, fewer individuals and species colonised sediments covered by a thin layer of barite. No adverse effects on faecal production, growth, and adult tube production were observed in the polychaete *Mediomastus ambiseta* living in barite-covered sediments, although migration out of patches of 100% barite was observed (Starczak *et al.* 1992). Olsgard and Gray (1995) suggested that the effects of barite are more likely to be detected at a community level than at individual species levels.

Most toxicological studies have determined that sensitivity to barite was related to physical interactions with gills, the gastrointestinal tract, and integument due to elevated concentrations of particulate barite in suspension, rather than to direct chemical toxicity (see for example Barlow & Kingston 2001). Dilute suspensions have been shown to inhibit gonad development (Cranford *et al*. 1999), and food ingestion rates in the scallop *Placopecten magellanicus* leading to reduced growth rates and increased mortality (Muschenheim & Milligan 1996). In contrast, Cranford *et al*. (1998) reported no significant effect on survivorship or growth following acute and chronic exposure of scallops to 100 mg/ℓ water based drilling mud. At concentrations of >1 000 mg/ℓ, Barium (as barite) was toxic to embryos of the crab *Cancer anthonyi* (MacDonald *et al*. 1988). Most bioassays have produced effects at median lethal concentrations >7 000 mg/ℓ suspended barite (National Research Council 1983, in Neff 2005).

Bentonite, the second most abundant ingredient of most WBMs, is a naturally occurring, insoluble and non-biodegradable clay added to drilling muds to provide viscosity. When in suspension, the clay-sized bentonite solids have smothering effects through burial and clogging of the gills, ultimately leading to mortality (Cabrera 1971; Sprague & Logan 1979) (assessed in Section 4.4.2 above). It may cause physical damage through abrasion and erosion (Sprague & Logan 1979), or shading effects reducing photosynthesis in the alga (Neff 2005). In particular, clay additives have been found to induce changes in respiratory and cardiac activities in cod, haddock, salmon and rays exposed to concentrations up to 40 mg/ℓ for 2-5 minutes (Shparkovski *et al*. 1989) with reduced survival in cod and flounder at 5 mg/ℓ for exposures of 10-30 days (Kozak & Shparkovski 1991). Dethlefsen *et al*. (1996) also reported some indications of effects of WBMs on fish embryos and larvae. However, once the clay settles to the bottom, no further effects were observed (Carls & Rice 1984). Most 96-hr acute toxicity studies have thus found bentonite to be non-toxic, with LC_{50}s ranging from 22 000 to >100 000 ppm for various organisms.

In modern WBMs and NADFs, bentonite has been supplemented or replaced by organic polymers (e.g. carboxymethyl cellulose, hydroxyethyl cellulose, guar gum), which are primarily used in shallow parts of a well due to their poor thermal stability. This is, however, not the case in the WBMs used for drilling of the riserless sections in the current project. These organic polymers are similarly non-toxic to aquatic organisms, but being highly biodegradable, require a biocide to control bacterial growth. The biocide most frequently used is gluteraldehyde (a liquid derivative of glutaric acid), which is a toxic irritant. However, when discharged to the marine environment, it is rapidly destroyed by biological degradation and reduction by oxidation of organic matter. Gluteraldehyde is moderately toxic to non-toxic to various freshwater and marine animals with LC_{50}s ranging from >6 - 2 200 ppm for several crustaceans. If used in excess in polymer muds, sufficient gluteraldehyde could persist in the mud/cuttings plume to be toxic to pelagic organisms.

Some of the inorganic salts added to WBM for alkalinity/pH or shale control are slightly toxic to freshwater plants and animals due to their ionic or pH effects. Caustic soda is corrosive. Because of the high ionic strength and buffer capacity of seawater, it is unlikely that these salts would be toxic to marine organisms at the concentrations at which they occur in drilling muds (Neff 2005).

Some chrome and ferrochrome lignosulfonate thinners used in WBMs are slightly toxic to marine organisms (Neff 2005). Chronic toxicity testing identified that their effects include alterations in feeding behaviour of lobsters; cessation of swimming by crab and mysid larvae, inhibition of shell formation, reduced rate of shell regeneration, and damage to gills in various molluscs; reduction in calcification, respiration, and growth rates of corals; and a decrease in growth rate, depressed heart rate, developmental abnormalities, and reduced survival of several marine fish species. Whether these effects would be manifested under conditions of exposure to discharged drilling muds and cuttings is uncertain, as field studies have generally failed to find evidence of the long-lasting ecological impacts of lignosulfonate muds near WBM and cuttings discharges. Nonetheless, chrome lignosulfonates have to

some extent been replaced with less-toxic chrome-free lignosulfonate salts. Other clay thinners, such as lignites and tannins, are not toxic.

Of the minor additives (based on volumes discharged) sometimes used in WBMs, the most toxic include diesel fuel, corrosion inhibitors, detergents, defoamers, and emulsion breakers. Toxicity of whole drilling mud was attributed primarily to chrome, in cases where chromate and chrome lignosulfonate concentrations in the mud were very high (Conklin *et al*. 1983). Other additives such as zinc-based H_2S scavengers, tributyl phosphate surfactant defoamers, and fatty acid high-temperature lubricants are also toxic, but are usually not present in concentrations high enough to contribute significantly to whole mud toxicity. Where hydrocarbons are added to the mud to aid in lubricating the drill string or to free stuck pipes, the toxicity of WBM to water column and benthic marine animals increases significantly (Breteler *et al*. 1988). Although common in the past, with the banning of the discharge of drilling muds containing free oils, diesel and mineral oil additives to WBMs have declined, and this practice is seldom implemented today. Drilling fluids containing a high-sulphur diesel fuel (Group I NADFs containing 25% total aromatic hydrocarbons) are the most toxic, followed by those containing a low-sulphur diesel (containing 8.7% total aromatics); drilling fluids containing a low-aromatic mineral (Group III NADFs, as proposed by TEEPNA) oil were the least toxic.

In addition to the multitude of ecotoxicological studies undertaken to date, many field monitoring studies have been performed since the 1970s to determine short- and long-term impacts of drilling discharges on the marine environment (e.g. Neff *et al*. 1989; Daan *et al*. 1992; Steinhauer *et al*. 1994; Hyland *et al*. 1994; Olsgard & Gray 1995, amongst others). Most of the monitoring conducted prior to 1993, focused on the impacts of Oil-Based Mud (OBMs) cuttings discharges. Some of these earlier studies (e.g. Neff *et al*. 1989; Steinhauer *et al*. 1994; Hyland *et al*. 1994) reported no detectable changes in benthic communities that could be attributed to oil and gas extraction, possibly due to dispersal of drilling mud solids over a wide area in the high-energy environment in which the drilling occurred (Neff *et al*. 1989). Many monitoring studies, however, showed a clear chemical contamination gradient of sediment within a few hundred metres of the well, decreasing beyond 750 m (Daan *et al*. 1992; Hernandez Arana *et al*. 2005), but in some cases still being detectable at distances of several kilometres from the well (Olsgard & Gray 1995; Bakke *et al*. 2013), and persisting over the long term (>15 years) (OSPAR 2008; Daan *et al*. 2006; Bakke *et al*. 2013; Henry *et al*. 2017), although recovery of benthos can start within just a few years post-drilling (Tait *et al*. 2016). This compares well with the modelling results undertaken for the current project, which predicted that the environmental risk of contaminants in the sediments from the risered sections extends to a maximum 7.7 km from the well site (Worst case: Season 3) and persists beyond 10 years after operations. These contamination gradients manifested themselves as reduced abundance and biomass of dominant faunal species that serve as food for demersal fish, declines in diversity and loss of sensitive macrofaunal species, with an increase in abundance of opportunistic species (IOGP 2003, 2016; Daan *et al*. 2006; Henry *et al*. 2017). The effects were shown to be predominantly linked to the presence of total hydrocarbons, barium and strontium. Although taint studies on fish caught near North Sea platforms discharging OBM cuttings where unable to determine an off taste (reviewed in Davies *et al*. 1983), Husky (2001b) reported external lesions (indicative of contaminant stress) in fish in the vicinity of drilling sites. Similarly, cod and haddock from a Norwegian oil field, located at much shallower depths than the proposed wells for the current project, were found to have different lipid content or lipid composition of the cell membranes, possibly due to the fish feeding on old NADF cuttings piles (OSPAR 2008). The physical and physiological impacts to benthic biota, were found to be greater at depths of <600 m, whereas at depths >600 m impacts tend to be lower as increased water depths allow small particles to disperse over greater distances, thereby lessening the effects on the benthos (IOGP 2016). This is an important

point to note for the current project where the Area of Interest extends from water depths of 2 950 m to as much as 3 400 m.

Table 13 below provides a summary of acute toxicities of the ingredients of WBMs and NADF to marine algae and animals. Neff (2005) notes that the requirements for toxicity testing of drilling mud and drilling mud ingredients differ in different regions of the world. In the U.S., a mysid (crustacean), *Americamysis [Mysidopsis] bahia*, is used for toxicity tests with dispersions of used whole drilling muds. In contrast, the North Sea countries test the individual drilling mud components with at least three organisms from different taxonomic levels: alga, crustacean, fish. In Russia, toxicity testing is undertaken with several species on individual drilling mud components.

Table 13: Acute toxicities, measured as median lethal concentration (LC_{50}) after 48 – 96 hours, and expressed as mg/ℓ (ppm) of the ingredient or its suspended particulate phase (summarized from Neff 2005).

Ingredient	Range of LC_{50} for different species (mg/ℓ)
Weighting Materials	
Barite (barium sulfate: $BaSO_4$)	385[a] - >100 000
Hematite (iron oxide: $Fe2O_3$)	>100 000
Siderite (iron carbonate: $FeCO_3$)	>100 000
Viscosifiers	
Bentonite (montmorillonite clay)	9 600[a] - >100 000
Hydroxyethyl cellulose (HEC) polymer/viscosifier	7 800 – 29 000
Sodium carboxymethyl cellulose (CMC)	500[a] - >100 000
Polyanionic cellulose	60 000 – 100 000
Organic polymers	7 800 - >100 000
Xanthan gum	420
Salts for pH and Shale Control	
Potassium chloride (KCl: muriate of potash)	2 100[b]
Lime (CaO)	70 – 450[b]
Calcite (calcium carbonate: $CaCO_3$)	>100 000
Sodium hydroxide (NaOH: caustic soda)	105 – 110[b]
Lost Circulation Materials	
Mica	>7 500
Jellflake® shredded cellophane	>7 500
Thinners, Clay Dispersants	
Ferrochrome lignosulfonate	12 – 1 500
Chrome lignosulfonate	12 200 – 100 000
Chrome-treated lignosulfonate	465 – 12 200
Chrome-free lignosulfonate	31 000 – 100 000
Iron lignosulfonate	2 100
Modified chrome lignite	20 100
Potassium lignite	>100 000
Carbonox® lignitic material	6 500 - >7 500
Generic lignite	>15 000

Ingredient	Range of LC_{50} for different species (mg/ℓ)
Sulfomethylated tannin	33 900 - >100 000
Sodium acid pyrophosphate ($Na_4P_2O_7$)	870[b] - >100 000
Lubricants	
Diesel fuel	0.1 – 1 112
Fatty acid high pressure lubricant	3 500 - >100 000
Blended organic ester lubricant	10 400 – 49 400
Graphite	86 500
Other Additives	
Corrosion inhibitors (several types)	2.0 – 7 000
Ammonium bisulfite corrosion inhibitor	75 000
H_2S scavengers (zinc salts)	235 – 7 800
Low MW polyacrylate reverse breaker	3 500
Polyacrylate scale inhibitor	77 300
Scale inhibitors	>10 000
Glutaraldehyde (biocide) (25%)	41 – 465
Flocculant WT-40	5 300
Surfactants	40 – 429
Detergents	0.4 – 340
Defoamers	5.4 – 84
Tributyl phosphate surfactant defoamer	5 100
Emulsion breakers	3.6 - 930
Oxygen scavenger (sodium bisulfite)	175 – 185

LC_{50} median lethal concentration; measure of toxicity that will kill 50% of a given population of organisms in a specified period.

[a] microalgal test; effects probably caused by turbidity.

[b] Freshwater species used in test; marine species expected to be more tolerant due to high ionic strength and buffer capacity of seawater

Biological effects associated with the use of NADFs are not typically found beyond 250 – 500 m from the drilling unit (Husky 2000, 2001a; Buchanan *et al*. 2003; IOGP 2003). The potential for significant bioaccumulation of NADFs in aquatic species is unlikely due to their extremely low water solubility and consequent low bioavailability (IOGP 2003). However, certain hydrocarbons are known to have tainting effects on fish and shellfish. Sediment toxicity tests for NADFs have shown that these base fluids have relatively low toxicity to sessile organisms with LC_{50} >1 000 mg/ℓ. Esters are the least toxic and impacts to benthic community structure did not persist beyond 2 years (reviewed by IOGP 2003). This was followed by internal olefin and polymerised olefin, where complete recovery of impacted communities was anticipated within 3 – 5 years (Neff *et al*. 2000). The differences in toxicity may be due to differences in molecular size and polarity, which affects water solubility and bioavailability (IOGP 2003).

With changes to the use of WBMs, and low-toxicity NADFs, field results have clearly indicated "a reduction in environmental contamination and biological impact, compared to effects reported for OBM drill cuttings" (Olsgard & Gray 1995). Due to the low acute and chronic toxicities of WBMs, and NADFs to marine life, and as a result of the high dilution and wide dispersal of the dissolved and particulate

components following discharge, the effects of these muds are restricted primarily to the seabed in the immediate vicinity of the drilling unit and for a short distance down current from the discharge (OSPAR 2008). Rather than direct chemical toxicity, impacts to sessile marine organisms arise primarily through smothering effects (see previous Section 4.4.2.1.1) and oxygen depletion due to rapid biodegradation of the base fluid in the sediment (see Section 4.4.2.1.4 below).

In summary, toxicity testing of WBMs in use today has indicated that they constitute a low risk of chemical toxicity to marine communities. The most abundant ingredient in WBMs, barite is insoluble and non-biodegradable and would therefore have a smothering effect only. Other additives are only mildly toxic to marine life, but are present in such low concentrations that evidence of long-lasting ecological impacts is lacking. The most toxic additives include diesel fuel (in some NADFs), corrosion inhibitors, detergents, defoamers, and emulsion breakers, but are usually not present in concentrations high enough to contribute significantly to whole mud toxicity. These are not specifically listed in Appendix 1 as being part of the drilling mud constituents for the current project.

The potential toxic effects of drilling muds on marine benthic communities and the associated food chain, or the potential for bioaccumulation of mud constituents is considered of LOW intensity for cement and WBMs (riserless stage) and HIGH intensity for NADFs (risered stage) as sensitive and potentially vulnerable habitats in the ESAs in the Area of Interest could be impacted, although most of the chemical constituents are biodegradable or rapidly dilute in the receiving water. The intensity of the impact on the water column is LOW as the block lies well offshore of the egg and larval distribution of important commercial fish species (see Figure 23). Furthermore, the maximum cumulative risk throughout the entire water column would remain LOCALISED (*i.e.* Riserless: confined to a maximum distance of 7.7 km from the well site in the direction of the prevailing current (N); Risered: confined to a maximum distance of 20.5 km in a WSW direction). Releases of chemical constituents are pulsed, with those above the Predicted No Effect Environmental Concentration (PNEC) persisting for only a few hours during the risered drilling stages and therefore not influencing benthic communities. Chemicals released during the risered drilling stages and adsorbed onto the cuttings contribute minimally to the environmental risk to the water column as most of the NADF is recycled. For example, the high toxicity INVERMUL NT and EZ MUL NT contribute only 1.1 – 3.2% to the total environmental risk due to the low quantities used in the NADFs. However, the base oil EDC 99 DW, which forms the bulk of the drilling mud constituents, and had a low PNEC, contributes most to the total EIF at between 82.5% and 85.2%. Rapid dilution of these constituents ensures that impacts would persist only over the SHORT TERM in the water column (i.e. rapidly diluted and dispersed (few hours) and are not extending beyond the 34 days required for the drilling of the base case) (see ProOceano 2023 for details). Due to the short duration and localised nature of the risk, nearby sensitive areas are not affected.

In the sediments, however, the impact persists for up to 10 years to a distance of 760 m. Thus, the duration for sediment toxicity is LONG TERM.

The magnitude of the potential toxicological impacts of drilling fluids is thus considered **LOW** for up to 10 wells regardless of season but **VERY LOW** for the water column.

Impact Significance

In the case of discharges of cements and WBM at the well bore and NADFs below the sea surface, the potential toxicological effects of drilling mud constituents and cement additives on the low-sensitivity receptors expected in the unconsolidated sediments on the continental slope and in the water column are deemed to be of **VERY LOW** significance for sediment toxicity due to the high magnitude, and

NEGLIGIBLE significance for the water column. However, should near-bottom currents disperse the drilling muds into the ESA located within the Area of Interest, the significance of potential toxicological effects would be deemed of **HIGH** significance due to the potentially high sensitivity of the receptors and the high magnitude.

Identification of Mitigation Measures

No.	Mitigation measure	Classification
1	Refer to Section 4.4.2 for mitigation measures for sensitive hard-ground habitats.	Avoid / reduce at source
2	Careful selection of drilling fluid additives taking into account their concentration, toxicity, bioavailability and bioaccumulation potential; Ensure only low-toxicity, low bioaccumulation potential and partially biodegradable additives are used. Maintain a full register of Material Safety Data Sheets (MSDSs) for all chemical used, as well as a precise log file of their use and discharge.	Avoid / reduce at source
3	If NADFs are used for drilling the risered sections, ensure regular maintenance of the onboard solids control package and avoid inappropriate discharge of NADF cuttings.	Abate on site
4	Monitoring requirements: • Test drilling fluids for toxicity, barite contamination and zero oil content to ensure the specified discharge standards are maintained. • Monitor (using ROV) cement returns and if significant discharges are observed on the seafloor terminate cement pumping, as far as possible. • Monitor (using ROV) hole wash out to reduce discharge of fluids, as far as possible.	Reduce at source/Abate on site

Residual Impact Assessment

This potential impact cannot be eliminated due to the nature of the drilling approach and the necessity for cementing and the use of WBMs and NADFs in the drilling process. For communities in unconsolidated sediments and on hardgrounds, the residual impact on marine fauna will have a lower intensity, and the significance of residual impacts would reduce to **NEGLIGIBLE significance** (unconsolidated sediments) and **MEDIUM significance** (sensitive hardgrounds, EBSAs and ESAs), but remains of NEGLIGIBLE significance for the water column.

As pre-drilling ROV surveys would reveal the presence of hard grounds, the likelihood of such occurring in the Area of Interest for drilling is low.

8	*Biochemical Impacts of residual WBMs, NADFs and cements additives on marine organisms in unconsolidated sediments*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**LOW**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
Significance	**VERY LOW**	**NEGLIGIBLE**
Probability	**HIGHLY LIKELY**	**HIGHLY LIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**POSSIBLE**	**POSSIBLE**

9	*Biochemical Impacts of residual WBMs, NADFs and cements additives on marine organisms on hard grounds*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**HIGH**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**HIGH**	**MEDIUM**
Intensity	HIGH	MEDIUM
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
Significance	**HIGH**	**MEDIUM**
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**PARTIALLY REVERSIBLE**	**PARTIALLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**POSSIBLE**	**POSSIBLE**

10	*Biochemical Impacts of residual WBMs, NADFs and cements additives on marine organisms in the water column*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**LOW**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	LOCAL	LOCAL
Duration	SHORT TERM	SHORT TERM
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.4.2.1.3 Increased Water Turbidity and reduced Light Penetration on marine ecology

Impact Description

Cuttings discharged from the drill rig would lead in increased water turbidity and reduced light penetration resulting in both direct and indirect effects on primary producers (phytoplankton) in surface waters, and direct effects on pelagic fish and invertebrate communities in the water column. The heavier cuttings and particles discharged at the seabed or from the drilling unit would settle near the wellbore where a localised smothering effect can be expected (see Section 4.4.2). The finer components of the surface discharge generate a plume in the upper water column, which is dispersed away from the drilling unit by prevailing currents, diluting rapidly to background levels at increasing distances from the drill unit. The finer components of discharges on the seabed would generate a plume near the seabed, which would persist for longer due to weaker bottom currents. Increased turbidity near the surface may limit light penetration thereby negatively affecting primary productivity of phytoplankton communities (indirect negative impact). In contrast, increased turbidity near the seabed may have direct physiological effects on filter-feeding organisms and/or indirect effects on predation success of demersal species.

Project Controls

The operator will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT. In this regard TEEPNA has various project controls in place for the proposed drilling operations. These include:

- TEEPNA has indicated it plans to use WBMs (riserless sections) and low toxicity Group III NADFs (risered sections). Drill cuttings from the risered sections would be treated to reduce the oil content to <6% Oil On Cutting (OOC) and discharged overboard.
- Cuttings will be discharge 10 m below surface during risered drilling.

Sensitive Receptors

The taxa most vulnerable to increased turbidity and reduced light penetration are phytoplankton. Due to the deep offshore location of the Area of Interest, the abundance of phytoplankton and pelagic fish and invertebrate fauna is likely to be low. Although higher productivity and shelf-edge upwelling occurs in the Lüderitz and Namaqua upwelling cell inshore of the Area of Interest for drilling, phytoplankton abundance in Block 2912 is expected to be negligible. Surface waters will thus be clearer and less productive as they are beyond the influence of coastal and shelf-edge upwelling. Furthermore, being dependent on nutrient supply, plankton abundance is typically spatially and temporally highly variable and is thus considered to have a low sensitivity. The major spawning areas are also all located on the continental shelf, inshore of the Area of Interest (see Figure 23). Seasonally high abundances of ichthyoplankton (hake, sardine and anchovy eggs and larvae), particularly in late winter and early spring may however, occur in the inshore of the Area of Interest. Phytoplankton and ichthyoplankton are considered to be of low sensitivity, as any potential overlap of turbid water plumes generated during cutting disposal on phytoplankton and ichthyoplankton production, fish migration routes and spawning areas in the area would be negligible.

For details of sensitivities of benthos in unconsolidated sediments and deep-water hard grounds see section 4.4.3 above. In summary, the benthic communities of unconsolidated sediments are considered of LOW sensitivity. In contrast, the receptors associated with potential deep-water reefs / hard grounds are considered to have a HIGH sensitivity to physical disturbance. In waters beyond the influence of natural turbidity (through inputs such as rivers, 'berg wind' events or sediment resuspension by swells), biota may be more susceptible to increased turbidity near the seabed, but are expected to have behavioural and physiological mechanisms for coping with increased turbidity in their near bottom habitats. In addition, demersal species in the area of interest may be more tolerant of reduced light considering the deepwater environment. Overall, the sensitivity to turbidity can be considered LOW.

Impact Magnitude

Several studies have shown that in areas where current speeds are high, cuttings discharges are diluted rapidly (within an hour) to very low concentrations, within 1 000 – 2 000 m down-current of the drilling unit (see Neff 2005 for references). Morant (1999) reported that a typical near-surface plume is 30 – 40 m in vertical height, 40 - 60 m wide and can extend in excess of 10 km from the drilling unit.

Although the cuttings dispersion modelling studies undertaken as part of this project (ProOceano 2023) did not predict the spatial extent of elevated total suspended solids (TSS) from the risered drilling phase, the sediment footprints generated for the maximum depositional risk of drilling operations largely confirm the reports of international studies that predicted that the drilling cuttings plumes remain localised (see Perry 2005).

The model results identified that the maximum cumulative risk throughout the entire water column would be as follows for the two drilling phases:

- Riserless: risk is confined up to a maximum horizontal distance of 7.7 km (Season 3) from the discharge location along the axis of the prevailing Northerly current. Maximum total concentrations reached ranged from 92 - 165 ppm. The maximum value reached was for Season 1.

- Risered: risk confined to a maximum distance of 20.5 km in a Westerly direction (Season 3). Maximum total concentrations reached ranged from 2 - 18 ppm. The maximum value reached was for Season 1.

The risk in the water column is pulsed, corresponding to the various drilling stages and ceases once operations have been completed. The modelling study identified that the longest period of risk above 5% to the same grid point in the water column was 16 days extending to a distance of 820 m from the discharge point onboard the drillship (Season 3). Water column risks from the riserless sections persisted in the same grid point for 6 days to a distance of 400 m from the wellbore. At greater distances from the well, the percentage of time with risk >5% did not exceed 10%, equating to approximately 1 day for the riserless sections and 2 days for the risered sections. The variation in current direction between the scenarios modelled, however, result in different directional spreads of the turbidity plumes, although the NW and WNW directions are the most dominant.

One of the more apparent effects of increased concentrations of suspended sediments and consequent increase in turbidity, is a reduction in light penetration through the water column with potential adverse effects on the photosynthetic capability of phytoplankton (Poopetch 1982; Kirk 1985; Parsons *et al*. 1986a, 1986b; Monteiro 1998; O'Toole 1997) and the foraging efficiency of visual predators (Simmons 2005; Braby 2009; Peterson *et al*. 2001). However, due to the rapid dilution and widespread dispersion of settling particles, any adverse effects in the water column would be ephemeral and highly localised and short term. Any biological effects on nectonic and planktonic communities would be negligible (Aldredge *et al*. 1986). Turbid water is a natural occurrence along the Southern African coast, resulting from aeolian and riverine inputs, resuspension of seabed sediments in the wave-influenced nearshore areas and seasonal phytoplankton production in the upwelling zones. Further offshore (e.g. in the Area of Interest for drilling), surface waters tend to be clearer and less productive as they are beyond the influence of coastal and shelf-edge upwelling. Consequently, the major spawning areas are all located on the continental shelf, inshore of the Area of Interest (see Figure 23). However, seasonally high abundances of ichthyoplankton (hake, sardine and anchovy eggs and larvae), particularly in late winter and early spring may occur inshore of the Area of Interest, but these are not expected to be influenced by turbidity plumes generated during drilling operations. The rapid dilution and widespread dispersion of settling particles would ensure that any impacts are ephemeral, localised and short-term. Thus, any potential effects of turbid water plumes generated during cutting disposal on phytoplankton and ichthyoplankton production, fish migration routes and spawning areas, or on benthic and demersal species in the area would thus be negligible. Pabortsava *et al*. (2011) demonstrated that exposure to drill cuttings resulted in a higher settling velocity of aggregated phytoplankton cells. Sinking of phytoplankton aggregates is a crucial mechanism for transporting carbon to the seafloor and benthic ecosystem, with such aggregates often scavenging particulate material from the water column as they sink. Furthermore, once settled, greater seabed stress was required to resuspend the aggregates. This together with increased turbidity of near-bottom waters through disposal of WBMs and cuttings at the wellbore, may place transient stress on sessile and mobile benthic organisms, by negatively affecting filter-feeding efficiency of suspension feeders (reviewed by Clarke & Wilber 2000). However, in most cases sub-lethal or lethal responses occur only at concentrations well in excess of those anticipated at the discharge.

The impact of increased turbidity in the water column and elevated suspended sediment concentrations around the wellbore would thus be of LOW intensity as dispersion will be rapid, and concentrations are expected to be sublethal and would be easily tolerated by marine fauna. Impacts would persist only over the very SHORT TERM (days), and would be LOCALISED (within a distance of 20.5 km (surface) and

7.7 km (seafloor) of the well site). The biochemical impact of reduced water quality through increased turbidity is thus considered of **VERY LOW** magnitude.

Impact Significance

Due to the low sensitivity of the receptors expected in the offshore pelagic and soft-sediment benthic environment and the very low magnitude, the impact is deemed to be of **NEGLIGIBLE** significance. In the case of benthic communities from deep-water hard grounds, the sensitivity to increased turbidity is also considered to be low, despite their high sensitivity to physical disturbance. The impact of increased turbidity on deep-water reef communities is therefore also deemed to be of **NEGLIGIBLE** significance.

Identification of Mitigation Measures

No mitigation measures for potential indirect impacts on the water column or benthic habitats are proposed or deemed necessary.

Residual Impact Assessment

This potential impact cannot be eliminated due to the necessity of disposal of drill cuttings. Thus the impact remains NEGLIGIBLE.

11	***Indirect impacts of drill cuttings discharge on the water column (turbidity and light) and seabed (turbidity)***	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	LOW	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	LOCAL	LOCAL
Duration	SHORT TERM	SHORT TERM
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**-**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.4.2.1.4 Reduced physiological functioning of marine organisms due to indirect biochemical effects in the sediments

Impact Description

An indirect impact associated with cuttings disposal is the potential development of hypoxic conditions in the near-surface sediment layers through bacterial decomposition of organic matter (indirect negative impact). Generally speaking, biodegradable organic matter in cuttings piles often has a greater effect on the structure and function of benthic communities than sediment texture, deposition rate or, in some cases, chemical toxicity (Hartley *et al*. 2003). Bacterial decomposition of organic matter may deplete oxygen in the near-surface sediment layers, thereby changing the chemical properties of the sediments by generating potentially toxic concentrations of sulfide and ammonia (Wang & Chapman 1999; Gray *et al*. 2002; Wu 2002). The rapid biodegradation of drilling solids (particularly those containing NADFs) may therefore lead indirectly yet rapidly to sediment toxicity, particularly in fine-grained sediments (Munro *et al*. 1998; Jensen *et al*. 1999; Trannum *et al*. 2010). Organically enriched sediments are often hypoxic or anoxic, and consequently harbour markedly different benthic communities to oxygenated sediments (Pearson & Rosenberg 1978; Gray *et al*. 2002; Tait *et al*. 2016). Organic matter concentration in the sediments would decrease in response to microbial degradation, resulting in increases in oxygen concentration in the surface-sediment layers leading to succession in the benthic community structure toward a more stable state. Such biochemical effects in the sediments can have substantial effects on the structure and function of benthic communities.

Project Controls

The operator will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT. In this regard TEEPNA has various project controls in place for the proposed drilling operations. These include:

- TEEPNA has indicated it plans to use WBMs (riserless sections) and Group III NADFs for the risered sections. Drill cuttings from the risered sections would be treated to reduce the oil content to <6% Oil On Cutting (OOC) and discharged overboard.
- Cuttings will be discharge 10 m below surface during risered drilling.

Sensitive Receptors

The drilling activities would be undertaken in the offshore marine environment, more than 290 km offshore where the Namib Lower Slope and Abyss habitats been rated as 'Least Threatened'. The benthic biota inhabiting unconsolidated sediments of the outer shelf and abyss are very poorly known, but at the depths of the proposed well drilling are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise urchins, holothurians, sea stars, brittle stars, burrowing anemones, molluscs, seapens, crabs and shrimps, and sponges, many of which are longer lived and therefore more sensitive to disturbance. No rare or endangered species have been reported or are known from the continental slope unconsolidated sediments. The South Atlantic Central Water comprising the bulk of the seawater in the study area has depressed oxygen concentrations (~80% saturation value), but lower oxygen concentrations (<40% saturation) frequently occur. Biota can thus be expected to be well

adapted to periodic low oxygen conditions and consequently receptors can be considered of LOW sensitivity.

Impact Magnitude

WBM and NADF cuttings piles typically contain low concentrations of biodegradable organic matter and do not support large populations of bacteria (Dow *et al*. 1990). As most of the organic chemicals in WBMs are biodegradable under aerobic conditions, sediments containing WBM cuttings show only slight and short-term reductions in redox potential. Similarly, the NADF typically degrade rapidly and can cause localised hypoxia in underlying sediments (EPA 2000; IOGP 2003). In the case of sediments containing OBM cuttings, the anoxic conditions that developed not only persisted over the long term (>1 year), but stimulated production of hydrogen sulphide by anaerobic sulphate-reducing bacteria (Dow *et al*. 1990).

Marine organisms respond to hypoxia by first attempting to maintain oxygen delivery (e.g. increases in respiration rate, number of red blood cells, or oxygen binding capacity of haemoglobin), then by conserving energy (e.g. metabolic depression, down regulation of protein synthesis and down regulation/modification of certain regulatory enzymes), and upon exposure to prolonged hypoxia, organisms eventually resort to anaerobic respiration (Wu 2002). Hypoxia reduces growth and feeding, which may eventually affect individual fitness. The effects of hypoxia on reproduction and development of marine animals remains almost unknown. Many fish and marine organisms can detect, and actively avoid hypoxia. Some macrobenthos may leave their burrows and move to the sediment surface during hypoxic conditions, rendering them more vulnerable to predation. Hypoxia may eliminate sensitive species, thereby causing changes in species composition of benthic, fish and phytoplankton communities. Decreases in species diversity and species richness are well documented, and changes in trophodynamics and functional groups have also been reported. Under hypoxic conditions, there is a general tendency for suspension feeders to be replaced by deposit feeders, demersal fish by pelagic fish and macrobenthos by meiobenthos (see Wu 2002 for references). Further anaerobic degradation of organic matter by sulphate-reducing bacteria may additionally result in the production of hydrogen sulphide, which is detrimental to marine organisms (Brüchert *et al*. 2003).

Development of anoxic conditions beneath re-deposited riserless and risered cuttings is likely due to the relatively high deposition thicknesses (316 – 338 mm) closer to the wellbore and discharge point and the use of chemicals in the NADFs with low biodegration rate (e.g. EDC-99 DW C, SureMul Plus A, Invermul NT B and EZMUL NT A). The results of the modelling study indicated that although there was no significant risk in changes in oxygen concentrations in the sediments at the end of drilling operations (34 days) (Figure 55, left), these manifested over the longer term with maximum values for the entire simulation period reached more than 1 year after the start of simulation and persisting beyond 10 years (Figure 55, right). Maximum values reached ranged from -67% (Season 4) to -74% (Season 1), with the maximum distances ranging from 0.885 km (Season 4) to 1.850 km (Season 3) from the well site. Changes in oxygen concentrations were the highest contributer to the EIF over the entire simulation period, contributing between 89.7% and 91.1% of the EIF results in all seasons.

Due to the low deposition thicknesses (0.1 mm) predicted in the cuttings fallout footprint for distances beyond ~2 000 m from the modelled well location, the development of anoxic conditions beneath re-deposited cuttings beyond a maximum of ~2 km km is highly unlikely (Figure 56) (ProOceano 2023). Anoxic conditions are thus limited to the area of maximum deposit thickness of the cuttings pile around the wellbore (SITE SPECIFIC), and although persistent in the LONG TERM, they would have an impact of LOW intensity on the benthic macrofauna as deep-water communities typically show a degree of

tolerance to hypoxic sediment conditions. The modelling study did not specify whether bioturbation effects were taken into consideration in predicting the duration of anoxic conditions, but typically recovery of affected communities would be expected over the SHORT TERM (within a few months) to MEDIUM TERM due to bioturbation. The impact is thus considered to be of **LOW** magnitude.

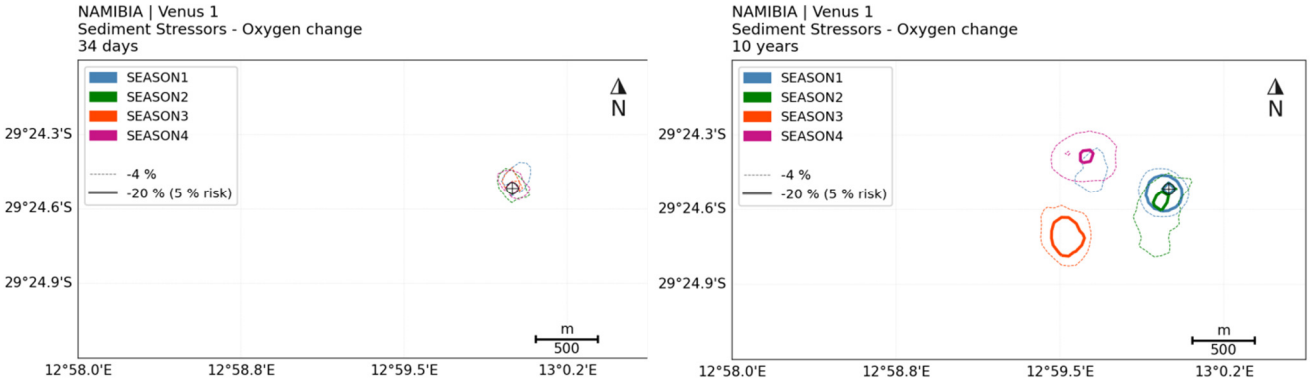


Figure 55: Changes in oxygen concentration in the sediments due to discharge of cuttings during the risered sections at the end of drilling operations (left) and after 10 years (right) (Source: ProOceano 2023).

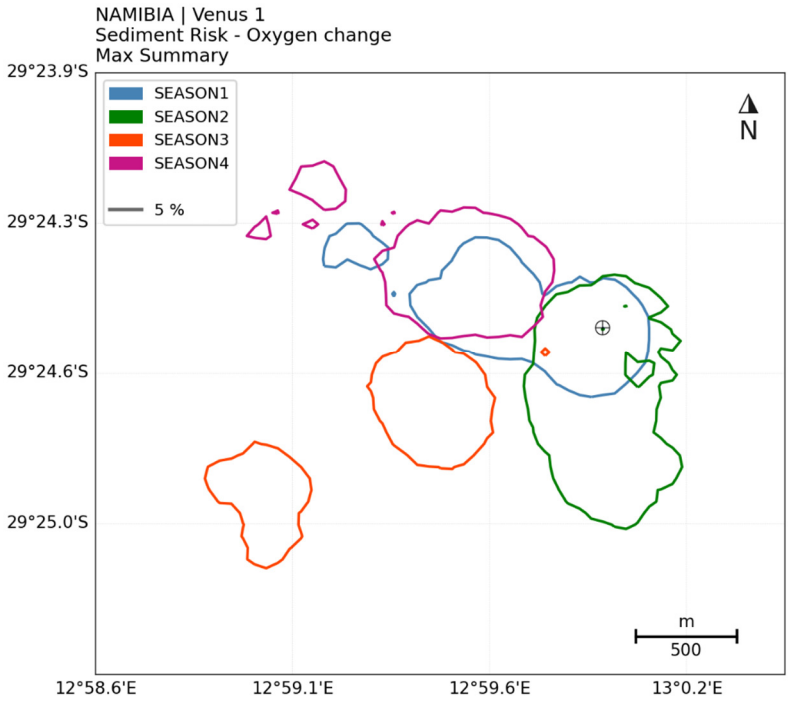


Figure 56: The maximum summary of risk of changes in oxygen concentration on the seafloor due to cuttings discharges during the entire simulation (Source: ProOceano 2023).

Impact Significance

Due to the low sensitivity of the receptors expected in the offshore soft-sediment environment and the very low magnitude, the impact is deemed to be of **VERY LOW** significance. Potential deep-water hardground habitats occurring beyond 1.8 km from the well site are unlikely to be impacted.

Identification of Mitigation Measures

No mitigation measures for potential biochemical effects on the sediments and their associated communities are proposed or deemed necessary. For mitigation measures proposed for sensitive hard-ground habitats refer to Section 4.4.2.

Residual Impact Assessment

This potential impact cannot be eliminated due to the necessity of disposal of drill cuttings. Thus the impact remains of NEGLIGIBLE significance.

12	***Indirect Impacts of Cuttings Discharges: development of anoxic sediments in unconsolidated sediments around the wellbore***	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	LOW	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	SITE	SITE
Duration	LONG TERM	SHORT TERM
Significance	**VERY LOW**	**NEGLIGIBLE**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.4.2.1.5 Summary of the Risks to Sensitive Habitats of Drilling Discharges

The greatest risk of drill cuttings discharge on marine communities is that of smothering. Cuttings discharged at the seabed during the spudding of a well form a highly localised spoil mound around the wellbore, thinning outwards. In contrast, the cuttings discharged at the surface from the drilling unit form two plumes. The larger particles and flocculated solids, which constitute ~90% of the discharge, settle to the seabed nearest the wellbore while the fine-grained unflocculated solids and soluble components of the mud 10% of the discharge) are rapidly diluted in the receiving waters and are dispersed in the water column at increasing distances from the drill unit.

In the high energy environment of Block 2912, strong surface currents will rapidly dispersed and redistributed drilling solids discharged at the surface. The accumulation of drilling discharges on the seabed from from surface discharges will therefore be minimal and any adverse smothering effects on benthic community composition will be difficult to detect above the natural variability. Nonetheless, the benthos of deep-water hard substrata are considered highly sensitivity and potential smothering effects on these biota need to be considered when planning well locations.

The first point to consider is that the Area of Interest does not overlap directly with offshore MPAs or proposed EBSAs. Furthermore, drilling discharge modelling studies were undertaken for a theoretical well location located closest to the coast, and therefore considered the worst-case scenario. Modelling results indicate that the maximum sediment thickness observed at the wellbore was 338 mm (Season 4), with the maximum distance with a significant total environmental risk to the sediments (thickness deposits, grain size variation and changes in oxygen concentrations) above 5% extending as far as 2 km from the Discharge Point (Season 3) in a south-westerly direction and across a highly localised area of the Namib Lower Slope and Namib Abyss habitats, which have been assigned a threat status of 'Least Threatened'. The environmental risk from the discharged drilling solids is primarily due to changes to the oxygen concentration of the receiving sediments, with risks persisting beyond 10 years after the end of drilling operations. This, however, is a conservative estimate as it did not take into account any reworking of the impacted sediments through bioturbation, or resuspension or background sediment transport due to the Benguela Current. Physical recovery of the sediments is thus likely to occur much faster thereby facilitating rapid recolonisation and recovery of the benthic community structure to functional similarly with those originally present.

Significant environmental risk above 5% associated with the water column, due to the release of Bentonite used in the drilling of the riserless sections, was observed up to maximum distance of 7.7 km to the north of the modelled Discharge Point. Depending on the location of the well, the environmental risk to the near-bottom water column could thus extend into the Namib Lower Slope or Namib Abyss habitat types, both of which have been assigned a threat status of 'Least Threatened'. Seasonal effects in the length, height and spread of the contaminant plume during riserless drilling are evident. In contrast, chemicals released at the surface through discharge of drilling wastes during the risered stages are rapidly diluted and dispersed (few hours) and are not detectable beyond the cessation of drilling operations. For the modelled discharge location, **the chemical footprints lies well offshore and at a considerable distance from sensitive spawning areas, but some overlap with proposed ESAs that extends west of the Orange Seamount and Canyon Complex EBSA, and across Block 2912, may occur**.

4.4.6 Generation of Underwater Noise

4.4.6.1 Impact of Marine Fauna

Source of Impact

The project activities that will result in an increase in noise impacts on marine fauna are listed below.

Project phase	Activity
Mobilisation	Transit of survey vessel, drilling unit and support vessels to the drill site
Pre-drilling Survey	Multi- and single beam echo sounding and sub-bottom profiling of target areas within the Area of Interest
Operation	Operation of drilling unit and transit of support vessels between the drill area and Lüderitz
	Vertical seismic profiling (VSP) of the well
Demobilisation	Transit of survey vessel, drilling unit and support vessels from drill site

These activities are described further below:

- Single and multibeam echo sounding and sub-bottom profiling are standard methods used in geophysical surveying to obtain images of the seafloor at a resolution and accuracy sufficient to image the typical scale of active seafloor seeps. The multi-beam echo sounder emits a fan of acoustic beams on either side of the vessel's track across a swath width of approximately two times the water depth. The beams are emitted from a transducer at frequencies ranging from 70 kHz to 100 kHz and typically produces sound levels in the order of 200 dB re 1 µPa at 1 m. Single beam echo sounders operate in the frequency range of 38 to 200 kHz. Sub-bottom profilers (boomers and sparkers) emit an acoustic pulse from a transducer at frequencies ranging from 2 - 16 kHz and typically produces sound levels in the order of 200-230 dB re 1 µPa at 1 m.
- The presence and operation of the survey vessel, drilling unit and support vessels during transit to the drill site, during the proposed surveying and drilling activities and during demobilisation will introduce a range of underwater noises into the surrounding water column that may potentially contribute to and/or exceed ambient noise levels in the area. For non-impulsive noise, the overall noise level from **combined noise emissions from drilling unit and three support vessels** is approximately 201.9 dB re 1 µPa @ 1 m (or dB re 1 $\mu Pa^2 \cdot S$ @ 1 m) (SLR Consulting Canada 2023).
- Vertical seismic profiling (VSP) is a standard method used during well logging and can generate noise that could exceed ambient noise levels. VSP source generates a pulse peak sound pressure level around 245.8 dB re 1 µPa @ 1 m, the root-mean-square sound pressure level (RMS SPL) 227.2 re 1 µPa @ 1 m, and the sound exposure level (SEL) 224.5 dB re $\mu Pa^2 \cdot s$ @ 1 m, decreasing rapidly with distance from the source. VSP uses a small airgun array; volumes and the energy released into the marine environment are significantly smaller than what is required or generated during conventional seismic surveys. The airgun array would be discharged approximately five times at 20 second intervals. This process is repeated, as required, for different sections of the well. A VSP is expected to take approximately 9 hours and ~250 shots per well to complete, depending on the well's depth and number of stations being profiled.

Impact Description

The cumulative impact of increased background anthropogenic noise levels in the marine environment is an ongoing and widespread issue of concern (Koper & Plön 2012). The sound level generated by drilling operations fall within the 120-190 dB re 1 µPa range at the drilling unit, with main frequencies less than 0.2 kHz. For the current project, noise would be generated by a number of sources (e.g. heavy lift vessel, drill ship in transit and operational, semi-submersible drill rig, support vessels and drill ship maintenance) with the noise levels ranging from 197 – 200 dB re 1 µPa @ 1m depending on the drill unit and support vessels used. The noise generated by vessels and well-drilling operations in general, therefore falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges before attenuating to below threshold levels.

The operating frequencies of the single beam and multi-beam sonar falls into the high frequency kHz range, and is thus beyond the low frequency hearing ranges of fish species and sea turtles (from below 100 Hz to up to a few kHz) (see Figure 57). The high frequency active sonar sources, however, have energy profiles that clearly overlap with cetacean's hearing sensitivity frequency range, particularly for cetaceans of High Frequency and Very High Frequency hearing groups, and would be audible for considerable distances (in the order of tens of km) before attenuating to below threshold levels. The noise emissions from the MBES sources are highly directional, spreading as a fan from the sound source, predominantly in a cross-track direction. The noise impact would therefore be highly localised for the majority of marine mammal species.

In the case of VSP, the frequency of the pulse is below the peak hearing sensitivity of most odontocetes, but overlaps broadly with the vocalisation frequency and peak hearing sensitivity of many mysticetes (Erbe *et al*. 2017). Humpback and Southern right whales mostly communicate at frequencies above 100 Hz while the calls of Sei, Blue and Fin whales (from ~20 Hz upwards) overlaps more directly with the VSP frequency band (McDonald *et al*. 2001, 2005, 2006; Hofmeyr-Juritz & Best 2011; Erbe *et al*. 2017). The received level of noise (and risk of physiological injury or behavioural changes) would depend on the animal's proximity to the sound source. Nonetheless, the underwater noise generated during the project could affect a wide range of fauna; from demersal species residing on the seabed in the vicinity of the wellhead, to those occurring throughout the water column and in the pelagic habitat near the surface.

Elevated noise levels could impact marine fauna by:

- Causing direct physical injury to hearing or other organs (direct negative impact), including permanent (PTS)[9] or temporary threshold shifts (TTS)[10];
- Masking or interfering with other biologically important sounds (e.g. communication, echolocation, signals and sounds produced by predators or prey) (indirect negative impact); and
- Causing disturbance to the receptor resulting in behavioural changes or displacement from important feeding or breeding areas (direct negative impact).

[9] A permanent threshold shift is a shift in the auditory threshold, which results in permanent hearing loss.

[10] A temporary threshold shift is a shift in the auditory threshold, which results in temporary hearing loss.

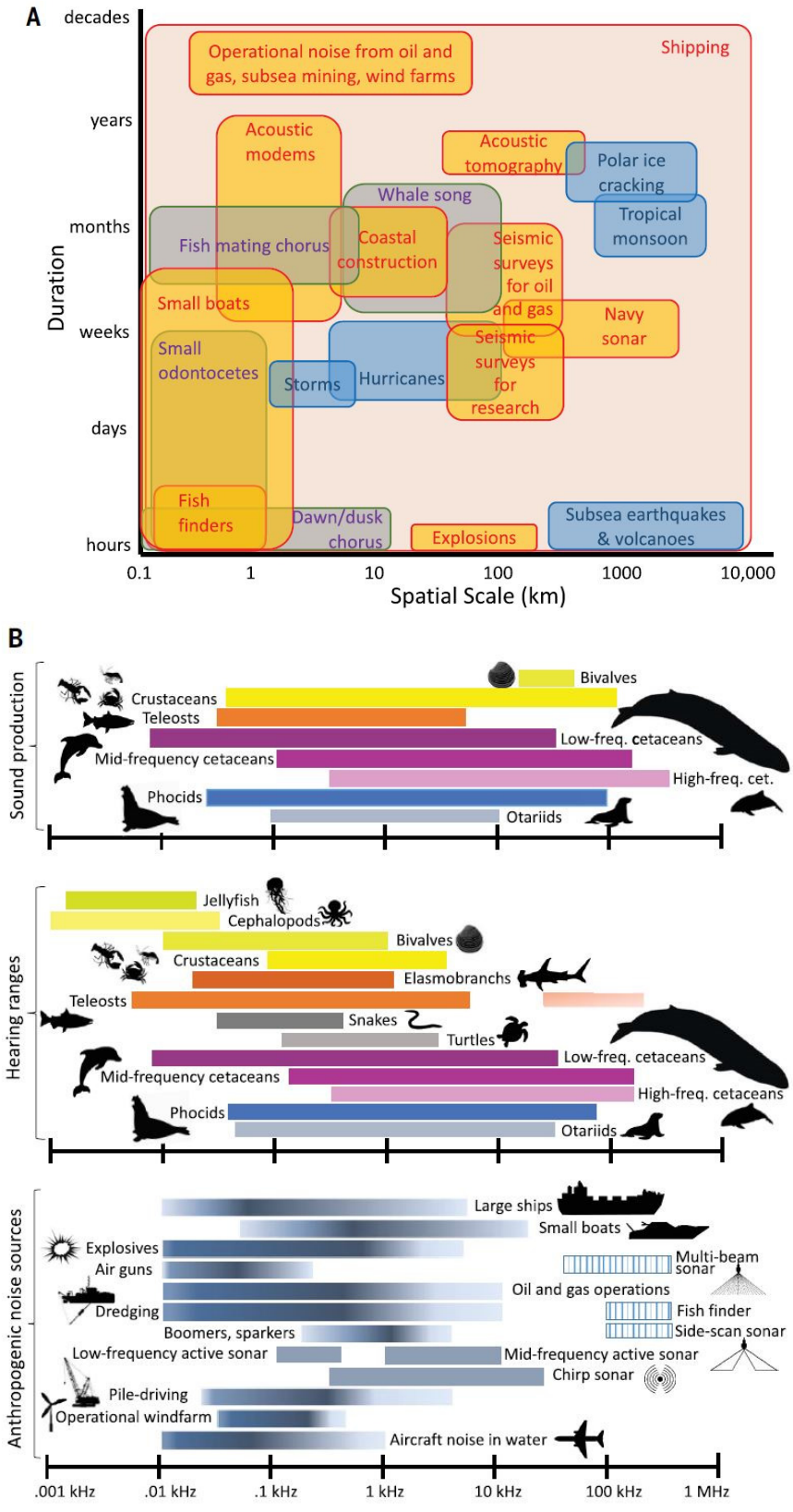


Figure 57: Sources and animal receivers of sound in the ocean. A) Spatial extent and duration of selected sound producing events, and B) Approximate sound production and hearing ranges of marine taxa and frequency ranges of selected anthropogenic sound sources. (Source: Duarte *et al*. 2021).

Exposure to high sound levels can result in physiological injury to marine fauna through a number of avenues, including shifts of hearing thresholds (as either permanent (PTS) or temporary threshold shifts (TTS)), tissue damage, acoustically induced decompression sickness (particularly in beaked whales), and non-auditory physiological effects. Both PTS and TTS represent actual changes in the ability of an animal to hear, usually at a particular frequency, whereby it is less sensitive at one or more frequencies as a result of exposure to sound. In assessing injury from noise, a dual criterion is adopted based on the peak sound pressure level (SPL) and sound exposure level (SEL) (a measure of injury that incorporates the sound pressure level and duration), with the one that is exceeded first used as the operative injury criterion. PTS-onset and TTS-onset thresholds differ between impulsive and non-impulsive noise, with ranges for marine mammals summarised in Table 14. The assessment criterion for the onset of behavioural disruption in marine mammals of all hearing groups is root-mean-square (RMS) SPL of 160 dB re 1µPa for impulsive noise and 120 dB re 1µPa for non-impulsive noise (NMFS 2013). Peak sound pressure levels for impulsive noise resulting in mortality or potential mortal injury for fish eggs and larvae, turtles and fish range from 207 - 213 dB re 1 µPa, with TSS in fish occurring at cumulative sound exposure levels of above 186 dB re 1 µPa2·s (see Table 4 in SLR Canada 2023 for details). The behavioural threshold for impulsive sound events for sea turtles was established at RMS SPL 166 dB re 1µPa by McCauley *et al*. (2000).

The risk of TSS close to continuous shipping sounds is generally low, however, although masking of calls and behavioural changes would be likely. For VSP in particular, masking of calls is likely for those species of baleen whales whose calls overlaps with the VSP frequency band.

Project Controls

The drilling contractor will ensure that the proposed exploration activities are undertaken in a manner consistent with good international industry practice and BAT. All whales and dolphins are given protection under the Namibian Law. The regulations under the Namibian Marine Resources Act, 2000 (No. 27 of 2000) states that no whales or dolphins may be harassed, killed or fished. Although not legislated in Namibia, no vessel or aircraft should approach closer than 300 m to any whale and a vessel or aircraft should move to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft.

Sensitivity of Receptors

Vessel noise would primarily take place in the Area of Interest for drilling, around the drill site and along the route taken by the support vessels between the drill area and Lüderitz. The Area of Interest for drilling is located approximately 290 km offshore at its closest point and far removed from MPAs and any sensitive coastal receptors. Although higher productivity and shelf-edge upwelling occurs inshore of the Area of Interest for drilling, the surface waters in Block 2912 will be clear and less productive as they are beyond the influence of coastal and shelf-edge upwelling. Furthermore, being dependent on nutrient supply, plankton abundance is typically spatially and temporally highly variable and is thus considered to have a **LOW** sensitivity. The major spawning areas are also all located on the continental shelf, inshore of the Area of Interest (see Figure 23). Seasonally high abundances of ichthyoplankton (hake, sardine and anchovy eggs and larvae), particularly in late winter and early spring will occur inshore of the Area of Interest.

Migratory pelagic species transiting through the drill area may be directly affected. The taxa most vulnerable to disturbance by underwater noise are turtles, and large migratory pelagic fish and marine mammals. Some of the species potentially occurring in the drill area, are considered regionally or

globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles and blue whales), 'Endangered' (e.g. Black-Browed and Yellow-Nosed Albatross, whale shark, shortfin mako shark, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, loggerhead turtles, oceanic whitetip shark, dusky shark, great white shark, longfin mako and sperm whale, Bryde's and humpback whales) or 'near threatened' (e.g. striped marlin, blue shark, longfin tuna/albacore and yellowfin tuna). Although species listed as 'Critically Endangered' or 'Endangered' may potentially occur in the drill area, the drill area is located in a main marine traffic route and thus is in an area already experiencing increased marine traffic and vessel noise. Thus, the sensitivity of receptors to vessel and drilling noise is considered to be **MEDIUM**. However, receptor sensitivity to noise from VSP is considered to be **HIGH**.

Impact Magnitude

4.4.6.1.1 Geophysical Survey Noise

The noise generated by the acoustic equipment utilized during geophysical surveys falls within the hearing range of most fish, turtles and marine mammals and at sound levels of between 200 to 240 dB re 1 µPa at 1 m, will be audible for considerable distances (in the order of tens of km) before attenuating to below threshold levels (Findlay 2005). High frequency active sonar sources, in particular, have energy profiles that clearly overlap with cetacean's hearing sensitivity frequency range, particularly for cetaceans of High Frequency (e.g. odontocetes: dolphins, toothed whales (e.g. sperm), beaked whales, bottle-nose whales) and Very High Frequency (e.g. Heavisides dolphins, pygmy sperm and dwarf sperm whales) hearing groups. However, unlike the noise generated by airguns during seismic surveys, the emission of underwater noise from geophysical surveying and vessel activity is not considered to be of sufficient amplitude to cause auditory or non-auditory trauma in marine animals in the region.

As surveys using single- and MBES sources have much lower noise emissions compared with seismic airgun sources, no specific considerations have been put in place in developing assessment criteria for MBES sources. For the proposed Kongsberg MBES, a cross-track beam fan width 140° and an along-track beam width up to 2° is expected. The noise emissions are thus highly directional, spreading as a fan from the sound source, predominantly in a cross-track direction, and only directly below or adjacent to the systems (within 10 m of the source) would sound levels be in the 240 dB range where exposure would result in PTS. In the case of the most sensitive very-high-frequency cetaceans the maximum zones of PTS effects were predicted to occur at a range of 760 m from the source along the cross-track direction (SLR Consulting Canada 2023), with TTS onset expected at 1 020 m from the source for the deep water location (3 700 m depth) and 990 m from the source for the deep water location (3 040 m depth). For the other hearing groups TTS and PTS onset occurred at between 70 m and 380 m. Noise impacts related to PTS and TTS on sea turtles are similarly expected to occur along the cross-track direction from the MBES source. The maximum zones of impact are predicted to range within 70 m for PTS and 125 m for TTS. Therefore, only directly below or within the sonar beam would received sound levels be in the range where exposure results in trauma or physiological injury. As most pelagic species likely to be encountered within the area of interest are highly mobile, they would be expected to flee and move away from the sound source before trauma could occur. Furthermore, the statistical probability of crossing a cetacean, pinniped or turtle with the narrow moving multi-beam fan several times, or even once, is very small.

The underwater noise from the survey systems may, however, induce localised behavioural changes (e.g. avoidance of the source) in some marine mammal, turtles and fish but there is no evidence of significant behavioural changes that may impact on the wider ecosystem (Perry 2005) and no evidence

of physical damage (i.e. PTS and TTS) (Childerhouse & Douglas 2016). The maximum impact distance for the behavioural disturbance caused by the immediate exposure to individual MBES pulses was predicted to reach 1.62 km from the source for fish, within 1.15 km from the source for marine mammals of all hearing groups and up to 540 m from the array source for turtles at cross-track directions.

With the exception of low-frequency cetaceans, no other marine mammal hearing groups were predicted to suffer cumulative PTS impacts. The zones of cumulative PTS impact low-frequency cetaceans were predicted to range up to 320 m from the MBES source location along the cross-track directions, with the zones of cumulative TTS impact predicted to be around 800 m from the MBES source. For cetaceans of other hearing groups, such as VHF and PCW, the zones of TTS impact are predicted to range between 25 and 80 m from the source location. For turtles, no cumulative PTS impact was predicted, with cumulative impacts related to TTS expected to occur within 10 m from the source.

4.4.6.1.2 Vessel and Drilling Noise

The ocean is a naturally noisy place and marine animals are continually subjected to both physically produced sounds from sources such as wind, rainfall, breaking waves and natural seismic noise, or biologically produced sounds generated during reproductive displays, territorial defence, feeding, or in echolocation (see references in McCauley 1994; Duarte *et al*. 2021). Such acoustic cues are thought to be important to many marine animals in the perception of their environment as well as for navigation purposes, predator avoidance, and in mediating social and reproductive behaviour. Anthropogenic sound sources in the ocean can thus be expected to interfere directly or indirectly with such activities thereby affecting the physiology and behaviour of marine organisms (NRC 2003). A comparison of the various noise sources in the ocean is shown in Figure 57. Natural ambient noise will vary considerably with weather and sea state, typically ranging from about 80 to 120 dB re 1 µPa for the frequency range 10 Hz – 10k Hz (Croft & Li 2017). As Block 2912 is located within the main offshore shipping routes that pass around southern Africa (Figure 58), the shipping noise component of the ambient noise environment is expected to be significant within and around the licence block and Area of Interest for drilling (OceanMind Limited 2020). Given the significant local shipping traffic and relatively strong metocean conditions specific to the area surrounding Block 2912, the ambient noise levels are expected to be at least 10 dB higher than the lowest level, within the higher range of the typical ambient noise levels, i.e. 90 - 130 dB re 1 µPa for the frequency range 10 Hz – 10 kHz (SLR Consulting Canada 2023).

Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping (Erbe *et al*. 2018, 2019). Depending on size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 µPa at 1 m with main frequencies from 1 to 500 Hz (McCauley 1994; NRC 2003). Especially at low frequencies between 5 to 100 Hz, vessel traffic is a major contributor to noise in the world's oceans, and under the right conditions, these sounds can propagate 100s of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al*. 2003; Duarte *et al*. 2021).

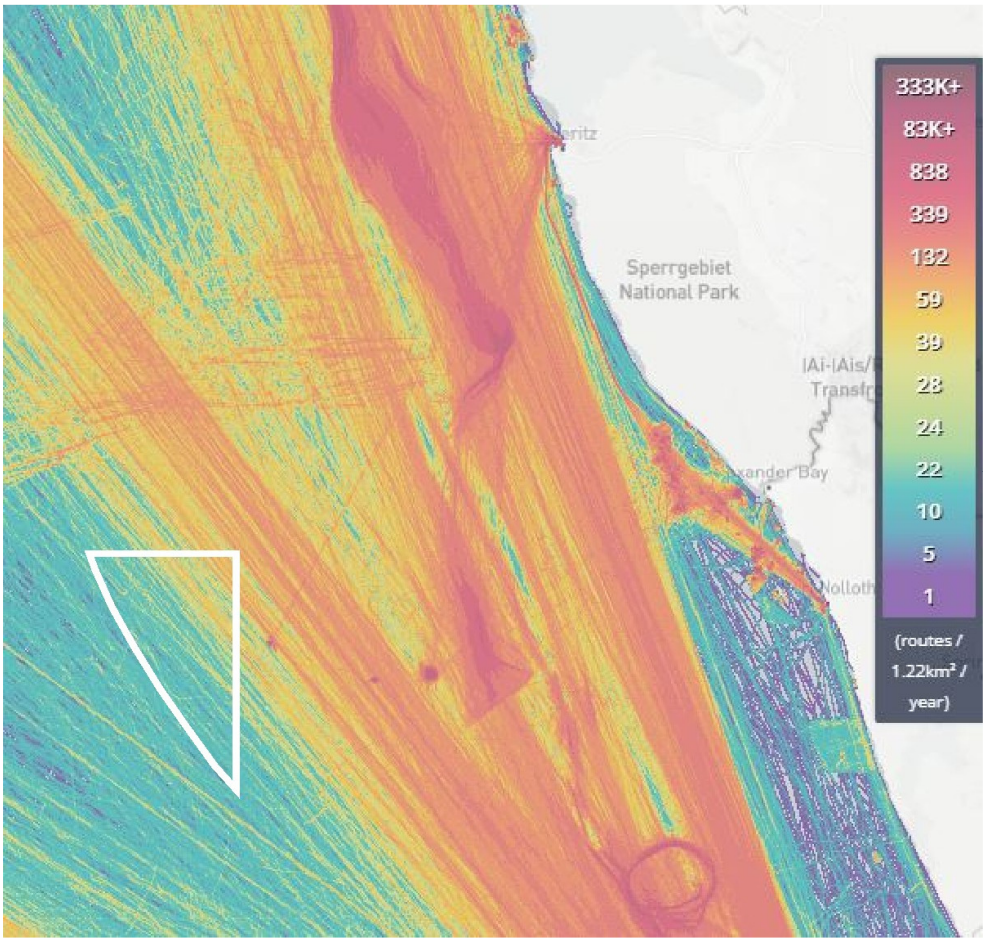


Figure 58: Block 2912 (white polygon) in relation to offshore vessel traffic (adapted from www.marinetraffic.com/en/ais/home, accessed November 2022).

Physiological Injury

The overall sound level generated by drilling operations (drill rig and support vessels) is ~198 dB re 1 µPa. The noise generated by the drill rig thus falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges before attenuating to below threshold levels. However, the sound emissions are not considered to be of sufficient amplitude to cause direct physical injury or mortality to marine life, except at close range.

For the current proposed well-drilling project in Block 2912 it was estimated that that the zones of cumulative impact for 24 hours exposure duration of non-impulsive noise from drilling activities at two sites (shallowest point within drilling area and closest to the coast, and a deep-water location) could potentially lead to TTS and PTS, but that effects did not extend beyond 3 200 m and 290 m from the drill site, respectively for marine mammals (see

Table 15). As most pelagic species likely to be encountered within the Area of Interest are highly mobile, they would be expected to move away from the sound source before trauma could occur. With a decreased exposure of 0.5 hours, the zones of impact would be significantly reduced, with TTS- and PTS-onset zones within 450 m and 40 m, respectively. Therefore, if marine mammals only pass through the site near the non-impulsive stationary noise sources in a very short period of time, their noise exposure is not expected to exceed PTS-onset thresholds. The extent of the noise impacts would, however, also depend on the variation in the background noise level with weather and with the proximity of other vessel traffic (not associated with the project), the depth of the drill site and the marine mammal hearing group, with low frequency cetaceans (i.e. mysticetes: southern right, humpback, sei, fin, blue, Bryde's, minke) showing the highest sensitivity.

Temporary threshold shifts may occur at close range for sea turtles and fish species lacking swim bladders or where the swim bladders are not involved in hearing, but generally the non-impulsive drilling noise is predicted to have low physiological impacts (both mortality and recovery injury) on fish and sea turtle species (SLR Consulting Canada 2023).

The Area of Interest for drilling overlaps with the distributions of a number of pelagic seabirds. As the Area of Interest lies offshore of the distribution of small pelagic fish species that constitute the main prey of these seabirds, numbers are expected to be low.

Due to their extensive distributions, the numbers of pelagic species (large pelagic fish, turtles and cetaceans) encountered during the drilling campaign is expected to be low and considering they are highly mobile and able to move away from the sound source before trauma could occur, the intensity of potential physiological injury as a result of drilling and vessel noise would be rated as LOW.

Behavioural Avoidances

The underwater noise from well drilling operations may induce localised behavioural changes or masking of biologically relevant sounds in some marine fauna, but there is no evidence of significant behavioural changes that may impact on the wider ecosystem (Perry 2005).

For the current proposed well-drilling project in Block 2912 it was estimated that non-impulsive noise from drilling activities at two sites (shallowest point within drilling area and closest to the coast and a deep-water location) could result in behavioural disturbance in cetaceans to distances of between 33.6 km (deep water site – 3 700 m Water Depth) and 30.6 km (shallow water site – 3 040 m Water Depth). Whales such as humpbacks and southern rights migrating and/or breeding along the coast are therefore not expected to be affected by the drilling noise. Similarly, whales potentially associated with Tripp Seamount located ~120 km east of the Area of Interest, are unlikely to be affected by the vessel and drilling noise.

In a study evaluating the potential effects of vessel-based diamond mining on the marine mammal community off the southern African West Coast, Findlay (1996) concluded that the significance of the impact is likely to be minimal based on the assumption that the radius of elevated noise level would be restricted to ~20 km around the mining vessel. The responses of cetaceans to noise sources are often also dependent on the perceived motion of the sound source as well as the nature of the sound itself. For example, many whales are more likely to tolerate a stationary source than they are one that is approaching them (Watkins 1986; Leung-Ng & Leung 2003), or are more likely to respond to a stimulus with a sudden onset than to one that is continuously present (Malme *et al*. 1985).

According to Popper *et al*. (2014), for non-impulsive noise sources in general, relatively high to moderate behavioural risks are expected for fish species at near to intermediate distances (tens to hundreds of meters) from the source location. Relatively low behavioural risks are expected for fish

species at far field distances (thousands of meters) from the source location. The major spawning areas, as well as egg and larval drift pathways of commercially important species, such as hake, pilchards, horse mackerel and anchovy lie inshore of the Area of Interest for drilling, and are unlikely to be impact by the behavioural disturbance zone. Thus, the intensity of the impact on fish and turtles is considered to be low.

Since the Area of Interest is located in a main marine traffic route experiencing increased vessel noise and as the sound source during drilling operations will be stationary, the intensity of the impact of potential behavioural disturbance as a result of drilling and vessel noise on cetaceans is considered to be LOW. Being highly mobile, cetaceans would also be able to move away from the sound source before injury occurs.

Furthermore, the drill area is located in a main marine traffic route and thus is in an area already experiencing increased marine traffic and vessel noise. The duration of the impact on the populations would be limited to the short-term (3-4 months per well) and extend LOCALLY (behavioural disturbances would be expected within ±33 km from the drill site, as well as vessel movement between the drilling area and the logistics base in Lüderitz). The potential physiological injury or behavioural disturbance as a result of drilling and vessel noise would thus be of **VERY LOW** magnitude for up to 10 wells.

4.4.6.1.3 Vertical Seismic Profiling

Physiological Injury

The peak pressure levels from VSP seismic pulses, are likely to cause both PTS and TTS on-set in marine mammals, and potential mortal injury in fish, turtles and plankton. The animals would, however, need to be directly adjacent to or below the VSP source (marine mammals: <20 m; fish and turtles: <35 m) to be affected. An exception are the very high-frequency cetaceans, which are predicted to experience PTS-onset within 55 m from the VSP source, and TTS-onset within 90 m from the VSP source (SLR Consulting Canada 2023).

There is growing recognition that the sub-lethal effects of noise disturbance, which are both difficult to identify and measure, are likely to be relatively widespread and may have a greater impact than direct physical injury (Forney *et al*. 2017). Due to the highly localised and extremely short-term noise generated by VSP, sub-lethal effects (should they occur) would likely be acute rather than chronic (longer-term and associated with many overlapping activities). These authors point out that a lack of observed response to the various faunal groups does not imply an absence of costs such as physiological stress and reduced reproduction, survival or feeding success. Apparent tolerance of disturbance may in fact have population-level impacts that are more subtle and difficult to record with conventional methodologies. As most pelagic species likely to be encountered within the licence area are highly mobile, they would be expected to flee and move away from the sound source before trauma could occur. However, assuming the animal does not move away from the noise source, the cumulative maximum threshold distances would apply (see

Table 15). Considering the cumulative impact (250 discharges within 9 hours) on marine mammals, the maximum threshold distances will be in the order of up to 320 m and 250 m for TTS onset in deep and shallower water, respectively, and up to 70 m for PTS onset for the most sensitive low frequency cetaceans, with the threshold distances for the remaining hearing groups being considerably lower. For turtles, the cumulative impact (250 discharges within 9 hours) will result in PTS and TTS onset at maximum distances of 25m and 70 m, respectively. For fish and ichtyoplankton maximum distances were predicted to be in the order of 65 m for recovery injury and 330 m for TTS-onset.

The zone of impact for zooplankton to suffer physiological injury is in relatively close proximity to the operating sound source. This faunal group, however, cannot move away from the approaching sound source, and is therefore likely to suffer mortality and/or physiological injury within the zone of impact. Potential impacts on ichthyoplankton and pelagic invertebrates would thus be of high intensity at close range, but highly localised and transient due to the localised and short-term nature of the VSP operations. Impacts are therefore not comparable to the significant declines in zooplankton abundance within a maximum range of 1.2 km of an airguns' passage as reported by McCauley *et al*. (2017). For large seismic arrays, mortalities and physiological injuries to zooplankton are reported to occur only at very close range (<5 m) (reviewed in Carroll *et al*. 2017 and Sivle *et al*. 2021). The major spawning areas, as well as egg and larval drift pathways of commercially important species, such as hake, pilchards, horse mackerel and anchovy, however, all lie inshore of the Area of Interest, and should in no way be affected by the highly localised VSP operations. Declines in zooplankton abundance as a result of VSP operations are therefore likely to be negligible.

It is evident from Table 15 that animals would need to be in relatively close proximity to the operating sound source (VSP) to suffer physiological injury, and in reality, marine fauna in the offshore habitat of Block 2912 would not stay in the same location for the entire period and therefore cumulative effects would not be expected. It is thus considered likely that most would avoid sound sources at distances well beyond those at which injury is likely to occur.

In the case of noise generated during VSP, the effects on marine fauna (ichthyoplankton, fish, diving seabirds, turtles, marine mammals) are considered to be of MEDIUM intensity, with the worst case being possible TTS onset in cetaceans within 320 m of the sound source. Effects would, however, remain LOCAL and for the duration of the VSP activities (SHORT TERM; 9 hours per well). In the case of other marine fauna effects would be even more localised and confined to a few 10s of metres from the VSP array. The impact of underwater noise generated during VSP is thus considered of **VERY LOW** magnitude (or consequence) for up to ten wells.

Behavioural Avoidance and Masking of Sounds

Potential behavioural disturbance from the VSP pulses is predicted to occur for marine mammals of all hearing groups up to 1.4 km from the source. In the case of turtles, potential behavioural disturbance is predicted to occur up to 340 m from the source.

According to Popper *et al*. (2014), for impulsive noise sources in general, relatively high to moderate behavioural risks are expected for fish species at near to intermediate distances (tens to hundreds of meters) from the source location. Relatively low behavioural risks are expected for fish species at far field distances (thousands of meters) from the source location. Behavioural responses of fish, such as avoidance of seismic survey areas and changes in feeding behaviours in response to seismic sounds, have been documented to occur at received levels of between 130 and 180 dB re 1 µPa, with disturbance ceasing at noise levels below this (Slabbekoorn *et al*. 2019). Only in cases where animals remain in specific coastal areas for the purposes of calving or spawning, or are associated with specific oceanic

focal features such as seamounts, may cumulative effects on behaviour be realised. This said, the key Southern Right calving and nursing areas in Lüderitz and Elizabeth Bay, and major fish spawning areas fall outside of the maximum threshold distances for TTS, PTS and behaviour. Therefore, the zones of impact represent the worst case consideration and will reduce logarithmically with decreased exposure time period.

In the case of noise generated during VSP, the effects on behavioural avoidance of marine fauna are considered to be of LOW intensity and would remain LOCAL as behavioural disturbances would be expected within 1.4 km from the drilling location and for the duration of the VSP activities (SHORT TERM; 9 hours per well).

It is possible that the noise generated by VSP may mask biologically significant sounds, and cause disturbance and behavioural changes in the receptors, but as the impact would persist for a few hours only, impacts would be fully reversible once VSP operations are completed. The impact of underwater noise generated during VSP on behavioural avoidance and masking of sounds is thus considered of **VERY LOW** magnitude for all ten wells.

Table 14: PTS- and TTS-onset threshold levels for marine mammals exposed to impulsive and non-impulsive noise (Southall *et al*. 2019).

Marine mammal hearing group	PTS and TTS threshold levels impulsive noise				PTS and TTS threshold levels non-impulsive noise	
	Injury (PTS) onset		TTS onset		Injury (PTS) onset	TTS onset
	Pk SPL, dB re 1µPa (unweighted)	SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$ (weighted)	Pk SPL, dB re 1µPa (unweighted)	SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$ (weighted)	SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$ (weighted)	SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$ (weighted)
Low-frequency cetaceans	219	183	213	168	199	179
High-frequency cetaceans	230	185	224	170	198	178
Very high-frequency cetaceans	202	155	196	140	173	153
Sirenians	226	203	220	175	206	186
Phocid carnivores in water	218	185	212	170	201	181
Other marine carnivores in water	232	203	226	188	219	199

Table 15 Summary of the maximum zones of estimate for all assessed drilling activities. For details see the relevant table in SLR Consulting Canada (2023).

Animal Type	Drilling activities		Maximum threshold distances, m		
			PTS onset	TTS onset	Behavioural disturbance
Marine mammals	VSP – immediate impact		55	90	1 400
	VSP – cumulative	250 VSP pulses	70	Deep: 320 Shallow: 250	-
	VSP – cumulative	50 VSP pulses	35	150	
	Drilling – immediate behavioural impact		-	-	33 600
	Drilling – cumulative	24 hr	290	3 200	-
	Drilling – cumulative	0.5 hr	40	450	
	Single MBES Pulse - immediate impact		760	1 020	1 150
	Single MBES Pulse - cumulative impact		320	800	-
Sea Turtles	VSP – immediate impact		<10	<10	340
	VSP – cumulative	250 VSP pulses	25	70	-
	VSP – cumulative	50 VSP pulses	<10	30	-
	Single MBES Pulse - immediate impact		70	125	540
	Single MBES Pulse - cumulative impact		-	<10	-
Fish, fish eggs and fish larvae			**Mortality and potential mortal injury**	**Recovery injury**	**TTS**
	VSP – immediate impact		35	35	-
	VSP – cumulative	250 VSP pulses	50	65	330
	VSP – cumulative	50 VSP pulses	20	30	150
	Single MBES Pulse				1 620

Note: a dash indicates the threshold is not applicable

Impact Significance

The potential impact of vessel and drilling noise causing physiological injury to, or behavioural avoidance by, pelagic and coastal sensitive species, is deemed to be of **VERY LOW** significance considering their medium sensitivity and very low magnitude.

The potential impact of VSP noise causing physiological injury to, or behavioural avoidance by, pelagic and coastal sensitive species, is deemed to be of **LOW** significance considering their high sensitivity and very low magnitude.

Identification of Mitigation Measures

Despite the low significance of impacts of geophysical sonars, the Joint Nature Conservation Committee (JNCC) provides a list of guidelines to be followed by anyone planning marine sonar operations that could cause acoustic or physical disturbance to marine mammals. These have been revised to be more applicable to the southern African situation. Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Appoint a minimum of two dedicated Marine Mammal Observer (MMO) [11], with a recognised MMO training course, on board for marine fauna observation (360 degrees around survey vessel), distance estimation and reporting. One MMO should also have Passive Acoustic Monitoring (PAM) training. The MMO must ensure compliance with mitigation measures during seismic geophysical surveying.	Abate on site
2	Ensure survey vessel is fitted with PAM technology (one or more hydrophones), which detects animals through their vocalisations, should it be possible to safely deploy PAM equipment.	Abate on site
3	Pre-survey scans should be limited to 15 minutes prior to the start of survey equipment.	Avoid
4	"Soft starts" should be carried out for any equipment of source levels greater than 210 dB re 1 µPa at 1 m over a period of 20 minutes to give adequate time for marine mammals to leave the vicinity.	Avoid / Abate on site
5	If several types of sonar equipment are to be started sequentially or interchanged during the operation, only one pre-shoot search is required prior to the start of acoustic output. A pre-shoot search will, however, be required for gaps in data acquisition of greater than 10 minutes.	Avoid
6	Terminate the survey if any marine mammals show affected behaviour within 500 m of the survey vessel or equipment until the mammal has vacated the area.	Avoid / Abate on site
7	Avoid planning geophysical surveys during the movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters (beginning of June to end of November). As no seasonal patterns of abundance are known for odontocetes occupying the area, a precautionary approach to avoiding impacts throughout the year is recommended.	Avoid / Abate on site
8	Ensure that PAM is incorporated into any surveying taking place between June and November	Avoid / Abate on site
9	No sonar survey-related activities are to take place within declared Marine Protected Areas.	Avoid

[11] Non-dedicated MMOs can be implemented for short surveys using low-energy sources. Such personnel are trained MMOs who may undertake other roles on the vessel when not undertaking their mitigation role (JNCC 2017).

The generation of vessel noise and drilling noise cannot be eliminated due to the nature of the drilling operations. The following measures will be implemented to reduce noise at the source:

No.	Mitigation measure	Classification
1	Implement a maintenance plan to ensure all diesel motors and generators receive adequate maintenance to minimise noise emissions.	Avoid/reduce at source
2	Ensure vessel transit speed between the drill area and port is a maximum of 12 knots (22 km/hr), except within 25 km of the coast where it is reduced further to 10 knots (18 km/hr).	Avoid/reduce at source

For VSP, recommendations for mitigation include:

No.	Mitigation measure	Classification
1	**Key personnel and equipment**	
1.1	Appoint a minimum of two dedicated Marine Mammal Observer (MMO), with a recognised MMO training course, on board for marine fauna observation (360 degrees around drilling unit), distance estimation and reporting. One MMO should also have Passive Acoustic Monitoring (PAM) training should a risk assessment, undertaken ahead of the VSP operation, indicate that the PAM equipment can be safely deployed considering the metocean conditions (specifically current).	Abate on site
1.2	Ensure drilling unit vessel is fitted with PAM technology (one or more hydrophones), which detects animals through their vocalisations, should it be possible to safely deploy PAM equipment.	Abate on site
2	**Pre-start Protocols for airgun testing and profiling**	
2.1	VSP profiling should, as far as possible, only commence during daylight hours with good visibility. However, if this is not possible due to prolonged periods of poor visibility (e.g. thick fog) or unforeseen technical issue which results in a night-time start, refer to "periods of low visibility" below.	Avoid / Abate on site
2.2	Undertake a 1-hr (as water depths > 200 m) pre-shoot visual and possible acoustic scan (prior to soft-starts / airgun tests) within the 500 m radius mitigation zone in order to confirm there is no cetaceans, turtles, penguins and shoaling large pelagic fish activity close to the source.	Abate on site
2.3	Implement a “soft-start” procedure of a minimum of 20 minutes’ duration when initiating the acoustic source (except if testing a single airgun on lowest power). This requires that the sound source be ramped from low to full power rather than initiated at full power, thus allowing a flight response by marine fauna to outside the zone of injury or avoidance. Delay “soft-starts” if cetaceans, turtles and shoaling large pelagic fish are observed / detected within the mitigation zone during the pre-shoot visual / acoustic scan. A “soft-start” should not begin until 20 minutes after cetaceans depart the mitigation zone or 20 minutes after they are last seen or acoustically detected by PAM in the mitigation zone. In the case of penguins, shoaling large pelagic fish and turtles, delay the “soft-start” until animals move outside the 500 m mitigation zone.	Abate on site
2.4	Maintain visual and possibly acoustic observations within the 500 m mitigation zone continuously during VSP operation to identify if there are any cetaceans present.	Abate on site

No.	Mitigation measure	Classification
3	**Shut-Downs**	
3.1	Shut down the acoustic source if cetaceans, penguins, shoaling large pelagic fish or turtles are sighted within 500 m mitigation zone until such time as the mitigation zone is clear of cetaceans for 20 minutes or in the case of penguins, shoaling large pelagic fish or turtles, the animals move outside the 500 m mitigation zone before the soft-start procedure and production may commence.	Abate on site
4	**Breaks in Airgun Firing**	
4.1	Breaks of less than 20 minutes: • there is no requirement for a soft-start and firing can recommence at the same power level as at prior to the break (or lower), provided that continuous monitoring was ongoing during the silent period and no cetaceans, penguins, shoaling large pelagic fish or turtles were detected in the mitigation zone during the breakdown period. • If a cetaceans is detected in the mitigation zone during the breakdown period, there must be a minimum of a 20-minute delay from the time of the last detection within the mitigation zone and a soft-start must then be undertaken. In the case of penguins, shoaling large pelagic fish or turtles, the animals move outside the 500 m mitigation zone within the 20 minute period.	Abate on site
4.2	Breaks of longer than 20 minutes: • If it takes longer than 20 minutes to restart the airguns, a full pre-watch and soft-start process should be carried out before the survey re-commences. If an MMO/PAM operator has been monitoring during the breakdown period, this time can contribute to the 60-minute pre-watch time.	Abate on site
5	**Period of low visibility**	
5.1	Ensure that during periods of low visibility (where the mitigation zone cannot be clearly viewed out to 500 m), including night-time, the VSP source is only used if PAM technology is in place to detect vocalisations (subject to a risk assessment indicating that the PAM equipment can be safely deployed considering the metocean conditions) or: • there have not been three or more occasions where cetaceans, penguins, shoaling large pelagic fish or turtles have been sighted within the 500 m mitigation zone during the preceding 24-hour period; and • a two-hour period of continual observation of the mitigation zone was undertaken (during a period of good visibility) prior to the period of low visibility and no cetaceans, penguins, shoaling large pelagic fish or turtles were sighted within the 500 m mitigation zone.	Abate on site

Residual impact

The generation of noise from the drilling unit and support vessels cannot be eliminated due to the operating requirements of dynamic positioning. Despite mitigation for drilling and vessel noise, the intensity, extent or duration of the impact remains unchanged; thus, impact remains VERY LOW. With the implementation of the above-mentioned mitigation measures for VSP, although the intensity decreases, the residual impact on marine fauna would remain **LOW** due to the sensitivity of the receptors.

13	*Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in seabirds, seals, turtles and cetaceans due to drilling and vessel noise (continuous noise)*	
Project Phase:	**Mobilisation, Operation and Decommissioning**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	MEDIUM	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	LOCAL	LOCAL
Duration	SHORT	SHORT
Significance	**VERY LOW**	**VERY LOW**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**LIKELY**	**LIKELY**

14	*Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to Geophysical Surveys and Vertical Seismic Profiling (impulsive noise)*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	MEDIUM	LOW
Extent	LOCAL	LOCAL
Duration	SHORT	SHORT
Significance	**LOW**	**LOW**
Probability	**LIKELY**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**LIKELY**	**LIKELY**

4.4.7 Presence of Subsea Infrastructure on Marine Fauna

Source of Impact

The table below summarises the project activities that will result in an increase in hard substrata on the seabed.

Project phase	Activity
Mobilisation	n/a
Operation	Placement of wellhead on the seabed
	Discharge of residual cement during riserless casing and plugging stages
Demobilisation	Abandonment of wellhead on seabed

These activities and their associated aspects are described further below.

- During initial riserless cementing of the conductor pipe, excess cement (100 m^3 in the worst case for all cementing / plugging operations) emerges out of the top of the well onto the cuttings pile or is discarded on the seabed, where (depending on its mix) it may set and remain in a pile to subsequently be colonised by epifauna and attract fish and other mobile predators (Buchanan *et al*. 2003). Excess cement may therefore act as an artificial reef.
- The risered drilling stage commences with the installation of a wellhead onto of the 20-inch casing. Once the wellhead has been installed a BOP is lowered to the seabed and installed onto the wellhead. The BOP stack extends ~10 m above the seabed into the water column, thereby providing a pillar of hard substrate in an area of otherwise unconsolidated sediments. The BOP will be removed during decommissioning.
- After the exploration wells have been sealed, tested for integrity and abandoned, the wellheads (with a height of 3 m and a diameter of 1 m) will be left on the seafloor, where it is deemed safe to do so, thereby providing hard substrate in an area of otherwise unconsolidated sediments. If deemed unsafe, the wellheads will be removed.

Impact Description

Placement of the wellheads on the seabed and subsequent abandonment provide islands of hard substrata in an otherwise uniform area of unconsolidated sediments. The availability of hard substrata on the seabed provides opportunity for colonisation by sessile benthic organisms and provides shelter for demersal fish and mobile invertebrates thereby potentially increasing the benthic biodiversity and biomass in the continental slope region. Although the impact is direct, it can be considered neutral.

Project Controls

The contractors will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT. Based on pre-drilling ROV survey(s), the well(s) will specifically be sited to avoid sensitive hardgrounds, as the preference will be to have a level surface area to facilitate spudding and installation of the wellhead.

Sensitive Receptors

The drilling activities would be undertaken in the offshore marine environment (290 km from the coastline at its nearest point) where the Namib Lower Slope and Namib Abyss habitat types have been rated as of 'Least Threatened. Proposed ESAs do, however, occur within the Area of Interest for drilling.

The benthic biota inhabiting unconsolidated sediments of the outer shelf and abyss are very poorly known, but at the depths of the proposed well drilling are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise urchins, holothurians, sea stars, brittle stars, burrowing anemones, molluscs, seapens, crabs and shrimps, and sponges, many of which are longer lived and therefore more sensitive to disturbance. The availability of hard substrata on the seabed provides opportunity for colonisation by sessile benthic organisms and provides shelter for demersal fish and mobile invertebrates. The benthic biota inhabiting islands of hard substrata in otherwise unconsolidated sediments of the outer shelf and continental slope are very poorly known. Likely taxa would include urchins, anemones, sponges, gorgonians, bryozoans and octocorals, many of which could potentially be sensitive to disturbance. No rare or endangered species have been reported or are known from the continental slope unconsolidated sediments. The sensitivity of the benthic communities of unconsolidated sediments is therefore considered **LOW**.

In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. No potential VME indicator taxa have been reported for the area. While the sensitivity of such deep water reef communities is considered HIGH, none are known from the Area of Interest for drilling, and pre-drilling surveys will ensure that such sensitive areas would specifically been avoided should they occur.

Thus, the overall sensitivity of receptors to physical seabed disturbance, considering the small percentage of the habitats potentially affected, despite the presence of ESAs, is considered to be low.

Impact Magnitude

Many studies have reported on the rich biodiversity of marine species associated with the infrastructure provided by oil platforms (Hall 2001; Love *et al*. 2005; Love & York 2006), or the increase in abundance of macroepibenthic invertebrates and demersal fish near the rig site (Wolfson *et al*. 1979; Bull & Kendall 1994; Ellis *et al*. 1996; Fechhelm *et al*. 2001; EG&G, Environmental Consultants 1982, in Neff 2005). These changes in biodiversity were, however, associated with permanent production rigs. For the current project, the drilling unit and the BOP will be on site for up to a 3- to 4-month period, and the establishment of alternative communities on drilling infrastructure is thus not expected. Similarly, if the wellheads were removed upon abandonment, they would not contribute this impact.

The presence of wellheads left on the seabed can, however, alter the community structure in an area, and effectively increase the availability of hard substrate for colonisation by sessile benthic organisms, thereby locally altering and increasing biodiversity and biomass. Similarly, but to a lesser extent, solidified excess cement discarded during cementing of the casings would provide hard substratum for benthic organisms to colonise in an environment otherwise dominated by

unconsolidated sediments. This is however unlikely as the residual cement will be covered with drill cuttings, which form a highly localised spoil mound around the wellbore, and likely sink into the sediments and dissolve over time. These alterations to community structure would occur at a much smaller scale than that reported on production infrastructure. While this may have positive implications to certain fish species (e.g. kingklip *Genypterus capensis* and jacopever *Helicolenus dactylopterus*, which show a preference for structural seabed features), and benthic invertebrates (deep-water hard substrata can support sensitive species some of which may be longer-lived VME species), it may enhance colonisation by non-indigenous species. However, due to the water depths in the Area of Interest (2 950 m and 3 400 m), colonisation by invasive species is unlikely to pose a significant threat to natural biodiversity in the deep sea habitats.

The increase or modification of a site's biodiversity (neutral impact) due to the presence of subsea structures would be considered a secondary impact of LOW intensity. The impact would be highly localised (SITE SPECIFIC for each well). As TEEPNA has indicated that the wellheads would be abandoned, the impact would be PERMANENT, resulting in the magnitude of the impact being **LOW**. However, if the wellheads were removed upon abandonment, the duration would be short-term and the magnitude to **VERY LOW**.

Impact Significance

Due to the low sensitivity of benthic communities of unconsolidated sediments and the low (well abandonment) to very low (wellhead removal) magnitude of the impact, the presence of sub-sea structures on seabed biodiversity is deemed to be **NEGLIGIBLE** (wellhead removal) or of **VERY LOW** (well abandonment) significance.

Identification of Mitigation Measures

In addition to the measures recommended to avoid vulnerable hardground habitats, the following measures will be implemented:

No.	Mitigation measure	Classification
1	Monitor (by ROV) cement returns and if significant discharges are observed on the seafloor terminate cement pumping.	Reduce at source/Abate on site
2	Undertake a post drilling ROV survey to scan seafloor for any dropped equipment and other removable features (e.g. excess cement) around the well site. Retrieve these objects, where practicable, after assessing the safety and metocean conditions.	Repair / restore
3	Ensure any excess cement onboard the drilling unit is shipped to shore for storage or disposal.	Reduce at source

Residual impact

This potential impact cannot be eliminated if the wellheads are abandoned on the seafloor. The residual impact remains NEGLIGIBLE (wellhead removal) or of VERY LOW (well abandonment) significance.

15	*Impacts of petroleum infrastructure and residual cement on marine biodiversity*	
Project Phase:	**Well drilling**	
Type of Impact	**Direct**	
Nature of Impact	**Neutral**	
Sensitivity of Receptor	LOW	
	Alternative 1: Wellhead Removal	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	SITE	SITE
Duration	SHORT-TERM	SHORT TERM
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**VERY LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**
	Alternative 1: Wellhead Abandonment	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	SITE	SITE
Duration	PERMANENT	PERMANENT
Significance	**VERY LOW**	**VERY LOW**
Probability	**HIGHLY LIKELY**	**HIGHLY LIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**IRREVERSIBLE**	**IRREVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**VERY LOW**
Cumulative potential	**POSSIBLE**	**POSSIBLE**

4.4.8 Well Testing

Source of Impact

The table below summarises the project activities related to well (flow) testing.

Project phase	Activity
Mobilisation	n/a
Operation	Flaring during well tests
	Possible discharge of produced water
Demobilisation	n/a

These activities and their associated aspects are described further below.

- Well (flow) testing is undertaken to determine the economic potential of any discovery before the well is abandoned or suspended. During well testing it may be necessary to flare off some of the oil and gas brought to the surface. Flaring produces a flame of intense light at the drill unit. One test would be undertaken per exploration well if a resource is discovered and up to two tests per appraisal well. Each test would take up to 7 days to complete (5 days of build-up and 2 days of flowing and flaring) and involves burning hydrocarbons at the well site. A high-efficiency flare is used to maximise combustion of the hydrocarbons. The amount of hydrocarbons produced would depend on the quality of the reservoir but is kept to a minimum to minimise the impact on the environment and avoid wasting potentially marketable oil and/or gas. However, an estimated 10 200 bbl oil could be flared per test, i.e. up to 20 400 bbl over the two tests associated with an appraisal well.
- If produced water arises during well flow testing (note: 20 bbl was produced during the recent Venus 1Z well drilling campaign), these would be separated from the oily components and treated onboard to reduce the remaining hydrocarbons from these produced waters and discharged overboard, or be shipped to shore for disposal.

Impact Description

Flaring during well testing produces a flame of intense light and heat at the drill unit. Increased ambient lighting may disturb and disorientate pelagic seabirds feeding in the area (direct negative impact). This increase lighting may also result in indirect physiological and behavioural effects on fish and cephalopods, as these maybe drawn to the lights at night where they maybe more easily preyed upon by other fish and seabirds (indirect negative impact).

If water flows during well testing, the hydrocarbon component will be separated and piped to a flare boom where it would be incinerated, while the water will be treated and possibly discharged. This product water contains hydrocarbons, which if released overboard without treatment would have toxic effects on marine fauna (indirect negative impact).

Inefficient combustion of hydrocarbons can result in the release of unburnt hydrocarbons, which 'drop-out' onto the sea surface and may form a visible slick of oil (indirect negative impact).

Project Controls

The operator will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT.

Once the produced water has been separated from the hydrocarbon component, the hydrocarbon component will be burned off *via* the flare booms, while the water will be temporarily collected in a slop tank. The product water is then either directed to:

- a settling tank prior to transfer to supply vessel for onshore treatment and disposal; or
- a dedicated treatment unit where, after treatment, it is either:
    (i) if hydrocarbon content is < 30 mg/l, discharged overboard; or
    (ii) if hydrocarbon content is > 30 mg/l, subject to a 2nd treatment or directed to tank prior to transfer to supply vessel for onshore treatment and disposal.

Reinjection of the produced water may be considered if volumes are large and cannot be managed onboard the drilling unit.

Sensitive Receptors

Flaring during well testing could directly and indirectly affect migratory pelagic species (pelagic seabirds, marine mammals and fish) transiting through the Area of Interest for drilling. The taxa most vulnerable to light disturbance would be pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans may also be affected by the 'drop-out'. Many of these are considered globally 'Critically Endangered' (e.g. Leatherback turtle), 'Endangered' (e.g. Black-browed and Yellow-nosed albatross, Fin and Sei whales, shortfin mako) 'Vulnerable' (e.g. longfin mako, whitetip sharks, sperm whale) or 'Near threatened' (e.g. blue shark). Although species listed as 'Critically Endangered' or 'Endangered' may potentially occur in the drill area, it is located in a main marine traffic route and thus is in an area already experiencing increased marine traffic and operational lighting. Thus, the sensitivity of receptors to increased lighting and produced water with low concentration of hydrocarbons is considered to be **MEDIUM**.

Impact Magnitude

4.4.8.1 Impacts on Marine Fauna from Lighting from Flare

Drilling activities would be undertaken in the offshore marine environment, 290 km from the shore at its closest points and thus far removed from any sensitive coastal receptors (e.g. bird or seal colonies) and range of most coastal seabirds (10-30 km), but could still directly affect some migratory pelagic species (pelagic seabirds, marine mammals and fish) transiting through the Area of Interest for drilling. The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans may also be attracted by the lights. The intense lighting flaring at night may disturb and disorientate pelagic seabirds feeding in the area.

Flare lighting may also result in physiological and behavioural effects of fish and cephalopods, as these may be drawn to the increased lighting at night where they may be more easily preyed upon by other fish, marine mammals and seabirds. As seals are known to forage up to 220 km offshore, the Area of Interest for drilling falls beyond the foraging range of seals from the seal colony at Bakers Bay and Van Reenen Bay, which lie about 300 km inshore of the Area of Interest.

Odontocetes, however, are also highly mobile, supporting the notion that various species are likely to occur in the licence area and thus potentially be attracted to the area.

The increase in ambient lighting in the offshore environment due to flaring would be of LOW intensity and limited to the area in the immediate vicinity of the drill rig (SITE SPECIFIC) over the short-term (4 days of flaring over a period of up to 14 days assuming two tests). The potential for behavioural disturbance as a result of flaring would thus be of **VERY LOW** magnitude.

4.4.8.2 Impact on Marine Fauna from Discharge of Produced water

A maximum of 20 bbl/day of produced waters is expected per well. Following combustion of the hydrocarbon components, the water will be collected in a slop tank and either transferred to shore for treatment or it would be treated on board in a dedicated treatment unit. If following onboard treatment the hydrocarbon content is <30 mg/l, the produced water would be discharged overboard. If the content is >30 mg/l it would either undergo a second treatment or be transferred to shore. Assuming treatment to 30 mg/l, the discharge of 20 bbl/day would result in 960 g (0.03 g x 32 000 litres) of diluted reservoir hydrocarbons being discharge to sea per well. Furthermore, the Area of Interest for drilling would be located approximately 290 km from the coast at its closest point and is thus far removed from any coastal receptors. The dominant wind and current direction will also ensure that any discharges will disperse rapidly mainly in a north-westerly direction away from coast (refer to drilling discharge modelling results in Section 4.4.2).

The overboard discharge of treated product water would be of VERY LOW intensity and limited to the area in the immediate vicinity of the drill rig (SITE SPECIFIC) over the short-term (up to 10 days). The potential for toxic effects on marine fauna would thus be of **VERY LOW** magnitude.

4.4.8.3 Impacts on Marine Fauna from Hydrocarbon 'drop-out' during flaring:

The drill area is located approximately 290 km from the coast at its closest point and is thus far removed from any coastal receptors. The dominant wind and current direction will also ensure that any discharges move mainly in a north-westerly direction away from coast (refer to drilling discharge modelling results in Section 4.4.2). Given the offshore location of the drill area, hydrocarbon 'drop-out' is expected to disperse rapidly and is unlikely to have an impact on sensitive coastal receptors. Due to the distance offshore, it is only likely to be pelagic species of fish, birds, turtles and cetaceans that may be affected by potential hydrocarbon 'drop-out', some of which are species of conservation concern, but they are unlikely to respond to the minor changes in water quality.

The impact of hydrocarbon 'drop-out' during flaring would be of LOW intensity and limited to the drilling location (SITE SPECIFIC) over the SHORT-TERM (4 days of flaring over a period of up to 14 days). The impact of well testing is therefore considered of **VERY LOW** magnitude.

Impact Significance

Due to the medium sensitivity of the receptors and the very low magnitude of the impact, the flaring of hydrocarbons, generation of product water and drop-out during well testing is deemed to be of **VERY LOW** significance.

Identification of Mitigation Measures

The following measures are recommended to reduce and manage 'drop-out' onto the sea surface and lighting during flaring[12]:

No.	Mitigation measure	Classification
1	Use high efficiency burners for flaring to optimise combustion of the hydrocarbons in order to minimise emissions and hydrocarbon 'drop-out' during well testing.	Avoid / reduce at source
2	Optimise well test programme to reduce flaring as much as possible during the test.	Reduce at source/Abate on site
3	Commence with well testing during daylight hours, as far as possible.	Reduce at source/ Abate on site
4	Monitor flare (continuous) for any malfunctioning, etc. (including any drop-out).	Avoid/reduce at source
5	Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard box) for subsequent release during daylight hours.	Repair or restore

Residual impact

Should flow-testing be required, the need for flaring and discharge of treated product water (if not shipped to shore) cannot be eliminated. Despite the implementation of the above-mentioned best management practices, the residual impact remains **VERY LOW**.

16	***Impacts of flare lighting on marine fauna***	
Project Phase:	**Operation**	
Type of Impact	**Indirect/ Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	MEDIUM	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW to LOW
Extent	SITE	SITE
Duration	SHORT TERM	SHORT TERM
Significance	**VERY LOW**	**VERY LOW**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

[12] Based on the International Finance Corporation's (IFC) Environmental, Health and Safety Guidelines for offshore oil and gas development, April 2007

17	*Impact on marine fauna from the discharge of treated produced water*	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	MEDIUM	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	VERY LOW	VERY LOW
Extent	SITE	SITE
Duration	SHORT TERM	SHORT TERM
Significance	**VERY LOW**	**VERY LOW**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

18	*Impact on marine fauna from hydrocarbon 'drop-out'*	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	MEDIUM	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	SITE	SITE
Duration	SHORT TERM	SHORT TERM
Significance	**VERY LOW**	**VERY LOW**
Probability	**POSSIBLE**	**POSSIBLE**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.5 Cumulative Impacts

Introduction

Cumulative effects are the combined potential impacts from different actions that result in a significant change larger than the sum of all the impacts. Consideration of 'cumulative impact' should include "past, present and reasonably foreseeable future developments or impacts". This requires a holistic view, interpretation and analysis of the biophysical, social and economic systems (DEAT 2004).

Cumulative impact assessment is limited and constrained by the method used for identifying and analysing cumulative effects. As it is not practical to analyse the cumulative effects of an action on every environmental receptor, the list of environmental effects being considered to inform decision makes and stakeholders should focus on those that can be meaningfully (DEAT 2004).

The individual and population level consequences of other exploration activities or multiple smaller and more localised stressors (see for example Booth *et al*. 2020; Derous *et al*. 2020) are difficult to assess. A significant adverse residual environmental effect is considered one that affects marine biota by causing a decline in abundance or change in distribution of a population(s) over more than one generation within an area. Natural recruitment may not re-establish the population(s) to its original level within several generations or avoidance of the area becomes permanent. For example, despite the density of seismic survey coverage off the southern African West Coast over the past 17 years, the southern right whale population is reported to be increasing by 6.5% per year (Brandaõ *et al*. 2017), and the humpback whale by at least 5% per annum (IWC 2012;) over a time when seismic surveying frequency has increased, suggesting that, for these population at least, there is no evidence of long-term negative change to population size as a direct result of exploration activities.

Reactions to sound or other anthropogenic disturbances by marine fauna depend on a multitude of factors including species, state of maturity, experience, current activity, reproductive state, time of day (Wartzok *et al*. 2004; Southall *et al*. 2007). If a marine animal does react briefly to a disturbance by changing its behaviour or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the population as a whole (NRC 2005). However, if a disturbance displaces a species from an important feeding or breeding area for a prolonged period, impacts at the population level could be significant. The increasing numbers of southern right and humpback whales around the Southern African coast, and their lingering on West Coast feeding grounds long into the summer, suggest that acoustic surveys and exploration activities conducted over the past 17 years have not negatively influenced the distribution patterns of these two migratory species at least. Information on the population trends of resident species of baleen and toothed whales is unfortunately lacking, and the potential effects of seismic noise on such populations remains unknown.

While it is foreseeable that further exploration (seismic and well-drilling) and future production activities could arise if the current application is granted, there is not currently sufficient information available to make reasonable assertions as to nature of such future activities. This is primarily due to the current lack of relevant geological and resource potential information, which the proposed exploration process aims to address. While there are many other rights holders in the offshore environment (e.g. marine diamonds and gemstones, heavy minerals, precious metals and ferrous and base metals), most of these are located well inshore of Block 2912 and are not

undertaking any exploration activities at present or would be concurrently with the proposed TEEPNA exploration drilling campaign. A possible exception is further proposed exploration well drilling in PEL39, ~48 km east of Block 2912. There are a number of current reconnaissance permit applications being undertaken for proposed seismic surveys off the northern West Coast of South Africa (as of December 2022), although it is unlikely that all these will be undertaken as they are targeting similar areas in the Deep Water Orange Basin. A number of speculative seismic survey application processes are also underway in Namibian waters. One of these is proposed inshore of Block 2912 and one immediately to the north of Block 2912. None of the proposed survey areas overlap with Block 2912. Thus, the possible range of the future prospecting, mining, exploration and production activities that could arise will vary significantly in scope, location, extent, and duration depending on whether a resource(s) is discovered, its size, properties and location, etc. As these cannot at this stage be reasonably defined, it is not possible to undertake a reliable assessment of the potential cumulative environmental impacts. It is also possible that the proposed, or future, exploration fails to identify an economic petroleum resource, in which case the potential impacts associated with the production phase would not be realised.

Furthermore, the assessment methodology used in the ESIA by its nature already considers past and current activities and impacts. In particular, when rating the sensitivity of the receptors, the status of the receiving environment (benthic ecosystem threat status, protection level, protected areas, etc.) or threat status of individual species is taken into consideration, which is based to some degree on past and current actions and impacts (e.g. the IUCN conservation rating is determined based on criteria such as population size and rate of decline, area of geographic range / distribution, and degree of population and distribution fragmentation. Thus, past and existing offshore activities (including shipping, prospecting, mining, exploration, production, commercial fishing, etc.) have been taken into account in the assessment of potential impacts related to the proposed project.

The primary impacts associated with the drilling of exploration wells (normal drilling operations) in the Namib Biozone, relate to physical disturbance of the seabed, discharges of drilling solids to the benthic environment, the presence of infrastructure remaining on the seabed and associated vessels and drill unit. Other marine exploration and mining activities off the southern Namibian coast are all located well inshore of the Area of Interest, with the proposed subsea fibreoptics cable planned for well inshore and offshore of the Area of Interest (see Figure 42). Cumulative impacts on benthic ecosystems in Block 2912 are therefore expected to be minimal.

Cuttings discharge and Sediment plume

The development of the proposed exploration well(s) in this assessment would generate a risk plume of cuttings and drilling muds in the water column. The maximum instantaneous risk would correspond to a footprint in the water column that would impact a maximum cumulative volume of 0.146 km^3 for a maximum duration of 14 days, which can be considered an insignificant percentage of the ecoregion as a whole. Oil and gas exploration and production activities in Namibia have focused on the Kudu gas field, which lies inshore and to the east of Block 2912. In the order of 32 wells have been drilled in the Namibian offshore environment to date, the majority of which have been drilled off southern Namibia, most of these in less than 300 m water depth (see Figure 42). A further 2 wells have recently been drilled in adjacent Block 2913B, with a further two wells in PEL39, with a further two wells planned for PEL39 in the third quarter of 2023. Prior to 1983, technology was not available to remove wellheads from the seafloor, and most of the wells drilled

off Namibia remain with wellhead on the seabed. Despite the number of wells drilled in the Namibian offshore environment, there is no evidence of long-term negative change (cumulative impacts) to faunal population sizes or irreparable harm as a direct result of these exploration drilling activities. In fact Atkinson (2009) reported that in South Africa, abandoned wellheads in the vicinity demersal trawling grounds provide some *de facto* "protection" to marine infaunal, epifaunal and fish assemblages (see also Wilkinson & Japp 2005).

There is no current development or production from the South African West Coast offshore. The Ibhubesi Gas Field (Block 2A) (off the South African West Coast, approximately 350 km east of the southern point og Block 2912) and Kudu Gas Field (off southern Namibia) have been identified for development.

Assuming a conservative estimate of 2.64 km^2 of cumulative seabed affected per well (based on the footprint calculated for a single well, TEEPNA, pers. comm.), the total cumulative area impacted by the installation and cuttings fall-out of 32 wells in the Namibian EEZ (which has a total area of approximately 562 212 km^2) is estimated at 84.5 km^2. In reality the total cumulative impacted area at any one time is considerably less, due to the natural dispersion and recovery of benthic communities over the short to medium (shallow waters) and long term (deeper waters). Furthermore, as the Area of Interest for drilling and the associated depositional footprints will avoid MPAs and EBSAs, impacts will affect mostly communities in unconsolidated habitats, which are less sensitive to disturbance and recover more quickly than those inhabiting hard grounds. In addition, TEEPNA will actively avoid and reduce potential impacts on sensitive and potentially vulnerable habitats by ensuring that wells are > 100 m from such habitats (using ROV survey prior to drilling). Cumulative impacts are therefore less likely.

Underwater Noise

Noise associated with the proposed exploration programme would also have cumulative impact on marine fauna. Due to the licence area being located within the main vessel traffic routes that pass around southern Africa, ambient noise levels are naturally elevated. Sensitive receptors and faunal species (cetaceans, turtles and certain fish) are unlikely to be significantly additionally affected as faunal behaviour will not be affected beyond 34 km during drilling and beyond 1.4 km during VSP operations. Noise levels would return back to ambient after drilling is complete.

Data on behavioural reactions to noise and drill rig presence acquired over the short-term could, however, easily be misinterpreted as being less significant than the cumulative effects over the long-term and with multiple exposures, i.e. what is initially interpreted as an impact not having a detrimental effect and thus being of low significance, may turn out to result in a long-term decline in the population, particularly when combined with other acoustic and non-acoustic stressors (e.g. temperature, competition for food, climate change, shipping noise) (Przeslawski *et al*. 2015; Erbe *et al*. 2018, 2019; Booth *et al*. 2020; Derous *et al*. 2020). Physiological stress, for example, may not be easily detectable in marine fauna, but can affect reproduction, immune systems, growth, health, and other important life functions (Rolland *et al*. 2012; Lemos *et al*. 2021). Confounding effects are, however, difficult to separate from those due to exploration drilling.

Despite the density of seismic survey coverage over the past years in the southern Namibian offshore and particularly off the South African West Coast, the number of Southern right and Humpback whales around the southern African coast have increased, suggesting that, for these species at least, there is no evidence of long-term negative change to population size or irreparable

harm as a direct result of seismic survey activities. Although surveys have revealed a steady population increase since the protection of the species from commercial whaling, more recent results, however, indicate changes in the prevalence of southern rights on the South African breeding ground, including a marked decline of unaccompanied adults since 2010 and extreme fluctuations in the number of cow-calf pairs since 2015. Vermeulen *et al*. 2020, however, contribute the change in demographics to likely spatial and/or temporal displacement of prey due to climate variability, and not seismic surveys. To date no trophic cascades off the South African coast have been documented despite the completion of a number of seismic surveys having been completed.

There are a number of reconnaissance permit applications being undertaken for proposed seismic surveys in the Deep Water Orange Basin off the South African West Coast, although it is unlikely that all these will be undertaken as they are targeting a similar area. These surveys are proposed to the south of the Namibian – South African border, but are unlikely to have any overlapping noise impacts.

Vessel lighting and Operational Discharges

There are numerous light sources and operational discharges from vessels operating within and transiting through the area, although each is isolated in space and most are mobile. Given the extent of the ocean and the point source nature of the lighting, the prevalence of sensitive receptors and faunal species interactions with the light sources is expected to be very low. Light levels would return back to ambient once operations are completed. Each of the vessels (fishing, shipping, exploration) operating within the area will make routine discharges to the ocean, each with potential to cause a local reduction in water quality, which could impact marine fauna. However, each point source is isolated in time and widely distributed within the very large extent of the open ocean. At levels compliant with MARPOL conventions no detectable cumulative effects are anticipated.

Conclusion

Although possible future activities cannot be reasonably defined and it is unlikely that concurrent exploration activities will occur at the same time as the TEEPNA drilling campaign in Block 2912, with the implementation of the proposed mitigation measures, most of the potential impacts will be of short duration, typically ceasing once drilling is completed. Such light source impacts are, therefore, considered unlikely to contribute to future cumulative impacts, and thus no more significant than assessed in the preceding sections.

The one impact that is expected to continue into the long term is the impact relating to smothering of benthic biota due to cuttings discharge, which the drilling discharge modelling study predicted can last in excess of 10 years. While there is currently further interest to undertake exploration drilling in the blocks adjacent to Block 2912, the targets are suitably far away that these would result in depositional overlap within the Area of Interest. Cumulative impacts would thus be no more significant than assessed in the preceding sections.

Although cumulative impacts from other hydrocarbon ventures in the area may increase in future, the cumulative impacts of the proposed drilling of exploration wells in the Namib Biozone can be considered of **LOW** significance.

4.6 Impact Summary for Planned Events

The residual impacts on marine habitats and communities associated with the proposed drilling of up to 5 exploration wells in Block 5/6/7 are summarised in the Table below, and the main mitigation measures are listed. The total area to be impacted by the proposed exploration drilling can be considered negligible with respect to the total area of the Southeast Atlantic Deep Ocean ecoregion.

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Biological component		
Reduction in water quality due to normal vessel discharges	• Implement a waste management system that addresses all wastes generated. • Use drip trays to collect run-off from equipment that is not contained within a bunded area and route contents to the closed drainage system. • Implement leak detection and repair programs for valves, flanges, fittings, seals, etc. • Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages. • Prohibit operational discharges within the NIMPA during transit to and from the drill site.	Very Low
Risks to biodiversity due to discharge of ballast water	• Avoid the unnecessary discharge of ballast water. • Use filtration procedures during loading. • Ensure that routine cleaning of ballast tanks. • Ensure all infrastructure is thoroughly cleaned prior to deployment.	Negligible
Disturbance of marine fauna due to helicopter noise	• Pre-plan flight paths to ensure that no flying occurs over the Atlas Bay, Wolf Bay and Long Island seal colonies or any of the Islands within the NIMPA. • Avoid extensive low-altitude coastal flights • Maintain a flight altitude >1 000 m at all times, except when taking off and landing or in a medical emergency. • Maintain an altitude of at least 1 000 m above the NIMPA islands within a radius of one nautical mile around islands' low water mark. • Over-flight restrictions of a minimum altitude of 3000 feet/1000 meters apply to seal colonies at Van Reenen Bay, Wolf and Atlas Bays and Bakers Bay on the mainland of the NIMPA, except for Diaz Point provided Diaz Point is only approached from the North by air. • Comply fully with aviation and authority guidelines and rules. • Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Disturbance of marine fauna due to vessel lighting and flaring	• Light sources should, if possible and consistent with safe working practices, be positioned in places where emissions to the surrounding environment can be minimised. • Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard boxes) for subsequent release during daylight hours. • Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring).	Very Low
Disturbance of Seabed Sediments and Associated Biota by ROV Surveys and Drilling	• Do not land ROVs on the seabed as part of normal operations. • Design of pre-drilling site surveys to ensure there is sufficient information on seabed habitats, including the mapping potentially sensitive and vulnerable habitats within 100 m of a proposed well site thereby preventing potential conflict with the well site. • If vulnerable habitats are detected, adjust the well position accordingly or implement appropriate technologies, operational procedures and monitoring surveys to reduce the risks of, and assess the damage to, vulnerable seabed habitats and communities. • Limit the area directly affected by physical contact with infrastructure to the smallest area required.	Negligible
Disturbance and/or smothering of benthic and deep-water reef communities due to drilling solids discharge	• Meticulous design of pre-drilling site surveys to provide sufficient information on seabed habitats, and to map potentially vulnerable habitats thereby preventing potential conflict with the well site. • Pre-drilling site surveys should ensure that drilling locations are not located within a 1 km radius of any vulnerable habitats (e.g. hard grounds), species (e.g. cold corals, sponges) or structural features (e.g. rocky outcrops). Expert review of ROV footage of pre-drilling surveys to identify potential vulnerable habitats within 100 m[13] of the drill site.	Low

[13] A 500 m radius area for the ROV survey would be preferable. Because of the considerable depth in the area of interest, this would, however, not be technically feasible. Based on evidence from the baseline visual information gathered during a survey across the area of interest in Block 2912 in October 2022 (BSL, unpublished), the seabed at > 3 000 m depth is seen as homogenous unconsolidated sediment and the presence of vulnerable habitats unlikely. Considering this and the limited distance around the drill site that smothering of benthic fauna would be expected (maximum deposition layer up to 88 m from drill site), a minimum 100 m radius ROV survey would be deemed appropriate in this deepwater environment.

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
	• If vulnerable habitats are detected, adjust the well position accordingly or implement appropriate technologies, operational procedures and monitoring surveys to reduce the risks of, and assess the damage to, vulnerable seabed habitats and communities.	Medium
Biochemical Impacts of residual drilling fluids, cuttings and cement on marine organisms in unconsolidated sediments and the water column	• Ensure only low-toxicity and partially biodegradable additives are used. • Use high efficiency solids control equipment • Ensure regular maintenance of the onboard solids control equipment.	Negligible
Biochemical Impacts of residual drilling fluids, cuttings and cement on marine organisms on hard grounds	• Test drilling fluids for toxicity, barite contamination and oil content to ensure the specified discharge standards are maintained. • Monitor (using ROV) cement returns and if significant discharges are observed on the seafloor terminate cement pumping, as far as possible. • Monitor (using ROV) hole wash out to reduce discharge of fluids, as far as possible.	Low
Impacts of drill cuttings discharge on water column (turbidity & light) and seabed (turbidity)	None	Negligible
Impacts of Cuttings Discharges: development of anoxic sediments around the wellbore	None	Negligible
Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in shoaling large pelagic fish, seabirds, seals, turtles and cetaceans due to drilling and vessel noise	• Implement a maintenance plan to ensure all diesel motors and generators receive adequate maintenance to minimise noise emissions. • Ensure vessel transit speed between the drill area and port is a maximum of 12 knots (22 km/hr), except within 25 km of the coast where it is reduced further to 10 knots (18 km/hr).	Very Low
Disturbance and behavioural changes in shoaling large pelagic fish, seabirds, seals, turtles and cetaceans due to VSP	• Apply marine mammal observation and monitoring procedures during VSP operations (visual surveillances by trained staff, soft start procedures, low visibility procedures). • All initiation of airgun firing should be carried out as “soft-starts” of at least 20 minutes duration, allowing sensitive species to move out of the area and thus avoid potential physiological injury.	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Impacts of petroleum infrastructure and residual cement on marine biodiversity	• Monitor (by ROV) cement returns and if significant discharges are observed on the seafloor terminate cement pumping. • Undertake a post drilling ROV survey to scan seafloor for any dropped equipment and other removable features (e.g. excess cement) around the well site. • Ensure any excess cement onboard the drilling unit is shipped to shore for storage or disposal.	Negligible
Well testing: flaring, produced water discharge, hydrocarbon dropouts	• Use high efficiency burners for flaring to optimise combustion of the hydrocarbons in order to minimise emissions and hydrocarbon 'drop-out' during well testing. • Optimise well test programme to reduce flaring as much as possible during the test. • Commence with well testing during daylight hours, as far as possible, and operational monitoring. • Monitor flare (continuous) for any malfunctioning, etc. (including any drop-out). • Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard box) for subsequent release during daylight hours.	Very Low

4.7 Mitigation and Management Plan

The mitigation measures are based largely on the guidelines currently accepted for exploratory well drilling in Namibia, but have been revised to include salient points from international guidelines and industry best practices discussed above.

The mitigation measures proposed are the outcome after having defined the performance objectives, indicators and targets in the various assessments. Performance objectives are influenced by international standards, legal requirements and scientific knowledge.

In their review to guide management strategies for the environmental impacts of deep-water oil and gas operations, Cordes *et al.* (2016) present various recommendations of which the following are applicable to, and in some cases have been implemented in, this project:

- Surface infrastructure and any discharge sites should be at least 2 km away from known EBSAs.
- Any high-density, high-biomass, high-relief, or specialized deep-sea habitat should be identified and mapped and avoidance rules or formal MPA designations implemented to minimize adverse impacts. The definition of these significant communities will vary from region to region and will depend on national regulations within the region of interest.
- Adopt an integrated approach to conservation, which should include spatial management in conjunction with activity management in the form of restrictions on discharge and the use

of water-based drilling fluids, and temporal management in areas where the drilling activity is near breeding aggregations or seasonally spawning sessile organisms.

- Incorporate buffer zones into spatial management plans to protect vulnerable deep-sea habitats and communities.

Although at this stage the Marine Spatial Planning process implemented in Namibia lacks legislation and has only weak links to broader ocean governance, the Area of Interest overlaps with a small proportion of ESA, and should drilling targets be identified within, or immediately adjacent to this area, provision would need to be made to undertake the required site specific assessments and collect quantitative baseline data. This may take the form of surveys including high-resolution mapping, visual seafloor imagery and benthic samples to characterize the faunal community and ensure proper species identifications (Cordes *et al*. 2016).

4.8 Environmental Acceptability

The proposed exploration activities (normal operations) to be undertaken by TEEPNA are expected to result in impacts on marine invertebrate fauna in the approved drilling area of Block 2912, ranging from negligible to low significance without mitigation. Only in the case of potential impacts of drilling wastes on vulnerable deep-water reef communities are impacts of high significance expected. The potential impacts can be adequately mitigated with the implementation of the proposed mitigation measures (as included in the ESMP), which are in line with current industry good practice for drilling undertaken in Namibian waters. With implementation of recommended mitigation measures, the significance would reduce to medium.

Despite the 32 wells that have been drilled in the Namibian offshore, there is no evidence of long-term negative change (i.e. cumulative impacts) to faunal population sizes or irreparable harm as a direct result of these exploration drilling activities.

Pisces Environmental Services is of the opinion that this assessment is sufficiently robust and provides sufficient information for the competent authority to make an informed decision on the proposed project taking into consideration the significance of potential impacts on marine fauna and National strategic policy issues relating to energy and climate change. It is recommended that the commitments presented in this report should be conditional to the Environmental Clearance Certificate, should the Ministry of Environment and Tourism approve the application.

4.9 Potential Impacts related to Unplanned Events

4.9.1 Vessel Strikes

4.9.1.1 Collision of Vessels with Marine Fauna

Source of Impact

Activities that could result in faunal strikes are indicated below:

Project phase	Activity
Mobilisation	Transit of drilling unit and support vessels to drill site
Operation	Transit of support /supply vessels between the drilling unit and port
Demobilisation	Transit of drilling unit and support vessels from drill site

These activities and their associated aspects are described further below.

- During the passage of the drill rig and support vessels to and from the Area of Interest for drilling collisions with turtles or marine mammals basking or resting on the sea surface may occur.

Impact Description

The potential effects of vessel presence on marine fauna (especially turtles and cetaceans) include physiological injury or mortality due to the drill rig or support vessels colliding with animals basking or resting at the sea surface (direct negative impact).

Project Controls

Contractors will ensure that the proposed drilling campaign is undertaken in a manner consistent with good international industry practice and BAT.

All whales and dolphins are given protection under the Namibian Law. The regulations under the Namibian Marine Resources Act, 2000 (No. 27 of 2000) states that no whales or dolphins may be harassed, killed or fished. Although not legislated in Namibia, no vessel or aircraft should approach closer than 300 m to any whale and a vessel or aircraft should move to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft.

Sensitive Receptors

The leatherback and loggerhead turtles that occur in offshore waters around southern Africa, and likely to be encountered in Block 2912 are considered regionally 'critically endangered' and 'near threatened', respectively. However, due to their extensive distributions and feeding ranges, the numbers of individuals encountered during the drilling campaign are likely to be low.

Thirty-three species or sub species/populations of cetaceans (whales and dolphins) are known or likely to occur off southern Namibia. The majority of migratory cetaceans in Namibian waters are baleen whales (mysticetes), while toothed whales (odontocetes) may be resident or migratory. Of the 33 species, the blue whale is listed as 'Critically endangered', the sei whales is 'Endangered'

and the fin and sperm, are considered 'Vulnerable' (IUCN Red Data list Categories). However, due to the block location far offshore, and the extensive distributions of the various species concerned and mobility of these animals to avoid project vessels, the numbers of individuals encountered during the drilling campaign are likely to be low.

The overall sensitivity is considered to be **HIGH**.

Impact Magnitude

Ship strikes are globally the biggest threat to large whales, having direct, long-term and population-level consequences (Schoeman *et al*. 2020). Although most scientific publications to date have focussed on collisions between vessel and whales and manatees, there is growing evidence that at least 75 marine species, including smaller whales, dolphins, porpoises, dugongs, manatees, whale sharks, sharks, seals, sea otters, turtles, penguins, and fish are at risk of collision, especially within coastal areas frequented by smaller vessels (reviewed by Schoeman *et al*. 2020). As the Area of Interest for drilling is located in a region of very high vessel traffic (see Figure 58), potential collisions between marine fauna and vessels would not be limited to project-specific support vessels and drill rigs. For the duration of the exploration drilling an exclusion zone would be established around the drill rig, potentially requiring adjustment of vessel traffic routes. Such re-routing and associated changes in the concentrations of vessels needs to ensure that whale migration routes or feeding aggregation sites are not compromised as a result of the re-routing thereby potentially leading to increased risk of ship strikes (Schoeman *et al*. 2020). Although ship strikes from project vessels are unlikely, they may occur during the transit of the drill rig to or from the Area of Interest for drilling or during transit of the support vessels between Lüderitz and the drill site.

Ship strikes have been reported to result in medium-term effects such as evasive behaviour by animals experiencing stress, or longer-term effects such as decreased fitness or habitual avoidance of areas where disturbance is common and in the worst case death (see for example Constantine 2001; Hastie *et al*. 2003; Lusseau 2004, 2005; Bejder *et al*. 2006; Lusseau *et al*. 2009). Ship strikes have been documented from many regions and for numerous species of whales (Panigada *et al*. 2006; Douglas *et al*. 2008; Elvin & Taggart 2008) and dolphins (Bloom & Jager 1994; Elwen & Leeney 2010), with large baleen whales being particularly susceptible to collision (Pirotta *et al*. 2019). Any increase in vessel traffic through areas used as calving grounds or through which these species migrate will increase the risk of collision between a whale and a vessel. Although Block 2912 does not fall within a recognized IMMA, and the chances of collisions would increase between June and December (inclusive) when humpback and fin whales are known to migrate through the area, and in the vicinity of Elizabeth Bay, which serves as calving grounds for humpbacks.

The potential for ship strikes of turtles and cetaceans is dependent on the spatial and temporal abundance and behaviour of cetaceans in the area and vessel speed. For example, Keen *et al*. (2019) modelled fin whale ship strike risk in the California Current System and found that night-time collision risk was twice as high as the daytime risk. The Area of Interest is located within the main shipping lane around southern Africa, with major demersal trawling lanes being located inshore on the western edge of the shelf. Due to their extensive distributions and feeding ranges, the number of cetaceans encountered by project vessels in the offshore environment is expected to be low for much of the year. Bimodal peaks in abundance of species migrating northwards to their breeding grounds and on their return migrations to low-latitude feeding grounds (e.g. Humpback, Southern Right, Fin, Sei whales) and winter distributions of sperm whales off the shelf edge may, however,

occur. For turtles, due to the extensive turtle distributions and feeding ranges, and the extended distance from their nesting sites (>1 000 km), the numbers of individuals encountered during the survey are likely to be low. Should ship strikes occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole for vessel transits. Furthermore, as the duration of the impact would be limited to the short-term (3-4 months per well) and be restricted to the Area of Interest for drilling and to/from the port (REGIONAL), the potential for ship strikes is therefore considered to be of **VERY LOW** magnitude.

Impact Significance

The potential for collision with marine fauna (primarily turtles and cetaceans) during the transit of the vessel to or from the drilling area is deemed to be of **LOW** significance, due to the high sensitivity of the receptors and the very low magnitude.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Keep a constant watch from all vessels (Vessel Captain and crew) for cetaceans and turtles in the path of the vessel. Alter course and avoid animals when necessary.	Abate on site
2	Ensure vessel transit speed between the drill area and port is a maximum of 12 knots (22 km/hr), except within 25 km of the coast where it is reduced further to 10 knots (18 km/hr) as well as when sensitive marine fauna are present in the vicinity.	Avoid/reduce at source
3	Report any collisions with large whales to the International Whaling Commission (IWC) database, which has been shown to be a valuable tool for identifying the species most affected, vessels involved in collisions, and correlations between vessel speed and collision risk (Jensen & Silber 2003).	Repair or restore

Residual Impact Assessment

With the implementation of the mitigation measures above, the residual impact would remain **LOW**.

19	*Impacts on turtles and cetaceans due to ship strikes*	
Project Phase:	**Unplanned Activities**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Significance	**LOW**	**LOW**
Probability	**POSSIBLE**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**POSSIBLE**	**POSSIBLE**

4.9.2 Accidental Loss of Equipment

4.9.2.1 Impact on Marine Ecology/Environment

Source of Impact

The project activities that will result in the accidental loss of equipment are listed below.

Project phase	Activity
Mobilisation	Accidental loss of equipment to the water column or the seabed during transit to drill site
Operation	Accidental loss of equipment to the water column or the seabed during operation and transit to / from port
Demobilisation	Accidental loss of equipment to the water column or the seabed during transit from drill site

These activities and their associated aspects are described further below:

- Accidental loss of unsecured equipment / waste on deck during transit;
- Accidental loss of equipment during vessel transfer with crane (i.e. waste containers, equipment, tools, consumable package, etc.).

Impact Description

The potential impacts associated with lost equipment include (direct negative impact):

- Potential disturbance and damage to seabed habitats and associated fauna within the equipment footprint.
- Potential physiological injury or mortality to pelagic and neritic marine fauna due to collision or entanglement in equipment drifting on the surface or in the water column.
- The accidental loss of equipment onto the seafloor would provide a localised area of hard substrate for colonisation by benthic organisms (assessed in Section 4.4.7).

Project Controls

Contractors will ensure that the proposed drilling activities undertaken in a manner consistent with good international industry practice and BAT. Gear will be recovered, where possible, near the surface.

Sensitivity of Receptors

The drilling activities would be undertaken in the offshore marine environment, more than 290 km from the coast where the Namib Lower Slope and Namib Abyss habitats have been rated as of 'Least Threatened' due to the expansive areas they occupy. The benthic biota inhabiting unconsolidated sediments of the outer shelf and abyss are very poorly known, but at the depths of the proposed well are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise urchins, holothurians, sea stars, brittle stars, burrowing anemones, molluscs, seapens, crabs and shrimps, and sponges, many of which are longer lived and therefore more sensitive to disturbance. No rare or endangered species have been reported or are known from the continental slope unconsolidated sediments. The sensitivity of the benthic communities of unconsolidated sediments in therefore considered LOW.

In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. While the sensitivity of such deep water reef communities is considered HIGH, no such habitats are known from Block 2912, and the well(s) will specifically be sited to avoid sensitive hardgrounds (ROV survey).

The overall sensitivity of benthic and pelagic receptors is considered LOW.

Impact Magnitude

In the event of the accidental and irretrievable loss of equipment to the seabed, this could potentially disturb and damage seabed habitats and crush any epifauna and infauna within the equipment footprint. Considering the available area of similar habitat on and off the edge of the continental shelf in the Namib Biozone, this disturbance of, and reduction in, benthic biodiversity can be considered of LOW intensity, highly localised and limited to the footprint of the lost equipment (SITE SPECIFIC). Any impacts would persist over the SHORT-TERM only, as lost equipment will be retrieved or if left in place on the seabed would offer hard substratum for colonisation by sessile benthic organisms in an area of otherwise unconsolidated sediments or will likely sink into the sediments and be buried over time. The impact for equipment lost is thus considered to be of **VERY LOW** magnitude.

Impact Significance

The impacts associated with the accidental loss of equipment are deemed to be of **NEGLIGIBLE** significance, due to the low sensitivity of the offshore receptors and the very low magnitude.

Identification of Mitigation Measures

The following measures will be implemented to manage accidental loss of equipment:

No.	Mitigation measure	Classification
1	Ensure containers are sealed / covered during transport and loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system.	Avoid
2	Minimise the lifting path between vessels.	Avoid
3	Maintain an inventory of all equipment and undertake frequent checks to ensure these items are stored and secured safely on board each vessel.	Avoid
4	Undertake a post drilling ROV survey to scan seafloor for any dropped equipment and other removable features around the well site. In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations.	Repair/restore
5	Notify SAN Hydrographer of any hazards left on the seabed or floating in the water column, with the dates of abandonment/loss and locations and request that they send out a Notice to Mariners with this information.	Repair / restore

Monitoring

- Establishing a hazards database listing the type of gear left on the seabed and/or in the licence area with the dates of abandonment/loss and location, and where applicable, the dates of retrieval.

Residual Impact Assessment

In the case of large lost items such as cables, anchors, drill string sections etc, this potential residual impact could be mitigated by retrieval of the lost item (if possible and safe to do so) or if it becomes buried over time. This would, however, only occur within the programmed exploration-drilling period due to the financial and environmental risk of the rig staying on site longer than scheduled. The environmental impact of retrieving lost equipment (disturbance of seabed habitats through dragging snag anchors) must also be weighed up against the impact of leaving the lost equipment in place. With the implementation of the above-mentioned mitigation measures, the residual impact is considered to remain of **NEGLIGIBLE** significance.

20	*Impacts on benthic and pelagic fauna due to accidental loss of equipment to the seabed and water column*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	LOW	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	SITE	SITE
Duration	SHORT	SHORT
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**PARTIALLY to FULLY REVERSIBLE**	**PARTIALLY to FULLY REVERSIBLE**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.9.3 Accidental oil release to the sea due to vessel collisions, bunkering accident and line / pipe rupture

4.9.3.1 Impact on Marine Ecology/Environment

Source of Impact

The project activities that will result in the accidental release of diesel / oil are listed below.

Project phase	Activity
Mobilisation	Transit of drilling unit and support vessels to drill site
Operation	Operation of drilling unit at the drill site and transit of support /supply vessels between the drilling unit and port
	Bunkering of fuel
Demobilisation	Transit of drilling unit and support vessels from drill site

These activities and their associated aspects are described further below:

- The movement of the support vessel between the survey area and the port of Lüderitz, and presence of drilling unit, may result in limited interaction with commercial, recreational and fishing boats and other marine recreational activities during their approach to the ports. Such interaction may cause a vessel strike or collision resulting in oil tank damage.

- Instantaneous spills of marine diesel at the surface of the sea can potentially occur during bunkering of fuel and such spills are usually of a low volume. Similarly, there could be small spills of hydraulic fluid due to line/ pipe ruptures.
- Larger volume spills of marine diesel would occur in the event of a vessel collision or vessel accident.

Impact Description

Marine diesel spilled in the marine environment would have an immediate detrimental effect on water quality, with the toxic effects potentially resulting in mortality (e.g. suffocation and poisoning) of marine fauna or affecting faunal health (e.g. respiratory damage) (direct negative impact). Sub-lethal and long-term effects can include disruption of physiological and behavioural mechanisms, reduced tolerance to stress and incorporation of carcinogens into the food chain. If the spill reaches the coast, it can result in the smothering of sensitive coastal habitats.

Note: the impact associated with the release of unburnt hydrocarbons during well testing ('drop-out') is assessed under normal operations in Section 4.4.8.

Project Controls

Compliance with COLREGS (the Convention dealing with safety at sea, particularly to reduce the risk of collisions at sea) and SOLAS (the Convention ensuring that vessels comply with minimum safety standards).

A 500 m safety zones will be enforced around the drilling unit within which fishing and other vessels would be excluded.

Regulation 37 of MARPOL Annex I will be applied, which requires that all ships of 400 gross tonnage and above carry an approved Shipboard Oil Pollution Emergency Plan (SOPEP). The purpose of a SOPEP is to assist personnel in dealing with unexpected discharge of oil, to set in motion the necessary actions to stop or minimise the discharge, and to mitigate its effects on the marine environment.

As standard practice, an Emergency Response Plan (ERP) and an Oil Spill Contingency Plan (OSCP) will be prepared and available at all times during the drilling operation.

Project vessels will be equipped with appropriate spill containment and clean-up equipment, e.g. booms, dispersants and absorbent materials. All relevant vessel crews will be trained in spill clean-up equipment use and routine spill clean-up exercises.

Sensitivity of Receptors

Accidental spills and loss of marine diesel during bunkering or in the event of a vessel collision could take place in the drill area and along the route taken by the support vessels between the drill area and Lüderitz. The drill area is located in the marine environment, more than 290 km offshore at its closest point, far removed from coastal MPAs and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks); however, discharges could still directly affect migratory pelagic species transiting through the drill area or be transported into the NIMPA. Diesel spills or accidents *en route* to the onshore supply base in Lüderitz could result in fuel loss closer to shore, thereby potentially having an

environmental effect on the sensitive coastal environment, especially seabird colonies (HIGH sensitivity).

Oil or diesel spilled in the offshore marine environment will have an immediate detrimental effect on water quality. Being highly toxic, marine diesel released during an operational spill would negatively affect any marine fauna it comes into contact with. The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring inshore the drill area, are considered regionally 'Endangered' (e.g. African Penguin, Cape Gannet, Cape Cormorant, Bank Cormorant, Roseate Tern) or 'vulnerable' (e.g. White Pelican, Caspian Tern, Damara Tern). Although pelagic seabird species listed as 'Endangered' (e.g. Atlantic Yellow-nosed Albatross, Black-browed Albatross) or 'Vulnerable' (e.g. Wandering Albatross, Spectacles Petrel, White-chinned Petrel) may potentially occur in the drill area, due to their extensive distributions their numbers are expected to be low.

The overall sensitivity of receptors to a spill incident is considered to be **HIGH**.

Impact Magnitude

Petroleum discharges, both from natural seeps at the seabed and discharges occurring during the production and transport of petroleum are a common source of toxic substances in marine ecosystems (National Research Council 2003). Satellite imagery analysis covering an extensive area of the west coast between Meob Bay and Cape Columbine was used by TEEPSA/TEEPNA (in 2021) in an oil slicks detection study. The large radar dataset covering 12 years included medium and high resolution 864 ENVISAT (2002 - 2012) and 1 864 SENTINEL (2015 - 2021) radar images, respectively.

The following was concluded from the oil slicks detection study:

- No oil seep anomaly was detected.
- Potential oil slicks detected were identified off the West Coast:
    - oil spills (pollution) from boats were identified orientated mainly NNW-SSE, and thus in agreement with the orientation of the shipping lanes
    - potential oil seeps corresponding to light oil associated with gas, but they are not recurrent.

Although no oil seep anomalies were detected, the study did demonstrate the punctual presence of oil from other sources in the offshore areas.

Various factors determine the impacts of oil released into the marine environment. The physical properties and chemical composition of the oil, volume spilled, local weather and sea state conditions and currents greatly influence the transport and fate of the released product. As a general rule, oils with a volatile nature, low specific gravity and low viscosity (e.g. marine diesel) are less persistent and tend to disappear rapidly from the sea surface. In contrast, high viscosity oils containing bituminous, waxy or asphaltenic residues, dissipate more slowly and are more persistent, usually requiring a clean-up response (see section 4.9.4).

The consequences and effects of small (2 000 – 20 000 litres) diesel fuel spills into the marine environment are summarised below (NOAA 1998). Diesel is a light oil that, when spilled on water, spreads very quickly to a thin film and evaporates or naturally disperses within a few days or less, even in cold water. Diesel oil can be physically mixed into the water column by wave action, where due to its hydrophobic nature it adheres to fine-grained suspended sediments, which can subsequently settle out on the seafloor. Marine sediments can therefore act as deposits for

hydrocarbons that can have lethal and sublethal effects on benthic invertebrates (Zhou *et al*. 2019) and affect the structure and function of the meio- and macrofaunal communities inhabiting the sediments (Egres *et al*. 2019). As it is not very sticky or viscous, diesel tends to penetrate porous sediments quickly, but wave action and currents in coastal waters contributes to rapid weathering of the oil and therefore its low persistence in the sediments (Sandrini-Neto *et al*. 2016). In combination with biological processes such as biodegradation by microbial communities and the release of oil toxic compounds from the sediment to the water column by bioturbation by benthic fauna (Powell *et al*. 2005; Queirós *et al*. 2013), hydrocarbon concentrations in the sediments can be rapidly reduced, resulting in fast recovery of macrobenthic assemblages and the development of resistance in communities exposed to recurrent impacts (Egres *et al*. 2019). In the case of a coastal spill, shoreline clean up is thus usually not needed. Nonetheless, in terms of toxicity to marine organisms, diesel is considered to be one of the most acutely toxic oil types and recovery of biota following high concentration spills in sheltered environments can take years. Many of the compounds in petroleum products are known to smother organisms, lower fertility and cause disease. In the offshore environment surface spills are unlikely to have an immediate effect on the seabed, but surface spills near the coast may result in the death of intertidal invertebrates and seaweed that come in direct contact with a diesel spill. Fish kills, however, have never been reported for small spills in open water as the diesel dilutes so rapidly. Due to differential uptake and elimination rates, filter-feeders (particularly mussels) can bio-accumulate hydrocarbon contaminants. Crabs and shellfish can be tainted from small diesel spills in shallow, nearshore areas.

Chronic and acute oil pollution is a significant threat to both pelagic and inshore seabirds. Diving sea birds that spend most of their time on the surface of the water are particularly likely to encounter floating oil and will die as a result of even moderate oiling which damages plumage and eyes. The majority of associated deaths are as a result of the properties of the oil and damage to the water repellent properties of the birds' plumage. This allows water to penetrate the plumage, decreasing buoyancy and leading to sinking and drowning. In addition, thermal insulation capacity is reduced requiring greater use of energy to combat cold.

Impacts of oil spills on turtles is thought to primarily affect hatchling survival (CSIR & CIME 2011). Turtles encountered in the project area would mainly be migrating adults and vagrants. Similarly, little work has been done on the effect of an oil spill on fur seals.

The effects of oil pollution on marine mammals are poorly understood (White *et al*. 2001), with the most likely immediate impact of an oil spill on cetaceans being the risk of inhalation of volatile, toxic benzene fractions when the oil slick is fresh and unweathered (Geraci & St Aubin 1990, cited in Scholz *et al*. 1992). Common effects attributable to the inhalation of such compounds to include absorption into the circulatory system and mild irritation to permanent damage to sensitive tissues such as membranes of eyes, mouth and respiratory tract. Direct oiling of cetaceans is not considered a serious risk to the thermoregulatory capabilities, as cetacean skin is thought to contain a resistant dermal shield that acts as a barrier to the toxic substances in oil. Baleen whales may experience fouling of the baleen plates, resulting in temporary obstruction of the flow of water between the plates and, consequently, reduce feeding efficiency. Field observations record few, if any, adverse effects among cetaceans from direct contact with oil, and some species have been recorded swimming, feeding and surfacing amongst heavy concentrations of oil (Scholz *et al*. 1992) with no apparent effects.

In the unlikely event of an operational spill or a spill from a vessel collision, the intensity of the impact would depend on whether the spill occurred in offshore waters where encounters with pelagic seabirds, turtles and marine mammals would be low due to their extensive distribution ranges, or whether the spill occurred closer to the shore where encounters with sensitive receptors will be higher. Due to the dominant winds and currents in the Area of Interest (Pimentel *et al*. 2022), a diesel slick would be blown as a narrow plume extending in a north-westerly direction. The diesel would most likely remain at the surface for a number of days (5 days) with a negligible probability of reaching sensitive coastal habitats. In offshore environments, impacts associated with a spill or vessel collision would thus be of LOW intensity, REGIONAL (depending on the nature of the spill), over the short-term (5 days). The impact magnitude for a marine diesel spill is therefore considered **VERY LOW**.

However, in the case of a spill or collision *en route* to the drill area, the spill may extend into coastal MPAs and reach the shore affecting intertidal and shallow subtidal benthos and sensitive coastal bird species, in which case the intensity would be considered HIGH, but still remaining LOCAL over the MEDIUM-TERM. The magnitude would however remain **MEDIUM**.

Impact Significance

Based on the high sensitivity of receptors and the very low (offshore) and medium magnitude (nearshore), the potential impact on the marine fauna is considered to range from **LOW significance** (offshore) to **MEDIUM significance** (nearshore) without mitigation. It must be pointed out that the probability of a spill or collision is unlikely.

Identification of Mitigation Measures

In addition to the best industry practices and project standards, the following measures will be implemented to manage the impacts associated with small accidental spills:

No.	Mitigation measure	Classification
Hydrocarbon Spills		
1	Ensure personnel are adequately trained in both accident prevention and immediate response, and resources are available on each vessel.	Avoid / reduce at source
2	Obtain permission from MFMR to use low toxicity dispersants; Use cautiously.	Abate on and off site
3	As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill	Abate on site
4	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
5	Ensure offshore bunkering is not undertake in the following circumstances: • Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; • During any workboat or mobilisation boat operations; • During helicopter operations; • During the transfer of in-sea equipment; and • At night or times of low visibility.	Avoid / Reduce at source

Residual Impact Assessment

With the implementation of the project controls and mitigation measures, which would reduce the intensity of a nearshore impact to low, the residual impact will be of **very low magnitude** and of **LOW significance** for both offshore and nearshore spills.

21	***Impacts of an operational spill on marine fauna***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW (offshore) to MEDIUM (nearshore)**	**VERY LOW**
Intensity	HIGH (nearshore)	LOW
Extent	LOCAL (nearshore) to REGIONAL (offshore)	LOCAL (nearshore) to REGIONAL (offshore)
Duration	SHORT TERM (offshore) to MEDIUM TERM (nearshore)	SHORT TERM (offshore) to MEDIUM TERM (nearshore)
Significance	**MEDIUM** (nearshore)	**LOW** (nearshore and offshore)
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**FULLY REVERSIBLE**	**FULLY REVERSIBLE**
Loss of Resources	**LOW (offshore) to MEDIUM (nearshore)**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**UNLIKELY**	**UNLIKELY**

4.9.4 Well Blow-out

Source of Impact

The project activities that will result in the accidental release of diesel / oil are listed below.

Project phase	Activity
Mobilisation	n/a
Operation	Loss of well control / well blow-out
Demobilisation	n/a

The greatest environmental threat from offshore drilling operations is the risk of a major spill of crude oil occurring either from a blow-out or loss of well control. A blow-out is the uncontrolled release of crude oil and/or natural gas from a well after pressure control systems have failed.

Impact Description

Oil spilled in the marine environment would have an immediate detrimental effect on water quality, with the toxic effects potentially resulting in mortality (e.g. suffocation and poisoning) of marine fauna or affecting faunal health (e.g. respiratory damage). If the spill reaches the coast, it can result in the smothering of sensitive coastal habitats.

Project Controls

Refer to Section 4.9.3.

The primary safeguard against a blow-out is the column of drilling fluid in the well, which exerts hydrostatic pressure on the wellbore. Under normal drilling conditions, this pressure should balance or exceed the natural rock formation pressure to help prevent an influx of gas or other formation fluids. As the formation pressures increase, the density of the drilling fluid is increased to help maintain a safe margin and prevent "blow-outs". However, if the density of the fluid becomes too heavy, the formation can break down. If drilling fluid is lost in the resultant fractures, a reduction of hydrostatic pressure occurs. Maintaining the appropriate fluid density for the wellbore pressure regime is therefore critical to safety and wellbore stability. Abnormal formation pressures are detected by primary well control equipment (pit level indicators, return mud-flow indicators and return mud gas detectors) on the drill unit. The drilling fluid is also tested frequently during drilling operations and its composition can be adjusted to account for changing downhole conditions. The likelihood of a blow-out is further minimised by installation of a blow-out preventer (BOP) on the wellhead at the start of the risered drilling stage. The BOP is a secondary control system, which contain a stack of independently-operated cut-off mechanisms, to ensure redundancy in case of failure. The BOP is designed to close in the well to prevent the uncontrolled flow of hydrocarbons from the reservoir. A blow-out occurs in the highly unlikely event of these pressure control systems failing.

If the BOP does not successfully shut off the flow from the well, the drilling rig would disconnect and move away from the well site while crews mobilise a capping system. The capping system would be lowered into place from its support barge and connected to the top of the BOP to stop the flow of oil or gas.

Oil Spill Response Limited (OSRL), the global oil spill response co-operative funded by more than 160 oil and energy companies, has a base in Saldanha Bay and another base in Aberdeen, which houses cutting-edge well capping equipment designed to shut-in an uncontrolled subsea well. The Saldanha based capping stack is available to oil and gas companies across the industry and provides for swift subsea incident response around the world. The equipment is maintained ready for immediate mobilisation and onward transportation by sea and/or air in the event of an incident. TEEPNA is a member of OSRL. This would significantly reduce the spill period. All of TEEPNA's wells are designed to allow for capping.

Other project controls include the preparation and implementation of a Shipboard Oil Pollution Emergency Plan (SOPEP), an Oil Spill Response Plan, an Oil Spill Contingency Plan (OSCP) and a Well Control Contingency Plan (WCCP).

Sensitivity of Receptors

Although the Area of Interest is located in the marine environment, more than 290 km offshore, far removed from coastal MPAs and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks), a large spill could still directly affect these sensitive coastal receptors, as well as migratory pelagic species transiting through the drill area.

The benthic biota inhabiting unconsolidated sediments of the outer shelf and abyss are very poorly known, but at the depths of the proposed well are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise taxa which are longer lived and therefore more sensitive to disturbance. No rare or endangered species are known. In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. The sensitivity of soft-sediment macrofauna is thus considered **LOW**, whereas the sensitivity of potential VME species from deep-water hard substrata is considered **HIGH**. There are, however, no known hard grounds in the Area of Interest for drilling.

Being highly toxic, oil released during a blow-out would negatively affect any marine fauna it comes into contact with. The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring in the drill area, are considered regionally 'Endangered' (e.g. African Penguin, Cape Gannet, Cape Cormorant, Bank Cormorant, Roseate Tern, Atlantic and Indian Yellow-nosed Albatross, Northern Royal Albatross, Sooty Albatross, Grey-headed Albatross) or 'Vulnerable' (e.g. White Pelican, Caspian Tern, Damara Tern, Wandering Albatross, Southern Royal Albatross, Leach's Storm Petrel, White-chinned Petrel, Spectacled Petrel). Numerous species of fish, turtles and cetaceans occurring in the project area are also considered regionally 'Critically Endangered' (e.g. Leatherback turtle, blue whale), 'Endangered' (e.g. loggerhead and green turtles, Fin and Sei whales, shortfin mako, whale shark, southern bluefin tuna) 'Vulnerable' (e.g. longfin mako, great white shark, whitetip sharks, sperm whale) or 'Near threatened' (e.g. blue shark). Although species listed as 'Endangered' or 'Vulnerable' may potentially occur in the drill area, due to their extensive distributions their numbers are expected to be low. Overall sensitivity of offshore receptors to a large oil spill is considered to be **HIGH**.

The worst case stochastic scenario modelled was for a release duration of 20 days before capping with no surface response. The oil was predicted to not reach the shore, regardless of the season. Sensitive nearshore and coastal receptors need thus not be considered.

The overall sensitivity of marine ecology/environment to a large oil spill is considered **HIGH**.

Impact Magnitude

Oil Spill Behaviour:

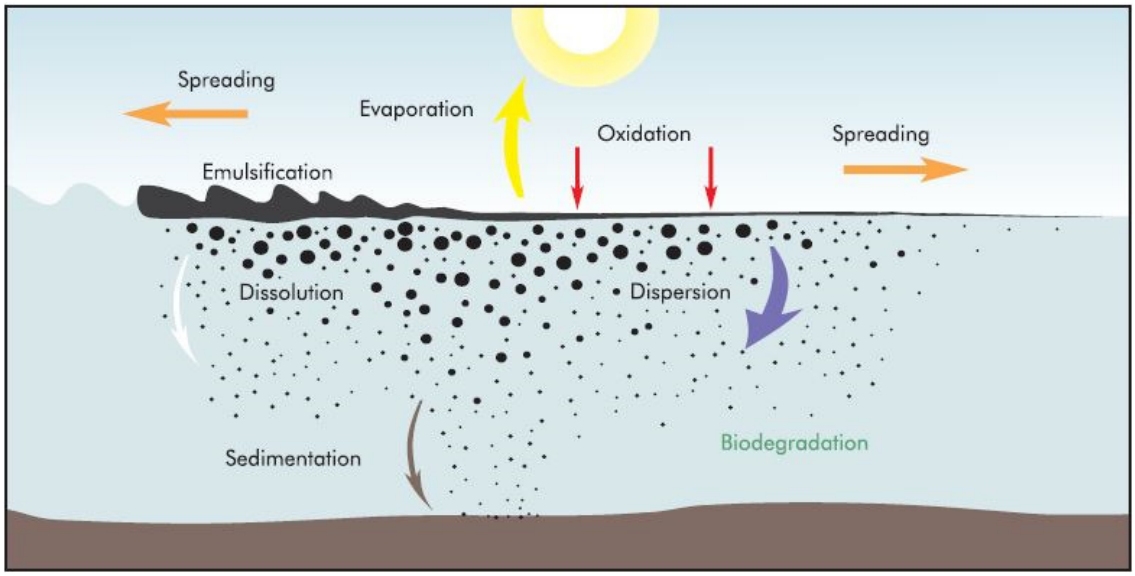
The environmental impacts associated with the various oil spill scenarios modelled by Pimentel *et al*. (2022) for a potential well site at 3 166 m depth on the eastern boundary of the Area of Interest are assessed below, based on the worst case footprints for the probability of surface oiling from spill events.

IMPORTANT NOTE: The oil spill modelling study assumed the worst case scenario of a spill of a continuous blowout of 33 375 bbl of oil for a period of 20 days assuming the characteristics of OSELVAR_2011_13°C oil as the closest equivalent of the fluid expected from an exploration well in Block 2912.

Various factors determine the impacts of oil released into the marine environment. The physical properties and chemical composition of the oil, local weather and sea state conditions and currents greatly influence the transport and fate of the released product. The physical properties that affect the behaviour and persistence of an oil spilled at sea are specific gravity (API), viscosity and pour point, all of which are dependent on the oils chemical composition (e.g. the amount of asphaltenes, resins and waxes). As soon as oil is spilled, it undergoes physical and chemical changes (collectively termed 'weathering') (Figure 59A), which in combination with its physical transport, determine the spatial extent of oil contamination and the degree to which the environment will be exposed to the toxic constituents of the released product. It is estimated that of the oil forming surface layers during a spill, ~40% is rapidly lost to weathering (McNutt *et al*. 2012). Although the individual weathering processes may act simultaneously, their relative importance varies with time (Figure 59B). Whereas spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill, the ultimate fate of oil is determined by the longer term processes of oxidation, sedimentation and biodegradation.

The components of oil known to be toxic to marine organisms include volatile organic compounds (VOCs) such as benzene, toluene, ethylbenzene, and xylene, collectively known as BTEX, as well as polycyclic aromatic hydrocarbons (PAHs), which are known for their persistence in the environment. The polar components of oil (defined as the nitrogen-sulfur-oxygen (NSO)- containing compounds), have a less established toxicity, but can account for ~70% of all oil compounds dissolved in water and are therefore thought to be more toxic to marine organisms and more persistent in the environment than other crude oil components (Liu & Kujawinski 2015). When considering the impact of oil on marine organisms, it is important to consider the composition and comparative toxicity of the specific oil compounds that are present as well as the amount and duration of the oil exposure and the bioavailability of the oil (Saadoun 2015). Oil is most toxic in the first few days after the spill, losing some of its toxicity as it begins to weather and emulsify (Reddy *et al*. 2012; Gros *et al*. 2014). Most of the toxic effects are associated with the monoaromatic compounds and low molecular weight polycyclic hydrocarbons, as these are the most water-soluble components of the oil (NRC 2003). When the additive toxic levels of hydrocarbons exceed the threshold concentration, their effects can lead to mortality. On ingestion, oil hydrocarbons travel to the liver where the resulting metabolites of PAHs become highly toxic and carcinogenic due to their ability to attack and bind to DNA and proteins. As hydrocarbons are highly volatile, the inhalation of concentrated petroleum vapours by mammals, turtles and birds can results in the inflammation of and damage to the mucus membranes of airways, lung congestion or even pneumonia. Inhalation of benzene and toluene, results in these volatiles being rapidly transferred into the bloodstream where accumulation in the brain and liver, can cause neurological disorders (e.g. narcosis) and hepatic damage (Saadoun 2015). Physical contact with the oil is the major route of exposure usually affecting birds and furred mammals at the sea surface. As these rely on their coats for buoyancy and warmth, they typically succumb to hypothermia, drowning and smothering when oil adheres to them.

A)



B)

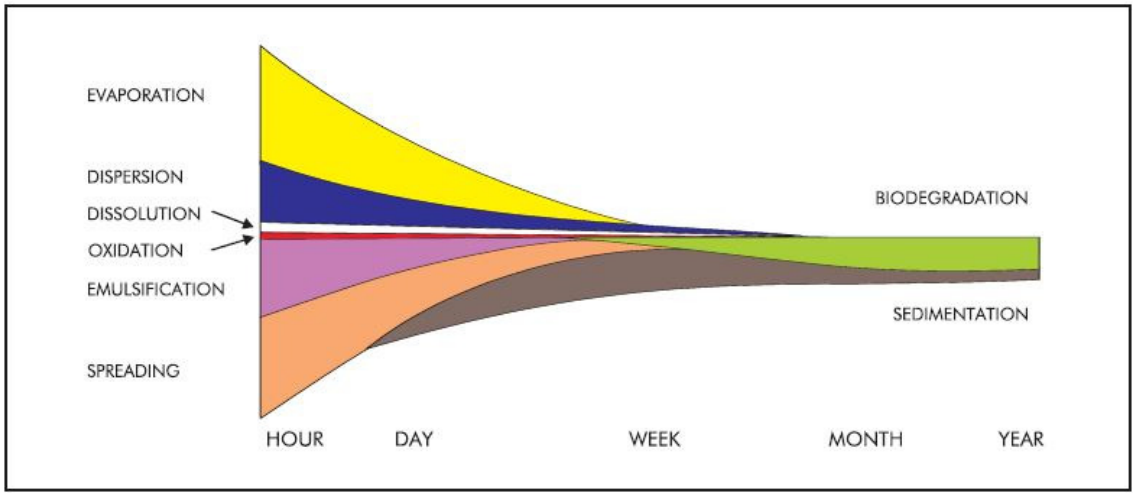


Figure 59: A) The weathering processes acting on spilled crude oil, and B) the fate of a typical medium crude oil under moderate sea conditions - the width of each band indicates the importance of the process (ITOPF 2002).

Oil spilled in the marine environment will have an immediate detrimental effect on water quality. Any release of liquid hydrocarbons thus has the potential for direct, indirect and cumulative effects on the marine environment. The catastrophic Deepwater Horizon (DWH) blow-out in the Gulf of Mexico in 2010 provided opportunity for increasing our understanding of how an oil spill impacts the marine environment. Beyer *et al*. (2016) provide an excellent review of the plethora of research papers emanating from the research programmes initiated following the spill. The biological effects of the DWH spill are summarised in the conceptual

Figure 60, below. This figure illustrates the biological effects as a constellation of relationships between oil exposure and toxicological effects in organisms affected by the spill. All exposure and effect elements shown are supported by information in the DWH oil spill research literature (Source: Beyer *et al*. 2016).

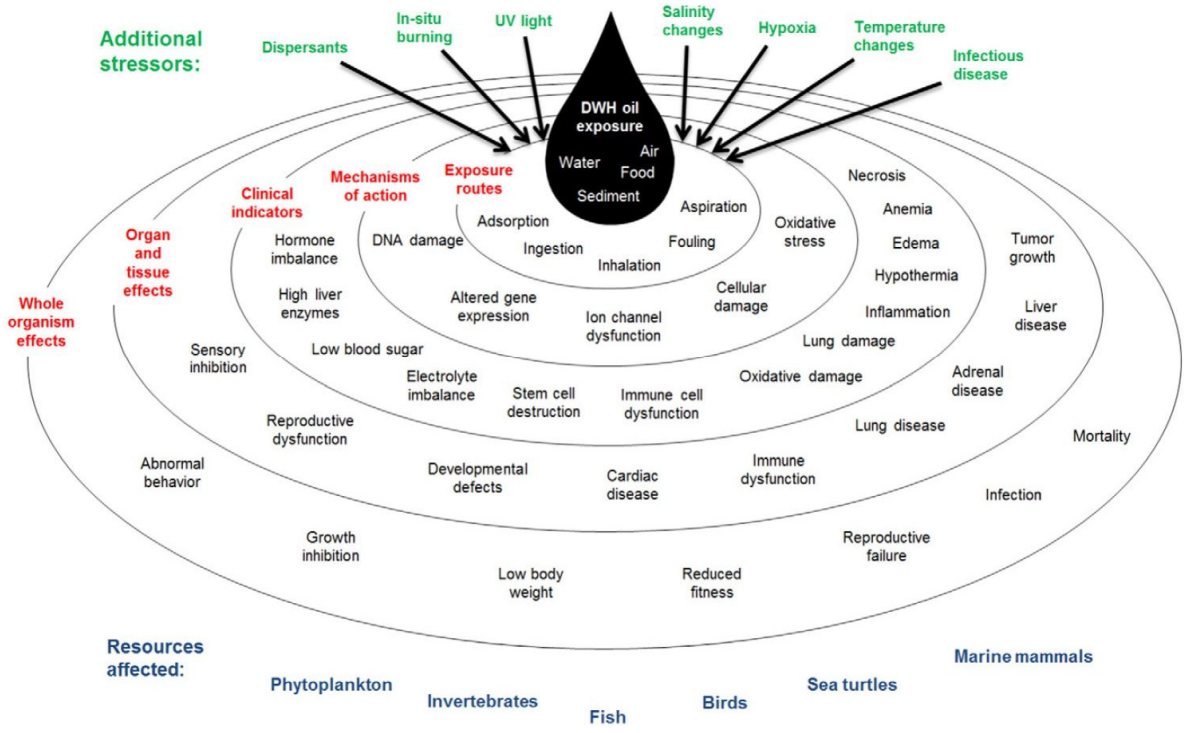


Figure 60: Conceptual figure illustrating the biological effects of the Deepwater Horizon oil spill (Source: Beyer *et al*. 2016).

The fate of the released hydrocarbons during DWH was influenced by an array of factors including the great depth, the composition and magnitude of the blow-out, high sea surface temperature, strong solar irradiation, the presence of a community of indigenous oil degrading microbes, the oceanic circulation pattern in deep and surface waters during the spill and the extensive use of dispersants (both deep and surface applied). It must be pointed out that, as the factors influencing the fate of the hydrocarbons were thus fairly site specific, some of the biological effects described for the DWH spill may not be applicable to a potential blow-out of the continental slope of the western Agulhas Bank. For example, sea surface temperatures off the South African West Coast are likely to be lower, and communities of oil degrading microbes less well established (if present at all) (see Blaizot 2019). Furthermore, many of the ecological impacts reported for the DWH spill were the result of the application of dispersants, both at the leaking well head and at the sea surface. Dispersants applied to the DWH spill modified the spreading, dispersal, weathering, biodegradation, and toxicity of the spilled oil, and their use is now thought to have negatively influenced the total environmental impact of the DWH spill as some of the components proved to be considerably more persistent than originally thought (Kujawinski *et al*. 2011; White *et al*. 2014).

Plankton: Crude oil spills affect phytoplankton communities in a variety of ways and estimates of toxicity varies widely depending on the species involved (Abbriano *et al*. 2011; Zhou *et al*. 2013; Buskey *et al*. 2016). Oil toxicity can impact both phytoplankton community composition and abundance, but while productivity and growth may be reduced (Hallare *et al*. 2011), some species appear to be highly tolerant of oil exposure, and in some cases it may even stimulate their growth (Ozhan *et al*. 2015; D'Souza *et al*. 2016; Tang *et al*. 2019).

Zooplankton similarly respond to oil in a variety of ways ranging from significant but short-term impacts on zooplankton assemblages (Almeda *et al*. 2013b, 2014a, 2014b; Carassou *et al*. 2014; Cohen *et al*. 2014), with some taxa decreasing in density, while others increased. The stimulation of microbial activity in response to oil may also result in increased production of zooplankton. Small ciliates and copepods are particularly sensitive to oil exposure responding by reduced egg production rates, faecal pellet production rates, and egg hatching. Copepods, euphasiids and mysids will ingest emulsified oil droplets leading to acute toxicity, bioaccumulation and transfer to hydrocarbon contaminants to higher order consumers (Buskey *et al*. 2016) and to benthic detritivores (Almeda *et al*. 2015). Larger gelatinous zooplankton are also sensitive to bioaccumulation effects (Almeda *et al*. 2013a), potentially acting as vehicles for contaminant transfer up the food web to apex predators such as turtles. However, there is still insufficient evidence of the extent to which oil transfers to the next trophic level.

A further consideration regarding impacts on plankton is photo-enhanced toxicity, especially where drilling is proposed in areas known as fish spawning habitats. Certain PAHs are classified as phototoxic, raising an additional level of complexity regarding the exact chemical composition of different oils. Photo-enhanced toxicity occurs when certain wavelengths enhance the observed toxicity of a compound, thereby posing additional risks to the buoyant eggs of pelagic fish and the shallow spawning habitat of many nearshore species, as these areas are likely to receive higher intensities of ultraviolet light. However, in nearshore habitats off the Southwest Coast, water turbidity may mitigate some of this concern.

The time of year during which a large spill takes place will significantly influence the magnitude of the impact on plankton and pelagic fish eggs and larvae. Should the spill coincide with a major spawning peak in the kingklip, squid, hake, anchovy and pilchard spawning areas (see Figure 23) during spring and summer, it could result in severe mortalities and consequently a reduction in recruitment (Baker *et al*. 1990; Langangen *et al*. 2017), although Neff (1991) maintains that temporally variable and environmental conditions are likely to have a far greater impact on spawning and recruitment success than a single large spill. Sensitivity of fish eggs and larvae was thought to be primarily associated with exposure to fresh (unweathered) oils (Teal & Howarth 1984; Neff 1991), but recent studies have demonstrated that the weathered water accommodated fraction of the spill results in increased toxicity (Esbaugh *et al*. 2016).

Benthic biota: In a deep-water blow-out, oil can reach the sediments by a number of pathways (reviewed in NRC 2003). The hydrocarbon mixture escaping from the well has a density lower than that of seawater and rises towards the surface. Typically, some of the rising hydrocarbons split off and form a subsurface plume of neutrally buoyant oil droplets that are distributed by deep currents and may become trapped at depth by stratification of the water column. The finely dispersed oil droplets in the subsurface plume stay suspended in the water column and undergo microbial degradation or are sorbed onto suspended sediments that are then deposited on the seabed. Depending on the characteristics of the deep currents these deep plumes may extend over substantial distances and cover large areas before the hydrocarbons settle out thereby potential impacting habitats far removed from the well site (Gong *et al*. 2014; Payne & Driskell 2015; Stout *et al*. 2017). Following the DWH spill, it was discovered that a substantial fraction of the hydrocarbons that reached the surface, were returned to the seabed over a period of weeks as bacteria-mediated, mucous-rich marine snow that had proliferated in the near surface waters during the spill (Passow 2014, 2016). Several mechanisms have been proposed to explain the formation of the marine snow, including coagulation of phytoplankton and/or suspended matter with oil droplets and

production of mucosoid material from bacterial degradation of the oil both at the surface and at depth. Oil-degrading microbial communities, present naturally in the area due to deep-water hydrocarbon seeps, grew and multiplied rapidly following the spill event (Passow *et al*. 2012), with successions of diverse oil-degrading bacterial communities responding to post-spill conditions (Arnosti *et al*. 2016; Yang *et al*. 2016).

Oil may be transported to the seabed *via* oil–particle aggregates (Khelifa *et al*. 2005; Niu *et al*. 2011) or sink directly in the form of tar-like residues from weathered oil. As the use of dispersants can enhance the formation of sediment aggregates, oil-particle interactions can play a significant role in more ecologically sensitive nearshore areas where suspended sediment concentrations are typically higher than in offshore waters (NRC 2005; Gong *et al*. 2014; Cai *et al*. 2017). Following the DWH event, oil deposited in deep-sea sediments was estimated to cover an area in excess of 2 000 km^2 (Stout *et al*. 2017). This pulse in sedimentation resulted in changes in sedimentary redox conditions over a period of two years (Hastings *et al*. 2016) with concomitant changes in benthic communities.

A wide range of effects of oil on benthic invertebrates has been recorded, with much of the research focussing on meiofauna and the various life stages of polychaetes, molluscs and crustaceans (Elmgren *et al*. 1983; Frithsen *et al*. 1985; Volkman *et al*. 1994; Qu *et al*. 2016). Following the DWH spill Montagna *et al*. (2013) reported severe reduction in abundance and diversity of soft-bottom benthic macrofauna and meiofauna extending 3 km from the wellhead in all directions and covering an area of 24 km^2 with moderate impacts extending over 148 km^2 (see also Fisher *et al*. 2014a). Effects over larger spatial scales were, however, also reported (Salcedo *et al*. 2017). However, as tolerances and sensitivities vary greatly, generalisations cannot be confidently made. Some burrowing infauna show high tolerances to oils, as the weathered product serves as a source of organic material that is suitable as a food source. Deposit- and suspension-feeding polychaetes in particular can take advantage of bioturbation and degradation of oiled sediments (Scholtz *et al*. 1992; Kotta *et al*. 2007). Volkman *et al*. (1994) suggest that some epifauna produce complex responses to oiling and that bioaccumulation of petroleum hydrocarbons can in some cases readily occur, with cascade effects to higher order consumers. Sessile and motile mussels and crustaceans are frequent victims of direct oiling or coating, although the latter appear capable of metabolising and excreting accumulated hydrocarbons quite rapidly due to a well-developed mixed-function oxygenase system. Filter-feeders in particular are susceptible to ingestion of oil in solution, in dispersion or adsorbed on fine particles (Saadoun 2015). Chronic oiling is known to cause a multitude of sub-lethal responses in taxa at different life stages, variously affecting their survival and potential to re-colonise oiled areas. Tolerances to oil vary between life stages, with larvae and juvenile stages generally being more sensitive to the water-soluble fractions of oil than adults. This results in highly modified benthic communities with (potentially lethal) 'knock-on' effects for higher order consumers.

Abundance and diversity of megafauna (Valentine & Benfield 2013; Felder *et al*. 2014; McClain *et al*. 2019) were also reported to be negatively affected by oiling, with significant toxicity effects from both oil and dispersants reported for deep-water corals (White *et al*. 2012; Fisher *et al*. 2014a, b; Prouty *et al*. 2014; DeLeo *et al*. 2016). In Block 2912, the fauna inhabiting unconsolidated sediments is expected to be relatively ubiquitous, usually comprising fast-growing species able to rapidly recruit into disturbed areas. In contrast, benthic biota associated with hard grounds are typically more vulnerable to disturbance due to their long generation times.

Sandy shores: Although only a portion of the oil spilled from an offshore well typically reaches the shoreline (see Figure 59), even small amounts can cause widespread contamination of coastal habitats and ecosystems, including estuaries and wetlands. Landfall of oil is generally considered an unfavourable situation as stranding causes a multitude of new environmental impacts compared to those experienced in the offshore environment. Kostka *et al*. (2011) reported a rapid response in the development of oil-degrading microbial communities in beach sands following the DWH spill (see also Mortazavi *et al*. 2013), resulting in a significant fraction of the oil buried in beaches expected to have biodegraded within 5 years. Following a spill, weathered oil can appear on beaches as tar mats, and despite clean-up efforts can remain on sandy shorelines for a number of years, as smaller oil fragments and mats can become buried in the sediments to depths of over a metre through accretion (Fernández-Fernández *et al*. 2011; Michel *et al*. 2013). Heavy weather conditions and littoral drift can re-expose these deposits, redistributing the oil particles and mats along the shore and resulting in the re-oiling of beaches even three years after the initial oil stranding (Bejarano & Michel 2016; Beyer *et al*. 2016). On sheltered sandy beaches, buried oil can persist for decades (Bejarano & Michel 2010; Bernabeu *et al*. 2013). Oil burial and persistence is strongly influenced by beach erosion and deposition cycles, with the grain characteristics and degree of shoreline exposure influencing the penetration and weathering of the oil.

From the comprehensive review of Bejarano and Michel (2016) it becomes evident that oil spilled on beaches results in significant declines in abundance, biomass and diversity of meiofaunal and macrofaunal communities, with recovery of macrofaunal communities typically occurring at between 2-5 years but with recovery of burrowing and long-lived species potentially taking up to 10 years on heavily oiled beaches. Recovery of meiobenthos is typically more rapid. In some cases, recovery of the invertebrate communities was hampered by both re-oiling frequency and the type and degree of beach clean-up following the spill, while in other cases clean-up attempts promoted recovery.

Rocky shores: In the case of oiling of rocky shores, natural recolonisation begins after the processes of physical and chemical degradation have started, with recovery of benthic communities typically occurring within three years. Active clean-up operations of the shores can have a negative or marginal influence on the rate of recovery by sterilising the substratum by removing or killing those biota that survived the initial effects of oiling and would have formed the basis of the subsequent recovery process (Sell *et al*. 1995). In high-energy environments, where the natural removal and degradation of oil is relatively rapid, non-intervention is considered the most effective means of ensuring recovery. Alternatively, adding nutrients to the affected area enriches oil-degrading microorganisms thereby enhancing biodegradation of the oil while preserving the substratum (Serrano *et al*. 2011).

Fish: Adult free-swimming fish in the open sea seldom suffer long-term damage from oil spills because oil concentrations in the water column decline rapidly following a spill, rarely reaching levels sufficient to cause mortality or significant harm. Adult pelagic fish are expected to actively avoid very contaminated waters, and consequently documented cases of fish-kills in offshore waters are sparse (ITOPF 2014). Only in extreme cases of coastal spills when gills become coated with oil can effects be lethal, particularly for benthic or inshore species. Sub-lethal and long-term effects can include disruption of physiological and behavioural mechanisms, reduced tolerance to stress and opportunistic pathogens, and incorporation of PAHs through ingestion of contaminated sediments or prey that has accumulated oil (Thomson *et al*. 2000; Beyer *et al*. 2016).

Following the DWH spill, high PAH metabolites were recorded in the bile of certain fish species, with higher concentrations closer to the spill. However, as metabolites, as chemical markers of oil exposure, were inconsistent among species surveyed and the metabolites measured, their validation is required before use as an indicator of oil contamination (Weisberg *et al*. 2016). In contrast, gene expression and potential effects on sex determination, sexual differentiation, growth regulation and DNA damage in fish was found to be a robust indicator of oil exposure in fish (Beyer *et al*. 2016). Furthermore, the well-developed hepatic mixed function oxygenase (MFO) system in fish ensures that accumulation and retention of high concentrations of petroleum hydrocarbons does not occur and hydrocarbons are thus unlikely to be transfered to predators (Saadoun 2015). Experimental exposure of fish to oil-contaminated sediments was found to reduced fitness and thereby increase the potential for population-level impacts, but field studies of population impacts related to sediment contamination are lacking (Pearson 2014). In a comprehensive field study to determining PAH exposures in demersal fish species in the Gulf of Mexico, Pulster *et al*. (2020) recently concluded that complex interactions exist between multiple hydrocarbon input sources and possible re-suspension or bioturbation of oil-contaminated sediments.

The embryonic and larval life stages of fish, however, show acute toxicity to PAHs, even at low concentrations, although effects vary depending on the species and the extent of exposure. Toxicity effects on the early life stages of fish are generally defined by the occurrence of pericardial edema, which is often accompanied by reduced heart rate and atrial contractility, particularly in large predatory pelagic species such as tunas and billfish (Incardona *et al*. 2014; Esbaugh *et al*. 2016). The cardiotoxic effect may also be accompanied by spinal curvature, finfold damage, and craniofacial malformations (Incardona *et al*. 2014). Impaired cardiovascular development in fish embryos thought to reduce individual cardiovascular performance reduced swimming performance in later life and therefore a high risk for reduced productivity of these commercially-important species.

Seabirds: Chronic and acute oil pollution is a significant threat to both pelagic and inshore seabirds, many of which breed on the Saldanha Bay Islands, Dassen Island, Robben Island and Dyer Island, which could be impact by a large spill. Diving sea birds that spend most of their time on the surface of the water are particularly likely to encounter floating oil and will die as a result of even moderate oiling, which damages plumage and eyes. The majority of associated deaths are as a result of the properties of the oil and damage to the water repellent properties of the birds' plumage. This allows water to penetrate the plumage, decreasing buoyancy and leading to sinking and drowning. In addition, thermal insulation capacity is reduced requiring greater use of energy to combat cold. Oil is also ingested as the birds preen in an attempt to clear oil from plumage and may furthermore be ingested over the medium to long term as it enters the food chain (Integral Consulting Inc. 2006). The effects of ingested oil include anaemia, pneumonia, intestinal irritation, kidney damage, altered blood chemistry, decreased growth, impaired osmoregulation, and decreased production and viability of eggs (Scholz *et al*. 1992; Finch 2011, 2012). Furthermore, even small concentrations of oil transferred from adult birds to the eggs can cause embryo mortalities and significantly reduce hatching rate. Oil spills can thus affect shorebirds through direct acute mortality, as well as indirectly or long term by sub-lethal effects on bird health and behaviour. Habitat degradation of distant feeding or breeding areas may affect bird populations in ways that carry over to subsequent seasons.

Turtles: Impacts of oil spills on turtles is thought to primarily affect hatchling survival (CSIR & CIME 2011), but direct coating of nesting females, contamination of nests and absorption of oil by eggs

and hatchlings will occur with heavy shoreline oiling (Hale *et al*. 2017), potentially with far-reaching effects on recruitment success and population status (Putman *et al*. 2015). As the nesting sites in South Africa are all located over 1 500 km away on the KwaZulu Natal coastline, these would not be affected in the event of a spill, but hatchlings carried southwards in the Agulhas Current and into the Agulhas retroflection zone may become oiled. As turtles spend much of their time at the surface, inhalation of the volatile oil fractions will occur leading to respiratory stress, while coating of eyes, nostrils and mouths with oil will cause vision loss, inhalation and ingestion. Indirect ingestion of oil through contamination of their gelatinous prey or coastal foraging sites is also possible. As turtles often feed in convergence zones, they are particularly at risk to oiling as such oceanic features tends to accumulate oil (NOAA 2010; Wallace *et al*. 2016). Direct miring in oil is the most likely impact, decreasing an animal's ability to move and dive, causing exhaustion, dehydration, overheating, and eventually death. Any turtle deaths from oil exposure would remove them from the breeding population. For species considered 'endangered' or 'critically endangered' such a loss can be significant.

Seals: Little work has been done on the effect of an oil spill on fur seals and sea lions (pinnipeds), but they are expected to be particularly vulnerable as oil would clog their fur and depending on how they maintain their core body temperature, they may die of hypothermia. Seal colonies within the broader project area that may be affected by a spill are at Bucchu Twins near Alexander Bay, and Atlas Bay, Wolf Bay and Long Islands, approximately 320 km northeast of Block 2912 representing the largest colonies in southern Namibia, with smaller colonies at Van Reenen Bay and Baker's Bay, about 290 km inshore of the Block. The following description is summarised from Helm *et al*. (2015). Although pinnipeds should be able to detect oil through vision and/or smell, they apparently do not actively avoid oil, and are therefore likely to come in contact with it if it comes into their habitat. Acute and long-term chronic exposure to oil in pinnipeds negatively affects the mucous membranes, eyes, ears, external genitalia, and internal organ systems. However, due to small sample sizes, the magnitude of the harm and its long-term consequence to individuals and local populations remain unknown. For those pinnipeds that rely primarily on blubber for insulation (sea lions, seals, walrus), external oiling does not significantly impact their ability to maintain their core body temperature. In fur seals and sea lions, the vulnerability to an oil spill will probably be determined by the degree and time of exposure. Wide-ranging species (e.g. elephant seals) that do not congregate in nearshore waters except to breed and moult, are likely less vulnerable than fur seals and sea lions that spend most of their time nearshore. Fur seals rely mostly on air trapped in their fur, rather than blubber for insulation. Individuals would likely face a serious challenge in maintaining their core body temperature if oiled. Population-level impacts are also likely if spilled oil reaches the haul-out sites and rookeries where these seals rest or annually mass to breed. An ill-timed large spill in the vicinity of a fur seal breeding colony would thus likely be devastating. The feeding and movement pattern of pinnipeds would also directly affect their susceptibility to an oil spill, especially in species that forage at great distances from their breeding colonies. Fur seals tend to forage in the coastal zone along the continental shelf and will thus be more susceptible to both the acute and chronic effects of an oil spill, especially where the oil is transported to the coast. Differences in foraging behaviour will also result in differences in exposure after an oil spill, with benthic foragers being more susceptible to chronic exposure through bioaccumulation of PAHs in their prey than pelagic-feeding species.

Cetaceans: The effects of oil pollution on cetaceans are poorly understood (White *et al*. 2001), but their low vulnerability to oil has also been attributed to their ability to detect and avoid slicks

(Helm *et al*. 2015), although conflicting reports exist (see for example Evans 1982; Smultea & Würsig 1995; Matkin *et al*. 2008; Helm *et al*. 2015). Field observations record few, if any, adverse effects among cetaceans from direct contact with oil, and some species have been recorded swimming, feeding and surfacing amongst heavy concentrations of oil (Scholz *et al*. 1992) with no apparent effects. As oil does not adhere to the skin of cetaceans, is not expected to accumulate in or around the eyes, mouth, blow hole, or other potentially sensitive external areas. The skin is thought to contain a resistant dermal shield that acts as a barrier to the toxic substances in oil, and direct oiling of cetaceans is thus not considered a serious risk to the thermoregulatory capabilities. Dispersants added to oil spills have, however, been found to be cytotoxic and genotoxic to whale skin fibroblast cells (Wise *et al*. 2014a, 2014b).

The most likely immediate impact of an oil spill on cetaceans is the risk of inhalation of volatile, toxic benzene fractions when the oil slick is fresh and unweathered (Geraci & St Aubin 1990, cited in Scholz *et al*. 1992). Common effects attributable to the inhalation of such compounds include absorption into the circulatory system leading to narcosis and drowning (St Aubin & Geraci 1994; Matkin *et al*. 2008), inflame mucous membranes, lung congestion leading to pneumonia, neurological damage and liver disorders (Matkin *et al*. 2008), compromised health status and increased disease prevalence (Venn-Watson *et al*. 2015), and mild irritation to permanent damage to membranes of eyes, mouth and respiratory tract. For certain species that frequent or live in nearshore waters, a spill may pose significant risk. For example, populations of coastal-oriented odontocetes that show strong site fidelity restricted to nearshore habitats could be significantly impacted by a spill oiling nearshore waters. If those habitats were oiled, the animals would experience both acute and chronic exposure through their respiratory system and through ingestion of oil-contaminated prey. This may have long-term effects on population structure and size (Matkin *et al*. 2008; Beyer *et al*. 2016; Frasier *et al*. 2019). In contrast, in highly mobile, wide-ranging species, the contact with an oil spill would be relatively brief.

In offshore species, the potential for oil disrupting the reproductive behaviour is remote. However, it is a concern for inshore reproducers, particularly in highly social species, where the disruption of social groups through loss of some key individuals could potentially impact reproductive success over the long-term (see for example Matkin *et al*. 2008).

The impact of oil pollution on local and migrating cetacean populations will obviously depend on the timing and extent of the spill. It is assumed that the majority of cetaceans will be able to avoid oil pollution, though effects on the population could occur where the region of avoidance is critical to population survival. However, oil pollution in areas of cetacean critical habitat (areas important to the survival of the population), such as the extreme near-shore calving / nursing grounds of the humpback whale (e.g. in Elizabeth Bay), could be the most likely to impact populations.

Oil Spill Modelling:

In the order of 32 wells have been drilled in the Namibian offshore environment to date and no well blow-outs have been recorded. Global data maintained by Lloyds Register indicates that frequency of a blow-out from normal exploration wells is in the order of 1.43×10^{-4} per well drilled. While the probability of a major spill happening is thus extremely small, the impact nonetheless needs to be considered as it could have devastating effects on the marine environment. Following the DWH incident, however, Muehlenbacks *et al*. (2013) undertook an empirical analysis of performance indicators on offshore platforms in the Gulf of Mexico and identified that water depth played a

statistically significant role in determining the probability of an incident, with every 30 m of added water depth increasing the probability of an incident by 8.5%.

The assessment below assumes the worst-case scenario of a 20-day blow-out of light crude oil at a rate of 33 375 bbls/day. The modelling assumed various spill response combinations, namely:

- Capping stack only after 20th day
- Subsea dispersant injection (SSDI) kit after 15th day and surface dispersion using aircrafts and vessels for chemical dispersion and vessels for containment and recovery.

Two scenarios were modelled, namely:

- Capping only
- Combination of surface response + SSDI + capping

Threshold values applied to illustrate modelling output results are 58 ppb for oil in the water column, 5 µm for the surface oil thickness and 10 g/m^2 for shoreline oiling (see Pimentel *et al*. 2022 for details).

The discussion of modelling results and impact assessment below is based on the worst case scenario of assuming **capping only** in the event of a blow out. Should a combination of surface response, capping and SSDI be implemented in the unlikely event of a blow out, oil spill footprints would be much reduced.

Stochastic Modelling Results:

It is important to note that the stochastic model outputs do not represent the extent of any one oil spill event (which would be substantially smaller) but rather provides a probability summary of the total individual simulations for a given scenario.

Surface Layer and Water Column Probability of Contamination

Depending on the season, stochastic simulation results of the oil spill modelling study indicated that the hydrocarbon mixture escaping from the well reaches the higher probability for contamination of the surface (**capping only**) forming a plume that is transported in a northwesterly direction by the current. For this surface layer, 90% probability is reached at distances between ~36 km (Season 3) and ~70 km (Season 1) but spreading to a maximum of 330 km to the NNW (Season 2) (Figure 61). There is no spread of the 90% probability to the SE in the direction of Tripp Seamount or the Orange Shelf Edge offshore MPA in South Africa. The probability of contamination of shallow layers (2-72 m depth) extends up to 53 km to the WNW (90% probability) but spreading up to 255 km to the N (Worst case: Season 2). The probability of contamination of the deep layers (2 242 – 2 312 m) remains largely centred around the release point, with the 90% probability spreading to a maximum of 3 km south (Season 2 and Season 4).

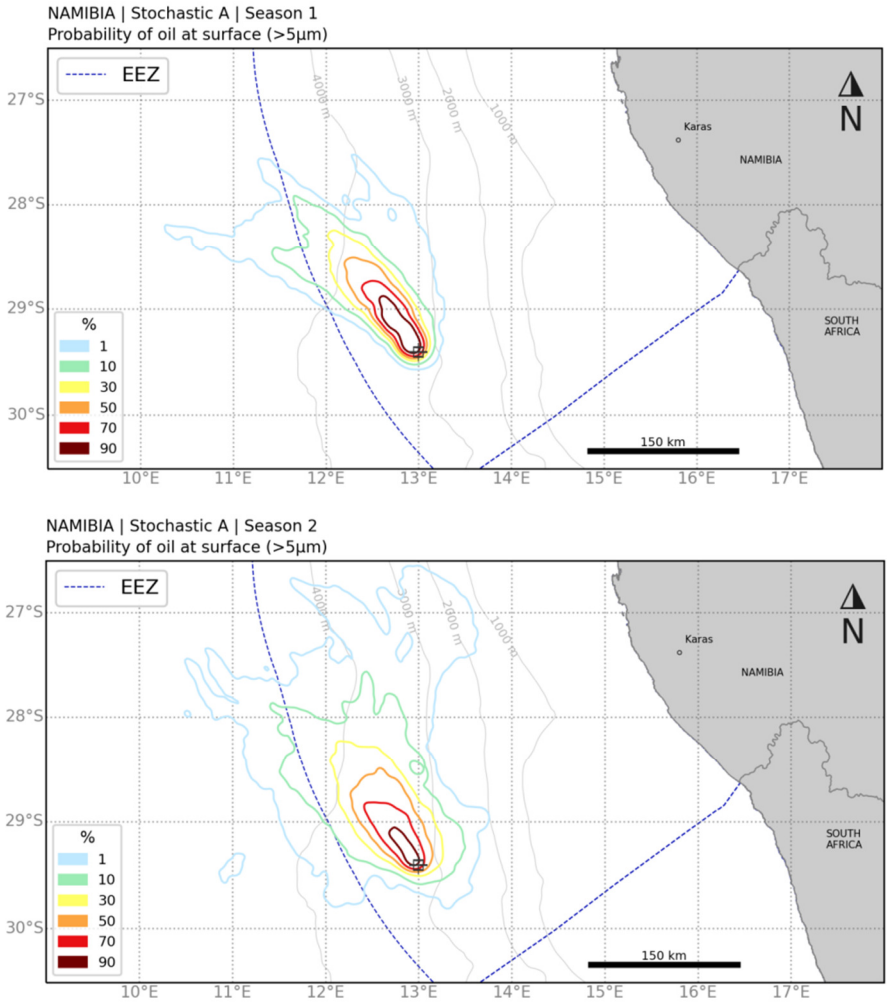


Figure 61: Surface probability of contamination >58 ppb for worst case 90% probability (Season 1) and maximum spread (Season 2) with capping only (Source: Pimentel *et al*. 2022).

When integrated across the entire water column, the oil spill modelling study indicated that in the worst case (Season 1) the plume of the 90% probability extends to 50 km from the release point in a NW direction spreading westwards to beyond 540 km (Figure 62.

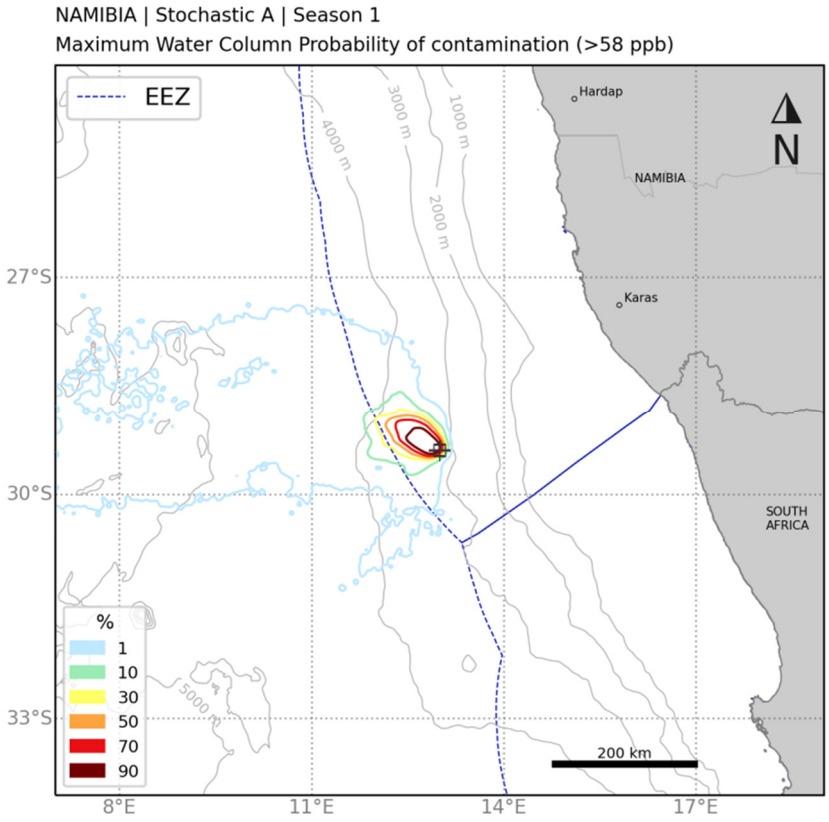


Figure 62: Maximum probability of the presence of oil in the integrated water column with capping only (Source: Pimentel *et al*. 2022).

Implementation of SSDI and surface response after 15 days results in a decrease of the surface slicks as well as those integrated across the water column indicating that in this case the deployment of these control measures is efficient in reducing the oil surface presence probability areas. For the shallow layers, implementation of SSDI does not always result in a significant reduction on the size of the subsurface plume. Some of the finely dispersed oil droplets in the subsurface plume would remain suspended in the water column and undergo microbial degradation or may be absorbed onto suspended sediments that are then deposited on the seabed. In areas where benthic turbidity events are common and termination depths are relatively close to the seabed, a fraction of the hydrocarbons may therefore be returned to the seabed via redepositing sediments. Once the oil reaches the surface it is distributed by prevailing winds and currents surface.

Surface and Shoreline Oil Presence Probability

The behaviour and spread of the slick (>5 µm threshold), the likelihood of it reaching the shore (10 g/m^2 threshold) and the minimum time for oil to reach the shore is subsequently determined by both the seasonality and the type of spill response implemented.

The stochastic modelling results indicate that even for the **capping only response** to a blowout, there is no probability of shoreline oiling, with the slick not even extending as far as the NIMPA.

In the event of a blow-out, the period December to January (Season 1) was identified as the worst in respect of the maximum extent of oil integrated across the water column. This is due to the

prevalence of strong SSE winds during this season which result in the dominant surface currents being directed towards the NW thereby driving the spill away from the coast. However, the stronger currents and winds result the oil being distributed further, with oil leaving Namibian waters and spreading westwards into international waters beyond the country's EEZ.

Deterministic Simulations

The deterministic predictions for the worst-case persistent oil on the surface (with capping only) indicated that the simulation that swept the largest surface area was for Season 2. For Season 3, however, surface oil above 5 µm thickness threshold was still present after 60 days (Figure 63). This is primarily due to winds being weaker during these seasons resulting in surface oil still contributing over 12 000 tons up to 20 days after the start of the simulation. For these seasons, evaporation rates of the surface oil were highest. During Seasons 1 and 4 when surface winds are strongest, entrainment of oil in the water column is higher and the oil in the water column persists for longer. With the application of surface response and SSDI, the deterministic simulations indicate that the spill responses result in the effective dispersion of oil and reduction in the area of the slick after 60 days.

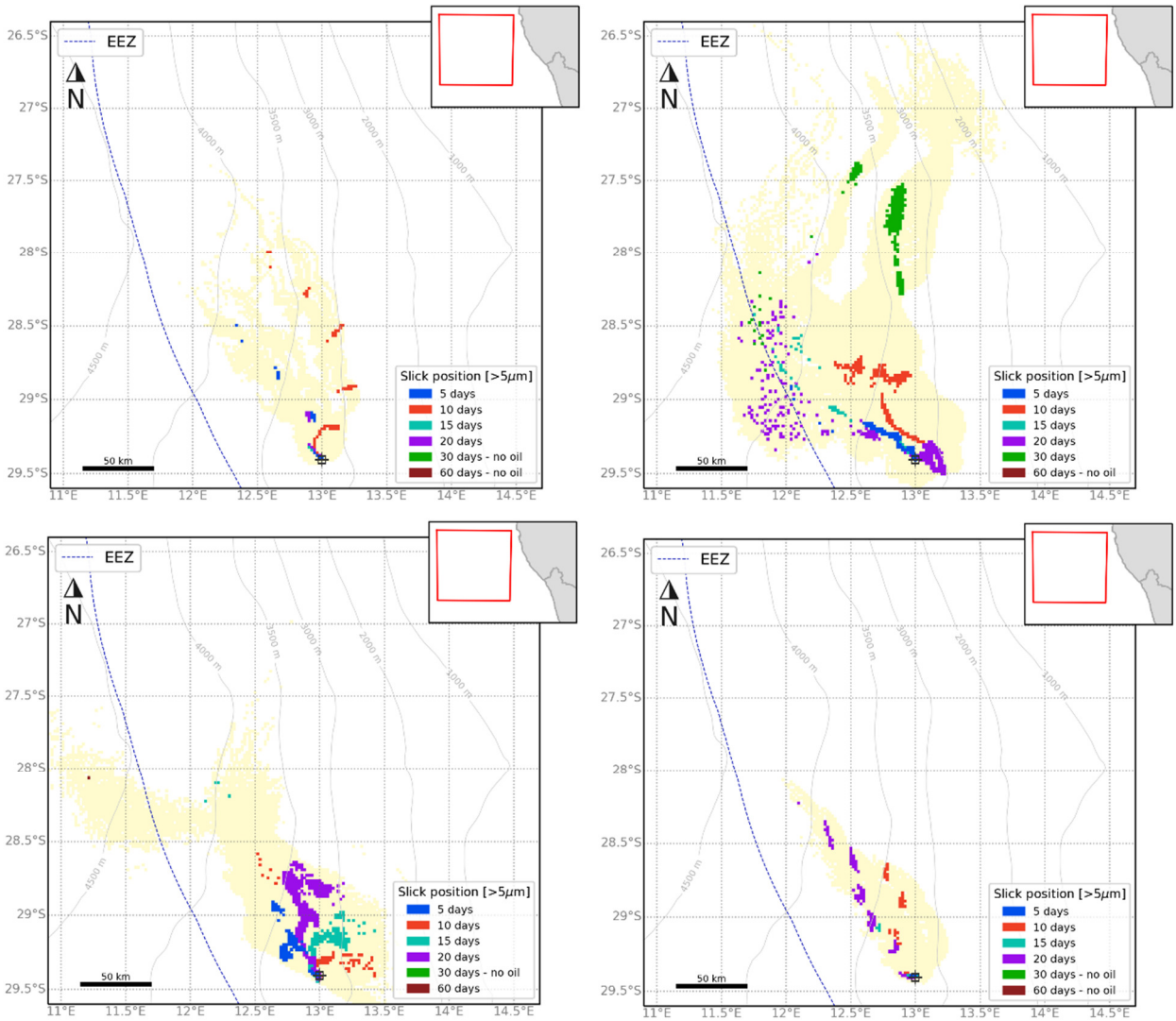


Figure 63: Deterministic Simulations of surface spill drift evolution: Season 1 (top left), Season 2 (top right), Season 3 (bottom left) and Season 4 (bottom right).

From the **mass balance** figures it becomes evident that the majority of the oil released during a blow-out is evaporated and biodegraded, and that a substantial proportion of the spilled oil remains in the water column (submerged). The effect of the response procedures implemented in the control of the spill also becomes clear. Placing a capping stack only (after 20 days release) results in the highest amount of oil remaining at the surface, with the degree of biodegradation and evaporation determined largely by metocean conditions. Implementation of SSDI has the effect of substantially reducing oil droplets size thereby promoting entrainment and dispersion in the water column and natural biodegradation processes. Consequently, the amount of oil reaching the surface is usually reduced. However, the entrained plume could potentially extend over substantial distances and cover large areas before the hydrocarbons settle out thereby potentially impacting habitats far removed from the well site.

Assuming the worst-case scenario, the intensity of the potential impact of a blow-out of hydrocarbons varies depending on the faunal group affected ranging from MEDIUM for offshore benthic macrofauna, marine mammals and turtles, and deep-water reefs to HIGH for pelagic seabirds. As the area does not have confirmed oil seep anomalies, and is therefore unlikely to have established oil-degrading microbial communities (especially considering the harsh offshore oceanographic conditions), the impacts of deposited oil on the seabed is likely persisting over the MEDIUM- to LONG-TERM. In the unlikely event of a blow-out the slick would spread regionally, but could potentially extend beyond the EEZ and thus be of INTERNATIONAL extent. The impact magnitude would therefore range from **MEDIUM** to **VERY HIGH** magnitude depending on the faunal group affected. However, collectively, the impact on marine fauna is assessed to be of **VERY HIGH** magnitude.

Impact Significance

In the unlikely event of a spill, the impact on the marine fauna before mitigation are thus considered to be of **VERY HIGH** significance. In all cases impacts are partially reversible.

Identification of Mitigation Measures

The following measures and Project Control standards should be implemented:

No.	Mitigation measure	Classification
1	As far as possible, avoid scheduling drilling operations during the periods when weather and metocean conditions make drilling safe operations less than optimal, when the likelihood of shoreline oiling for a blow-out is highest (namely the Austral Winter). In the case of exploration wells drilled in a sequence covering this period, response needs to be enhanced (see Section 2 below).	Avoid / Reduce
2	Develop a well-specific response strategy and plans (OSCP and BOCP), aligned with the National OSCP, for each well location that identifies the resources and response required to minimise the risk and impact of oiling (shoreline and offshore). This response strategy and associated plans must take cognisance to the local oceanographic and meteorological seasonal conditions, local environmental receptors and local spill response resources. The development of the site-specific response strategy and plans must include the following:	Avoid / Abate on and off site / Restore

No.	Mitigation measure	Classification
2.1	Assessment of onshore and offshore response resources (equipment and people) and capabilities at time of drilling, location of such resources (in-country or international), and associated mobilisation / response timeframes.	
2.2	Selection of response strategies that reduce the mobilisation / response timeframes as far as is practicable. Use the best combination of local and international resources to facilitate the fastest response.	
2.3	Well-specific oil spill modelling for planning purposes taking into consideration site- and temporal-specific information, the planned response strategy, and associated resources.	
2.4	Develop intervention plans for the most sensitive areas to minimise risks and impacts and integrate these into the well-specific response strategy and associated plans.	
2.5	If modelling and intervention planning indicates that the well-specific response strategy and plans cannot reduce the response times to less than the time it would take oil to reach the shore, additional proactive measures must be committed to. For example: • Implement measures to reduce surface response times (e.g. pre-mobilise a portion of the dispersant stock on the support vessels, contract additional response vessels and aircrafts, minimise the time it takes to install the SSDI kit by ensuring there is a kit on standby, improve dispersant spray capability, etc.). • Deploy and/or pre-mobilise shoreline response equipment (e.g. response trailers, shoreline flushing equipment, shoreline skimmers, storage tanks, shoreline booms, skirt booms, shore sealing booms, etc.) to key localities for the full duration of drilling operation phase to proactively protect sensitive coastal habitats and areas.	
3	Schedule joint oil spill exercises including TEEPNA and local departments / organisations to test the Tier 1, 2 & 3 responses.	Abate on site / Restore
4	Ensure contract arrangements and service agreements are in place to implement the OSCP, e.g. capping stack in Saldanha Bay and other international locations, SSDI kit, surface response equipment (e.g. booms, dispersant spraying system, skimmers, etc.), dispersants, response vessels, etc.	Abate on site / Restore
5	Use low toxicity dispersants that rapidly dilute to concentrations below most acute toxicity thresholds. Dispersants should be used cautiously and only with the permission of MFMR.	Abate on and off site
6	Ensure a standby vessel is within 30 minutes of the drilling unit, equipped for dispersant spraying and can be used for mechanical dispersion (using the propellers of the ship and/or firefighting equipment). It should have at least 5 m^3 of dispersant onboard for initial response.	Abate on site
7	As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill	Abate on site

No.	Mitigation measure	Classification
8	In the event of a spill, use drifter buoys and satellite-borne Synthetic Aperture Radar (SAR)-based oil pollution monitoring to track the behaviour and size of the spill and optimise available response resources	Abate off site
9	The Operator is to submit all forms of financial insurance and assurances to PASA to manage all damages and compensation requirements in the event of an unplanned pollution event.	Restore

Residual Impact Assessment

With the implementation of the above-mentioned best management practices, the residual impact to deep-sea benthic macrofauna, pelagic fish and larvae, seabirds, marine mammals and turtles would still be of high intensity but the extent and duration would decrease. Overall, the residual impacts would be of **VERY HIGH** significance.

22	***Impacts of a major spill following a blow out on deepwater benthic macrofauna, pelagic fish and larvae, seabirds, marine mammals and turtles***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	LOW - MEDIUM* - HIGH**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY HIGH**	**MEDIUM**
Intensity	MEDIUM – HIGH (seabirds)	HIGH
Extent	REGIONAL - INTERNATIONAL	REGIONAL
Duration	MEDIUM (pelagic fish, larvae, turtles, marine mammals) – LONG TERM	MEDIUM
Significance	**VERY HIGH**	**VERY HIGH**
Probability	**UNLIKELY**	**UNLIKELY**
Confidence	**HIGH**	**HIGH**
Reversibility	**PARTIALLY REVERSIBLE**	**PARTIALLY REVERSIBLE**
Loss of Resources	**LOW - MEDIUM* - HIGH****	**HIGH**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**UNLIKELY – POSSIBLE (seabirds)**	**UNLIKELY – POSSIBLE (seabirds)**

* if the spill affects sensitive deepwater reef communities.

** if the spill affects offshore receptors

4.10 Impact Summary for Unplanned Events

The residual impacts on marine habitats and communities associated with the unlikely event of an oil spill or other unplanned events are summarised in the Table below, and the main mitigation measures are listed

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Biological component		
Collision of Vessels with marine fauna and entanglement in gear	• Keep a constant watch from all vessels (Vessel Captain and crew) for cetaceans and turtles in the path of the vessel. Alter course and avoid animals when necessary. • Ensure vessel transit speed between the drill area and port is a maximum of 12 knots (22 km/hr), except within 25 km of the coast where it is reduced further to 10 knots (18 km/hr) as well as when sensitive marine fauna are present in the vicinity. • Report any collisions with large whales to the IWC database	Low
Accidental loss of equipment to seabed and water column	• Ensure containers are sealed / covered and loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system. • Minimise the lifting path between vessels. • Maintain an inventory of all equipment and undertake frequent checks to ensure these items are stored and secured safely on board each vessel. • Undertake a post drilling ROV survey to scan seafloor for any dropped equipment and other removable features around the well site. In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. • Notify Ministry of Works and Transport (Directorate of Maritime Affairs) and the SAN Hydrographer of any hazards left on the seabed or floating in the water column, with the dates of abandonment/loss and locations and request that they send out a Notice to Mariners with this information.	Negligible

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Accidental oil release to the sea due to vessel collisions, bunkering accident and line / pipe rupture	• Ensure personnel are adequately trained in both accident prevention and immediate response, and resources are available on each vessel. • Use low toxicity dispersants cautiously and only with the permission of MFMR. • As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill. • Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station. • Ensure offshore bunkering is not undertake in the following circumstances: – Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; – During any workboat or mobilisation boat operations; – During helicopter operations; – During the transfer of in-sea equipment; and – At night or times of low visibility.	Low
Effects of blow-out on marine fauna	• As far as possible, all effort will be made to not schedule drilling operations during the Austral Winter when the likelihood of shoreline oiling following the unlikely event of a blow-out is highest. In the case of exploration wells drilled in a sequence covering this period, response needs to be enhanced. • Develop a well-specific response strategy and plans (OSCP and BOCP), aligned with the National OSCP, for each well location that identifies the resources and response required to minimise the risk and impact of oiling (shoreline and offshore). This response strategy and associated plans must take cognisance to the local oceanographic and meteorological seasonal conditions, local environmental receptors and local spill response resources. The development of the site-specific response strategy and plans must include the following: – Assessment of onshore and offshore response resources (equipment and people) and capabilities at time of drilling, location of such resources (in-country or international), and associated mobilisation / response timeframes.	Very High

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blow-out on marine fauna (cont.)	– Selection of response strategies that reduce the mobilisation / response timeframes as far as is practicable. Use the best combination of local and international resources to facilitate the fastest response. – Should there be any significant changes in the modelling input data closer to the spud date of the well, these should be considered and the modelling report must be updated accordingly in order to guide the final response strategy – The sensitivity maps used for all future studies must be regularly updated and used to guide all activities and response. – Develop intervention plans for the most sensitive areas to minimise risks and impacts and integrate these into the well-specific response strategy and associated plans. – If modelling and intervention planning indicates that the well-specific response strategy and plans cannot reduce the response times to less than the time it would take oil to reach the shore, additional proactive measures must be committed to. • Schedule joint oil spill exercises including TEEPNA and local ministries / organisations to test the Tier 1, 2 & 3 responses. • Ensure contract arrangements and service agreements are in place to implement the OSCP, e.g. capping stack in Saldanha Bay and other international locations, SSDI kit, surface response equipment (e.g. booms, dispersant spraying system, skimmers, etc.), dispersants, response vessels, etc. • Use low toxicity dispersants that rapidly dilute to concentrations below most acute toxicity thresholds. Dispersants should be used cautiously and only with the permission of MFMR • Ensure a standby vessel is within 30 minutes of the drilling unit, equipped for dispersant spraying and can be used for mechanical dispersion (using the propellers of the ship and/or firefighting equipment). It should have at least 5 m^3 of dispersant onboard for initial response.	Very High

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blow-out on marine fauna (cont.)	• As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill • In the event of a spill, use satellite-borne Synthetic Aperture Radar (SAR)-based oil pollution monitoring to track the behaviour and size of the spill and optimise available response resources. • Ensure that the following aspects are included in insurance cover to financially manage the consequences of any unplanned pollution event on environmental and social aspects: – Damages and compensation to Third-Parties. • Evidence to be provided to NAMCOR.	Very High

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APPENDIX 1

Table 16: Mud composition for each section.

Section	Composition	Concentration (kg/ton)	Mass (ton)
1 (42'')	Caustic soda	0.6	0.18
	Soda Ash	0.6	0.18
	Bentonite	69	22.5
2 (26'')	Caustic soda	0.6	0.3
	Soda Ash	0.6	0.3
	Bentonite	69	37.5
2 disp. mud (26'')	Caustic Soda	0.8	0.8
	Soda Ash	0.8	0.8
	Barazan	0.8	0.8
	Calcium chloride	385	400
	PAC R	0.8	0.8
3 (17 ½'')	EDC-99 DW A	435	13.6
	EDC-99 DW B		0.0026
	EDC-99 DW C		0.65
	EDC-99 DW D		1.9
	EDC-99 DW E		0.78
	Invermul NT A	61	0.75
	Invermul NT B		0.75
	Invermul NT C		0.125
	Invermul NT D		0.125
	EZMUL NT A	35	1
	EZMUL NT B		0.29
	EZMUL NT C		0.0715
	EZMUL NT D		0.0715
	Duratone-E	22	0.89
	Liquitone	39	1.61
	Lime	26	1.07
	GELTON E A	26	0.053
	GELTON E B		0.0107
	BARAVIS IE 568	13	0.54

Section	Composition	Concentration (kg/ton)	Mass (ton)
3 (17 ½'')	Calcium chloride	61	2.5
	Barite	304	12.49
	Baracarb	0.8	0.03
	SteelSeal	0.6	0.02
4 (12 ¼'')	EDC-99 DW A	435	11.55
	EDC-99 DW B		0.02
	EDC-99 DW C		0.55
	EDC-99 DW D		1.65
	EDC-99 DW E		0.66
	Invermul NT A	61	0.63
	Invermul NT B		0.63
	Invermul NT C		0.105
	Invermul NT D		0.105
	EZMUL NT A	35	0.84
	EZMUL NT B		0.24
	EZMUL NT C		0.06
	EZMUL NT D		0.06
	Duratone-E	22	0.8
	Liquitone	39	1.4
	Lime	26	0.9
	GELTON E A	26	0.045
	GELTON E B		0.009
	BARAVIS IE 568	13	0.5
	Calcium chloride	61	2.1
	Barite	304	10.6
5 (8 ½'')	EDC-99 DW A	435	2.05
	EDC-99 DW B		0.0039
	EDC-99 DW C		0.1
	EDC-99 DW D		0.29
	EDC-99 DW E		0.12
	Invermul NT A	61	0.09
	Invermul NT B		0.09
	Invermul NT C		0.015
	Invermul NT D		0.015

Section	Composition	Concentration (kg/ton)	Mass (ton)
5 (8 ½'')	EZMUL NT A	35	0.14
	EZMUL NT B		0.04
	EZMUL NT C		0.01
	EZMUL NT D		0.01
	Duratone-E	22	0.1
	Liquitone	39	0.2
	Lime	26	0.1
	GELTON E A	26	0.006
	GELTON E B		0.0012
	Baravis IE 568	13	0.1
	Calcium Chloride	61	0.3
	Baracarb	522	2.4

APPENDIX 2

Curriculum Vitae Dr Andrea Pulfrich

Personal Details

Born:	Pretoria, South Africa on 11 August 1961
Nationality and Citizenship:	South African and German
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Academic Qualifications

BSc (Zoology and Botany), University of Natal, Pietermaritzburg, 1982
BSc (Hons) (Zoology), University of Cape Town, 1983
MSc (Zoology), University of Cape Town, 1987
PhD, Department of Fisheries Biology of the Institute for Marine Science at the Christian-Albrechts University, Kiel, Germany, 1995

Membership in Professional Societies

South African Council for Natural Scientific Professions (Pr.Sci.Nat. No: 400327/06)
South African Institute of Ecologists and Environmental Scientists
International Association of Impact Assessment (South Africa)
Registered Environmental Assessment Practitioner (Certification Board for Environmental Assessment Practitioners of South Africa).

Employment History and Professional Experience

1998-present: Director: Pisces Environmental Services (Pty) Ltd. Specifically responsible for environmental impact assessments, baseline and monitoring studies, marine specialist studies, and environmental management plan reports.

1999: Senior researcher on contract to Namdeb Diamond Corporation and De Beers Marine South Africa, at the University of Cape Town; investigating and monitoring the impact of diamond mining on the marine environment and fisheries resources; experimental design and implementation of dive surveys; collaboration with fishermen and diamond divers; deep water benthic sampling, sample analysis and macrobenthos identification.

1996-1999: Senior researcher at the University of Cape Town, on contract to the Chief Director: Marine and Coastal Management (South African Department of Environment Affairs and Tourism); investigating and monitoring the experimental fishery for periwinkles on the Cape south coast; experimental design and implementation of dive surveys for stock assessments; collaboration with fishermen; supervision of Honours and Masters students.

1989-1994: Institute for Marine Science at the Christian-Albrechts University of Kiel, Germany; research assistant in a 5 year project to investigate the population dynamics of mussels and cockles in the Schleswig-Holstein Wadden Sea National Park (employment for Doctoral degree); extensive and intensive dredge sampling for stock assessments, collaboration with and mediation between, commercial fishermen and National Park authorities, co-operative interaction with colleagues working in the Dutch and Danish Wadden Sea, supervision of Honours and Masters projects and student assistants, diving and underwater scientific photography. Scope of doctoral study: experimental design and implementation of a regular sampling program including: (i) plankton sampling and identification of lamellibranch larvae, (ii) reproductive biology and condition indices of mussel populations, (iii) collection of mussel spat on artificial collectors and natural substrates, (iv) sampling of recruits to the established populations, (v) determination of small-scale recruitment patterns, and (vi) data analysis and modelling. Courses and practicals attended as partial fulfilment of the degree: Aquaculture, Stock Assessment and Fisheries Biology, Marine Chemistry, and Physical and Regional Oceanography.

1988-1989: Australian Institute of Marine Science; volunteer research assistant and diver; implementation and maintenance of field experiments, underwater scientific photography, digitizing and analysis of stereo-photoquadrats, larval culture, analysis of gut contents of fishes and invertebrates, carbon analysis.

1985-1987: Sea Fisheries Research Institute of the South African Department of Environment Affairs and Tourism: scientific diver on deep diving surveys off Cape Agulhas; censusing fish populations, collection of benthic species for reef characterization.

South African National Research Institute of Oceanography and Port Elizabeth Museum: technical assistant and research diver; quantitative sampling of benthos in Mossel Bay, and census of fish populations in the Tsitsikamma National Park.

University of Cape Town, Department of Zoology and Percy Fitzpatrick Institute of African Ornithology; research assistant; supervisor of diving survey and collection of marine invertebrates, Prince Edward Islands.

1984-1986: University of Cape Town, Department of Zoology; research assistant (employment for MSc Degree) and demonstrator of first year Biological Science courses. Scope of MSc study: the biology, ecology and fishery of the western Cape linefish species Pachymetopon blochii, including (i) socio-economic survey of the fishery and relevant fishing communities, (ii) collection and analysis of data on stomach contents, reproductive biology, age and growth, (iii) analysis of size-frequency and catch statistics, (iv) underwater census, (v) determination of hook size selectivity, (vi) review of historical literature and (vii) recommendations to the Sea Fisheries Research Institute of the South African Department of Environment Affairs and Tourism for the modification of existing management policies for the hottentot fishery.