PROPOSED EXPLORATION DRILLING IN BLOCK 3B/4B OFF THE WEST COAST OF SOUTH AFRICA

Marine Biodiversity Specialist Assessment

Prepared for:

ENVIRONMENTAL IMPACT MANAGEMENT SERVICES

On behalf of

Africa Oil South Africa Corp.

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Contact Details:

Andrea Pulfrich
Pisces Environmental Services
PO Box 302, McGregor 6708, South Africa,
Tel: +27 21 782 9553
E-mail: apulfrich@pisces.co.za
Website: www.pisces.co.za

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EXECUTIVE SUMMARY

Africa Oil South Africa Corp (AOSAC) is the operator and holder of an exploration right in Block 3B/4B in the Deep Water Orange Basin off the West Coast of South Africa. Commencement is not confirmed, but the first well will possibly be drilled between first and fourth quarter of 2024. Water-based Muds (WBM) will be used during the first (riserless) drilling stage and KCl/Glycol mud during the second (risered) drilling stage.

The area of Interest for drilling is 9 711.21 km^2 in extent and located in water depths between 1 000 m and 3 000 m roughly between Port Nolloth and Hondeklip Bay, approximately 190 km from the coast at its closest point. According to Rogers (1977), the seabed sediments comprise sandy muds and muds, with muddy sands being dominant in the eastern portions. The drill cuttings modelling study lists the particle size in the Area of Interest as silty clay. Although influenced by the Benguela Current the licence area is located well offshore of the coastal upwelling cells. Winds come primarily from the southeast, whereas virtually all swells throughout the year come from the S and SSW direction. The bulk of the seawater in the Area of Interest is South Atlantic Central Water characterised by low oxygen concentrations, especially at depth. Surface waters in the licence area will primarily be nutrient poor and clear, being beyond the influence of coastal upwelling.

Block 3B/4B falls into the Atlantic Offshore Bioregion. Although there is a lack of knowledge of the community structure and diversity of benthic macrofauna off the shelf edge, the South Atlantic unclassified slopes and unclassified abyssal unconsolidated habitat types have been rated as 'least threatened', reflecting the great extent of these habitats in the South African Exclusive Economic Zone (EEZ). Two geological features of note in the vicinity of the proposed area of interest are Child's Bank, situated ~50 km due east of the area of interest for exploration drilling at about 31°S, and Tripp Seamount situated at about 29°40'S, ~25 km north-northwest of the area of interest. Features such as banks and seamounts often host deepwater corals and boast an enrichment of bottom-associated communities relative to the otherwise low profile homogenous seabed habitats.

Due to its offshore location, plankton abundance is expected to be low, with the major fish spawning and migration routes occurring further inshore on the shelf. The dominant fish in the area would include the migratory large pelagic species such as tunas, billfish and pelagic sharks. Seabirds will be dominated by the pelagic species such as albatross, petrels and shearwaters. Migrating turtles in the area would include the leatherback and loggerhead turtles. Marine mammals likely to occur offshore include a variety of baleen whales including humpbacks, Antarctic minke, fin and sei whales. Toothed whales will include sperm and killer whales, as well as a variety of beaked whales and dolphins. The licence area overlaps with the Orange Shelf Edge MPA and the Orange Seamount and Canyon Complex EBSA. The Area of Interest for drilling, however, specifically avoids these areas.

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 of cement additives 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 (upper water column)
  - 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 Vertical Seismic Profiling (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 in 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 ~25 km northwest of the area of interest, that potentially supports vulnerable, long-lived benthic invertebrate species;
- Numerous vulnerable and endangered pelagic shark species;
- Leatherback turtles that migrate through the area;
- Sperm whales, which occur in the area year-round;
- Humpback and Fin whales, which migrate through the area between May and December; and
- The Orange Shelf Edge MPA, 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 MPAs during transit to and from the drill site.	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

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Disturbance of marine fauna due to helicopter noise	• Pre-plan flight paths to ensure that no flying occurs over seal colonies and seabird nesting areas. • 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. • 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 • Pre-plan flight paths to ensure that no flying occurs over seal colonies and seabird nesting areas.	Low
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. Capturing and transportation of seabirds must be undertaken according to specific protocols as outlined in the OWCP. • Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring).	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 1 000 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.	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
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 1 000 m of the drill site. • If vulnerable habitats are detected, seek the advice of a benthic specialist and 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. • As information gathered during ROV surveys is of high scientific value, such information should be made available to contribute to the knowledge base of deep-water environments.	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.	Low
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.	Medium
Impacts of drill cuttings discharge on water column (turbidity & light) and seabed (turbidity)	None	Low
Impacts of Cuttings Discharges: development of anoxic sediments around the wellbore during drilling of the riseless sections	None	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
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 Area of Interest 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).	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, procedures undertaken during low visibility). • 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
Impacts of petroleum infrastructure and residual cement on marine biodiversity (Wellhead Abandonment)	• 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. • Install over-trawlable abandonment caps over the wellheads only if these fall within the footprint of the demersal trawl fishery. • 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 to the seabed during the operational stage, assess safety and metocean conditions before performing any retrieval operations	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
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. • Contant operational monitoring of flare for any malfunctioning. • Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard box) for subsequent release during daylight hours. Capturing and transportation of seabirds must be undertaken according to specific protocols as outlined in the OWCP.	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
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 Area of Interest 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

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
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 of abandonment/loss and locations and request that they send out a Notice to Mariners with this information. • 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	Negligible
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 DFFE. • 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 as per specific protocols for capturing oiled and injured seabirds as outlined in the Oiled Wildlife Contingency Plan. • 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

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blowout on marine fauna	• 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. – 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. – Develop an Oiled Wildlife Contingency Plan (OWCP) in collaboration with specialist wildlife response organisations with experience in oiled wildlife response to integrate into the site-specific OSCP. The OWCP should include detailed protocols on the collection, handling and transport of oiled marine fauna. – 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.	Medium

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blowout on marine fauna (cont.)	• Schedule joint oil spill exercises including AOSAC and local departments / 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. • Although the use of dispersants will have insignificant effects on the surface presence in the case of a condensate spill, should they be used this must be done cautiously and only with the permission of the Department of Forestry, Fisheries and Environment (DFFE). • 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. • 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. • 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.	Medium

ACRONYMS, 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	Blowout 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
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
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
NBHF	narrow band, high frequency
NEMBA	National Environmental Management: Biodiversity Act
NDP	Namibian Dolphin Project
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)*
OSRL	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
AOSAC	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
VSP	Vertical Seismic Profiling
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 Programmes relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents. She is a registered Environmental Assessment Practitioner and member of the South African Council for Natural Scientific Professions, South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist report was compiled for EIMS for their use in preparing an Environmental and Social Impact Assessment (ESIA) and Environmental Management Programme Report (EMPr) for proposed exploration well-drilling by Africa Oil South Africa Corp. (AOSAC) in Block 3B/4B in the Deep Water Orange Basin off the West Coast of South Africa.

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

Andrea Pulfrich

Dr Andrea Pulfrich

1. GENERAL INTRODUCTION

Africa Oil South Africa Corp. (AOSAC), Azinam Limited and Ricocure (Pty) Ltd are currently the holders of the exploration right over Block 3B/4B. The current exploration right was issued in March 2019, with the First Renewal Period covering the two years from October 2022 to October 2024. AOSAC is planning to undertake sonar surveys, seabed coring and to drill up to 10 exploration wells. Commencement is not confirmed, but the first well will possibly be drilled between first and fourth quarter of 2024. The Licence Block, which is 11 100 km^2 in extent is situated offshore of the West Coast on the continental shelf in water depths ranging from 200 m to 2 000 m. The area of primary interest is in the north of this block, but this could also cover other areas in future. Within Block 3B/4B the Area of Interest (AOI) for drilling is 9 711.21 km^2 in extent and is located offshore roughly between Port Nolloth and Hondeklip Bay, approximately 190 km from the coast at its closest point and 340 km at its furthest, in water depths between 1 000 m and 3 000 m.

AOSAC has appointed Environmental Impact Management Services (Pty) Ltd (EIMS) as the Independent Environmental Practitioner to undertake the Environmental Impact Assessment (EIA) process for the proposed exploration activities. EIMS in turn approached Pisces Environmental Services (Pty) Ltd to provide a specialist assessment of potential impacts of the proposed exploration well-drilling operations on marine fauna and ecological processes in the area.

1.1 Terms of Reference

The Terms of Reference for the Marine Ecology Specialist Study as provided by EIMS are:

- Provide a general description of the marine fauna off the West Coast of South Africa, based on current available literature, with specific relevance to Block 3B/4B 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.

1.2 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 five 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.

1.2.1 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 (Child's Bank, 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.

1.2.2 Assessment Procedure

The assessment methodology applied to the impact assessment section is detailed in Appendix 1.

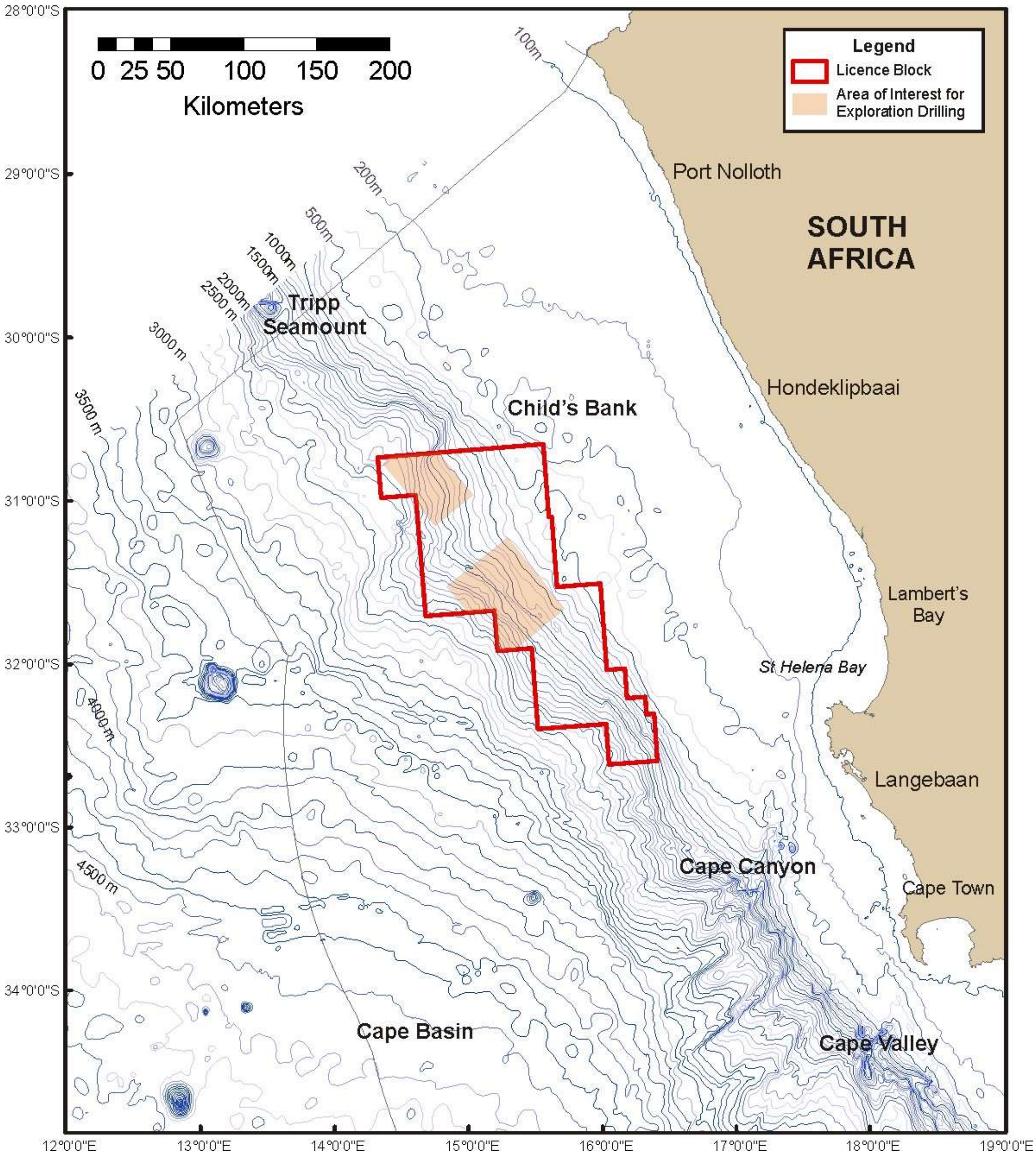

Figure 1: Map indicating location of Block 3B/4B and the Area of Interest for exploration drilling in relation to bathymetric features off the West Coast. Places mentioned in the text are also indicated.

2. DESCRIPTION OF THE PROPOSED PROJECT

Block 3B/4B off the West Coast of South Africa has an area of approximately 11 100 km^2. The Area of Interest for drilling is located in the northern portion of the licence area and covers 9 711.21 km^2 ranging in water depths between 1 000 m and 3 000 m.

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 will 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 a combination of 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. These surveys would not be limited to a specific time of the year but would be of short duration (around 10 days per survey) and focused on selected areas of interest within the block. The interpretation of the survey would take up to four weeks to complete.

2.1.2 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. AOSAC 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 200 dB re 1µPa at 1m source level) that are capable of receiving many return "pings". This system produces a digital terrain model of the seafloor.

2.1.3 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.

2.1.4 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 potentially removing a cumulative volume of ~ 35 m^3. The sediment sampling process would take between three to five weeks to complete, depending on weather conditions.

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

2.1.5 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.

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.

2.1.6 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. AOSAC 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

AOSAC is proposing to drill up to five exploration wells within an Area of Interest within Block 3B/4B. The expected target drilling depth is not confirmed yet and a notional well depth of 3 570 m below sea floor (Water depth range 500 -1 700 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). AOSAC's strategy for future drilling is that drilling could be undertaken throughout the year (i.e. not limited to a specific seasonal window period).

The schedule for drilling the wells is not confirmed yet; however, the earliest anticipated date for commencement of drilling is third quarter of 2024 (Q3 2024) and is expected to take approximately 90 days per well.

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, AOSAC 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 support 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 support 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 Springbok Airport (fixed-wing trip from Cape Town) using local providers. It is estimated that there may be up to four return flights per week between the drilling unit and the helicopter support base at Springbok (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, in which case the flights are likely to be directly to Cape Town.

2.3.4 Onshore Logistics Base

The primary onshore logistics base will most likely be located at the Port of Cape Town (preferred option), but alternatively at the Port of Saldanha.

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

Core specialist and skilled personnel would arrive in South Africa onboard the drilling unit and the rest of the personnel will be flown to Cape Town.

Drilling materials, such as casings, mud components 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 support vessels will transfer it to the drilling unit. Cement and chemicals will be sourced locally.

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 pre-existing 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 Table 4 of the drillings discharge modelling Report (Livas 2023a). This may vary slightly depending on the contractor's selection and may be modified to suit operational needs.

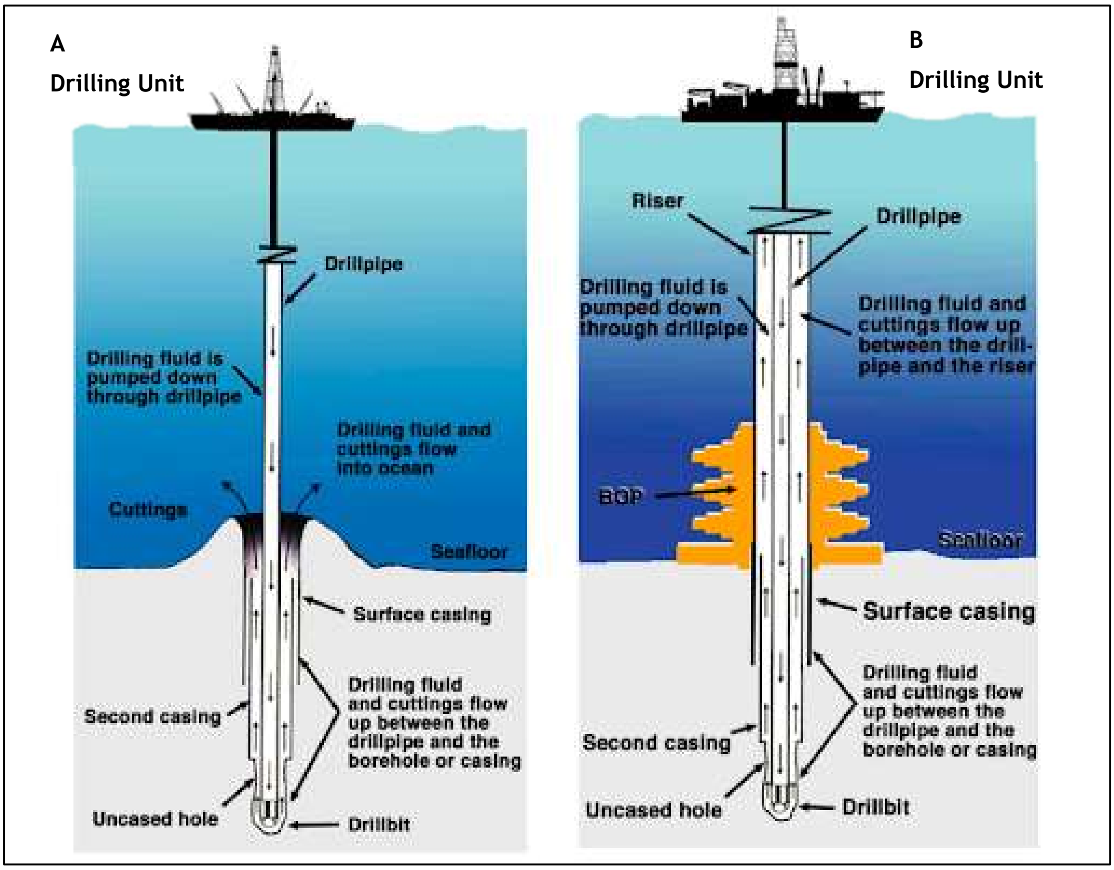

Figure 3: Drilling stages: (a) Riserless Drilling Stage; and (b) Risered Drilling Stage.

Table 1a: Cuttings and mud volumes per phase for notional base-case well design and estimated drilling discharges using water-based muds as the drilling fluid.

Drill Section	Hole diameter (inches)	Depth of section (m)	Type of drilling fluid used	Mass of drilling fluid discharged (tons)	Volume of cuttings released (m^3)	Drilling fluid and cuttings discharge location
Riserless drilling stage						
1	36”	70	Seawater, viscous sweeps & WBM	209	40	At sea bottom
2	26”	320		135	76	
-	Suspension / Displacement before drilling Section 3	-	High Viscous Gel sweeps / KCl Polymer PAD mud	30	-	1 m above seabed
Total Riserless		**390**		374	116	
Risered drilling stage						
3	17.5”	700	KCl/Glycol WBM	133	74	10 m below mean sea level
4	12.25”	1 250		109	61	
5	8.5”	1 160		61	27	
Total Risered		3 110		303	162	
Totals	-	**3 500**	-	**677**	**278**	-

Note: * Total quantity of mud discharged including Oil On Cuttings (OOC) @ 6.9% by weight of cuttings (metricT) + Other constituents.

Table 1b: Cuttings and mud volumes per phase for notional base-case well design and estimated drilling discharges using Non-Aqueous Drilling Fluid (NADF) for the deeper sections.

<table>
<tr><th>Drill Section</th><th>Hole diameter (inches)</th><th>Depth of section (m)</th><th>Type of drilling fluid used</th><th>Mass of drilling fluid discharged (tons)</th><th>Mass of cuttings released (tonnes)</th><th>Drilling fluid and cuttings discharge location</th></tr>
<tr><td colspan="7">Riserless drilling stage</td></tr>
<tr><td>1</td><td>36”</td><td>100</td><td rowspan="2">Seawater, viscous sweeps & WBM</td><td>338</td><td>160</td><td rowspan="2">At sea bottom</td></tr>
<tr><td>2</td><td>26”</td><td>775</td><td>541</td><td>879</td></tr>
<tr><td>-</td><td>Suspension / Displacement before drilling Section 3</td><td>-</td><td>High Viscous Gel sweeps / CaCl Polymer PAD mud</td><td>1 047</td><td>-</td><td>1 m above seabed</td></tr>
<tr><td colspan="2">Total Riserless</td><td>875</td><td></td><td>1 926</td><td>1 039</td><td></td></tr>
<tr><td colspan="7">Risered drilling stage</td></tr>
<tr><td>3</td><td>17.5”</td><td>800</td><td rowspan="3">NADF</td><td>57</td><td>411</td><td rowspan="3">10 m below mean sea level</td></tr>
<tr><td>4</td><td>12.25”</td><td>1 325</td><td>46</td><td>334</td></tr>
<tr><td>5</td><td>8.5”</td><td>750</td><td>13</td><td>92</td></tr>
<tr><td colspan="2">Total Risered</td><td>2 875</td><td></td><td>116</td><td>837</td><td></td></tr>
<tr><td>Totals</td><td>-</td><td>3 750</td><td>-</td><td>2 042</td><td>1 876</td><td>-</td></tr>
<tr><td colspan="7">Note: * Total quantity of mud discharged including Oil On Cuttings (OOC) @ 6.9% by weight of cuttings (metricT) + Other constituents.</td></tr>
</table>

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 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 320 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 Blowout 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 'blowout'). 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 external 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, sampled for analysis 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 between 3 300 m and 3 750 m below the seafloor with a final hole diameter between of 8.5 and 12.25 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 could be tested depending on the drilling results.

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 450 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 at each station. 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 six hours to complete approximately 125 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 10 000 bbl oil could be flared per test, i.e. up to 20 000 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 remove the wellheads from the sea floor on non productive wells. On productive wells, it may be decided to abandon the wellheads on the seafloor after installation of over trawlable protective equipment. The risk assessment criteria will consider factors such as the water depth and use of the area by other sectors (e.g. fishing).

It is proposed temperature and pressure monitoring gauges be installed on wells where the Applicant will return in the future for appraisal / production purposes. The gauges will be placed and remain on the wellhead. Monitoring gauges are not proposed to be installed on exploration wells which are earmarked for abandonment.

With the exception of the over-trawlable protective equipment over abandoned wellheads (if these fall within the demersal trawl footprint) 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 support 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 as defined by the UK and Norway. 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, AOSAC proposes to use the "offshore treatment and disposal" option for their drilling campaign in Block 3B/4B in the Deep Water Orange Basin. The same method was applied and approved for drilling other deep-water 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 131 m^3 of cuttings and 374 t of drilling fluid will be discharged per well during the riserless drilling stage (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, 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. During the risered drilling stage, an estimated volume of 257 m^3 of cuttings and 444 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. Discharge is 10 m below sea level.

Further drilling fluid totalling 200 bbl (30 m^3) 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 (Livas 2023a), 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 % 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 50 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.

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 m^3/day, which will result in approximately 35 g salt for each litre of 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. Regardless of whether a drill ship or semi-submersible rig is implemented for drilling operations, ballasting would only occur on set-up at or close to the drill site, with deballasting on departure also occurring at site.

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), support 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, sonar acquisition takes 1.5 to 3 days to acquire with short bursts of the sound source and the VSP onboard between 4 to 6 hours dependent on the programme 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 700 m and 1 900 m depth ranges covering a survey area of approximately 150 km^2. Each wellsite survey would take up to 10 days 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 support 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 150 cubic inch airguns and three 150 cubic inch airguns with a total volume of 450 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 150 shots. A VSP is expected to take up to six 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 support 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 support 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 South African West Coast focus primarily on the study area between the Orange River mouth and Cape Point. The description of the marine environment includes the various biophysical receptors that may be affected both directly and indirectly by the project activities. The area of direct influence would include those receptors located within or immediately adjacent to the area of interest for exploration well drilling within the Orange Basin, which may be affected by drilling discharges, whereas the area of indirect influence will vary in extent depending on the type of receptor potentially affected by more far-reaching impacts, such as potential oil spills in the unlikely event of a blowout. The summaries presented below are based on information gleaned from Lane & Carter (1999), Morant (2006), and Penney *et al.* (2007), supplemented with more recent information available in peer-reviewed publications and internal reports. Natasha Karenyi of the University of Cape Town contributed to a previous version of the description of benthic macrofaunal communities. Dr Simon Elwen of the Namibian Dolphin Project and Mammal Research Institute (University of Pretoria) provided input into a previous version of the section on marine mammals.

3.1 Geophysical Characteristics

3.1.1 Bathymetry

The continental shelf along the West Coast is generally wide and deep, although large variations in both depth and width occur. The shelf maintains a general NNW trend, widening north of Cape Columbine and reaching its widest off the Orange River (180 km) (see Figure 1). The nature of the shelf break varies off the South African West Coast. Between Cape Columbine and the Orange River, there is usually a double shelf break, with the distinct inner and outer slopes, separated by a gently sloping ledge. The immediate inshore[1] area consists mainly of a narrow (about 8 km wide) rugged rocky zone and slopes steeply seawards to a depth of around 80 m. The middle (-50 to -150 m) and outer shelf (-150 to -350 m) normally lacks relief and slopes gently seawards reaching the shelf edge at a depth of between -350 to -500 m (Sink *et al.* 2019). The three shelf zones characterising the West Coast are recognised following both abiotic (de Wet 2013) and biotic (Karenyi *et al.* 2016) patterns.

Banks on the continental shelf 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 Child's Bank, situated ~150 km offshore at about 31°S, and adjacent to the northeastern corner of the licence block. Child's Bank is a major feature on the West Coast margin and is the only known submarine bank within South Africa's Exclusive Economic Zone (EEZ), rising from a depth of 350 - 400 m water to less than -200 m at its shallowest point. It is a rounded, flat topped, sandy plateau, which lies at the edge of the continental shelf. The bank has a gentle northern, eastern and southern margin but a steep, slump-generated outer face (Birch & Rogers 1973; Dingle *et al.* 1983; de Wet 2013). At its southwestern edge, the continental slope drops down steeply from -350 to -1 500 m over a distance of less than 60 km (de Wet 2013) creating precipitous cliffs at least 150 m high (Birch & Rogers 1973). The bank consists of resistant, horizontal beds of Pliocene sediments, similar to that of the Orange Banks, and

[1]As per the 2019 National Biodiversity Assessment inshore is defined as the area influenced by wave energy and light, with the fair weather wave base at a depth ranging between -30 to -50 m used to determine the outer limits of this zone in South Africa. Offshore areas are those that extend beyond this zone.

represents another perched erosional outlier formed by Post-Pliocene erosion (Dingle 1973; Siesser *et al*. 1974). The top of this feature, has been estimated to cover some 1 450 km^2 (Sink *et al*. 2012).

Tripp Seamount, a geological feature ~25 km to the north-northwest of the area of interest, rises from the seabed at ~1 000 m to a depth of 150 m. It is a roughly circular feature with a flat apex that drops steeply on all sides.

A further two unnamed seamounts are situated ~110 km and ~140 km to the west of the western boundary of the licence block rising from depths of 3 000 m and 3 500 m.

Further underwater features in the vicinity of the licence block include the Cape Canyon and Cape Point Valley, which lie ~100 km and ~245 km to the southeast of the southern boundary of the licence block (Simpson & Forder 1968; Dingle 1986; Wigley 2004; Wigley & Compton 2006). The Cape Canyon was discovered in the 1960s. The canyon head forms a well-developed trench on the continental shelf, 100 m deep and 4 km wide (Wigley 2004; Wigley & Compton 2006). South of Cape Columbine the canyon becomes progressively narrower and deeper. Adjacent to Cape Town in a water depth of 1 500 m, the canyon has a local relief in the order of 500–800 m (Simpson & Forder 1968; Dingle *et al*. 1987). The Cape Canyon has a longitudinal extent of at least 200 km and can be traced to a water depth of at least 3 600 m (Dingle 1970), where the topography of the distal end is rugged and complex (Dingle *et al*. 1987). Sediments in the canyon are predominately unconsolidated sands and muds. The canyon serves as an upwelling feature funneling cold, nutrient-rich South Atlantic Central Water up the canyon slope providing highly productive surface waters which in turn power feeding grounds for cetaceans and seabirds (Filander *et al*. 2018; www.environment.gov.za/ dearesearchteamreturnfromdeepseaexpedition).

The Cape Point Valley, which lies about 70 km south of the Cape Peninsula, is another large canyon breaching the shelf. This canyon has sustained the highest fishing effort and catches in the South African demersal trawl fishery for almost a century (www.marineprotectedareas.org.za/canyons).

Using high-resolution bathymetry collected between 315 – 3 125 m depth, Palan (2017) identified numerous new and previously undocumented submarine canyon systems, most of which are less extensive than the Cape Canyon and Cape Point Valley and do not incise the shelf (Figure 4). Canyon morphology was highly variable and included linear, sinuous, hooked and shelf-indenting types. Large fluid seep/pockmark fields of varying morphologies were similarly revealed situated in close proximity to the sinuous, hooked and shelf-indenting canyon types thereby providing the first evidence of seafloor fluid venting and escape features from the South African margin. These pockmarks represent the terminus of stratigraphic fluid migration from an Aptian gas reservoir, evidenced in the form of blowout pipes and brightened reflectors. This area lies well to the southeast of the licence block.

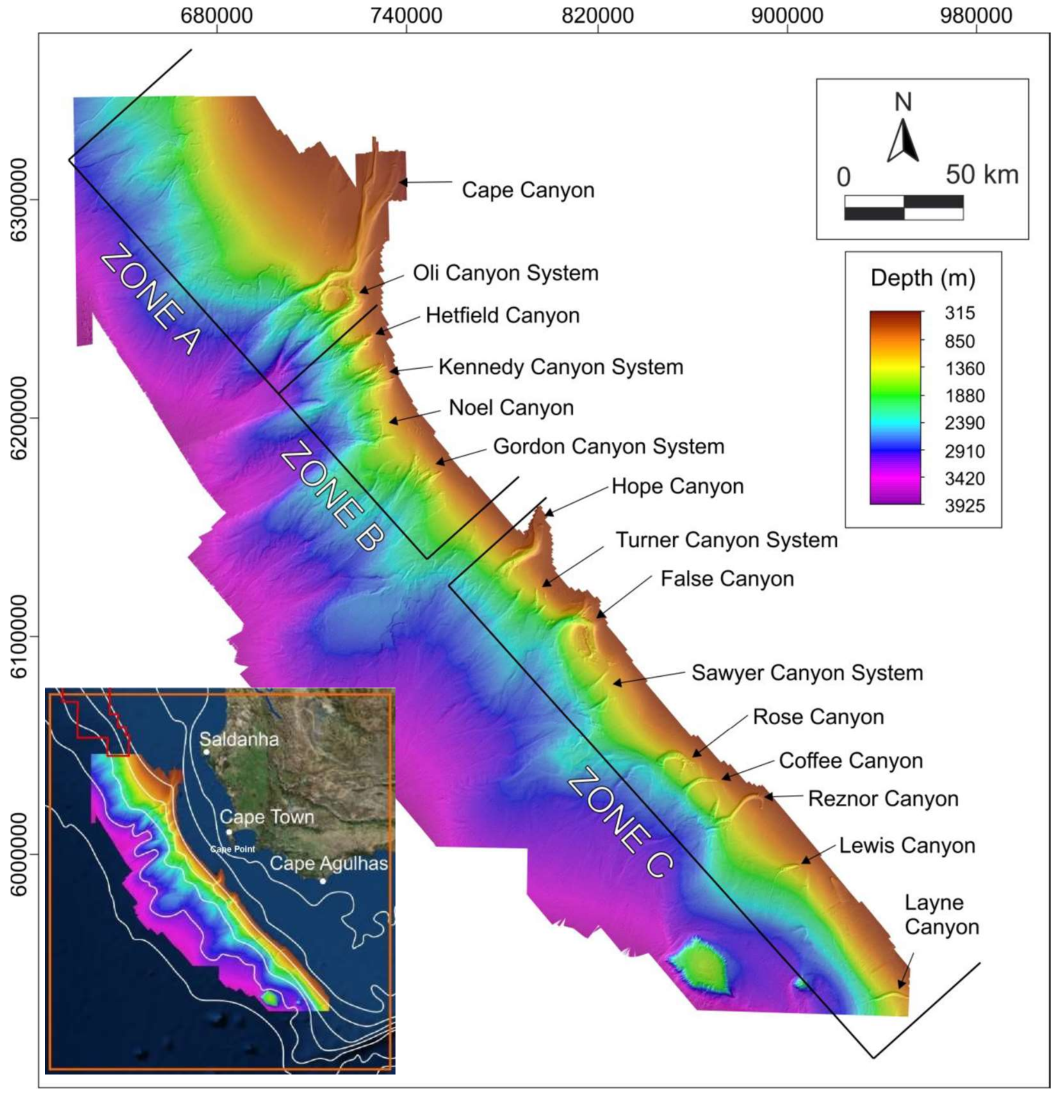

Figure 4: Submarine canyon domains of the southwestern Cape continental margin identified by Palan (2017). Insert shows the locality of the study area in relation to Block 3B/4B (red polygon).

3.1.2 Coastal and Inner-shelf Geology and Seabed Geomorphology

Figure 5 illustrates the distribution of seabed surface sediment types off the South African north-western coast. The inner shelf is underlain by Precambrian bedrock (Pre-Mesozoic basement), whilst the middle and outer shelf areas are composed of Cretaceous and Tertiary sediments (Dingle 1973; Dingle *et al*. 1987; 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 innershelf shelf between the Orange River and St Helena Bay (Birch *et al*. 1976). Further offshore and within the licence block, sediment is dominated by muds and sandy muds, with the eastern portion of the licence block having muddy sands and sands being present in the northeastern corner of the block. The continental slope, seaward of the shelf break, has a smooth seafloor, underlain by calcareous ooze.

Present day sedimentation is limited to input from the Orange River. This sediment is generally transported northward. Most of the sediment in the area 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.

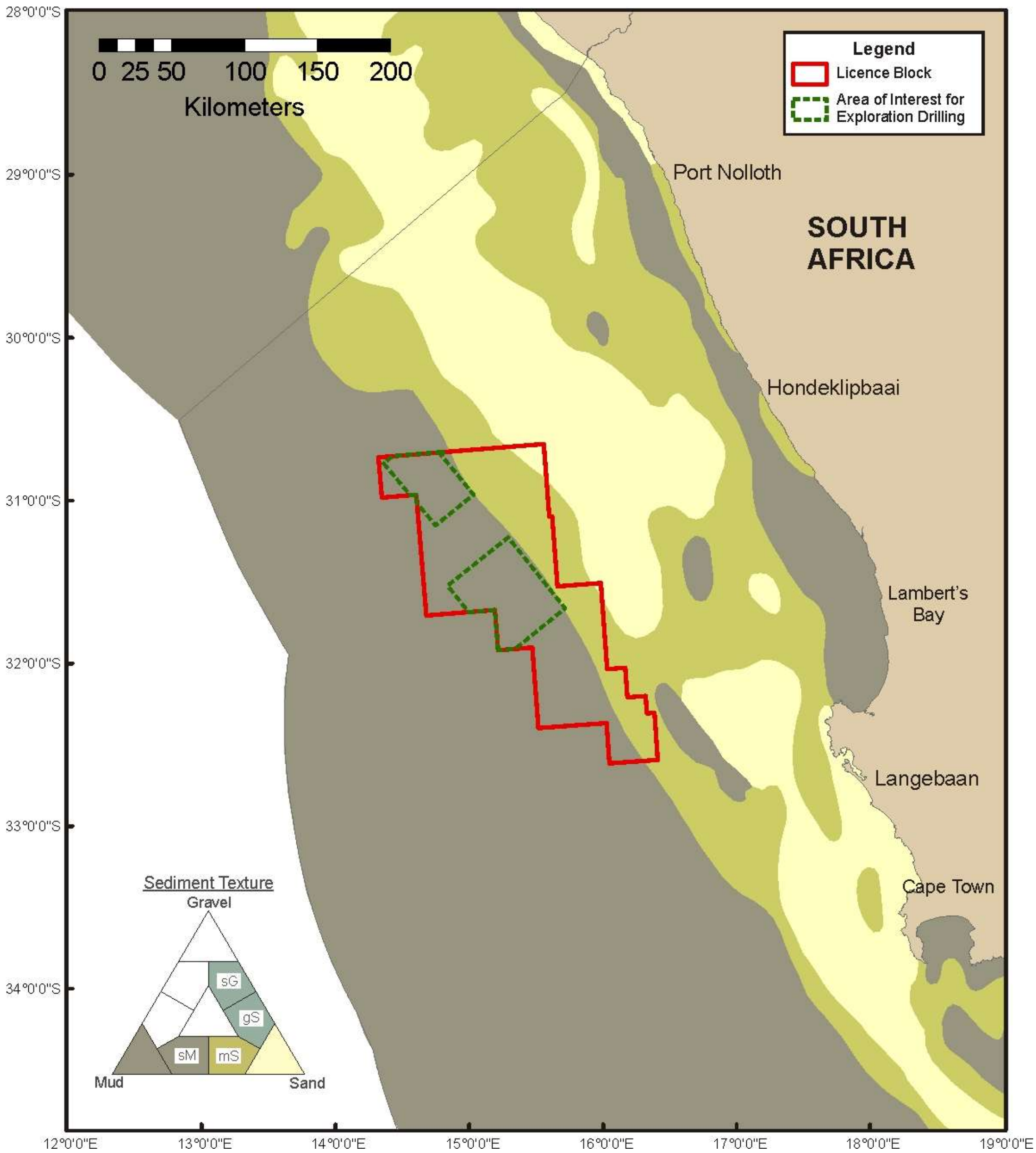

Figure 5: Block 3B/4B (red polygon) in relation to sediment distribution on the continental shelf of the South African West Coast (Adapted from Rogers 1977). Based on information in Holness *et al*. (2014) and Sink *et al*. (2019), the mud/sandy mud sediments have been extended to the edge of the EEZ beyond that shown in Rogers (1977).

The benthic habitat types of the West Coast were classified and mapped in detail through the 2011 National Biodiversity Assessment (NBA) (Sink *et al*. 2012a). These were refined in the 2018 NBA (Sink *et al*. 2019) to provide substratum types (Figure 6).

In the Area of Interest the water depth ranges from ~1 000 m to 3 000 m. The Southeast Atlantic Unclassified Slopes substratum dominates across the area. The shelp inshore of the licence block boasts a diversity of substrata (Sink *et al*. 2019).

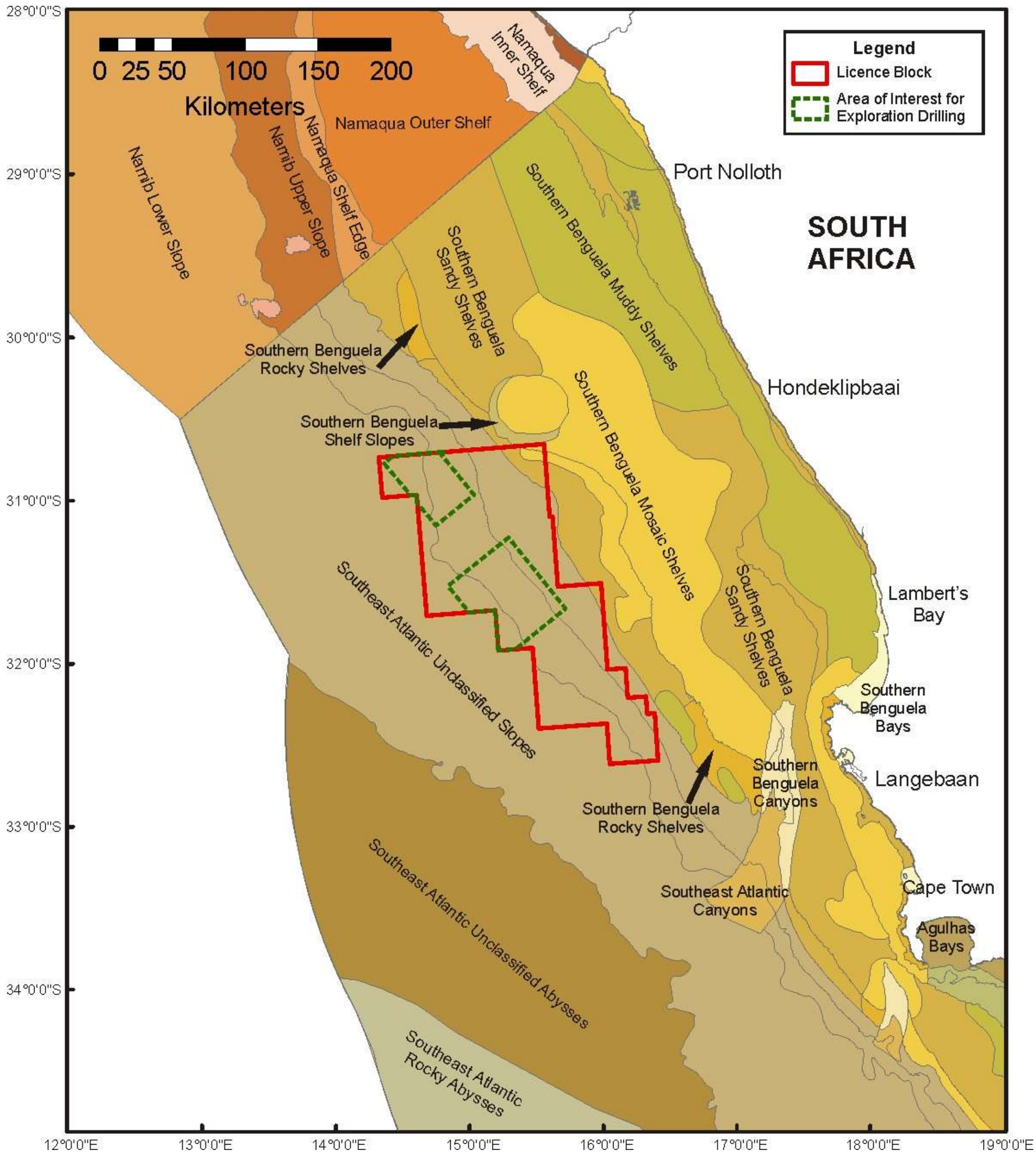

Figure 6: Block 3B/4B (red polygon) in relation to the distribution of seabed substratum types along the West Coast (adapted from Sink *et al*. 2019). The adjacent Namibian substratum types (adapted fom Holness *et al*. 2019) are also shown.

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 (Figure 7, left) or as series of unconsolidated sediments (Morant 2013). Several types of sedimentary phosphates occur offshore and onshore in South Africa, the largest of which is the diagenetic replacement resource on the Agulhas Bank. These replacement phosphate resources occur as near-continuous 'pavements' or cappings of limestones at depths between 200 m and 500 m on the continental shelf between Cape Agulhas and Cape Recife, covering an approximate area of 21 500 km^2. Further sporadic phosphate mantles over the continental shelf are known to occur from Lamberts Bay, north to the mouth of the Orange River (Figure 7, right). Block 3B/4B lies offshore of the phosphorite hard grounds.

The "open shelf" phosphorite deposits were formed during several episodes over the last 1.7 – 65 million years. They originated from the precipitation of phosphate in the form of calcium phosphate in an environment of intense upwelling and high biological activity along the continental margin of South Africa. The 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).

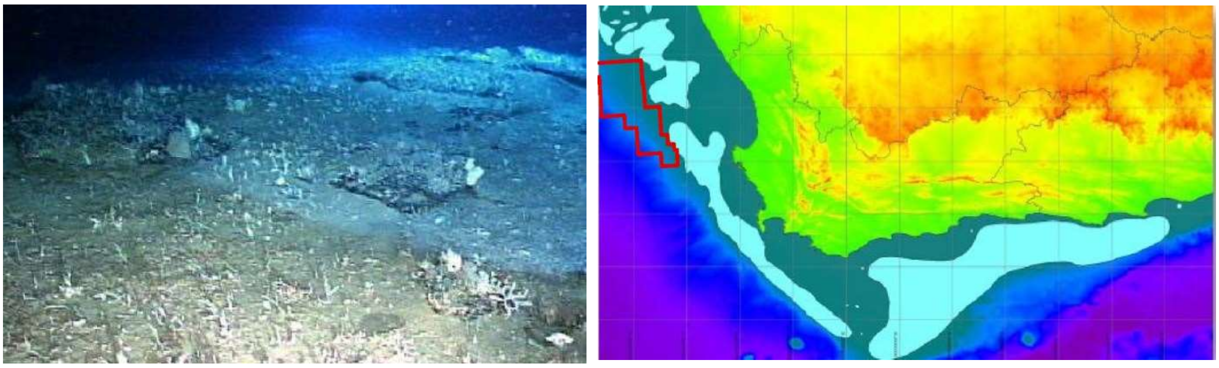

Figure 7: Phosphorite hard ground (left) and its distribution (cyan) on the South African continental shelf (right) in relation to Block 3B/4B (red polygon) (adapted from Morant 2013).

During repeated sea level changes, the phosphate-rich rocks were extensively re-worked, eroding the hard capping pavements thereby liberating the heavy phosphate-bearing minerals (mainly glauconite and apatite) and concentrating them in the overlying unconsolidated sediments. Migrating zones of deposition and erosion occurred during repeated transgressive/regressive cycles. Renewed carbonate deposition and a further period of phosphatization occurred when the deposition zones migrated back across the shelf in response to a rising sea level, thereby incorporating boulders and cobbles of phosphatized limestone and glauconite left behind after the previous regressive cycle into the second-generation phosphatic deposits, forming conglomeratic rock types. Two main periods of phosphatization have been identified, namely the Middle Miocene (ca 15 million years ago), and possibly the Upper Eocene (ca 37 million years ago) (Birch 1990; Morant 2013).

The phosphate-bearing lithologies comprise three non-conglomeratic and two conglomeratic rock types. The non-conglomeratic types are phosphatized foraminiferal lime packstones (a type of limestone), which are either poor in glauconite and quartz, rich in goethite, or highly glauconitic. The first conglomeratic type is also rich in glauconite, but contains pebble inclusions of phosphatized foraminiferal limestone. The second conglomeratic type is distinguished by its low glauconite content and high macrofossil and goethite abundance. The depth of mineralization within the conglomeratic ores is typically restricted to the upper few metres of sediment. The phosphate-rich rocks on the Agulhas Bank are estimated to have an average P_2O_5 content of 16.2%. With an area of 35 000 million m^2, an average thickness of 0.5 m, the Agulhas Bank offshore phosphate deposits are estimated to contain in the order of 5 000 million tons of P_2O_5 (Birch 1990).

Block 3B/4B and the Area of Interest for drilling lies offshore of the known phosphate-bearing hard grounds, and drilling operations and associated drill cuttings discharges should not affect these areas.

3.2 Biophysical Characteristics

3.2.1 Wind Patterns

Winds are one of the main physical drivers of the nearshore 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 which 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-pressures system, and the associated series of cold fronts, moves northwards in winter, and southwards in summer. The strongest winds occur in summer (October to March), during which winds blow 98% of the time (PRDW 2013), with a total of 226 gales (winds exceeding 18 m/s or 35 kts) being recorded over the period (CSIR 2006). Virtually all winds in summer come from the south to south-southeast (Figure 8). These southerlies occur over 40% of the time, averaging 20 – 30 kts and reaching speeds in excess of 60 kts, bringing cool, moist air into the coastal region and driving 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.

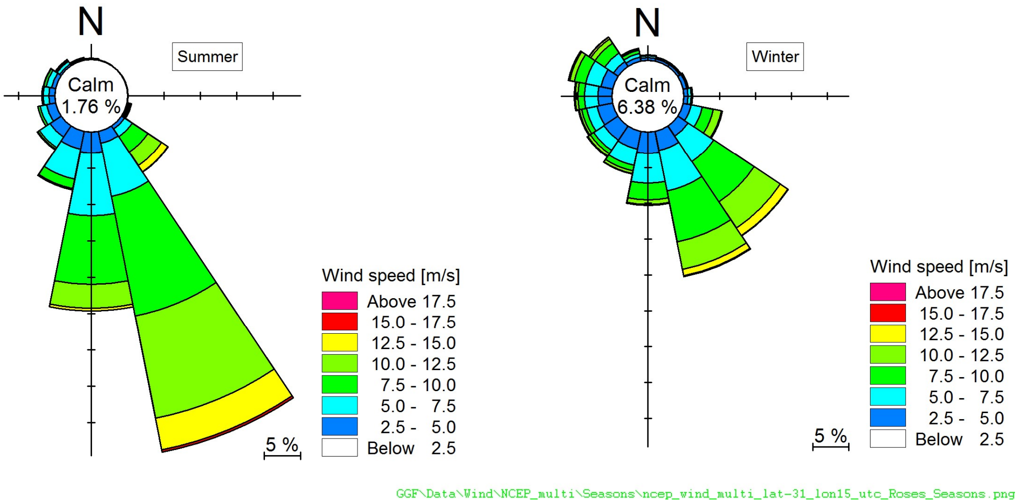

Figure 8: Wind Speed vs. Wind Direction for NCEP hind cast data at location 15°E, 31°S (From PRDW 2013).

Winter remains dominated by southerly to south-easterly winds, but the closer proximity of the winter cold-front systems results in a significant south-westerly to north-westerly component (Figure 8). 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 westerly winds blow in synchrony with the prevailing south-westerly swell direction, resulting in heavier swell conditions in winter.

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).

3.2.2 Large-Scale Circulation and Coastal Currents

The southern African West Coast is strongly influenced by the Benguela Current. Current velocities in continental shelf areas generally range between 10–30 cm/s (Boyd & Oberholster 1994), although localised flows in excess of 50 cm/s occur associated with eddies (PRDW 2013). On its western side, flow is more transient and characterised by large eddies shed from the retroflection of the Agulhas Current. This results in considerable variation in current speed and direction over the domain (PRDW 2013). In the south the Benguela current has a width of 200 km, widening rapidly northwards to 750 km. The surface flows are predominantly wind-forced, barotropic and fluctuate between poleward and equatorward flow (Shillington *et al*. 1990; Nelson & Hutchings 1983) (Figure 10b). Fluctuation periods of these flows are 3 - 10 days, although the long-term mean current residual is in an approximate northwest (alongshore) direction. Current speeds decrease with depth, while directions rotate from predominantly north-westerly at the surface to south-easterly near the seabed. Near bottom shelf flow is mainly poleward with low velocities of typically <5 cm/s (Nelson 1989; PRDW 2013). The poleward flow becomes more consistent in the southern Benguela.

Figure 9: Block 3B/4B (red polygon) in relation to aerosol plumes of sand and dust due to a 'berg' wind event on the southern African west coast in October 2019 (Image Source: LandWaterSA).

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. There are three upwelling centres in the southern Benguela, namely the Namaqua (30°S), Cape Columbine (33°S) and Cape Point (34°S) upwelling cells (Taunton-Clark 1985) (Figure 10a). Upwelling in these cells is seasonal, with maximum upwelling occurring between September and March. The licence area is located well offshore of these upwelling events and should therefore not be influenced by upwelling related processes.

Where the Agulhas Current passes the southern tip of the Agulhas Bank (Agulhas Retroflection area), it may shed a filament of warm surface water that moves north-westward along the shelf edge towards Cape Point, and Agulhas Rings, which similarly move north-westwards into the South Atlantic Ocean (Figure 10). These rings may extend to the seafloor and west of Cape Town may split, disperse or join with other rings. During the process of ring formation, intrusions of cold subantarctic water moves into the South Atlantic. The contrast in warm (nutrient-poor) and cold (nutrient-rich) water is thought to be reflected in the presence of cetaceans and large migratory pelagic fish species (Best 2007). The licence area lies offshore of 15°E on the outer edge of these features.

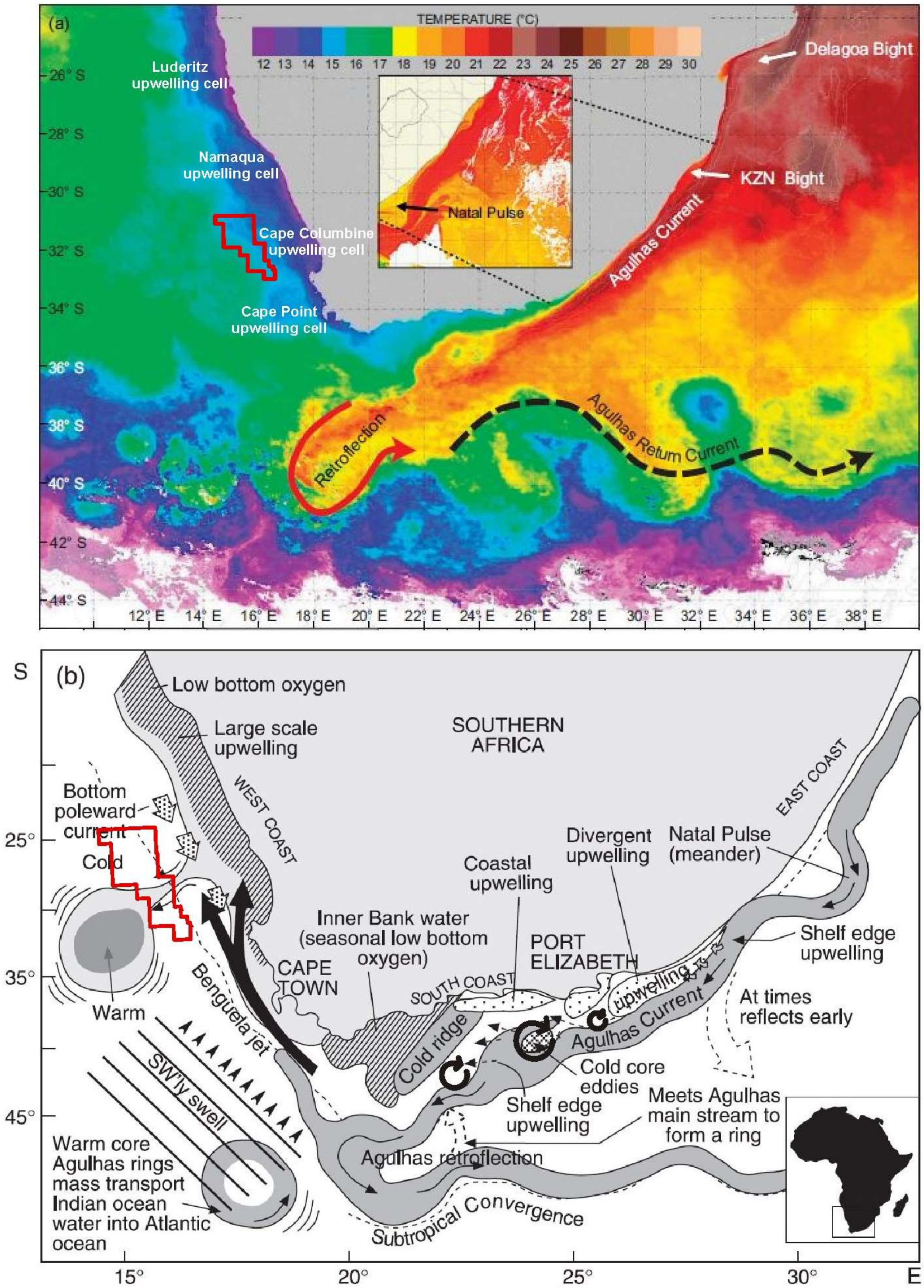

Figure 10: (a) Satellite sea-surface temperature image showing the predominance of the warm Agulhas Current along the South African south coast and the colder upwelled water on the west coast (adapted from Roberts *et al*. 2010), and (b) physical processes and features associated with the Southwest Coast (adapted from Roberts 2005) in relation to Block 3B/4B (red polygon).

3.2.3 Waves and Tides

Most of the west coast of southern Africa is classified as exposed, experiencing strong wave action, rating between 13-17 on the 20 point exposure scale (McLachlan 1980). Much of the coastline is therefore impacted by heavy south-westerly swells generated in the roaring forties, as well as significant sea waves generated locally by the prevailing moderate to strong southerly winds characteristic of the region (Figure 11). The peak wave energy periods fall in the range 9.7 – 15.5 seconds.

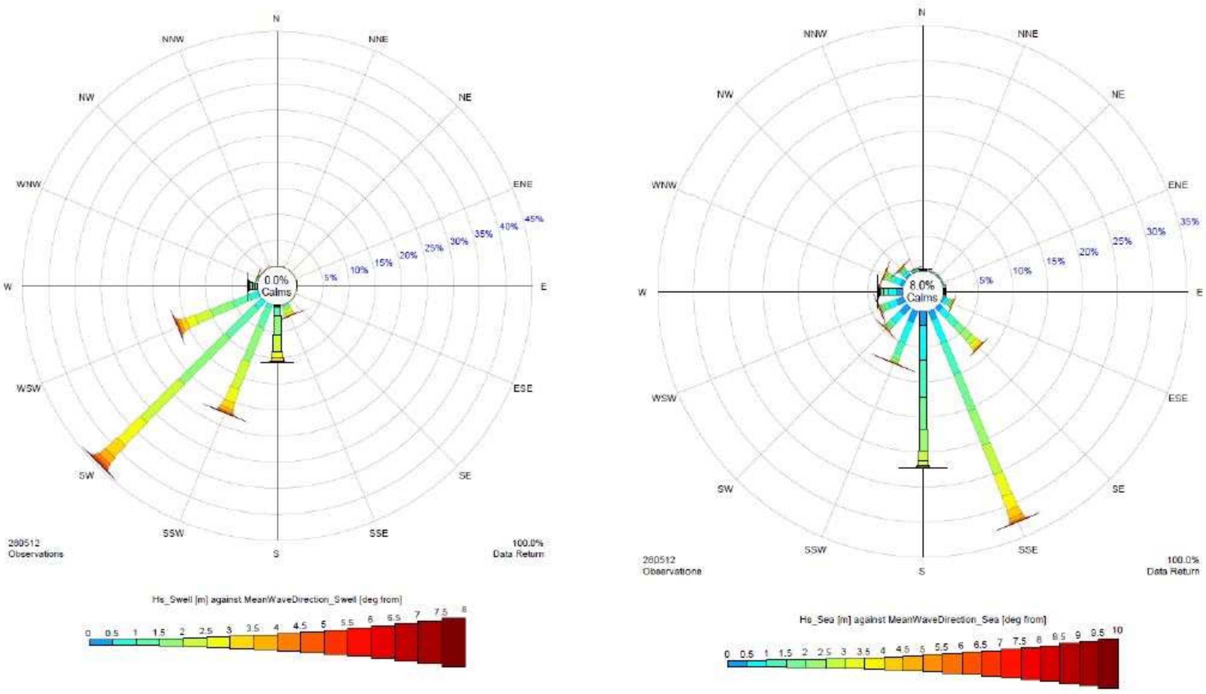

Figure 11: Annual roseplots of significant wave height partitions of swell (left) and wind-sea (right) for GROW1012 hind cast data at location 15°E, 31°S.

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 S and SSW direction. Winter swells are strongly dominated by those from the S and SSW, which occur almost 80% of the time, and typically exceed 2 m in height, averaging about 3 m, and often attaining over 5 m. With wind speeds capable of reaching 100 km/h during heavy winter south-westerly storms, winter swell heights can exceed 10 m.

In comparison, summer swells tend to be smaller on average, typically around 2 m, not reaching the maximum swell heights of winter. There is also a slightly 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.

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.

3.2.4 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 temperatures on the continental shelf of the southern Benguela typically vary between 6°C and 16°C. Well-developed thermal fronts 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. South and east of Cape Agulhas, the Agulhas retroflection area is a global "hot spot" in terms of temperature variability and water movements.

The continental shelf waters of the Benguela system are characterised by low oxygen concentrations, especially on the bottom. SACW itself has depressed oxygen concentrations (oligoxic: ~80% saturation value), but lower oxygen concentrations (<40% saturation) and hypoxia (<20% saturation) frequently occur (Bailey *et al*. 1985; Chapman & Shannon 1985; Montiero & van der Plas 2006; Montiero *et al*. 2006).

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.

3.2.5 Upwelling & Plankton Production

The cold, upwelled water is rich in inorganic nutrients, the major contributors being various forms of nitrates, phosphates and silicates (Chapman & Shannon 1985). During upwelling the comparatively nutrient-poor surface waters are displaced by enriched deep water, supporting substantial seasonal 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 (jackass 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. Block 3B/4B is located well offshore (>100 km) of these upwelling events and waters are expected to be comparatively warm and nutrient poor (see Figure 10).

3.2.6 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 (jackass penguins, cormorants, pelicans, 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. Block 3B/4B lies offshore of the zone of influence of upwelling-induced low-oxygen concentrations through remineralisation of linked phytoplankton productivity.

An associated phenomenon ubiquitous in the Benguela system is red tides (dinoflagellate and/or ciliate blooms) (see Shannon & Pillar 1985; Pitcher 1998; Pitcher & Calder 2000). Also referred to as Harmful Algal Blooms (HABs), these red tides can reach very large proportions, extending over several square kilometres of ocean (Figure 12, left). 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 (Figure 12, right). HABs, being associated primarily with upwelling cells, are unlikely to occur within Block 3B/4B, but may occur inshore of the block.

Figure 12: Red tides can reach very large proportions (Left, Photo: www.e-education.psu.edu) and can lead to mass stranding, or 'walk-out' of rock lobsters, such as occurred at Elands Bay in March 2022 (Right, Photo: Henk Kruger/African News Agency).

3.2.7 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 5), there are corresponding preferential areas for the formation of oxygen-poor water. The two main areas of low-oxygen water formation in the southern Benguela region are in the Orange River Bight and St Helena 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 the occurrence of low oxygen water off Lambert's Bay is seasonal, with highest development in summer/autumn. Bailey & Chapman (1991), on the other hand, demonstrated that in the St Helena Bay area 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 phytoplankton 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 are 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.

3.2.8 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 Namaqualand, the PIM loading in nearshore waters is strongly related to natural inputs from the Orange River or from 'berg' wind events. Although highly variable, annual discharge rates of sediments by the Orange River is estimated to vary from 8 - 26 million tons/yr (Rogers 1979). '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). For example, a 'berg' wind event in May 1979 described by Shannon and Anderson (1982) was estimated to have transported in the order of 50 million tons of sand out to sea, affecting an area of 20 000 km^2.

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 vicinity of the Orange River mouth, where river outflow strongly influences the turbidity of coastal waters, measured concentrations ranged from 14.3 mg/l at Alexander Bay just south of the mouth (Zoutendyk 1995) to peak values of 7 400 mg/l immediately upstream of the river mouth during the 1988 Orange River flood (Bremner *et al.* 1990).

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 typical of those depths, and re-suspension and shoreward movement of these by wave-induced currents occur primarily under storm conditions (see also Drake *et al.* 1985; Ward 1985). Data from a Waverider buoy at Port Nolloth have indicated that 2-m waves are capable of re-suspending medium sands (200 μm diameter) at ~10 m depth, whilst 6-m waves achieve this at ~42 m depth. Low-amplitude, long-period waves will, however, penetrate even deeper. Most of the sediment shallower than 90 m can therefore be subject to re-suspension and transport by heavy swells (Lane & Carter 1999).

Offshore of the continental shelf, the oceanic waters are typically clear as they are beyond the influence of aeolian and riverine inputs. The waters in Block 3B/4B are thus expected to be comparatively clear.

3.2.9 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). No oil seep anomalies have been reported off the West Coast.

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). Within this bioregion, Block 3B/4B falls primarily into the Southwest Atlantic Deep Ocean Ecoregion (Sink *et al*. 2019) (Figure 13). The coastal, wind-induced upwelling characterising the Western Cape coastline, is the principle physical process which shapes the marine ecology of the southern 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.

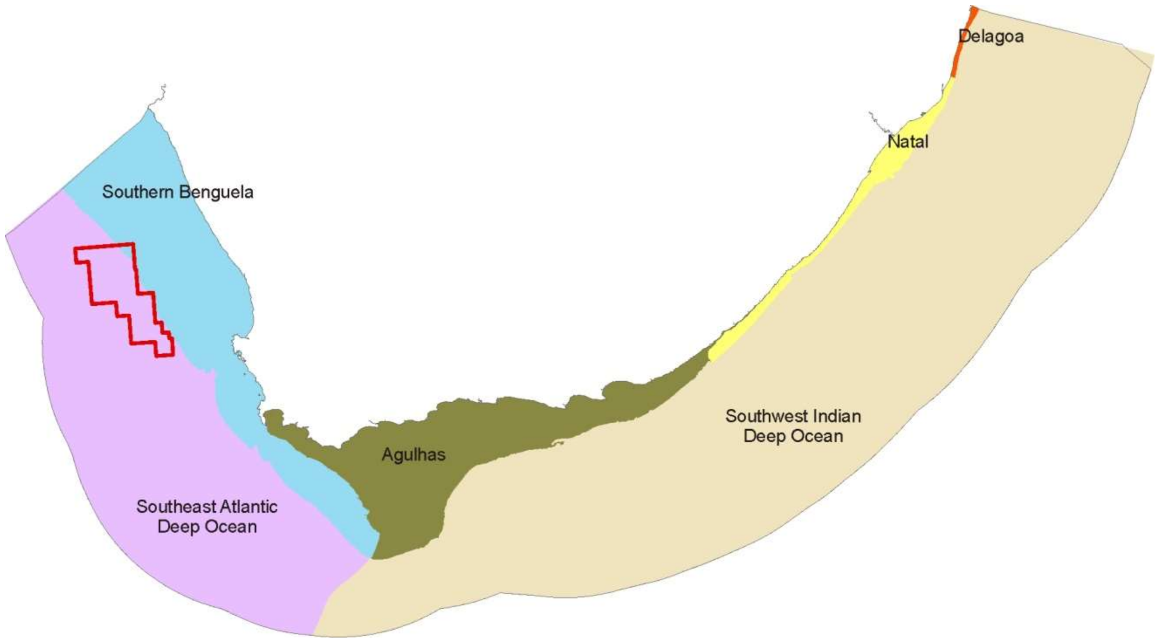

Figure 13: Block 3B/4B (red polygon) in relation to the inshore and offshore ecoregions of the South African coast (adapted from Sink *et al*. 2019).

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). The offshore marine ecosystems comprise a limited range of habitats, namely unconsolidated seabed sediments, deepwater reefs 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 activities.

3.3.1 Demersal Communities

3.3.1.1 Benthic Invertebrate Macrofauna

The seabed communities in the Deep Water Orange Basin area lie within the Namaqua sub-photic and continental slope biozones, which extend from 30 m depth to the shelf edge, and beyond to the lower deepsea slope, respectively. The benthic habitats of South Africa were mapped as part of the 2018 National Biodiversity Assessment (Sink *et al*. 2019) to develop assessments of the ecosystem threat status and ecosystem protection level. The benthic ecosystem types were subsequently mapped

(Figure 14) and assigned an ecosystem threat status based on their level of protection (Figure 15). The Licence Area is characterised by a limited variety of ecosystem types, with the majority of Block 3B/4B characterised by Southeast Atlantic Lower-, Mid- and Upper Slope habitats, with some representation in the northeastern corner by Southern Benguela Sandy Shelf Edge and Shelf Edge Mosaic Abyss habitats.

The Area of Interest for drilling coincides with three ecosystem types, namely:

- Southeast Atlantic Lower Slope - Unknown seabed type on the lower slope of Southeast Atlantic with a depth range of -1 800 m to -3 500 m.
- Southeast Atlantic Mid Slope - Unknown seabed type on the mid slope in the Southeast Atlantic ecoregion spanning depths of -1 000 m to -1 800 m.
- Southeast Atlantic Upper Slope - Unknown seabed type and associated water column on the upper slope (-500 m to -1 000 m) in the Southeast Atlantic ecoregion.

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 1998; Pulfrich & Penney 1999; Goosen *et al.* 2000; Savage *et al.* 2001; Steffani & Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b; Atkinson 2009; Steffani 2009a, 2009b, 2010a, 2010b, 2010c; Atkinson *et al.* 2011; Steffani 2012a, 2012b, 2014; Karenyi 2014; Steffani *et al.* 2015; Biccard & Clark 2016; Biccard *et al.* 2016; Duna *et al.* 2016; Karenyi *et al.* 2016; Biccard *et al.* 2017, 2018; Gihwala *et al.* 2018; Biccard *et al.*2019; Giwhala *et al.* 2019). These studies, however, concentrated on the continental shelf and nearshore regions, and consequently the benthic fauna of the outer shelf and continental slope (beyond ~450 m depth) are very poorly known. This is primarily due to limited opportunities for sampling as well as the lack of access to Remote Operated Vehicles (ROVs) for visual sampling of hard substrata.

To date very few areas on the continental slope off the West Coast have been biologically surveyed (Sink *et al.* 2019; Harris *et al.* 2022). Although sediment distribution studies (Rogers & Bremner 1991) suggest that the outer shelf is characterised by unconsolidated sediments (see Figure 5), surveys conducted between 180 m and 480 m depth offshore of the Northern Cape coast revealed high proportions of hard ground rather than unconsolidated sediment, although this requires further verification (Karenyi unpublished data).

There have also to date been no studies examining connectivity between slope, plateau or abyssal ecosystems in South Africa and there is thus limited knowledge on the benthic biodiversity of all three of these broad ecosystem groups in South African waters (Sink *et al.* 2019). There is no quantitative data describing bathyal ecosystems in South Africa and hence limited understanding of ecosystem functioning and sensitivity (Anderson & Hulley 2000; Harris *et al.* 2022). Due to the lack of information on benthic macrofaunal communities beyond the shelf break, no description can be provided specifically for the Licence Area. The description below for areas on the continental shelf, offshore of the Northern Cape coast is drawn from recent surveys by Karenyi (2014), Duna *et al.* (2016), Mostert *et al.* (2016), and Giwhala *et al.* (2018, 2019).

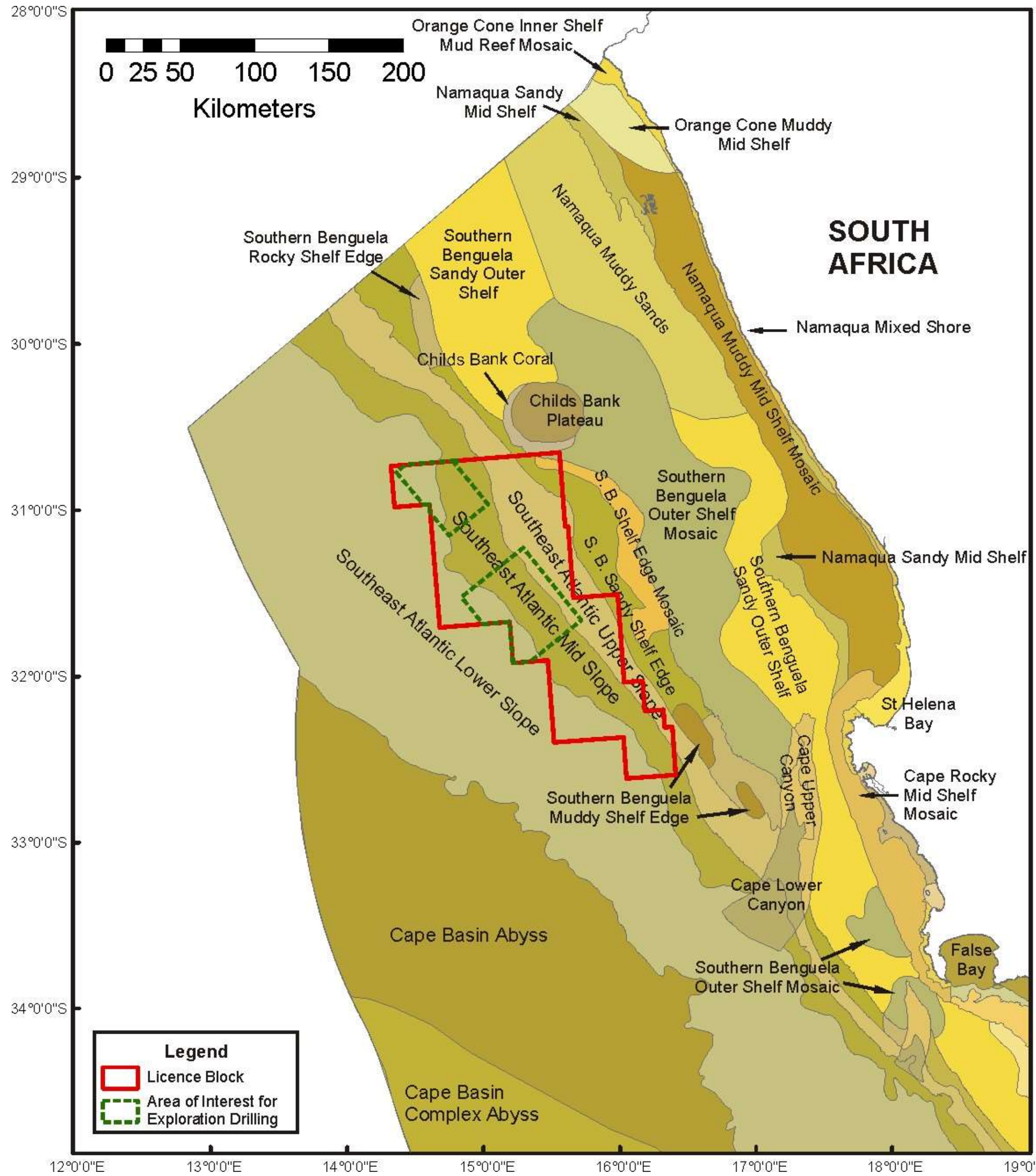

Figure 14: Block 3B/4B (red polygon) in relation to the distribution of ecosystem types along the West Coast (adapted gfrom Sink *et al*. 2019).

Three macro-infauna communities have been identified on the inner- (0-30 m depth) and mid-shelf (30-150 m depth, Karenyi *et al*. 2016). Polychaetes, crustaceans and molluscs make up the largest proportion of individuals, biomass and species on the west coast. The inner-shelf community, which is affected by wave action, is characterised by various mobile gastropod and polychaete predators and sedentary polychaetes and isopods. The mid-shelf community inhabits the mudbelt and is characterised by mud prawns. A second mid-shelf community occurring in sandy sediments is characterised by various deposit-feeding polychaetes. 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 2004).

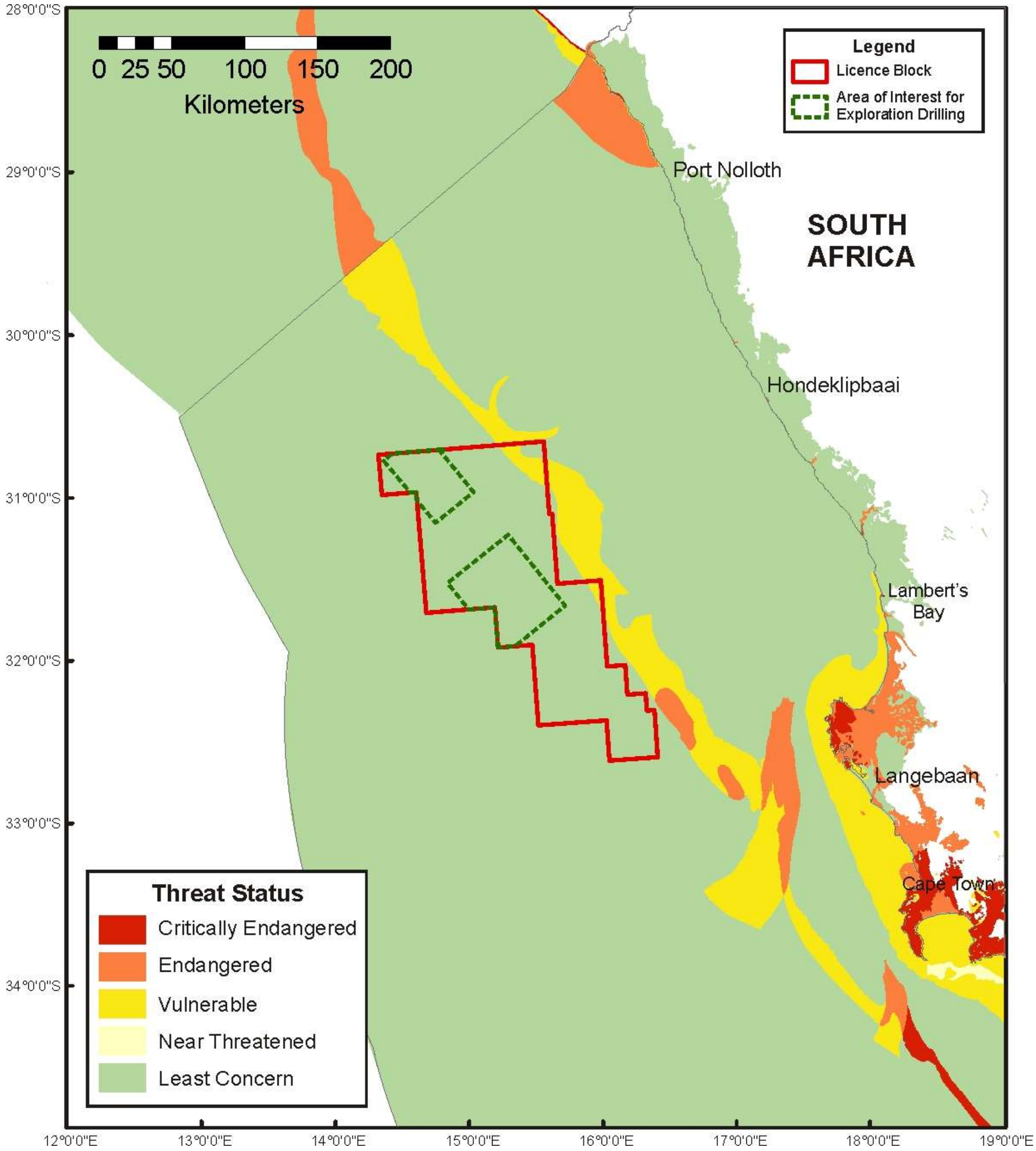

Figure 15: Block 3B/4B (red polygon) in relation to the ecosystem threat status for coastal and offshore benthic and pelagic habitat types on the South African West Coast (adapted from Sink *et al*. 2019). The adjacent Namibian threat status (adapted fom Holness *et al*. 2019) is also shown.

Despite the current lack of knowledge of the community structure and endemicity of South African macro-infauna off the edge of the continental shelf, the marine component of the 2018 National Biodiversity Assessment (Sink *et al*. 2019), rated the South Atlantic bathyal and abyssal unconsolidated habitat types that characterise depths beyond 500 m, as being of 'Least Concern' (Figure 15), with only those communities occurring along the shelf edge (-500 m) in the eastern portions of Block 3B/4B being considered 'Vulnerable'. This primarily reflects the great extent of these habitats in the South African Exclusive Economic Zone (EEZ).

Karenyi *et al.* (2016) found that off Namaqualand, species richness increases from the inner-shelf across the mid-shelf and is influenced by sediment type. 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 decreases across the mid-shelf averaging around 30 g/m^2 wet weight. This is contrary to Christie (1974) who found that biomass was greatest in the mudbelt at 80 m depth off Lamberts Bay, where the sediment characteristics and the impact of environmental stressors (such as low oxygen events) are likely to differ from those off the northern Namaqualand coast.

Benthic communities are structured by the complex interplay of a large array of environmental factors. Water depth and sediment grain size are considered the two major factors that determine benthic community structure and distribution on the South African west coast (Christie 1974, 1976; Steffani & Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b) and elsewhere in the world (e.g. Gray 1981; Ellingsen 2002; Bergen *et al.* 2001; Post *et al.* 2006). However, studies have shown that bed shear stress - a measure of the impact of current velocity on sediment – oxygen concentration (Post *et al.* 2006; Currie *et al.* 2009; Zettler *et al.* 2009, 2013), productivity (Escaravage *et al.* 2009), organic carbon and seafloor temperature (Day *et al.* 1971) may also strongly influence the structure of benthic communities. There are clearly other natural processes operating in the continental shelf areas of the West Coast that can over-ride the primacy of sediments in determining benthic community structure, and 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). In areas of frequent oxygen deficiency, benthic communities will be characterised either by species able to survive chronic low oxygen conditions, or colonising and fast-growing species able to rapidly recruit into areas that have suffered oxygen depletion. The combination of local, episodic hydrodynamic conditions and patchy settlement of larvae will tend to generate the observed small-scale variability in benthic community structure. On the continental shelf slope and deeper areas, near-bottom conditions are oligoxic (Berg *et al.* 2015), with benthic communities characterised by greater stablility and longer-lived species.

The invertebrate macrofauna are important in the marine benthic environment as they influence major ecological processes (e.g. remineralisation and flux of organic matter deposited on the sea floor, organic pollutant metabolism, sediment stability) and serve as important food source for commercially valuable fish species and other higher order consumers. As a result of their comparatively limited mobility and permanence over seasons, these animals provide an indication of historical environmental conditions and provide useful indices with which to measure environmental impacts (Gray 1974; Warwick 1993; Salas *et al.* 2006).

Also associated with soft-bottom substrates are demersal communities that comprise epifauna and bottom-dwelling vertebrate species, many of which are dependent on the invertebrate benthic macrofauna as a food source. According to Lange (2012) the continental shelf on the West Coast between depths of 100 m and 250 m, contained a single epifaunal community characterised by the hermit crabs *Sympagurus dimorphus* and *Parapaguris pilosimanus*, the prawn *Funchalia woodwardi* and the sea urchin *Brisaster capensis*. Atkinson (2009) also reported numerous species of urchins and burrowing anemones beyond 300 m depth off the West Coast. Unconsolidated sediments beyond 2 000 m depth host a variety of sea pens, sea whips, holothurians, brittle stars and cushion stars, sea urchins, burrowing anemones, crustaceans (shrips, crabs), larvaceans and cepahlopods (TEEPSA, unpublished data).

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. However, deep water benthic sampling was undertaken (Benthic Solutions Ltd 2019) as part of the Environmental Baseline Survey for Total E&P Namibia's Block 2913B to the north of Block 3B/4B. This provided valuable information on the benthic infaunal communities of the lower continental slope. As conditions in such deep water habitats tend to be more uniform (low temperatures and oligoxic conditions characterising the SACW that comprises the bulk of the water in the area), similar communities may be expected in Block 3B/4B.

The macrofauna in Block 2913B were 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 Namibian Block 2913B area located ~135 km to the west-northwest of Block 3B/4B are illustrated in Figure 16. A wide diversity of macroinvertebrates has been recorded inshore of the 1 000 m depth contour, and the reader is referred to the comprehensive field guide compiled by Atkinson & Sink (2018).

The 2018 National Biodiversity Assessment for the marine environment (Sink *et al*. 2019) points out that very few national IUCN Red List assessments have been conducted for marine invertebrate species to date owing to inadequate taxonomic knowledge, limited distribution data, a lack of systematic surveys and limited capacity to advance species red listing for these groups.

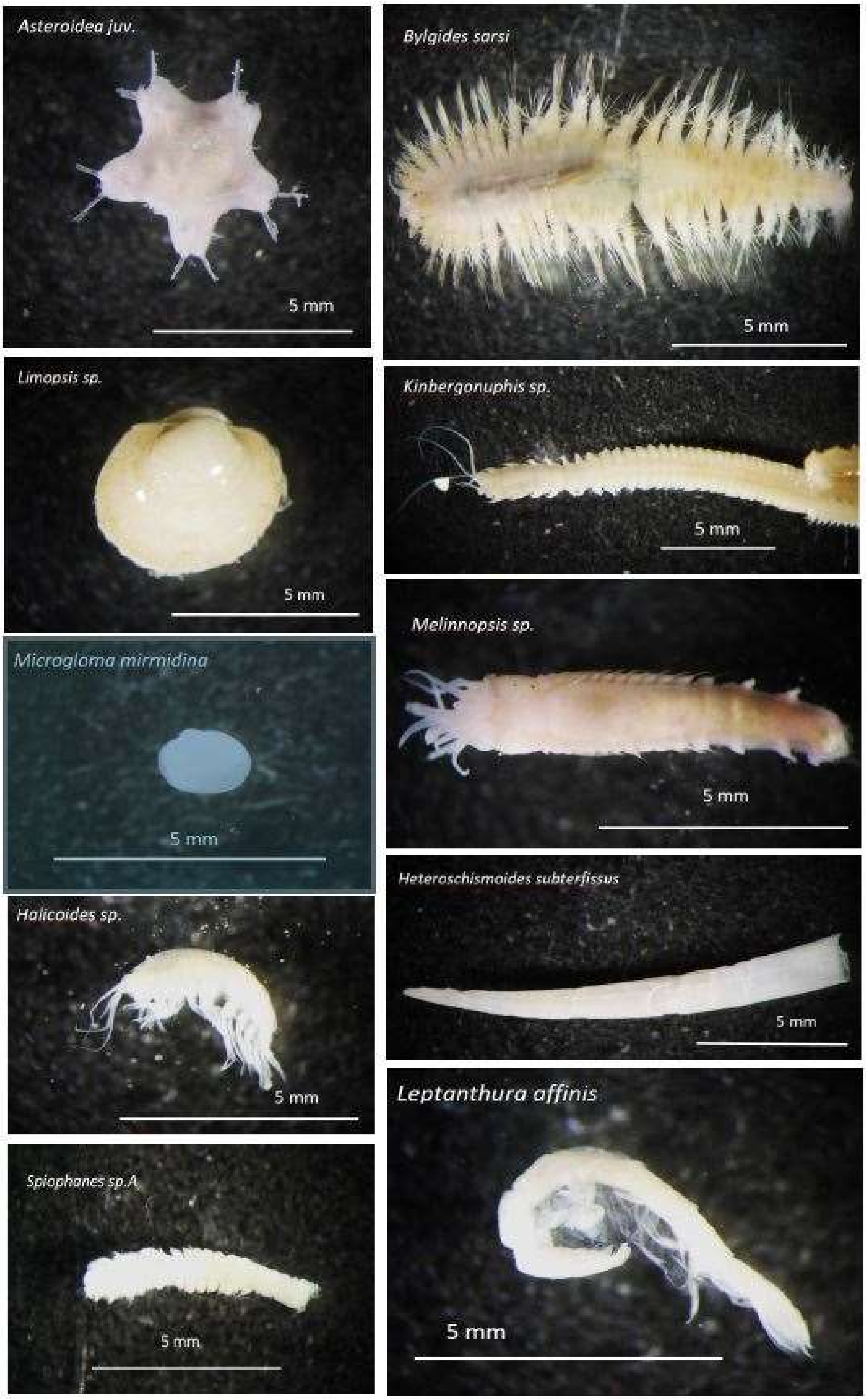

Figure 16: Examples of macroinvertebrates recorded in Block 2913B to the west-northwest of Block 3B/4B (Source Benthic Solutions Ltd 2019).

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 below 150 m with some species being recorded from as deep as 3 000 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). In the productive Benguela region, substantial areas on and off the edge of the shelf should thus potentially be capable of supporting rich, cold water, benthic, filter-feeding communities, and various species of scleractine and stylastrine corals have been reported from depths beyond -200 m in the Orange Basin.

Such communities would also be expected with topographic features such as seamounts located adjacent to the northern boundary of Block 3B/4B (see Figure 1). Nonetheless, our understanding of the invertebrate fauna of the sub-photic zone is relatively poor (Gibbons *et al.* 1999) and the conservation status of the majority of invertebrates in this bioregion is not known.

3.3.1.3 Demersal Fish Species

Demersal fish are those species that live and feed on or near the seabed. As many as 110 species of bony and cartilaginous fish have been identified in the demersal communities on the continental shelf of the West Coast (Roel 1987). Changes in fish communities occur both latitudinally (Shine 2006, 2008; Yemane *et al.* 2015) and with increasing depth (Roel 1987; Smale *et al.* 1993; Macpherson & Gordoa 1992; Bianchi *et al.* 2001; Atkinson 2009; Yemane *et al.* 2015), 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). The shelf community (<380 m) is dominated by the Cape hake *M. capensis*, and includes jacopever *Helicolenus dactylopterus*, Izak catshark *Holohalaelurus regain*, soupfin shark *Galeorhinus galeus* and whitespotted houndshark *Mustelus palumbes*. The more diverse deeper water community is dominated by the deepwater hake *Merluccius paradoxus*, monkfish *Lophius vomerinus*, kingklip *Genypterus capensis*, bronze whiptail *Lucigadus ori* and hairy conger *Bassanago albescens* and various squalid shark species. There is some degree of species overlap between the depth zones.

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 north of Cape Point 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.* 2008).

The diversity and distribution of demersal cartilagenous fishes on the West Coast is discussed by Compagno *et al*. (1991). The species that may occur in the general project area and on the continental shelf inshore thereof, and their approximate depth range, are listed in

Table 2. Details on demersal cartilaginous species beyond the shelf break and in the Deep Water Orange Basin area are lacking, however. The shelf-associated[2] distribution of some of these species was provided in Harris *et al*. (2022) (Figure 17a, 17b).

There is limited information about bathyal fish communities in South Africa. South Africa defines its bathyal zone as extending from 500 m to 3 500 m, recognising an upper slope (500-1 000 m), mid slope (1 000-1 800 m) and lower slope (1 800-3 500 m). Typical upper slope fishes include rattails (Macrouridae), tripod and grideyefish (Ipnopidae), greeneyes (*Chlorophthalmus* species), oreos, notacanthids, halosaurs, chimaeras, skates, bythitids such as *Cataetyx* spp. and morids (deepsea cods) (Smith & Heemstra 2003). Rattails, bythitids, liparidids (snail fishes) and notacanthids (*Polyacanthonotus* species and halosaurs) are characteristic of the lower bathyal (see also Iwamoto & Anderson 1994; Jones 2014).

Table 2: Demersal cartilaginous species found on the continental shelf along the West Coast, with approximate depth range at which the species occurs (Compagno *et al*. 1991) and their IUCN conservation status. The National Assessment is provided in parentheses where available.

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

[2] The distributions provided by Harris *et al*. (2022) are based on data from demersal fisheries. The apparent absence of fish offshore is thus due to a lack of survey data rather than an indication that no species occur there.

Common Name	Scientific name	Depth Range (m)	IUCN Conservation Status
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
Tigar 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 (EN)
Houndshark	*Mustelus mustelus*	<100	EN (DD)
Whitespotted houndshark	*Mustelus palumbes*	>350	LC
Little guitarfish	*Rhinobatos annulatus*	>100	VU (LC)
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 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
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 (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

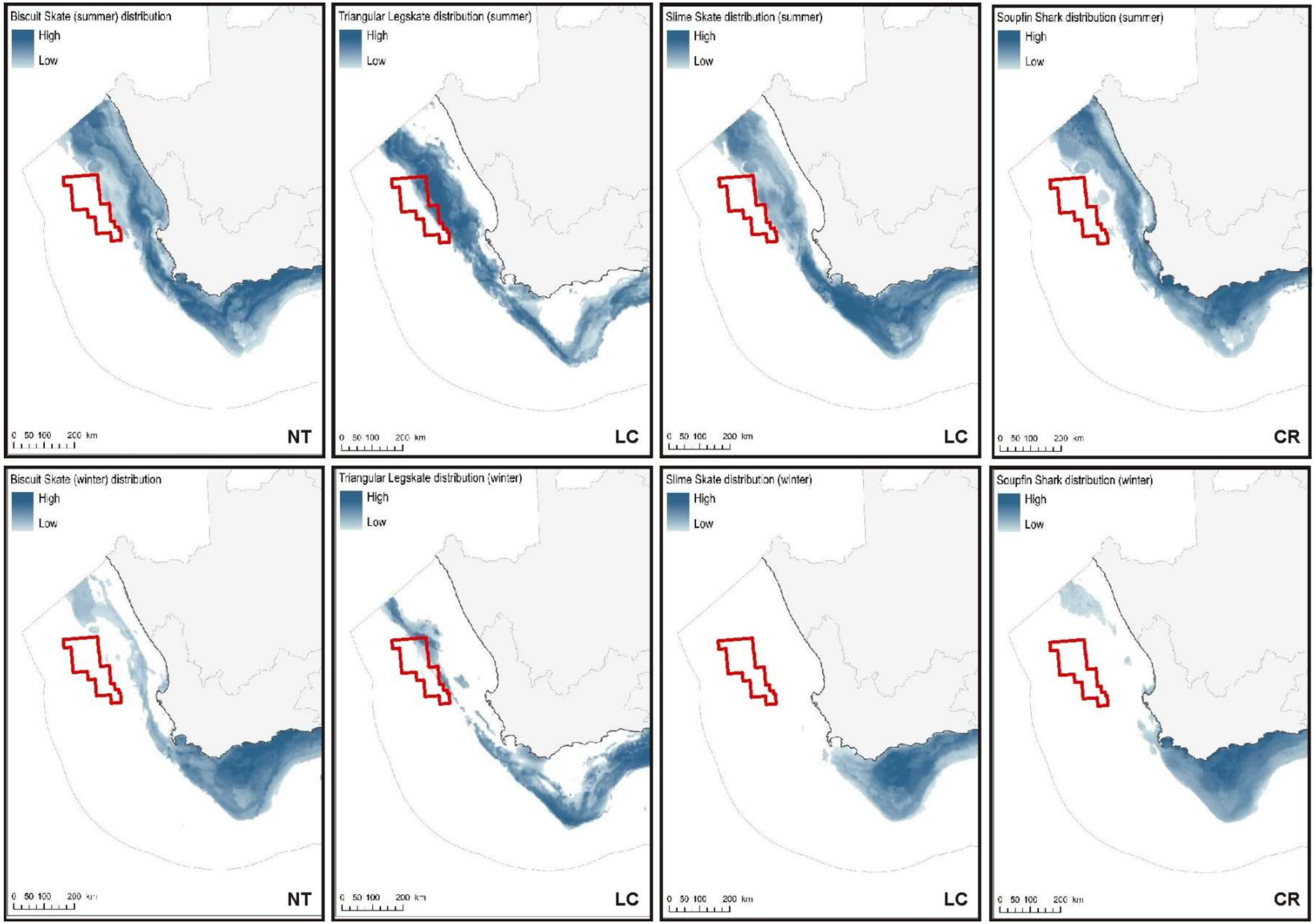

Figure 17a: The summer (top) and winter (bottom) distribution of biscuit skate, triangular legskate, slime skate and soupfin shark in relation to Block 3B/4B (red polygon) (adapted from Harris *et al*. 2022). The IUCN conservation status is provided.

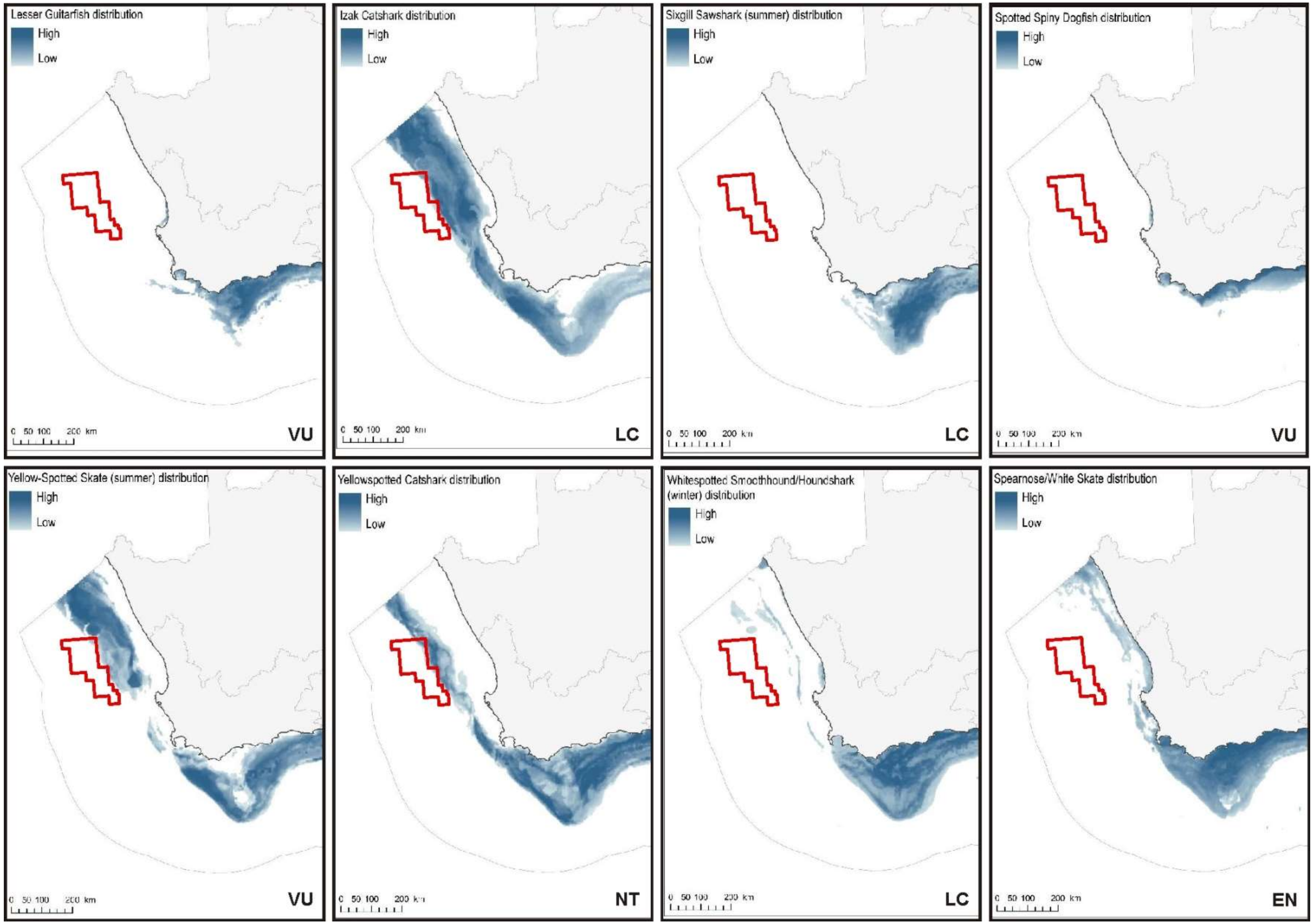

Figure 17b: The distribution of various cartilaginous species mentioned in Table 2 in relation to Block 3B/4B (red polygon) (adapted from Harris *et al*. 2022). The IUCN conservation status is provided.

3.3.2 Seamount and Submarine Canyon 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 influence 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.

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; Derville *et al.* 2020).

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; Kenyon *et al.* 2003). Some of the smaller cnidarians species remain solitary while others form reefs thereby adding structural complexity to otherwise uniform seabed habitats.

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). As a result of conservative life histories (*i.e.* very slow growing, slow to mature, high longevity, low fecundity and unpredictable 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).

Geological features of note within the broader project area are Child's Bank and Tripp Seamount, with an unnamed seamount located in ~3 500 m at ~32°20'S; 13°30'E, as well as the Cape Canyon and Cape Point Valley. Child's Bank, which is situated at about 31°S, was described by Dingle *et al.* (1987) to be a carbonate mound (bioherm). The top of this feature is a sandy plateau with dense aggregations of brittle stars, while the steeper slopes have dense invertebrate assemblages including unidentified cold-water corals/rugged limestone feature, bounded at outer edges by precipitous cliffs at least 150 m high (Birch & Rogers 1973). Composed of sediments and the calcareous deposits from an accumulation of carbonate skeletons of sessile organisms (e.g. cold-water coral, foraminifera or marl), such features typically have topographic relief, forming isolated seabed knolls in otherwise low profile homogenous seabed habitats (Kopaska-Merkel & Haywick 2001; Kenyon *et al*. 2003, Wheeler *et al*. 2005, Colman *et al*. 2005). Tripp Seamount situated at about 29°40'S, lies ~25 km northwest of the area of interest. It rises from the seabed at ~1 000 m to a depth of 150 m and roughly circular with a flat apex that drops steeply on all sides. There is reference to decapod crustaceans from Tripp Seamount (Kensley 1980, 1981) and exploratory deepwater trawl fishing (Hampton 2003), but otherwise knowledge of benthic communities characterising this seamount is lacking.

The Cape Rise comprises a group of NE-SW trending seamounts – the Southeast Atlantic Seamounts - which include Argentina and Protea Seamounts and the recently discovered Mount Marek. These rise up from over -2 500 m depth in the Cape Basin abyss to 700 m deep. Other than a geoscience survey conducted in 1986 using a deep water camera to sample the lower bathyal and abyssal zones, including the seamount flanks, of the Cape Basin (Rogers 1986) no biodiversity surveys are known to have been conducted at Protea and Argentina seamounts. Southern Africa's seamounts and their associated benthic communities have not been sampled by either geologists or biologists (Sink & Samaai 2009) and little is known about the benthic and neritic communities associated with them.

A recent study reporting on the megabenthos and benthopelagic fish on the Southeast Atlantic Seamounts (Bergstad *et al*. 2019) over 250 km to the southeast of the licence area, provides descriptions of the Erica and Schmitt-Ott Seamounts that lie approximately 450 – 500 km southwest of the Argentina Seamount and rise from the surrounding abyss to depths of 770 m and 920 m, respectively. Corals were the most frequent and widespread sessile invertebrate recorded on video transects, dominated by gorgonians whose abundance increased towards the seamount summits. Scleractinian and hydrocorals were also observed as was a diversity of sponges, echinoderms and crustaceans. Fish associated with the seamount included oreo dories, grenadiers and lanternshark. Similar communities might therefore be expected from the seamounts to the west of the licence area.

During 2016-2018 the Department of Environmental Affairs: Oceans and Coast Branch (DEA: O&C) undertook research cruises to explore some of the undocumented areas of seabed off the West Coast, among them the Cape Canyon. Using tow-cameras, benthic grabs and dredges, the biota of the canyon head to -500 m depth were sampled (Figure 18). A diversity of echinoderms, molluscs, and crustaceans were reported to dominate the canyon head, while scavengers such as ophuiroidea and decapoda were prevalent within habitats ranging from sandy areas, to patches of inshore and offshore mud belts. At depths of <100 m inshore of the canyon head, boulder beds hosted gorgonian and stylasterine corals.

The concept of a 'Vulnerable Marine Ecosystem' (VME) centres upon the presence of distinct, diverse benthic assemblages that are limited and fragmented in their spatial extent, and dominated (in terms of biomass and/or spatial cover) by rare, endangered or endemic component species that are physically fragile and vulnerable to damage (or structural/biological alteration) by human activities (Parker *et al*. 2009; Auster *et al*. 2011; Hansen *et al*. 2013).

Figure 18: Deep water benthic macrofauna from various depths in the Cape Canyon (Source: www.environment.gov.za/dearesearchteamreturnfromdeepseaexpedition).

VMEs are known to be associated with higher biodiversity levels and indicator species that add structural complexity, resulting in greater species abundance, richness, biomass and diversity compared to surrounding uniform seabed habitats (Buhl-Mortensen *et al*. 2010; Hogg *et al*. 2010; Barrio Froján *et al*. 2012; Beazley *et al*. 2013, 2015). Compared to the surrounding deep-sea environment, VMEs typically form biological hotspots with a distinct, abundant and diverse fauna, many species of which remain unidentified. Levels of endemism on VMEs are also relatively high compared to the deep sea. 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. The skeletal remains of Scleractinia coral rubble and Hexactinellid poriferans can also represent another important deep-sea habitat, acting to stabilise seafloor sediments allowing for colonisation by distinct infaunal taxa that show elevated abundance and biomass in such localised habitats (Bett & Rice 1992; Raes & Vanreusel 2005; Beazley *et al*. 2013; Ashford *et al*. 2019).

VMEs are also thought to contribute toward the long-term viability of a stock through providing an important source of habitat for commercial species (Pham *et al*. 2015; Ashford *et al*. 2019). They can provide a wide range of ecosystem services ranging from provision of aggregation- and spawning sites to providing shelter from predation and adverse hydrological conditions (Husebø & Nøttestad *et al*. 2002; Krieger & Wing, 2002; Tissot *et al*., 2006; Baillon *et al*. 2012; Pham *et al*. 2015). Indicator taxa for VMEs are also known to provide increased access to food sources, both directly to associated benthic fauna, and indirectly to other pelagic species such as fish and other predators due to the high abundance and biomass of associated fauna (Krieger & Wing, 2002; Husebø & Nøttestad *et al*. 2002; Buhl-Mortensen *et al*, 2010; Hogg *et al*., 2010; Auster *et al*. 2011).

VME frameworks are typically elevated from the seabed, increasing turbulence and raising supply of suspended particles to suspension feeders (Krieger & Wing 2002; Buhl-Mortensen & Mortensen 2005; Buhl-Mortensen *et al*. 2010). Poriferans and cold-water corals have further been shown to provide a strong link between pelagic and benthic food webs (Pile & Young 2006; Cathalot *et al*. 2015). VMEs are increasingly being recognised as providers of important ecosystem services due to associated increased biodiversity and levels of ecosystem functioning (Ashford *et al*. 2019).

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 and to the south-east of Child's Bank (De Beers Marine, unpublished data) (Figure 19), and in 190-527 m depth on Child's Bank (Sink *et al*. 2019) suggest that vulnerable communities including gorgonians, octocorals and reef-building sponges and hard-corals do occur on the continental shelf, some of which are thought to be Vulnerable Marine Ecosystem (VME) indicator species (Table 3). The distribution of 22 potential VME indicator taxa for the South African EEZ was recently mapped, with those from the West Coast listed in Table 3 (Atkinson & Sink 2018; Sink *et al*. 2019).

Figure 19: Gorgonians and bryozoans communities recorded on deep-water reefs (100-120 m) off the southern African West Coast (Photos: De Beers Marine).

Table 3: Table of Potential VME species from the the continental shelf and shelf edge on the West Coast (Atkinson & Sink 2018)

Phylum	Name	Common Name
Porifera	*Suberites dandelenae*	Amorphous solid sponge
	Rossella cf. antarctica	Glass sponge
Cnidaria	*Melithaea* spp.	Colourful sea fan
	Thouarella spp.	Bottlebrush sea fan
Family: Isididae	?	Bamboo coral
	Anthoptilum grandiflorum	Large sea pen*
	Lophelia pertusa	Reef-building cold water coral
	Stylaster spp.	Fine-branching hydrocoral
Bryozoa	*Adeonella* spp.	Sabre bryozoan
	Phidoloporidae spp.	Honeycomb false lace coral
Hemichordata	*Cephalodiscus gilchristi*	Agar animal

As sampling beyond 1 000 m depth has not taken place (Atkinson & Sink 2018) it is not known whether similar communities may be expected in Block 3B/4B. The distribution of known and potential Vulnerable Marine Ecosystem habitat based on potential VME features, DFFE and SAEON trawl survey data, and many visual surveys indicating the presence of indicator taxa were mapped by Harris *et al*. 2022 (Figure 20). Some sites need more research to determine their status. The location of Block 3B/4B is offshore of these known and potential VMEs emphasising the gaps in our knowledge specific to the vulnerability of marine communities of abyssal habitats.

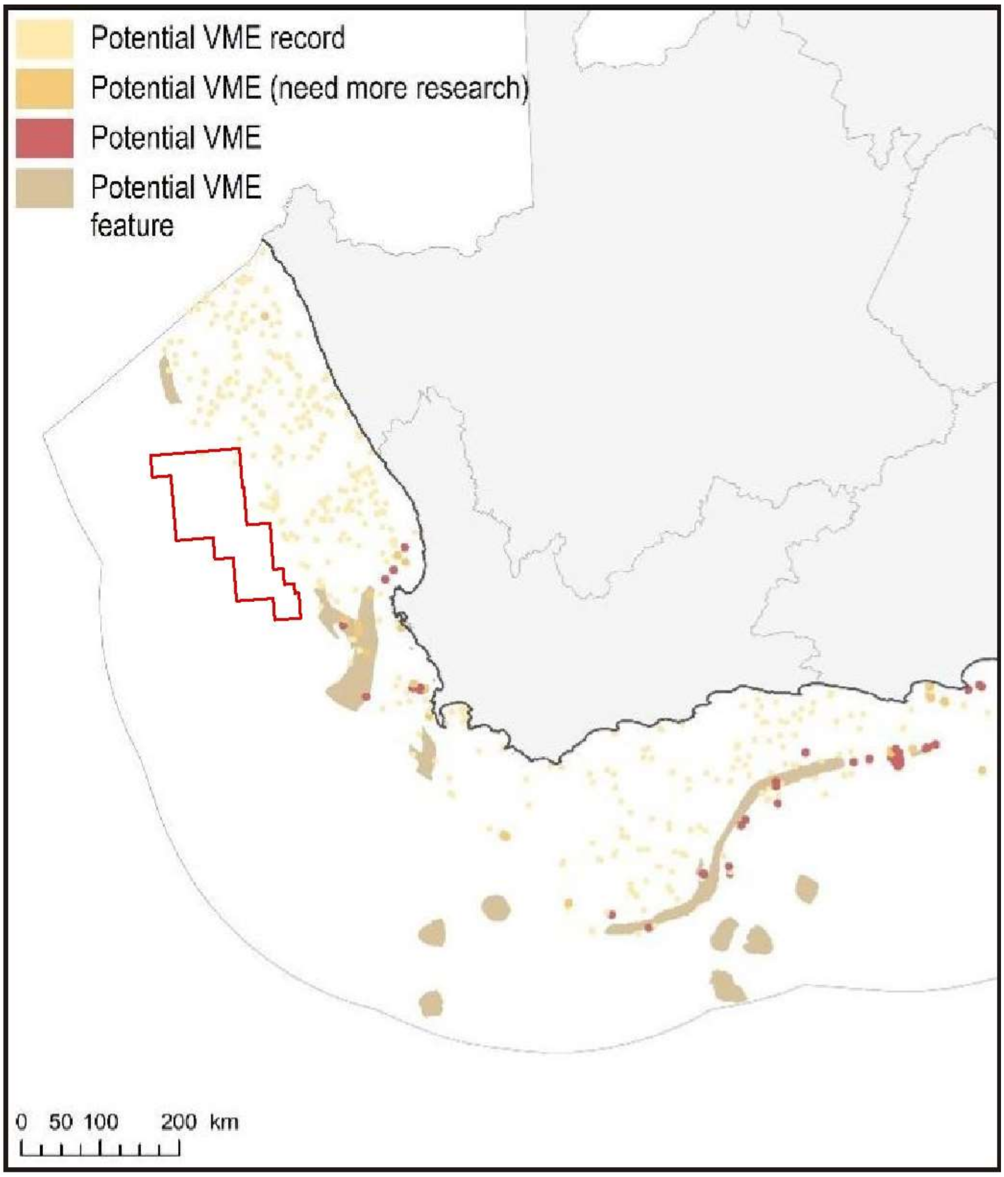

Figure 20: Block 3B/4B (red polygon) in relation to the distribution of known and potential Vulnerable Marine Ecosystem habitat (adapted from Harris *et al*. 2022).

Sediment samples collected at the base of Norwegian cold-water coral reefs revealed high interstitial concentrations of light hydrocarbons (methane, propane, ethane and higher hydrocarbons C4+) (Hovland & Thomsen 1997), which are typically considered indicative of localised light hydrocarbon micro-seepage through the seabed. Bacteria and other micro-organisms thrive on such hydrocarbon pore-water seepages, thereby providing suspension-feeders, including corals and gorgonians, with a substantial nutrient source. Some scientists believe there is a strong correlation between the occurrence of deep-water coral reefs and the relatively high values of light hydrocarbons (methane, ethane, propane and n-butane) in near-surface sediments (Hovland *et al*. 1998, Duncan & Roberts 2001, Hall-Spencer *et al*. 2002, Roberts & Gage 2003). A recent study by January (2018) identified that hydrocarbon seeps and gas escape structures have been identified in the Orange Basin area. Large fluid seep/pockmark fields of varying morphologies were also reported by Palan (2017) to the south of Block 3B/4B.

3.3.3 Pelagic Communities

In contrast to demersal and benthic biota that are associated with the seabed, pelagic species live and feed in the open water column. The pelagic communities are typically divided into plankton and fish, and their main predators, marine mammals (seals, dolphins and whales), seabirds and turtles. These are discussed separately below.

3.3.3.1 Plankton

Plankton is particularly abundant in the shelf waters off the West Coast, 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 21).

Phytoplankton are the principle primary producers with mean productivity ranging from 2.5 - 3.5 g C/m^2/day for the midshelf region and decreasing to 1 g C/m^2/day inshore of 130 m (Shannon & Field 1985; Mitchell-Innes & Walker 1991; Walker & Peterson 1991). The phytoplankton is dominated by large-celled organisms, which are adapted to the turbulent sea conditions. The most common diatom genera are *Chaetoceros*, *Nitschia*, *Thalassiosira*, *Skeletonema*, *Rhizosolenia*, *Coscinodiscus* and *Asterionella* (Shannon & Pillar 1985). Diatom blooms occur after upwelling events, whereas dinoflagellates (e.g. *Prorocentrum*, *Ceratium* and *Peridinium*) 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.

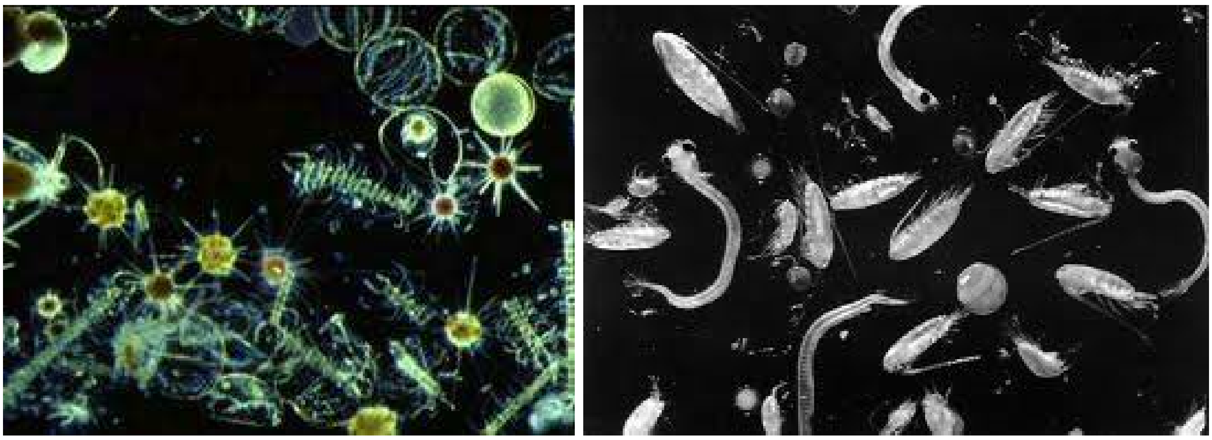

Figure 21: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

Red-tides are ubiquitous features of the Benguela system (see Shannon & Pillar, 1986). The most common species associated with red tides (dinoflagellate and/or ciliate blooms) are *Noctiluca scintillans*, *Gonyaulax tamarensis*, *G. polygramma* and the ciliate *Mesodinium rubrum*. *Gonyaulax* and *Mesodinium* have been linked with toxic red tides. Most of these red-tide events occur quite close inshore although Hutchings *et al.* (1983) have recorded red-tides 30 km offshore. They are unlikely to occur in the offshore regions of Block 3B/4B.

The mesozooplankton (≥200 μm) is dominated by copepods, which are overall the most dominant and diverse group in southern African zooplankton. Important species are *Centropages brachiatus*, *Calanoides carinatus*, *Metridia lucens*, *Nannocalanus minor*, *Clausocalanus arcuicornis*, *Paracalanus parvus*, *P. crassirostris* and *Ctenocalanus vanus*. All of the above species typically occur in the phytoplankton rich upper mixed layer of the water column, with the exception of *M. lucens* which undertakes considerable vertical migration.

The macrozooplankton (≥1 600 μm) are dominated by euphausiids of which 18 species occur in the area. The dominant species occurring in the nearshore are *Euphausia lucens* and *Nyctiphanes capensis*, although neither species appears to survive well in waters seaward of oceanic fronts over the continental shelf (Pillar *et al.* 1991).

Standing stock estimates of mesozooplankton for the southern Benguela area range from 0.2 - 2.0 g C/m^2, with maximum values recorded during upwelling periods. Macrozooplankton biomass ranges from 0.1-1.0 g C/m^2, with production increasing north of Cape Columbine (Pillar 1986). Although it shows no appreciable onshore-offshore gradients, standing stock is highest over the shelf, with accumulation of some mobile zooplanktors (euphausiids) known to occur at oceanographic fronts. Beyond the continental slope biomass decreases markedly. Localised peaks in biomass may, however, occur in the vicinity of Child's Bank and Tripp seamount in response to topographically steered upwelling around such seabed features.

Zooplankton biomass varies with phytoplankton abundance and, accordingly, seasonal minima will exist during non-upwelling periods when primary production is lower (Brown 1984; Brown & Henry 1985), and during winter when predation by recruiting anchovy is high. More intense variation will occur in relation to the upwelling cycle; newly upwelled water supporting low zooplankton biomass due to paucity of food, whilst high biomasses develop in aged upwelled water subsequent to significant development of phytoplankton. Irregular pulsing of the upwelling system, combined with seasonal recruitment of pelagic fish species into West Coast shelf waters during winter, thus results in a highly variable and dynamic balance between plankton replenishment and food availability for pelagic fish species.

Although ichthyoplankton (fish eggs and larvae) comprise a minor component of the overall plankton, it remains significant due to the commercial importance of the overall fishery in the region. Various pelagic and demersal fish species are known to spawn in the inshore regions of the southern Benguela, (including pilchard, round herring, chub mackerel lanternfish and hakes (Crawford *et al.* 1987; Hutchings 1994; Hutchings *et al.* 2002) (see Figure 22, Figure 23a and 23b, and Figure 24), and their eggs and larvae form an important contribution to the ichthyoplankton in the region. Spawning of key species is presented below.

- Hake, snoek and round herring move to the western Agulhas Bank and southern west coast to spawn in late winter and early spring (key period), when offshore Ekman losses are at a minimum and their eggs and larvae drift northwards and inshore to the west coast nursery grounds. Figure 23a and 23b highlight the temporal variation in hake eggs and larvae with there being a greater concentration of eggs and larvae between September - October compared to March - April. However, hake are reported to spawn throughout the year (Strømme *et al*. 2015). Snoek spawn along the shelf break (150-400 m) of the western Agulhas Bank and the West Coast between June and October (Griffiths 2002).

- Horse mackerel spawn over the east/central Agulhas Bank during winter months.
- Sardines spawn on the whole Agulhas Bank during November, but generally have two spawning peaks, in early spring and autumn, on either side of the peak anchovy spawning period (Figure 24, left). There is also sardine spawning on the east coast and even off KwaZulu-Natal, where sardine eggs are found during July–November.
- Anchovies spawn on the whole Agulhas Bank (Figure 24, right), with spawning peaking during mid-summer (November–December) and some shifts to the west coast in years when Agulhas Bank water intrudes strongly north of Cape Point.

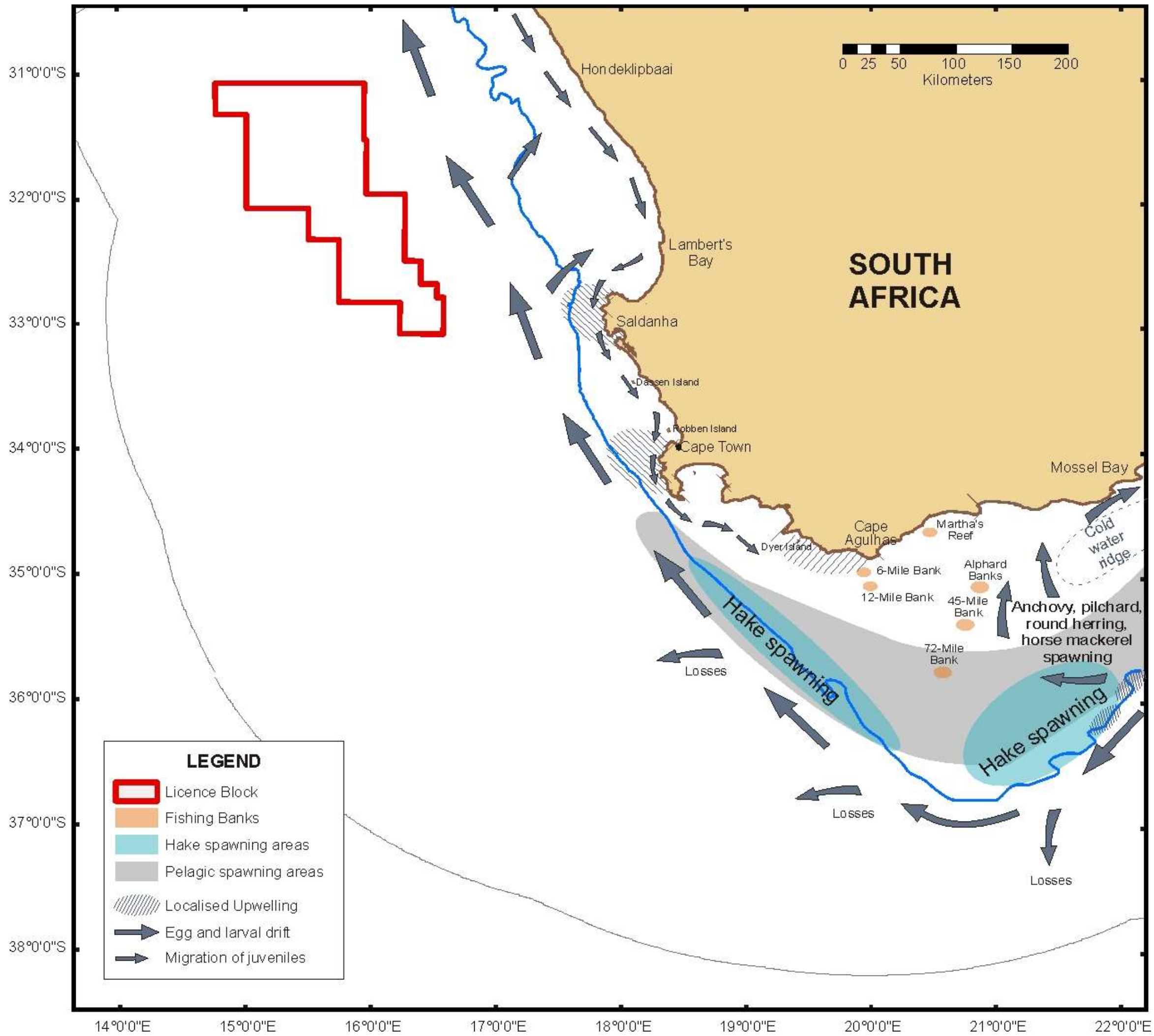

Figure 22: Block 3B/4B (red polygon) in relation to major spawning, recruitment and nursery areas in the southern Benguela region (adapted from Crawford *et al*. 1987; Hutchings 1994; Hutchings *et al*. 2002).

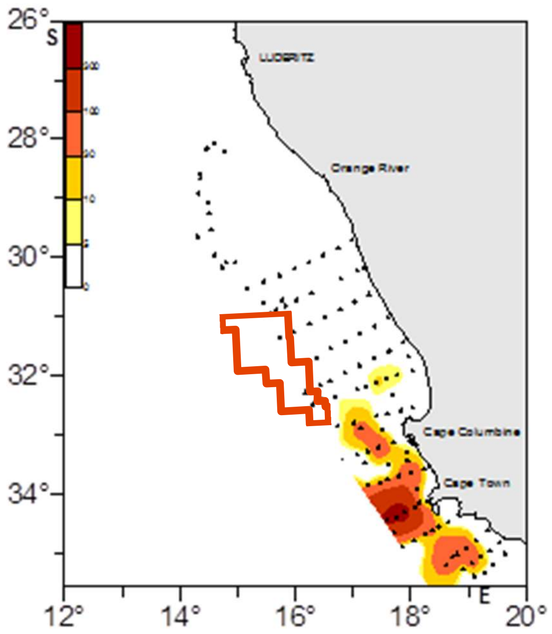

Figure 23a: Distribution of hake eggs (left) and larvae (right) off the West Coast of South Africa between September and October 2005 (adapted from Stenevik *et al*. 2008) in relation to Block 3B/4B (red polygon).

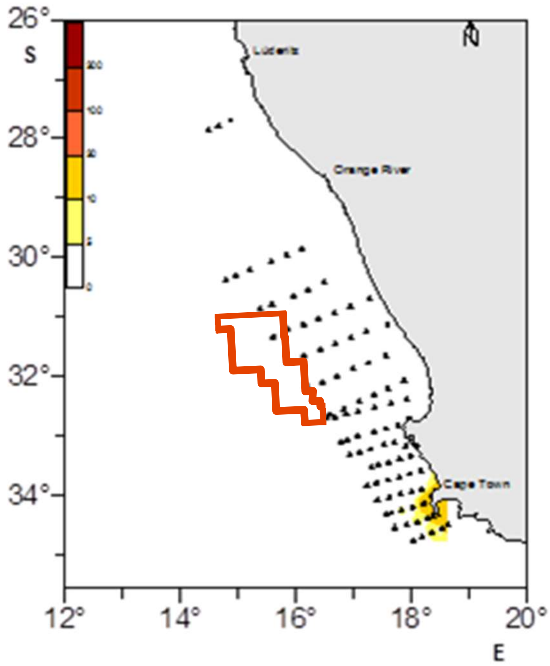

Figure 23b: Distribution of hake eggs (left) and larvae (right) off the West Coast of South Africa between March and April 2007 (adapted from Stenevik *et al*. 2008) in relation to Block 3B/4B (red polygon).

The eggs and larvae are carried around Cape Point and up the coast in northward flowing surface waters. At the start of winter every year, the juveniles recruit in large numbers into coastal waters across broad stretches of the shelf between the Orange River and Cape Columbine to utilise the shallow shelf region as nursery grounds before gradually moving southwards in the inshore southerly flowing surface current, towards the major spawning grounds east of Cape Point. Following spawning, the eggs and larvae of snoek are transported to inshore (<150 m) nursery grounds north of Cape Columbine and east of Danger Point, where the juveniles remain until maturity. There is only limited overlap of the inshore portions of Block 3B/4B with the northward egg and larval drift of commercially important species, and the return migration of recruits (Figure 22). In the offshore oceanic waters of Block 3B/4B, ichthyoplankton abundance is, therefore, expected to be low.

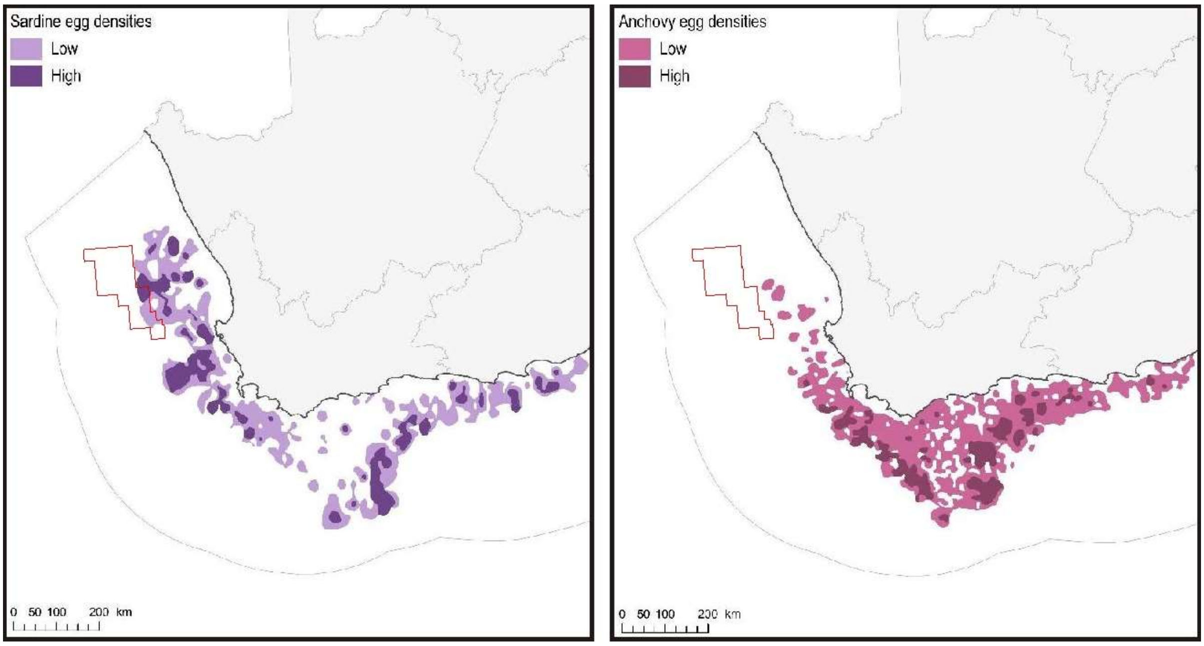

Figure 24: Distribution of sardine (left) and anchovy (right) spawning areas, as measured by egg densities, in relation to Block 3B/4B (red polygon) (adapted from Harris *et al*. 2022).

3.3.3.2 Cephalopods

Fourteen species of cephalopds have been recorded in the southern Benguela, the majority of which are sepiods/cuttlefish (Lipinski 1992; Augustyn *et al*. 1995). Most of the cephalopod resource is distributed on the mid-shelf with *Sepia australis* being most abundant at depths between 60-190 m, whereas *S. hieronis* densities were higher at depths between 110-250 m. *Rossia enigmatica* occurs more commonly on the edge of the shelf to depths of 500 m. Biomass of these species was generally higher in the summer than in winter.

Cuttlefish are largely epi-benthic and occur on mud and fine sediments in association with their major prey item; mantis shrimps (Augustyn *et al*. 1995). They form an important food item for demersal fish.

The colossal squid *Mesonychoteuthis hamiltoni* and the giant squid *Architeuthis* sp. may also be encountered in the project area. Both are deep dwelling species, with the colossal squid's distribution confined to the entire circum-antarctic Southern Ocean (Figure 25, top) while the giant squid is usually found near continental and island slopes all around the world's oceans (Figure 25, bottom). Both species could thus potentially occur in the pelagic habitats of the project area, although the likelihood of encounter is extremely low.

Growing to in excess of 10 m in length, they are the principal prey of the sperm whale, and are also taken by beaked whaled, 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.

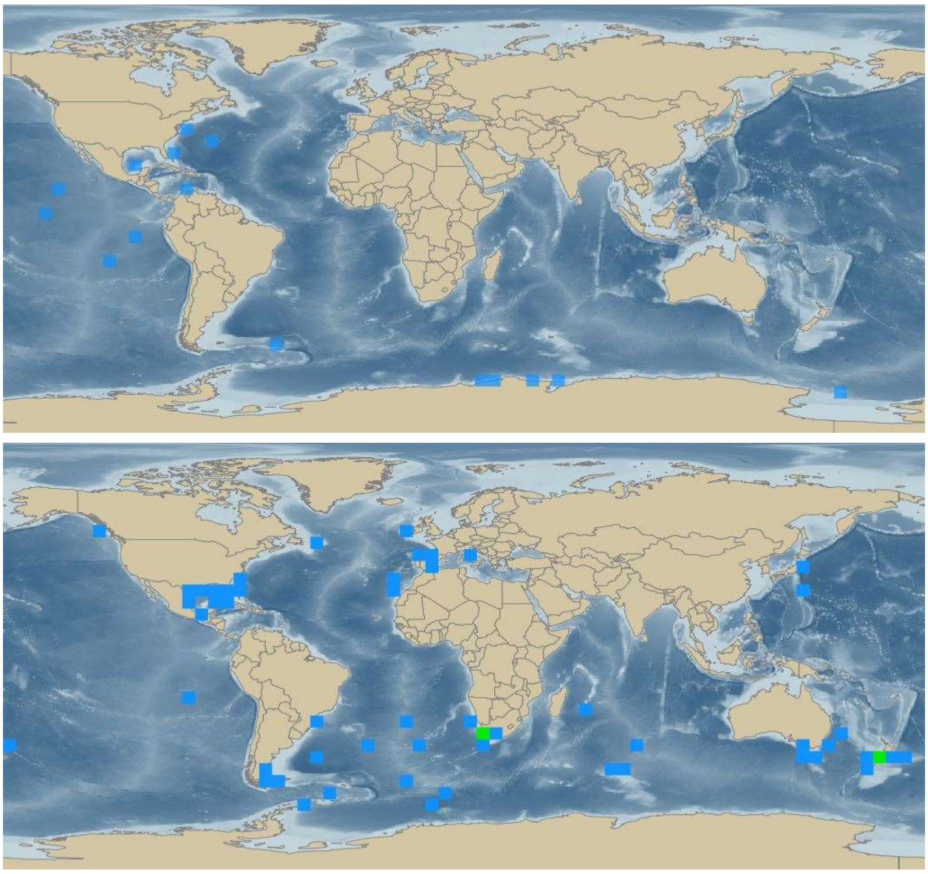

Figure 25: Distribution of the colossal squid (top) and the giant squid (bottom). Blue squares <5 records, green squares 5-10 records (Source: http://iobis.org).

3.3.3.3 Pelagic Fish

Small pelagic species include the sardine/pilchard (*Sadinops ocellatus*) (Figure 26, left), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) (Figure 26, 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 and thus likely to only be encountered in southeastern inshore portion of the project area. Most of the pelagic species exhibit similar life history patterns involving seasonal migrations between the west and south coasts. The spawning areas of the major pelagic species are distributed on the continental shelf and along the shelf edge extending from south of St Helena Bay to Mossel Bay on the South Coast (Shannon & Pillar 1986) (see Figure 22). They spawn downstream of major upwelling centres in spring and summer, and their eggs and larvae are subsequently carried around Cape Point and up the coast in northward flowing surface waters.

At the start of winter every year, juveniles of most small pelagic shoaling species recruit into coastal waters in large numbers between the Orange River and Cape Columbine. They recruit in the pelagic stage, across broad stretches of the shelf, to utilise the shallow shelf region as nursery grounds before gradually moving southwards in the inshore southerly flowing surface current, towards the major spawning grounds east of Cape Point. Recruitment success relies on the interaction of oceanographic events, and is thus subject to spatial and temporal variability. Consequently, the abundance of adults and juveniles of these small, short-lived (1-3 years) pelagic fish is highly variable both within and between species.

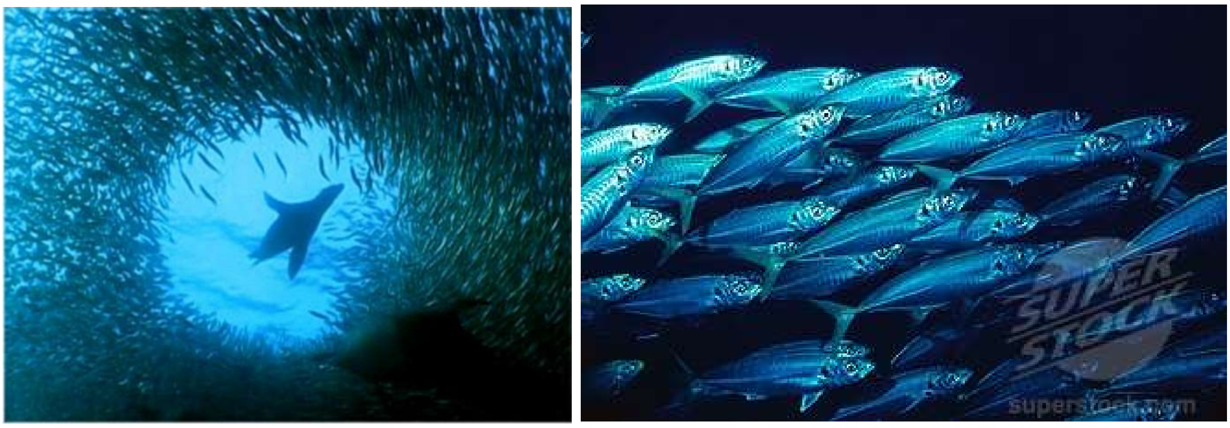

Figure 26: Cape fur seal preying on a shoal of pilchards (left). School of horse mackerel (right) (photos: www.underwatervideo.co.za; www.delivery.superstock.com).

Two species that migrate along the 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). While the appearance of chub mackerel along the West and South-West coasts is highly seasonal, adult snoek are found throughout their distribution range and longshore movements are random and without a seasonal basis (Griffiths 2002). Initially postulated to be a single stock that undergoes a seasonal longshore migration from southern Angola through Namibia to the South African West Coast (Crawford & De Villiers 1985; Crawford *et al*. 1987), Benguela snoek are now recognised as two separate sub-populations separated by the Lüderitz upwelling cell (Griffiths 2003). On the West Coast, snoek move offshore to spawn and there is some southward dispersion as the spawning season progresses, with females on the West Coast moving inshore to feed between spawning events as spawning progresses. In contrast, those found further south along the western Agulhas Bank remain on the spawning grounds throughout the spawning season (Griffiths 2002) (Figure 27). They are voracious predators occurring throughout the water column, feeding on both demersal and pelagic invertebrates and fish. Chub mackerel similarly migrate along the southern African West Coast reaching South-Western Cape waters between April and August. They move inshore in June and July to spawn before starting the return northwards offshore migration later in the year. Their abundance and seasonal migrations are thought to be related to the availability of their shoaling prey species (Payne & Crawford 1989). The distribution of snoek and chub mackerel therefore lies well inshore of Block 3B/4B.

The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of Block 3B/4B 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 and illegal overfishing has severely damaged the stocks of many of these species. Similarly, pelagic sharks, are either caught as bycatch in the pelagic tuna longline fisheries, or are specifically targeted for their fins, where the fins are removed and the remainder of the body discarded.

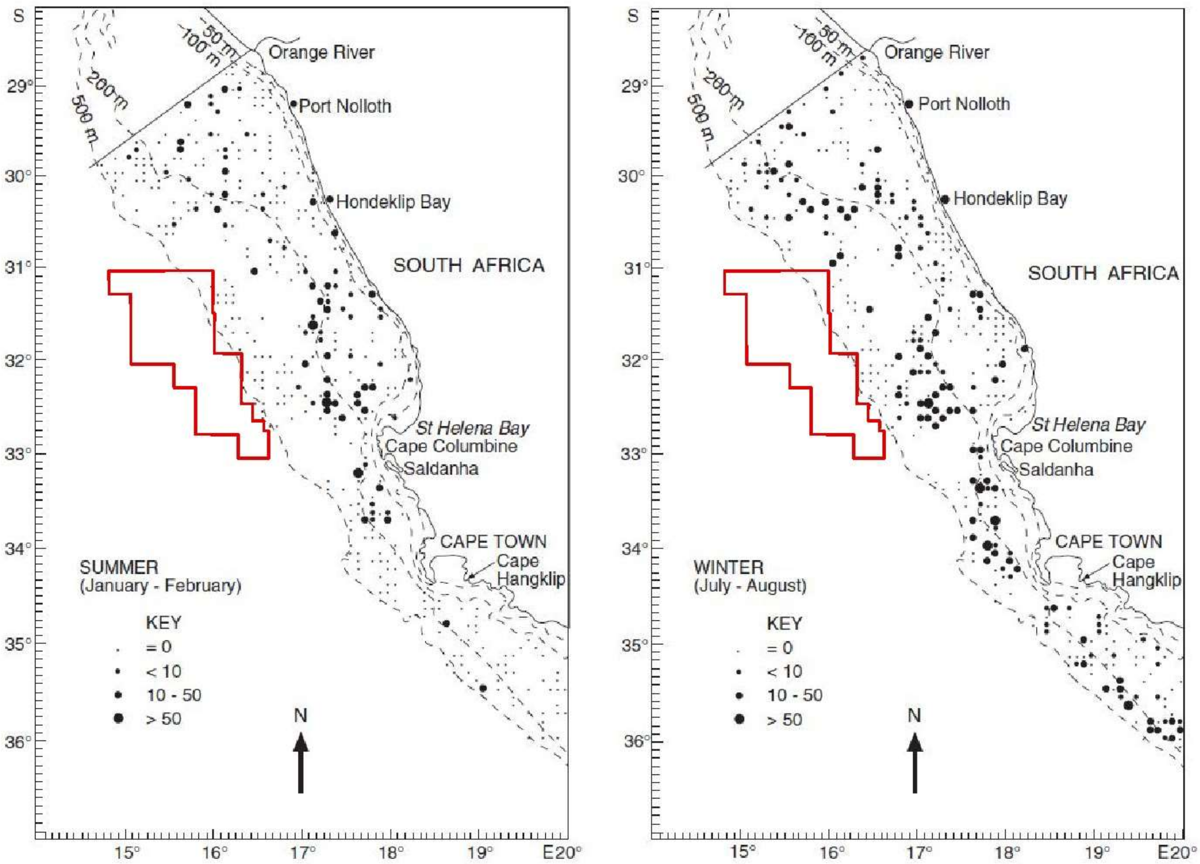

Figure 27: Mean number of snoek per demersal trawl per grid block (5 × 5 Nm) by season for (A) the west coast (July 1985–Jan 1991) and (B) the south coast in relation to Block 3B/4B (red polygon) (adapted from Griffiths 2002).

These large pelagic species migrate throughout the southern oceans, between surface and deep waters (>300 m) and have a highly seasonal abundance in the Benguela. Species occurring off western southern Africa include the albacore/longfin tuna *Thunnus alalunga* (Figure 28, right), yellowfin *T. albacares*, bigeye *T. obesus*, and skipjack *Katsuwonus pelamis tunas*, as well as the Atlantic blue marlin *Makaira nigricans* (Figure 28, left), the white marlin *Tetrapturus albidus* and the broadbill swordfish *Xiphias gladius* (Payne & Crawford 1989). The distribution of these species is 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 (Shannon *et al.* 1989; Penney *et al.* 1992). Seasonal association with Child's Bank and Tripp Seamount occurs between October and June, with commercial catches often peaking in March and April (www.fao.org/fi/fcp/en/ NAM/body.htm; see CapMarine 2023 – Fisheries Specialist Study).

Table 4: Some of the more important large migratory pelagic fish likely to occur in the offshore regions of the West Coast (TOPS list under NEMBA, Act 10 of 2004; Sink *et al*. 2019; www.iucnredlist.org;). The National and Global IUCN Conservation Status are also provided. Species reported from Deep Water Orange Basin Area by MMOs are highlighted (CapFish 2013a).

Common Name	Species	National Assessment	IUCN Conservation Status
Tunas			
Southern Bluefin Tuna	*Thunnus maccoyii*	Not Assessed	Endangered
Bigeye Tuna	*Thunnus obesus*	Vulnerable	Vulnerable
Longfin Tuna/Albacore	*Thunnus alalunga*	Near Threatened	Least concern
Yellowfin Tuna	*Thunnus albacares*	Near Threatened	Least concern
Frigate Tuna	*Auxis thazard*	Not Assessed	Least concern
Eastern Little Tuna	*Euthynnus affinis*	Least concern	Least concern
Skipjack Tuna	*Katsuwonus pelamis*	Least concern	Least concern
Atlantic Bonito	*Sarda sarda*	Not Assessed	Least concern
Billfish			
Black Marlin	*Istiompax indica*	Data deficient	Data deficient
Blue Marlin	*Makaira nigricans*	Vulnerable	Vulnerable
Striped Marlin	*Kajikia audax*	Near Threatened	Least concern
Sailfish	*Istiophorus platypterus*	Least concern	Vulnerable
Swordfish	*Xiphias gladius*	Data deficient	Near Threatened
Pelagic Sharks			
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Not Assessed	Critically Endangered
Dusky Shark	*Carcharhinus obscurus*	Data deficient	Endangered
Bronze Whaler Shark	*Carcharhinus brachyurus*	Data deficient	Vulnerable
Great White Shark	*Carcharodon carcharias*	Least concern	Vulnerable
Shortfin Mako	*Isurus oxyrinchus*	Vulnerable	Endangered
Longfin Mako	*Isurus paucus*	Not Assessed	Endangered
Whale Shark	*Rhincodon typus*	Not Assessed	Endangered
Blue Shark	*Prionace glauca*	Least concern	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).

A number of species of pelagic sharks are also known to occur on the 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 on the West Coast. Great whites *Carcharodon carcharias* and whale sharks *Rhincodon typus* may also be encountered in coastal and offshore areas, although the latter occurs more frequently along the South and East coasts. 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 Block 3B/4B *en route* to South America (da Silva *et al*. 2010).


Figure 28: Large migratory pelagic fish such as blue marlin (left) and longfin tuna (right) occur in offshore waters (photos: www.samathatours.com; www.osfimages.com).

The shortfin mako inhabits offshore temperate and tropical seas worldwide. It can be found from the surface to depths of 500 m, and as one of the few endothermic sharks is seldom found in waters <16 °C (Compagno 2001; Loefer *et al*. 2005). As the fastest species of shark, shortfin makos have been recorded to reach speeds of 40 km/h with burst of up to 74 km/h, and can jump to a height of 9 m (http://www.elasmo-research.org/education/shark_profiles/ i_oxyrinchus.htm). Most makos caught by longliners off South Africa are immature, with reports of juveniles and sub-adults sharks occurring near the edge of the Agulhas Bank and off the South Coast between June and November (Groeneveld *et al*. 2014), whereas larger and reproductively mature sharks were more common in the inshore environment along the East Coast (Foulis 2013).

Until recently, the Southern Bluefin Tuna was globally assessed as 'Critically Endangered' by the IUCN, and in South Africa the stock is considered collapsed (Sink *et al*. 2019). 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 as globally 'Endangered'.

Whale sharks are regarded as a broad ranging species typically occurring in offshore epipelagic areas with sea surface temperatures of 18–32°C (Eckert & Stewart 2001). Adult whale sharks reach an average size of 9.7 m and 9 tonnes, making them the largest non-cetacean animal in the world. They are slow-moving filter-feeders and therefore particularly vulnerable to ship strikes (Rowat 2007). Although primarily solitary animals, seasonal feeding aggregations occur at several coastal sites all over the world, those closest to the project area being off Sodwana Bay in KwaZulu Natal (KZN) (Cliff *et al*. 2007). Satellite tagging has revealed that individuals may travel distances of tens of 1 000s of kms (Eckert & Stewart 2001; Rowat & Gore 2007; Brunnschweiler *et al*. 2009). On the West Coast their summer and winter distributions are centred around the Orange River mouth and between Cape Columbine and Cape Point (Harris *et al*. 2022). The likelihood of an encounter in the offshore waters of Block 3B/4B is relatively low.

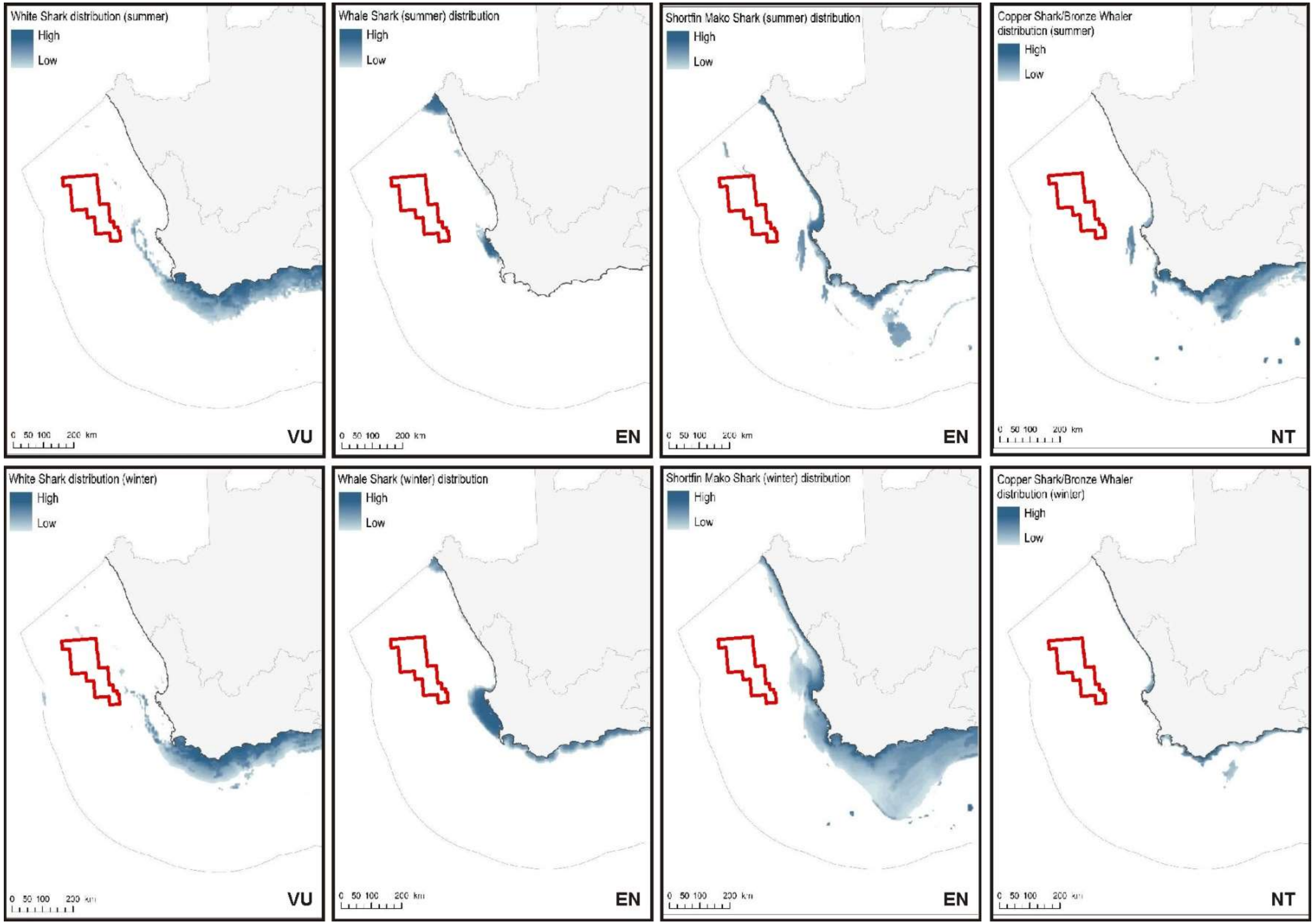

Figure 29: The summer (top) and winter (bottom) distribution of white shark, whale shark, shortfin mako and bronze whaler shark in relation to Block 3B/4B (red polygon) (adapted from Harris *et al*. 2022).

The whale shark and shortfin mako are listed in Appendix II (species in which trade must be controlled in order to avoid utilization incompatible with their survival) of CITES (Convention on International Trade in Endangered Species) and Appendix I and/or II of the Bonn Convention for the Conservation of Migratory Species (CMS). The whale shark is also listed as 'vulnerable' in the List of Marine Threatened or Protected Species (TOPS) as part of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA).

The shelf-associated[3] distributions of some of the pelagic sharks (Great white, Bronze whaler, shortfin mako and whale shark) were provided in Harris *et al.* (2022) (Figure 29).

3.3.3.4 Turtles

Three species of turtle occur along the West Coast, namely the Leatherback (*Dermochelys coriacea*) (Figure 30, left), and occasionally the Loggerhead (*Caretta caretta*) (Figure 30, right) and the Green (*Chelonia mydas*) turtle. Green turtles are non-breeding residents often found feeding on inshore reefs on the South and East Coasts and are expected to occur only as occasional visitors along the West Coast. They nest mainly along the coast of Mozambique and on Europa and Tromelin Islands, well to the northeast of Block 3B/4B (Lauret-Stepler *et al.* 2007). The most recent conservation status, which assessed the species on a sub-regional scale, is provided in Table 5.

Figure 30: Leatherback (left) and loggerhead turtles (right) occur along the West Coast of Southern Africa (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

Table 5: Global and Regional Conservation Status of the turtles occurring off the West Coast showing variation depending on the listing used.

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

NT – Near Threatened V – Vulnerable E – Endangered CR – Critically Endangered
DD – Data Deficient UR – Under Review * - not yet assessed

[3] The distributions provided by Harris *et al.* (2022) are based on data from pelagic fisheries. In reality these species all have wide-ranging distributions in offshore temperate and/or tropical seas.

After completion of the nesting season (October to January) both Leatherbacks and Loggerheads undertake long-distance migrations to foraging areas. Loggerhead turtles are coastal specialists keeping inshore, hunting around reefs, bays and rocky estuaries along the African South and East Coast, where they feed on a variety of benthic fauna including crabs, shrimp, sponges, and fish. In the open sea their diet includes jellyfish, flying fish, and squid (www.oceansafrica.com/turtles.htm). Satellite tagging of loggerheads suggests that they seldom occur west of Cape Agulhas (Harris *et al.* 2018; Robinson *et al.* 2018). A green turtle and loggerhead turtle recently released on the Cape Peninsula by the Two Oceans Aquarium has, however stayed in the West Coast waters, spending time in St Helena Bay and travelling up the Namaqualand coast before heading northwards into Namibian waters, suggesting that occurrence in West Coast waters does arise (https://www.aquarium.co.za/foundation/news/tracking-our-turtles-the-first-update-of-2024). A sighting of a Loggerhead turtle in the Deep Water Orange Basin Area has, however, been reported by an MMO (CapFish 2013a). The Leatherback is the turtle most likely to be encountered in the offshore waters of west South Africa. The Benguela ecosystem, especially the northern Benguela where jelly fish numbers are high, 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; SASTN 2011[4]).

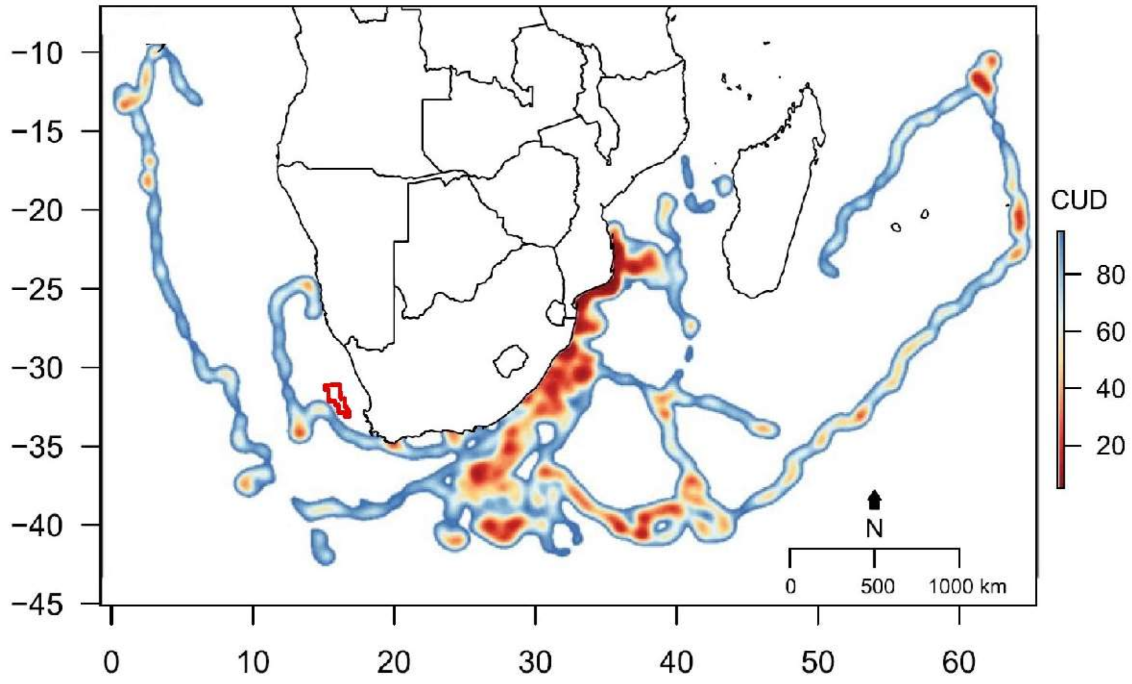

Figure 31: Block 3B/4B (red polygon) in relation to the migration corridors of leatherback turtles in the south-western Indian Ocean. Relative use (CUD, cumulative utilization distribution) of corridors is shown through intensity of shading: light, low use; dark, high use (adapted from Harris *et al.* 2018).

[4] *SASTN Meeting – Second meeting of the South Atlantic Sea Turtle Network, Swakopmund, Namibia, 24-30 July 2011.*

Loggerheads and leatherbacks nest along the sandy beaches of the northeast coast of KZN, as well as southern Mozambique during summer months. Loggerhead and leatherback females come ashore to nest from October to March, with peak nesting for both species occurring in December – January (Le Gouvello *et al*. 2020). Hatchlings emerge from their nests from mid-January to mid-March. Those hatchlings that successfully escape predation *en route* to the sea, enter the surf and are carried ~10 km offshore by coastal rip currents or swim actively offshore for 24-48 hours (frenzy period) to reach the Agulhas Current (Hughes 1974). Although they can actively swim to influence their dispersal trajectories (Scott *et al*. 2014; Putman & Mansfield 2015), hatchlings are not powerful swimmers and will primarily drift south-westwards in the current. The Agulhas Current migration corridor will therefore be very active with migrating sea turtles between January and April (Harris *et al*. 2018), some of which may be distributed along the West Coast through mass transport of Agulhas Current water into the southeast Atlantic by warm core rings. Le Gouvello *et al*. (2024) estimated that juvenile loggerhead and leatherback turtles leaving the iSimagaliso MPA would take 200-365 days to reach Block 3B/4B (Figure 32). Despite their extensive distributions and feeding ranges, the numbers of adult and neonate turtles encountered in Block3B/4B may therefore be seasonally high, particularly in the Child's Bank and Orange Shelf Edge MPAs, and the Orange Seamount and Canyon Complex transboundary EBSA, which may be frequented by leatherbacks and loggerheads on their migrations.

Ocean circulation models and numerical dispersal simulations have recently provided insights into the cryptic 'lost years' of neonate turtles (Hamann *et al*. 2011; Putman *et al*. 2012; Putman & Naro-Maciel 2013; Gouvello *et al*. 2020; Putman *et al*. 2020; DuBois *et al*. 2021; Gouvello *et al*. 2024). After ~10 years, juvenile loggerheads return to coastal areas to feed on crustaceans, fish and molluscs and subsequently remain in these neritic habitats (Hughes 1974). In contrast, leatherbacks remain in pelagic waters feeding primarily on jellyfish until they become sexually mature and return to coastal regions to breed. While hunting they may dive to over 600 m and remain submerged for up to 54 minutes (Hays *et al*. 2004).

Satellite tracking of female loggerhead and leatherback turtles during inter-nesting periods revealed that loggerheads remained close to the shore (within the boundaries of the iSimangaliso Wetland Park MPA) between nesting events, whereas leatherbacks travelled greater distances (more than 300 km) and beyond the borders of the MPA (Harris *et al*. 2018; Robinson *et al*. 2018).

Turtles marked with titanium flipper tags have revealed that South African loggerheads and leatherbacks have a remigration interval of 2 – 3 years, migrating to foraging grounds throughout the South Western Indian Ocean (SWIO) as well as in the eastern Atlantic Ocean. They follow different post-nesting migration routes (Hughes *et al*. 1998; Luschi *et al*. 2006). Loggerheads use one of 3 migration corridors between their nesting and foraging grounds of which the coast-associated Mozambique Corridor is the most commonly used (>80% of the population). Leatherbacks largely follow the same corridors as the loggerheads, with most riding the Agulhas Current southward to forage in high seas regions of the Agulhas Plateau (Hughes *et al*. 1998; Luschi *et al*. 2003b; Luschi *et al*. 2006), at which point they either swim east following the Agulhas Retroflection (Agulhas-Retroflection Corridor) as far north as the Mascarene Plateau or enter the Benguela Current to migrate into the southeastern Atlantic, as far north as central Angola (Agulhas-Benguela Corridor) (Figure 31) (Lambardi *et al*. 2008; de Wet 2013; Harris *et al*. 2018).

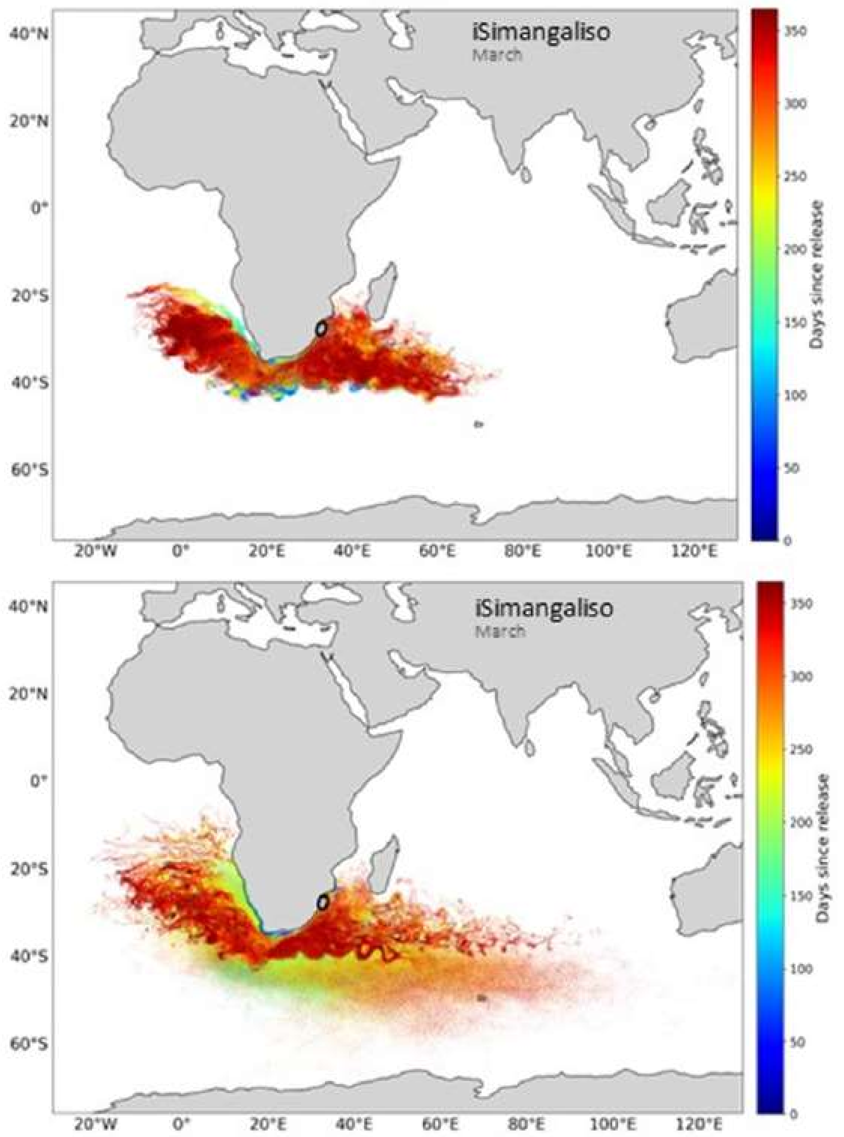

Figure 32: Dispersal maps showing trajectories of 5000 particles released from the respective nesting sites (white circles) in March 2018 for loggerheads (top) and leatherbacks (bottom). Colours (blue to red) indicate the number of days since release (adapted from Le Gouvelle *et al*. 2020).

Leatherback Turtles are listed as 'Critically endangered' 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). The 2017 South African list of Threatened and Endangered Species (TOPS) similarly lists the species as 'Critically endangered', whereas on the National Assessment (Hughes & Nel 2014) leatherbacks were listed as 'Endangered', whereas Loggerhead and green turtles are listed globally as 'Vulnerable' and 'Endangered', respectively, whereas on TOPS both species are listed as 'Endangered'. As a signatory of CMS, South Africa has endorsed and signed a CMS International Memorandum of Understanding specific to the conservation of marine turtles. South Africa is thus committed to conserve these species at an international level.

3.3.3.5 Seabirds

Large numbers of pelagic seabirds exploit the pelagic fish stocks of the Benguela system. Of the 49 species of seabirds that occur in the Benguela region, 15 are defined as resident, 10 are visitors from the northern hemisphere and 25 are migrants from the southern Ocean. The species classified as being common in the southern Benguela, and likely to occur in Block 3B/4B, are listed in Table 6. The area between Cape Point and the Orange River supports 38% and 33% of the overall population of pelagic seabirds in winter and summer, respectively. Most of the pelagic species in the region reach highest densities offshore of the shelf break (200 – 500 m depth), and are therefore likely to occur in the proposed Area of Interest, with highest population levels during their non-breeding season (winter). Pintado petrels and Prion spp. show the most marked variation here. Support vessels and possible helicopter flights may, however, encounter more coastal seabirds when *en route* between the seismic vessel and/or drilling unit and the port or airport. On the South Coast, 60 seabird species are known, or thought likely to occur. These can be categorised into three categories: 'breeding resident species', 'non-breeding migrant species' and 'rare vagrants' (Shaughnessy 1977; Harrison 1978; Liversidge & Le Gras 1981; Ryan & Rose 1989).

Fifteen species of seabirds breed in southern Africa, including Cape Gannet (Figure 33, left), African Penguin (Figure 33, right), African Black Oystercatcher, four species of Cormorant, White Pelican, three Gull and four Tern species (

Figure 34: Block 3B/4B (red polygon) in relation to aggregate core home ranges of Cape Gannet (top left), African Penguin (top right) for different colonies and life-history stages, and foraging areas of Wandering Albatross (bottom left) and Atlantic Yellow-nosed Albatross (bottom right). For foraging areas, darker shades are areas of higher use and where foraging areas from different colonies overlap (adapted from Harris *et al.* 2022).

Table 7). The breeding areas are distributed around the coast with islands being especially important. The closest breeding islands to Block 3B/4B are Bird Island in Lambert's Bay, the Saldanha Bay islands, Dassen Island, Robben Island and Seal Island approximately 180 km, 130 km, 145 km, 190 km and 225 km to the east and southeast of the southern section of Block 3B/4B, respectively. The number of successfully breeding birds at the particular breeding sites varies with food abundance. Most of the breeding seabird species forage at sea with most birds being found relatively close inshore (10-30 km). Cape Gannets, which breed at only three locations in South Africa (Bird Island Lamberts Bay, Malgas Island and Bird Island Algoa Bay) are known to forage within 200 km offshore (Dundee 2006; Ludynia 2007; Grémillet *et al*. 2008; Crawford *et al*. 2011), and African Penguins have also been recorded as far as 60 km offshore. Block 3B/4B lies on the western extent of Cape Gannet foraging and distribution areas and well offshore of African Penguin foraging and distribution areas, but overlaps with the foraging ranges of various pelagic bird species, particularly Wandering Albatross and Atlantic Yellow-nosed Albatross (Figure 34). Cape Cormorant and Bank Cormorant core usage areas lie well inshore of Block 3B/4B (BirdLife South Africa 2021; Harris *et al*. 2022).


Figure 33: Cape Gannets *Morus capensis* (left) (Photo: NACOMA) and African Penguins *Spheniscus demersus* (right) (Photo: Klaus Jost) breed primarily on the offshore Islands.

Table 6: Pelagic seabirds common in the southern Benguela region (Crawford *et al*. 1991; BirdLife 2021). IUCN Red List and Regional Assessment status are provided (Sink *et al*. 2019). Species reported from the adjacent Deep Water Orange Basin Area by MMOs are highlighted (CapFish 2013a, 2013b).

Common Name	Species name	Global IUCN	Regional Assessment
Shy Albatross	*Thalassarche cauta*	Near Threatened	Near Threatened
Black-browed Albatross	*Thalassarche melanophrys*	Least concern	Endangered
Atlantic Yellow-nosed	*Thalassarche chlororhynchos*	Endangered	Endangered
Indian Yellow-nosed Albatross	*Thalassarche carteri*	Endangered	Endangered
Wandering Albatross	*Diomedea exulans*	Vulnerable	Vulnerable
Southern Royal Albatross	*Diomedea epomophora*	Vulnerable	Vulnerable
Northern Royal Albatross	*Diomedea sanfordi*	Endangered	Endangered
Sooty Albatross	*Phoebetria fusca*	Endangered	Endangered
Light-mantled Albatross	*Phoebetria palpebrata*	Near Threatened	Near Threatened
Tristan Albatross	*Diomedea dabbenena*	Critically Endangered	Critically Endangered
Grey-headed Albatross	*Thalassarche chrysostoma*	Endangered	Endangered
Giant Petrel sp.	*Macronectes halli/giganteus*	Least concern	Near Threatened
Southern Fulmar	*Fulmarus glacialoides*	Least concern	Least concern
Pintado Petrel	*Daption capense*	Least concern	Least concern
Blue Petrel	*Halobaena caerulea*	Least concern	Near Threatened
Salvin's Prion	*Pachyptila salvini*	Least concern	Near Threatened
Arctic Prion	*Pachyptila desolata*	Least concern	Least concern
Slender-billed Prion	*Pachyptila belcheri*	Least concern	Least concern
Broad-billed Prion	*Pachyptila vittata*	Least concern	Least concern
Kerguelen Petrel	*Aphrodroma brevirostris*	Least concern	Near Threatened
Greatwinged Petrel	*Pterodroma macroptera*	Least concern	Near Threatened
Soft-plumaged Petrel	*Pterodroma mollis*	Least concern	Near Threatened
White-chinned Petrel	*Procellaria aequinoctialis*	Vulnerable	Vulnerable
Spectacled Petrel	*Procellaria conspicillata*	Vulnerable	Vulnerable
Cory's Shearwater	*Calonectris diomedea*	Least concern	Least concern
Sooty Shearwater	*Puffinus griseus*	Near Threatened	Near Threatened
Flesh-footed Shearwater	*Ardenna carneipes*	Near Threatened	Least concern
Great Shearwater	*Puffinus gravis*	Least concern	Least concern
Manx Shearwater	*Puffinus puffinus*	Least concern	Least concern
Little Shearwater	*Puffinus assimilis*	Least concern	Least concern
European Storm Petrel	*Hydrobates pelagicus*	Least concern	Least concern
Leach's Storm Petrel	*Oceanodroma leucorhoa*	Vulnerable	Critically Endangered
Wilson's Storm Petrel	*Oceanites oceanicus*	Least concern	Least concern
Black-bellied Storm Petrel	*Fregetta tropica*	Least concern	Near Threatened
White-bellied Storm Petrel	*Fregetta grallaria*	Least concern	Least concern
Pomarine Jaeger	*Stercorarius pomarinus*	Least concern	Least concern
Subantarctic Skua	*Catharacta antarctica*	Least concern	Endangered
Parasitic Jaeger	*Stercorarius parasiticus*	Least concern	Least concern
Long-tailed Jaeger	*Stercorarius longicaudus*	Least concern	Least concern
Sabine's Gull	*Larus sabini*	Least concern	Least concern
Lesser Crested Tern	*Thalasseus bengalensis*	Least concern	Least concern
Sandwich Tern	*Thalasseus sandvicensis*	Least concern	Least concern
Little Tern	*Sternula albifrons*	Least concern	Least concern
Common Tern	*Sterna hirundo*	Least concern	Least concern
Arctic Tern	*Sterna paradisaea*	Least concern	Least concern
Antarctic Tern	*Sterna vittata*	Least concern	Endangered

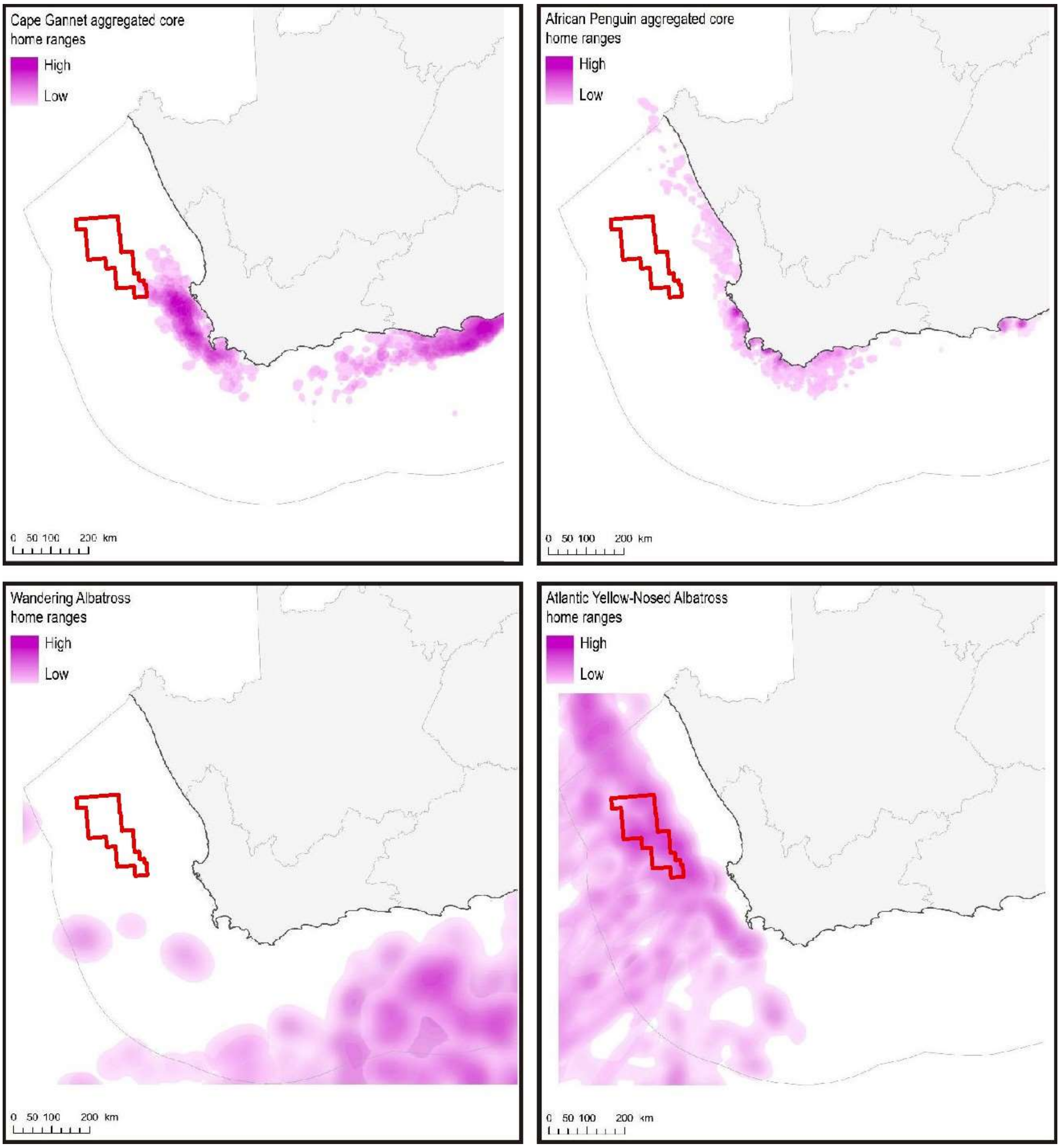

Figure 34: Block 3B/4B (red polygon) in relation to aggregate core home ranges of Cape Gannet (top left), African Penguin (top right) for different colonies and life-history stages, and foraging areas of Wandering Albatross (bottom left) and Atlantic Yellow-nosed Albatross (bottom right). For foraging areas, darker shades are areas of higher use and where foraging areas from different colonies overlap (adapted from Harris *et al.* 2022).

Table 7: Breeding resident seabirds present along the South-West Coast (adapted from CCA & CMS 2001). IUCN Red List and National Assessment status are provided (Sink *et al*. 2019). Species reported from from the adjacent Deep Water Orange Basin Area by MMOs are highlighted (CapFish 2013a, 2013b). * denotes endemicity.

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

Interactions with commercial fishing operations, either through incidental bycatch or competition for food resources, is the greatest threat to southern African seabirds, impacting 56% of seabirds of special concern. Crawford *et al*. (2014) reported that four of the seabirds assessed as Endangered compete with South Africa's fisheries for food: African Penguins, Cape Gannets and Cape Cormorants for sardines and anchovies, and Bank Cormorants for rock lobsters (Crawford *et al*. 2015). Populations of seabirds off the West Coast have recently shown significant decreases, with the population numbers of African Penguins currently only 2.5% of what the population was 80 years ago; declining from 1 million breeding pairs in the 1920s, 25 000 pairs in 2009 and 15 000 in 2018 (Sink *et al*. 2019). For Cape Gannets, the global population decreased from about 250 000 pairs in the 1950s and 1960s to approximately 130 000 in 2018, primarily as a result of a >90% decrease in Namibia's population in response to the collapse of Namibia's sardine resource. In South Africa, numbers of Cape Gannets have increased since 1956 and South Africa now holds >90% of the global population. However, numbers have recently decreased in the Western Cape but increased in Algoa Bay mirroring the southward and eastward shift sardine and anchovy. Algoa Bay currently holds approximately 75% of the South African Gannet population.

Cape cormorants and Bank cormorants showed a substantial decline from the late 1970s/early 1980s to the late 2000s/early 2010s, with numbers of Cape cormorants dropping from 106 500 to 65 800 breeding pairs, and Bank cormorants from 1 500 to only 800 breeding pairs over that period (Crawford *et al*. 2015).

Demersal and pelagic longlining are key contributors to the mortality of albatrosses (Browed albatross 7%, Indian and Atlantic Yellow-Nosed Albatross 3%), petrels (white-chinned petrel 66%), shearwaters and Cape Gannets (2%) through accidental capture (bycatch and/or entanglement in fishing gear), with an estimated annual mortality of 450 individuals of 14 species for the period 2006 to 2013 (Rollinson *et al*. 2017). Other threats include predation by mice on petrel and albatross chicks on sub-Antarctic islands, predation of chicks of Cape, Crowned and Bank Cormorants by Great White

Pelicans, and predation of eggs and chicks of African Penguins, Bank, Cape and Crowned Cormorants by Kelp gulls. Disease (avian flu), climate change (heat stress and environmental variability) and oil spills are also considered major contributors to seabird declines (Sink *et al.* 2019).

3.3.3.6 Marine Mammals

The marine mammal fauna occurring off the southern African coast includes several species of whales and dolphins and one resident seal species. Thirty five species or sub-species/populations of whales and dolphins are known (based on historic sightings or strandings records) or likely (based on habitat projections of known species parameters) to occur in the waters of the South-West Coast (Table 8). Of the species listed, the blue whale is considered 'Critically Endangered', fin and sei whales are 'Endangered' and one is considered vulnerable (IUCN Red Data list Categories). Altogether 17 species are listed as 'data deficient' underlining how little is known about cetaceans, their distributions and population trends. The offshore areas have been particularly poorly studied with most available information from deeper waters (>200 m) arising from historic whaling records prior to 1970. In the past ten years, passive acoustic monitoring and satellite telemetry have begun to shed light on current patterns of seasonality and movement for some large whale species Best 2007; Elwen *et al.* 2011; Rosenbaum *et al.* 2014; Shabangu *et al.* 2019; Thomisch *et al.* 2019) but information on smaller cetaceans in deeper waters remains poor. Records from marine mammal observers on seismic survey vessels have provided valuable data into cetacean presence although these are predominantly during summer months (Purdon *et al.* 2020). Information on general distribution and seasonality is improving but data population sizes and trends for most cetacean species occurring on the west coast of southern Africa is lacking.

Block 3B/4B extends from Hondeklipbaai to Cape Columbine from roughly the 300 m isobath to ~2 600 m water depth. Oceanographically this area lies largely within the cool waters of the Benguela Ecosystem and receives some input from the warm Agulhas Current as well as the warm waters of the South Atlantic. In terms of cetacean distribution patterns, the area thus covers a broad range of habitats and species associated with each of those water masses may occur within the target area. Records from stranded specimens show that the area between St Helena Bay (~32° S) and Cape Agulhas (~34° S, 20° E) is an area of transition between Atlantic and Indian Ocean species, and includes records from Benguela associated species such as dusky dolphins, Heaviside's dolphins and long finned pilot whales, and those of the warmer east coast such as striped and Risso's dolphins (Findlay *et al.* 1992). Species such as rough toothed dolphins, Pan-tropical spotted dolphins and short finned pilot whales are known from the southern Atlantic. Owing to the uncertainty of species occurrence offshore, species that may occur there have been included here for the sake of completeness.

The distribution of cetaceans 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 on the continental slope (200 – 2 000 m) making this the most species rich area for cetaceans and also high in density (De Rock *et al.* 2019; SLR data). 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 km. The most common species within the project area (in terms of likely encounter rate not total population sizes) are likely to be the long-finned pilot whale, common dolphin, sperm whale and humpback whale.

Cetaceans are comprised of two taxonomic groups, the mysticetes (filter feeders with baleen) and the odontocetes (predatory whales and dolphins with teeth). The term 'whale' is used to describe species in both groups and is taxonomically meaningless (e.g. the killer whale and pilot whale are members of the Odontoceti, family Delphinidae and are thus dolphins). Due to differences in sociality, communication abilities, ranging behavior and acoustic behavior, these two groups are considered separately.

Table 8 lists the cetaceans likely to be found within the project area, based on all available data sources but mainly: Findlay *et al.* (1992), Best (2007), Weir (2011), De Rock *et al.* (2019), Purdon *et al.* (2020a, 2020b, 2020c), and unpublished records held by Sea Search and those held by SLR Consulting and shared for this report (see also Figure 35, Figure 36a-b, Figure 37). The majority of data available on the seasonality and distribution of large whales in the project area is the result of commercial whaling activities mostly dating from the 1960s. Changes in the timing and distribution of migration may have occurred since these data were collected due to extirpation of populations or behaviours (e.g. migration routes may be learnt behaviours). The large whale species for which there are current data available are the humpback and southern right whale, although almost all data is limited to that collected on the continental shelf close to shore. A review of the distribution and seasonality of the key cetacean species likely to be found within the project area is provided below.

Mysticete (Baleen) whales

The majority of mysticetes whales fall into the family Balaenopeteridae. Those occurring in the area include the blue, fin, sei, Antarctic minke, dwarf minke, humpback and Bryde's whales. The southern right whale (Family Balaenidae) and pygmy right whale (Family Neobalaenidae) are from taxonomically separate groups. The majority of mysticete species occur in pelagic waters with only occasional visits to shelf waters. All of these species show some degree of migration either to or through the latitudes encompassed by the broader project area when *en route* between higher latitude (Antarctic or Subantarctic) feeding grounds and lower latitude breeding grounds.

Depending on the ultimate location of these feeding and breeding grounds, seasonality may be either unimodal, usually in winter months (June-August, e.g. minke and blue whales), or bimodal (e.g. May to July and October to 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. Because of the complexities of the migration patterns, each species is discussed separately below.

Bryde's whales: Two genetically and morphologically distinct populations of Bryde's whales (Figure 38, left) live off the 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 summer 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 area in January - March. The "inshore population" of Bryde's whale lives mainly on the continental shelf and Agulhas Bank, and is unique amongst baleen whales in the region by being non-migratory. The inshore population has recently been recognised as its own (yet to be named) sub species (*Balaenoptera brydei edeni*, Penry *et al.* 2018) with a total population for this subspecies of likely fewer than 600 individuals. 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 up the West Coast and into Namibia during the winter months (Best 2007). The offshore stock was subjected to heavy whaling in the mid-20th century (Best 2001) and there are no current data on population size or stock recovery therefrom and is currently listed as 'Data deficient' (offshore population) and Vulnerable (inshore population) on the South

Table 8: Cetaceans occurrence off the West Coast of South Africa, 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	*Beradius arnouxii*	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 brydei (subspp)*	LF	Yes	Edge	Year round	Vulnerable	Least Concern
Bryde's (offshore)	*B. brydei*	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 9.

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

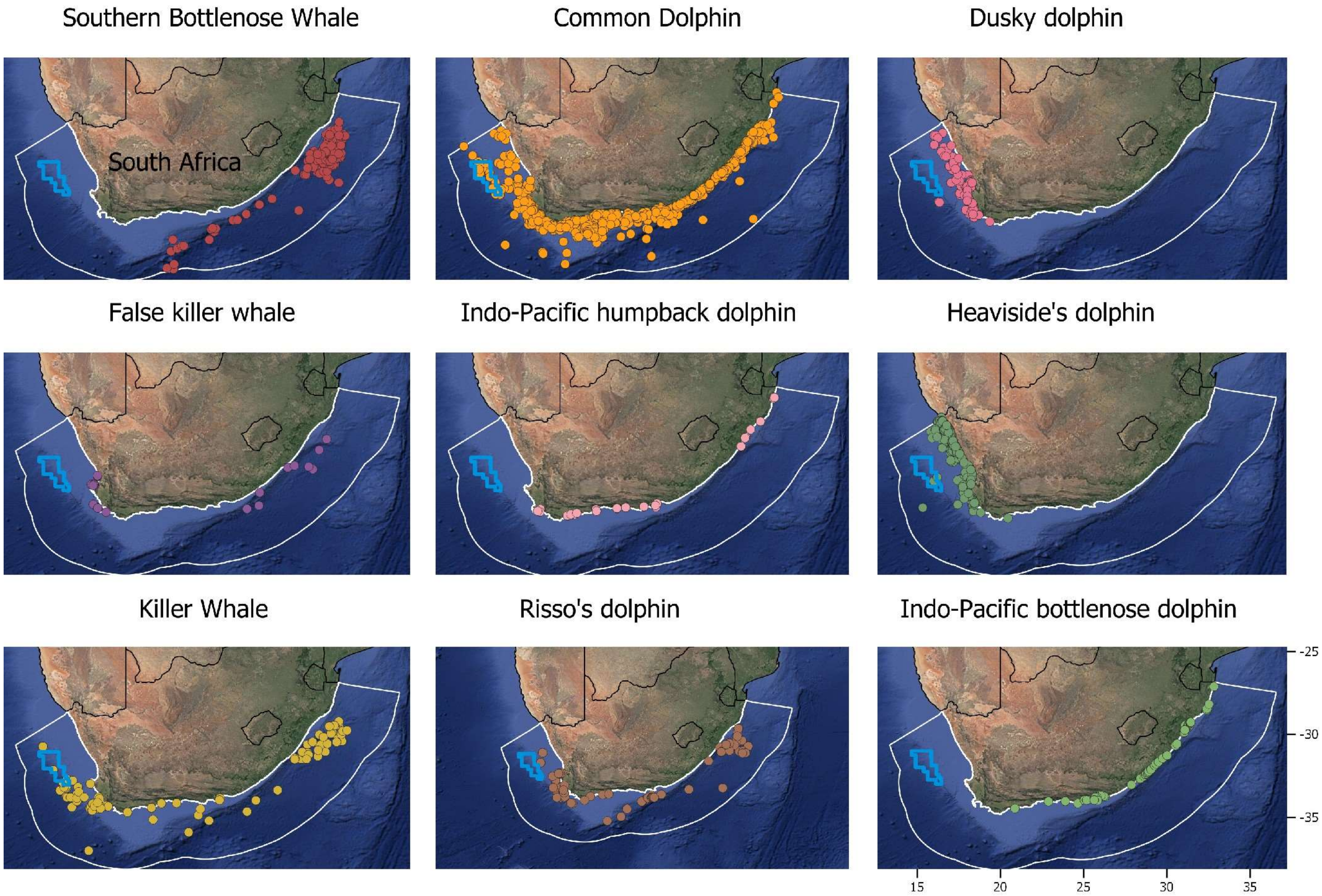

Figure 35: Block 3B/4B (cyan polygon) in relation to projections of predicted distributions for nine odontocete species off the coast of South Africa (adapted from: Purdon *et al*. 2020a).

African Red List. The inshore stock is regarded as extremely vulnerable and listed as such on the South African red list as it regularly suffers losses from entanglement in trap fisheries and has been subject to significant changes in its prey base due to losses and shifts in the sardine and small pelagic stocks around South Africa. Encounters in the offshore waters of the licence block are unlikely.

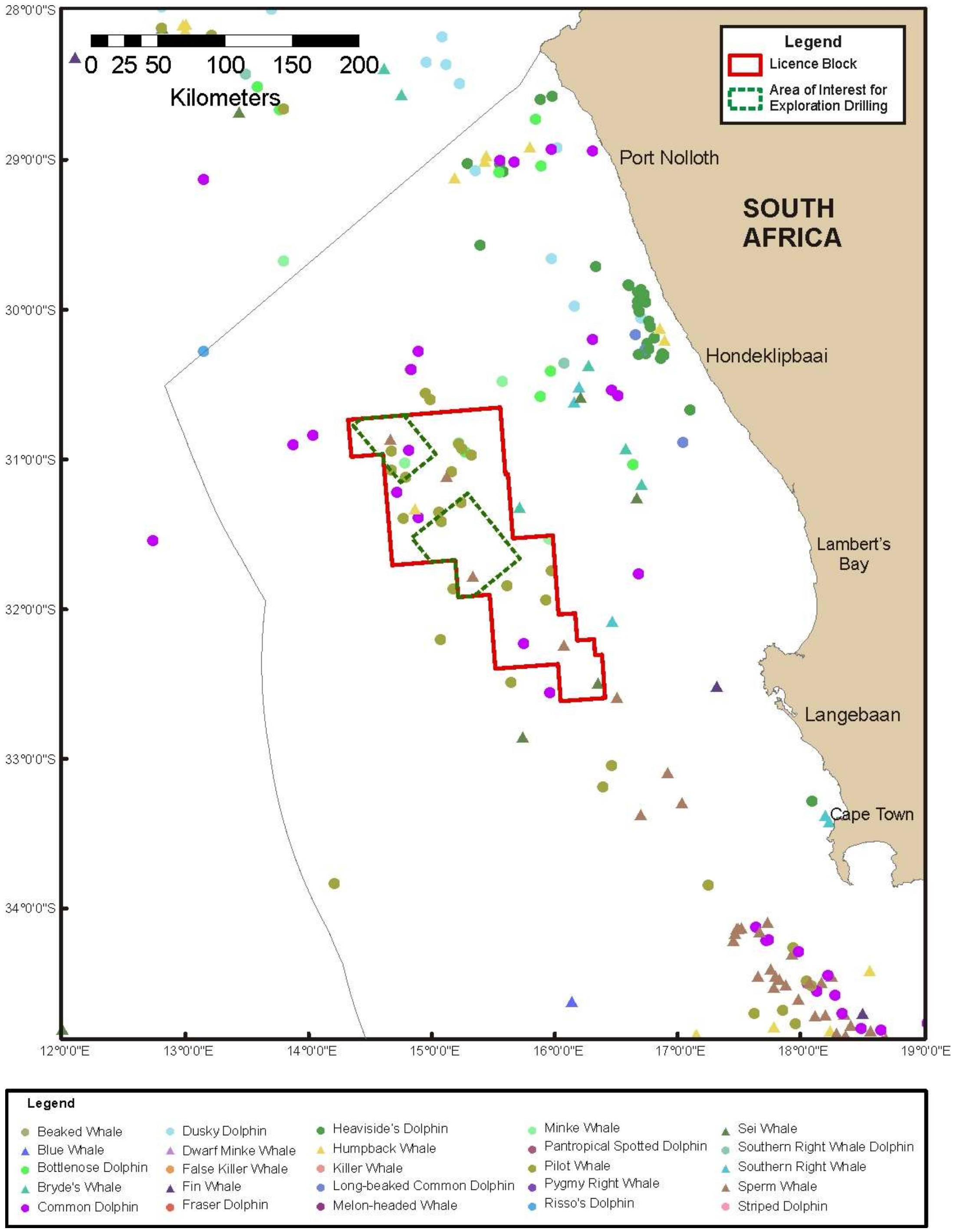

Figure 36a: Block 3B/4B (red polygon) in relation to the distribution and movement of cetaceans along the West and South Coasts collated between 2001 and 2020 (SLR MMO database). Note: Figure depicts MMO sightings from seismic surveys undertaken between 2001 and 2020.

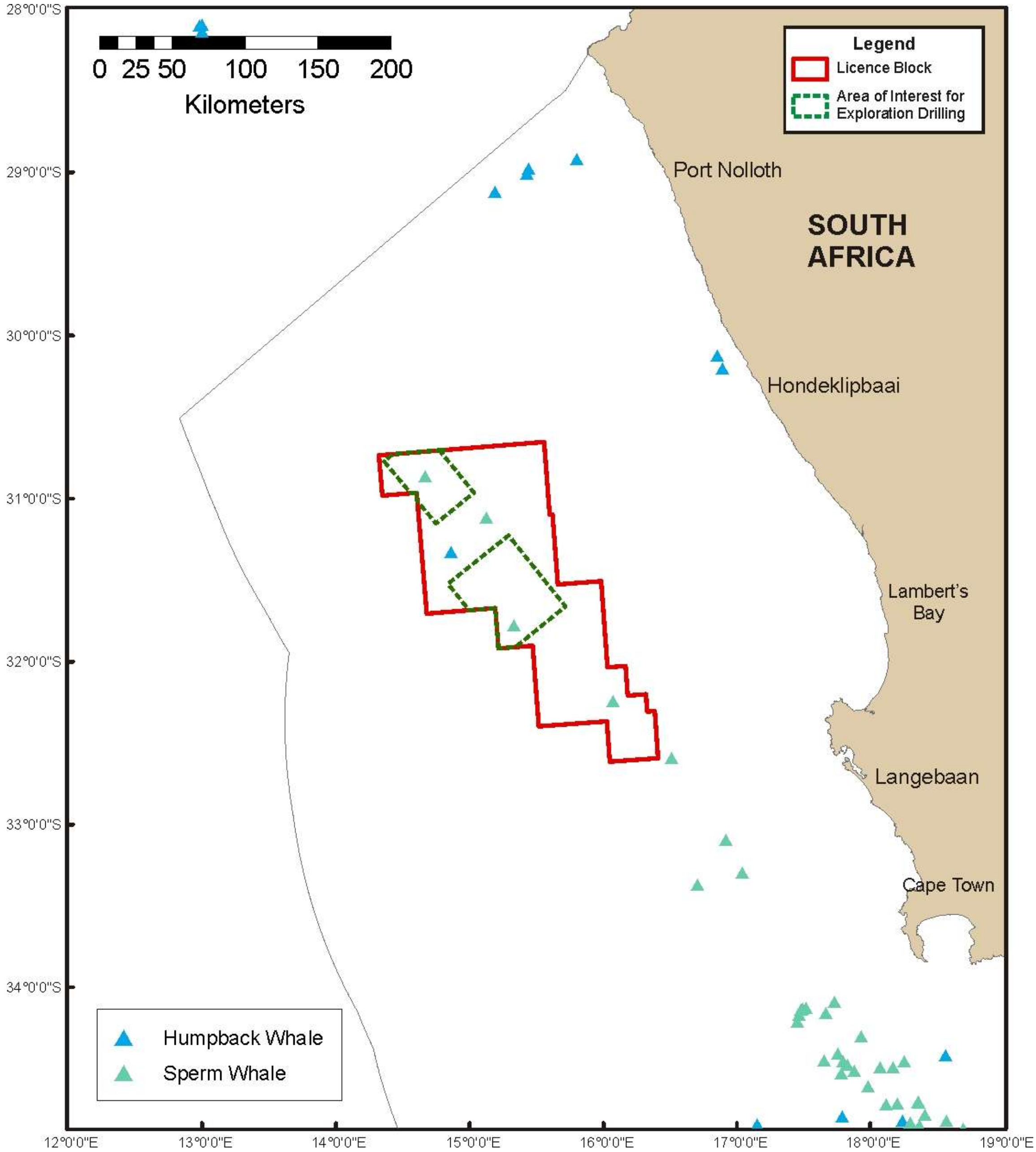

Figure 36b: Block 3B/4B (red polygon) in relation to the distribution and movement of Humpback whales and Sperm whales along the southern African coast collated between 2001 and 2020 (SLR MMO database).

Sei whales: Almost all information is based on whaling records 1958-1963, most from shore-based catchers operating within a few hundred km of Saldanha Bay. At this time the species was not well differentiated from Bryde's whales and records and catches of the two species intertwined. There is no current information on population recovery, abundance or much information on distribution patterns outside of the whaling catches and the species remains listed as 'Endangered' on the South African Red List. Sei whales feed at high latitudes (40-50˚S) during summer months and migrate north through South African waters to unknown breeding grounds further north (Best 2007). Their migration pattern thus shows a bimodal peak with numbers west of Saldanha Bay being highest in May and June, and again in August, September and October. All whales were caught in waters deeper than 200 m with most occurring deeper than 1 000 m (Best & Lockyer 2002). A recent survey to Vema Seamount ~1 000 km west of Cape Town during October to November 2019, encountered a broadly-spread feeding aggregation of over 30 sei and fin whales at around 200 m water depth (Elwen *et al.* in prep). This poorly surveyed area (roughly 32˚S, 15˚E) is just to the Northwest of the historic whaling grounds suggesting this region remains an important feeding area for the species. As sei whales have been reported by MMOs to the east of and within Block 3B/4B, encounters are possible.

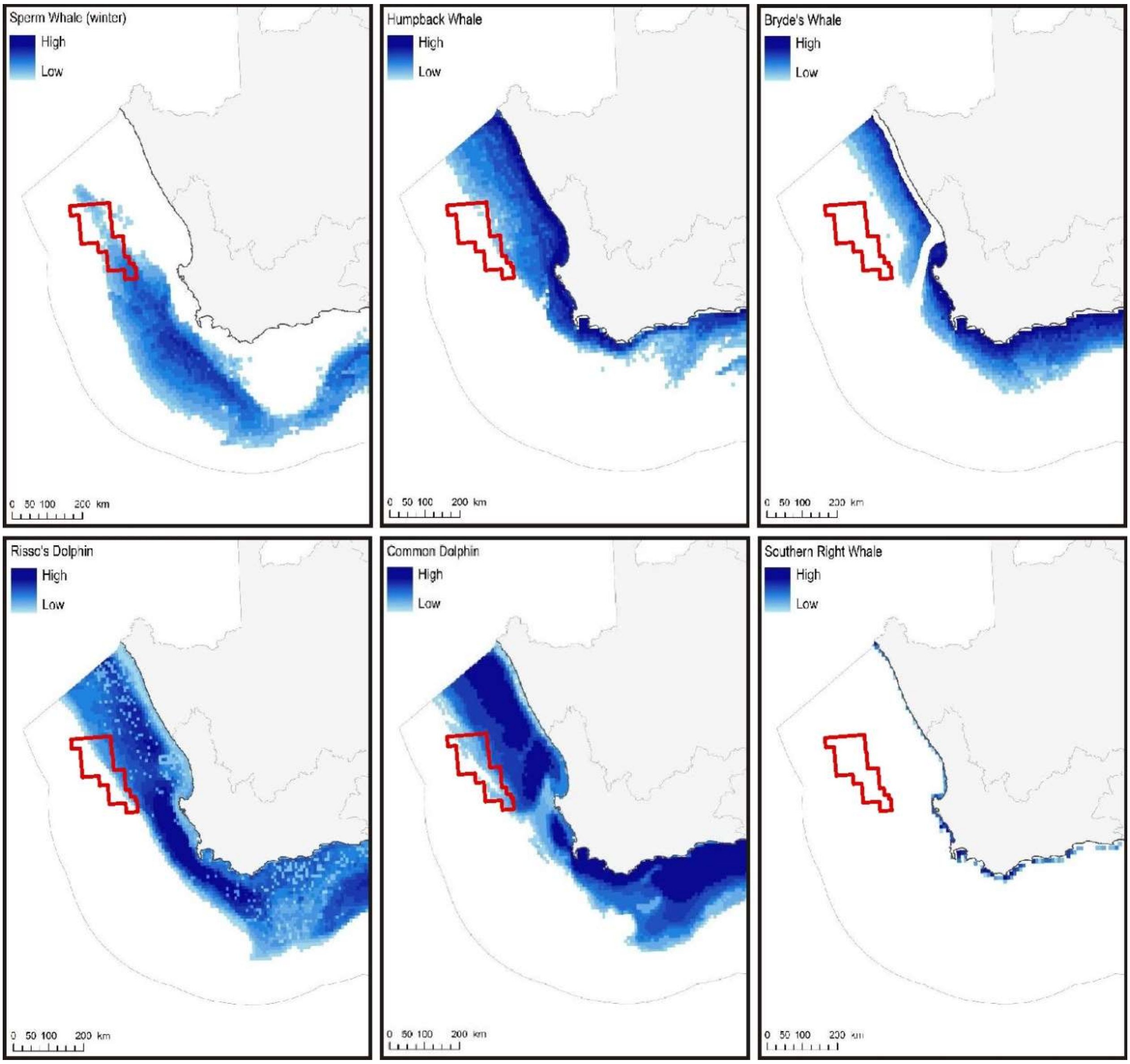

Figure 37: Block 3B/4B (red polygon) in relation to the predicted distribution of sperm whales (winter distribution)(top left), humpback whale (top middle), Bryde's whale (top right), Risso's dolphin (bottom left), common dolphin (bottom middle) and southern right whale (bottom right) with darker shades of blue indicating highest likelihood of occurrence (adapted from Harris *et al.* 2022).

Figure 38: The Bryde's whale *Balaenoptera brydei* (left) and the Minke whale *Balaenoptera bonaerensis* (right) (Photos: www.dailymail.co.uk; www.marinebio.org).

Fin whales: Fin whales were historically caught off the West Coast of South Africa, with a bimodal peak in the catch data suggesting animals were migrating further north during May-June to breed, before returning during August-October *en route* to Antarctic feeding grounds. 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). The occasional single whale has been reported during humpback whale research in November in the southern Benguela, and a feeding aggregation of ~30 animals was observed in November 2019 ~200 km west of St Helena Bay in ~2 000 m of water. Current sightings records support the bimodal peak in presence observed from whaling data (but with some chance of year-round sightings) with animals apparently feeding in the nutrient rich Benguela during their southward migration as is observed extensively for humpback and right whales (see below) there is clearly is a chance of encounters year round. There are no recent data on abundance or distribution of fin whales off western South Africa. The sighting of a fin whale was reported by MMOs during a 3D seismic survey in the Deep Water Orange Basin Area (CapFis 2013a). Encounters in the licence area are thus possible.

Blue whales: Although Antarctic blue whales were historically caught in high numbers off the South African West Coast, with a single peak in catch rates during July in Namibia and Angola suggesting that these latitudes are close to the northern migration limit for the species in the eastern South Atlantic (Best 2007). Although there were only two confirmed sightings of the species in the area between 1973 and 2006 (Branch *et al*. 2007), evidence of blue whale presence off Namibia is increasing. Recent acoustic detections of blue whales in the Antarctic peak between December and January (Tomisch *et al*. 2016) and off the South African West Coast (Shanbangu *et al*. 2019; Seakamela *et al*. 2022) and in northern Namibia between May and July (Thomisch 2017) support observed timing from whaling records. Several recent (2014-2015) sightings of blue whales during seismic surveys off the southern part of Namibia (water depth >1 000 m) confirm their existence in the area and occurrence in Autumn months (April to June). Blue whales have previously been sighted by MMOs in the Deep Water Orange Basin Area (CapFish 2013a) although the chance of encounters is considered low. As the species is 'Critically Endangered' all precautions must be taken to avoid impact.

Minke whales: Two forms of minke whale (Figure 38, right) occur in the southern Hemisphere, the Antarctic minke whale (*Balaenoptera bonaerensis*) and the dwarf minke whale (*B. acutorostrata* subsp.); both species occur in the Benguela (Best 2007). Antarctic minke whales range from the pack ice of Antarctica to tropical waters and are usually seen more than ~50 km offshore. Although adults migrate from the Southern Ocean (summer) to tropical/temperate waters (winter) to breed, some animals, especially juveniles, are known to stay in tropical/temperate waters year-round. Recent data available from passive acoustic monitoring over a two-year period off the Walvis Ridge (Namibia) shows acoustic presence in June - August and November - December (Thomisch *et al*. 2016), supporting a bimodal distribution in the area. 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 minkes have a similar migration pattern to Antarctic minkes with at least some animals migrating to the Southern Ocean during summer. 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 Block 3B/4B, although sightings have been reported in the general project area (SLR data). Thus, encounters within Block 3B/4B 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 with records from southern and central Namibia being the northern most for the species (Leeney *et al*. 2013). Its distribution off the West Coast of South Africa is thus likely to be limited to the cooler shelf waters of the main Benguela upwelling areas and encounters within Block 3B/4B may thus occur.

The most abundant baleen whales in the Benguela are southern right whales and humpback whales (Figure 39). Both species have long been known to feed in the Benguela Ecosystem and numbers since 2000 have grown substantially. The feeding peak in the Benguela is spring and early summer (October – February) and follows the ‘traditional’ South African breeding season (June – November) and its associated migration (Johnson *et al*. 2022). Some individual right whales are known to move directly from the south coast breeding area into the west coast feeding area where they remained for several months (Barendse *et al*. 2011; Mate *et al*. 2011). Increasing numbers of summer records of both species, from the southern half of Namibia suggest that animals may also be feeding in the Lüderitz upwelling cell (NDP unpubl. data).

Figure 39: The Humpback whale *Megaptera novaeangliae* (left) and the Southern Right whale *Eubalaena australis* (right) are the most abundant large cetaceans occurring along the southern African West Coast (Photos: www.divephotoguide.com; www.aad.gov.au).

Humpback whales: 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). Until recently it was believed that that these breeding grounds were functionally separate from those off east (Mozambique-Kenya-Madagascar), with only rare movements between them (Pomilla & Rosenbaum 2005) and movements to other continental breeding grounds being even more rare. Recent satellite tagging of animals between Plettenberg Bay and Port Alfred during the northward migration, showed them to turn around and end up feeding in the Southern Benguela

(Seakamela *et al.* 2015) before heading offshore and southwards using the same route as whales tracked off Gabon and the West Coast of South Africa. Unexpected results such as this highlight the complexities of understanding whale movements and distribution patterns and the fact that descriptions of broad season peaks in no way captures the wide array of behaviours exhibited by these animals. Furthermore, four separate matches have been made between individuals off South Africa and Brazil by citizen scientist photo-identification (www.happywhale.com; Ramos *et al.* 2023). This included whales from the Cape Town and Algoa Bay-Transkei areas. Analysis of humpback whale breeding song on Sub-Antarctic feeding grounds also suggests exchange of singing male whales from western and eastern South Atlantic populations (Darling & Sousa-Lima 2005; Schall *et al.* 2021; but see also Darling *et al.* 2019; Tyarks *et al.* 2021).

In southern African coastal waters, the northward migration stream is larger than the southward peak (Best & Allison 2010; Elwen *et al.* 2014), suggesting that animals migrating north strike the coast at varying places north of St Helena Bay, resulting in increasing whale density on shelf waters and into deeper pelagic waters as one moves northwards. On the southward migration, many humpbacks 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.* 2014; Rosenbaum *et al.* 2014). 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). The only available abundance estimate put the number of animals in the West African breeding population (Gabon) to be in excess of 9 000 individuals in 2005 (IWC 2012) and it is likely to have increased substantially since this time at about 5% per annum (IWC 2012; see also Wilkinson 2021). The number of humpback whales feeding in the southern Benguela has increased substantially since estimates made in the early 2000s (Barendse *et al.* 2011). Since ~2011, 'supergroups' of up to 200 individual whales have been observed feeding within 10 km from shore (Findlay *et al.* 2017) with many hundred more passing through and whales are now seen in all months of the year around Cape Town. It has been suggested that the formation of these super-groups may be in response to anomalous oceanographic conditions in the Southern Benguela, which result in favourable food availability, thereby leading to these unique humpback whale feeding aggregations (Dey *et al.* 2021; see also Avila *et al.* 2019; Meynecke *et al.* 2020; Cade *et al.* 2021). Humpback whales are thus likely to be the most frequently encountered baleen whale in the project area (see Figure 36b; Figure 37), ranging from the coast out beyond the shelf, with year round presence but numbers peaking during the northward migration in June – February 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. Humpback whale sightings have been reported by MMOs during a 2012 3D seismic survey in the adjacent Deep Water Orange Basin Area (CapFish 2013a) and encounters within Block 3B/4B are thus likely.

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 South African west 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 (Siciliano *et al.* 2013) was linked to possible infectious disease or malnutrition. 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 40: Block 3B/4B (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).

Southern right whales: The southern African population of southern right whales historically extended from southern Mozambique (Maputo Bay) to southern Angola (Baie dos Tigres) and is considered to be a single population within this range (Roux *et al*. 2011). The most recent abundance estimate 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 in 1920, the range contracted down to just the south coast of South Africa, but as the population recovers, it is repopulating its historic grounds including Angola (Whitt *et al*. 2023), Namibia (Roux *et al*. 2001, 2015; de Rock *et al*. 2019) and Mozambique (Banks *et al*. 2011).

Some southern right whales move from the South Coast breeding ground directly to the West Coast feeding ground (Mate *et al*. 2011). When departing from feeding ground all satellite tagged animals in that study took a direct south-westward track, which would take them across the southern portion of Block 3B/4B. Mark-recapture data from 2003-2007 estimated roughly one third of the South African right whale population at that time were using St Helena Bay for feeding (Peters *et al.* 2005). While annual surveys have revealed a steady population increase since the protection of the species from commercial whaling, the South African right whale population has undergone substantial changes in breeding cycles and feeding areas (Van Den Berg *et al.* 2020), and numbers of animal using our coast since those studies were done – notably a significant decrease in the numbers of cow-calf-pairs following the all-time record in 2018, a marked decline of unaccompanied adults since 2010 and variable presence of mother-calf pairs since 2015 (Roux *et al.* 2015; Vermeulen *et al.* 2020). The change in demographics are indications of a population undergoing nutritional stress and has been attributed to likely spatial and/or temporal displacement of prey due to climate variability (Vermeulen *et al.* 2020; see also Derville *et al.* 2019; Kershaw *et al.* 2021; van Weelden *et al.* 2021). Recent sightings (2018-2021) confirm that there is still a clear peak in numbers on the West Coast (Table Bay to St Helena Bay) between February and April. Given this high proportion of the population known to feed in the southern Benguela, and current numbers reported, it is highly likely that several hundreds of right whales can be expected to pass through the southern portion of Block 3B/4B when migrating southwards from the feeding areas between April and June (Figure 40).

Odontocetes (toothed) whales and dolphins

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 (see Figure 35). Those in the region can range in size from 1.6-m long (Heaviside’s dolphin) to 17 m (bull sperm whale).

Sperm whales: Most information about sperm whales in the southern African sub-region results from data collected during commercial whaling activities prior to 1985 when over 10 000 whales were taken, (Best 1974; Best 2007) although passive acoustic monitoring (Shabangu & Andrew 2020) and sightings from MMOs are beginning to provide insights into current behaviour. 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 onto the shelf in water 500 - 200 m deep (Best 2007) (

Figure 41, left). They are considered to be relatively abundant globally (Whitehead 2002), although no estimates are available for South African waters. Seasonality of historical 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). Analysis of recent passive acoustic monitoring data from the edge of the South African continental shelf (800 – 1 000 m water depth, roughly 80 km WSW of Cape Point) confirms year-round presence. Sperm whales have also been regularly identified by Marine Mammal Observers (MMOs) working in this area (see Figure 35b). Sperm whales feed at great depths during dives in excess of 30 minutes making them difficult to detect visually, however, the regular echolocation clicks made by the species when diving make them relatively easy to detect acoustically using Passive Acoustic Monitoring (PAM). Sperm whales were the most commonly reported species sighted by MMOs and detected with PAM during 2D and 3D seismic surveys undertaken in the adjacent Deep Water Orange Basin Area (CapFish 2013a, 2013b).

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 (>200 m) off the shelf of the southern African West Coast. Beaked whales are all considered to be true deep water species usually being seen in waters in excess of 1 000 – 2 000 m deep (see various species accounts in

Best 2007). Presence in the project area may fluctuate seasonally, but insufficient data exist to define this clearly. 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.

Figure 41: Sperm whales *Physeter macrocephalus* (left) and killer whales *Orcinus orca* (right) are toothed whales likely to be encountered in offshore waters (Photos: www.onpoint.wbur.org; www.wikipedia.org).

Pygmy and Dwarf Sperm Whales: The genus *Kogia* currently contains two recognised species, the pygmy (*K. breviceps*) and dwarf (*K. sima*) 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). Their abundance and population trends in South African waters are unknown (Seakamela *et al.* 2021). Due to their small body size, cryptic behaviour, low densities 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 leas to the genus) using passive acoustic monitoring equipment. The majority of what is known about the distribution and ecology of Kogiid whales in the southern African subregion is derived mainly from stranding records (e.g. Ross 1979; Findlay *et al.* 1992; Plön 2004; Elwen *et al.* 2013, but see also Moura *et al.* 2016). *Kogia* species most frequently occur in pelagic and shelf edge waters, and are thus likely to occur in Block 3B/4B at low levels. 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.

During 2020 the incidence of kogiid strandings between Strandfontein on the West Coast and Groot Brak River on the South Coast (n=17), was considerably higher than the annual average during the previous 10 years (n=7). The dwarf sperm whale (*K. sima*) accounted for 60% of these strandings, of which most were recorded during autumn and winter. These seasonal stranding patterns are consistent with previously published accounts for the South African coast. In 2020, 40% of the total strandings were recorded in winter and 15% during summer. The occurrence of strandings throughout the year may, however, indicate the presence of a resident population with a seasonal distributiuon off the South Coast in autumn and winter (Seakamela *et al*. 2020, 2021). The cause of the strandings is unknown.

Killer whales: Killer whales in South African waters were referred to a single morphotype, Type A, although recently a second 'flat-toothed' morphotype that seems to specialise in an elasmobranch diet has been identified but only 5 records are known all from strandings (Best *et al*. 2014). Killer whales (

Figure 41) 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 South Africa (Best *et al*. 2010, Elwen *et al*. in prep), Namibia (Elwen & Leeney 2011) and in the Eastern Tropical Atlantic (Weir *et al*. 2010). Historically sightings were correlated with that of baleen whales, especially sei whales on their southward migration. In more recent years – their presence in coastal waters (e.g. False Bay) has been strongly linked to the presence and hunting of common dolphins (Best *et al*. 2010; Sea Search unpublished data) and great white sharks (Towner *et al*. 2022). Further from shore, there have been regular reports of killer whales associated with long-line fishing vessels on the southern and eastern Agulhas Bank, and the Cape Canyon to the south-west of Cape Point. Killer whales are found in all depths from the coast to deep open ocean environments and may thus be encountered in the project area at low levels.

False killer whale: Although the false killer whale is globally recognized as one species, 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). False killer whales are more likely to be confused with the smaller melon-headed or pygmy killer whales with which they share all-black colouring and a similar head-shape, than with killer whales. The species has a tropical to temperate distribution and most sightings off southern Africa have occurred in water deeper than 1 000 m, but with a few recorded close to shore (Findlay *et al*. 1992). They usually occur in groups ranging in size from 1 - 100 animals (Best 2007). 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, all between St Helena Bay and Cape Agulhas). There is no information on population numbers or conservation status and no evidence of seasonality in the region (Best 2007). Encounters within the project area may occur.

Pilot Whales: Long finned pilot whales display a preference for temperate waters and are usually associated with the continental shelf or deep water adjacent to it but moving inshore to follow prey (primarily squid) (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. The distinction between long-finned and short finned pilot whales is difficult to make at sea. As the latter are regarded as more tropical species confined to the southwest Indian Ocean (Best 2007), it is likely that the majority of pilot whales encountered in the project area will be long-finned. There are many confirmed sighting of pilot whales along the shelf edge of South Africa and Namibia including within the project area since 2010 (de Rock *et al*. 2019; Sea Search unpublished data, SLR data, CapFish 2013a, 2013b). Observed group sizes range from 8-100 individuals (Seakamela *et al*. 2022). Pilot whales were commonly sighting by MMOs and detected by PAM during 2D and 3D seismic surveys in the adjacent Deep Water Orange Basin Area (CapFish 2013a, 2013b). A recent tagging study showed long-finned pilot whale movements within latutudes of 33-36°S, along the shelf-edge from offshore of Cape Columbine to the Agulhas Bank, with concentrations in canyon areas, especially around the Cape Point Valley, and to a lesser degree around the Cape Canyon. It is postulated that the pilot whales target prey species in these productive areas (Seakamela *et al*. 2022).

Common dolphin: 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 MMO sightings suggest presence to 1 000 m or more (SLR data, Sea Search data). Group sizes of common dolphins can be large, averaging 267 (± *SD* 287) for the South Africa region (Findlay *et al*. 1992). 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 in the Northern Cape or deeper than 2 000 m are of the short-beaked form. Sightings of common dolphins were reported by MMOs during the 2012/13 3D seismic survey in the adjacent Deep Water Orange Basin Area (CapFish 2013a). Encounters in Block 3B/4B are thus likely to occur.

Dusky dolphin: In water <500 m deep, dusky dolphins (Figure 42, right) are likely to be the most frequently encountered small cetacean as they are very "boat friendly" and often approach vessels to bowride. The species is resident year round throughout the Benguela ecosystem in waters from the coast to at least 500 m deep (Findlay *et al*. 1992). A recent abundance estimate from southern Namibia calculated roughly ~3 500 dolphins in the ~400 km long Namibian Islands Marine Protected area (Martin *et al*. 2020), at a density of 0.16 dolphins/km^2 and similar density is expected to occur off the South African coast where they are regularly encountered in nearshore waters between Cape Town and Lamberts Bay (Elwen *et al*. 2010; NDP unpubl. data) with group sizes of up to 800 having been reported (Findlay *et al*. 1992). Encounters in the offshore waters of Block 3B/4B are unlikely.

Figure 42: The dusky dolphin *Lagenorhynchus obscurus* (left) and endemic Heaviside's Dolphin *Cephalorhynchus heavisidii* (right) (Photos: Simon Elwen, Sea Search Research and Conservation).

Heaviside's dolphins: Heaviside's dolphins (Figure 42, left) are relatively abundant in the Benguela ecosystem region with 10 000 animals estimated to live in the 400 km of coast between Cape Town and Lamberts Bay (Elwen *et al*. 2009) and ~1 600 in the ~400 km long Namibian Islands Marine Protected Area (Martin *et al*. 2020). This species occupies waters from the coast to at least 200 m depth, (Elwen *et al*. 2006; Best 2007; Martin *et al*. 2020), and may show a diurnal onshore-offshore movement pattern (Elwen *et al*. 2010a, 2010b), as they feed offshore at night. Heaviside's dolphins are resident year-round but will mostly occur inshore of Block 3B/4B.

Bottlenose dolphin: Two species of bottlenose dolphins occur around southern Africa. The smaller Indo-Pacific bottlenose dolphin (*aduncus* form) occurs exclusively to the east of Cape Point in water usually less than 50 m deep and generally within 1 km of the shore (Ross 1984; Ross *et al*. 1987). The larger common bottlenose dolphin (*truncatus* form) is widely distributed in tropical and temperate waters throughout the world, but frequently occur in small (10s to low 100s) isolated coastal populations. 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. Encounters in the offshore waters of Block 3B/4B are likely to be low.

Risso's Dolphin: A medium sized dolphin with a distinctively high level of scarring and a proportionally large dorsal fin and blunt head. Risso's dolphins are distributed worldwide in tropical and temperate seas and show a general preference for shelf edge waters <1 500 m deep (Best 2007; Purdon *et al*. 2020a, 2020b). Many sightings in southern Africa have occurred around the Cape Peninsula and along the shelf edge of the Agulhas bank. Presence within Block 3B/4B is possible (see also Figure 37).

Other Delphinids: Several other species of dolphins that might occur in deeper waters at low levels include the pygmy killer whale, southern right whale dolphin, rough toothed dolphin, pantropical spotted dolphin and striped dolphin (Findlay *et al*. 1992; Best 2007). Nothing is known about the population size or density of these species in the project area but encounters are likely to be rare.

Beaked whales: These whales were never targeted commercially and their pelagic distribution makes them the most poorly studied group of cetaceans. They are all considered to be true deep-water species usually being seen in waters in excess of 1 000 – 2 000 m deep (see various species accounts in Best 2007). 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). 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 are frequently echo-locating when on foraging dives. 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 mid-frequency naval sonar (Cox *et al*. 2006; MacLeod & D'Amico 2006) and a seismic survey for hydrocarbons also running a low frequency multi-beam echo-sounder and sub bottom profiler (Southall *et al*. 2008; Cox *et al*. 2006; DeRuiter *et al*. 2013). Although the exact reason that beaked whales seem particularly vulnerable to man-made noise is not yet fully understood, existing evidence suggests that animals change their dive behaviour in response to acoustic disturbance (Tyack *et al*. 2011), showing a fear-response and surfacing too quickly with insufficient time to release nitrogen resulting in a form on decompression sickness. Necropsy of stranded animals has revealed gas embolisms and haemorrhage in the brain, ears and acoustic fat - injuries consistent with decompression sickness (acoustically mediated bubble formation) (Fernandez *et al*. 2005). Beyond decompression sickness, the fear/flee response may be the first stage in a multi-stage process ultimately resulting in stranding (Southall *et al*. 2008; Jepson *et al*. 2013). This type of stranding event has been linked to both naval sonar and low frequency multi-beam echosounders used for commercial-scale side scan sonar (Southall *et al*. 2008). Thus, although hard to detect and avoid, beaked whales are amongst the most sensitive marine mammals to noise exposure and all cautions must be taken to reduce impact. Sightings of beaked whales in the project area are expected to be very low.

All whales and dolphins are given protection under the South African Law. The Marine Living Resources Act, 1998 (No. 18 of 1998) states that no whales or dolphins may be harassed, killed or fished. No vessel or aircraft may, without a permit or exemption, approach closer than 300 m to any whale and a vessel 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.

3.3.3.7 Seals (Pinnipeds)

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 43) 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 52). The South African population, which includes the West Coast colonies, was estimated at ca. 725 000 individuals in 2020. This is about 40% of the total southern African population, which has previously been estimated at up to 2 million (Seakamela *et al*. 2022). Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* subantarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989).

Figure 43: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich).

There are a number of Cape fur seal breeding colonies within the broader study area: at Bucchu Twins near Alexander Bay, at Cliff Point (~17 km north of Port Nolloth), at Kleinzee (incorporating Robeiland), Strandfontein Point (south of Hondeklipbaai), Paternoster Rocks and Jacobs Reef at Cape Columbine, Vondeling Island, Robbesteen near Koeberg and Seal Island in False Bay. The colony at Kleinzee has the highest seal population and produces the highest seal pup numbers on the South African Coast (Wickens 1994). The closest breeding colonies to Block 3B/4B are at Bucchu Twins, Cliff Point, Kleinzee, Strandfontein Point and Cape Columbine located between 150 km and 250 km inshore of the Block.

Non-breeding colonies and haul-out sites occur at Doringbaai south of Cliff Point, Rooiklippies, Swartduin and Noup between Kleinzee and Hondeklipbaai, at Spoeg River and Langklip south of Hondeklip Bay, on Bird Island at Lambert's Bay, at Paternoster Point at Cape Columbine and Duikerklip in Hout Bay. These colonies all fall well inshore and to the east of Block 3B/4B, although overlap with foraging trips may occur in the inshore portions of the licence area.

Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles offshore (Shaughnessy 1979), with bulls ranging further out to sea than females (Figure 44). Their diet varies with season and availability and includes pelagic species such as horse mackerel, pilchard, and hake, as well as squid and cuttlefish. Although Cape fur seals are primarily epipelagic foragers, some degree of geographic and temporal variation in resource and habitat use have been demonstrated (Botha *et al*. 2023). Benthic feeding to depths of up to 454 m has been recorded in females from the Kleinzee colony on the West Coast, with individual modal dive durations of 0.2 – 5.6 minutes (Kirkman *et al*. 2015; Kirkman *et al*. 2019). Botha *et al*. (2020) reported diel foraging patterns in females from the Kleinzee and False Bay colonies, with dive depth and benthic foraging increasing during daylight hours likely reflecting the vertical movements of prey species.

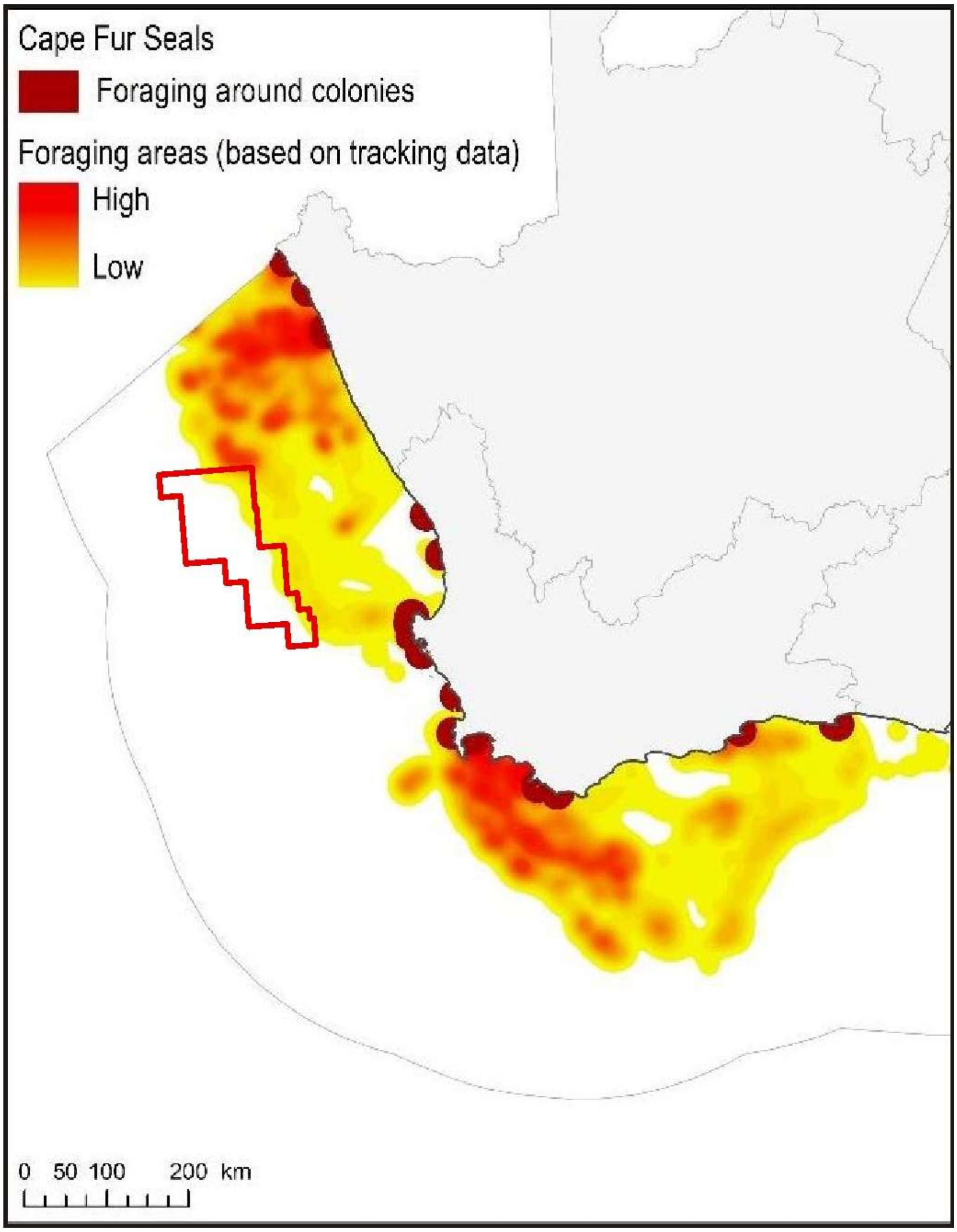

Figure 44: Block 3B/4B (red polygon) in relation to seal foraging areas on the West and South Coasts. Brown areas are generalised foraging areas around colonies, and areas in shades of red are foraging areas based on tracking data. Darker shades of red indicate areas of higher use (Adapted from Harris *et al*. 2022).

The timing of the annual breeding cycle is very regular, occurring between November and January, after which the breeding colonies break up and disperse. 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).

Historically the Cape fur seal was heavily exploited for its luxurious pelt. Sealing restrictions were first introduced to southern Africa in 1893, and harvesting was controlled until 1990 when it was finally prohibited. The protection of the species has resulted in the recovery of the populations, and numbers continue to increase. Consequently, their conservation status is not regarded as threatened. The Cape Fur Seal population in South Africa is regularly monitored by the Department of Forestry, Fisheries and Environment (DFFE) (e.g. Kirkman *et al*. 2013). The overall population is considered healthy and stable in size, although there has been a westward and northward shift in the distribution of the breeding population (Kirkman *et al*. 2013).

An unprecedented mortality event was recorded in South Africa 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).

3.3.4 Coastal Communities

The coastline of the broader project area is characterised by a mixture of intertidal sandy beaches and rocky shores, but also estuaries, rocky subtidal habitats and kelp beds. These were categorised into ecosystem types by Sink et al. (2019) and assigned a threat status depending on their geographic extent and extent of ecosystem degradation.

Table 10 summarises the threat status of these ecosystem types in the broader project area.

A general description of intertidal and shallow subtidal habitats on the West Coast is provided below. Although well inshore of Block 3B/4B and unlikely to be directly impacted by proposed exploration drilling operations, these habitats fall into the area of indirect influence possibly affected in the event of an oil spill.

Table 10: Threat status of the intertidal and shallow subtidal ecosystem types in the broader project area (Sink *et al*. 2019).

Ecosystem Type	2019 Threat Status
Agulhas Boulder Shore	Near threatened
Agulhas Dissipative Intermediate Sandy Shore	Least Concern
Agulhas Dissipative Sandy Shore	Near threatened
Agulhas Exposed Rocky Shore	Vulnerable
Agulhas Exposed Stromatolite Rocky Shore	Vulnerable
Agulhas Intermediate Sandy Shore	Least Concern
Agulhas Island	Vulnerable
Agulhas Kelp Forest	Vulnerable
Agulhas Mixed Shore	Near threatened
Agulhas Reflective Sandy Shore	Vulnerable

Ecosystem Type	2019 Threat Status
Agulhas Sheltered Rocky Shore	Endangered
Agulhas Stromatolite Mixed Shore	Vulnerable
Agulhas Very Exposed Rocky Shore	Vulnerable
Agulhas Very Exposed Stromatolite Rocky Shore	Near threatened
Cape Bay	Endangered
Cape Boulder Shore	Vulnerable
Cape Exposed Rocky Shore	Vulnerable
Cape Island	Endangered
Cape Kelp Forest	Vulnerable
Cape Mixed Shore	Vulnerable
Cape Sheltered Rocky Shore	Endangered
Cape Very Exposed Rocky Shore	Near threatened
Eastern Agulhas Bay	Vulnerable
False and Walker Bay	Vulnerable
Namaqua Exposed Rocky Shore	Vulnerable
Namaqua Kelp Forest	Vulnerable
Namaqua Mixed Shore	Vulnerable
Namaqua Sheltered Rocky Shore	Vulnerable
Namaqua Very Exposed Rocky Shore	Vulnerable
Southern Benguela Dissipative Intermediate Sandy Shore	Least Concern
Southern Benguela Dissipative Sandy Shore	Least Concern
Southern Benguela Intermediate Sandy Shore	Near threatened
Southern Benguela Reflective Sandy Shore	Endangered
St Helena Bay	Vulnerable
Western Agulhas Bay	Endangered

3.3.4.1 Intertidal Sandy Beaches

Sandy beaches are one of the most dynamic coastal environments. With the exception of a few beaches in large bay systems (such as St Helena Bay, Saldanha Bay, Table Bay), the beaches along the South African West Coast are typically highly exposed. Exposed sandy shores consist of coupled surf-zone, beach and dune systems, which together form the active littoral sand transport zone (Short & Hesp 1985). The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope and sand particle size, which is termed beach morphodynamics. Three morphodynamic beach types are described: dissipative, reflective and intermediate beaches (McLachlan *et al*. 1993). Generally, dissipative beaches are relatively wide and flat with fine sands and low wave energy. Waves start to break far from the shore in a series of spilling breakers that 'dissipate' their energy along a broad surf zone. This generates slow swashes with long periods, resulting in less turbulent conditions on the gently sloping beach face. These beaches usually harbour the richest intertidal faunal communities. Reflective beaches in contrast, have high wave energy, and are coarse grained (>500 µm sand) with narrow and steep intertidal beach faces. The relative absence of a surf-zone causes the waves to break directly on the shore causing a high turnover of sand. The result is depauperate faunal communities. Intermediate beach conditions exist between these extremes and have a very variable species composition (McLachlan *et al*. 1993; Jaramillo *et al*. 1995, Soares 2003). This variability is mainly attributable to the amount and quality of food available. Beaches with a high input of e.g. kelp wrack have a rich and diverse drift-line fauna, which is sparse or absent on beaches lacking a drift-line (Branch & Griffiths 1988). As a result of the combination of typical beach characteristics, and the special adaptations of beach fauna to these, beaches act as filters and energy recyclers in the nearshore environment (Brown & McLachlan 2002).

Numerous methods of classifying beach zonation have been proposed, based either on physical or biological criteria. The general scheme proposed by Branch & Griffiths (1988) is used below (Figure 45), supplemented by data from various publications on West Coast sandy beach biota (e.g. Bally 1987; Brown *et al*. 1989; Soares *et al*. 1996, 1997; Nel 2001; Nel *et al*. 2003; Soares 2003; Branch *et al*. 2010; Harris 2012). The macrofaunal communities of sandy beaches are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone. Due to the exposed nature of the coastline in the study area, most beaches are of the intermediate to reflective type. The upper beach dry zone (supralittoral) is situated above the high water spring (HWS) tide level, and receives water input only from large waves at spring high tides or through sea spray. This zone is characterised by a mixture of air breathing terrestrial and semi-terrestrial fauna, often associated with and feeding on kelp deposited near or on the driftline. Terrestrial species include a diverse array of beetles and arachnids and some oligochaetes, while semi-terrestrial fauna include the oniscid isopod *Tylos granulatus*, and amphipods of the genus *Talorchestia*. The mid-beach retention zone and low-beach saturation zone (intertidal zone or mid-littoral zone) has a vertical range of about 2 m. This mid-shore region is characterised by the cirolanid isopods *Pontogeloides latipes*, *Eurydice* (*longicornis*=) *kensleyi*, and *Excirolana natalensis*, the polychaetes *Scolelepis squamata*, *Orbinia angrapequensis*, *Nepthys hombergii* and *Lumbrineris tetraura*, and amphipods of the families Haustoridae and Phoxocephalidae (Figure 46). In some areas, juvenile and adult sand mussels *Donax serra* may also be present in considerable numbers.

The surf zone (inner turbulent and transition zones) extends from the Low Water Spring mark to about -2 m depth. The mysid *Gastrosaccus psammodytes* (Mysidacea, Crustacea), the ribbon worm *Cerebratulus fuscus* (Nemertea), the cumacean *Cumopsis robusta* (Cumacea) and a variety of polychaetes including *Scolelepis squamata* and *Lumbrineris tetraura*, are typical of this zone, although they generally extend partially into the midlittoral above. In areas where a suitable swash climate exists, the gastropod *Bullia digitalis* (Gastropoda, Mollusca) may also be present in considerable numbers, surfing up and down the beach in search of carrion.

The transition zone spans approximately 2 - 5 m depth beyond the inner turbulent zone. Extreme turbulence is experienced in this zone, and as a consequence this zone typically harbours the lowest diversity on sandy beaches. Typical fauna include amphipods such as *Cunicus profundus* and burrowing polychaetes such as *Cirriformia tentaculata* and *Lumbrineris tetraura*.

The outer turbulent zone extends beyond the surf zone and below 5 m depth, where turbulence is significantly decreased and species diversity is again much higher. In addition to the polychaetes found in the transition zone, other polychaetes in this zone include *Pectinaria capensis*, and *Sabellides ludertizii*. The sea pen V*irgularia schultzi* (Pennatulacea, Cnidaria) is also common as is a host of amphipod species and the three spot swimming crab *Ovalipes punctatus* (Brachyura, Crustacea).

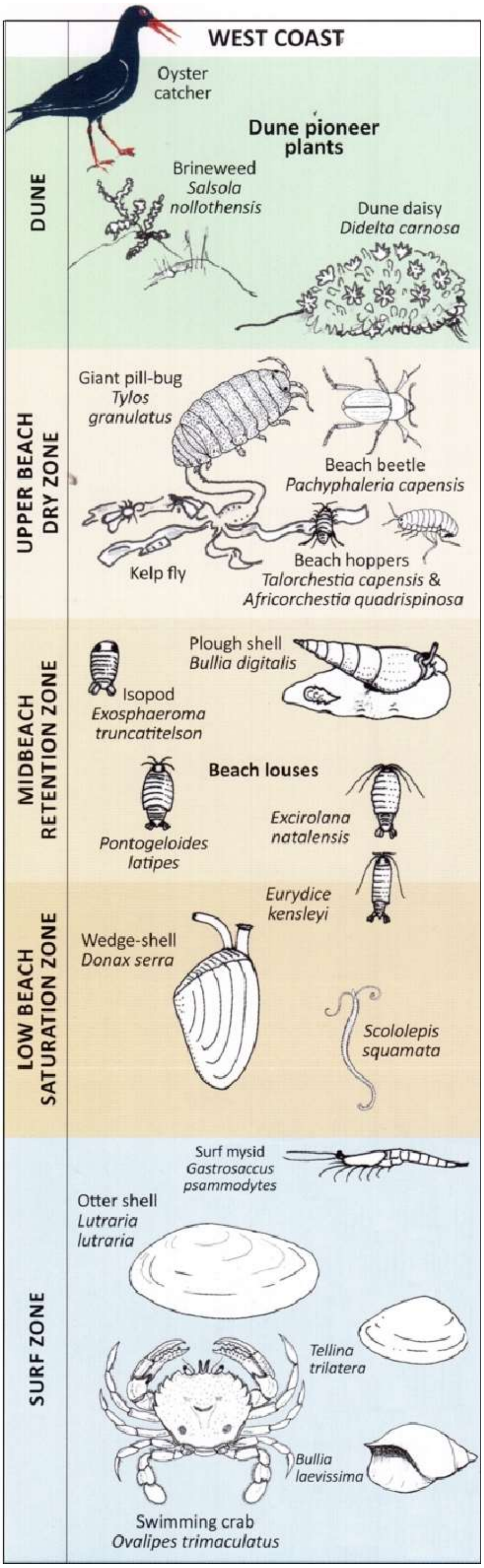

Figure 45: Schematic representation of the West Coast intertidal beach zonation (adapted from Branch & Branch 2018).

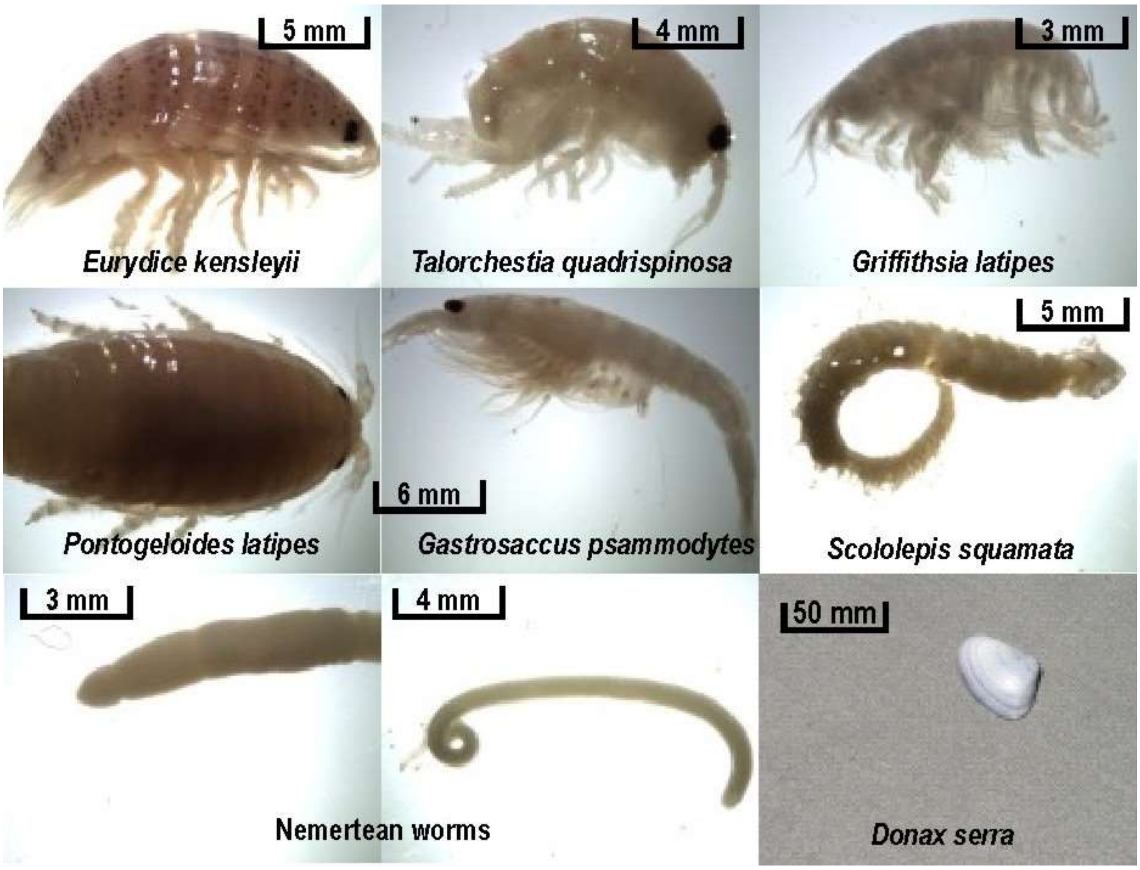

Figure 46: Common beach macrofaunal species occurring on exposed West Coast beaches.

3.3.4.2 Intertidal Rocky Shores

The following general description of the intertidal and subtidal habitats for the West Coast is based on Field *et al.* (1980), Branch & Griffiths (1988), Field & Griffiths (1991) and Branch & Branch (2018).

Several studies on the west coast of southern Africa have documented the important effects of wave action on the intertidal rocky-shore community. Specifically, wave action enhances filter-feeders by increasing the concentration and turnover of particulate food, leading to an elevation of overall biomass despite low species diversity (McQuaid & Branch 1985, Bustamante & Branch 1995, 1996a, Bustamante *et al.* 1997). Conversely, sheltered shores are diverse with relatively low biomass, and only in relatively sheltered embayments does drift kelp accumulate and provide a vital support for very high densities of kelp trapping limpets, such as *Cymbula granatina* that occur exclusively there (Bustamante *et al.* 1995). In the subtidal, these differences diminish as wave exposure is moderated with depth.

West Coast rocky intertidal shores can be divided into five zones on the basis of their characteristic biological communities: The Littorina, Upper Balanoid, Lower Balanoid, Cochlear/Argenvillei and the Infratidal Zones. These biological zones correspond roughly to zones based on tidal heights (Figure 47 and Figure 48). Tolerance to the physical stresses associated with life on the intertidal, as well as biological interactions such as herbivory, competition and predation interact to produce these five zones.

The uppermost part of the shore is the supralittoral fringe, which is the part of the shore that is most exposed to air, perhaps having more in common with the terrestrial environment. The supralittoral is characterised by low species diversity, with the tiny periwinkle *Afrolittorina knysnaensis*, and the red alga *Porphyra capensis* constituting the most common macroscopic life.

The upper mid-littoral is characterised by the limpet *Scutellastra granularis*, which is present on all shores. The gastropods *Oxystele variegata*, *Nucella dubia*, and *Helcion pectunculus* are variably present, as are low densities of the barnacles *Tetraclita serrata*, *Octomeris angulosa* and *Chthalamus dentatus*. Flora is best represented by the green algae *Ulva* spp.

Toward the lower Mid-littoral or Lower Balanoid zone, biological communities are determined by exposure to wave action. On sheltered and moderately exposed shores, a diversity of algae abounds with a variable representation of: green algae – *Ulva* spp, *Codium* spp.; brown algae – *Splachnidium rugosum*; and red algae – *Aeodes orbitosa*, *Mazzaella (=Iridaea) capensis*, *Gigartina polycarpa* (=*radula*), *Sarcothalia* (=*Gigartina*) *stiriata*, and with increasing wave exposure *Plocamium rigidum* and *P. cornutum*, and *Champia lumbricalis*. The gastropods *Cymbula granatina* and *Burnupena* spp. are also common, as is the reef building polychaete *Gunnarea capensis*, and the small cushion starfish *Patiriella exigua*. On more exposed shores, almost all of the primary space can be occupied by the dominant alien invasive mussel *Mytilus galloprovincialis*. First recorded in 1979 (although it is likely to have arrived in the late 1960's), it is now the most abundant and widespread invasive marine species spreading along the entire West Coast and parts of the South Coast (Robinson *et al*. 2005). *M. galloprovincialis* has partially displaced the local mussels *Choromytilus meridionalis* and *Aulacomya ater* (Hockey & Van Erkom Schurink 1992), and competes with several indigenous limpet species (Griffiths *et al*. 1992; Steffani & Branch 2003a, b). Recently, another alien invasive has been recorded, the acorn barnacle *Balanus glandula*, which is native to the west coast of North America where it is the most common intertidal barnacle. The presence of *B. glandula* in South Africa was only noticed a few years ago as it had always been confused with the native barnacle *Cthamalus dentatus* (Simon-Blecher *et al*. 2008). There is, however, evidence that it has been in South Africa since at least 1992 (Laird & Griffith 2008). At the time of its discovery, the barnacle was recorded from 400 km of coastline from Elands Bay to Misty Cliffs near Cape Point (Laird & Griffith 2008). Thus, it is likely that it occurs inshore of Block 3B/4B. When present, the barnacle is typically abundant at the mid zones of semi-exposed shores.

Along the sublittoral fringe, the large kelp-trapping limpet *Scutellastra argenvillei* dominates forming dense, almost monospecific stands achieving densities of up to 200/m^2 (Bustamante *et al*. 1995). Similarly, *C. granatina* is the dominant grazer on more sheltered shores, also reaching extremely high densities (Bustamante *et al*. 1995). On more exposed shores *M. galloprovincialis* dominates. There is evidence that the arrival of the alien *M. palloprovincialis* has led to strong competitive interaction with *S. argenvillei* (Steffani & Branch 2003a, 2003b, 2005). The abundance of the mussel changes with wave exposure, and at wave-exposed locations, the mussel can cover almost the entire primary substratum, whereas in semi-exposed situations it is never abundant. As the cover of *M. galloprovincialis* increases, the abundance and size of *S. argenvillei* on rock declines and it becomes confined to patches within a matrix of mussel bed. As a result exposed sites, once dominated by dense populations of the limpet, are now largely covered by the alien mussel. Semi-exposed shores do, however, offer a refuge preventing global extinction of the limpet. In addition to the mussel and limpets, there is variable representation of the flora and fauna described for the lower mid-littoral above, as well as the anemone *Aulactinia reynaudi*, numerous whelk species and the sea urchin *Parechinus angulosus*. Some of these species extend into the subtidal below.

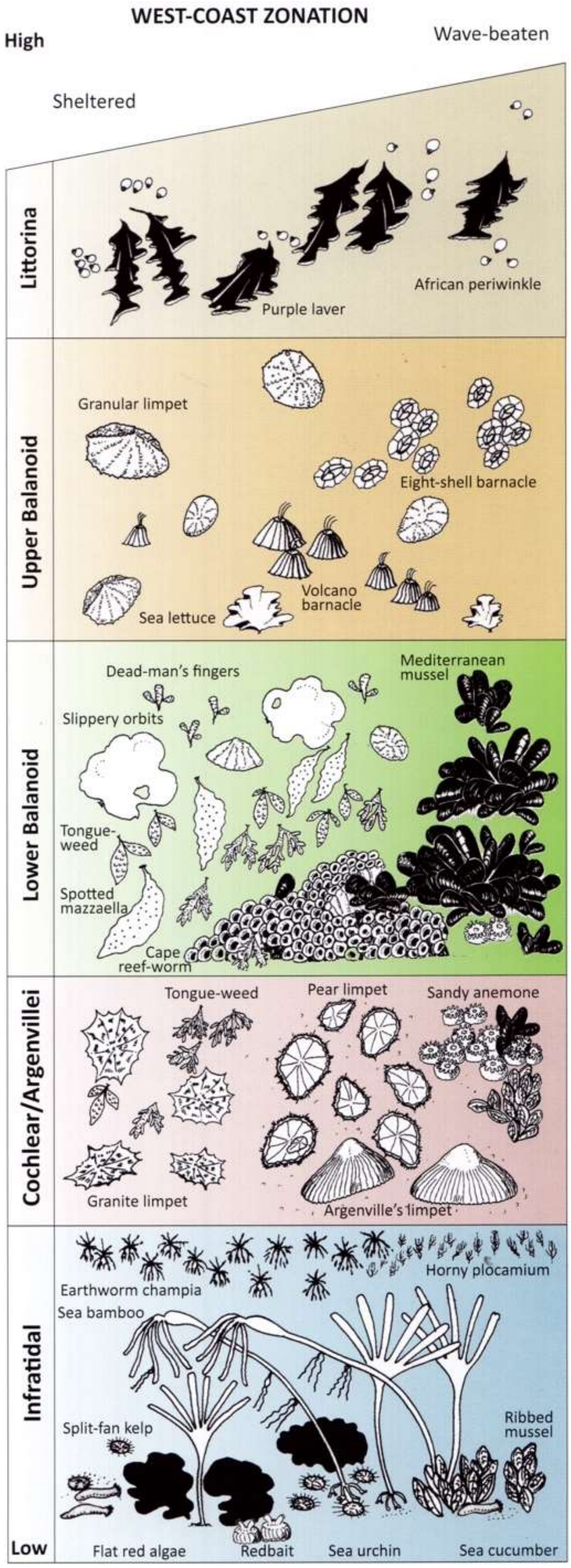

Figure 47: Schematic representation of the West Coast intertidal rocky shore zonation (adapted from Branch & Branch 2018).

Figure 48: Typical rocky intertidal zonation on the southern African west coast.

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

3.3.4.3 Rocky Subtidal Habitat and Kelp Beds

Biological communities of the rocky sublittoral on the southwest coast can be broadly grouped into an inshore zone from the sublittoral fringe to a depth of about 10 m dominated by flora, and an offshore zone below 10 m depth dominated by fauna. This shift in communities is not knife-edge, and rather represents a continuum of species distributions, merely with changing abundances.

From the sublittoral fringe to a depth of between 5 and 10 m, the benthos is largely dominated by algae, in particular two species of kelp. The canopy forming kelp *Ecklonia maxima* extends seawards to a depth of about 10 m. The smaller *Laminaria pallida* forms a sub-canopy to a height of about 2 m underneath *Ecklonia*, but continues its seaward extent to about 30 m depth, although further north up the west coast increasing turbidity limits growth to shallower waters (10-20 m) (Velimirov *et al*. 1977; Jarman & Carter 1981; Branch 2008). *Ecklonia maxima* is the dominant species in the south forming extensive beds from west of Cape Agulhas to north of Cape Columbine, but decreasing in abundance northwards. *Laminaria* becomes the dominant kelp north of Cape Columbine and thus in the project area, extending from Danger Point east of Cape Agulhas to Rocky Point in northern Namibia (Stegenga *et al*. 1997; Rand 2006).

Kelp beds absorb and dissipate much of the typically high wave energy reaching the shore, thereby providing important partially-sheltered habitats for a high diversity of marine flora and fauna, resulting in diverse and typical kelp-forest communities being established (Figure 49). Through a combination of shelter and provision of food, kelp beds support recruitment and complex trophic food webs of numerous species, including commercially important rock lobster stocks (Branch 2008).

Figure 49: The canopy-forming kelp *Ecklonia maxima* provides an important habitat for a diversity of marine biota (Photo: Geoff Spiby).

Growing beneath the kelp canopy, and epiphytically on the kelps themselves, are a diversity of understorey algae, which provide both food and shelter for predators, grazers and filter-feeders associated with the kelp bed ecosystem. Representative under-storey algae include *Botryocarpa prolifera*, *Neuroglossum binderianum*, *Botryoglossum platycarpum*, *Hymenena venosa* and *Rhodymenia* (=*Epymenia*) *obtusa*, various coralline algae, as well as subtidal extensions of some algae occurring primarily in the intertidal zones (Bolton 1986). Epiphytic species include *Polysiphonia virgata*, *Gelidium vittatum (=Suhria vittata)* and *Carpoblepharis flaccida*. In particular, encrusting coralline algae are important in the under-storey flora as they are known as settlement attractors for a diversity of invertebrate species. The presence of coralline crusts is thought to be a key factor in supporting a rich shallow-water community by providing substrate, refuge, and food to a wide variety of infaunal and epifaunal invertebrates (Chenelot *et al*. 2008).

The sublittoral invertebrate fauna is dominated by suspension and filter-feeders, such as the mussels *Aulacomya ater* and *Choromytilus meriodonalis*, and the Cape reef worm *Gunnarea capensis*, and a variety of sponges and sea cucumbers. Grazers are less common, with most herbivory being restricted to grazing of juvenile algae or debris-feeding on detached macrophytes. The dominant herbivore is the sea urchin *Parechinus angulosus*, with lesser grazing pressure from limpets, the isopod *Paridotea reticulata* and the amphipod *Ampithoe humeralis*. The abalone *Haliotis midae*, an important commercial species present in kelp beds south of Cape Columbine is naturally absent north of there. Key predators in the sub-littoral include the commercially important West Coast rock lobster *Jasus lalandii* and the octopus *Octopus vulgaris*. The rock lobster acts as a keystone species as it influences community structure *via* predation on a wide range of benthic organisms (Mayfield *et al*. 2000). Relatively abundant rock lobsters can lead to a reduction in density, or even elimination, of black mussel *Choromytilus meriodonalis*, the preferred prey of the species, and alter the size structure of populations of ribbed mussels *Aulacomya ater*, reducing the proportion of selected size-classes (Griffiths & Seiderer 1980). Their role as predator can thus reshape benthic communities, resulting in large reductions in taxa such as black mussels, urchins, whelks and barnacles, and in the dominance of algae (Barkai & Branch 1988; Mayfield 1998).

Of lesser importance as predators, although numerically significant, are various starfish, feather and brittle stars, and gastropods, including the whelks *Nucella* spp. and *Burnupena* spp. Fish species commonly found in kelp beds off the West Coast include hottentot *Pachymetopon blochii*, two tone finger fin *Chirodactylus brachydactylus*, red fingers *Cheilodactylus fasciatus*, galjoen *Dichistius capensis*, rock suckers *Chorisochismus dentex* and the catshark *Haploblepharus pictus* (Branch *et al*. 2010).

There is substantial spatial and temporal variability in the density and biomass of kelp beds, as storms can remove large numbers of plants and recruitment appears to be stochastic and unpredictable (Levitt *et al*. 2002; Rothman *et al*. 2006). Some kelp beds are dense, whilst others are less so due to differences in seabed topography, and the presence or absence of sand and grazers.

3.3.4.4 Estuaries

Estuaries along the West Coasts generally fall within the Cool Temperate bioregion. There are three perennial river mouths that are always open to the sea and have estuarine systems in their lower reaches: the Orange, Olifants and Berg Rivers. The Berg River Estuary has the largest and most diverse associated saline and freshwater wetlands compared to all other permanently open estuaries in South Africa. Langebaan is an estuarine lagoon comprising shallow intertidal sand banks and deeper channels that experience tidally driven input of nutrient rich, upwelled water from the sea and groundwater input in the upper reaches. Together, this creates an ecologically productive system that supports long-standing fisheries. Other estuaries include the Verlorenvlei and Klein estuarine lakes. The numerous smaller estuaries along the West Coast are intermittently, or seasonally, open (Holgat, Buffels, Swartlintjies, Bitter, Spoeg, Groen, Brak, Sout and Jakkals Rivers).

Predominantly open estuaries, estuarine lagoons and estuarine bays are particularly important for recruitment for some inshore linefish species and are the most vulnerable to marine pollution events as they receive tidal inflows almost constantly.

Estuarine habitats are highly variable environments with salinity, temperature pH and other variables change with the tides, seasons and climatic conditions. Changes in the extent of water coverage and flow may alternately expose estuarine organisms to desiccation and scouring floods. This high variability has led to a high degree of specialisation within estuaries.

The smaller estuaries are generally wave-dominated, with little freshwater inflow to maintain inlet stability and over 75% of South African estuaries close periodically due to wave-driven sandbar formation. If these periods persist for lengthy time periods, warm, hypersaline conditions can form (van Niekerk *et al*. 2019), which are unfavourable to most estuarine fauna. Toxic algal blooms are also common under these conditions and increase the likelihood of fish and invertebrate mortality.

There are 64 estuarine systems along the West Coast between the Orange River and Cape Agulhas (SANBI 2018). Approximately 75% of the Cool Temperate bioregion estuarine ecosystem (West Coast) types are 'Critically Endangered' or 'Endangered', while 13% are considered 'Vulnerable' (Even the common species in the West and Southwest Coast estuaries have ranges restricted to southern Africa; sand and mud prawns *Callichirus krausii* and *Upogebia africana* are limited to southern Africa, while the freshwater sand-shrimp (*Paleamon capensis*) is endemic to South Africa (van Niekerk *et al*. 2019). Turpie *et al*. (2012) and Hockey *et al*. (2005) also list 35 bird species that are likely to be dependent on estuaries, many of which occur throughout the West and Southwest Coast.

Estuaries are highly productive systems and offer rich feeding grounds, warmer temperatures and sheltered habitat for many organisms. The high productivity is exploited by many line-fish and harvested invertebrate species either as a nursery or later in life either directly through habitat availability or indirectly through the contribution to overall coastal productivity (van Niekerk *et al*. 2019). Turpie *et al*. (2017) estimated the contribution of the estuarine nursery function as R960 million in 2018 terms (equivalent to over R1 billion in 2020) to the South African economy, with the highest value attributed to the estuaries of the south Western and Eastern Cape.

Location of estuaries on the West and South-West Coast and their conservation status are summarised in

Table 11.

Table 11). Of the estuaries on the West Coast, the Orange River wetlands, Verlorenvlei and Langebaan are proclaimed as Ramsar Sites. Although Langebaaan falls within a National Park (National Protected Areas Register 2020), the Orange and Verlorenvlei estuaries do not have formal protection.

Approximately 176 estuarine associated plant species are known within South Africa, with 56 species associated with salt marsh habitat. Salt marsh dominates the vegetation in the cool temperate estuaries along the West coast. The Langebaan and Olifants estuaries support large salt marsh habitat, with the combined area of inter- and supratidal habitat of 1 350 ha and 1 010 ha, respectively. There is a high degree of endemism with only 66 estuarine plant species occurring in five or more estuaries nationally (van Niekerk *et al*. 2019).

The vulnerable freshwater mullet *Pseudomyxus capensis* is one of the few marine fish species that spawns at sea but makes extensive use of the estuarine environment as a nursery area. Endemic to South Africa it occurs predominantly from Kosi Bay to Table Bay but has recently been recorded in a few estuaries on the West Coast as far north as the Orange River indicating that it may be expanding its range in response to climate change. The razor clam *Solen capensis* is endemic to estuaries in the cool temperate bioregions in South Africa, occurring from the Olifants Estuary on the West Coast to St Lucia on the East Coast.

Even the common species in the West and Southwest Coast estuaries have ranges restricted to southern Africa; sand and mud prawns *Callichirus krausii* and *Upogebia africana* are limited to southern Africa, while the freshwater sand-shrimp (*Paleamon capensis*) is endemic to South Africa (van Niekerk *et al*. 2019). Turpie *et al*. (2012) and Hockey *et al*. (2005) also list 35 bird species that are likely to be dependent on estuaries, many of which occur throughout the West and Southwest Coast.

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Location of estuaries on the West and South-West Coast and their conservation status are summarised in

Table 11.

Table 11: Threat status of the estuaries in the broader project area from the Namibian Border to Cape Agulhas (Van Niekerk *et al*. 2019). Only true estuaries, not micro-systems are listed.

Estuary	2018 Threat Status	Estuary	2018 Threat Status
Orange	Endangered	Krom	Endangered
Buffels	Endangered	Silwermyn	Critically Endangered
Swartlintjies	Endangered	Zand	Critically Endangered
Spoeg	Endangered	Zeekoei	Endangered
Groen	Endangered	Eerste	Critically Endangered
Sout (noord)	Endangered	Lourens	Endangered
Olifants	Endangered	Sir Lowry's Pass	Endangered
Jakkals	Critically Endangered	Steenbras	Least Concern
Wadrift	Endangered	Rooiels	Endangered
Verlorenvlei	Endangered	Buffels (Oos)	Endangered
Groot Berg	Endangered	Palmiet	Critically Endangered
Langebaan	Vulnerable	Bot/Kleinmond	Endangered
Diep/Rietvlei	Critically Endangered	Onrus	Endangered
Sout (Wes)	Critically Endangered	Klein	Endangered
Disa	Critically Endangered	Uilkraals	Endangered
Wildevoëlvlei	Critically Endangered	Ratel	Endangered
Schuster	Endangered	Heuningnes	Endangered

3.3.4.4 Coastal Sensitivity

The last coastal sensitivity map for the South African coastline was compiled by Jackson & Lipschitz (1984). An updated National Coastal Assessment is currently being established by the CSIR and DEFF based on the biological components of the 2018 National Biodiversity Assessment (Harris *et al*. 2019). It includes the detection of coastal erosion hotspots and was completed in June 2020 (DEFF & CSIR 2020). A further report on the analysis of hotspots is in draft form and was released in early 2021 (DEFF & CSIR 2021). This will take the form of a website with customisable GIS layers including natural resources, ecosystem infrastructure and services, human infrastructure, threats etc. Harris *et al*. (2019) compiled a GIS habitat map for the entire South African coastline, which identified that 60% of coastal ecosystem types are threatened, thereby having proportionally three times more threatened ecosystem types than the rest of the country. The spatial distribution of threatened coastal ecosystem types in the broader project area is illustrated in Figure 15 (page 36). Coastal sensitivity would need to be taken into consideration in the event of an oil spill.

3.4 Other Uses of the Area

3.4.1 Beneficial Uses

Block 3B/4B is located well offshore beyond the 300 m depth contour. Other users of the offshore areas include the commercial fishing industry (see CapFish 2021 – Fisheries Specialist Study), with marine diamond mining concessions being located inshore of the eastern portion of Block 3B/4B (Figure 51). Recreational activities along the coastline north of St Helena Bay are limited to the area around Lambert's Bay, Hondeklip Bay and Port Nolloth.

Figure 50: Typical crawler-vessel (left) and drillship (right) operating in the Atlantic 1 Mining Licence Area (Photos: De Beers Marine).

On the Namaqualand coast marine diamond mining activity is restricted to nearshore, diver-assisted operations from small, converted fishing vessels working in the a-concessions, which extend to 1 000 m offshore of the high water mark. No deep-water diamond mining is currently underway in the South African offshore concession areas, although prospecting activities are ongoing. In Namibian waters, deep-water diamond mining by De Beers Marine Namibia is currently operational in the Atlantic 1 Mining Licence Area, to the northeast of Block 3B/4B.

These mining operations 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. The vessels operate as semi-mobile mining platforms, anchored by a dynamic positioning system, commonly on a three to four anchor spread (Figure 50). 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 industrial uses of the marine environment include the intake of feed-water for mariculture, or diamond-gravel treatment, submarine telecommunications cables, ammunition dumps and hydrocarbon wellheads (Figure 51). None of these activities should in any way be affected by exploration drilling activities offshore.

There are a number of existing and proposed subsea fibreoptics cables that make landfall between Cape Town and Saldanha Bay (Figure 51), most of which pass to the west of Block 3B/4B. Of the ammunition dump sites off the West Coast, none fall within Block 3B/4B.

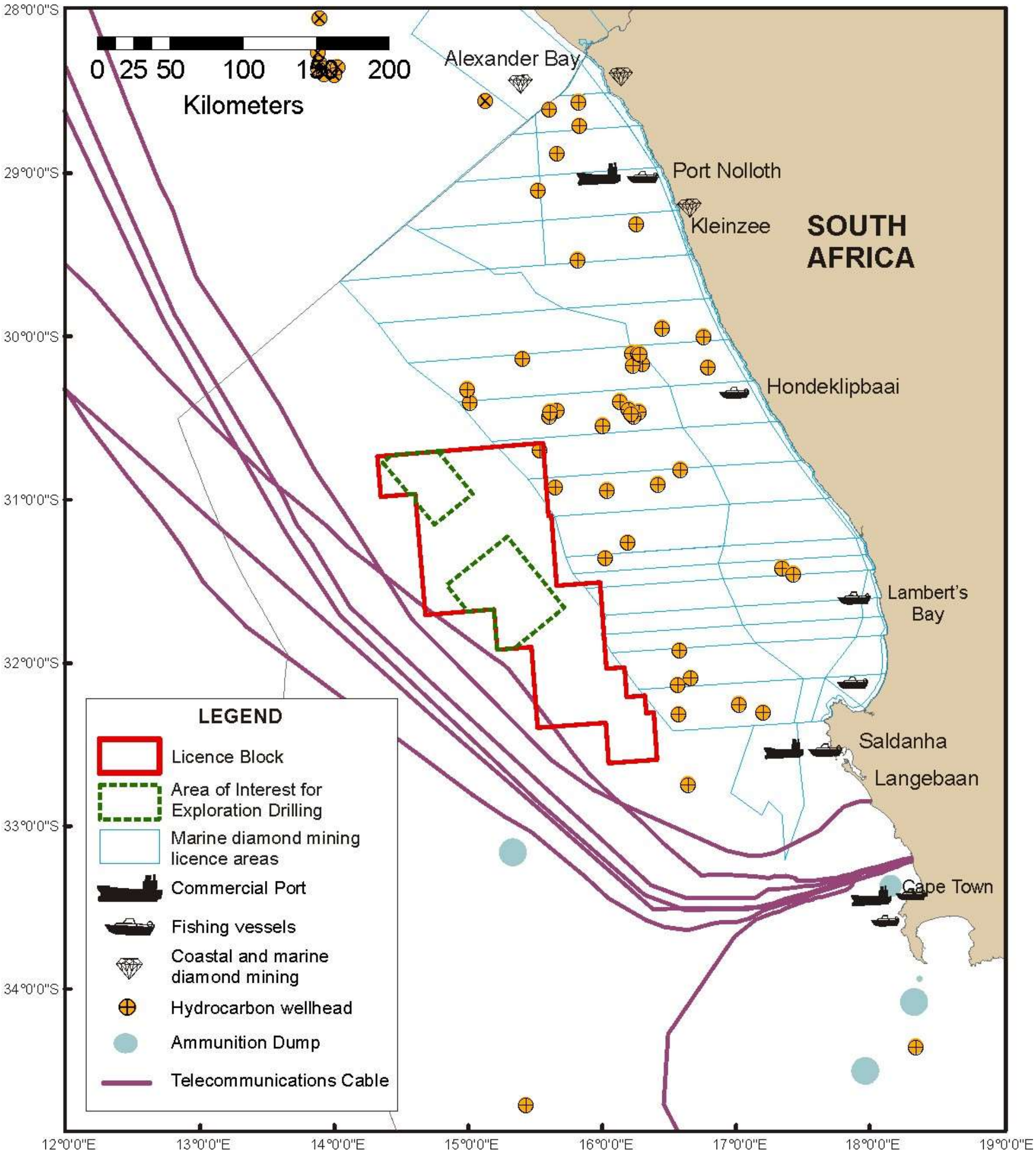

Figure 51: Block 3B/4B (red polygon) in relation to other marine infrastructure on the West Coast, illustrating the location of well heads, diamond mining concessions, submarine telecommunications cables and ammunition dumps.

3.4.2 Sanctuaries, Marine Protected Areas and other Sensitive Areas

Numerous conservation areas and a coastal marine protected area (MPA) exist along the coastline of the Western Cape, although none overlap with Block 3B/4B.

Sanctuaries

Sanctuaries are considered a type of management area within South Africa's multi-purpose expanded MPA network in which access and/or resource use is prohibited. Sanctuaries in the vicinity of the project area in which restrictions apply are the McDougall's Bay, Stompneusbaai, Saldanha Bay, Table Bay and Hout Bay rock lobster sanctuaries, which are closed to commercial exploitation of rock lobsters. These sanctuaries were originally proclaimed early in the 20th century under the Sea Fisheries Act of 1988 as a management tool for the protection of the West Coast rock lobster (Mayfield *et al*. 2005). They lie well inshore or to the south of Block 3B/4B.

Marine Protected Areas

'No-take' MPAs offering protection of the Namaqua biozones (sub-photic, deep-photic, shallow-photic, intertidal and supratidal zones) are absent northwards from Cape Columbine (Emanuel *et al*. 1992; Lombard *et al*. 2004). This resulted in substantial portions of the coastal and shelf-edge marine biodiversity in the area being assigned a threat status of 'Critically Endangered', 'Endangered' or 'Vulnerable' in the 2011 National Biodiversity Assessment (NBA) (Lombard *et al*. 2004; Sink *et al*. 2012). Using biodiversity data mapped for the 2004 and 2011 NBAs a systematic biodiversity plan was developed for the West Coast (Majiedt *et al*. 2013) with the objective of identifying both coastal and offshore priority areas for MPA expansion. Potentially vulnerable marine ecosystems (VMEs) that were explicitly considered during the planning included the shelf break, seamounts, submarine canyons, hard grounds, submarine banks, deep reefs and cold water coral reefs. To this end, nine focus areas were identified for protection on the West Coast between Cape Agulhas and the South African – Namibian border. These focus areas were carried forward during Operation Phakisa, which identified potential offshore MPAs. A network of 20 MPAs was gazetted on 23 May 2019, thereby increasing the ocean protection within the South African Exclusive Economic Zone (EEZ) to 5%. The approved MPAs within the broad project area are shown in Figure 52. There is no overlap with Block 3B/4B and any of these offshore MPAs, but the northern boundary of Block 3B/4B lies adjacent to the Child's Bank MPA and the Benguela Muds MPA lies ~12 km east of the southeastern boundary of Block 3B/4B. The Area of Interest for drilling specifically avoids both this MPA and the associated EBSA (see later). These are described briefly below.

Coastal Marine Protected Areas

The **Namaqua National Park MPA** provides the first protection to habitats in the Namaqua bioregion, including several 'critically endangered' coastal ecosystem types. The area is a nursery area for Cape hakes, and the coastal areas support kelp forests and deep mussel beds, which serve as important habitats for the West Coast rock lobster. This 500 km^2 MPA was proclaimed in 2019, both to boost tourism to this remote area and to provide an important baseline from which to understand ecological changes (e.g. introduction of invasive alien marine species, climate change) and human impacts (harvesting, mining) along the West Coast. Protecting this stretch of coastline is part of South Africa's climate adaptation strategy.

The **Rocher Pan MPA**, which stretches 500 m offshore of the high water mark of the adjacent Rocher Pan Nature Reserve, was declared in 1966. The MPA primarily protects a stretch of beach important as a breeding area to numerous waders. It is located in St Helena Bay inshore of Block 3B/4B.

The **West Coast National Park**, which was established in 1985 incorporates the Langebaan Lagoon and Sixteen Mile Beach MPAs, as well the islands Schaapen (29 ha), Marcus (17 ha), Malgas (18 ha) and Jutten (43 ha). Langebaan Lagoon was designated as a Ramsar site in April 1988 under the Convention on Wetlands of International Importance especially as Waterfowl Habitat. The lagoon is divided into three different utilization zones namely: wilderness, limited recreational and multi-purpose recreational areas. The wilderness zone has restricted access and includes the southern end of the lagoon and the inshore islands, which are the key refuge sites of the waders and breeding seabird populations respectively. The limited recreation zone includes the middle reaches of the lagoon, where activities such as sailing and canoeing are permitted. The mouth region is a multi-purpose recreation zone for power boats, yachts, water-skiers and fishermen. However, no collecting or removal of abalone and rock lobster is allowed. The length of the combined shorelines of Langebaan Lagoon MPA and Sixteen Mile Beach is 66 km. The uniqueness of Langebaan lies in its being a warm oligotrophic lagoon, along the cold, nutrient-rich and wave exposed West Coast.

The **Table Mountain National Park (TMNP) MPA** was declared in 2004, and includes 996 km^2 of the sea area and 137 km of coastline around the Cape Peninsula from Moullie Point in the North to Muizenberg in the south. Although fishing is allowed in the majority of the MPA (subject to Department of Agriculture, Forestry and Fisheries (DAFF) permits, regulations and seasons), the MPA includes six 'no-take' zones where no fishing or extractive activities are allowed. These 'no-take' zones are important breeding and nursery areas for a wide variety of marine species thereby providing threatened species with a chance to recover form over-exploitation.

Offshore Marine Protected Areas

The **Orange Shelf Edge MPA** covers depths of between 250 m and 1 500 m and is unique as it has to date never been trawled. Proclaimed in 2019, this MPA provides a glimpse into what a healthy seabed should look like, what animals live there and how the complex relationships between them support important commercial fish species such as hake, thereby contributing fundamentally towards sustainable fisheries development. This MPA also protects the pelagic habitats that are home to predators such as blue sharks, as well as surface waters where thousands of seabirds such as Atlantic yellow-nosed albatrosses feed.

The 1 335 km^2 **Child's Bank MPA**, located on the northern boundary of Block 3B/4B at its closest point, supports seabed habitats inhabited by a diversity of starfish, brittle stars and basket stars, many of which feed in the currents passing the bank's steep walls. Although trawling has damaged coral in the area, some pristine coral gardens remain on the steepest slopes. The Child's Bank area was first proposed for protection in 2004 but was only proclaimed in 2019, after reducing its size to avoid petroleum wellheads and mining areas. The MPA provides critical protection to these deep sea habitats (180 - 450 m) as they allow for the recovery of important nursery areas for young fish. Located on the northern edge of the licence block, this MPA is 38 km east of the northern Area of Interest at its closest point.

The **Benguela Muds MPA**, is the smallest of the South African offshore MPAs. At only 72 km^2 the muddy habitats located in this area are created by sediment washed down the Orange River and out to sea. These mud habitats are of limited extent and were considered 'critically endangered' on South Africa's deep continental margin of the west coast (Sink *et al*. 2014). The MPA represents the least trawled stretch of muddy seabed on the west coast. It lies ~ 12 km east of the southeastern boundary of Block 3B/4B and ~90 km southest of the southern Area of Interest.

The **Namaqua Fossil Forest MPA,** which lies ~165 km northeast of Block 3B/4B, provides evidence of age-old temperate yellowwood forests from a hundred million years ago when the sea-level was more than 200 m below what it is today; trunks of fossilized yellowwood trees covered in delicate corals. These unique features stand out against surrounding mud, silt and gravel habitats. The fossilized trees are not known to be found anywhere else in our oceans and are valuable for research into past climates. In 2014 this area was recognised as globally important and declared as an Ecologically and Biologically Significant Area (EBSA). The 1 200 km^2 MPA protects the unique fossil forests and the surrounding seabed ecosystems and including a new species of sponge previously unknown to science.

The **Cape Canyon** is a deep and dramatic submarine canyon carved into the continental shelf and extending to a maximum depth of 3,600 m. The 580 km^2 MPA was proclaimed in 2019 and protects the upper part of the canyon where depths range from 180 to 500 m. Underwater footage has revealed a rich diversity of seafans, hermit crabs and mantis shrimps, with hake, monk and john dory resident on the soft canyon floor. Rocky areas in the west of the canyon support fragile rocky habitat, but the area also includes sandy and muddy habitats, which have been trawled in the past. Interaction of nutrient-rich bottom water with a complex seascape results in upwelling, which in turn provides productive surface waters in which seabirds, humpback whales and Cape fur seals feed. The MPA lies ~75 km east of the southeastern boundary of Block 3B/4B and, approximately 155 km southeast of the southern Area of Interest.

The 612 km^2 **Robben Island MPA** was proclaimed in 2019 to protect the surrounding kelp forests - one of the few areas that still supports viable stocks of abalone. The island harbours the 3rd largest penguin colony, with the breeding population peaking in 2004 at 8 524, but declining since. The island also holds the largest numbers of breeding Bank Cormorant in the Western Cape (120 pairs in 2000) and significant populations of Crowned Cormorant, African Black Oystercatcher (35 breeding pairs in 2000), Hartlaub's Gull and Swift Tern.

Sensitive Areas

Despite the current lack of knowledge of the community structure and endemicity of South African macro-infauna off the edge of the continental shelf, the marine component of the 2018 National Biodiversity Assessment (Sink *et al*. 2019), rated the South Atlantic bathyal and abyssal unconsolidated habitat types that characterise depths beyond 500 m, as being of 'Least concern' (see Figure 15), reflecting the great extent of these habitats in the South African Exclusive Economic Zone (EEZ). However, those ecosystem types occurring along the shelf edge (-500 m) and Cape Canyon are considered 'Vulnerable', with isolated portions being rates as 'Endangered' (Cape Upper Canyon and Southern Benguela Muddy Shelf Edge), and 'Critically Endangered' (Brown's Bank Rocky Shelf Edge). Block 3B/4B and the Area of Interest for drilling is dominated by ecosystems rated as 'Least Concern' by the 2018 National Biodiversity Assessment.

Despite the development of the offshore MPA network, most of the ecosystem types in Block 3B/4B (i.e. Southeast Atlantic Upper, Mid and Lower Slopes, Cape Basin Abyss) are currently considered 'not protected' or 'poorly protected' and further effort is needed to improve protection of these threatened ecosystem types (Sink *et al*. 2019) (Figure 53). Ideally, all highly threatened ('Critically Endangered' and 'Endangered') ecosystem types should be well protected. Currently, however, most of the Southeast Atlantic Upper- and Mid-Slope are poorly protected receiving only 0.2-10% protection, whereas the Southeast Atlantic Lower Slope receives no protection at all (Sink *et al*. 2019). Expanding the size of the Orange Shelf Edge MPA to form a single MPA along the South African Border could improve protection of these threatened habitats.

Ecologically or Biologically Significant Areas

As part of a regional Marine Spatial Management and Governance Programme (MARISMA 2014-2020), the Benguela Current Commission (BCC) and its member states have identified a number of Ecologically or Biologically Significant Areas (EBSAs) both spanning the border between Namibia and South Africa and along the South African West, South and East Coasts, with the intention of implementing improved conservation and protection measures within these sites. South Africa currently has 12 EBSAs solely within its national jurisdiction with a further three having recently been proposed. It also shares eight trans-boundary EBSAs with Namibia (3), Mozambique (2) and the high seas (3). The principal objective of these EBSAs is identification of features of higher ecological value that may require enhanced conservation and management measures. They currently carry no legal status. The impact management and conservation zones within the EBSAs are under review and currently constitute a subset of the biodiversity priority areas map (see next section); EBSA conservation zones equate to Critical Biodiversity Areas (CBAs), whereas impact management zones equate to Ecological Support Area (ESAs). The relevant sea-use guidelines accompanying the CBA areas would apply.

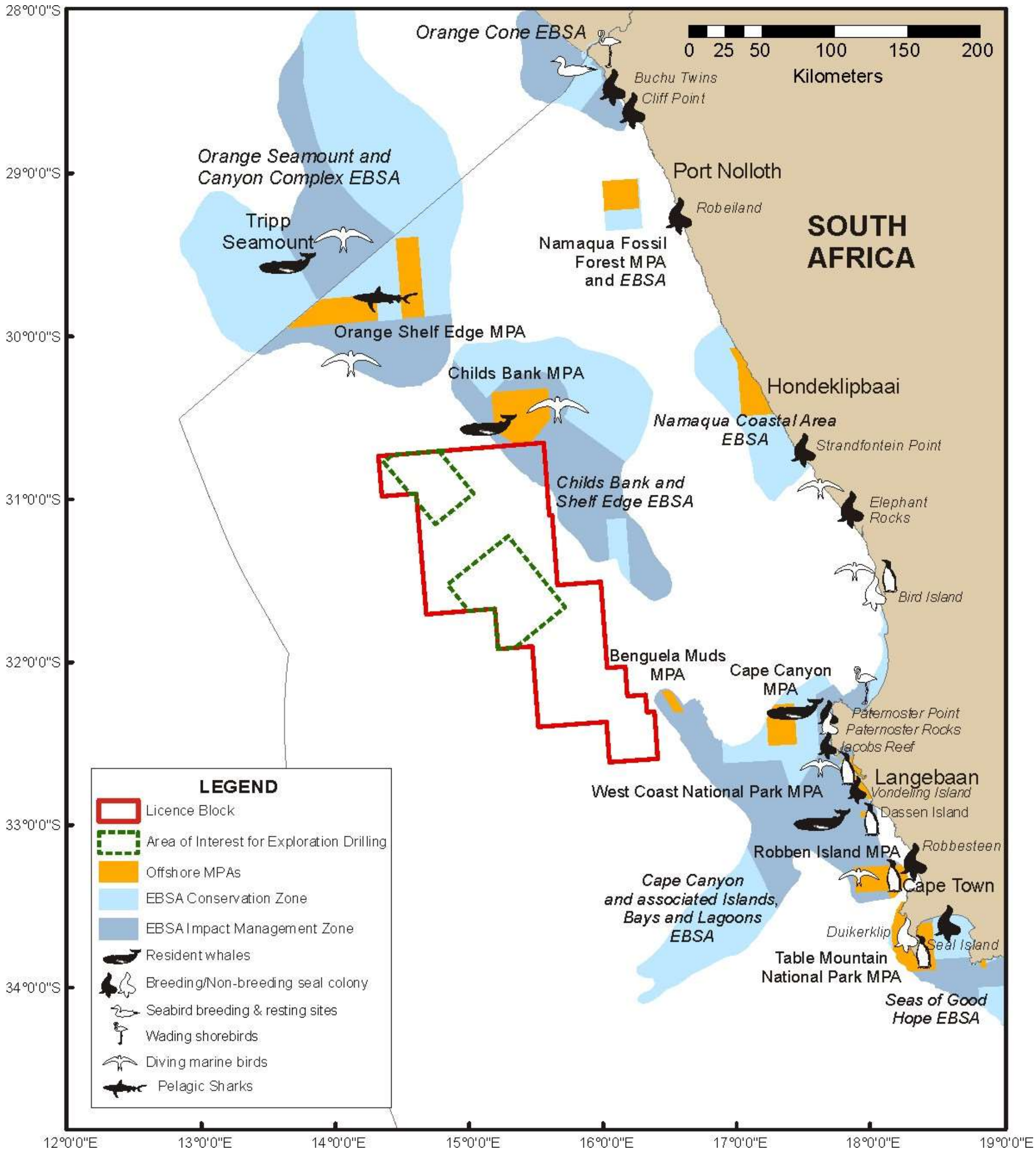

Figure 52: Block 3B/4B (red polygon) in relation to project - environment interaction points on the West Coast, illustrating the location of seabird and seal colonies and resident whale populations, Marine Protected Areas (MPAs) and Ecologically and Biologically Significant Areas (EBSAs) (Adapted from MARISMA Project 2020).

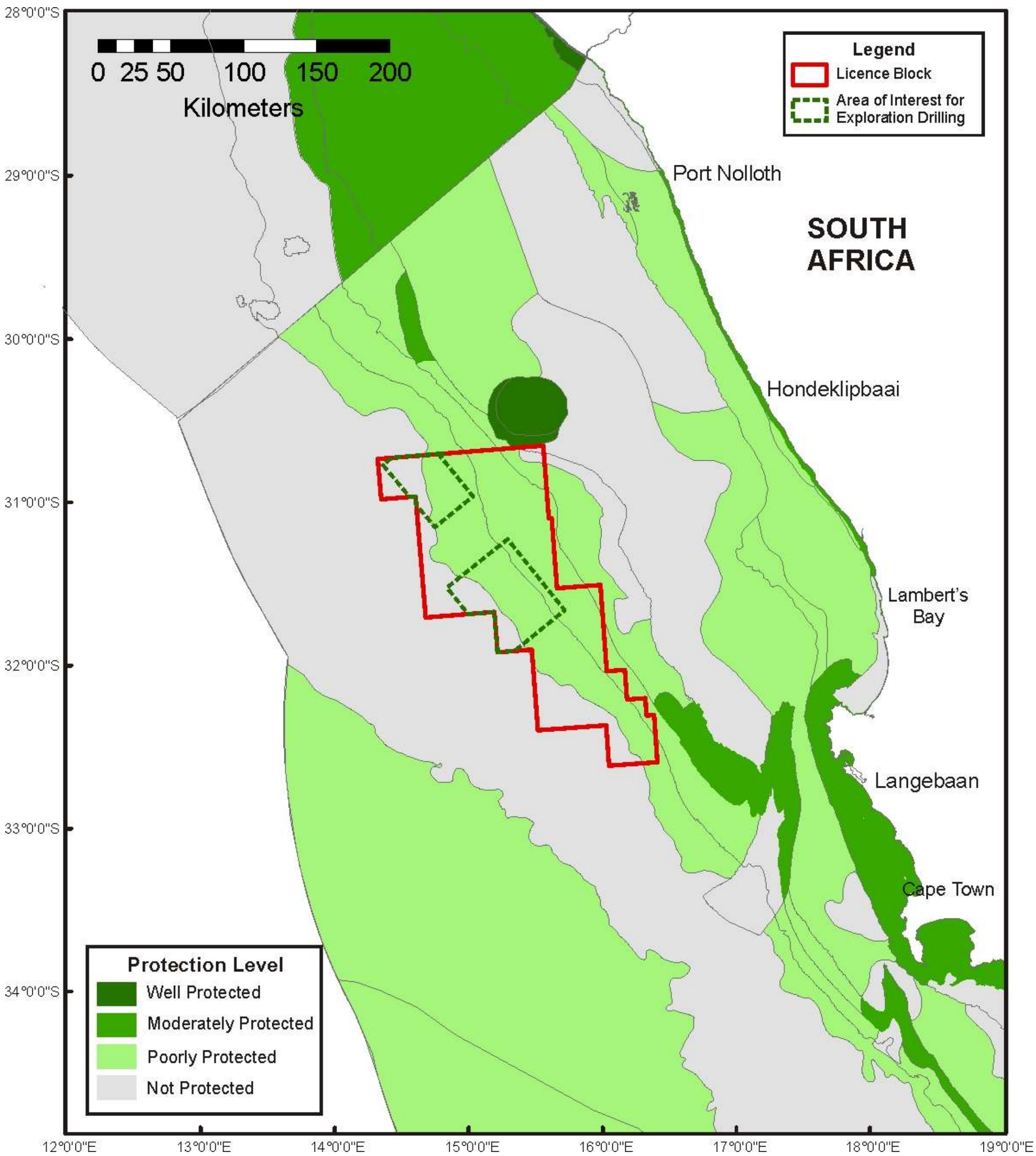

Figure 53: Block 3B/4B (red polygon) in relation to protection levels of 150 marine ecosystem types as assessed by Sink *et al*. (2019). The adjacent Namibian protection levels (adapted fom Holness *et al*. 2019) are also shown.

The following summaries of the EBSAs in the project area are adapted from http://cmr.mandela.ac.za/EBSA-Portal/Namibia/. Although Block 3B/4B overlaps to some extent with the Child's Bank EBSA, the Area of Interest for exploration drilling avoids all EBSAs. The text and figures below are based on the EBSA status as of October 2020.

- The **Childs Bank and Shelf Edge** EBSA is a unique submarine bank feature rising from -400 m to -180 m on the western continental margin on South Africa (approximately 300 km north-west of the Area of Interest). 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. This EBSA overlaps to some extent with Block 3B/4B.

There are also a number of EBSAs in the indirect area of influence to the north, south and east of Block 3B/4B. These are described briefly below.

- The **Orange Cone** transboundary EBSA is a transboundary EBSA, spanning the mouth of the Orange River (approximately 610 km north of the Area of Interest). 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 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 (RAMSAR site) by South Africa, and is an Important Bird and Biodiversity Area. This EBSA lies ~220 km to the northeast of Block 3B/4B at its closest point.
- The **Orange Seamount and Canyon Complex EBSA**, occurs at the western continental margin of southern Africa, spanning the border between South Africa and Namibia (approximately 500 km north-west of the Area of Interest). 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. This EBSA lies ~45 km to the north of Block 3B/4B at its closest point.
- The **Namaqua Fossil Forest** EBSA 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 approximately 545 km north of the Area of Interest). 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. This EBSA lies ~150 km to the northeast of Block 3B/4B at its closest point.
- The **Namaqua Coastal Area** EBSA encompasses the Namaqua Coastal Area MPA and is characterized by high productivity and community biomass along its shores (approximately 345 km north of the Area of Interest). The area is important for several threatened ecosystem types represented there, including two ‘Endangered’ and four ‘Vulnerable’ ecosystem types, and is important for conservation of estuarine areas and coastal fish species. This EBSA lies ~115 km to the east of Block 3B/4B at its closest point.
- The **Cape Canyon and Associated Islands** EBSA includes the Benguela Muds MPA and the Cape Canyon, which is thought to hosts fragile habitat-forming species. The area is considered

important for pelagic fish, foraging marine mammals and several threatened seabird species and serves to protect nine 'Endangered' and 12 'Vulnerable' ecosystem types, and two that are 'Near Threatened'. There are several small coastal MPAs within the EBSA. Block 3B/4B lies approximately 4 km westward of this EBSA at its closest point.

- The proposed **Seas of Good Hope EBSA** is located at the coastal tip of Africa, wrapping around Cape Point and Cape Agulhas. It extends from the coast to the inner shelf, and includes key islands (Seal Island, Dyer Island and Geyser Rocks), two major bays (False Bay and Walker Bay), and is of key importance for threatened species and habitats. The threatened habitats include coastal, inshore and inner shelf ecosystem types. The important life-history stages supported by the area are breeding and/or foraging grounds for a myriad of top predators, including sharks, whales, and seabirds, some of which are threatened species. This EBSA is also the place where the Benguela and Agulhas Currents meet. This EBSA lies over 200 km to the southeast of Block 3B/4B at its closest point.
- The **Benguela Upwelling System** EBSA is a transboundary EBSA and 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.

Biodiversity Priority Areas

The National Coastal and Marine Spatial Biodiversity Plan[5] comprises a map of Critical Biodiversity Areas (CBAs), Ecological Support Area (ESAs) and accompanying sea-use guidelines. The CBA Map presents a spatial plan for the marine environment, designed to inform planning and decision-making in support of sustainable development. The sea-use guidelines enhance the use of the CBA Map in a range of planning and decision-making processes by indicating the compatibility of various activities with the different biodiversity priority areas so that the broad management objective of each can be maintained. The intention is that the CBA Map (CBAs and ESAs) and sea-use guidelines inform the MSP Conservation Zones and management regulations, respectively.

Block 3B/4B overlaps with areas mapped as Critical Biodiversity Area 1 (CBA 1) Natural, CBA 1 Restore, Critical Biodiversity Area 2 (CBA 2) Natural, CBA 2 Restore and Ecological Support Area (ESA). There is minima1 overlap of the northern Area of Interest for proposed exploration drilling with CBA 1 Natural (2.6 km^2) and CBA 2 Natural (35.9 km^2) areas but for the southern Area of Interest, the overlap with CBA 1 Natural and CBA2 Natural, amounts to 520.1 km^2 and 251.2 km^2, respectively (see Figure 54). CBA 1 indicates irreplaceable or near-irreplaceable sites that are required to meet biodiversity targets with limited, if any, option to meet targets elsewhere, whereas CBA 2 are "best design sites" and there are often alternative areas where feature targets can be met; however, these will be of higher cost to other sectors and / or will be larger areas.

[5] The latest version of National Coastal and Marine Spatial Biodiversity Plan (v1.2 was released in April 2022) (Harris *et al*. 2022). The Plan is intended to be used by managers and decision-makers in those national government departments whose activities occur in the coastal and marine space, e.g., environment, fishing, transport (shipping), petroleum, mining, and others. It is relevant for the Marine Spatial Planning Working Group where many of these departments are participating in developing South Africa's emerging marine spatial plans. It is also intended for use by relevant managers and decision-makers in the coastal provinces and coastal municipalities, EIA practitioners, organisations working in the coast and ocean, civil society, and the private sector.

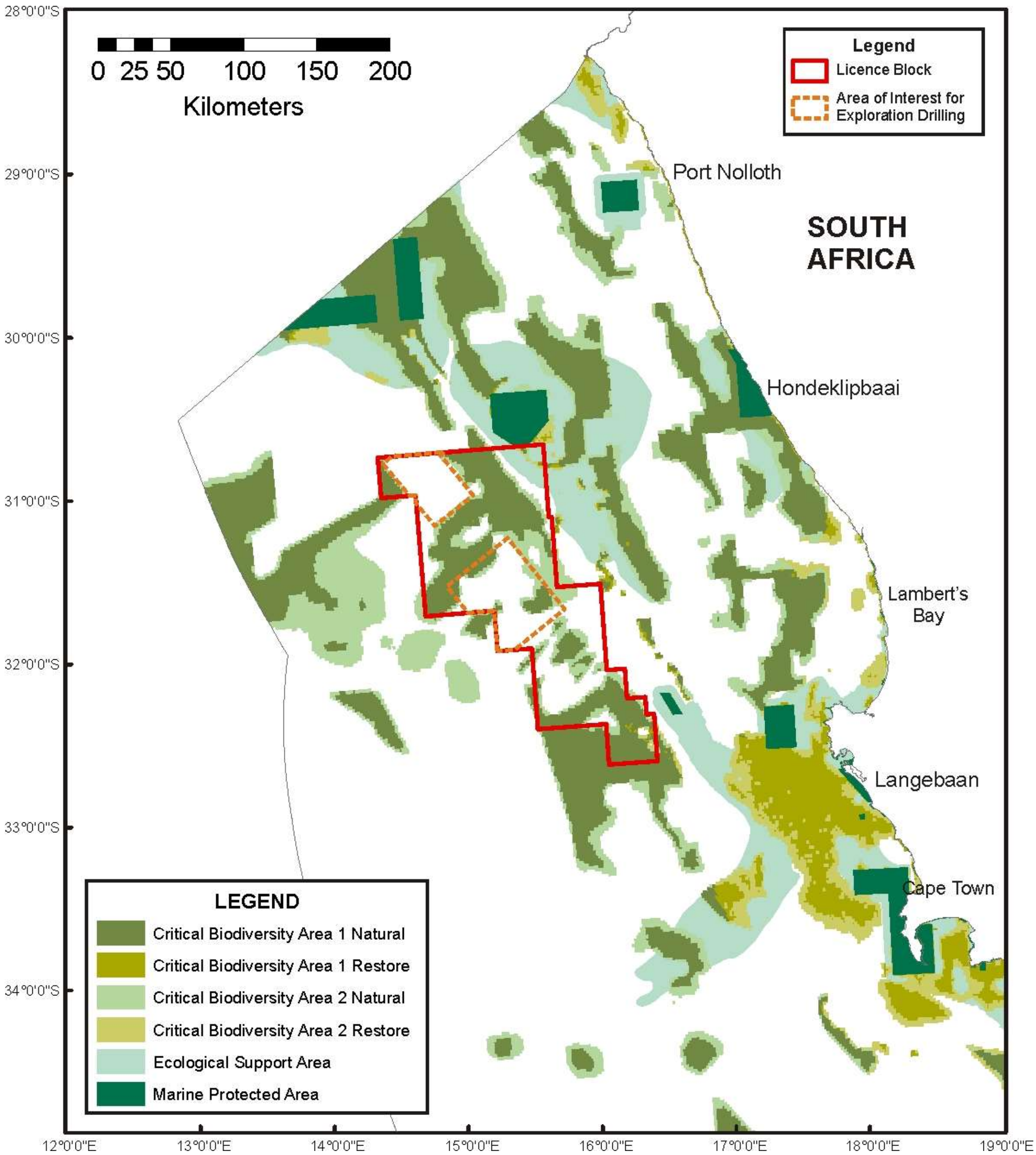

Figure 54: Block 3B/4B (red polygon) and the Area of Interest for exploration drilling (orange dashed polygons) in relation to Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) (Version 1.2) (Harris *et al.* 2022).

Regardless of how CBAs are split, CBAs are generally areas of low use and with low levels of human impact on the marine environment, but can also include some moderately to heavily used areas with higher levels of human impact. Given that some CBAs are not in natural or near-natural ecological condition, but still have very high biodiversity importance and are needed to meet biodiversity feature targets, CBA 1 and CBA 2 were split into two types based on their ecological condition. CBA Natural sites have natural / near-natural ecological condition, with the management objective of maintaining the sites in that natural / near natural state; and CBA Restore sites have moderately modified or poorer ecological condition, with the management objective to improve ecological condition and, in the long-term, restore these sites to a natural/near-natural state, or as close to that state as possible. ESAs include all portions of EBSAs that are not already within MPAs or CBAs, and a 5-km buffer area around all MPAs (where these areas are not already CBAs or ESAs), with the exception of the eastern edge of Robben Island MPA in Table Bay where a 1.5-km buffer area was applied (Harris *et al.* 2022).

Activities within these management zones are classified into those that are "compatible", those that are "not compatible", and those that have "restricted compatibility". Non-invasive (e.g. seismic surveys) and invasive (e.g. exploration wells) exploration activities are classified as having "restricted compatibility". Activities with restricted compatibility require a detailed assessment to determine whether the recommendation is that they should be permitted (general), permitted subject to additional regulations (consent), or prohibited, depending on a variety of factors. Table 9 in Harris *et al.* (2022) states that as part of the site-specific, context-specific assessment "*particularly careful attention would need to be paid in areas containing irreplaceable to near-irreplaceable features where the activity may be more appropriately evaluated as not permitted. The ecosystem types in which the activities take place may also be a consideration as to whether or not the activity should be permitted, for example. Where it is permitted to take place, strict regulations and controls over and above the current general rules and legislation would be required to be put in place to avoid unacceptable impacts on biodiversity features. Examples of such regulations and controls include: exclusions of activities in portions of the zone; avoiding intensification or expansion of current impact footprints; additional gear restrictions; and temporal closures of activities during sensitive periods for biodiversity features.*" Petroleum production is, however, classified as "not compatible" in CBAs, but may be compatible, subject to certain conditions, in ESAs (Harris *et.al.* 2022).

Important Bird Areas (IBAs) and RAMSAR Sites

There are numerous coastal Important Bird Areas (IBAs) in the general project area (

Table 12) (https://maps.birdlife.org/marineIBAs). These are all located well inshore of Block 3B/4B.

Various marine IBAs have also been proposed in South African territorial waters, with a candidate marine IBA suggested off the Orange River mouth and a further candidate marine IBA suggested in international waters west of the Cape Peninsula (Figure 55). Block 3B/4B does not overlap with any of these proposed marine IBAs.

A Ramsar site is considered wetland designated to be of international importance under the Ramsar Convention, also known as "The Convention on Wetlands", an intergovernmental environmental treaty established by UNESCO in 1971. The convention entered into force in South Africa on 21 December 1975. It provides for national action and international cooperation regarding the conservation of wetlands, and wise sustainable use of their resources. South Africa currently has 27 sites designated as Ramsar Sites, with a surface area of 571 089 hectares. These should in no way be influenced by well-drilling operations in Block 3B/4B.

Table 12: List of confirmed coastal Important Bird Areas (IBAs) and their criteria listings. (www.BirdLife.org.za). Those incorporating or listed as RAMSAR sites are shaded.

Site Name	IBA Criteria
Orange River Mouth Wetlands (ZA023)	A1, A3, A4i, A4iii
Olifants River Estuary (ZA078)	A3, A4i
Verlorenvlei Estuary (ZA082)	A4i
Berg River Estuary (ZA083)	A4i
West Coast National Park and Saldanha Bay Islands (ZA 084) (incorporating Langebaan RAMSAR site)	A1, A4i, A4ii, A4iii
Dassen Island (ZA088)	A1, A4i, A4ii, A4iii
Robben Island (ZA089)	A1, A4i, A4ii, A4iii
Rietvlei Wetland: Table Bay Nature Reserve (ZA090)	A1, A4i
Boulders Beach (ZA096)	A1
False Bay Nature Reserve (ZA095)	A1, A4i, A4iii

A1. Globally threatened species

A2. Restricted-range species

A3. Biome-restricted species

A4. Congregations

- **i**. applies to 'waterbird' species
- **ii**. This includes those seabird species not covered under i.
- **iii**. modelled on criterion 5 of the Ramsar Convention for identifying wetlands of international importance. The use of this criterion is discouraged where quantitative data are good enough to permit the application of A4i and A4ii.

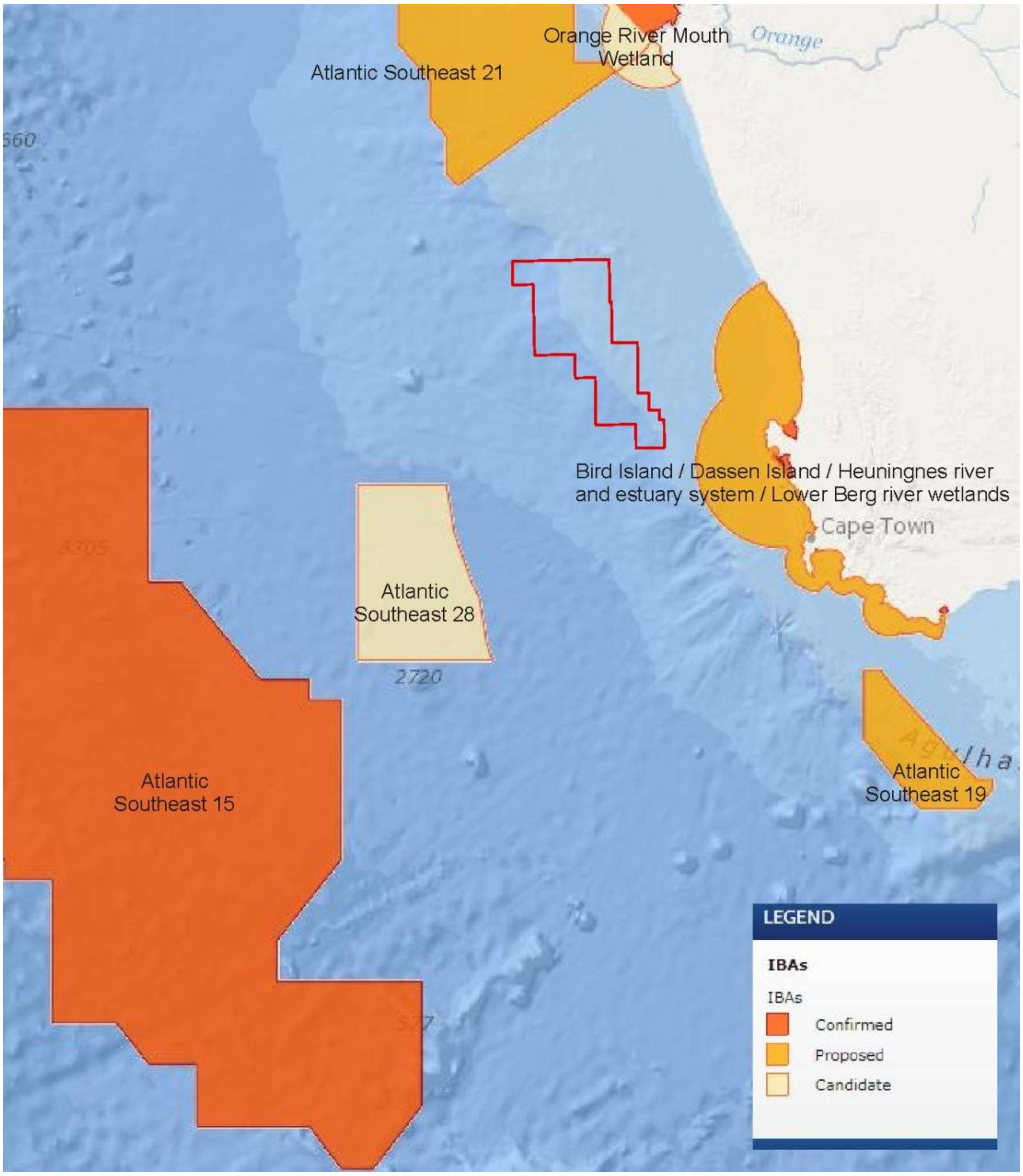

Figure 55: Block 3B/4B (red polygon) in relation to coastal and marine IBAs (Source: https://maps.birdlife.org/marineIBAs).

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

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

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

Criterion C – Key Life Cycle Activities

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

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

<u>Sub-criterion C3</u> – 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

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

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

Although much of the West Coast of South 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 56) 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 are described briefly below based on information provided in IUCN-Marine Mammal Protected Areas Task Force (2021) (www.marinemammalhabitat.org).

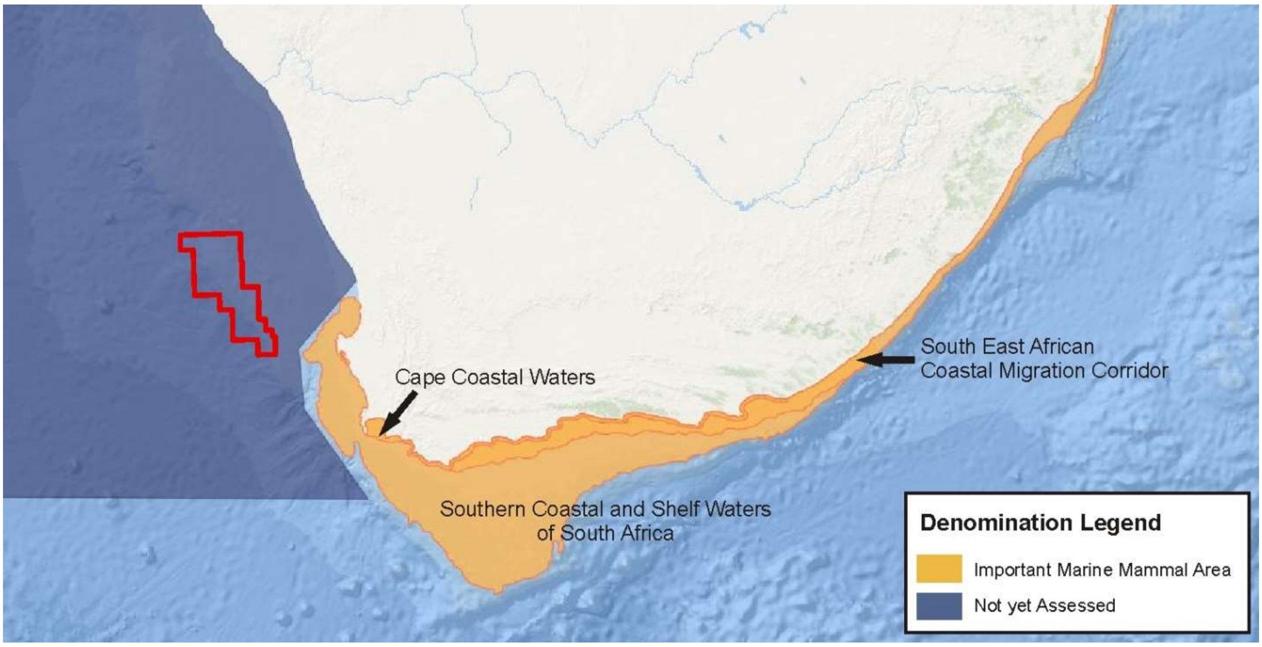

Figure 56: Block 3B/4B (red polygon) in relation to coastal and marine IMMAs (Source: www.marinemammalhabitat.org/imma-eatlas/).

The 166 700 km^2 Southern Coastal and Shelf Waters of South Africa IMMA extends from the Olifants River mouth to the mouth of the Cintsa River on the Wild Coast. Qualifying species are the Indian Ocean Humpback dolphin (Criterion A, B1), Bryde's whale (Criterion C2), Indo-Pacific bottlenose dolphin (Criterion B1, C3, D1), Common dolphin (Criterion C2) and Cape fur seal (criterion C2). The IMMA covers the area supporting the important 'sardine run' and the marine predators that follow and feed on the migrating schools (Criterion C2) as well as containing habitat that supports an important diversity of marine mammal species (Criterion D2) including the Indian Ocean humpback dolphin, the inshore form of Bryde's whale, Indo-Pacific bottlenose dolphin, common dolphin, Cape fur seal, humpback whales, killer whales and southern right whales.

The Cape Coastal Waters IMMA extends from Cape Point to Woody Cape at Algoa Bay and extends over some 6 359 km^2. It serves as one of the world's three most important calving and nursery grounds for southern right whales, which occur in the extreme nearshore waters (within 3 km of the coast) from Cape Agulhas to St. Sebastian Bay between June and November (Criterion B2, C1). Highest densities of cow-calf pairs occur between Cape Agulhas and the Duivenhoks River mouth (Struisbaai, De Hoop, St Sebastian Bay), while unaccompanied adult densities peak in Walker Bay and False Bay. The IMMA also contains habitat that supports an important diversity of marine mammal species including the Indian Ocean humpback dolphin and Indo-Pacific bottlenose dolphin.

The South East African Coastal Migration Corridor IMMA extends some 47 060 km^2 from Cape Agulhas to the Mozambiquan border and serves as the primary migration route for C1 substock of Southern Hemisphere humpback whales (Criterion C3). On their northward migration between June and August, they are driven closer to shore due to the orientation of the coast with the Agulhas Current, whereas during the southward migration from September to November, they remain further offshore (but generally within 15 km of the coast) utilising the southward flowing Agulhas Current as far west as Knysna. The IMMA also contains habitat that supports an important diversity of marine mammal species including the Indian Ocean humpback dolphin, Common dolphin, Indo-Pacific bottlenose dolphin, Spinner dolphin, Southern Right whale, and killer whale.

There is no overlap of Block 3B/4B with the IMMA.

3.5 Ecological Network Conceptual Model

Figure 57 provides a simplified conceptual model for the nearshore and offshore receiving environment on the West Coast illustrating key variables, processes, linkages, relationships, dependencies and feed-back-loops.

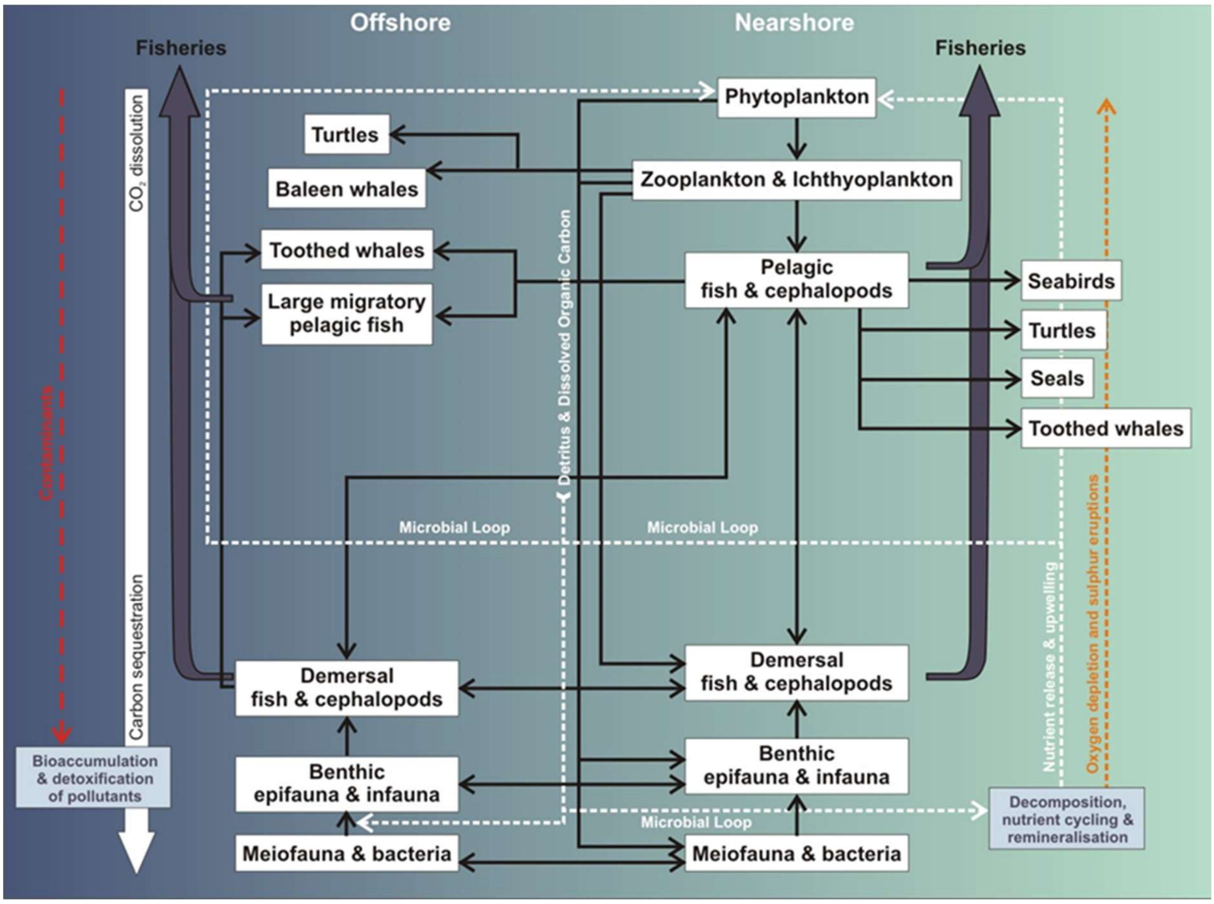

Figure 57: Simplified network diagram indicating the interaction between the key ecosystem components off the South-west and West Coasts.

The upwelling of nutrients in the southern Benguela is the main driver that supports substantial seasonal phytoplankton production, which in turn serves as the basis for a rich food chain up through zooplankton, pelagic fish, cephalopods, and marine mammals, as well as demersal species and benthic fauna. High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters, resulting in a wind-related cycle of plankton production, mortality, sinking of detritus and eventual nutrient enrichment and remineralisation through the microbial loops active in the water column and on the seabed. The natural annual input of millions of tonnes of organic material onto the seabed provides most of the food requirements of the particulate and filter-feeding benthic communities, resulting in the high organic content of the muds in the region. Organic detritus not directly consumed enters the seabed decomposition cycle, potentially resulting in the depletion of oxygen in deeper waters and the formation of hydrogen sulphide by anaerobic bacteria.

In the offshore oceanic environment in the vicinity of a seamount or a submarine canyon, similar processes of decomposition and remineralisation, upwelling of nutrients and enhanced localised primary and secondary production would apply, thereby serving as focal points for higher order consumers. The cold-water corals typically associated with seamounts and canyons also add structural complexity to otherwise uniform seabed habitats thereby creating areas of high biological diversity and the development of detritivore-based food-webs, which in turn lead to the presence of seamount scavengers and predators. Seamounts also provide an important habitat for commercial deepwater fish stocks.

Ecosystem functions of the offshore deepwater environment include the support of highly productive fisheries, the dissolution of CO_2 from the atmosphere and subsequent sequestering of carbon in seabed sediments, as well as waste absorption and detoxification. The structure and function of these nearshore and offshore marine ecosystems is influenced both by natural environmental variation (e.g. El Niño Southern Oscillation (ENSO)) and multiple human uses, such as hydrocarbon developments and the harvest of marine living resources.

A brief discussion of potential population-level and ecosystem-wide effects of disturbance and the application of the integrated ecosystem assessment framework for evaluating the cumulative impacts of multiple pressures on multiple ecosystem components is provided below. This focuses mainly on the ecosystem-wide effects of anthropogenic noise, as similar research approaches to determining the effects of exploration-well drilling and hydrocarbon production at population and ecosystem level are as yet lacking.

With growing evidence of the ecosystem-wide effects of anthropogenic noise in the ocean (Nieukirk *et al*. 2012; Kavanagh *et al*. 2019; Kyhn *et al*. 2019) and the potential consequences of sub-lethal anthropogenic sounds affecting marine animals at multiple levels (e.g. behaviour, physiology, and in extreme cases survival), there is increasing recognition for the need to consider the effects of anthropogenic noise at population and ecosystem level. The sub-lethal effects of sound exposure may seem subtle, but small changes in behaviour can lead to significant changes in feeding behaviour, reductions in growth and reproduction of individuals (Pirotta *et al*. 2018) and can have effects that go beyond a single species, which may cause changes in food web interactions (Francis *et al*. 2009; Hubert *et al*. 2018; Slabbekoorn & Halfwerk 2009).

For example, the intensified upwelling events associated with the Cape Canyon, provide highly productive surface waters, which power feeding grounds for cetaceans and seabirds (www.environment.gov.za/dearesearchteam returnfromdeepseaexpedition). Roman & McCarthy (2010) demonstrated the importance of marine mammal faecal matter in replenishing nutrients in the euphotic zone, thereby locally enhancing primary productivity in areas where whales and/or seals gather to feed (Kanwisher & Ridgeway 1983; Nicol *et al*. 2010). Surface excretion may also extend seasonal plankton productivity after a thermocline has formed, and where diving and surfacing of deep-feeding marine mammals (e.g. pilot whales, seals) transcends stratification, the vertical movement of these air-breathing predators may act as a pump bringing nutrients below the thermocline to the surface thereby potentially increasing the carrying capacity for other marine consumers, including commercial fish species (Roman & McCarthy 2010). Behavioural avoidance of marine mammals from such seasonal feeding areas in response to increasing anthropogenic disturbance may thus alter the nutrient fluxes in these zones, with possible ecosystem repercussions.

Likewise, long-lived, slow-reproducing species play important stabilising roles in the marine ecosystem, especially through predation, as they play a vital role in balancing and structuring food webs, thereby maintaining their functioning and productivity. Should such predators be impacted by hydrocarbon exploration at population level, and this have repercussions across multiple parts of a food web, top-down trophic cascades in the marine ecosystem could result (Ripple *et al.* 2016).

At the other end of the scale, significant impacts on plankton by anthropogenic sources can have significant bottom-up ripple effects on ocean ecosystem structure and health as phytoplankton and their zooplankton grazers underpin marine productivity. Healthy populations of fish, top predators and marine mammals are not possible without viable planktonic productivity. Furthermore, as a significant component of zooplankton communities comprises the egg and larval stages of many commercial fisheries species, large-scale disturbances (both natural and anthropogenic) on plankton communities can therefore have knock-on effects on ecosystem services across multiple levels of the food web.

Due to the difficulties in observing population-level and/or ecosystem impacts, numerical models are needed to provide information on the extent to which sound or other anthropogenic disturbances may affect the structure and functioning of populations and ecosystems. Attempts to model noise-induced changes in population parameters were first undertaken for marine mammals using the population consequences of acoustic disturbance (PCAD) or Population Consequences of Disturbance (PCoD) approach (NRC 2005). The PCAD/PCoD framework assesses how observed behavioural responses on the health of an individual translates into changes in critical life-history traits (e.g. growth, reproduction, and survival) to estimate population-level effects. Since then, various frameworks have been developed to enhance our understanding of the consequences of behavioural responses of individuals at a population level. This is typically done through development of bio-energetics models that quantify the reduction in bio-energy intake as a function of disturbance and assess this reduction against the bio-energetic need for critical life-history traits (Costa *et al.* 2016; Keen *et al.* 2021). The consequences of changes in life-history traits on the development of a population are then assessed through population modelling. These frameworks are usually complex and under continual development but have been successfully used to assess the population consequences and ecosystem effects of disturbance in real-life conditions both for marine mammals (Villegas-Amtmann 2015, 2017; Costa *et al.* 2016; Ellison *et al.* 2016; McHuron *et al.* 2018; Pirotta *et al.* 2018; Dunlop *et al.* 2021), fish (Slabbekoorn & Halfwerk 2009; Hawkins *et al.* 2014; Slabbekoorn *et al.* 2019) and invertebrates (Hubert *et al.* 2018). The PCAD/PCoD models use and synthesise data from behavioural monitoring programmes, ecological studies on animal movement, bio-energetics, prey availability and mitigation effectiveness to assess the population-level effects of multiple disturbances over time (Bröker 2019).

There is a wealth of studies on the effects of drilling discharges on benthic communities (reviewed by Bakke *et al.* 2013; Beyer *et al.* 2020). Population and ecosystem effects from drilling discharges is relatively easy to study as they primarily affect the sediment ecosystem for which analysis of community responses to natural and anthropogenic disturbance has a long tradition in marine environmental monitoring (e.g. Gray *et al.* 1988, 1990). The sessile nature of benthic communities more readily facilitates repeated studies of the same sites to assess temporal changes and recovery over time. All evidence suggests that the effects of drilling discharges remain confined to within 12 km from an outlet both in the waters and on the seabed, that the risk of widespread impact from the operational discharges is low and that recovery of benthic communities at drill sites occurs within 4-10 years (Bakke *et al.* 2011). While some studies suggest that meiofauna respond to cuttings discharges in a similar way to macrofauna (Montagna & Harper 1996; Netto *et al.* 2010), there is, however, very little knowledge on the sensitivity of microfauna, epifauna, hyperfauna and coral and sponge communities to drilling discharges, and there is virtually no information of potential long term effects on benthic population and community functions such as production, reproduction, and trophic interaction (Bakke *et al.* 2013). It is also notoriously difficult to study the effects of drilling discharges on populations of higher order consumers (e.g. of commercial fish stocks) and the structure and function of marine ecosystems.

Although risk assessments on the effects of drilling discharges suggest that population-wide effects are unlikely, the possibility of subtle, cumulative effects from the operational discharges at population or ecosystem level cannot be ignored.

Ecosystem-based management is a holistic living resource management approach that concurrently addresses multiple human uses and the effect such stressors may have on the ability of marine ecosystems to provide ecosystem services and processes (e.g. recreational opportunities, consumption of seafood, coastal developments) (Holsman *et al.* 2017; Spooner *et al.* 2021). Within complex marine ecosystems, the integrated ecosystem assessment framework, which incorporates ecosystem risk assessments, provides a method for evaluating the cumulative impacts of multiple pressures on multiple ecosystem components (Levin *et al.* 2009, 2014; Holsman *et al.* 2017; Spooner *et al.* 2021). It, therefore, has the potential to address cumulative impacts and balance multiple, often conflicting, objectives across ocean management sectors and explicitly evaluate trade-offs. It has been repeatedly explored in fisheries management (Large *et al.* 2015) and more recently in marine spatial planning (Hammar *et al.* 2020; Carlucci *et al.* 2021; Jonsson *et al.* 2021; Harris *et al.* 2022).

However, due primarily to the multi-dimensional nature of both ecosystem pressures and ecosystem responses, quantifying ecosystem-based reference points or thresholds has proven difficult (Large *et al.* 2015). Ecosystem thresholds occur when a small change in a pressure causes either a large response or an abrupt change in the direction of ecosystem state or function. Complex numerical modelling that concurrently identifies thresholds for a suite of ecological indicator responses to multiple pressures is required to evaluate ecosystem reference points to support ecosystem-based management (Large *et al.* 2015).

The required data inputs into such models are currently limited in southern Africa. Slabbekoorn *et al.* (2019) point out that in such cases expert elicitation would be a useful method to synthesise existing knowledge, potentially extending the reach of explicitly quantitative methods to data-poor situations.

4. ASSESSMENT OF IMPACTS

For this project, the identification and assessment of impacts relating specifically to the marine ecology cover the four main activity phases (see for an outline of the activities in these phases) of the proposed exploration drilling 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 13 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 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. When impacts were of low or negligible significance, appropriate project Standards are to be used along with best management practices.

Table 13: Aspects and Impacts Register for marine ecological impacts.

Activity Phase	Activity	Aspect	Potential Impact
1. Mobilisation Phase	Transit of survey vessel, drilling unit and support 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 of physiological and behavioural effects on 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 fauna 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 or obstruction in water column	Physical damage to and mortality of benthic species / habitats
	Loss of well control / well blowout	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

<u>**Source of Impact**</u>

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 Area of Interest and Cape Town
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 drill rig/semi-submersible intends to discharge bilge 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 drill rig 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).

<u>**Impact Description**</u>

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, especialy 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.

<u>Project Controls</u>

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 drill rig / semi-submersible 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 proceding 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 Cape Town. The Area of Interest for drilling is located ~190 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 Orange Shelf Edge MPA is located some 12 km north of the Area of Interest, whereas the Orange Seamount and Canyon Complex EBSA borders on the northern edge of the Area of Interest. Discharges could also directly affect migratory pelagic species transiting through the Area of Interest. Vessel discharges *en route* to the onshore supply base in Cape Town/Saldanha could result in discharges closer to shore, thereby potentially having an environmental effect on the sensitive coastal environment. It must be kept in mind, however, that these areas are already exposed to effects from high shipping traffic, so added risk from project vessels should be negligible.

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 Area of Interest, 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 Area of Interest, compliance with MARPOL will ensure reduced discharges and reduced sensitivity of marine fauna to these discharges. In addition, the Area of Interest 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**.

Environmental Risk

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 Area of Interest 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 Area of Interest overlaps with various MPAs between Cape Town and the Area of Interest; 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 AOSAC. 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 MINOR intensity, IMMEDIATE duration and REGIONAL (although localised at any one time around the project vessels). As the impact is fully reversible with a low probability of occurring, the environmental risk of the impact is therefore considered **LOW**.

Impact Significance

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

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 MPAs and 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 **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**
Environmental Risk	**LOW**	**LOW**
Intensity	MINOR	MINOR
Extent	REGIONAL	LOCAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**LOW**	**LOW**

4.3.2 Discharge of Ballast Water as a source of Exotic Species

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 Area of Interest 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 Area of Interest, 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 (1 000 m to 3 000 m), colonisation by invasive species released in ballast water and/or from biofouling on the seabed is considered unlikely. Thus, the sensitivity of benthic receptors in the offshore waters of Block 3B/4B is considered **VERY LOW**.

Environmental Risk

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 South Africa'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 South African waters. The risk of this impact is, however, significantly reduced 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 Area of Interest, 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 (1 000 m to 3 000 m) will ensure that colonisation of invasive species on the seabed is unlikely. De-ballasting in the Area of Interest, complying with IMO requirements, will thus not pose an additional risk to the introduction of invasive species.

In terms of hull fouling, the Area of Interest is located in the main traffic routes that pass around southern Africa. Thus, the introduction of invasive species into local 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 South African coastal waters on a daily basis.

Considering the remote location of the Area of Interest 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 MINOR 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. As the impact is fully reversible with a low probability of occurring, the environmental risk of the impact is therefore considered **LOW**.

Impact Significance

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

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 Area of Interest from other parts of the world, and the need for de-ballasting once on site. Ballasting of a semi-submersible rig would only occur on set-up at or close to the drill site, with deballasting on departure also occurring at site. With the implementation of the mitigation measures above, the residual impact would reduce to **low** environmental risk 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**
Environmental Risk	**LOW**	**LOW**
Intensity	MINOR	MINOR
Extent	REGIONAL	REGIONAL
Duration	SHORT TERM	SHORT TERM
Reversibility	IRREVERSIBLE	IRREVERSIBLE
Probability	IMPROBABLE	IMPROBABLE
Significance	**LOW**	**NEGLIGIBLE**
Confidence	**MEDIUM**	**MEDIUM**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW**	**LOW**

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 Area of Interest and Cape Town
Demobilisation	n/a

Possible crew transfers by helicopter from Cape Town 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 Cape Town (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 South African Law. The Marine Living Resources Act, 1998 (No. 18 of 1998) states that no whales or dolphins may be harassed, killed or fished. No vessel or aircraft may, without a permit or exemption, approach closer than 300 m to any whale and a vessel 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 Cape Town. Although the Area of Interest is located approximately 470 km northwest of Cape Town at its closest point, the flight path between the Area of Interest and Cape Town would cross over numerous MPAs, 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 Area of Interest 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 Area of Interest, 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 Area of Interest, due to their extensive distributions their numbers are expected to be low.

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), or 'Vulnerable' (e.g. Damara Tern). The overall sensitivity is considered to be **HIGH**.

Environmental Risk

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 migrate to the southern Africa subcontinent to breed and calve, where they tend to have an extremely coastal distribution mainly in sheltered bays. Winter concentrations have been recorded all along the southern and eastern coasts of South Africa, with the most significant concentration currently on the South Coast between Cape Town and Gqeberha (Port Elizabeth). They typically arrive in coastal waters off the South Coast between June and November, although animals may be sighted as early as April and as late as January. When moving from the South Coast breeding ground directly to the West Coast feeding ground, southern right whales would dosplay a clear peak in numbers on the West Coast (Table Bay to St Helena Bay) between February and April. When departing from the feeding grounds between April and June animals take a direct south-westward track. The southern portions of the Block would therefore lie to the north of this migration route. Southern right calving and nursing activities off the Cape Peninsula would thus fall within the direct flight path to the Area of Interest for drilling. Smaller cetaceans in the area include the common dolphin and dusky dolphin both of which can occur in large group sizes. The level of disturbance of cetaceans by aircraft depends 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 Cape Town or Springbok and the drill rig could affect seabirds and seals in breeding colonies and roosts on the mainland coast. The nearest seabird colonies to Cape Town airport are at Robben Island, Dassen Island and the Saldanha Bay Islands. Of these, Robben Island potentially falls within the flight paths between the airport and the Area of Interest for drilling and flight paths would need to be planned to avoid these colonies. The seal colonies in False Bay, at Robbesteen near Koeberg and at Cape Columbine all do not fall within the potential flight path to the AOI.

The seal colony at Strandfontein Point (south of Hondeklipbaai) falls within the flight paths between the airport and the Area of Interest for drilling and flight paths would need to be planned to avoid these colonies (Figure 58).

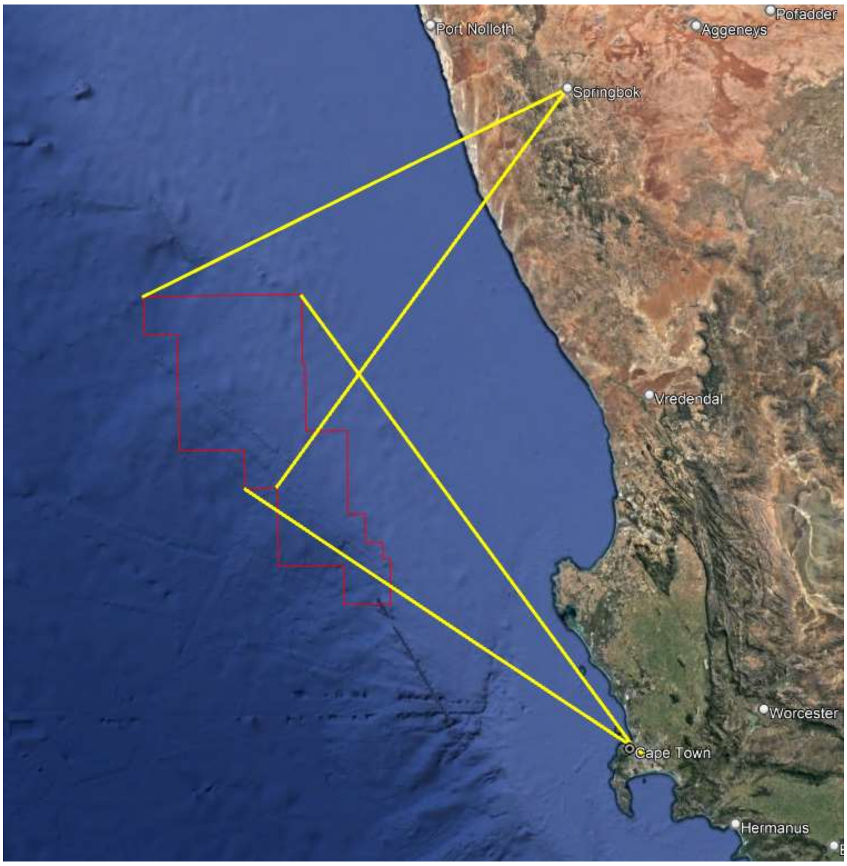

Figure 58: Area of potential flight paths (within yellow lines) from Cape Town airport to the north-eastern and south-western extremes of the Area of Interest for exploration drilling in Block 3B/4B.

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 MINOR 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), IMMEDIATE (4 months per well), fully reversible and with a low probability of occurring, the environmental risk of the impact is therefore considered **LOW**.

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 the low environmental risk. 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.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Plan flight paths to ensure that no flying occurs over seal colonies and seabird nesting areas.	Avoid / abate on site
2	Avoid extensive low-altitude coastal flights.	Avoid/ abate on site
3	Maintain a flight altitude >1 000 m except when taking off and landing or in a medical emergency.	Avoid/ abate on site
4	Maintain an altitude of at least 762 m or 2 500 ft above the highest point of a National Park or World Heritage Site.	Avoid/ abate on site
5	Comply fully with aviation and authority guidelines and rules.	Avoid/ abate on site
6	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 **low** environmental risk 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**
Environmental Risk	**LOW**	**LOW**
Intensity	MINOR	MINOR
Extent	REGIONAL	REGIONAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW**	**LOW**

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, 190 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 area / Area of Interest, 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 Area of Interest, 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.

Environmental Risk

Offshore platform structures are known to concentrate both seabirds and their prey due to structural stimuli, food concentrations, oceanographic processes and lights and flares (Wiese *et al*. 2001). Potential attraction may increase during fog when greater illumination is caused by refraction of light by moisture droplets. The strong operational lighting used to illuminate drilling units or vessels at night have been reported to attract primarily passerines (Hüppop *et al*. 2016), but also Little Auks, Storm-petrels and Shearwaters (Wiese *et al*. 2001), with documented mortalities being higher during migration periods. However, in relation to the huge numbers of migrant birds overflying the seas, collisions with man-made structures seem to be rare, although sometimes several thousand birds may be affected in a single event, particularly during adverse weather conditions (Hüppop *et al*. 2016). 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 associated with exploration drilling are rare (TEEPSA, pers.comm.). 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 Cape Town.

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 West Coast 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 within the Area of Interest to REGIONAL for project vessels) over the IMMEDIATE term (3-4 months for drilling). For support vessels travelling from Cape Town increase in ambient lighting would likewise be restricted to the immediate vicinity of the vessel over the immediate-term. As the impact is fully reversible with a low probability of occurring, the environmental risk of the impact is therefore considered **LOW**.

Impact Significance

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

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. Capturing and transportation of seabirds must be undertaken according to specific protocols as outlined in the OWCP.	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 of **LOW** significance.

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**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	REGIONAL	REGIONAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**VERY LOW**
Cumulative potential	**LOW**	**LOW**

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 on the South Coast, 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 on the South African West Coast. 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 Remotely Operated Vehicle (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. 4.5 m^2 cumulatively for 5 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. 15 m^2 cumulatively for 3 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 DWOB 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 (reviewed by Clarke & 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 (~190 km from the coastline near Hondeklipbaai) where the Southeast Atlantic Unclassified Slope habitat has been rated as 'Least Threatened' due to the expansive areas it covers.

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. While some of these benthic communities would comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance, the environmental stability of the deep sea suggests that much of the benthos may comprise longer-lived species. 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 **MEDIUM**.

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**.

Environmental Risk

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 MINOR intensity, and limited to the turbidity plume generated by the ROV thrusters (ACTIVITY SPECIFIC) (a few metres around the ROV and/or ROV flight track). However, in most cases sub-lethal or lethal responses may 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 South African West 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 IMMEDIATE-TERM (hours) only. As the impact is fully reversible with a low probability of occurring, the environmental risk of the impact is therefore considered **LOW**.

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 the West Coast 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 (ACTIVITY SPECIFIC). As the wellhead would become colonised by successional communities after abandonment, any impacts to benthic communities would persist over the SHORT-TERM only. The impact is reversible without incurring significant time and cost but with a high probability of occurring. The environmental risk of the impact is therefore considered **LOW**.

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 medium sensitivity of the receptors and the low environmental risk 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 and other survey data), 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 1 000 m[6] of a proposed well site.	Avoid
3	If sensitive and potentially vulnerable habitats are detected, adjust the well position accordingly to beyond 1 000 m[7] 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**.

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	MEDIUM	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	ACTIVITY	ACTIVITY
Duration	SHORT	SHORT
Reversibility	REVERSIBLE	REVERSIBLE
Probability	HIGHLY LIKELY	HIGHLY LIKELY
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW**	**LOW**

[6] In US territorial waters the set-back distances for sea-surface discharges to hard grounds is 2 000 ft (610 m) (Cordes *et al*. 2016).

[7] 1 000 m was used here based on the US set-back distances and using the precautionary principle.

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 116 m^3 of cuttings would be generated at the wellbore. In addition to the cuttings, approximately 374 tons of WBM will be discharged onto the seafloor over a period of 2.5 days (60 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 30 m^3 would occur over a period of a few 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 (50 m^3 in the worst case) emerges out of the top of the well onto the cuttings pile, where it dissolves slowly into the surrounding seawater.

- 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 high-performance KCL/glycol WBM) 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 162 m^3 of cuttings and 303 tons of KCl/Glycol mud 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 ~45 days (1 080 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 high performance WBM or 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 drilling muds discharged at the surface from the drill rig would disperse and settle over a wider area around the wellhead resulting in changes in sediment structure and possibly 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). As this would be in the area already affected by top hole cuttings, no additional effect except for possible cement toxicity would be expected.

Project Controls

The operator will 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 survey(s) (including ROV), 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 high-performance 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 <6.9% Oil On Cutting (OOC) and discharged overboard).
- Discharge of risered cuttings *via* a caisson at 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 190 km offshore where the Southeast Atlantic Unclassified Slopes habitat has 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 **MEDIUM**.

In contrast, the benthos of deep-water hard substrata is typically vulnerable to disturbance due to their long generation times. No canyons, valleys or hard grounds have been reported for the Area of Interest for drilling, with the closest being Child's Bank located ~75 km east of the eastern point of the Area of Interest for drilling. The Southern Benguela Rocky Shelf Edge, Child's Bank Corals and Southern Benguela Sandy Shelf Edge habitats have been assigned a threat status of 'Vulnerable' (see Figure 15). However, should they occur, the sensitivity of such deep-water reef communities to physical disturbance is considered **HIGH**.

Environmental Risk

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 59) (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 the Block 3B/4B, the effects of drilling discharges on benthic ecosystems can be 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).

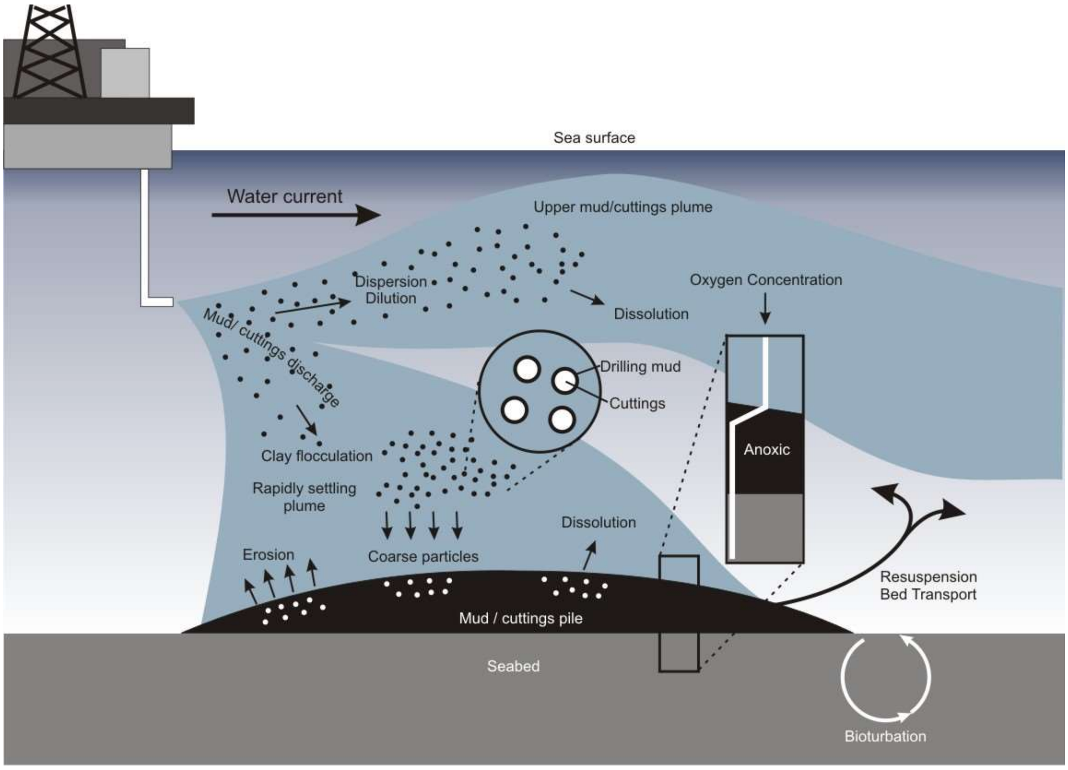

Figure 59: Hypothetical dispersion and fates of cuttings following discharge to the ocean, from a drilling unit. The solids undergo dispersion, dilution, dissolution, flocculation, and settling in the water column. If the discharge contains a high concentration of organic matter, the cuttings pile may 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. While some of the benthic communities would comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance, the environmental stability of the deep sea suggests that much of the benthos may comprise longer-lived species. Similarly, 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 the DWOB Block. 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 riseless discharges, which for the highest values (>0.1 mm) extend a maximum distance of 765 m to the N of the Discharge Point) 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).

<u>Cuttings dispersion modelling:</u>

The results of the cuttings dispersion modelling studies undertaken as part of this project (HES Expertise Services 2023) largely confirm the reports of international studies that predicted that the effects of discharged cuttings are localised (see Perry 2005). Two scenarios were modelled namely 1) using WMBs only at release point D and 2) using NADFs for the deeper well sections for release point A. For the current project and assuming drilling using high performance WBMs only, 278 m^3 of cuttings would be generated, of which 116 m^3 would be discharged directly at the seafloor (42% of the total volume of cuttings generated), with the remaining 162 m^3 discharged off the drill unit, after treatment to reduce oil content to <6.9% Oil On Cutting, into the water column. In addition, approximately 374 tons of WBM (riserless: 344 m^3; displacement: 30 m^3) will be discharged onto the seafloor at the wellbore with an additional 444 tons of high-performance KCl/glycol mud discharged from the drilling unit. These discharges are pulsed throughout the drilling campaign (Base case: 60 days), reflecting the five periods corresponding to the different wellbore diameters. Four seasons were modelled for a single discharge location (Discharge point D).

For scenario 2 using NADFs during the risered sections at release point A, 1 876 tons of cuttings would be generated, of which 1 039 tons would be discharged directly at the seafloor (55% of the total volume of cuttings generated), with the remaining 837 tons discharged off the drill unit, after treatment to reduce oil content to <6.9% Oil On Cutting, into the water column. In addition, approximately 879 tons of WBM will be discharged onto the seafloor at the wellbore during riserless drilling with an additional 116 tons of NADFs discharged from the drilling unit. These discharges are pulsed throughout the drilling campaign (Base case: 60 days), reflecting the five periods corresponding to the different wellbore diameters. Four seasons were modelled for a single discharge location (Discharge point A).

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 D at the end of drilling operations (i.e. at the end of both the riserless and risered drilling stages) is predicted to amount to a maximum depositional thickness of 5.4 mm, progressively thinning out in a NW to SE direction to 0.5 mm at a maximum distance of 175 m from the discharge point (Season 2) (Figure 60a and 60b). The threshold depositional thickness of >6.5 mm was not reached. For discharge point A, maximum cumulative thickness values of between 65.2 mm and 69.2 mm are predicted at the discharge point, progressively thinning out in a NW to SE direction to 0.5 mm at a maximum distance of 259 m from the discharge point (Season 4) (Figure 60c). The thickness deposit 10 years after the operations is still ~30 mm, which exceeds the 6.5 mm threshold value.
- 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 significant 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[8] associated with the riserless drilling stage are primarily physical, induced by the thickness deposit and contributing a maximum

[8] 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.

of 65% to the risk factor (Season 2) at the modelled discharge point D. For discharge point A, the environmental risk of changes in grain size and thickness deposit together contribute a,10% of the total risk.

- At discharge point A, oxygen depletion in the sediment in response to physical and chemical impacts is responsible for ~15% to the total risk.

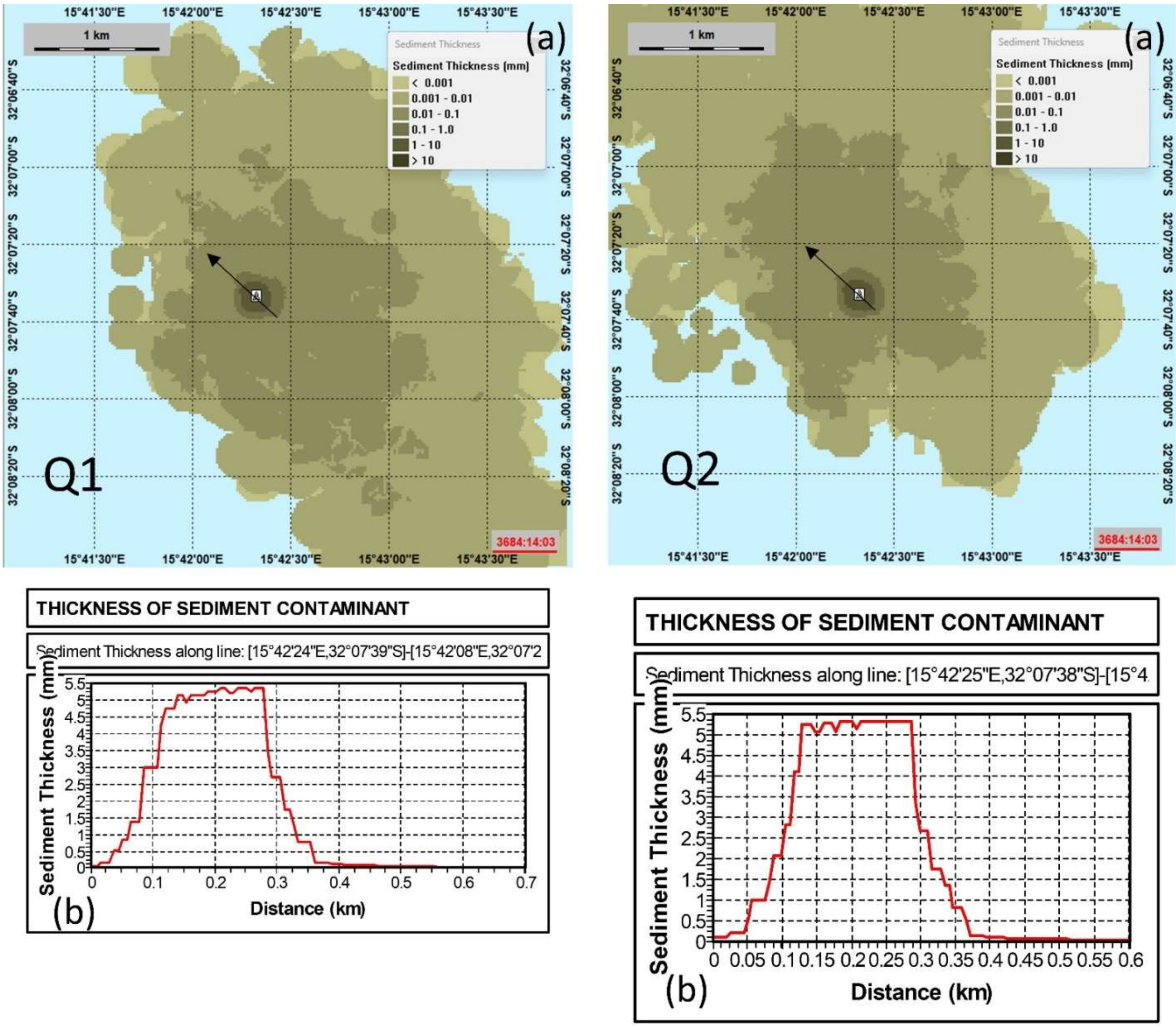

Figure 60a: Maximum thickness deposit on the seabed for Quarters 1 and 2, 10 years after operations (right) for discharge point D (Source Livas 2023a).

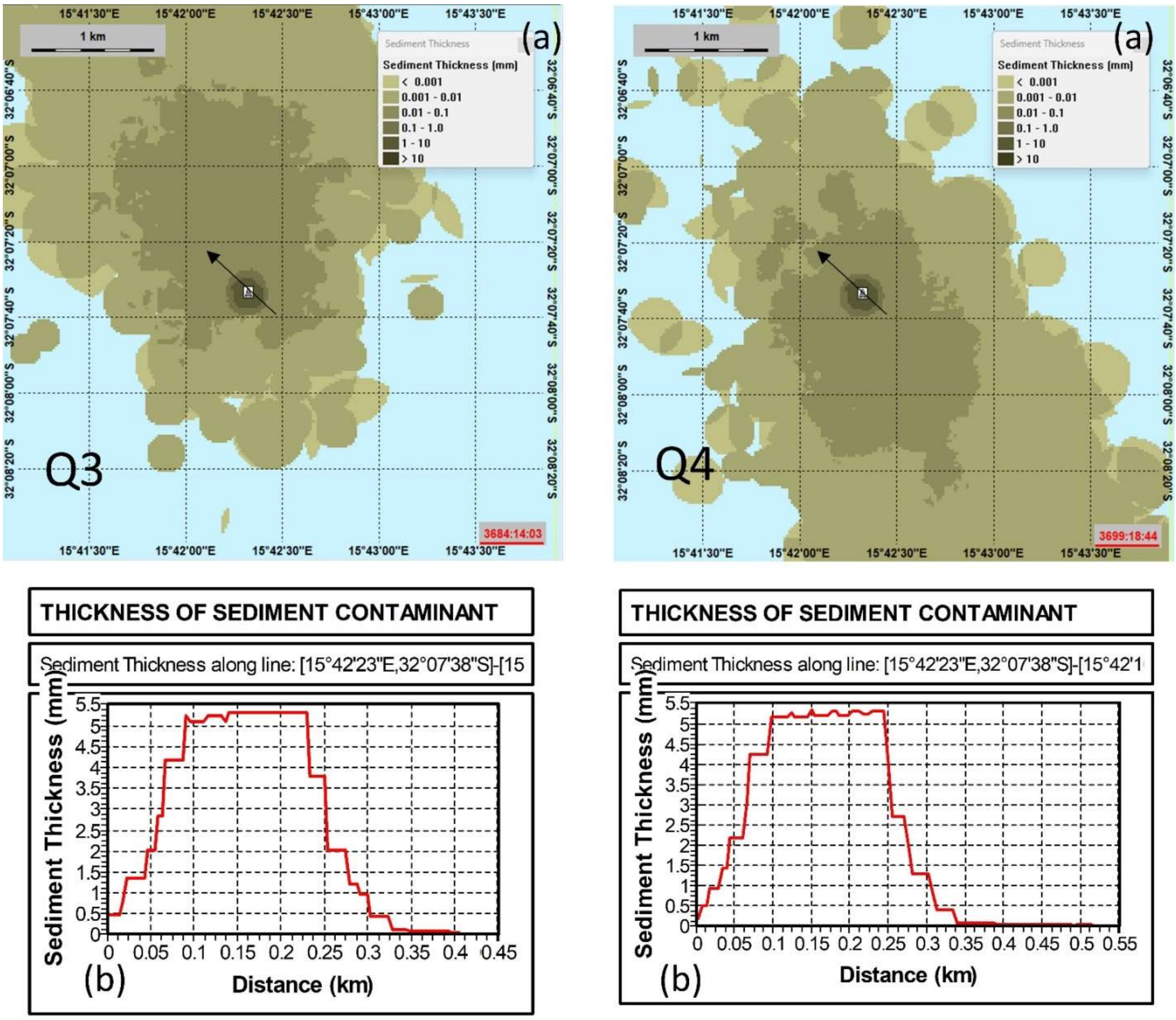

Figure 60b: Maximum thickness deposit on the seabed for Quarters 3 and 4, 10 years after operations (right) for discharge point D (Source Livas 2023a).

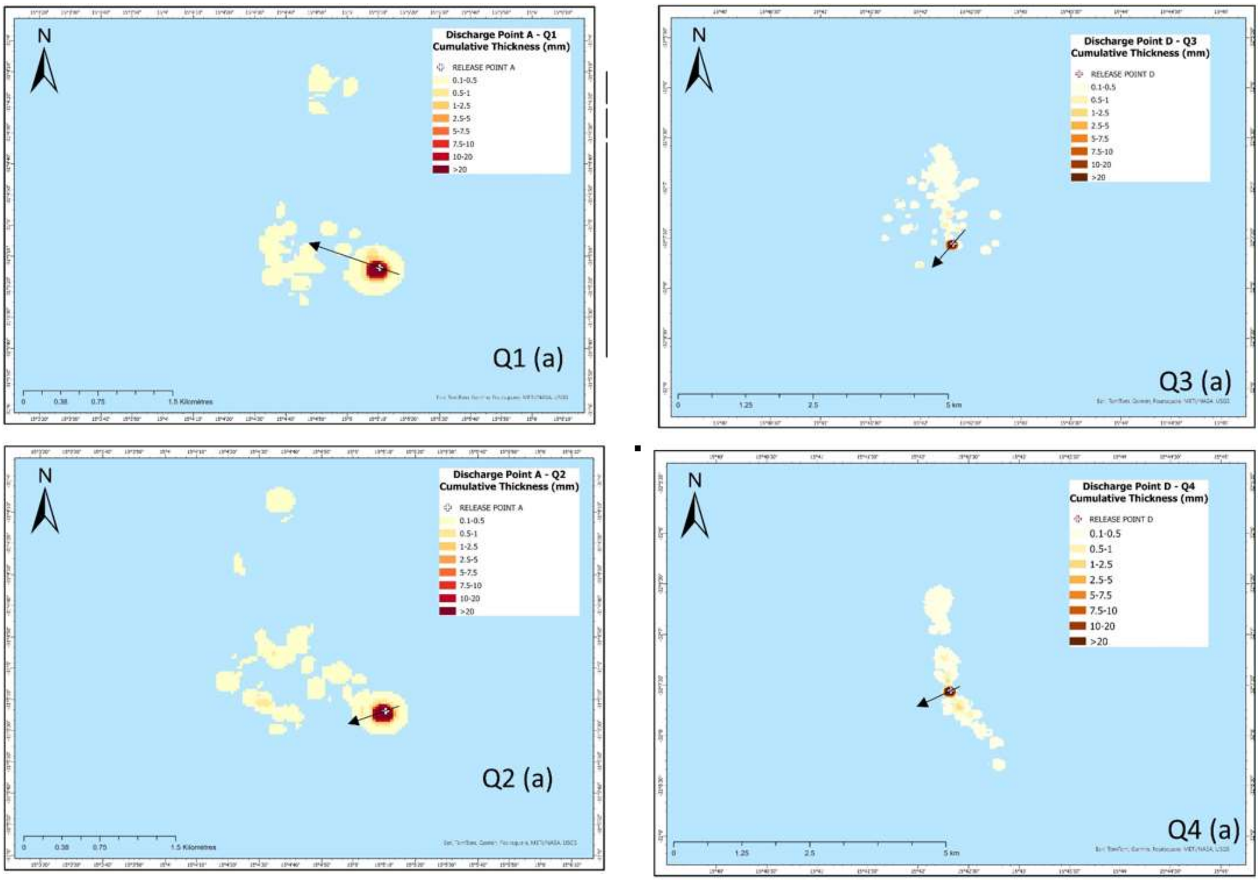

Figure 60c: Maximum thickness deposit on the seabed for discharge point A, 10 years after operations (right) (Source Livas 2023a).

Grain-size Variation

- As would be expected, in the model the riserless discharges resulted in the greatest variation in grain size in surficial sediments to those originally present, with the maximum variation recorded at discharge point D at the end of operations varying between 1 700% and 1 900% (compared to a natural median grain size of 7 µm) and that for discharge point A varying between 4 300% and 5 000%. Grain size variation is insignificant beyond 150 m from discharge point D and beyond 140 m from discharge point A. The grain size change is mostly due to discharges from drilling of the risered sections.
- Change in grain size around the wellbore associated with the riserless drilling stage are primarily physical, contributing a maximum of 48% (Season 4) to the overall Environmental Impact Factor for the sediments during drilling of the riserless sections at discharge point D.

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).

Risk 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 mid- and lower slope habitats rated as 'Least Threatened'. The depositional footprints are also highly localised, and overlap of concentrations of total discharge in the superficial layers of seabed sediments with any potential 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 on the Agulhas Bank, with eggs and larvae occurring along the West Coast but 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 MODERATE 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. This applies to cuttings with both WBMs and NADFs. 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 MINOR 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 burrowing up through the deposited drilling solids. For the discharge of drilling solids at the wellbore the impact is highly localised (SITE SPECIFIC maximum cumulative thickness of 5.4 mm located on the discharge point), whereas discharges from the drilling unit would have LOCAL impacts (up to 175 m 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 in the stable deep sea environment to functional similarity is expected to occur within the LONG TERM. The impact would be reversible only by incurring significant time and will definitely occur. Impacts from riserless and risered drilling are thus assessed to be of **MEDIUM** environmental risk for all 5 wells regardless of season.

Risk of smothering of sensitive hard substrata: Considering the avoidance of possible hardgrounds through the pre-drilling survey, including ROV (project control) the wells would be sited in unconsolidated sediments beyond the shelf edge. Modelling shows that the deposition footprints extend primarily in a northerly direction away from a drill sites. The depositional footprint does not overlap with any MPAs, EBSAs or CBAs (see Figure 54). 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 764 m from the drilling unit per well) 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. The impact would be reversible only by incurring prohibitively high time but with a high probability of occurring. The environmental risk of the impact is therefore considered **HIGH** for up to 5 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 **MEDIUM** significance due to the medium sensitivity of the receptors and the medium environmental risk for the impacts of smothering. However, the potential smothering effects of drilling discharges and cement on deep-water reef communities (should they occur) are considered of **HIGH** significance due to the high sensitivity of the biota and the high environmental risk.

Identification of Mitigation Measures

No.	Mitigation measure	Classification
1	Ensure there is meticulous design of pre-drilling site surveys and Ecological Baseline Surveys to provide sufficient information on seabed habitats, and to map sensitive and potentially vulnerable habitats (particularly in the modelled cuttings footprints) thereby preventing potential conflict with the 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 1 000 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 probability of the impacts being realised, and the residual impact would drop to **MEDIUM** significance.

As pre-drilling ROV surveys would reveal the presence of hard grounds and AOSAC will actively avoid known sensitive seabed communities by >1 000 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	MEDIUM	
	Pre-Mitigation Impact	Residual Impact
Environmental Risk	**MEDIUM**	**MEDIUM**
Intensity	MEDIUM	MEDIUM
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Probability	DEFINITE	DEFINITE
	MEDIUM	**MEDIUM**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW**	**LOW**

7	*Disturbance and/or Smothering of 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
Environmental Risk	**HIGH**	**MEDIUM**
Intensity	HIGH	MEDIUM
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
Probability	HIGH	IMPROBABLE
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Significance	**HIGH**	**MEDIUM**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**HIGH**	**LOW**
Mitigation Potential	**-**	**HIGH**
Cumulative potential	**LOW**	**LOW**

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 AOSAC has various project controls in place for the proposed drilling operations. These include:

- AOSAC has indicated it plans to use WBMs (riserless sections) and high-performance KCl/Glycol WBMs for the risered sections. Should low toxicity Group III NADFs be used as an alternative 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 <6.9% Oil On Cutting (OOC) and discharged overboard).
- Cuttings will be discharged 10 m below surface during risered drilling.

Sensitive Receptors

The drilling activities would be undertaken in the marine environment, more than 180 km offshore where the Southeast Atlantic Unclassified Slopes 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 MEDIUM 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.

Environmental Risk

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 390 m to 875 m riserless sections 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 116 m^3 of cuttings and 374 tons of WBMs will be discharged at the seabed during the riserless stage, with an additional 30 m^3 of High Viscous Gel sweeps / KCl Polymer PAD mud released during well suspension and displacement in a well drilled using only WBMs. For wells in which WBMs will be used during the riserless stage only, 1 039 tons of cuttings and 879 tons of WBMs will be discharged at the seabed during the riserless stage, with an additional 1 047 tons of High Viscous Gel sweeps / CaCl 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, high-performance KCl/glycol WBMs containing primarily barite (~90%) and a suite of chemicals 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.) have a log K_{ow} >3, and are considered potentially hazardous to the marine environment due to their low PNEC. During the risered stage, 257 m^3 of cuttings and 444 tons (58% of total drilling fluid discharge) of high-performance WBMs may be discharged 10 m below the sea surface at the drilling unit.

Should NADFs be used during the risered stage, drilling fluids containing primarily bentonite and barite and a suite of chemicals (see Table 7 in HES 2024) would be used, with 837 tons of cuttings and 116 tons of NADFs 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 binding 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).

<u>Cuttings dispersion modelling:</u>

<u>Environmental Risk due to Contaminant Concentrations in the Sediments</u>

- The risk related to the riserless sections is much higher than the potential risk induced by the risered sections due primarily to the high proportion of Bentonite present in the muds. There is no trace of chemical risk due to the riserless section discharges. The resulting impact is therefore physical rather than chemical.
- The sediment environmental risk of the sections drilled with a riser is similarly more physical than chemical, due to the high proportion of Barite released in the discharge.
- At the end of the operations, a significant risk above the threshold at which 5% of the species in the ecosystem are likely to be affected is observed up to a maximum distance of 115 m around the discharge point. A maximum risk of 17% has been calculated located on the release point (Season 4). This risk is primarily associated with the chemicals from the drilling muds remaining in the sediments.
- The trace of risk persisted for three years after the operations. Results for the maximum potential risk thus emphasise the slow recovery of seabed impacts at such depths under low current conditions. However, this risk remains highly localised (
- Figure 61a and 61b).
- 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.

<u>Contaminant Concentrations[9] in the Sediments</u>

- 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. The drilling discharge modelling report did not, however, provide concentrations.
- Once the marine riser has been set (risered drilling stage), cuttings and high-performance WBMs 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 deposit that extends from the well bore in the direction of the prevailing currents. Risered cuttings

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

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.

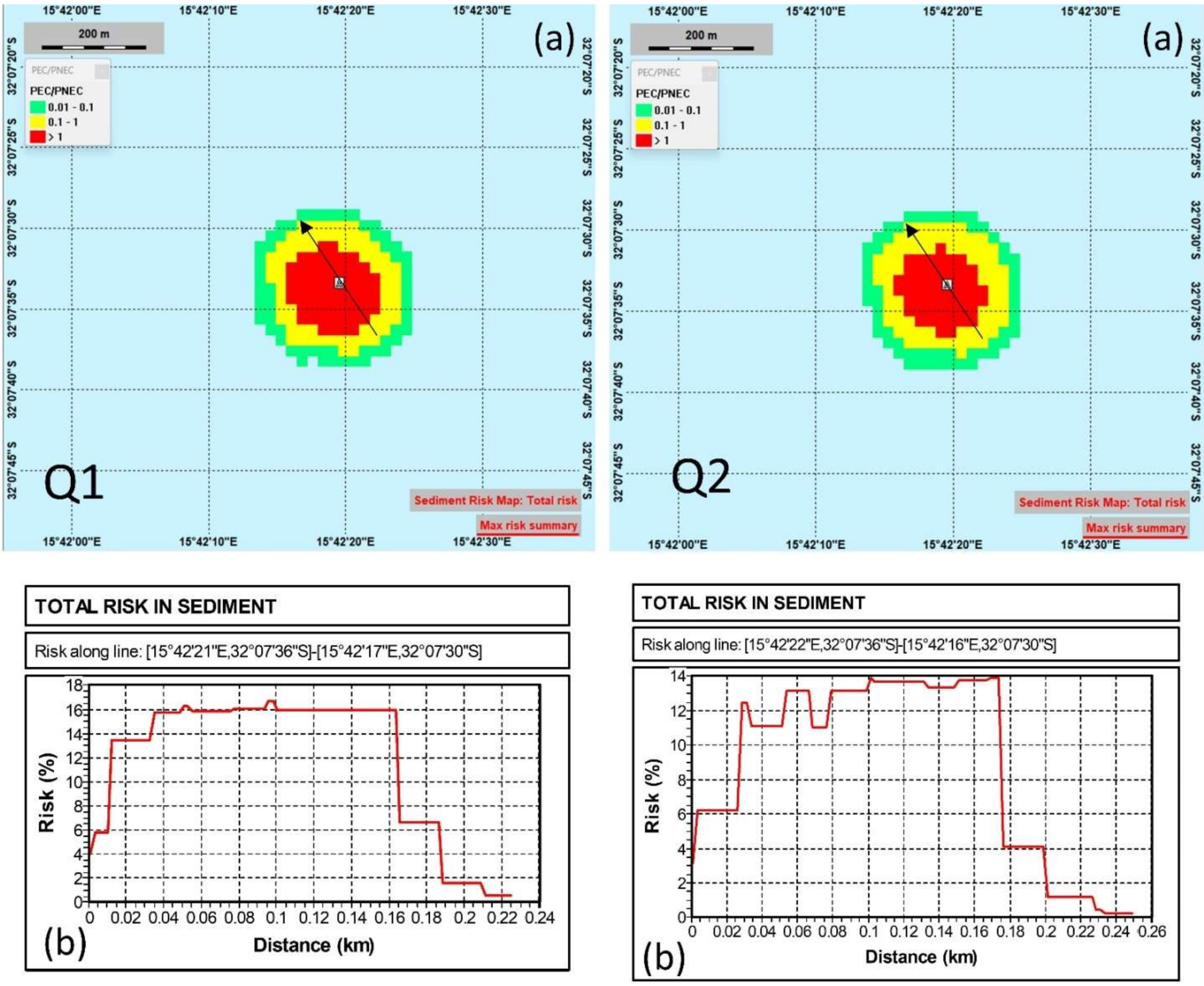

Figure 61: Maximum potential risk of contaminants in the sediments for Season 1 and Season 2: at the end of the drilling operations (Source: Livas 2023a).

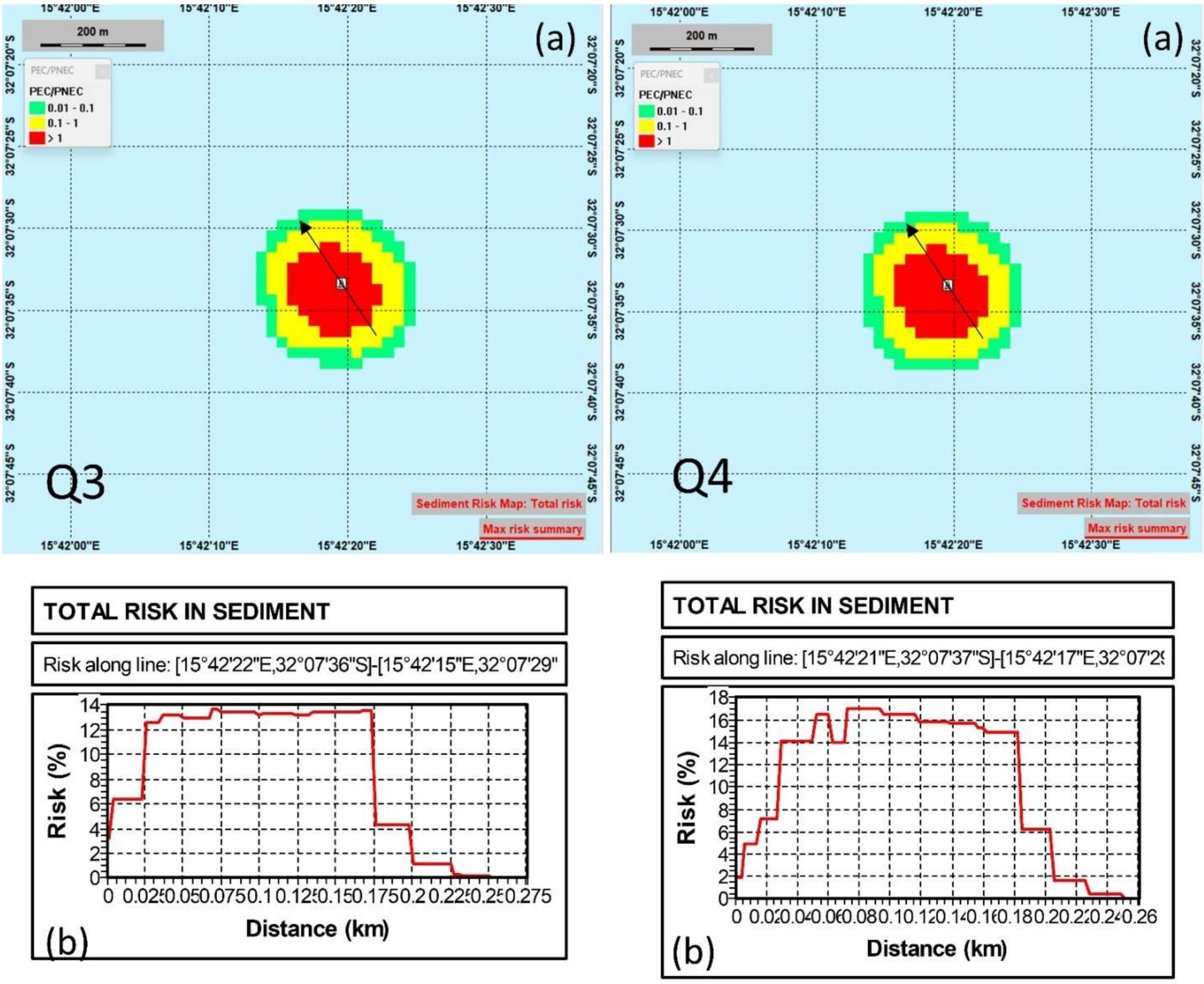

Figure 61b: Maximum potential risk of contaminants in the sediments for Season 3 and Season 4: at the end of the drilling operations (Source: Livas 2023a).

- A further two pulses in environmental risk typically occur due to the discharge of KCl-WBMs during well logging and plugging. Although these discharges were not modelled, they do constitute a risk to the water column, but 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 typically not attained during these discharges due to the rapid dilution and dispersion of the chemicals and particulates in the prevailing currents.

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

- The cuttings modelling studies for the current project (Livas 2023a) 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 1 240 – 1 500 m (*i.e.* 260 m above the modelled discharge point (1 499 m depth)). 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 distance from the discharge with a significant environmental risk[10] was 260 m during Season 4. This risk is not centralised around the discharge point but spreads to the N, thereby clearly showing the effect of water column currents near the seabed on the dispersion of drill cuttings and drilling muds (Figure 62).

- The cumulative risk[11] in the water column above the seabed is short-term, however, being concentrated around the discharge point and decreasing rapidly with distance as the plume dilutes.
- The main contributor to the environmental risk in the water column during the riserless drilling stages is bentonite, which 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 used during the riserless stage is caustic soda, which has chemical effects and which contribute <1% to the risk in the water column near the seabed.
- The maximum instantaneous Environmental Impact Factor value is reached during the drilling of the 26" section, representing a significant risk to a volume of water of 790 × 10^5 m^3.

Contaminant concentrations in the water column for the risered sections

With implementation of high-performance WBMs at the start of the 17.5″ section during the risered stages, the contaminant contributions in the muds increase slightly, producing a surface footprint from 0-240 m depth in the 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 risk in the water column for the risered discharges of high performance WBMs at the modelled discharge point is shown in Figure 62a.

- A significant environmental risk (i.e. >5%) from the discharge during risered drilling is not reached in the plume at the surface during any of the seasons.
- The cumulative risk in the water column is short-term being concentrated around the discharge point and decreasing rapidly with distance as the plume dilutes and disperses in surface currents.
- Plumes 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 main contributors to the environmental risk to the water column during the risered stages constitute the particulate compounds (barite and bentonite) as well as various chemical constituents.
- The maximum environmental risk throughout the water column for all discharges combined is 57%[12] (Season 2), and is mainly due to discharges from the riserless sections.

[10] 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.

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

[12] Note that the 57% combined risk is very conservative as it is the sum of the independent, individual 'toxicity' effects. This theoretically will be on the same community and ignores that any one of the stressors could 'remove' the sensitive components leaving only 'robust' components and thus lower toxicity effects of the balance of stressors.

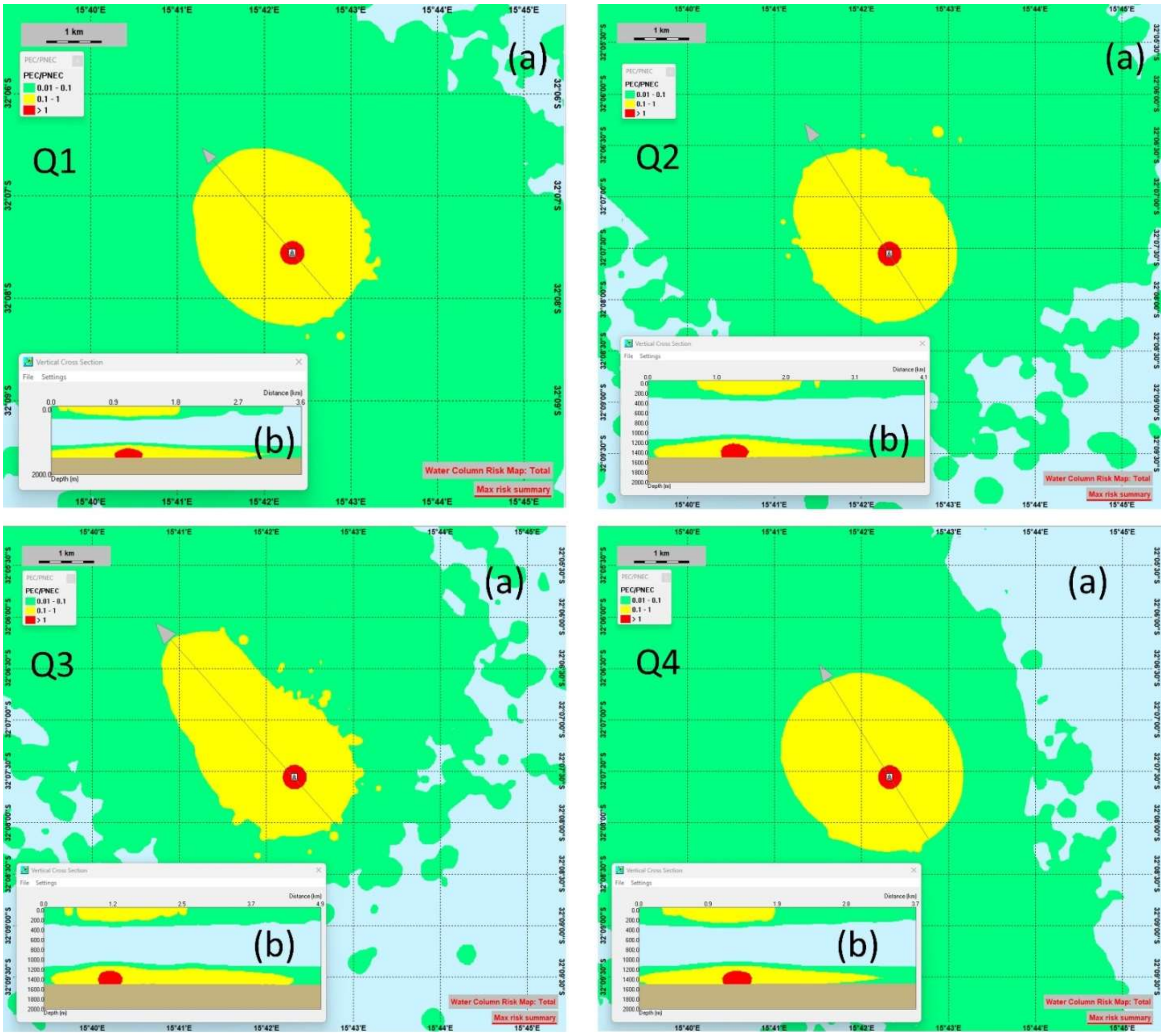

Figure 62a: Maximum cumulative environmental risk throughout the water column at any time for the discharge using WBMs (a) Risk map – (b) Vertical cross section of the water column for all four Seasons (Source: Livas 2023a).

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 that extends through the entire water column from the surface to the seabed for all seasons except Season 4, due to dispersion and dilution of the drilling fluid additives following release of drilling cuttings from the drill rig. The cumulative significant environmental risk in the water column for the risered discharges of NADFs at the modelled discharge point is shown in Figure 62b.

- A significant environmental risk (i.e. >5%) from the discharge during risered drilling is reached in the plume at the surface during all of the seasons, extending a maximum distance of 13.2 km to the NW during Season 2. The plume therefore dissipates and does not reach the shoreline or sensitive receptors.
- The cumulative risk in the water column is short-term being concentrated around the discharge point and decreasing rapidly with distance as the plume dilutes and disperses in surface currents.

The highest concentrations are reached during the drilling of the 17.5˝ section 9-10 days after the start of operations.

- Plumes are not detectable beyond the cessation of drilling operations. Chemical footprints are therefore ephemeral only due to the strong dispersion and dilution of the chemicals. 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 main contributors to the environmental risk to the water column during the risered stages constitute bentonite, which contributes 90% to the risk for the riserless section. During the risered section, bentonite contributes 6-13% to the risk in the water column.
- The maximum environmental risk throughout the water column is reached during the drilling of the 17.5˝ and 12.5˝ sections, due to the presence of the highly toxic hydrotreated light petroleum distillate present in the base oil (EDC-99DW). This component is responsible to 68% to 73% of the environmental risk during risered discharges.

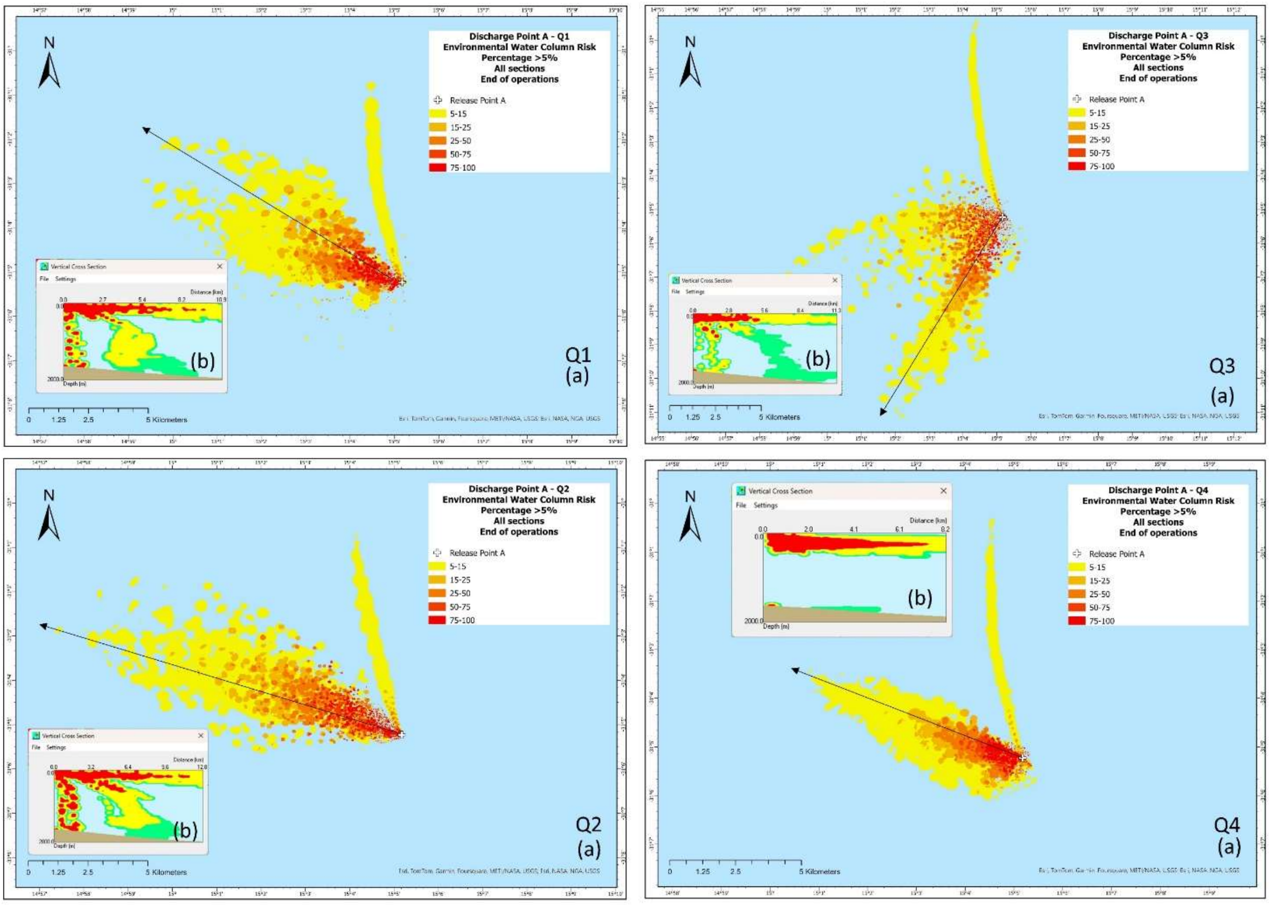

Figure 63b: Maximum cumulative environmental risk throughout the water column at any time for the discharge using NADFs (a) Risk map – (b) Vertical cross section of the water column for all four Seasons (Source: Livas 2023a).

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 are 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.

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 is 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 AOSAC) 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 130 m from the well site, and persists beyond five 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 1 000 m to as much as 3 000 m.

Table 14 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.

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).

Table 14: 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
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

Ingredient	Range of LC_{50} for different species (mg/l)
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

With changes to the use of high performance 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.

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 (should these be used for the risered stage) as sensitive and potentially vulnerable habitats adjacent to 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 MINOR as the block lies well offshore of the egg and larval distribution of important commercial fish species (see Figure 22). Furthermore, the maximum cumulative risk throughout the entire water column would remain LOCALISED (*i.e.* Riserless: confined to a maximum distance of 0.7 km from the well site; Risered: confined to a maximum distance of 0.9 in a N 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. Rapid dilution of these constituents ensures that impacts would persist only over the IMMEDIATE TERM in the water column (i.e. rapidly diluted and dispersed (few hours) and are not extending beyond the 60 days required for the drilling of the base case) (see Livas 2023a 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 beyond 5 years. Thus, the duration for sediment toxicity is MEDIUM TERM.

The impact is partially reversible and with a high probability of occurring. The environmental risk of the potential toxicological impacts of drilling fluids on biota in unconsolidated sediments is thus considered **LOW** for up to 5 wells regardless of season and **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 medium-sensitivity receptors expected in the unconsolidated sediments on the continental slope and in the water column are deemed to be of **LOW** significance for sediment toxicity due to the high magnitude, and LOW 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 **MEDIUM** significance due to the potentially high sensitivity of long-lived receptors and the high magnitude on the ESA communities, which are expected to have greater support functions than those in non-ESA areas.

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

No.	Mitigation measure	Classification
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, but the significance of residual impacts would remain at LOW **significance** (unconsolidated sediments) and **MEDIUM significance** (sensitive hardgrounds and EBSAs), and of **LOW** 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	**MEDIUM**	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	LOCAL	LOCAL
Duration	MEDIUM TERM	MEDIUM TERM
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	HIGH	HIGH
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**MEDIUM**	**MEDIUM**

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**
Environmental Risk	**HIGH**	**MEDIUM**
Intensity	HIGH	MEDIUM
Extent	LOCAL	LOCAL
Duration	LONG TERM	LONG TERM
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Probability	IMPROBABLE	IMPROBABLE
Significance	**MEDIUM**	**MEDIUM**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**LOW**	**LOW**

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**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	LOCAL	LOCAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW**	**LOW**

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 AOSAC has various project controls in place for the proposed drilling operations. These include:

- AOSAC has indicated it plans to use WBMs (riserless sections) and high-performance KCl/Glycol WBMs (risered sections). Drill cuttings from the risered sections would be treated to reduce the oil content to <6.9% 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 coastal upwelling occurs in the Namaqua upwelling cell inshore of the Area of Interest for drilling, phytoplankton abundance in Block 3B/4B 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 22). 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 portion 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.

Environmental Risk

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 (HES Expertise Services 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 260 m to the N of the Discharge Point. Maximum total concentrations of cuttings reached in the water column at the seabed were not provided.
- Risered: risk to the water column is confined up to a maximum horizontal distance of 260 km to the N of the Discharge Point. Maximum total concentrations of cuttings reached in the water column at the seabed were not provided.

The risk in the water column is pulsed, corresponding to the various drilling stages and ceases once operations have been completed.

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 22). 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 MINOR 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 IMMEDIATE TERM (days), and would be LOCALISED (within an overall maximum distance of 1 km of the well site). The impact is fully reversible and with a very low probability of occurring. The biochemical impact of reduced water quality through increased turbidity is thus considered of **LOW** environmental risk.

Impact Significance

Due to the low sensitivity of the receptors expected in the offshore pelagic and soft-sediment benthic environment and the low environmental risk, the impact is deemed to be of **LOW** 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 **LOW** 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**
Environmental Risk	**LOW**	**LOW**
Intensity	MINOR	MINOR
Extent	LOCAL	LOCAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	IMPROBABLE	IMPROBABLE
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**-**
Cumulative potential	**LOW**	**LOW**

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 AOSAC has various project controls in place for the proposed drilling operations. These include:

- AOSAC has indicated it plans to use WBMs (riserless sections) and high-performance KCl/Glycol WBMs for the risered sections. Drill cuttings from the risered sections would be treated to reduce the oil content to <6.9% Oil On Cutting (OOC) and discharged overboard.
- Cuttings will be discharged 10 m below surface during risered drilling.

Sensitive Receptors

The drilling activities would be undertaken in the offshore marine environment, more than 180 km offshore where the Southeast Atlantic Unclassified Slopes habitats have 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. While some of the benthic communities would comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance, the environmental stability of the deep sea suggests that much of the benthos may comprise longer-lived species. 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 MEDIUM sensitivity.

Environmental Risk

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, NADFs 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). Some WBMs, particularly those containing glycols or organic long chain screen binding polymers, have been found to cause temporary organic enrichment of sediments, which could similarly lead to the development of anoxic conditions in the sediments.

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 closer to the wellbore and discharge point and the use of chemicals with low biodegration rate. 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 (60 days), these manifested over the longer term and could contribute to the risk after 5 years.

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. Anoxic conditions are thus limited to the area of maximum deposit thickness of the cuttings pile around the wellbore (ACTIVITY SPECIFIC), and although persistent in the MEDIUM 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 due to bioturbation. The impact would be reversible and with a low probability of occurring. The environmental risk of the impact is therefore considered **LOW**.

Impact Significance

Due to the low sensitivity of the receptors expected in the offshore soft-sediment environment and the low environmental risk, the impact is deemed to be of **LOW** significance.

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**
Environmental Risk	**VERY LOW**	**VERY LOW**
Intensity	LOW	VERY LOW
Extent	ACTIVITY SPECIFIC	ACTIVITY SPECIFIC
Duration	MEDIUM TERM	SHORT TERM
Reversibility	REVERSIBLE	REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**LOW**
Cumulative potential	**LOW**	**LOW**

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 3B/4B, strong surface currents will rapidly dispersed and redistributed drilling solids discharged at the surface. The accumulation of drilling discharges on the seabed 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 sensitive 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 8 mm, with the maximum distance with a significant total environmental risk to the sediments (thickness deposits, grain size variation) above 5% extending as far as 60 m from the discharge point in the direction of the prevailing seabed currents and across a highly localised area of the Southeast Atlantic Mid- and Lower Slope habitats, which have been assigned a threat status of 'Least Threatened'. The environmental risk from the discharged drilling solids is primarily due to smothering of the receiving habitats, with risks persisting beyond 5 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 0.7 km to the N of the Discharge Point. Depending on the location of the well, the environmental risk to the near-bottom water column would thus extend into the Southeast Atlantic Mid- and Lower Slope 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, and no overlap with proposed CBAs located immediately adjacent to the Area of Interest for drilling is expected to occur**.

4.4.3 Generation of Underwater Noise

4.4.3.1 Impact of Marine Fauna

<u>Source of Impact</u>

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 Area of Interest and Cape Town
	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 the drilling unit and up to three support vessels** is approximately 198.8 dB re 1 µPa @ 1 m (or dB re 1 µPa^2·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 245.5 dB re 1 µPa @ 1 m, the root-mean-square sound pressure level (RMS SPL) 231.5 re 1 µPa @ 1 m, and the sound exposure level (SEL) 223.7 dB re µPa^2·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 audibility is determined by the individual’s threshold of hearing (i.e. the sound level at which a sound is just detectable by a particular species), which varies with frequency. The hearing ranges of marine taxa are presented in Figure 64B) and discussed further below.

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 64). 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. The sonar survey area is expected extend over an area of approximately 50 km^2 (approximately 7 km X 7 km) over a period of approximately 15 days.

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)[13] or temporary threshold shifts (TTS)[14];
- 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).

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 15. 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, and fish range from 207 - 213 dB re 1 µPa, with TTS in fish occurring at cumulative sound exposure levels of above 186 dB re 1 $\mu Pa^2 \cdot s$ (see Table 4 in SLR Canada 2023 for details). For turtles, peak sound pressure levels for impulsive noise resulting in mortality or potential mortal injury are 232 dB re 1 µPa and 226 dB re 1 µPa, respectively, with PTS onset in response to non-impulsive noise events occurring at cumulative sound exposure levels of above 220 dB re 1 $\mu Pa^2 \cdot s$ (see Tables 5 and 6 in SLR Canada 2023 for details). The behavioural threshold for impulsive sound events for sea turtles was established at RMS SPL 175 dB re 1µPa by Finneran *et al.* (2017).

The risk of TTS 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.

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

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

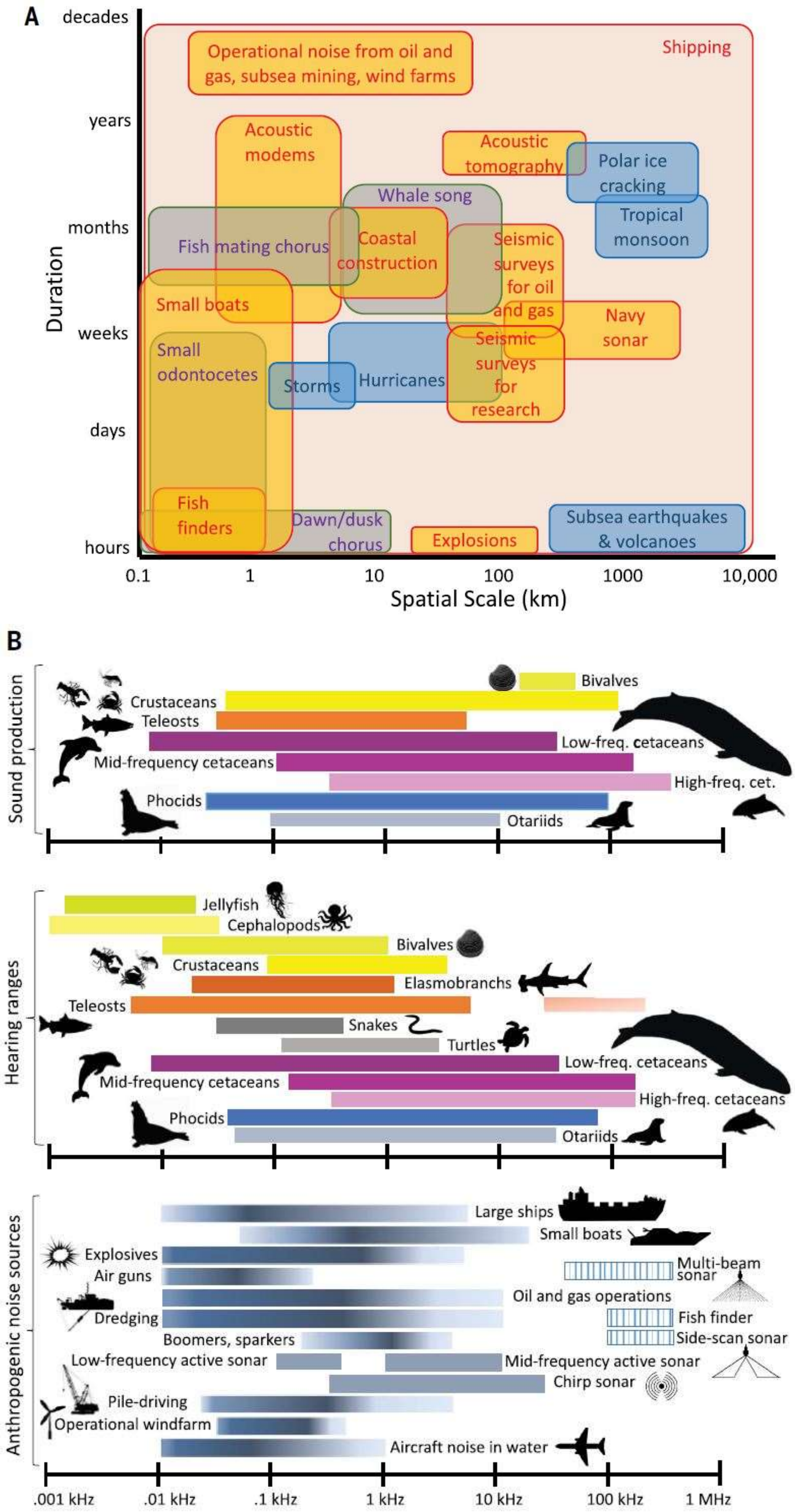

Figure 64: Sources and animal receivers of sound in the ocean. A) Spatial extent and duration of selected sound producing events, and B) Approximate sound production and hearing ranges of marine taxa and frequency ranges of selected anthropogenic sound sources. (Source: Duarte *et al*. 2021).

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 South African Law. The Marine Living Resources Act, 1998 (No. 18 of 1998) states that no whales or dolphins may be harassed, killed or fished. No vessel or aircraft may, without a permit or exemption, approach closer than 300 m to any whale and a vessel 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 Area of Interest and Cape Town. The Area of Interest for drilling is located approximately 190 km offshore at its closest point and far removed from coastal 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 3B/4B 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 22). 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 Area of Interest 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 Area of Interest, 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 Area of Interest, the Area of Interest 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**.

Environmental Risk

4.4.3.1.1 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 source 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 multi-beam echo sounder (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 230 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 66 m from the source along the cross-track direction (SLR Consulting Canada 2023), with TTS onset expected at 124 m from the source. For the other hearing groups TTS and PTS onset occurred at between 2 m and 24 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 2 m for PTS and 4 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 mammals, 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 occur within 290 m from the source for marine mammals of all hearing groups and up to 70 m from the array source for turtles at cross-track directions.

4.4.3.1.2 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 64. 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 3B/4B is located within the main offshore shipping routes that pass around southern Africa (Figure 65), 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 3B/4B, the ambient noise levels are expected to be at least 20 dB higher than the lowest level, within the higher range of the typical ambient noise levels, i.e. 100 - 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).

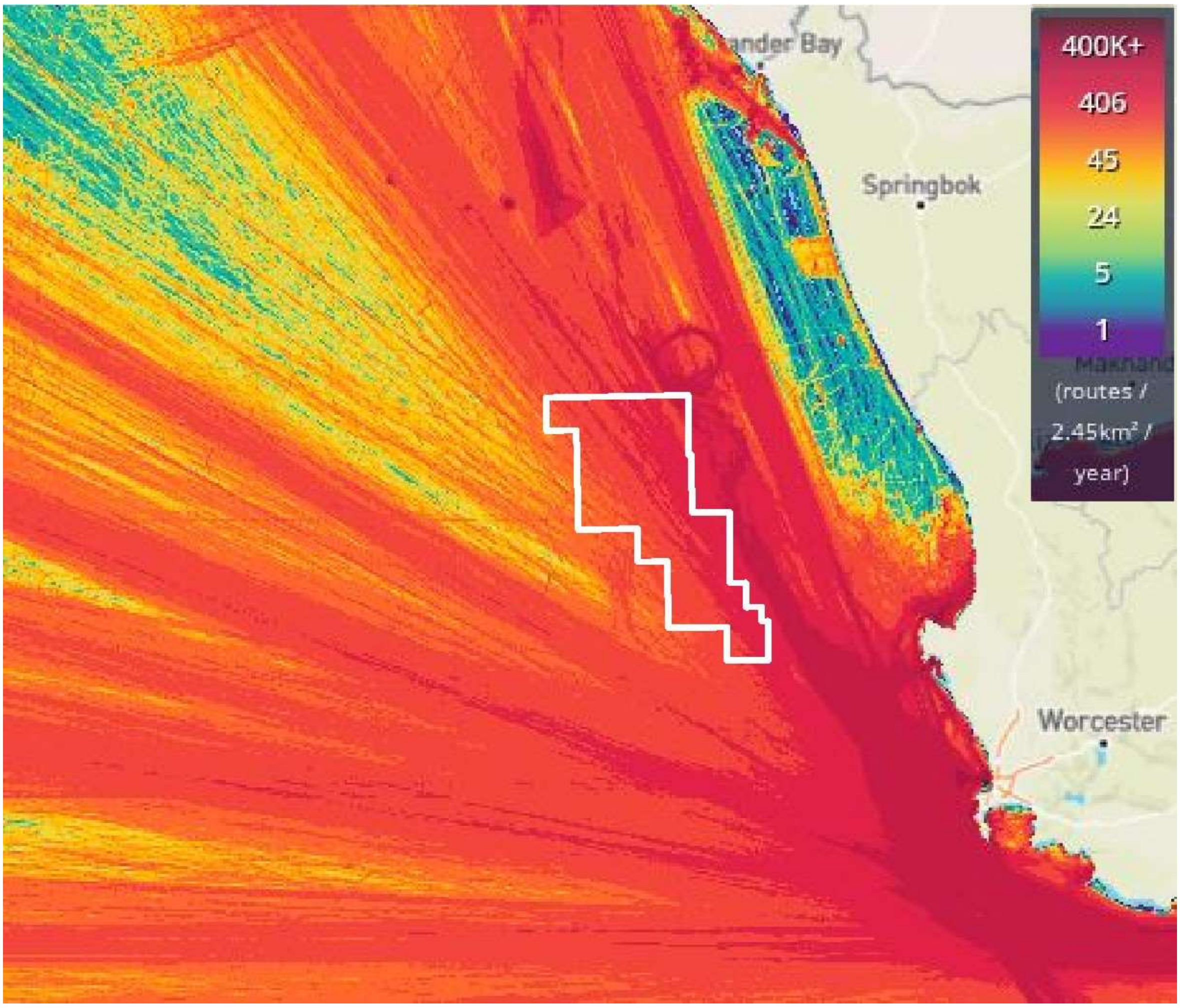

Figure 65: Block 3B/4B (white polygon) in relation to offshore vessel traffic (adapted from www.marinetraffic.com/en/ais/home, accessed November 2022).

Physiological Injury

The overall sound level generated by drilling operations (drill rig and support vessels) is 198.8 dB re 1 μPa. The frequency of 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 3B/4B it was estimated that the zones of cumulative impact for 24 hours exposure duration of non-impulsive noise from drilling activities could potentially lead to TTS and PTS, but that effects did not extend beyond 8 160 m and 280 m from the drill site, respectively for marine mammals (see

Table 16). LF and VHF cetaceans had the highest PTS-onset and TTS-onset impact zones among the marine mammal hearing groups. 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 400 m and 60 m, respectively for the highest impact zones for VHF cetaceans. 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 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 (SLR Consulting Canada 2023). For turtles the zones of cumulative impact for TTS and PTS were predicted to be 320 m and 60 m, respectively, over a 24 hour exposure, decreasing to 60 m and 20 m of the drilling location, respectively for continuous exposure over 0.5 hours.

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.

<u>Behavioural Avoidances</u>

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 3B/4B it was estimated that non-impulsive noise from drilling activities could result in behavioural disturbance in cetaceans to distances of between 21.8 km (1 645 m Water Depth) and 27.5 km (2 100 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. However, whales potentially associated with Tripp Seamount located ~25 km north-west of the Area of Interest, may be affected by the vessel and drilling noise. For fish and turtles, the maximum threshold distances were two to three orders of magnitude lower (420 m and 60 m, respectively).

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 metres) from the source location. Relatively low behavioural risks are expected for fish species at far field distances (thousands of metres) 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 impacted 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 Area of Interest 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 IMMEDIATE 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 Cape Town). The impact would be fully reversible and with a low probability of occurring. The environmental risk of potential physiological injury or behavioural disturbance as a result of drilling and vessel noise is therefore considered **LOW** for up to five wells.

4.4.3.1.3 Vertical Seismic Profiling

<u>Physiological Injury</u>

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: 40 m and turtles: <20 m) to be affected. An exception are the very high-frequency cetaceans, which are predicted to experience PTS-onset within 60 m from a single VSP pulse, and TTS-onset within 80 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 16). Considering the cumulative impact (125 discharges within 6 hours) on marine mammals, the maximum threshold distances will be in the order of up to 80 m and 40 m for TTS- and PTS-onset, respectively for the most sensitive LF cetaceans, with the threshold distances for the remaining hearing groups being considerably lower or not being reached at all. For turtles, the cumulative impact (125 discharges within 6 hours) will result in PTS and TTS onset at maximum distances of 20 m and 80 m, respectively. For fish and ichtyoplankton maximum distances were predicted to be in the order of 60 m for recovery injury and 260 m for TTS-onset, with mortality or potential mortal injury reached at maximum distances of 40 m.

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 16 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 3B/4B 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 MODERATE intensity, with the worst case being possible TTS onset in cetaceans within 180 m of the sound source. Effects would, however, remain LOCAL and for the duration of the VSP activities (IMMEDIATE TERM; 9 hours per well). In the case of other marine fauna effects would be even more localised (ACTIVITY SPECIFIC) and confined to a few 10s of metres from the VSP array. The impact would be fully reversible and with a medium probability of occurring. The environmental risk of potential physiological injury or behavioural disturbance as a result of drilling and vessel noise is therefore considered **LOW** for up to five wells.

Behavioural Avoidance and Masking of Sounds

Potential behavioural disturbance from single VSP pulses is predicted to occur for marine mammals of all hearing groups within a maximum of 580 m from the source. In the case of turtles, potential behavioural disturbance is predicted to occur within 80 m from the drilling location, with potential behavioural disturbance in fish occurring at between 600 m and 2 240 m from the drilling locations.

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 metres) from the source location. Relatively low behavioural risks are expected for fish species at far field distances (thousands of metres) 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

Table 15: 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 16 Summary of the maximum zones of estimate for all assessed drilling activities. For details see the relevant tables in SLR Consulting Canada (2023).

Animal Type	Drilling activities		Maximum threshold distances, m		
			PTS onset	**TTS onset**	**Behavioural disturbance**
Marine mammals	VSP – immediate impact		60	80	580
	VSP - cumulative	125 VSP pulses	40	80	220
	VSP - cumulative	50 VSP pulses	40	80	100
	Drilling – immediate behavioural impact		-	-	27 480
	Drilling – cumulative	24 hr	280	8 160	
	Drilling – cumulative	0.5 hr	60	400	
	Single MBES Pulse - immediate impact		66	124	290
Sea Turtles	VSP – immediate impact		--	<20	80
	VSP - cumulative	125 VSP pulses	20	80	-
	VSP - cumulative	50 VSP pulses	<20	60	-
	Single MBES Pulse - immediate impact		2	4	70
	Drilling – cumulative	24 hr	60	320	60
	Drilling – cumulative	0.5 hr	20	60	
Fish, fish eggs and fish larvae			**Mortality and potential mortal injury**	**Recovery injury**	**TTS**
	VSP – immediate impact		40	40	
	VSP - cumulative	125 VSP pulses	40	60	260
	VSP - cumulative	50 VSP pulses	40	40	180
	Single MBES Pulse		--	--	--

Note: a dash indicates the threshold is not applicable 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, 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 as the exposure time decreases, the impact decreases even faster.

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 km from the drilling location and for the duration of the VSP activities (IMMEDIATE TERM; 10 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 and with a low probability of the impact being realised. The impact of underwater noise generated during VSP on behavioural avoidance and masking of sounds is thus considered of **LOW** environmental risk for all five wells.

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 **LOW** significance considering their medium sensitivity and low environmental risk.

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 low environmental risk.

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) [15], 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

[15] 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).

No.	Mitigation measure	Classification
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	Although operations can be undertaken year-round, preference should be given to planning geophysical surveys to avoiding the movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters (beginning of June to end of November	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

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 Area of Interest 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

No.	Mitigation measure	Classification
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 are 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
2.5	Keep VSP operations under 200 pulses to remain within the 500 m exclusion zone for LF cetaceans.	Abate on site
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 cetaceans are 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

No.	Mitigation measure	Classification
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 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**
Environmental Risk	**VERY LOW**	**VERY LOW**
Intensity	LOW	LOW
Extent	LOCAL	LOCAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**MEDIUM**	**MEDIUM**

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**
Environmental Risk	**LOW**	**LOW**
Intensity	MODERATE	LOW
Extent	LOCAL	LOCAL
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	MEDIUM	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**MEDIUM**	**MEDIUM**

4.4.4 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 and installation of over-trawlable structures (if required).

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.
- If the abandoned wellheads are located within the footprint of the demersal trawl fishery, over-trawlable abandonment caps would be installed. These are estimated to measure approximately 5.2 m x 5.2 m, with a height of 4.4 m, and would add structural complexity to otherwise uniform unconsolidated seabed habitats thereby creating areas of higher biological diversity. As the Area of Interest for drilling lies beyond the trawling grounds, installation of these caps is unlikely.

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 (190 km from the coastline at its nearest point) where the Southeast Atlantic Mid- and Lower Slope habitat types have 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. While some of the benthic communities would comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance, the environmental stability of the deep sea suggests that much of the benthos may comprise longer-lived species. 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 MEDIUM.

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, is considered to be LOW.

Environmental Risk

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, unless over-trawlable abandonment caps are installed.

The presence of wellheads and abandonment caps 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 (between 1 000 m and 3 000 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 (ACTIVITY SPECIFIC for each well). As AOSAC has indicated that the wellheads would be abandoned, the impact would be HIGHLY LIKELY and PERMANENT, resulting in a **NEGLIGIBLE** environmental risk. However, if the wellheads were removed upon abandonment, the duration would be immediate-term and the environmental risk would be **LOW**.

Impact Significance

Due to the low sensitivity of benthic communities of unconsolidated sediments and the low environmental risk of the impact, the presence of sub-sea structures on seabed biodiversity is deemed to be of **NEGLIGIBLE** (wellhead removal) or of **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
4	Install over-trawlable abandonment caps over the wellheads only if these fall within the footprint of the demersal trawl fishery.	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 LOW (well abandonment) significance.

15	***Impacts of petroleum infrastructure and residual cement on marine biodiversity***	
Project Phase:	**Operation and Demobilisation**	
Type of Impact	**Direct**	
Nature of Impact	**Neutral**	
Sensitivity of Receptor	LOW	
	Alternative 1: Wellhead Removal	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**LOW**
Intensity	LOW	LOW
Extent	ACTIVITY	ACTIVITY
Duration	PERMANENT	PERMANENT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	HIGH	HIGH
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**VERY LOW**
Cumulative potential	**LOW**	**LOW**

	Alternative 2: Wellhead Abandonment	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	ACTIVITY	ACTIVITY
Duration	PERMANENT	PERMANENT
Reversibility	IRREVERSIBLE	IRREVERSIBLE
Probability	HIGH	HIGH
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential		**VERY LOW**
Cumulative potential	**LOW**	**LOW**

4.4.5 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 100 to 1 000 bbl oil could be flared per day but only for a maximum duration of 4 hours, i.e. up to 2 000 bbl over the two tests associated with an appraisal well.
- If produced water arises during well flow testing, it would be separated from the oily components and treated onboard to reduce the remaining hydrocarbons in 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.

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 Area of Interest, 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**.

Environmental Risk

4.4.5.1 Impacts on Marine Fauna from Lighting from Flare

Drilling activities would be undertaken in the offshore marine environment, over 190 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 extreme eastern corner of the Area of Interest for drilling falls within the foraging range of seals from the seal colony at Kleinzee, which lie about 200 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 (ACTIVITY SPECIFIC) over the IMMEDIATE-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 be fully reversible once operations are completed and with a low probability of the impact occurring and is thus considered of **LOW** environmental risk for all five wells.

4.4.5.2 Impact on Marine Fauna from Discharge of Produced water

Some produced water 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. The AOI for drilling would be located approximately 190 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 MINOR intensity and limited to the area in the immediate vicinity of the drill rig (ACTIVITY SPECIFIC) over the IMMEDIATE-term (4 days of flaring over a period of up to 14 days). The potential for toxic effects on marine fauna would be fully reversible once operations are completed and with a low probability of the impact occurring and is thus considered of **LOW** environmental risk for all five wells.

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

The Area of Interest is located approximately 190 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 Area of Interest, 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 (ACTIVITY SPECIFIC) over the IMMEDIATE-TERM (4 days of flaring over a period of up to 14 days). Impacts of 'drop-out' would be fully reversible once flaring is completed, with a low probability of the impact being realised. The impact of well testing is therefore considered of **LOW** environmental risk.

<u>**Impact Significance**</u>

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 **LOW** significance.

<u>**Identification of Mitigation Measures**</u>

The following measures are recommended to reduce and manage 'drop-out' onto the sea surface and lighting during flaring[16]:

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. Capturing and transportation of seabirds must be undertaken according to specific protocols as outlined in the OWCP.	Repair or restore

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

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 **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**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	ACTIVITY SPECIFIC	ACTIVITY SPECIFIC
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**LOW**	**LOW**

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**
Environmental Risk	**LOW**	**LOW**
Intensity	MINOR	MINOR
Extent	ACTIVITY SPECIFIC	ACTIVITY SPECIFIC
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**LOW**	**LOW**

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**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	ACTIVITY SPECIFIC	ACTIVITY SPECIFIC
Duration	IMMEDIATE	IMMEDIATE
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**VERY LOW**
Cumulative potential	**LOW**	**LOW**

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 interpreted (DEAT 2004).

The most reliable gauge of cumulative pressures on the marine environment by other users is provided by Sink *et al*. (2019) and Harris *et al*. (2022). The map was generated as part of the NBA 2018 by doing a cumulative pressure assessment in which the impact of both current and historical ocean-based activities on marine biodiversity was determined by spatially evaluating the intensity of each activity and the functional impact to, and recovery time of, the underlying ecosystem types (Figure 66, left). Based on the severity of modification across the marine realm, a map of ecological condition was generated (Figure 66, right). From this it can be determined that Block 3B/4B is located in an area experiencing very low cumulative impacts from other users and that the ecological condition is therefore mostly still natural or near-natural.

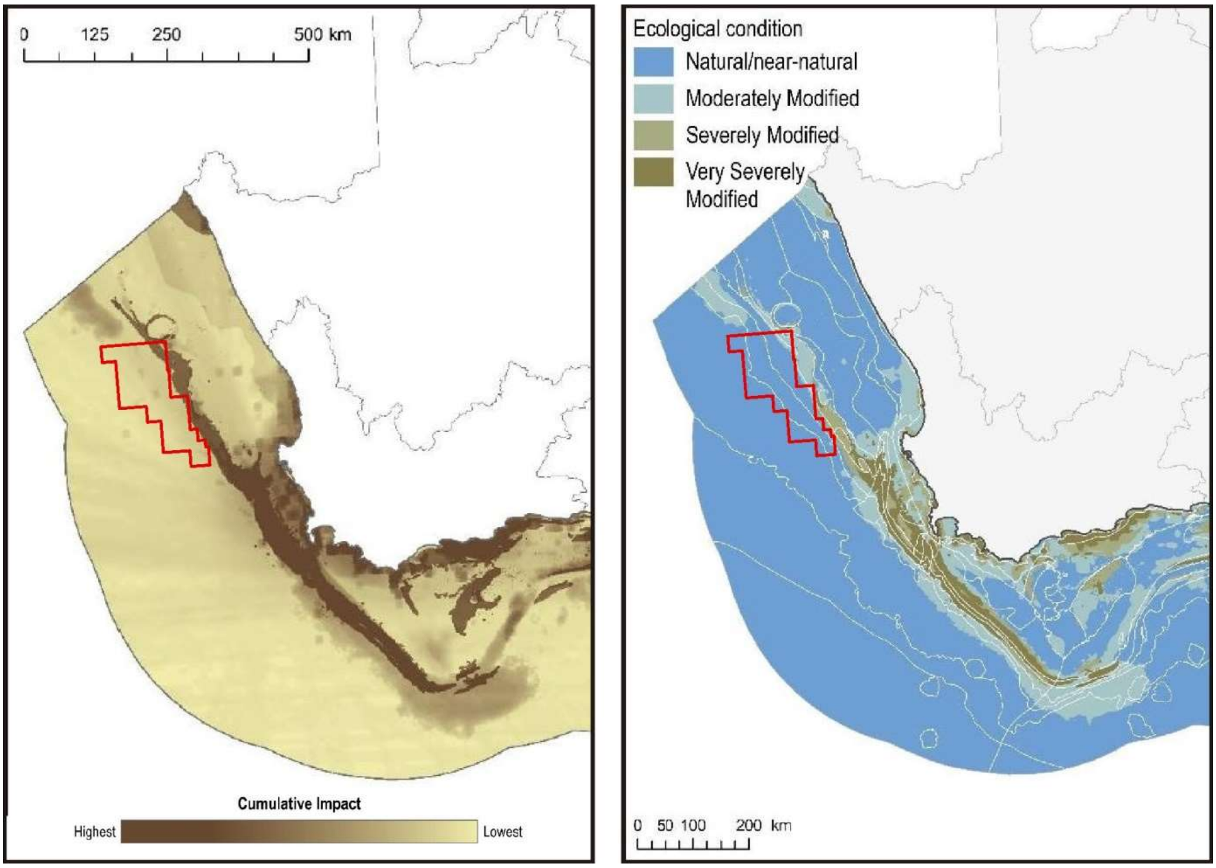

Figure 66: Block 3B/4B (red polygon) in relation to the cumulative impacts on marine biodiversity, based the intensity of all cumulative pressures and the sensitivity of the underlying ecosystem types to each of those pressures (left) and the ecological condition of the marine realm based on the severity of modification as a result of the cumulative impacts (adapted from Sink *et al.* 2019 and Harris *et al.* 2022).

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 and exploration activities 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 hydrocarbon exploration frequency has increased, suggesting that, for these populations 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. Information on the population trends of resident species of baleen and toothed whales is unfortunately lacking, and the potential effects of exploration activities 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 3B/4B and are not undertaking any exploration activities at present or would be concurrently with the proposed AOSAC exploration drilling campaign. A possible exception is further proposed exploration well drilling in the Deep Water Orange Basin block offshore of Block 3B/4B. The Searcher 3D seismic survey (scheduled for January 2023) is anticipated to have been completed by the time this project receives a decision.

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 Southeast Atlantic Deep Ocean 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 operational discharges from associated vessels and drill unit. Other marine exploration and mining activities off the West Coast are all located well inshore of the Area of Interest, but various existing and proposed subsea fibreoptics cables pass through the Block (see Figure 51). Cumulative potential impacts from actions by these different user groups on benthic ecosystems in Block 3B/4B are therefore expected to be minimal.

Cuttings discharge and Sediment plume

With respect to physical disturbance impacts, the existing cumulative impacts to the benthic environment include the development of hydrocarbon wells (see Section 4.3.4). Since 1976 approximately 40 wells have been drilled in the Southern Benguela Ecoregion. The majority of these occur in the iBhubesi Gas field in Block 2A inshore of Block 3B/4B (Eco Atlantic recently completed the drilling of the Gazania-1 well in Block 2B which was spudded on 10 October 2022). Prior to 1983, technology was not available to remove wellheads from the seafloor, thus of the approximately 47 wells drilled on the West Coast, 35 wellheads remain on the seabed. Assuming a conservative estimate of 2.64 km^2 of cumulative seabed affected per well (based on the footprint calculated for a single well, TEEPSA, pers. comm.), the total cumulative area impacted by the installation and cuttings fall-out of 5 petroleum exploration wells on the West Coast is estimated at 124 km^2.

In southern Namibia, oil and gas exploration and production activities have focused on the Kudu gas field, which lies inshore and to the north of Block 3B/4B. 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. A further 2 wells have recently been drilled in 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 West Coast 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). Assuming a conservative estimate of 2.64 km^2 of cumulative seabed affected per well, the total cumulative area impacted by the installation and cuttings fall-out of 32 petroleum exploration wells off southern Namibia 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, AOSAC will actively avoid and reduce potential impacts on sensitive and potentially vulnerable habitats by ensuring that wells are >1 000 m from such habitats (using ROV survey prior to drilling). Cumulative impacts are therefore less likely.

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 0.045 km^3 for a maximum duration of 2 days, which can be considered an insignificant percentage of the ecoregion as a whole. There is no more risk in the water column after the end of the discharge of the 26” displacement. In other words there is no risk to the water column from discharges during the risered sections.

There is no current development or production from the South African West Coast offshore. The Ibhubesi Gas Field (Block 2A) and Kudu Gas Field (off southern Namibia) have been identified for development. Cumulative impacts from other hydrocarbon ventures in the area are thus likely to increase in future. Other activities that may have contributed to cumulative impacts to the benthic environment in the licence area include limited historical deep water trawling along the shelf edge in the inshore portions of the licence block.

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 28 km during drilling and beyond 1 km during VSP operations. Noise levels would return 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 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, attribute 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.

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 AOSAC drilling campaign in Block 3B/4B, with the implementation of the proposed mitigation measures, most of the potential impacts will be of short duration, typically ceasing once drilling operations are completed. An exception is the changes in sediment grain size and thickness deposit as a consequence of the discharge of cuttings and drilling mud. Such impact footprints are highly localised and given the area of available seabed on the continental shelf are considered unlikely to contribute significantly 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 5 years. While there is currently further interest to undertake exploration drilling in the blocks adjacent to Block 4B/4B, the targets are suitably far away that these would not 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 Southeast Atlantic Deep Ocean Biozone can be considered of **LOW** significance.

16	*Impacts to marine fauna of concurrent exploration drilling by multiple operators*
Project Phase:	**Mobilisation, Operation & Decommissioning**
Type of Impact	**Direct - Cumulative**
Nature of Impact	**Negative**
Sensitivity of Receptor	Medium
Environmental Risk	**LOW**
Intensity	LOW
Extent	REGIONAL
Duration	MEDIUM TERM
Reversibility	IRREVERSIBLE
Probability	LOW
Significance	**LOW**
Confidence	**MEDIUM**
Loss of Resources	**LOW**
Mitigation Potential	**LOW**

4.6 Impact Summary for Planned Events

The residual impacts on marine habitats and communities associated with the proposed drilling of up to 10 exploration wells in Block 3B/4B 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 MPAs during transit to and from the drill site.	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 seal colonies and seabird nesting areas. • 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. • 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 • Pre-plan flight paths to ensure that no flying occurs over seal colonies and seabird nesting areas.	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. Capturing and transportation of seabirds must be undertaken according to specific protocols as outlined in the OWCP. • Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring).	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 1 000 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.	Low
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 1 000 m of the drill site.	Medium

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
	• If vulnerable habitats are detected, seek the advice of a benthic specialist and 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. • As information gathered during ROV surveys is of high scientific value, such information should be made available to contribute to the knowledge base of deep-water environments.	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.	Low
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.	Medium
Impacts of drill cuttings discharge on water column (turbidity & light) and seabed (turbidity)	None	Low
Impacts of Cuttings Discharges: development of anoxic sediments around the wellbore during drilling of the riseless sections	None	Low
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 Area of Interest 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).	Low

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
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, procedures undertaken during low visibility). • 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
Impacts of petroleum infrastructure and residual cement on marine biodiversity (Wellhead Abandonment)	• 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. • Install over-trawlable abandonment caps over the wellheads only if these fall within the footprint of the demersal trawl fishery. • 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 to the seabed during the operational stage, assess safety and metocean conditions before performing any retrieval operations	Low
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. • Constant operational monitoring of flare for any malfunctioning. • Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard box) for subsequent release during daylight hours. Capturing and transportation of seabirds must be undertaken according to specific protocols as outlined in the OWCP.	Low

4.7 Mitigation and Management Plan

The mitigation measures are based largely on the guidelines currently accepted for exploratory well drilling in South Africa, 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 MPAs and declared 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 South Africa lacks legislation and has only weak links to broader ocean governance, the Area of Interest borders on ESAs to the north and CBA1: Natural and CBA2: Natural areas to the west, south and east, and should drilling targets be identified immediately adjacent to these areas, 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 AOSAC are expected to result in impacts on marine invertebrate fauna in the approved drilling area of Block 3B/4B, 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 EMPr), which are in line with current industry good practice for drilling undertaken in South African waters. With implementation of recommended mitigation measures, the significance would reduce to medium.

In the order of 358 wells have been drilled in the South African offshore environment to date (based on information provided by PASA in 2021), the majority of which (200 wells) have been drilled off the South Coast on the Agulhas Bank, most of these in less than 250 m water depth (see Figure 51). A further 47 (including the recent well completed in 2022) have been drilled off the West Coast. Despite the 47 wells off the West Coast, 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. Although there is no current development or production from the South African West Coast offshore, the Ibhubesi Gas Field (Block 2A) (off West Coast, approximately 130 km east of the Area of Interest and Kudu Gas Field (off southern Namibia) have been identified for development. In fact, Atkinson (2009) reported that abandoned wellheads in the vicinity demersal trawling grounds provide some *de facto* “protection” to marine infaunal, epifaunal and fish assemblages.

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 Authorisation, should DMRE 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 South African Law. The Marine Living Resources Act, 1998 (No. 18 of 1998) states that no whales or dolphins may be harassed, killed or fished. No vessel or aircraft may, without a permit or exemption, approach closer than 300 m to any whale and a vessel 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 3B/4B 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-five species or sub species/populations of cetaceans (whales and dolphins) are known or likely to occur off the West Coast. The majority of migratory cetaceans in West Coast waters are baleen whales (mysticetes), while toothed whales (odontocetes) may be resident or migratory. Of the 35 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's 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**.

Environmental Risk

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 65), 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 Cape Town 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 3B/4B does not fall within a recognized Important Marine Mammal Area, 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. However, 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, the duration of the impact would be limited to the SHORT-term and be restricted to the Area of Interest for drilling and to/from the port (REGIONAL). As the impact would be PARTIALLY REVERSIBLE but with a LOW PROBABILITY, the potential for ship strikes is therefore considered to be of **LOW** environmental risk.

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 low environmental risk.

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 Area of Interest 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

No.	Mitigation measure	Classification
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**
Environmental Risk	**LOW**	**LOW**
Intensity	LOW	MINOR
Extent	REGIONAL	REGIONAL
Duration	SHORT TERM	SHORT TERM
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Probability	LOW	IMPROBABLE
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**LOW**	**LOW**

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 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. All loose gear on deck should be fully secured and if lost overboard, either on site or in transit, be recovered as soon as practically possible and when safety and metocean conditions allow.

Sensitivity of Receptors

The drilling activities would be undertaken in the offshore marine environment, more than 190 km offshore where the Southeast Atlantic Unclassified Slopes habitat has 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 is 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 3B/4B, and the well(s) will specifically be sited to avoid sensitive hardgrounds (ROV survey).

The overall sensitivity of benthic receptors is considered LOW.

Environmental Risk

The accidental and irretrievable loss of equipment to the seabed 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 Southeast Atlantic

Deep Ocean ecoregion, this disturbance of, and reduction in, benthic biodiversity can be considered of MINOR intensity, highly localised and limited to the footprint of the lost equipment (ACTIVITY SPECIFIC). Any impacts would persist over the IMMEDIATE-TERM only, as lost equipment will be retrieved or if irretrievable and 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 would be FULLY REVERSIBLE if retrieved with losses being IMPROBABLE. The impact is thus considered to be of **NEGLIGIBLE** environmental risk.

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 negligible environmental risk.

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, 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. Such recoveries 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**
Environmental Risk	**LOW**	**LOW**
Intensity	MINOR	MINOR
Extent	ACTIVITY	ACTIVITY
Duration	IMMEDIATE	IMMEDIATE
Reversibility	PARTIALLY to FULLY REVERSIBLE	PARTIALLY to FULLY REVERSIBLE
Probability	IMPROBABLE	IMPROBABLE
Significance	**NEGLIGIBLE**	**NEGLIGIBLE**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW**	**LOW**

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 Cape Town, 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 gas/oil 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 low sulphur marine gasoil would occur in the event of a vessel collision or vessel accident.

Impact Description

Marine gasoil 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 zone 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 gasoil during bunkering or in the event of a vessel collision could take place in the Area of Interest and along the route taken by the support vessels between the Area of Interest and Cape Town. The Area of Interest is more than 190 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 Area of Interest or be transported into the Orange Shelf Edge MPA. Diesel spills or accidents *en route* to the onshore supply base in Cape Town 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 gasoil 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 Area of Interest, 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 Area of Interest, 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**.

Environmental Risk

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 AOSAC/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 study demonstrated the isolated presence of oil from other sources in the offshore areas, particularly from vessels orientated mainly NNW-SSE, and thus in agreement with the orientation of the shipping lanes.

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 gasoil) 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). Such small spills of crude oil (<7 tons) represent an estimated 80% (by number) of all recorded spills, and yet many of such smaller spills may go unnoticed and remain unreported (ITOPF 2014). Despite such small spills typically disappearing visually within a few days, Brussaard *et al*. 2016 found that dissolved oil compounds in the water column below the slick remained high, spreading beyond the original slick footprint. The high bioavailability and toxicity of the dissolved and dispersed oil to as deep as 8 m below the slick, had immediate adverse effects on plankton communities.

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 IMMEDIATE-term (5 days). The impact of a marine gasoil spill would be fully reversible, with a low probability of occurring, and is therefore considered of **LOW** environmental risk.

However, in the case of a spill or collision *en route* to the Area of Interest, 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 remaining LOCAL over the SHORT-TERM. The impact of a marine gasoil spill near the coast would be reversible, with a low probability of occurring, and is therefore considered of **LOW** environmental risk.

Impact Significance

Based on the high sensitivity of receptors and the low (offshore) and medium environmental risk 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 low.

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	Develop an Oiled Wildlife Contingency Plan (OWCP) in collaboration with specialist wildlife response organisations with experience in oiled wildlife response. The OWCP should be integrated into the site-specific OSPC and include detailed protocols on the collection, handling and transport of oiled marine fauna.	Avoid / Reduce at source
3	Obtain permission from DEA to use low toxicity dispersants should these be required; Use cautiously.	Abate on and off site
4	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
5	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station. Capturing and transportation of oiled or injured seabirds must be undertaken according to specific protocols as outlined in the OWCP.	Restore
6	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;	Avoid / Reduce at source

No.	Mitigation measure	Classification
Hydrocarbon Spills		
	• During helicopter operations; • During the transfer of in-sea equipment; and • At night or times of low visibility.	

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**
Environmental Risk	**LOW (offshore) LOW (nearshore)**	**LOW**
Intensity	LOW (offshore) HIGH (nearshore)	LOW
Extent	LOCAL (nearshore) REGIONAL (offshore)	LOCAL (nearshore) REGIONAL (offshore)
Duration	IMMEDIATE TERM (offshore) to SHORT TERM (nearshore)	IMMEDIATE TERM (offshore) IMMEDIATE TERM (nearshore)
Reversibility	FULLY REVERSIBLE (offshore) REVERSIBLE (nearshore)	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW (offshore) to MEDIUM (nearshore)**	**LOW**
Mitigation Potential	**-**	**MEDIUM**
Cumulative potential	**LOW**	**LOW**

4.9.4 Well Blowout

Source of Impact

The project activities that will result in the accidental release of oil are listed below.

Project phase	Activity
Mobilisation	n/a
Operation	Loss of well control / well blowout
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 blowout or loss of well control. A blowout 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 blowout 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 "blowouts". 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 blowout is further minimised by installation of a blowout 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 blowout 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. AOSAC is a member of OSRL. This would significantly reduce the spill period, should a blowout occur. All AOSAC's wells are designed to allow for capping.

Other project controls include the preparation and implementation of plans that would include aspects related to Shipboard Oil Pollution Emergencies, Oil Spill Contingency and Well Control Contingency.

Sensitivity of Receptors

Although the Area of Interest is located in the marine environment, more than 180 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 sensitive receptors in the adjacent Orange Shelf Edge MPA, Tripp Seamount, as well as migratory pelagic species transiting through the Area of Interest.

Assuming that the released product is condensate, which rises rapidly, the benthic biota inhabiting unconsolidated sediments of the outer shelf and deep-water reefs are unlikely to be affected by a blowout. Similarly, the modelling study suggests that the spill would not reach the shore to impact sensitive coastal receptors.

Being highly toxic, oil released during a blowout 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 Area of Interest, 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 Area of Interest, due to their extensive distributions their numbers are expected to be low. Overall sensitivity of offshore receptors and the marine ecology/environment 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 were thus not considered in the assessment for condensate, but were considered for a crude oil blowout.

Environmental Risk

Oil Spill Behaviour:

There is a probability that the hydrocarbon resource targeted by the proposed exploration wells is condensate rather than crude oil. Condensate and crude oil have the same rock source and would have a similar composition, but would be produced in different volumes with gas taking the place of the liquid component should the resource be condensate. The release quantities for condensate are typically markedly lower and the persistence of the condensate at sea much lower than oil. The environmental impacts realised during a condensate blowout would therefore also be much lower. For the current project, the estimated potential blowout rate of condensate would be 238.8 m^3/day and 930 000 Sm^3 of gas per day. However, to ensure that all potential worst-case scenarios were covered, a further model assuming the release of crude oil was run.

Two oil spill modelling studies were undertaken assuming the worst-case scenario of:

1) **a continuous blowout of 238.8 m^3/d of condensate and 930 000 Sm^3/d of gas for a period of 20 days assuming the characteristics of Condensate SKARV 13 DEG -2014 as the closest equivalent of the condensate expected from an exploration well in Block 3B/4B. A single release point was modelled.**
2) **a continuous blowout of 5 405.6 m^3/d of crude oil and 1 443 243 Sm^3/d of gas for a period of 20 days assuming a crude oil analogous with OSEBERG BLEND 2006 as the closest equivalent of the crude oil from an exploration well in Block 3B/4B. Two release points were modelled.**

The environmental impacts associated with the oil spill scenarios modelled by Livas (2023b) for two potential well sites in 1 499 m depth (Release Point D) and 1 626 m depth (Release Point A) are assessed separately below, based on the worst case footprints for the probability of surface oiling from spill events of both condensate and crude oil.

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 oil's 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 67A), 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 (1B). 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.

A)

B)

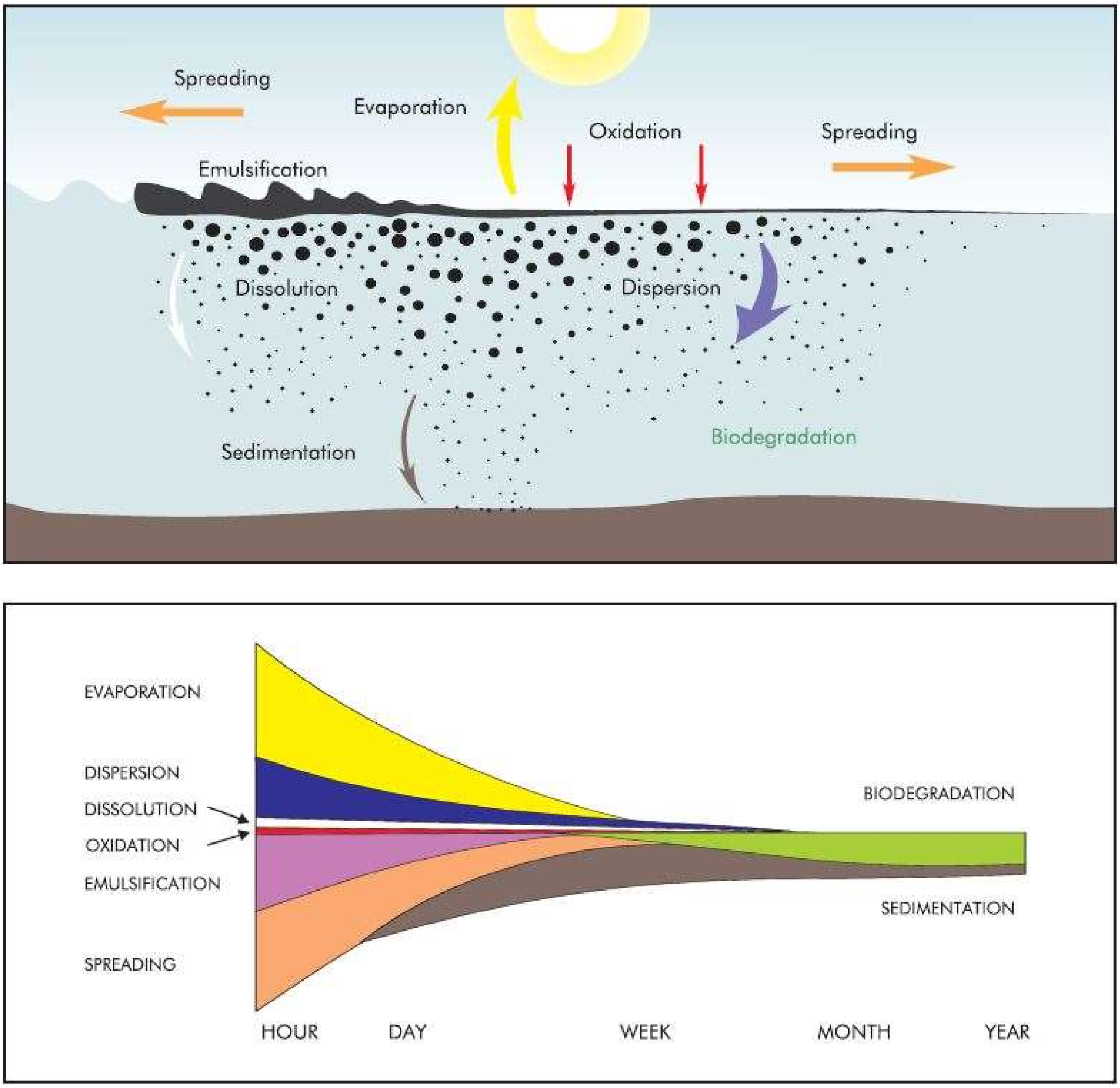

Figure 67: A) The weathering processes acting on spilled crude oil, and B) the fate of a typical medium crude oil under moderate sea conditions - the width of each band indicates the importance of the process (ITOPF 2002).

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.

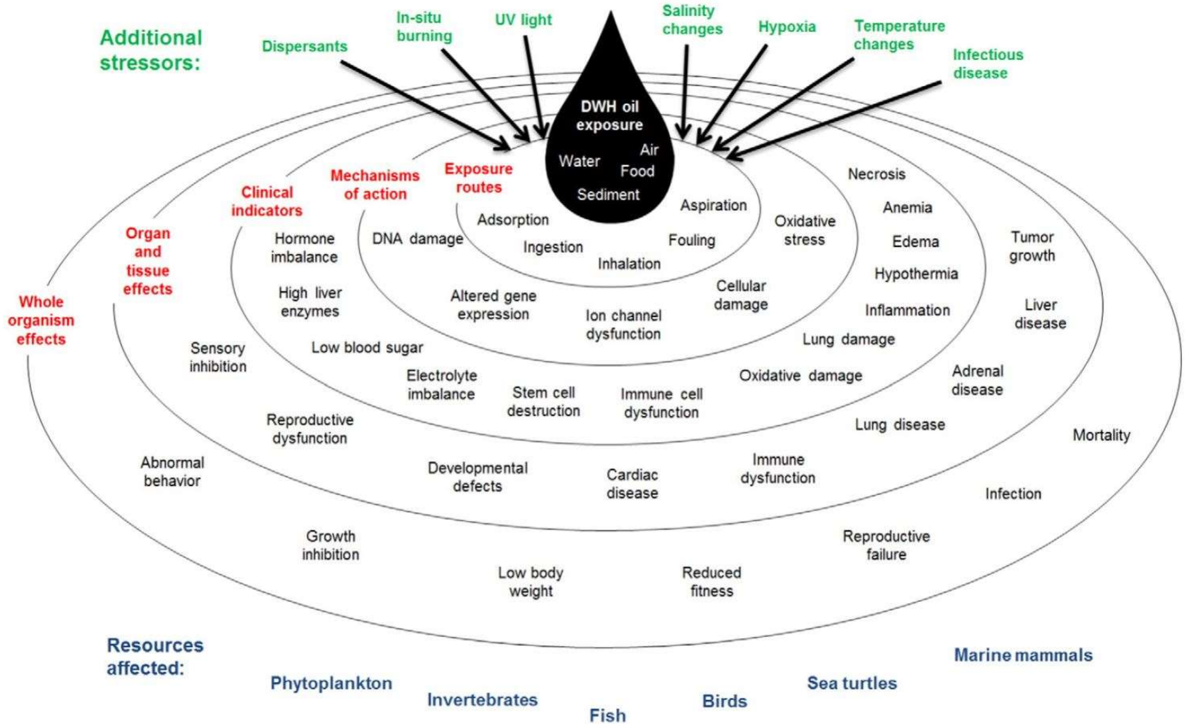

Figure 68: Conceptual figure illustrating the biological effects of the Deepwater Horizon oil spill (Source: Beyer *et al*. 2016).

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 blowout, 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 blowout of the continental slope of the South African West Coast. For example, sea surface temperatures off the 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; Brussaard *et al*. 2016), 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.

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 22) 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 blowout, 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 3B/4B, 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.

<u>Sandy shores</u>: Although only a portion of the oil spilled from an offshore well typically reaches the shoreline (see Figure 67), 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.

<u>Rocky shores</u>: 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).

<u>Fish</u>: 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.

<u>Seabirds</u>: 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 tend 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 Kleinzee Bucchu Twins near Alexander Bay, approximately 250 km northeast of the Area of Interest representing the largest colony on the West Coast, with smaller colonies at at Bucchu Twins near Alexander Bay, and Cliff Point (~17 km north of Port). 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 47 wells have been drilled on the West Coast offshore environment to date and no well blowouts have been recorded. Global data maintained by Lloyds Register indicates that frequency of a blowout 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.

Condensate and Gas

The assessment below assumes the worst-case scenario of a 20-day blowout of **condensate and gas** at a rate of 238.8 m^3/d and 930 000 Sm^3/d, respectively. The modelling assumed various spill response combinations, namely:

- Capping stack only on 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 stack only
- Combination of surface response + SSDI + capping stack

Threshold values applied to illustrate modelling output results are 58 ppb for oil in the water column, 0.04 µm for the surface oil thickness and 10 g/m^2 for shoreline oiling (see Livas 2023b 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, 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

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 N to NNW direction by the current. For this surface layer, 80 - 100% probability of surface oiling is reached at a maximum distance of 42 km to the N to the NW (Season 1) (Figure 69) spreading to a maximum of ~300 km towards the Namibian EEZ (<10% probability). No oil reaches the shore. The spread of the 80-100% probability to the N does not overlap with the Child's Bank or Orange Shelf Edge MPAs, or the Orange Seamount and Canyon Complex and Child's Bank and Shelf Edge EBSAs.

In the event of a blowout the oil would reach the surface above the release point within 3 hrs spreading a maximum of 71 km to the NW of the release point within a day (Season 2). The maximum emulsion thickness at the surface is 76 µm, reached at localised spots immediately above the release point (Season 2). Once at the surface, the condensate is rapidly evaporated, dispersed and biodegraded and no oil remained at the surface at the end of the simulations modelled (60 days). Oil dispersed on the surface will affect the upper water layers, but modelling results suggest that the probability of oil presence on the surface is <10%. The high proportion of gas contained in the release results in rapid ascent up to 600 m off the seabed. Consequently, there is no contamination of the deep layers (900 – 1 499 m). The most contaminated layer occurs in mid-water (725 – 900 m depth) but remains relatively contained around the release point, with 5-10% probability spreading to a maximum of 5 km to the NNW (Figure 70). The spread of the mid-water plume does not overlap with the Child's Bank or Orange Shelf Edge MPAs, or the Orange Seamount and Canyon Complex and Child's Ban k and Shelf Edge EBSAs, but may extend into CBA1 areas, depending on the final position(s) of the well (s).

The implementation of SSDI and surface response after 15 days results in an insignificant decrease of the surface slicks and spread in the shallower layers as condensate naturally disperses well in the water column and evaporates rapidly once at the surface. Deployment of these control measures would thus be ineffectual in reducing the oil presence probability areas. The same holds true for the minimum arrival time at the surface and maximum emulsion thickness at the surface.

<u>Surface and Shoreline Oil Presence Probability</u>

The stochastic modelling results indicate that even for the **capping only response** to a blowout at the Release Point modelled, there is no probability of shoreline oiling, with the slick extending offshore in a N direction into Namibian and International waters.

Deterministic Simulations

The deterministic predictions for the spill determined that the main drift direction is towards the NW and W of the release point, but that most of the oil remains dissolved in the water column. At the end of the simulation (60 days) oil remains in the water column having been dispersed into International and Namibian waters after 14 days following release. No oil remains on the surface after 60 days.

From the **mass balance** figures it becomes evident that the majority of the oil released during a blowout is evaporated and biodegraded, and that a substantial proportion of the spilled oil remains in the water column (submerged). Consequently, the Surface Response and the SSDI deployment have almost no effect on the dispersion of the spill.

Assuming the worst-case scenario, the intensity of the potential impact of a blowout of condensate and gas varies depending on the faunal group affected ranging from MODERATE for marine mammals and turtles to HIGH for pelagic seabirds. As the spill will rapidly disperse and evaporate, impacts of deposited oil on benthic communities associated with unconsolidated seabed or deep-water reefs are likely to be negligible. Impacts to pelagic fauna and seabirds would persist over the SHORT to MEDIUM-TERM and potentially be only partially reversible, but with impacts to marine fauna being of medium probability. In the unlikely event of a blowout the slick would spread into Namibia and International waters beyond the EEZ and thus be of INTERNATIONAL extent. The environmental risk would therefore range from **MEDIUM** to **HIGH** depending on the faunal group affected. However, collectively, the impact on marine fauna is assessed to be of **MEDIUM** environmental risk.

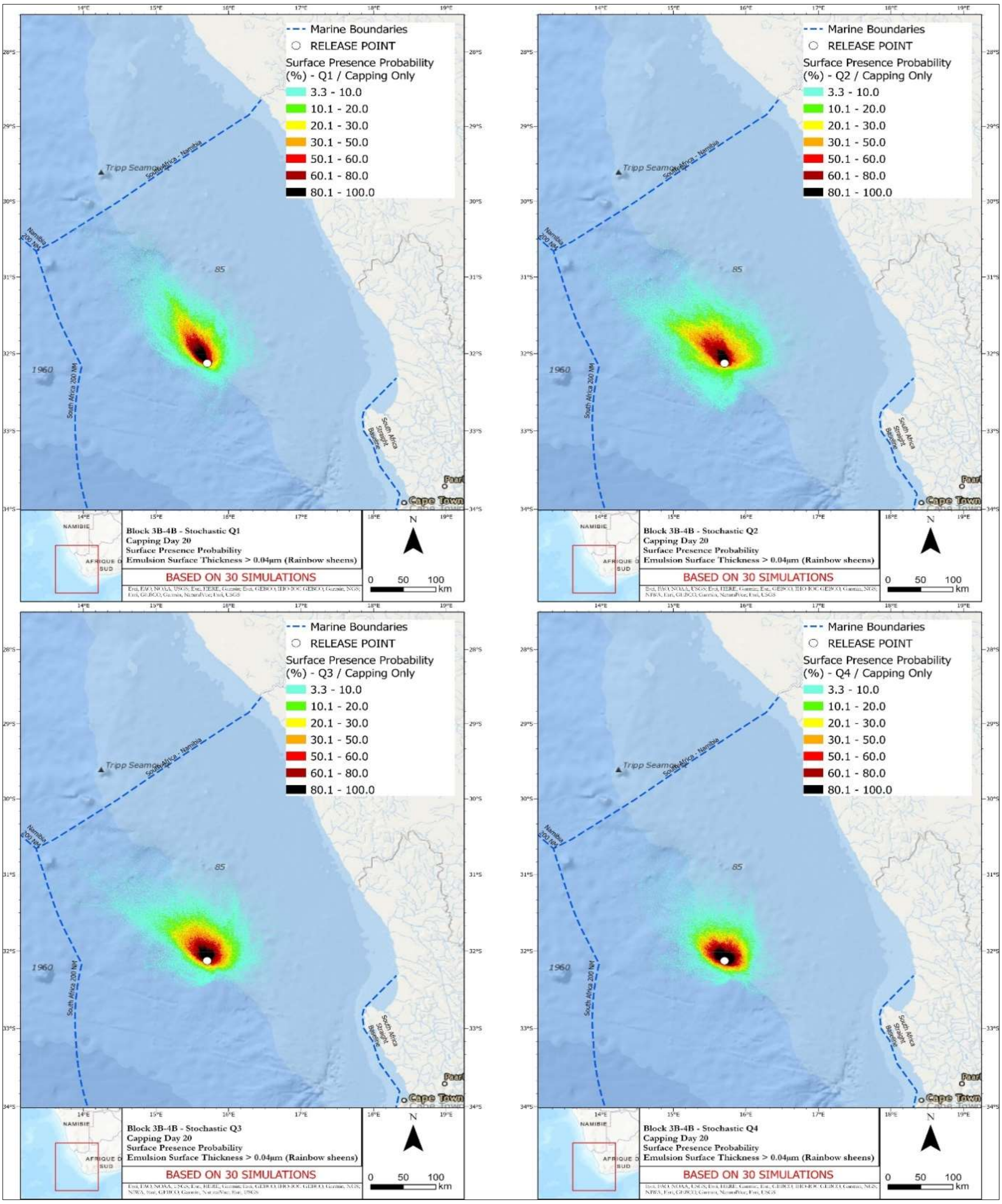

Figure 69: Surface presence probability of contamination >0.04 µm surface oil thickness for worst case 80-100% probability **of condensate** for all four seasons with capping only (Source: Livas 2023b).

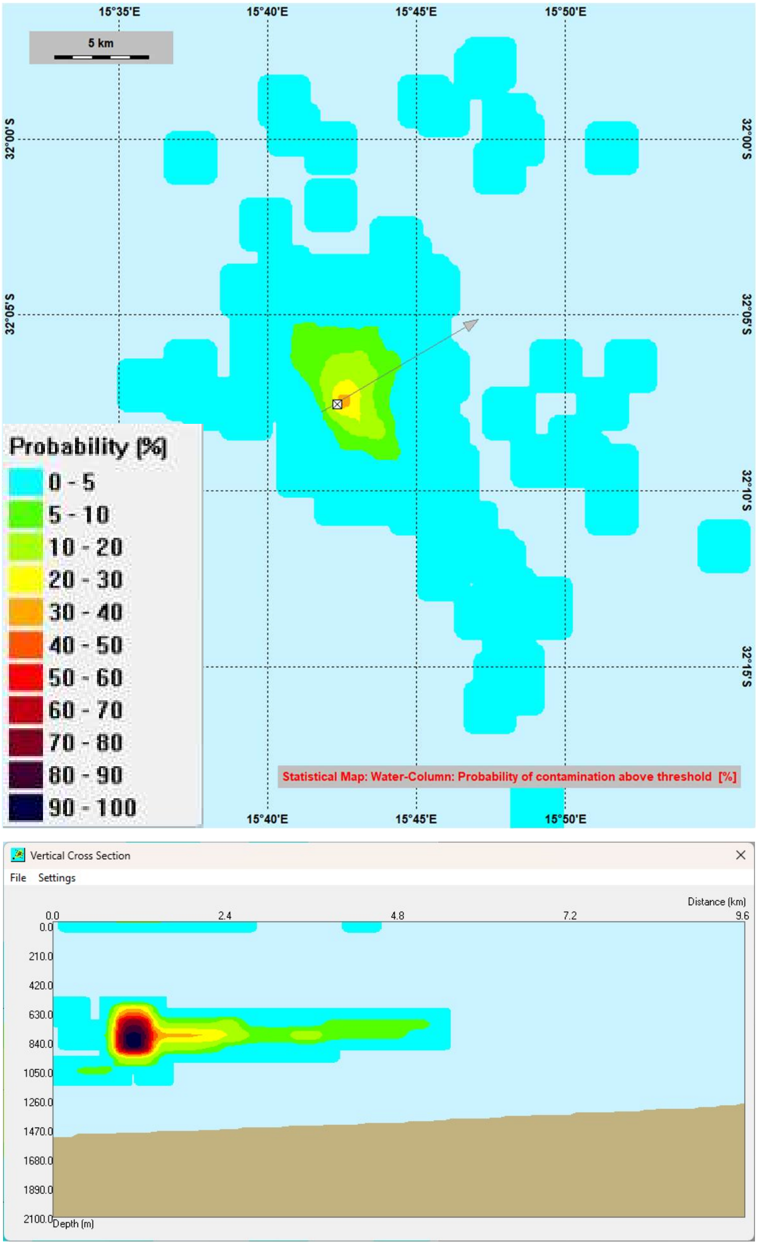

Figure 70: Water column probability of contamination >58 ppb (Season 3) with capping only (Source: Livas 2023b).

Crude Oil

The assessment below assumes the worst-case scenario of a continuous blowout of 5 405.6 m^3/d (34 000 barrels per day) and 1 443 243 Sm^3/d of crude oil and gas, respectively.

The modelling assumed the following spill response, namely:

- Capping stack only on 20th day

Threshold values applied to illustrate modelling output results are 58 ppb for oil in the water column, 0.04 µm for the surface oil thickness and 10 g/m^2 for shoreline oiling (see Livas 2023b 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 blowout.

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.

<u>Surface Layer and Water Column Probability of Contamination (Release Point D)</u>

Stochastic simulation results of the oil spill modelling study indicated that the crude oil and gas mixture escaping from the well reaches the higher probability for contamination of the surface (**capping only**) forming a plume that is transported in a WNW to NNW direction by the current. For this surface layer, 80 - 100% probability of surface oiling is reached at a maximum distance of 687 km to the NW (Season 1) (Figure 71a) spreading to a maximum of ~850 km NW through Namibian EEZ to the Walvis Ridge (<10% probability).

The spread of the 80-100% probability to the NW overlaps with both the Child's Bank and Orange Shelf Edge MPAs, as well as the Orange Seamount and Canyon Complex and Child's Bank and Shelf Edge EBSAs.

In the event of a blowout the oil would reach the surface between 900 m and 1 200 m to the S and SW of the release point within 3 hrs of the blowout. The maximum emulsion thickness reached at the surface is 619 µm, at localised spots to a maximum of 40 km W from the release point (Season 2). Although the oil is evaporated, dispersed and biodegraded once at the surface, some oil remains at the surface at the end of the simulations modelled (60 days) between 700 km and 1 000 km to the NW of Release Point D. Oil dispersed on the surface will affect the upper water layers. The high proportion of gas contained in the release results in rapid ascent to the surface. Consequently, there is no contamination of the deep layers (900 – 1 499 m), but some oil does remain in the water column as long as 20 days following release.

<u>Surface Layer and Water Column Probability of Contamination (Release Point A)</u>

Stochastic simulation results of the oil spill modelling study indicated that the crude oil and gas mixture escaping from the well reaches the higher probability for contamination of the surface (**capping only**) forming a plume that is transported in a WNW to NNW direction by the current. For this surface layer, 80 - 100% probability of surface oiling is reached at a maximum distance of 580 km to the NW (Season 1) (Figure 71b) spreading to a maximum of ~850 km NW through Namibian EEZ and across the Walvis Ridge in international waters (<10% probability). For probabilities >10%, no oil reaches the shore, but for Seasons 2 oil presence with low probabilities (<10%) occur east of the release point towards the shoreline, probably in response to short periods of westerly winds. The winds, however, do not persist for long enough to drift the oil to the coast.

The spread of the 80-100% probability to the NW overlaps with both the Child's Bank and Orange Shelf Edge MPAs, as well as the Orange Seamount and Canyon Complex and Child's Bank and Shelf Edge EBSAs.

In the event of a blowout the oil would reach the surface between 3 000 m to the S and 7 000 m to the N of the release point within 3 hrs of the blowout. The maximum emulsion thickness reached at the surface is 574 µm, at localised spots to a maximum of 19 km W of the release point (Season 2). Although the oil is evaporated, dispersed and biodegraded once at the surface, some oil remains at the surface at the end of the simulations modelled (60 days) between 920 km and 1 090 km to the NW of Release Point A. Oil dispersed on the surface will affect the upper water layers. The high proportion of gas contained in the release results in rapid ascent to the surface. Consequently, there is no contamination of the deep layers (1 200 – 1 600 m), but some oil does remain in the water column as long as 20 days following release.

Surface and Shoreline Oil Presence Probability

For Release Point D, and assuming that the oil on the surface is recovered within 60 days of the start of the spill, the stochastic modelling results indicate that no oil reaches the shore for probabilities >10%. In the case of Season 2 and Season 3, however, oil presence with low probabilities (<10%) occurs east of the release point towards the shoreline, probably in response to short periods of westerly winds. If the oil is not recovered from the surface, there is potential for it reaching the shoreline north of Saldanha Bay.

For Release Point A, the stochastic modelling results indicate that even for the **capping only response** to a blowout at the Release Points modelled, there is no probability of shoreline oiling, with the slick extending offshore in a N direction into Namibian and International waters. In the case of Season 2, however, if the oil is not recovered from the surface, there is potential for it extending towards the shoreline between the mouth of the Sout River and Hondeklipbaai.Assuming the worst-case scenario, the intensity of the potential impact of a blowout of crude oil varies depending on the faunal group affected ranging from HIGH for marine mammals, turtles, shoreline benthic communities, spawning areas and cetacean and seal breeding areas, to VERY HIGH for pelagic seabirds. As the spill will rise rapidly to the sea surface where it will disperse and evaporate over time, impacts of deposited oil on benthic communities associated with unconsolidated seabed or deep-water reefs are likely to be negligible, but should deposition of oil on the seabed occur the impacts of deposited oil is likely to persist over the MEDIUM- to LONG-TERM. Oil reaching the shore would likely also persist over the medium- to long-term. Impacts to pelagic fauna and seabirds would persist over the SHORT to MEDIUM-TERM and potentially be only partially reversible, but with impacts to marine fauna being of high probability considering the extensive area of the slick. In the unlikely event of a blowout the slick would spread into Namibia and International waters beyond the EEZ and thus be of INTERNATIONAL extent. The environmental risk would therefore range from **MEDIUM** to **HIGH** depending on the faunal group affected. However, collectively, the impact on marine fauna is assessed to be of **HIGH** environmental risk.

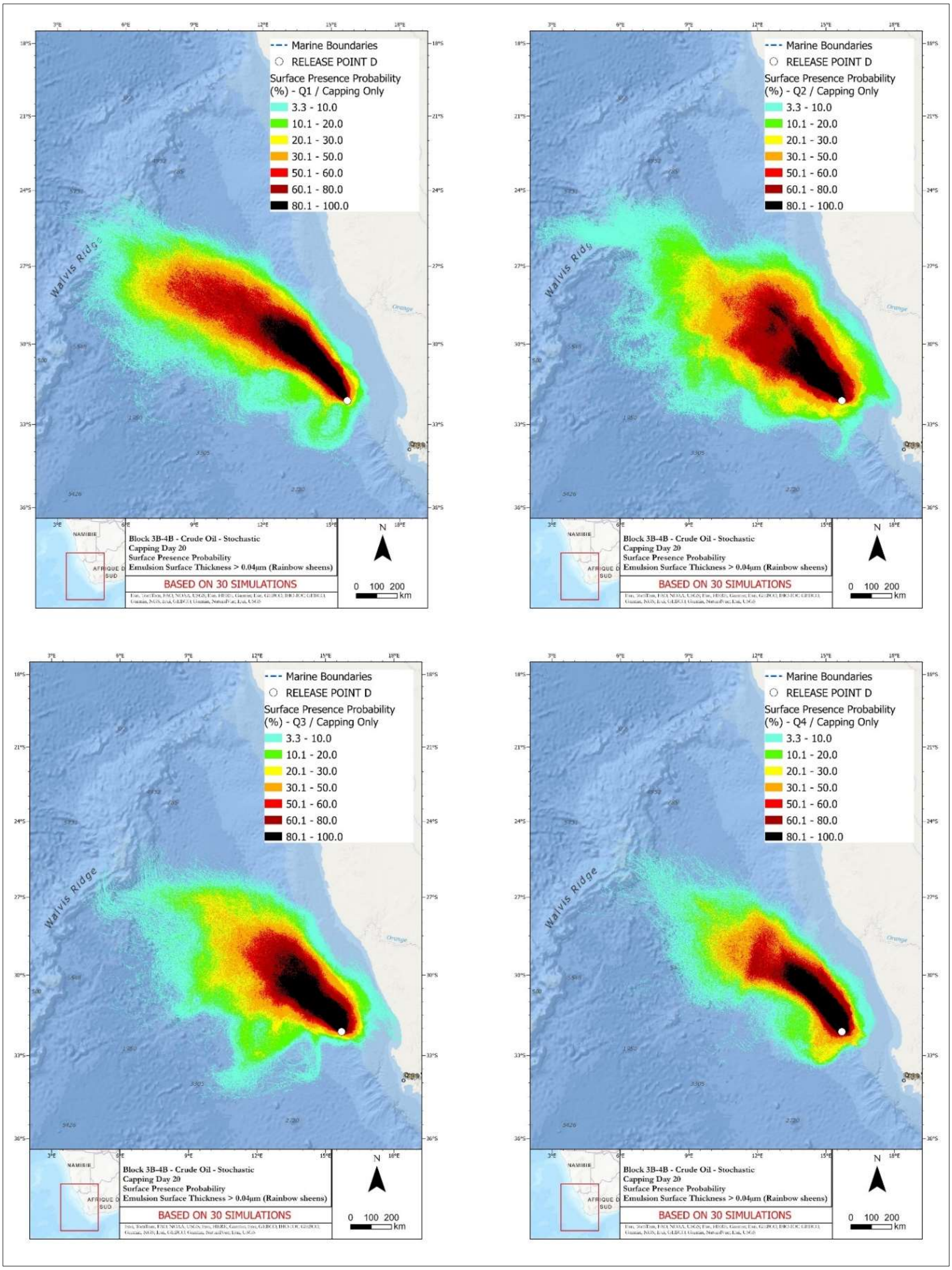

Figure 71: Surface presence probability of contamination >0.04 µm surface oil thickness for worst case 80-100% probability of **crude oil** for all four seasons with capping only from Release Point D (Source: Livas 2023b).

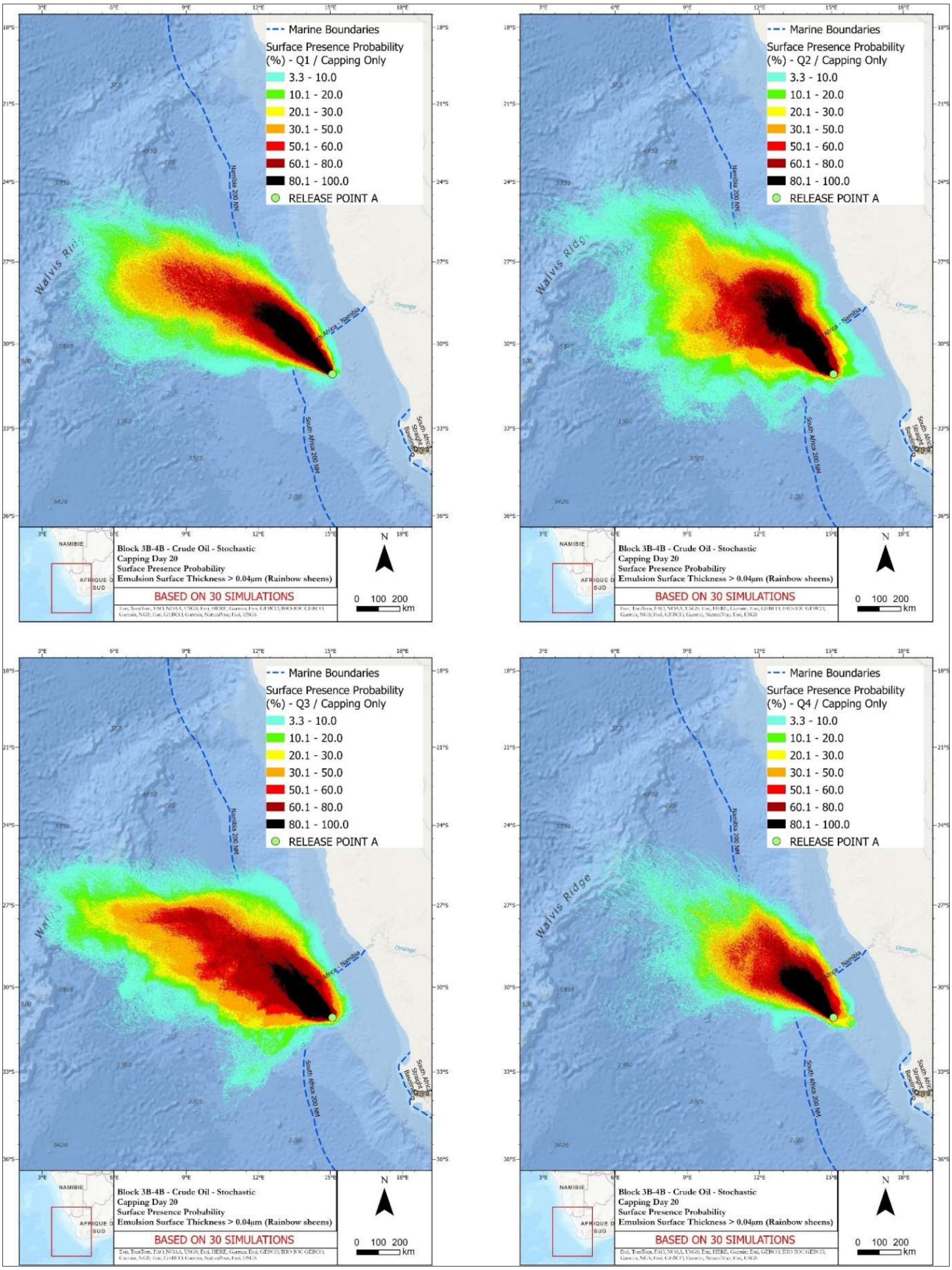

Figure 70b: Surface presence probability of contamination >0.04 µm surface oil thickness for worst case 80-100% probability of crude oil for all four seasons with capping only from Release Point A (Source: Livas 2023b).

Impact Significance

In the unlikely event of a spill, the impacts on the marine fauna before mitigation are thus considered to be of **MEDIUM** significance in the case of condensate and **HIGH** significance in the case of crude oil. It must be emphasised that the likelihood of a blowout occurring is extremely low.

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 safe drilling operations less than optimal.	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
2.1	Develop an Oiled Wildlife Contingency Plan (OWCP) in collaboration with specialist wildlife response organisations with experience in oiled wildlife response. The OWCP should be integrated into the site-specific OSPC and include detailed protocols on the collection, handling and transport of oiled marine fauna.	
2.2	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.	
2.3	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.	
2.4	Well-specific oil spill modelling for planning purposes taking into consideration site- and temporal-specific information, the planned response strategy, and associated resources.	
2.5	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.	
2.6	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 disperse, 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, improve dispersant spray capability, etc.).	
3	Schedule joint oil spill exercises including the operator and local departments / organisations to test the Tier 1, 2 & 3 responses.	Abate on site / Restore

No.	Mitigation measure	Classification
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, 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 DFFE.	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
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 pelagic fish and larvae, seabirds, marine mammals and turtles would still be of moderate to high intensity but the extent and duration would decrease. Overall, the residual impacts would be of **MEDIUM** significance.

22	*Impacts of a major spill following a blowout of condensate 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	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**HIGH**	**MEDIUM**
Intensity	MODERATE – HIGH (seabirds)	HIGH
Extent	REGIONAL - INTERNATIONAL	REGIONAL
Duration	MEDIUM	MEDIUM
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Probability	MEDIUM	MEDIUM
Significance	**MEDIUM**	**MEDIUM**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**LOW**	**LOW**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**LOW - MEDIUM (seabirds)**	**LOW - MEDIUM (seabirds)**

23	*Impacts of a major spill following a blowout of crude oil 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	HIGH	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**HIGH**	**MEDIUM**
Intensity	HIGH – VERY HIGH (seabirds)	HIGH
Extent	INTERNATIONAL	REGIONAL
Duration	MEDIUM	MEDIUM
Reversibility	PARTIALLY REVERSIBLE	PARTIALLY REVERSIBLE
Probability	DEFINITE	HIGH
Significance	**HIGH**	**MEDIUM**
Confidence	**HIGH**	**HIGH**
Loss of Resources	**HIGH**	**MEDIUM**
Mitigation Potential	**-**	**LOW**
Cumulative potential	**MEDIUM**	**MEDIUM**

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 Area of Interest 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 DFFE. • 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 as per specific protocols for capturing oiled and injured seabirds as outlined in the Oiled Wildlife Contingency Plan. • 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 blowout 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 blowout 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.	Medium

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blowout 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. – Develop an Oiled Wildlife Contingency Plan (OWCP) in collaboration with specialist wildlife response organisations with experience in oiled wildlife response to integrate into the site-specific OSCP. The OWCP should include detailed protocols on the collection, handling and transport of oiled marine fauna. – 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 AOSAC and local departments / 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.	Medium

IMPACT ASSESSMENT SUMMARY		
Main Impacts	Main Mitigations	Main residual impact
Effects of blowout on marine fauna (cont.)	• 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 DFFE • 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.	
	• 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. • 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.	Medium

5. LITERATURE CITED

ABBRIANO, R.M., CARRANZA, M.M., HOGLE, S.L., LEVIN, R.A., NETBURN, A.N., SETO, K.L., SNYDER, S.M. & P.J.S. FRANKS, 2011. Deepwater Horizon oil spill: a review of the planktonic response. Oceanography 24: 294–301.

ADAMS, N.J. & C.B. WALKER, 1993. Maximum diving depths of cape gannets. *The Condor*, **95**:136-138.

AKESSON, S., BRODERICK, A.C., GLEN, F., GODLEY, B.J., LUSCHI, P., PAPI, F. & G.C. HAYS, 2003. Navigation by green turtles: which strategy do displaced adults use to find Ascension Island. *Oikos* **103**: 363-372.

ALDREDGE, A.L., M. ELIAS & C.C. GOTSCHALK, 1986. Effects of drilling muds and mud additives on the primary production of natural assemblages of marine phytoplankton. *Mar. Environ. Res.* **19**: 157-176.

ALMEDA, R., BACA, S., HYATT, C. & E.J. BUSKEY, 2014a. Ingestion and sublethal effects of physically and chemically dispersed crude oil on marine planktonic copepods. Ecotoxicology 23, 988–1003.

ALMEDA, R., CONNELLY, T.L. & E.J. BUSKEY, 2015. How much crude oil can zooplankton ingest? Quantification of dispersed crude oil defecation by planktonic copepods. Environmental Pollution 208:645–654,

ALMEDA, R., HYATT, C. E.J. BUSKEY, 2014b. Toxicity of dispersant Corexit 9500A and crude oil to marine microzooplankton. Ecotoxicol. Environ. Saf. 106, 76–85.

ALMEDA, R.,WAMBAUGH, Z., CHAI, C.,WANG, Z.C., LIU, Z.F. & E.J. BUSKEY, 2013a. Effects of crude oil exposure on bioaccumulation of polycyclic aromatic hydrocarbons and survival of adult and larval stages of gelatinous zooplankton. Plos One 8 (15 pp.).

ALMEDA, R., WAMBAUGH, Z., WANG, Z.C., HYATT, C., LIU, Z.F. & E.J. BUSKEY, 2013b. Interactions between zooplankton and crude oil: toxic effects and bioaccumulation of polycyclic aromatic hydrocarbons. Plos One 8 (21 pp.).

ANDERSON, M. & P. HULLEY, 2000. Functional ecosystems: The Deep Sea. In: Durham B, Pauw J (eds), Marine Biodiversity Status Report for South Africa at the end of the 20th Century. Pretoria: National Research Foundation. pp 20–25.

ARNOSTI, C., ZIERVOGEL, K., YANG,T. & A. TESKE, 2014. Oil-derived marine aggregates – hot spots of polysacchride degradation by specialized bacterial communities. Deep Sea Research II, 129: 179-186.

ASHFORD, O.S., KENNY, A.J., BARRIO FROJÁN, C.R.S., DOWNIE, A-L., HORTON, T. & A.D. ROGERS, 2019. On the Influence of Vulnerable Marine Ecosystem Habitats on Peracarid Crustacean Assemblages in the Northwest Atlantic Fisheries Organisation Regulatory Area. Frontiers in Marine Science 11.

ATKINSON, L.J., 2009. Effects of demersal trawling on marine infaunal, epifaunal and fish assemblages: studies in the southern Benguela and Oslofjord. PhD Thesis. University of Cape Town, pp 141.

ATKINSON, L.J., FIELD, J.G. & L. HUTCHINGS, 2011. Effects of demersal trawling along the west coast of southern Africa: multivariate analysis of benthic assemblages. *Marine Ecology Progress Series* **430**: 241-255.

ATKINSON, L.J. & K.J. SINK (eds), 2018. Field Guide to the Offshore Marine Invertebrates of South Africa. Malachite Marketing and Media, Pretoria, pp498.

AUGUSTYN C.J., LIPINSKI, M.R. & M.A.C. ROELEVELD. 1995. Distribution and abundance of sepioidea off South Africa. S. Afr. J. Mar. Sci. 16: 69-83.

AUSTER, P.J., GJERDE, K., HEUPEL, E., WATLING, L., GREHAN, A. & A.D. ROGERS, 2011. Definition and detection of vulnerable marine ecosystems on the high seas: problems with the “move-on” rule. ICES Journal of Marine Science 68: 254–264.

AVILA, I.C., DORMANN, C.F., GARCÍA, C., PAYÁN, L.F. & M.X. ZORRILLA, 2019. Humpback whales extend their stay in a breeding ground in the Tropical Eastern Pacific. *ICES J. Mar. Sci.*, 77: 109–118.

AVINS, L. & K.J. LOHMANN, 2003. Use of multiple orientation cues by juvenile loggerhead sea turtles *Caretta caretta. The Journal of Experimental Biology* **206**: 44317-4325.

AVINS, L. & K.J. LOHMANN, 2004. Navigation and seasonal migratory orientation in juvenile sea turtles. *The Journal of Experimental Biology* **2067**: 1771-1778.

AWBREY, F.T. & B.S. STEWART, 1983. Behavioural responses of wild beluga whales *(Delphinapterus leucas*) to noise from oil drilling. *Journal of the Acoustical Society of America, Suppl*. 1, 74: S54.

BAAN, P.J.A., MENKE, M.A., BOON, J.G., BOKHORST, M., SCHOBBEN, J.H.M. & C.P.L. HAENEN, 1998. R*isico Analyse Mariene Systemen (RAM). Verstoring door menselijk gebruik*. Waterloopkundig Laboratorium, Delft.

BAILEY, G.W., 1991. Organic carbon flux and development of oxygen deficiency on the modern Benguela continental shelf south of 22°S: spatial and temporal variability. In: TYSON, R.V., PEARSON, T.H. (Eds.), Modern and Ancient Continental Shelf Anoxia. *Geol. Soc. Spec. Publ.*, **58**: 171–183.

BAILEY, G.W., 1999. Severe hypoxia and its effect on marine resources in the southern Benguela upwelling system. Abstract, *International Workshop on Monitoring of Anaerobic processes in the Benguela Current Ecosystem off Namibia.*

BAILEY, G.W., BEYERS, C.J. DE B. & S.R. LIPSCHITZ, 1985. Seasonal variation of oxygen deficiency in waters off southern South West Africa in 1975 and 1976 and its relation to catchability and distribution of the Cape rock-lobster *Jasus lalandii*. *S. Afr. J. Mar. Sci.*, **3**: 197-214.

BAILEY G.W. & P. CHAPMAN, 1991. Chemical and physical oceanography. In: Short-term variability during an Anchor Station Study in the southern Benguela Upwelling system. *Prog. Oceanogr.*, **28**: 9-37.

BAILLON, S., HAMEL, J-F., WAREHAM, V.E. & A. MERCIER, 2012. Deep cold-water corals as nurseries for fish larvae. Frontiers in Ecology and the Environment 10: 351–356.

BAKER, J.M., CLARK, R.B., KINGSTON, P.F. & R.H. JENKINS, 1990. Natural recovery of cold water marine environments after an oil spill. 13th Annual Arctic and Marine Oil spill Program Technical Seminar, Edmonton, Alberta. pp 1-111.

BAKKE, T., KLUNGSØYR, J. & S. SANNI, 2013. Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. *Mar. Environ. Res.* 92: 154-169.

BAKKE, T., GREEN, A.M.V. & P.E. IVERSEN, 2011. Offshore environmental monitoring in Norway - regulations, results and developments. In: LEE, K. & J. NEFF, (Eds.), Produced Water. Springer, NY (Chapter 25).

BALLY, R., 1987. The ecology of sandy beaches of the Benguela ecosystem. *S. Afr. J. mar. Sci.,* 5: 759-770

BANKS, A. BEST, P.B., GULLAN, A., GUISSAMULO, A., COCKCROFT, V. & K. FINDLAY, 2011. Recent sightings of southern right whales in Mozambique. Document SC/S11/RW17 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

BAPTIST, M.J., TAMIS, J.E., BORSJE, B.W. & J.J. VAN DER WERF, 2009. Review of the geomorphological, benthic ecological and biogeomorphological effects of nourishments on the shoreface and surf zone of the Dutch coast. Report IMARES C113/08, Deltares Z4582.50, pp69.

BARENDSE, J., BEST, P.B., THORNTON, M., POMILLA, C. CARVALHO, I. & H.C. ROSENBAUM, 2010. Migration redefined ? Seasonality, movements and group composition of humpback whales *Megaptera novaeangliae* off the west coast of South Africa. Afr. J. mar. Sci., 32(1): 1-22.

BARENDSE, J., BEST, P.B., THORNTON, M., ELWEN, S.H., ROSENBAUM, H.C., CARVALHO, I., POMILLA, C., COLLINS, T.J.Q. & M.A. MEŸER, 2011. Transit station or destination? Attendance patterns, regional movement, and population estimate of humpback whales *Megaptera novaeangliae* off West South Africa based on photographic and genotypic matching. African Journal of Marine Science, 33(3): 353-373.

BARKAI, A. & G.M.BRANCH, 1988. Contrasts between the benthic communities of subtidal hard substrata at Marcus and Malgas Islands: a case of alternative states? *S Afr J mar Sci* **7**: 117-137.

BARRIO FROJÁN, C.R.S., MACISAAC, K.G., MCMILLAN, A.K., DEL MAR SACAU CUADRADO, M., LARGE, P.A., KENNY, A.J., KENCHINGTON, E. & E. DE CÁRDENAS GONZÁLEZ, 2012. An evaluation of benthic community structure in and around the Sackville Spur closed area (Northwest Atlantic) in relation to the protection of vulnerable marine ecosystems. ICES Journal of Marine Science 69: 213–222.

BARLOW, M.J. & P.F. KINGSTON, 2001. Observations on the effects of barite on the gill tissues of the suspension feeder *Cerastoderma edule* (Linne) and the deposit feeder *Macoma balthica* (Linne). *Mar. Pollut. Bull.* **42**: 71-76.

BAX, N., WILLIAMSON, A., AGUERO, M., GONZALEZ, E. & W. GEEVES, 2003. Marine invasive alien species: a threat to global biodiversity. *Marine Policy,* 27: 313–323.

BEAL, L.M., BIASTOCH, A. & R. ZAHN, 2011. On the role of the Agulhas system in ocean circulation and climate. *Nature* 472: 429–436.

BEAZLEY. L., KENCHINGTON, E., YASHAYAEV, I. & F.J. MURILLO, 2015. Drivers of epibenthic megafaunal composition in the sponge grounds of the Sackville Spur, northwest Atlantic. Deep Sea Research Part I: Oceanographic Research Papers 98: 102–114.

BEAZLEY, L.I., KENCHINGTON, E.L., MURILLO, F.J. & M DEL M.SACAU, 2013. Deep-sea sponge grounds enhance diversity and abundance of epibenthic megafauna in the Northwest Atlantic. ICES Journal of Marine Science 70: 1471–1490.

BEJARANO, A.C. & J. MICHEL, 2010. Large-scale risk assessment of polycyclic aromatic hydrocarbons in shoreline sediments from Saudi Arabia: environmental legacy after twelve years of the Gulf war oil spill. *Environmental Pollution*, 158: 1561-1569.

BEJARANO, A.C. & J. MICHEL, 2016. Oil spills and their impacts on sand beach invertebrate communities: A literature review. *Environmental Pollution,* 218: 709-722.

BEJDER, L., SAMUELS, A., WHITEHEAD, H. & N. GALES, 2006. Interpreting short-term behavioral responses to disturbance within a longitudinal perspective. *Animal Behavior* 72: 1149-1158.

BENTHIC SOLUTIONS LIMITED, 2020. TOTAL E&P South Africa B.V. : Bibliographic Study. Project BSL_2003 South Africa, pp110.

BENTHIC SOLUTIONS LIMITED (BSL), 2021. TOTALENERGIES E&P South Africa: Bibliographic Study - Block 5/6/7. Project EPSA_BS_B567.

BEN-AVRAHAM, Z., HARTNADY, C.J.H. & K.A. KITCHIN, 1997. Structure and tectonics of the Agulhas-Falkland fracture zone. *Tectonophysics* 282: 83–98.

BERG, J.A. & R.I.E. NEWELL, 1986. Temporal and spatial variations in the composition of seston available to the suspension-feeder *Crassostrea virginica*. *Estuar. Coast. Shelf. Sci.*, **23**: 375–386.

BERG, W., GOSCHEN, S. & R.G. BARLOW, 2015. Hydrographic variability in the St. Helena Bay region of the southern Benguela ecosystem, *J. Geophys. Res. Oceans*, 120: 2920–2944.

BERGEN, M., WEISBERG, S.B., SMITH, R.W., CADIEN, D.B., DALKEY, A., MONTAGNE, D.E., STULL, J.K., VELARDE, R.G. & J. ANANDA RANASINGHE, 2001. Relationship between depth, sediment, latitude and the structure of benthic infaunal assemblages on the mainland shelf of southern California. *Marine Biology* **138**: 637-647.

BERGSTAD, O.A., GIL, M., HØINES, Å.S., SARRALDE, R., MALETZKY, E., MOSTARDA, E., SINGH, L., ANTÓNIO, M.A., RAMIL, F., CLERKIN, P. & G. CAMPANIS, 2019. Megabenthos and benthopelagic fishes on Southeast Atlantic seamounts, African Journal of Marine Science, 41(1): 29-50.

BERNABEU, A., FERN_ANDEZ-FERN_ANDEZ, S., BOUCHETTE, F., REY, D., ARCOS, A., BAYONA, J. & J. ALBAIGES, 2013. Recurrent arrival of oil to Galician coast: the final step of the Prestige deep oil spill. *J. Hazard. Mater.*, 250: 82-90.

BEST, P.B., 1974. The biology of the sperm whale as it relates to stock management. In: *The Whale Problem. A Status Report* (W.E. Schevill, ed.), pp. 257–293, Harvard University Press, Cambridge, Massachusetts.

BEST, P.B., 1990. Trends in the inshore right whale population off South Africa, 1969 1987. Marine Mammal Science, 6: 93 108.

BEST, P.B., 2001. Distribution and population separation of Bryde's whale *Balaenoptera edeni* off southern Africa. Mar. Ecol. Prog. Ser., 220: 277 – 289.

BEST, P.B., 2007. Whales and Dolphins of the Southern African Subregion. Cambridge University Press, Cape Town, South Africa.

BEST, P.B. & C. ALLISON, 2010. Catch History, seasonal and temporal trends in the migration of humpback whales along the west coast of southern Africa. IWC sc/62/SH5.

BEST, P.B. & C.H. LOCKYER, 2002. Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa in the 1960s. South African Journal of Marine Science, 24: 111-133.

BEST P.B., MEŸER, M.A. & C. LOCKYER, 2010. Killer whales in South African waters – a review of their biology. *African Journal of Marine Science*. **32**: 171–186.

BEST, P.B., MEYER, M.A., THORNTON, M., KOTZE, P.G.H., SEAKAMELA, S.M., HOFMEYR, G.J.G., WINTNER, S., WELAND, C.D. & D. STEINKE, 2014. Confirmation of the occurrence of a second killer whale morphotype in South African waters. *African Journal of Marine Science* **36**: 215-224.

BETT, B.J. & A.L. RICE, 1992. The influence of hexactinellid sponge (*Pheronema carpenteri*) spicules on the patchy distribution of macrobenthos in the porcupine seabight (bathyal ne atlantic). *Ophelia* 36: 217–226.

BEYER, J., TRANNUM, H.C., BAKKE, T., HODGESON, P.V. & T.K. COLLIER, 2016. Environmental effects of the Deepwater Horizon oil spill: a review. *Marine Pollution Bulletin*, 110: 28–51.

BEYER, J., GOKSØYR, A., HJERMANN, D.Ø. & J. KLUNGSØYR, 2020. Environmental effects of offshore produced water discharges: A review focused on the Norwegian continental shelf. *Mar. Environ. Res.*, 162: 105155.

BIANCHI, G., HAMUKUAYA, H. & O. ALVHEIM, 2001. On the dynamics of demersal fish assemblages off Namibia in the 1990s. *South African Journal of Marine Science* 23: 419-428.

BICCARD, A. & B.M. CLARK, 2016. De Beers Marine Namibia Environmental Monitoring Programme in the Atlantic 1 Mining Licence Area: 2013 Benthic Sampling Campaign. Report prepared for De Beers Marine Namibia by Anchor Environmental Consultants (Pty) Ltd. Report no. 1527/3.

BICCARD, A., CLARK, B.M. & E.A. BROWN, 2016. De Beers Marine Namibia Environmental Monitoring Programme in the Atlantic 1 Mining Licence Area: 2014 Benthic Sampling Campaign. Report prepared for De Beers Marine Namibia by Anchor Environmental Consultants (Pty) Ltd. Report no. 1527/4.

BICCARD, A., CLARK, B.M., BROWN, E.A., DUNA, O., MOSTERT, B.P., HARMER, R.W., GIHWALA, K. & A.G. WRIGHT, 2017. De Beers Marine Namibia Environmental Monitoring Programme: Atlantic 1 Mining Licence Area 2015 Benthic Sampling Campaign. Report prepared for De Beers Marine Namibia by Anchor Environmental Consultants (Pty) Ltd. Report no. 1527/4.

BICCARD, A., GIHWALA, K., CLARK, B.M., MOSTERT, B., BROWN, E., HUTCHINGS, K., MASSIE, V. & M. MELIDONIS, 2018. Desktop study of the potential impacts of marine mining on marine ecosystems and marine biota in South Africa – Final report. Report prepared by Anchor Research & Monitoring (Pty) Ltd for Council for Geoscience. Report no. 1795/1.

BICCARD A, GIHWALA K, CLARK BM, HARMER RW, BROWN EA, MOSTERT BP, WRIGHT AG & A MASOSONKE. 2018. De Beers Marine Namibia Environmental Monitoring Programme: Atlantic 1 Mining Licence Area 2016 Benthic Sampling Campaign. Report prepared for De Beers Marine Namibia by Anchor Environmental Consultants (Pty) Ltd. Report no. 1726/1.

BICCARD, A., K. GIHWALA, B.M. CLARK, E.A. BROWN, B.P. MOSTERT, A. MASOSONKE, C. SWART, S. SEDICK, B. TSHINGANA & J. DAWSON, 2019. De Beers Marine Namibia Environmental Monitoring Programme: Atlantic 1 Mining Licence Area 2017 Benthic Sampling Campaign. Report prepared for De Beers Marine Namibia by Anchor Environmental Consultants (Pty) Ltd. Report no. 1775/1.

BIJKERK, R., 1988. Ontsnappen of begraven blijven. De effecten op bodemdieren van een verhoogde sedimentatie als gevolg van baggerwerkzaamheden., RDD Aquatic Systems.

BIRCH, G., 1990. Phosphorite deposits on the South African continental margin and coastal terrace. In: BURNETT, W.C. & S.R. RIGGS (eds.) Phosphate deposits of the world, Vol. 3, Neogene to modern phosphorites. Cambridge University Press, Cambridge, UK:153-158

BIRCH, G.F. & J. ROGERS, 1973. Nature of the seafloor between Lüderitz and Port Elizabeth. *S. Afr. ship. news fish. ind. rev.*, **39 (7)**: 56-65.

BIRCH G.F., ROGERS J., BREMNER J.M. & G.J. MOIR, 1976. Sedimentation controls on the continental margin of Southern Africa. *First Interdisciplinary Conf. Mar. Freshwater Res. S. Afr.*, Fiche 20A: C1-D12.

BIRDLIFE INTERNATIONAL, 2013. Marine e-Atlas: Delivering site networks for seabird conservation. Proposed IBA site 'Atlantic, Southeast 19 – Marine'. Available online: http://54.247.127.44/marineIBAs/default.html. Accessed 11 March 2013.

BIRDLIFE SOUTH AFRICA, 2021. Threatened seabird habitats in the South African Economic Exclusive Zone: biodiversity feature layer submission to the National Coastal and Marine Spatial Biodiversity Plan. BirdLife South Africa SCP Report 2021/1.

BLAIZOT, C., 2019. Oil Seeps Detection in Offshore Frontier Areas Based on Multitemporal Satellite SAR Data and Manual Interpretation: Levantine and Natal Basins, Selected Historical and Recent SAR Data. 2018 International Conference and Exhibition, Cape Town, South Africa.

BLAKEMORE, R., 1975. Magnetotactic bacteria. *Science*. 190:377-379.

BLANCHARD, A.L. & H.M. FEDER, 2003. Adjustment of benthic fauna following sediment disposal at a site with multiple stressors in Port Valdez, Alaska. *Marine Pollution Bull*etin, **46**: 1590-1599.

BLECKMAN, H. & M.H. HOFMANN, 1999. Special senses. pp. 300-328. *In:* W.C. HAMLETT (Ed.) Sharks, Skates, and Ray: The Biology of Elasmobranch Fishes. The Johns Hopkins University Press, Baltimore.

BLOOM, P. & M. JAGER, 1994. The injury and subsequent healing of a serious propeller strike to a wild bottlenose dolphin (*Tursiops truncatus*) resident in cold waters off the Northumberland coast of England. *Aquatic Mammals*, 20(2: 59-64.

BODZNICK, D., MONTGOMERY, J. & T.C. TRICAS, 2003. Electroreception: extracting behaviorally important signals from noise. Chapter 20. pp. 389-403. *In:* Collins S.P. & N.J. Marshall, (eds) Sensory Processing in Aquatic Environments. Springer.

BOLTON, J.J., 1986. Seaweed biogeography of the South African west coast - A temperature dependent perspective. *Bot. Mar.*, **29**: 251-256.

BOOTH, C.G., SINCLAIR, R.R. & J. HARWOOD, 2020. Methods for Monitoring for the Population Consequences of Disturbance in Marine Mammals: A Review. *Front. Mar. Sci.*, 7: 115. doi: 10.3389/fmars.2020.00115

BOTHA, J. A., TRUEMAN, C. N., KIRKMAN, S. P., ARNOULD, J. P. Y., LOMBARD, A. T., CONNAN, M., HOFMEYR, G. J. G., SEAKAMELA, S. M., & PISTORIUS, P. A., 2023. Geographical, temporal, and individual-based differences in the trophic ecology of female Cape fur seals. Ecology and Evolution, 13, e9790

BOTHA, J. A., KIRKMAN, S. P., ARNOULD, J. P. Y., LOMBARD, A. T., HOFMEYR, G. J. G., MEŸER, M. A., KOTZE, P. G. H., & PISTORIUS, P. A., 2020. Geographic variation in at-sea movements, habitat use and diving behavior of female Cape fur seals. Marine Ecology Progress Series, 649, 201–218.

BOTHNER, M.H., RENDIGS, R.R., CAMPBELL, E.Y., DOUGHTON, M.W., PARMENTER, C.M., O'DELL, C.H., DILISIO, G.P., JOHNSON, R.G., GILSON, J.R. & N. RAIT. 1985. The Georges Bank Monitoring Program: analysis of trace metals in bottom sediments during the third year of monitoring. Final report submitted to the U.S. Dept. of the Interior, Minerals Management Service, Vienna, VA. Prepared by the U.S. Geological Survey, Woods Hole, MA. 99 pp.

BOYD, A..J. & G.P.J. OBERHOLSTER, 1994. Currents off the west and south coasts of South Africa. *S. Afr. Shipping News and Fish. Ind. Rev.*, **49**: 26-28.

BRABY, J., 2009. The Damara Tern in the Sperrgebiet: Breeding productivity and the impact of diamond mining. Unpublished report to Namdeb Diamond Corporation (Pty) Ltd.

BRANCH, G.M., 2008. Trophic Interactions in Subtidal Rocky Reefs on the West Coast of South Africa . In: MCCLANAHAN, T. & G.M. BRANCH (eds). Food Webs and the Dynamics of Marine Reefs. New York: Oxford University Press, 2008. Oxford Scholarship Online.Oxford University Press. pp 50-79

BRANCH, G. & M. BRANCH, 2018. *Living Shores : Interacting with southern Africa's marine ecosystems*. Struik Nature. Cape Town, South Africa.

BRANCH, G.M. & C.L. GRIFFITHS, 1988. The Benguela ecosystem Part V: the coastal zone. *Oceanog. Marine Biology: An Annual Re*view, **26**: 395-486.

BRANCH, G.M., GRIFFITHS, C.L., BRANCH, M.L., & BECKLEY, L.E. 2010. *Two Oceans*. Struik Nature, Cape Town, South Africa, revised edition, 456pp

BRANCH, T.A., STAFFORD, K.M., PALACIOS, D.M., ALLISON, C., BANNISTER, J.L., BURTON, C.L.K., CABRERA, E., CARLSON, C.A., GALLETTI VERNAZZANI, B., GILL, P.C., HUCKE-GAETE, R., JENNER, K.C.S., JENNER, M.-N.M., MATSUOKA, K., MIKHALEV, Y.A., MIYASHITA, T., MORRICE, M.G., NISHIWAKI, S., STURROCK, V.J., TORMOSOV, D., ANDERSON, R.C., BAKER, A.N., BEST, P.B., BORSA, P., BROWNELL JR, R.L., CHILDERHOUSE, S., FINDLAY, K.P., GERRODETTE, T., ILANGAKOON, A.D., JOERGENSEN, M., KAHN, B., LJUNGBLAD, D.K., MAUGHAN, B., MCCAULEY, R.D., MCKAY, S., NORRIS, T.F., OMAN WHALE AND DOLPHIN RESEARCH GROUP, RANKIN, S., SAMARAN, F., THIELE, D., VAN WAEREBEEK, K. & R.M. WARNEKE, 2007. Past and present distribution, densities and movements of blue whales in the Southern Hemisphere and northern Indian Ocean. Mammal Review, 37 (2): 116-175.

BRANDÃO, A., VERMEULEN, E., ROSS-GILLESPIE, A., FINDLAY, K. & D.S. BUTTERWORTH, 2017. Updated application of a photo-identification based assessment model to southern right whales in South African waters, focussing on inferences to be drawn from a series of appreciably lower counts of calving females over 2015 to 2017. Paper Sc/67B/SH/22 submitted to the scientific Committee of the International Whaling Commission, Bled, Slovenia, May 2018

BRABYN, M. & R. FREW, 1994. New Zealand herd stranding sites do not relate to geomagnetic topography. *Marine Mammal Science* **10**: 195-207.

BRANNON, E.L., QUINN, T.P., LUCCHETTI, G.L. & B.D. ROSS, 1981. Compass orientation of sockeye salmon fry from a complex river system. *Canadian Journal of Zoology* **59**: 1548-1553.

BRANOVER, G.G., VASIL'YEV, A.S., GLEYZER, S.I. & A.B. TSINOBER, 1970. A study of the behavior of the eel in natural and artificial and magnetic fields and an analysis of its reception mechanism. *Journal of Ichthyology* **11**: 608-614.

BRATTON, B. & J. AYERS, 1987. Observations on the electric organ discharge of two skate species (Chondrichthyes: Rajidae) and its relationships to behavior. *Environmental Biology of Fishes* **20**: 241-254.

BREEZE, H., DAVIS, D.S. BUTLER, M. & V. KOSTYLEV, 1997. Distrbution and status of deep sea corals off Nova Scotia. Marine Issues Special Committee Special Publication No. 1. Halifax, NS: Ecology Action Centre. 58 pp.

BREMNER, J.M., ROGERS, J. & J.P. WILLIS, 1990. Sedimentological aspects of the 1988 Orange River floods. *Trans. Roy. Soc. S. Afr.* **47** : 247-294.

BRETELER, R.J., REQUEJO, A.G. & J.M. NEFF, 1988. Acute toxicity and hydrocarbon composition of a water-based drilling mud containing diesel fuel or mineral oil additives. Pages 375-390 In: LICHTENBERG, J.J., WINTER, F.A., WEBER, C.I. & L. FRADKIN, Eds., Chemical and Biological Characterization of Municipal Sludges, Sediments, Dredge Spoils and Drilling Muds. American Society for Testing and Materials, Philadelphia, PA.

BREUER, E., STEVENSON, A.G., HOWE, J.A. & G.A. SHIMMIELD, 2004. Drill cutting accumulations in the Northern and Central North Sea: a review of environmental interactions and chemical fate. Mar. Pollut. Bull. 48: 12-25.

BRICELJ, V.M. & R.E. MALOUF, 1984. Influence of algal and suspended sediment concentrations on the feeding physiology of the hard clam *Mercenaria mercenari*a. *Mar. Biol.*, **84**: 155–165.

BROCK, L.G., ECCLES, M.E. & R.D. KEYNES, 1953. The discharge of individual electroplates in *Raja clavata*. *Journal of Physiology* **122**: 4-5.

BRÖKER, K.C.A., 2019. An Overview of Potential Impacts of Hydrocarbon Exploration and Production on Marine Mammals and Associated Monitoring and Mitigation Measures. *Aquatic Mammals*, 45(6): 576-611.

BROWN, A.C., STENTON-DOZEY, J.M.E. & E.R. TRUEMAN, 1989. Sandy beach bivalves and gastropods: a comparison between *Donax serra* and *Bullia digitalis*. *Adv. Mar. Biol.*, **25**: 179-247.

BROWN, A.C. & A. McLACHLAN, 2002. Sandy shore ecosystems and the treats facing them: some predictions for the year 2025. *Environmental Conservation,* **29 (1)**:1-16.

BROWN, P.C., 1984. Primary production at two contrasting nearshore sites in the southern Benguela upwelling region, 1977-1979. *S. Afr. J. mar. Sci.*, **2** : 205-215.

BROWN, P.C. & J.L. HENRY, 1985. Phytoplankton production, chlorophyll a and light penetration in the southern Benguela region during the period between 1977 and 1980. In: SHANNON, L.V. (Ed.) South African Ocean Colour and Upwelling Experiment. Cape Town, SFRI : 211-218.

BROWN, P.C. 1992. Spatial and seasonal variation in chlorophyll distribution in the upper30m of the photic zone in the southern Benguela/Agulhas region. *S. Afr. J. mar. Sci.*, **12**: 515-525.

BROWN, P.C., PAINTING, S.J. & COCHRANE, K.L. 1991. Estimates of phytoplankton and bacterial biomass and production in the northern and southern Benguela ecosystems. *S. Afr. J. mar. Sci.*, **11**: 537-564.

BRÜCHERT, V., BARKER JØRGENSEN, B., NEUMANN, K., RIECHMANN, D., SCHLÖSSER M. & H. SCHULZ, 2003. Regulation of bacterial sulfate reduction and hydrogen sulfide fluxes in the central Namibian coastal upwelling zone. *Geochim. Cosmochim. Acta*, **67(23)**: 4505-4518.

BRUNNSCHWEILER, J.M., BAENSCH, H., PIERCE, S.J. & D.W. SIMS, 2009. Deep-diving behaviour of a whale shark *Rhincodon typus* during long-distance movement in the western Indian Ocean. Journal of Fish Biology, 74: 706–714.

BRUSSAARD, C., PEPERZAK, L., BEGGAH, S. *et al*. 2016. Immediate ecotoxicological effects of short-lived oil spills on marine biota. *Nat Commun.*, 7: 11206. https://doi.org/10.1038/ncomms11206

BUCHANAN, R.A., COOK, J.A. & A. MATHIEU, 2003. Environmental Effects Monitoring for Exploration Drilling. Report for Environmental Studies Research Funds, Alberta. Solicitation No. ESRF – 018. Pp 182.

BUCHANAN, R.A., R. FECHHELM, J. CHRISTIAN, V.D. MOULTON, B.D. MACTAVISH, R. PITT & S. CANNING. 2006. Orphan Basin controlled source electromagnetic survey program environmental assessment. LGL Rep. SA899. Rep. by LGL Limited and Canning & Pitt Associates Inc., St. John's, NL, for ExxonMobil Canada Ltd., St. John's, NL. 128 p. + appendices.

BUHL-MORTENSEN, L. & P.B. MORTENSEN, 2005. Distribution and diversity of species associated with deep-sea gorgonian corals off Atlantic Canada. Cold-water corals and ecosystems. Springer. pp 849–879.

BUHL-MORTENSEN, L., VANREUSEL, A., GOODAY, A.J., LEVIN, L.A., PRIEDE, I.G., BUHL-MORTENSEN, P., GHEERARDYN, H., KING, N.J. & M. RAES, 2010. Biological structures as a source of habitat heterogeneity and biodiversity on the deep ocean margins. Marine Ecology 31: 21–50.

BULL, A.S. & J.J. KENDALL, Jr., 1994. An indication of the process: offshore platforms as artificial reefs in the Gulf of Mexico. *Bull. Mar. Sci*. **55**: 1086-1098.

BURD, B.J., 2002. Evaluation of mine tailings effects on a benthic marine infaunal community over 29 years. *Marine Environmental Research*, **53**: 481-519.

BURGER, A.E., 1991. Maximum diving depths and underwater foraging in alcids and penguins. In: MONTEVECCHI, W.A. & A.J. GASTON [eds.], Studies of high latitude seabirds.1. Behavioural, energetic, and oceanographic aspects of seabird feeding ecology. Canadian Wildlife Service, Occasional paper No. 68:9-15.

BUSKEY, E.J., WHITE, H.K. & A.J. ESBAUGH, 2016. Impact of oil spills on marine life in the Gulf of Mexico: Effects on plankton, nekton, and deep-sea benthos. *Oceanography* 29(3):174–181

BUSTAMANTE, R.H. & BRANCH, G.M., 1995. Large scale patterns and trophic structure of southern African rocky shores: the role of geographic variation and wave exposure. *Journal of Biogeography* **23**: 339-351.

BUSTAMANTE, R.H. & G.M. BRANCH, 1996a. The dependence of intertidal consumers on kelp-derived organic matter on the west coast of South Africa. *J. Exp. Mar. Biol. Ecol.*, **196**: 1-28.

BUSTAMANTE, R.H. & G.M. BRANCH, 1996b. Large scale patterns and trophic structure of southern African rocky shores: the role of geographic variation and wave exposure. *J. Biography,* **23**: 339-351.

BUSTAMANTE, R.H., BRANCH, G.M. & S. EEKHOUT, 1995b. Maintenance of exceptional intertidal grazer biomass in South Africa: Subsidy by subtidal kelps. *Ecology* **76(7)**: 2314-2329.

BUSTAMANTE, R.H., BRANCH, G.M. & S. EEKHOUT, 1997. The influences of physical factors on the distribution and zonation patterns of South African rocky-shore communities. *South African Journal of marine Science* **18**: 119-136.

BUSTAMANTE, R.H., BRANCH, G.M., EEKHOUT, S., ROBERTSON, B., ZOUTENDYK, P., SCHLEYER, M., DYE, A., HANEKOM, N., KEATS, D., JURD, M. & C. MCQUAID, 1995. Gradients of intertidal primary productivity around the coast of South Africa and their relationships with consumer biomass. *Oecologia* **102**: 189-201.

CABRERA, J., 1971. Survival of the oyster *Crassostrea virginica* (Gmelin) in the laboratory under the effects of oil drilling fluids spilled in the Laguna de Tamiahua, Mexico. *Gulf Research Reports* **3**: 197-213.

CADE, D.E., SEAKAMELA, S.M., FINDLAY, K.P., FUKUNAGA, J., KAHANE-RAPPORT, S.R., WARREN, J.D., *et al.*, 2021. Predator-scale spatial analysis of intra-patch prey distribution reveals the energetic drivers of rorqual whale super-group formation. *Funct. Ecol.*, 35: 894–908.

CAI, Z., FU, J., LIU, W., FU, K., O'REILLY, S.E. & D. ZHAO, 2017. Effects of oil dispersants on settling of marine sediment particles and particle-facilitated distribution and transport of oil components. Marine Pollution Bulletin, 114(1): 408-418.

CANTELMO, F.R., TAGATZ, M.E. & K.R. RAO, 1979. Effect of barite on meiofauna in a flow-through experimental system Mar. EnVirOn. Res., 2: 301-309.

CAPFISH, 2013. Environmental Observations and Fisheries Facilitation on board the 3D Seismic Survey Vessel *MV Polar Duchess*. Orange Basin Deep Water License Area West Coast, South Africa. 28th October 2012 to 22nd February 2013. For Shell South Africa Upstream BV, 300pp.

CAPFISH, 2013. Environmental Observations and Fisheries Facilitation on board the 2D Seismic Survey Vessel *MV Northern Explorer*. West Coast, South Africa. 24th December 2012 to 14th February 2013, 23rd March to 30th May 2013. For Spectrum, 335pp.

CAPP (Canadian Association of Petroleum Producers), 2001. Technical Report. Offshore Drilling Waste Management Review. Report 2001-0007 from Canadian Association of Petroleum Producers, Halifax, Nova Scotia, Canada. 240 pp.

CARASSOU, L., HERNANDWZ, F.J. & W.M. GRAHAM, 2014. Change and recovery of coastal mesozooplankton community structure during the Deepwater Horizon oil spill. Environ. Res. Lett., 9 (12pp.).

CARLS, M.G. & S.D. RICE. 1984. Toxic Contributions of Specific Drilling Mud Components to Larval Shrimp and Crabs. *Marine Environmental Research* **12**: 45-62.

CARLUCCI, R., MANEA, E., RICCI, P., CIPRIANO, G., FANIZZA, C., MAGLIETTA, R. & E. GISSI, 2021. Managing multiple pressures for cetaceans' conservation with an Ecosystem-Based Marine Spatial Planning approach. Journal of Environmental Management, 287:112240.

CARLTON, J.T., 1987. Patterns of transoceanic marine biological invasions in the Pacific Ocean. Bulletin of Marine Science 41: 452–465.

CARLTON, J.T., 1999. The scale and ecological consequences of biological invasions in the world's oceans. In: SANDLUND, O.T., SCHEI, P.J. & A. VIKEN (eds), Invasive species and biodiversity management. Dordrecht: Kluwer Academic Publishers. pp 195–212.

CARR, R.S., CHAPMAN, D.C., PRESLEY, B.J., BIEDENBACH, J.M., ROBERTSON, L., BOOTHE, P., KILADA, R., WADE, T. & P. MONTAGNA, 1996. Sediment pore water toxicity assessment studies in the vicinity of offshore oil and gas production platforms in the Gulf of Mexico. *Can. J. Fish. Aquat. Sci.*, **53**: 2618-2628.

CARROLL, A.G., PRZESLAWSKI, R., DUNCAN, A., GUNNING, M., BRUCE, B., 2017. A critical review of the potential impacts of marine seismic surveys on fish and invertebrates. *Marine Pollution Bulletin*, **114**: 9-24.

CATHALOT. C., VAN OEVELEN, D., COX, T.J.S., KUTTI, T., LAVALEYE, M., DUINEVELD, G. & F.J.R. MEYSMAN, 2015. Cold-water coral reefs and adjacent sponge grounds: Hotspots of benthic respiration and organic carbon cycling in the deep sea. Frontiers in Marine Science 2: 37.

CHANDRASEKARA, W.U. & C.L.J. FRID, 1998. A laboratory assessment of the survival and vertical movement of two epibenthic gastropod species, *Hydrobia ulvae* (Pennant) and *Littorina littorea* (Linnaeus), after burial in sediment. *Journal of Experimental Marine Biology and Ecol*ogy, **221**: 191-207.

CHAPMAN, P.M., POWER, E.A., DESTER, R.N. & H.B. ANDERSON, 1991. Evaluation of effects associated with an oil platform, using the sediment quality triad. *Environ. Toxicol. Chem.*, **10**: 407-424.

CHAPMAN, P. & L.V. SHANNON, 1985. The Benguela Ecosystem. Part II. Chemistry and related processes. *Oceanogr. Mar. Biol. Ann. Rev.*, **23**: 183-251.

CHENELOT, H., JEWETT, S. & M. HOBERG, 2008. Invertebrate Communities Associated with Various Substrates in the Nearshore Eastern Aleutian Islands, with Emphasis on Thick Crustose Coralline Algae. In: BRUEGGEMAN, P. & N.W. POLLOCK (eds.) Diving for Science. Proceedings of the American Academy of Underwater Sciences 27th Symposium.Dauphin Island, Alaska, AAUS, pp13-36.

CHILD, M.F., ROXBURGH, L., DO LINH SAN, E., RAIMONDO, D. & DAVIES-MOSTERT, H.T. (editors). 2016. The Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa. (https://www.ewt.org.za/Reddata/Order%20Cetacea.html).

CHRISTIE, N.D., 1974. Distribution patterns of the benthic fauna along a transect across the continental shelf off Lamberts Bay, South Africa. Ph.D. Thesis, University of Cape Town, 110 pp & Appendices.

CHRISTIE, N.D., 1976. A numerical analysis of the distribution of a shallow sublittoral sand macrofauna along a transect at Lambert’s Bay, South Africa. *Transactions of the Royal Society of South Africa*, **42**: 149-172.

CHRISTIE N.D. & A.G. MOLDAN, 1977. Effects of fish factory effluent on the benthic macro-fauna of Saldanha Bay. *Marine Pollution Bull*etin, **8**: 41-45.

CLARK, B.M. & G. RACTLIFFE (Ed.) 2007. Berg River Baseline Monitoring Programme Final Report. – Volume 5: Synthesis. Anchor Environmental Consultants CC and Freshwater Consulting Group for the Department of Water Affairs. 111pp.

CLARK, M.R., O’SHEA, S., TRACEY, D. & B. GLASBY, 1999. New Zealand region seamounts. Aspects of their biology, ecology and fisheries. Report prepared for the Department of Conservation, Wellington, New Zealand, August 1999. 107 pp.

CLARKE, D.G. & D.H. WILBER, 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. DOER Technical Notes Collection (ERDC TN-DOER_E9). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

CLARKE, R., 1956. Marking whales from a helicopter. *Norsk Hvalfangst-Tidende* **45**: 311-318.

CLIFF, G., ANDERSON-READE, M.D., AITKEN, A.O., CHARTER, G.E. & V.M. PEDDEMORS, 2007. Aerial census of whale sharks (*Rhincodon typus*) on the northern KwaZulu-Natal coast, South Africa. *Fish Res.*, 84: 41–46.

COCKCROFT, A.C, SCHOEMAN, D.S., PITCHER, G.C., BAILEY, G.W.& D.L. VAN ZYL, 2000. A mass stranding, or ‘walk out’ of west coast rock lobster, *Jasus lalandii*, in Elands Bay, South Africa: Causes, results and implications. In: VON VAUPEL KLEIN, J.C.& F.R. SCHRAM (Eds), *The Biodiversity Crisis and Crustacea: Proceedings of the Fourth International Crustacean Congress*, Published by CRC press.

COCKCROFT, A.C., VAN ZYL, D. & L. HUTCHINGS, 2008. Large-Scale Changes in the Spatial Distribution of South African West Coast Rock Lobsters: An Overview. *African Journal of Marine Science 2008, 30 (1) : 149-159.*

COETZEE, J.C., VAN DER LINGEN, C.D., HUTCHINGS, L., & T.P. FAIRWEATHER, 2008. Has the fishery contributed to a major shift in the distribution of South African sardine? – *ICES Journal of Marine Science*, 65: 1676–1688.

COHEN, J.H., MCCORMICK, L.R. & S.M. BURKHARDT, 2014. Effects of dispersant and oil on survival and swimming activity in a marine copepod. Bull. Environ. Contam. Toxicol., 92: 381–387.

COLEY, N.P. 1994. Environmental impact study: Underwater radiated noise. Institute for Maritime Technology, Simon's Town, South Africa. pp. 30.

COLEY, N.P. 1995. Environmental impact study: Underwater radiated noise II. Institute for Maritime Technology, Simon's Town, South Africa. pp. 31.

COLLIN, S.P. & D. WHITEHEAD, 2004. The functional roles of passive electroreception in non-electric fishes. *Animal Biology* **54**: 1-25.

COLMAN, J.G., GORDON, D.M., LANE, A.P., FORDE, M.J. & J.J. FITZPATRICK, 2005. Carbonate mounds off Mauritania, Northwest Africa: status of deep-water corals and implications for management of fishing and oil exploration activities. In: *Cold-water Corals and Ecosystems*, Freiwald, A & Roberts, J. M. (eds). Springer-Verlag Berlin Heidelberg pp 417-441.

COMPAGNO, L.J.V., 2001. Sharks of the World: an annotated and illustrated catalogue of shark species known to date. Bullhead, mackerel and carpet sharks (Heterodontiformes, Lamniformes and Orectolobiformes). FAO Species Catalogue for Fisheries Purposes No. 1, vol. 2. Food and Agriculture Organization of the United Nations, Rome, Italy

COMPAGNO, L.J.V., EBERT, D.A. & P.D. COWLEY, 1991. Distribution of offshore demersal cartilaginous fish (Class Chondrichthyes) off the West Coast of southern Africa, with notes on their systematics. *S. Afr. J. Mar. Sci.* 11: 43-139.

CONKLIN, P.J., DRYSDALE, D., DOUGHTIE, D.G., RAO, K.R., KAKAREKA, J.P., GILBERT, T.R. & R. SHOKES, 1983. Comparative toxicity of drilling muds: role of chromium and petroleum hydrocarbons. *Mar. Environ. Res.*, **10**: 105-125.

CONSTANTINE, R., 2001. Increased avoidance of swimmers by wild bottlenose dolphins (Tursiops truncatus) due to long-term exposure to swim-with-dolphin tourism. *Marine Mammal Science* 17: 689-702.

CORDES, E.E., JONES, D.O.B., SCHLACHER, T.A., AMON, D.J., BERNARDINO, A.F., BROOKE, S., CARNEY, R., DELEO, D.M., DUNLOP, K.M., ESCOBAR-BRIONES, E.G., *et al.* 2016. Environmental Impacts of the Deep-Water Oil and Gas Industry: A Review to Guide Management Strategies. *Frontiers in Environmental Science* 4: 1–26.

CORNWELL-HUSTON, C., 1986. *Marine anomalous conditions affecting cetacean live mass strandings. The case of Cape Cod Bay, Massachusetts.* M.S. Thesis. Department of Geography, Boston University, Boston, Massachusetts.

COSTA, D., SCHWARZ, L., ROBINSON, P., SCHICK, R., MORRIS, P.A., CONDIT, R., *et al.*, 2016. A bioenergetics approach to understanding the population consequences of disturbance: Elephant seals as a model system. In: POPPER, A.N. & A. HAWKINS (Eds.), *The effects of noise-on aquatic life II: Advances in experimental medicine and biology,* 875: 161-169.

COTE, D., MORRIS, C.J., REGULAR, P.M. & M.G. PIERSIAK, 2020. Effects of 2D Seismic on Snow Crab Movement Behavior, Fisheries Research, 20: 105661.

COX, T.M. & 35 others. 2006. Understanding the impacts of anthropogenic sound on beaked whales. *J. Cetacean Res. Manage.*, **7(3)**: 177-187.

CRANFORD, P.J., GORDON, JR., D.C., LEE, K., ARMSWORTHY, S.L. & G.H. TREMBLAY, 1999. Chronic toxicity and physical disturbance effects of water- and oil-based drilling fluids and some major constituents on adult sea scallops (*Placopecten magellanicus*). Mar. Environ. Res., 48: 225-256.

CRANFORD, P.J., QUERBACH, K., MAILLET, G., LEE, K., GRANT, J. & C. TAGGART, 1998. Sensitivity of larvae to drilling wastes (Part A): Effects of water-based drilling mud on early life stages of haddock, lobster, and sea scallop. Report to the Georges Bank Review Panel, Halifax NS, Canada. 22 pp.

CRAWFORD, R.J.M. & G. DE VILLIERS, 1985. Snoek and their prey – interrelationships in the Benguela upwelling system. *S. Afr. J. Sci.,* 81(2): 91–97.

CRAWFORD, R.J.M., SHANNON, L.V. & D.E. POLLOCK, 1987. The Benguela ecosystem. 4. The major fish and invertebrate resources. *Oceanogr. Mar. Biol. Ann. Rev.*, 25: 353 - 505.

CRAWFORD R.J.M., RYAN P.G. & A.J. WILLIAMS. 1991. Seabird consumption and production in the Benguela and western Agulhas ecosystems. *S. Afr. J. Mar. Sci.* 11: 357-375.

CRAWFORD, R.J.M., DUNDEE, B.L., DYER, B., KLAGES, N.T.W., MEYER, M.A. & L. UPFOLD, 2011. Trends in numbers of Cape gannets (*Morus capensis*), 1956/1957-2005/2006, with consideration of the influence of food and other factors. *ICES Journal of Marine Science*, 64: 169-177.

CRAWFORD, R.J., MAKHADO, A.B., WALLER, L.J. & P.A. WHITTINGTON, 2014. Winners and losers–Responses to recent environmental change by South African seabirds that compete with purse-seine fisheries for food. *Ostrich* 85: 111–117.

CRAWFORD, R.J., MAKHADO, A.B., WHITTINGTON, P.A., RANDALL, R.M., OOSTHUIZEN, W.H. & L.J. WALLER, 2015. A changing distribution of seabirds in South Africa—The possible impact of climate and its consequences. *Frontiers in Ecology and Evolution* 3: 1–10.

CROFT, B. & B. LI, 2017. Shell Namibia Deepwater Exploration Drilling: Underwater Noise Impact Assessment. Prepared by SLR Consulting Australia Pty Ltd. for SLR Consulting (Cape \Town) Pty Ltd. 19pp.

CROWTHER CAMPBELL & ASSOCIATES CC & CENTRE FOR MARINE STUDIES (CCA & CMS). 2001. Generic Environmental Management Programme Reports for Oil and Gas Prospecting off the Coast of South Africa. Prepared for Petroleum Agency SA, October 2001.

CRUIKSHANK, R.A., 1990. Anchovy distribution off Namibiadeduced from acoustic surveys with an interpretation of migration by adults and recruits. *S. Afr. J. Mar. Sci.*, **9**: 53-68.

CSIR, 1996. Elizabeth Bay monitoring project: 1995 review. *CSIR Report ENV/S-96066.*

CSIR, 1999. Synthesis and assessment of information on the BCLME. BCLME Thematic Report 4: Integrated overview of the offshore oil and gas industry in the Benguela Current Region. CSIR Report ENV-S-C 99057.

CSIR, 2006. Environmental Management Programme Report for Exploration/Appraisal Drilling in the Kudu Gas Production Licence No 001 on the Continental Shelf of Namibia. Prepared for: Energy Africa Kudu Limited, CSIR Report: CSIR/NRE/ECO/2006/0085/C.

CSIR & CIME, 2011. Environmental Impact Assessment for Exploration Drilling Operations, Yoyo Mining Concession and Tilapia Exploration Block, Offshore Cameroon. CSIR Report no. CSIR/CAS/EMS/ER/2011/0015/A.

CUNHA, H.A., DE CASTRO, R.L., SECCHI, E.R., CRESPO, E.A., LAILSON-BRITO, J., AZEVEDO, A.F., LAZOSKI, C. & A.M. SOLÉ-CAVA, 2015. Molecular and morphological differentiation of common dolphins (*Delphinus* spp.) in the southwestern Atlantic: testing the two species hypothesis in sympatry. PloS One 10:e0140251.

CURRIE, D.R. & L.R. ISAACS, 2005. Impact of exploratory offshore drilling on benthic communities in the Minerva gas field, Port Campbell, Australia. *Mar. Environ. Res.*, **59**: 217-233.

CURRIE, D.R., SOROKIN, S.J. & T.M. WARD, 2009. Infaunal macroinvertebrate assemblages of the eastern Great Australian Bight: effectiveness of a marine protected area in representing the region's benthic biodiversity. *Marine and Freshwater Research* **60**: 459-474.

DAAN, R. & M. MULDER, 1993. A study on possible environmental effects of WBM cuttings discharge in the North Sea, one year after termination of drilling. NIOZ Report 1993-16 from the Netherlands Institute of Sea Research, Texel, the Netherlands. 17 pp.

DAAN, R. & M. MULDER, 1996. Long-term effects of OBM cutting discharges at 12 locations on the Dutch Continental Shelf. NIOZ-report 1996-6, NIOZ, Texel, The Netherlands: 1-36.

DAAN, R., VAN HET GROENEWOUD, H., DE JONG, S.A., & M. MULDER, 1992. Physico-chemical and biological features of a drilling site in the North Sea, 1 year after discharges of oil-contaminated drill cuttings. *Marine Ecology Progress Series*, **91**: 37-45.

DARLING, J.D., ACEBES, J.M.V., FREY, O., URBÁN, R.J. & M. YAMAGUCHI, 2019. Convergence and divergence of songs suggests ongoing, but annually variable, mixing of humpback whale populations throughout the North Pacific. *Sci. Rep.*, 9: 1–14.

DARLING, J.D. & R. SOUSA-LIMA, 2005. Songs indicate interaction between humpback whale (*Megaptera novaeangliae*) populations in the Western and Eastern South Atlantic Ocean. Marine Mammal Science, 21(3): 557-566.

DA SILVA, C., KERWATH, S.E., WILKE, C., MEŸER, M. & S.J. LAMBERT, 2010. First documented southern transatlantic migration of blue shark *Prionace glauca* tagged off South Africa. *African Journal of Marine Science*, 32(3) : 639-642.

DAVID, J.H.M, 1989., Seals. In: Oceans of Life off Southern Africa, Eds. Payne, A.I.L. & Crawford, R.J.M. Vlaeberg Publishers. Halfway House, South Africa.

DAVIES, J., ADDY, J., BLACKMAN, R., BLANCHARD, J., FERBRACHE, J., MOORE, D., SOMMERVILLE, H., WHITEHEAD, A. & T. WILKINSON, 1983. Environmental effects of oil based mud cuttings. UKOOA, Aberdeen, Scotland. 24 pp. plus appendices.

DAY, J.H., FIELD, J.G. & M. MONTGOMEREY, 1971. The use of numerical methods to determine the distribution of the benthic fauna across the continental shelf of North Carolina. *Journal of Animal Ecology* **40**:93-126.

DEAT (Department of Environmental Affairs and Tourism). 2004. Cumulative Effects Assessment, Integrated Environmental Management, Information Series 7, Department of Environmental.

DE DECKER, A.H., 1970. Notes on an oxygen-depleted subsurface current off the west coast of South Africa. *Invest. Rep. Div. Sea Fish. South Africa*, **84**, 24 pp.

DE GREEF, K., GRIFFITHS, C.L. & Z. ZEEMAN, 2013. Deja vu? A second mytilid mussel, *Semimytilus algosus*, invades South Africa's west coast. *African Journal of Marine Science* **35(3)**: 307-313.

DeLEO, D.M., RUIZ-RAMOS, D.V., BAUMS, I.B. & E.E. CORDES, 2015. Response of deep-water corals to oil and chemical dispersant exposure. Deep-Sea Res. II Top. Stud. Oceanogr. (11 pp.).

DE ROCK, P., ELWEN, S.H., ROUX, J-P., LEENEY, R.H., JAMES, B.S., VISSER, V., MARTIN, M.J. & T. GRIDLEY, 2019. Predicting large-scale habitat suitability for cetaceans off Namibia using MinxEnt. *Marine Ecology Progress Series*, **619**: 149-167.

DEROUS, D., TEN DOESCHATE, M., BROWNLOW, A.C., DAVISON, N.J. & D. LUSSEAU, 2020. Toward New Ecologically Relevant Markers of Health for Cetaceans. *Front. Mar. Sci.*, 7: 367. doi: 10.3389/fmars.2020.00367

DeRUITER, S.L., SOUTHALL, B.L., CALAMBOKIDIS, J., ZIMMER, W.M.X., SADYKOVA, D., FALCONE, E.A., FRIEDLAENDER, A.S., JOSEPH, J.E., MORETTI, D., SCHORR, G.S., THOMAS, L. & P.L. TYACK, 2013. First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. *Biol. Lett.,* 9: 2013022320130223.

DERVILLE, S., TORRES, L.G., ALBERTSON, R., ANDREWS, O., BAKER, C.S., CARZON, P., *et al.*, 2019. Whales in warming water: assessing breeding habitat diversity and adaptability in Oceania's changing climate. *Glob. Change Biol.*, 25: 1466–1481.

DERVILLE, S., TORRES, L.G., ZERBINI, A.N., OREMUS, M. & C. GARRIGUE, 2020. Horizontal and vertical movements of humpback whales inform the use of critical pelagic habitats in the western South Pacific. *Sci. Rep.*, 10: 4871.

DETHLEFSEN, V., SOFFKER, K., BUTHER, H. & U. DAMM, 1996. Organochlorine compounds in marine organisms from the international North Sea incineration area Arch. *Fish. Mar. Res.*, **44(3)**: 215-242.

DE WET, A. 2013. *Factors affecting survivorship of loggerhead (Caretta caretta) and leatherback (Dermochelys coriacea) sea turtles of South Africa.* MSc, Nelson Mandela Metropolitan University.

DEY, S.P., VICHI, M., FEARON, G. *et al.*, 2021. Oceanographic anomalies coinciding with humpback whale super-group occurrences in the Southern Benguela. *Sci Rep.,* 11, 20896.

DINGLE, R.V., 1970. Bathymetry. Tech. Rep. Joint Geol. Surv./UCT Marine Geol. Prog. 3: 11 –12.

DINGLE, R.V., 1973. The Geology of the Continental Shelf between Lüderitz (South West Africa) and Cape Town with special reference to Tertiary Strata. *J. Geol. Soc. Lond.*, **129**: 337-263.

DINGLE, R.V., 1986. Revised bathymetric map of the Cape Canyon. *Technical Report, Joint Geological Survey, University of Cape Town Marine Geoscience Unit* 16: 20–25.

DINGLE, R.V., BIRCH, G.F., BREMNER, J.M., DE DECKER, R.H., DU PLESSIS, A., ENGELBRECHT, J.C., FINCHAM, M.J., FITTON, T, FLEMMING, B.W. GENTLE, R.I., GOODLAD, S.W., MARTIN, A.K., MILLS, E.G., MOIR, G.J., PARKER, R.J., ROBSON, S.H., ROGERS, J. SALMON, D.A., SIESSER, W.G., SIMPSON, E.S.W., SUMMERHAYES, C.P., WESTALL, F., WINTER, A. & M.W. WOODBORNE, 1987. Deep-sea sedimentary environments around Southern Africa (South-east Atlantic and South-west Indian Oceans). *Annals of the South African Museum* 98(1).

DINGLE, R.V., SIESSER, W.G. & A.R. NEWTON, 1983. *Mesozoic and Tertiary Geology of southern Africa.* Rotterdam, Netherlands: Balkema.

DODGE, R.E. & A. SZMANT-FROELICH, 1985. Effects of drilling fluids on reef corals: a review. In: Duedall IW, Kester DR, Park PK, Ketchum BH (eds) Wastes in the ocean, Vol 4. Wiley Interscience, New York, NY, p 341−364.

DOUGLAS, A.B., CALAMBOKIDIS, J., RAVERTY, S., JEFFRIES, S.J., LAMBOURN, D.M.& S.A. NORMA, 2008. Incidence of ship strikes of large whales in Washington State. J*ournal of the Marine Biological Association of the United Kingdom* 88: 1121-1132.

DOVING, K.B. & O.B. STABELL, 2003. Trails in open water: Sensory cues in salmon migration. Chapter 2. pp. 39-52. In : COLLINS S.P. N.J. MARSHALL (eds) Sensory Processing in Aquatic Environments. Springer.

DOW, F.K., DAVIES, J.M. & D. RAFFAELI, 1990. The effects of drilling cuttings on a model marine sediment system. *Mar. Environ. Res.*, **29**: 103-124.

DRAKE, D.E., CACCHIONE, D.A. & H.A. KARL, 1985. Bottom currents and sediment transport on San Pedro Shelf, California. *J. Sed. Petr.*, **55**: 15-28.

DREWITT, A., 1999. Disturbance effects of Aircraft on birds. English Nature. Birds Network Information Note. 14pp.

D'SOUZA,N.,SUBRAMANIAM,A.,JUHL,A.R.,CHEKALYUK,A.,PHAN,S.,YAN,B.,MACDONALD,I.R.,WEBER,S.C. & J.P. MONTOYA, 2016. Elevated surface chlorophyll associated with natural oil seeps in the Gulf of Mexico. Nat. Geosci., 9:215–218.

DUARTE, C.M., CHAPUIS, L., COLLIN, S.P., COSTA, D.P., DEVASSY, R.P., EGUILUZ, V.M., ERBE, C., GORDON, T.A., HALPERN, B.S., HARDING, H.R., HAVLIK, M.N., *et al.*, 2021. The soundscape of the Anthropocene ocean. *Science*, 371 (6529).

DUBOIS, M.J., PUTMAN, N.F. & S.E. PIACENZA, 2021. A Global Assessment of the Potential for Ocean-Driven Transport in Hatchling Sea Turtles. *Water*, 13: 757.

DUNA, O., CLARK, B.M., BICCARD, A., HUTCHINGS, K., HARMER, R., MOSTERT, B., BROWN, E., MASSIE, V., MAKUNGA, M., DLAKU, Z. & A, MAKHOSONKE, 2016. Assessment of mining-related impacts on macrofaunal benthic communities in the Northern Inshore Area of Mining Licence Area MPT 25-2011 and subsequent recovery. Technical Report. Report prepared for De Beers Marine by Anchor Environmental Consultants (PTY) Ltd. Report no. 1646/1.

DUNCAN, C. & J.M. ROBERTS, 2001. Darwin mounds: deep-sea biodiversity 'hotspots'. *Marine Conservation* **5**: 12.

DUNDEE, B.L., 2006. *The diet and foraging ecology of chick-rearing gannets on the Namibian islands in relation to environmental features: a study using telemetry*. MSc thesis, University of Cape Town, South Africa.

DUNLOP, R.A., BRAITHWAITE, J., MORTENSEN, L.O. & C.M. HARRIS, 2021. Assessing Population-Level Effects of Anthropogenic Disturbance on a Marine Mammal Population. *Front. Mar. Sci.*, 8: 1 12.

ECKERT, S.A. & B.S. STEWART, 2001. Telemetry and satellite tracking of whale sharks, *Rhincodon typus*, in the Sea of Cortez, Mexico, and the north Pacific Ocean. *Environmental Biology of Fishes*, **60**: 299–308.

ECKERT, S.A., ECKERT, K.L., PONGANIS, P. & G.L. KOOMAN, 1989. Diving and foraging behavior of leatherback sea turtles (*Dermochelys coriacea*). *Canadian Journal of Zoology* **67**: 28-34.

EDGE, K.J., JOHNSTON, E.L., DAFFORN, K.A., SIMPSON, S.L., KUTTI, T. & R.J. BANNISTER, 2016. Sub-lethal effects of water-based drilling mud on the deep-water sponge *Geodia barretti*. Environ. Pollut., 212: 525-534.

EGRES, A.G., HATJE, V., GALLUCCI, F., MACHADO, M.E. & F. BARROS, 2019. Effects of an experimental oil spill on the structure and function of benthic assemblages with different history of exposure to oil perturbation. Marine Environmental Research, 152: 104822.

ELLINGSEN, K.E., 2002. Soft-sediment benthic biodiversity on the continental shelf in relation to environmental variability. Marine Ecology Progress Series, 232: 15-27.

ELLIS, D.V., 2000. Effect of Mine Tailings on The Biodiversity of The Seabed: Example of The Island Copper Mine, Canada. In: SHEPPARD, C.R.C. (Ed), Seas at The Millennium: An Environmental Evaluation. Pergamon, Elsevier Science, Amsterdam, pp. 235-246.

ELLIS, D.V. & C. HEIM, 1985. Submersible surveys of benthos near a turbidity cloud. *Marine Pollution Bulletin*, **16**: 197-202.

ELLIS, J.I., FRASER, G. & J. RUSSELL, 2012. Discharged drilling waste from oil and gas platforms and its effects on benthic communities. Mar. Ecol. Prog. Ser., 456: 285–302.

ELLIS, M.S., WILSON-ORMOND, E.A. & E.N. POWELL, 1996. Effects of gas-producing platforms on continental shelf macroepifauna in the northwestern Gulf of Mexico: abundance and size structure. *Can. J. Fish. Aquat. Sci.*, **53**: 2589-2605.

ELLISON, W.T., RACCA, R., CLARK, C.W., STREEVER, B. *et al.* 2016. Modeling the aggregated exposure and responses of bowhead whales *Balaena mysticetus* to multiple sources of anthropogenic underwater sound. *Endang. Species Res.*, 30: 95–108.

ELMGREN, R., S. HANSON, U. LARSON, B. SUNDELIN, & P.D. BOEHM, 1983. The 'Tsesis' Oil SPill: Acute and long-term impact on the benthos. Marine Biology, 73: 51-65.

ELVIN, S.S. & C.T. TAGGART, 2008. Right whales and vessels in Canadian waters. *Marine Policy* 32 (3): 379-386.

ELWEN, S.H., GRIDLEY, T., ROUX, J.-P., BEST, P.B. & M.J. SMALE, 2013. Records of Kogiid whales in Namibia, including the first record of the dwarf sperm whale (*K. sima*). Marine Biodiversity Records. 6, e45 doi:10.1017/S1755267213000213.

ELWEN, S.H. & R.H. LEENEY, 2010. Injury and Subsequent Healing of a Propeller Strike Injury to a Heaviside's dolphin (*Cephalorhynchus heavisidii*). *Aquatic Mammals* 36 (4): 382-387.

ELWEN, S.H. & R.H. LEENEY, 2011. Interactions between leatherback turtles and killer whales in Namibian waters, including predation. *South African Journal of Wildlife Research,* **41(2)**: 205-209.

ELWEN, S.H., FINDLAY, K.P., KISZKA, J. & C.R. WEIR, 2011. Cetacean research in the southern African subregion: a review of previous studies and current knowledge, African Journal of Marine Science 32(3)

ELWEN, S.H. MEŸER, M.A.M, BEST, P.B., KOTZE, P.G.H, THORNTON, M. & S. SWANSON, 2006. Range and movements of a nearshore delphinid, Heaviside's dolphin *Cephalorhynchus heavisidii* a determined from satellite telemetry. *Journal of Mammalogy*, **87(5)**: 866–877.

ELWEN S.H., SNYMAN L. & R.H. LEENEY, 2010b. Report of the Nambian Dolphin Project 2010: Ecology and conservation of coastal dolphins in Namibia. Submitted to the Ministry of Fisheries and Marine Resources, Namibia. Pp. 1-36.

ELWEN S.H., THORNTON M., REEB D. & P.B. BEST, 2010a. Near-shore distribution of Heaviside's (*Cephalorhynchus heavisidii*) and dusky dolphins (*Lagenorhynchus obscurus*) at the southern limit of their range in South Africa. *African Journal of Zoology* 45: 78-91.

ELWEN, S.H., TONACHELLA, N., BARENDSE, J,. COLLINS, T.J.Q., BEST, P.B., ROSENBAUM, H.C., LEENEY, R.H. & T. GRIDLEY. 2014. Humpback Whales off Namibia: Occurrence, Seasonality, and a Regional Comparison of Photographic Catalogs and Scarring. *Journal of Mammalogy*, **95 (5)**: 1064–76. doi:10.1644/14-MAMM-A-108.

ENVIRONMENTAL PROTECTION AGENCY (EPA), 2000. Environmental assessment of fun] effluent limitations guidelines and standards for synthetic-based drilling fluids and other non-aqueous drilling fluids in the oil and gas extraction point source category. EPA-821-B-00-014. December 2000.

EMANUEL, B.P., BUSTAMANTE, R.H., BRANCH, G.M., EEKHOUT, S. & F.J. ODENDAAL, 1992. A zoogeographic and functional approach to the selection of marine reserves on the west coast of South Africa. S. Afr. J. Mar. Sci., 12: 341-354.

ENO, N.C., 1996. Non-native marine species in British waters: effects and controls. *Aquatic Conservation: Marine and Freshwater Ecosystems* 6: 215–28.

ERBE, C., DUNLOP, R.A. & S.J. DOLMAN, 2018. Effects of Noise on Marine Mammals. In: SLABBEKOORN, H., DOOLING, R. & A.N. POPPER (eds) Effects of Anthropogenic Noise on Animals. Springer, New York, p277 309.

ERBE, C., DUNLOP, R., JENNER, K.C.S., JENNER, M.N.M., MCCAULEY, R.D., PARNUM, I., PARSONS, M., ROGERS, T. & C. SALGADO-KENT, 2017. Review of Underwater and In-Air Sounds Emitted by Australian and Antarctic Marine Mammals. *Acoust Aust* **45,** 179–241 (2017).

ERBE, C., MARLEY, S.A., SCHOEMAN, R.P., SMITH, J.N., TRIGG, L.E. & C.B. EMBLING, 2019. The effects of ship noise on marine mammals—a review. *Front. Mar. Sci.*, 6: 606.

ERBE, C., WILLIAMS, R., PARSONS, M., PARSONS, S.K., HENDRAWAN, G. & I.M.I. DEWANTAMA, 2018. Underwater noise from airplanes: An overlooked source of ocean noise. *Mar. Pollut. Bull.*, 137: 656–661.

ESBAUGH, A.J., E.M. MAGER, J.D. STIEGLITZ, R. HOENIG, T.L. BROWN, B.L. FRENCH, T.L. LINBO, C. LAY, H. FORTH, N.L. SCHOLZ, *et al*. 2016. The effects of weathering and chemical dispersion on Deepwater Horizon crude oil toxicity to mahi-mahi (*Coryphaena hippurus*) early life stages. Science of the Total Environment 543: 644–651.

ESCARAVAGE, V., HERMAN, P.M.J., MERCKX, B., WŁODARSKA-KOWALCZUK, M., AMOUROUX, J.M., DEGRAER, S., GRÉMARE, A., HEIP, C.H.R., HUMMEL, H., KARAKASSIS, I., LABRUNE, C. & W. WILLEMS, 2009. Distribution patterns of macrofaunal species diversity in subtidal soft sediments: biodiversity-productivity relationships from the MacroBen database. *Marine Ecology Progress Series* **382**: 253-264.

ESSINK, K., 1999. Ecological effects of dumping of dredged sediments; options for management. *Journal of Coastal Conservation*, **5**: 12.

EVANS, W., 1982. A study to determine if gray whales detect oil. In: Geraci, J.R. & D.J. St. Aubin (eds) Study on the effects of oil on cetaceans. Contract AA 551-CT9-22. Final report to U.S. Dept. of Interior, BLM, Washington, DC, p 47–61.

FAO, 2008. International Guidelines for the Management of Deep-Sea Fisheries in the High Seas. SPRFMO-VI-SWG-INF01

FECHHELM, R.G., GALLAWAY, B.J., HUBBARD, G.F., MACLEAN, S. & L.R. MARTIN, 2001. Opportunistic sampling at a deep-water synthetic drilling fluid discharge site in the Gulf of Mexico. *Gulf of Mexico Science*, **2**: 97-106.

FEGLEY, S.R., MACDONALD, B.A. & T.R. JACOBSEN, 1992. Short-term variation in the quantity and quality of seston available to benthic suspension feeders. *Estuar. Coast. Shelf Sci.*, **34**: 393–412.

FELDER, D.L., B.P. THOMA, W.E. SCHMIDT, T. SAUVAGE, S.L. SELF-KRAYESKY, A. CHISTOSERDOV, H.D. BRACKEN-GRISSOM, & S. FREDERICQ, 2014. Seaweeds and decapod crustaceans on Gulf deep banks after the Macondo oil spill. BioScience, 64: 808–819.

FERNANDEZ, A., EDWARDS, J.F., RODRIGUEZ, F., ESPINOSA DE LOS MONEROS, A., HERRAEZ, P., CASTRO, P., JABER, J., *et al.*, 2005. "'Gas and Fat Embolic Syndrome'" Involving a Mass Stranding of Beaked Whales (Family Ziphiidae) Exposed to Anthropogenic Sonar Signals. Veterinary Pathology, 457: 446–457.

FERNÁNDEZ-FERNÁNDEZ, S., BERNABEU, A., BOUCHETTE, F., REY, D. & F. VILAS, 2011. Beach morphodynamic influence on long-term oil pollution: the Prestige oil spill. J. Coast. Res., 64: 890-893.

FIELDS, R.D., BULLOCK, T.H. & G.D. LANGE, 1993. Ampullary sense organs: peripheral, central and behavioral electroreception in Chimeras (Hydrolagus; Holocephali; Chondrichthyes). *Brain Behavior and Evolution* **41**: 269-289.

FIELD, J.G. & C.L. GRIFFITHS, 1991. Littoral and sublittoral ecosystems of southern Africa. In: Mathieson AC,. Nienhuis PH (eds.): Ecosystems of the World 24: Intertidal and Littoral Ecosystem.. Elsevier, Amsterdam. Pp. 323-346.

FIELD, J.G., GRIFFITHS, C.L., GRIFFITHS, R.J., JARMAN, N., ZOUTENDYK, P., VELIMIROV, B. & A. BOWES, 1980. Variation in structure and biomass of kelp communities along the south-west cape coast. *Trans. Roy. Soc. S. Afr.*, **44**: 145-203.

FIELD, J.G., PARKINS, C.A., WINCKLER, H., SAVAGE, C. & K. VAN DER MERWE, 1996. Specialist study #9: Impact on benthic communities. In: *Impacts of Deep Sea Diamond Mining, in the Atlantic 1 Mining Licence Area* *in Namibia, on the Natural Systems of the Marine Environment*. Environmental Evaluation Unit Report No. 11/96/158, University of Cape Town. Prepared for De Beers Marine (Pty) Ltd.: 370 pp.

FIELD J.G. & C.A. PARKINS, 1998. A Baseline Study of the Benthic Communities of the Unmined Sediments of the De Beers Marine SASA Grid. Marine Biology Research Institute, University of Cape Town. Compiled for De Beers Marine (Pty) Ltd. pp 29.

FILANDER, Z., 2018. First impressions of the benthic biodiversity patterns of the Cape Canyon and its surrounding areas. Oral presentation at 2018 Biodiversity Planning Forum (Abstract).

FINCH, B.E.,WOOTEN, K.J. & P.N. SMITH, 2011. Embryo toxicity of weathered crude oil from the Gulf of Mexico in mallard ducks (*Anas platyrhynchos*). Environ. Toxicol. Chem., 30: 1885–1891.

FINCH, B.E., WOOTEN, K.J., FAUST, D.R. & P.N.SMITH, 2012. Embryotoxicity of mixtures of weathered crude oil collected from the Gulf of Mexico and Corexit 9500 in mallard ducks (*Anas platyrhynchos*). Sci. Total Environ., 426: 155–159.

FINDLAY, K.P., 1996. The impact of diamond mining noise on marine mammal fauna off southern Namibia. Specialist Study #10. In: Environmental Impact Report. Environmental Evaluation Unit (ed.) Impacts of deep sea diamond mining, in the Atlantic 1 Mining Licence Area in Namibia, on the natural systems of the marine environment. No. 11-96-158, University of Cape Town. Report to De Beers Marine (Pty) Ltd. pp. 370

FINDLAY K.P., BEST P.B., ROSS G.J.B. & V.C. COCKROFT. 1992. The distribution of small odontocete cetaceans off the coasts of South Africa and Namibia. S. Afr. J. Mar. Sci. 12: 237-270.

FINDLAY, K.P., SEAKAMELA, S.M., MEŸER, M.A., KIRKMAN, S.P., BARENDSE, J., CADE, HURWITZ, D., KENNEDY, A.S., KOTZE, P.G.H., MCCUE, S.A., THORNTON, M., VARGAS-FONSECA, O.A., & C.G. WILKE, 2017. Humpback whale “super-groups” - A novel low-latitude feeding behaviour of Southern Hemisphere humpback whales (*Megaptera novaeangliae*) in the Benguela Upwelling System. PLoS ONE 12(3): e0172002. doi:10.1371/journal.pone.0172002

FINNERAN, J.J., E.E. HENDERSON, D.S. HOUSER, K. JENKINS, S. KOTECKI & J. MULSOW, 2017. Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III). Technical report by Space and Naval Warfare Systems Center Pacific (SSC Pacific). 183 p.

FISHER, C.R., A.W.J. DEMOPOULOS, E.E. CORDES, I.B. BAUMS, H.K. WHITE, & J.R. BOURQUE, 2014a. Coral communities as indicators of ecosystem- level impacts of the Deepwater Horizon spill. BioScience 64: 796–807.

FISHER, C.R., P.Y. HSING, C.L. KAISER, D.R YOERGER, H.H. ROBERTS, W.W. SHEDD, E.E. CORDES, T.M. SHANK, S.P. BERLET, M.G. SAUNDERS, *et al.*, 2014b. Footprint of Deepwater Horizon blowout impact to deep-water coral communities. Proceedings of the National Academy of Sciences of the United States of America 111: 11744–11749,

FITZBIBBON, Q.P., DAY, R.D., MCCAULEY, R.D., SIMON, C.J. & J.M. SEMMENS, 2017. The impact of seismic air gun exposure on the haemolymph physiology and nutritional condition of spiny lobster, *Jasus edwardsii*. *Mar. Poll. Bull.*, 125: 146–156.

FORNEY, K.A., SOUTHALL, B.L., SLOOTEN, E., DAWSON, S., READ, A.J., BAIRD, R.W. & R.L. BROWNELL JR., 2017. Nowhere to go: Noise impact assessments for marine mammal populations with high site fidelity. *Endanger. Species Res.*, 32: 391–413.

FOSSING, H., FERDELMAN, T.G. & P. BERG, 2000. Sulfate reduction and methane oxidation in continental margin sediments influenced by irrigation (South-East Atlantic off Namibia). *Geochim. Cosmochim. Acta*. **64(5)**: 897–910.

FOULIS, A.J., 2013. A retrospective analysis of shark catches made by pelagic longliners off the east coast of South Africa and biology and life history of shortfin mako shark, *Isurus oxyrinchus*. MSc. Thesis, University of KwaZulu-Natal, Durban, South Africa. pp. 117.

FRANCIS, C.D., ORTEGA, C.P. & A. CRUZ, 2009. Cumulative consequences of noise pollution: Noise changes avian communities and species interactions. *Current Biology*, 19: 1415–1419.

FRANKEL, R.B., BLAKEMORE, R.P. & R.S. WOLFE, 1979. Magnetite in freshwater magnetotactic bacteria. *Science*. **203**:1355-1356.

FRASIER, K.E., SOLSONA-BERGA, A., STOKES, L. & J.A. HILDEBRAND, 2019. Impacts of the Deepwater Horizon Oil Spill on Marine Mammals and Sea Turtles. In: Murawski, S., Ainsworth, C., Gilbert, S., Hollander, D., Paris, C., Schlüter, M., Wetzel, D. (Eds.). Deep Oil Spills: Facts, Fate, and Effects. Springer, pp431-462.

FRITHSEN, J. B., ELMGREN, R. & D.T. RUDNICK, 1985. Responses of benthic meiofauna to long-term low-level additions of No. 2 fuel oil. Mar. Ecol. Prog. Ser., 23: 1-14.

FRITTS, T.H., IRVINE, A.B., JENNINGS, R.D., COLLUM, L.A., HOFFMAN, W. & M.A. McGEHEE, 1983. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. FWS/OBS-82/65. Technical Report. U.S. Fish and Wildlife Service, Washington, D.C., USA.

FUGRO, 2018. Anadarko Petroleum Corporation Metocean Criteria Study – Blocks 5, 6 & 7, South Africa. Fugro Project No.: 116396-0115-R1, pp. 124.

FULLER, M., GORSE, W.S. & W.L. GOODMAN, 1985. An introduction to the use of squid magnetometers in biomagnetism. pp. 103-151. In: KIRSCHVINK, J.L., JONES, D.S. & B.J. MACFADDEN (eds) Magnetite Biomineralization and Magnetoreception in Organisms. Plenum Press, New York.

GAMBELL, R., 1968. Aerial observations of sperm whale behaviour. *Norsk Hvalangst-Tidende* **57**: 126-138.

GATES, A.R. AND D.O.B. JONES, 2012. Recovery of Benthic Megafauna from Anthropogenic Disturbance at a Hydrocarbon Drilling Well (380 m Depth in the Norwegian Sea). PLoS ONE 7(10): e44114. doi:10.1371/journal.pone.0044114

GETLIFF, J., ROACH, A., TOYO, J. & J. CARPENTER, 1997. An overview of the environmental benefits of LAO based drilling fluids for offshore drilling. Report from Schlumberger Dowell. 10 pp.

GIBBONS, M.J., ABIAHY, B.B., ANGEL, M., ASSUNCAO, C.M.L., BARTSCH, I., BEST, P., BISESWAR, R., BOUILLON, J., BRADFORD-GRIEVE, J.M., BRANCH, W., BURRESON, E., CANNON, L., CASANOVA, J.-P., CHANNING, A., CHILD, C.A., CORNELIUS, P.F.S., DAVID, J.H.M., DELLA CROCE, N., EMSCHERMANN, P., ERSEUS, C., ESNAL, G., GIBSON, R., GRIFFITHS, C.L., HAYWARD, P.J., HEARD, R., HEEMSTRA, P. C., HERBERT, D., HESSLER, R., HIGGINS, R., HILLER, N., HIRANO, Y.M., KENSLEY, B., KILBURN, R., KORNICKER, L., LAMBSHEAD, J., MANNING, R., MARSHALL, D., MIANZAN, H., MONNIOT, C., MONNIOT, F., NEWMAN, W., NIELSEN, C., PATTERSON, G., PUGH, P., ROELEVELD, M., ROSS, A., RYAN, P., RYLAND, J.S., SAMAAI, T., SCHLEYER, M., SCHOCKAERT, E., SEAPY, R., SHIEL, R., SLUYS, R., SOUTHWARD, E.C., SULAIMAN, A., THANDAR, A., VAN DER LAND, J., VAN DER SPOEL, S., VAN SOEST, R., VETTER, E., VINOGRADOV, G., WILLIAMS, G. & WOOLDRIDGE, T., 1999. The taxonomic richness of South Africa's marine fauna: crisis at hand. *South African Journal of Science* **95**: 8-12.

GIHWALA, K., BICCARD, A., CLARK, B.M., BROWN, E.A., MAKHOSONKE, A., SWART, C. & B. TSHINGANA, 2018. De Beers Marine Namibia Environmental Monitoring Programme: Mining-related impacts in mining license area MPT 25-2011 and subsequent recovery. Report prepared for De Beers Marine Namibia by Anchor Environmental Consultants (Pty) Ltd. Report no. 1800/1.

GIHWALA, K., BICCARD, A., CLARK, B.M., BROWN, E.A., MAKHOSONKE, A., SWART, C. & B. TSHINGANA, 2019. Mining-related impacts to soft bottom benthic habitats and associated macrofauna assemblages in mining license area SASA 2C and subsequent recovery. Report prepared for De Beers Group of Companies by Anchor Environmental Consultants (Pty) Ltd. Report no. 1800/1.

GONG, Y., ZHAO, X., CAI, Z., O'REILLY, S.E., HAO, X. & D. ZHAO, 2014. A review of oil, dispersed oil and sediment interactions in the aquatic environment: Influence on the fate, transport and remediation of oil spills. Mar. Pollut. Bull., 79: 16–33.

GOOSEN, A.J.J., GIBBONS, M.J., MCMILLAN, I.K., DALE, D.C. & P.A. WICKENS, 2000. Benthic biological study of the Marshall Fork and Elephant Basin areas off Lüderitz. Prepared by De Beers Marine (Pty) Ltd. for Diamond Fields Namibia, January 2000. 62 pp.

GRAY, J.S. 1974. Animal-sediment relationships. *Oceanography and Marine Biology Annual Reviews* **12**: 223-261.

GRAY, J. S. 1981. The ecology of marine sediments: an introduction to the structure and function of benthic communities. Cambridge University Press, Cambridge.

GRAY, J.S., ASCHAN, M., CARR, M.R., CLARKE, K.R., GREEN, R.H., PEARSON, T.H., ROSENBERG, R. & R.M. WARWICK, 1988. Analysis of community attributes of the benthic macrofauna of Frierfjord-Langesundfjord and in a mesocosm experiment. *Mar. Ecol. Prog. Ser.*, 46: 151-165.

GRAY, J.S., CLARKE, K.R., WARWICK, R.M. & G. HOBBS, 1990. Detection of initial effects of pollution on marine benthos e an example from the Ekofisk and Eldfisk oilfields, North-Sea. *Mar. Ecol. Prog. Ser.*, 66: 285-299.

GRAY, J.S., WU, R.S. & Y.Y. OR, 2002. Effects of hypoxia and organic enrichment on the coastal marine environment. *Mar. Ecol. Prog. Ser.*, **238**: 249-279.

GREEN, G.A., BRUEGGEMAN, J.J., GROTEFENDT, R.A., C.E. BOWLBY, C.E., M.L. BONNELL, M.L. & K.C. BALCOMB III., 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. In: J.J. BRUEGGEMAN, ed. Oregon and Washington Marine Mammal and Seabird Surveys. OCS Study MMS 91-0093. Minerals Management Service, Pacific OCS Region, Los Angeles, CA, USA, p. 1-100.

GRÉMILLET, D., LEWIS, S., DRAPEAU, L., VAN DER LINGEN, C.D., *et al.* 2008. Spatial match-mismatch in the Benguela upwelling zone:should we expect chlorophyll and seasurface temperature to predict marine predator distributions? *J Appl. Ecol.*, 45: 610−621

GRIFFITHS, C.L., HOCKEY, P.A.R., VAN ERKOM SCHURINK, C. & P.J. LE ROUX, 1992. Marine invasive aliens on South African shores: implications for community structure and trophic functioning. In: PAYNE, A.I.L., BRINK, K.H., MANN, K.H., HILBORN, R. (eds), Benguela trophic functioning. *South African Journal of Marine Science* 12: 713–722.

GRIFFITHS, C.L. & J.L. SEIDERER, 1980. Rock-lobsters and mussels - limitations and preferences in a predator-prey interaction. J. *Expl Mar. Biol. Ecol.*, **44(1)**: 95-109.

GRIFFITHS, M.H., 2002. Life history of South African snoek *Thyrsites atun* (Pisces: Gempylidae): a pelagic predator of the Benguela ecosystem. *Fishery Bull., Wash.* 100(4): 690-710.

GRIFFITHS, M.H., 2003. Stock structure of snoek *Thyrsites atun* in the Benguela: a new hypothesis. *Afr. J. Mar. Sci.*, 25: 383-386.

GROENEVELD, J.C., G. CLIFF, S.F.J. DUDLEY, A.J. FOULIS, J. SANTOS & S. P. WINTNER, 2014. Population structure and biology of Shortfin Mako, *Isurus oxyrinchus*, in the south-west Indian Ocean. *Marine and Freshwater Research* 65:1045–1058.

GROS, J., NABI, D., WÜRZ, B., WICK, L.Y., BRUSSAARD, C.P., *et al.*, 2014. First day of an oil spill on the open sea: early mass transfers of hydrocarbons to air and water. Environ Sci Technol 48: 9400-9411.

GRÜNDLINGH, M. 1988. Review of cyclonic eddies of the Moçambique Ridge Current. *South African Journal of Marine Science*, 6: 193–206.

HALE, C., GRAHAM, L., MAUNG-DOUGLASS, E., SEMPIER, S., SKELTON,T., SWANN, L., & M. WILSON, 2017. Oil spill science: Sea turtles and the Deepwater Horizon oil spill. TAMU-SG-17-501.

HALL, L.R., HEMMING, L.J., LEVAY, L.J., and the expedition 361 scientists. 2017. Site U1479. Proceedings of the International Ocean Discovery Program. 361.

HALL, S.J., 2001. Is offshore oil exploration good for benthic conservation? *Trends in Ecology and Evolution*, 16(1): 58.

HALL, S.J., 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanography and Marine Biology: An Annual Review*, **32**: 179-239.

HALLARE, A.V., K.J.A. LASAFIN, & J.R. MAGALLANES, 2011. Shift in phytoplankton community structure in a tropical marine reserve before and after a major oil spill event. International Journal of Environmental Research 5:651–660.

HALL-SPENCER, J., ALLAIN, V. & J.H. FOSSA, 2002. Trawling damage to Northeast Atlantic ancient coral reefs. *Proceedings of the Royal Society of London Series B - Biological Sciences* 269: 507–511.

HAMPTON, I., 2003. Harvesting the Sea. In: MOLLOY, F. & T. REINIKAINEN (Eds), 2003. *Namibia's Marine Environment*. Directorate of Environmental Affairs, Ministry of Environment and Tourism, Namibia, 31-69.

HAMANN, M., GRECH, A., WOLANSKI, E. & J. LAMBRECHTS, 2011. Modelling the fate of marine turtle hatchlings. *Ecol. Modelling* 22: 1515–1521.

HAMMAR, L., MOLANDER, S., PÅLSSON, J., CRONA SCHMIDTBAUER, J., CARNEIRO, C., JOHANSSON, T., HUME, D., KÅGESTEN, G., MATTSSON, D., TÖRNQVIST, O., ZILLÉN, L., MATTSSON, M., BERGSTRÖM, U., PERRY, D., CALDOW, C. & J. ANDERSEN, 2020. Cumulative impact assessment for ecosystem- based marine spatial planning. *Science of The Total Environment*, 734: 139024.

HANEY, J.C., HAURY, L.R., MULLINEAUX, L.S. & C.L. FEY, 1995. Sea-bird aggregation at a deep North Pacific seamount. *Marine Biology*, **123**: 1-9.

HANSON, M., WIRMARK, G., OBLAD, M.& L. STRID, 1984b. Iron-rich particles in European eel *Anguilla anguilla* L). *Comparative Biochemistry and Physiology A* **79**: 311-316.

HANSON, M., KARLSSON, L. & H. WESTERBERG, 1984a. Magnetic material in European eel (*Anguilla anguilla* L). *Comparative Biochemistry and Physiology A* **77**: 221-224.

HANSEN, S., WARD, P. & A. PENNEY, 2013. Identification of vulnerable benthic taxa in the western SPRFMO Convention Area and review of move-on rules for different gear types. La Jolla, United States of America.

HARRIS, L.R., 2012. An ecosystem-based spatial conservation plan for the South African sandy beaches. Published PhD Thesis, Nelson Mandela University, Port Elizabeth

HARRIS, L.R., SINK, K.J., SKOWNO, A.L. & L. VAN NIEKERK (eds), 2019. South African National Biodiversity Assessment 2018: Technical Report. Volume 5: Coast. South African National Biodiversity Institute, Pretoria. http://hdl.handle.net/20.500.12143/6374

HARRIS, L.R., NEL, R., OOSTHUIZEN, H., MEŸER, M., KOTZE, D., ANDERS, D., MCCUE, S. & S. BACHOO, 2018. Managing conflict between economic activities and threatened migratory species toward creating a multiobjective blue economy. *Conservation Biology,* 32(2): 411-423.

HARRIS, L.R., SINK, K.J., HOLNESS, S.D., KIRKMAN, S.P. & A. DRIVER, 2020. National Coastal and Marine Spatial Biodiversity Plan, Version 1.0 (Beta 2): Technical Report. South African National Biodiversity Institute, South Africa. 105 pp.

HARRIS, L.R., HOLNESS, S.D., KIRKMAN, S.P., SINK, K.J., MAJIEDT, P. & A. DRIVER, 2022. National Coastal and Marine Spatial Biodiversity Plan, Version 1.2 (Released 12-04-2022): Technical Report. Nelson Mandela University, Department of Forestry, Fisheries and the Environment, and South African National Biodiversity Institute. South Africa. 280 pp.

HARRISON, P., 1978. Cory's Shearwater in the Indian Ocean. *Cormorant*. **5**: 19-20.

HARTLEY, J., TRUEMAN, R., ANDERSON, S., NEFF, J., FUCIK, K. & P. DANDO, 2003. Drill Cuttings Initiative: Food Chain Effects Literature Review. United Kingdom Offshore Operators Association, Aberdeen, Scotland. 118 pp + Appendices.

HARVEY, M., GAUTHIER, D. & J. MUNRO, 1998. Temporal changes in the composition and abundance of the macro-benthic invertebrate communities at dredged material disposal sites in the Anse a Beaufils, Baie des Chaleurs, Eastern Canada. *Marine Pollution Bull*etin, **36**: 41-55.

HASTIE, G.D., WILSON, B., TUFFT, L.H. & P.M. THOMPSON, 2003. Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science* 19: 74-84.

HASTINGS, D.W., P.T. SCHWING, G.R. BROOKS, R.A. LARSON, J.L. MORFORD, T. ROEDER, K.A. QUINN, T. BARTLETT, I.C. ROMERO & D.J. HOLLANDER, 2016. Changes in sediment redox conditions following the BP DWH blowout event. Deep Sea Research Part II 129: 167–178.

HAWKINS, A.D., ROBERTS, L. & S. CHEESMAN, 2014. Responses of freeliving coastal pelagic fish to impulsive sounds. *Journal of the Acoustical Society of America*, 135: 3101–3116.

HAYS, G.C. HOUGHTON, J.D.R., ISAACS, C. KING, R.S. LLOYD, C. & P. LOVELL, 2004. First records of oceanic dive profiles for leatherback turtles, *Dermochelys coriacea*, indicate behavioural plasticity associated with long-distance migration. Animal Behaviour, 67: 733-743.

HAZIN, F.H.V., PINHEIRO, P.B. & M.K. BROADHURST, 2000. Further notes on reproduction of the blue shark, *Prionace glauca*, and a postulated migratory pattern in the South Atlantic Ocean. *Cienca e Cultura* 52: 114–120.

H-EXPERTISE SERVICES S.A.S., 2019. OSCAR Oil Spill Drift Modelling Study for South Africa. Detailed Technical Report. Report to TEPSA, December 2019, pp95.

HELM, R.C., COSTA, D.P., DEBRUYN, T.D., O'SHEA, T.J., WELLS, R.S. & T.M. WILLIAMS, 2015. Overview of Effects of Oil Spills on Marine Mammals. In: FINGAS, M. (Ed.) Handbook of Oil Spill Science and Technology, John Wiley & Sons Inc., 455-475.

HENRY, L-A., HARRIES, D., KINGSTON, P. & J.M. ROBERTS, 2017. Historic scale and persistence of drill cuttings impacts on North Sea benthos. *Marine Environmental Research*, 129: 219-228.

HERNANDEZ ARANA, H.A., WARWICK, R.M., ATTRILL, M.J., RODEN, A.A. & G. GOLD-BOUCHOT, 2005. Assessing the impact of oil-related activities on benthic macroinfauna assemblages of the Campeshe shelf, southern Gulf of Mexico. *Marine Ecology Progress Series,* **289**: 89-107.

HEWITT, C.L., CAMPBELL, M.L., THRESHER, R.E. & R.B. MARTIN, 1999. Marine biological invasions of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests Technical Report No. 20. Hobart: CSIRO Marine Research.

HEWITT, C.L., GOLLASCH, S. & D. MINCHIN, 2009. The vessel as a vector – biofouling, ballast water and sediments. In: Rilov, G. & J.A. Crooks (eds), Biological invasions in marine ecosystems. Berlin: Springer-Verlag. pp 117–131.

HEYDORN, A.E.F. & TINLEY, K.L. 1980. Estuaries of the Cape, Part I. Synopsis of the Cape coast. Natural features, dynamics and utilization. Stellenbosch, CSIR Research Report 380, 97 pp.

HINWOOD, J.B., POOTS, A.E., DENNIS, L.R., CAREY, J.M., HOURIDIS, H., BELL, R.J., THOMSON, J.R., BOUDREAU, P. & A.M. AYLING, 1994. Drilling activities. Pages 123-207 In: SWAN, J.M., NEFF, J.M. & P.C. YOUNG, Eds., Environmental Implications of Offshore Oil and Gas Development In Australia – Findings of an Independent Scientific Review. Australian Petroleum Production and Exploration Association, Canberra, Australia.

HOCKEY, P.A.R, DEAN, W.R.J. & P.G. RYAN, 2005. Roberts Birds of Southern Africa: 7th edition. John Voelker Bird Book Fund.

HOCKEY, P.A.R. & C. VAN ERKOM SCHURINK, 1992. The invasive biology of the mussel *Mytilus galloprovincialis* on the southern African coast. *Transactions of the Royal Society of South Africa* **48**: 123-139.

HOFMEYR-JURITZ, L. & P.B. BEST, 2011. Acoustic Behaviour of southern right whales in relation to numbers of whales present, Walker Bay, South Africa. *Afr. J. Mar. Sci.*, 33: 415-427.

HOGG, M.M., TENDAL, O.S., CONWAY, K.W., POMPONI, S.A., VAN SOEST, R.W.M., GUTT, J., KRAUTTER, M. & J.M. ROBERTS, 2010. Deep-sea sponge grounds: reservoirs of biodiversity. UNEP-WCMC Biodiversity Series No. 32. Cambridge, UK: UNEP-WCMC.

HOLNESS, S., KIRKMAN, S., SAMAAI, T., WOLF, T., SINK, K., MAJIEDT, P., NSIANGANGO, S., KAINGE, P., KILONGO, K., KATHENA, J., HARRIS, L., LAGABRIELLE, E., KIRCHNER, C., CHALMERS, R. & M. LOMBARD, 2014. Spatial Biodiversity Assessment and Spatial Management, including Marine Protected Areas. Final report for the Benguela Current Commission project BEH 09-01.

HOLSMAN, K., JAMEAL SAMHOURI, J., COOK, G., HAZEN, E., OLSEN, E., DILLARD, M., KASPERSKI, S., GAICHAS, S., KELBLE, C.R., FOGARTY, M. & K. ANDREWS, 2017. An ecosystem-based approach to marine risk assessment, Ecosystem Health and Sustainability, 3: 1, e01256.

HOUGHTON, J.P., BEYER, D.L. & E.D. THIELK, 1980a. Effects of oil well drilling fluids on several important Alaskan marine organisms. pp 1017-1044, In: Proceedings of Symposium, Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, January 21-24, 1980, Lake Buena Vista, Florida. Vol. II. American Petroleum Institute, Washington, DC.

HOVLAND, M. & E. THOMSEN, 1997. Cold-water corals – are they hydrocarbon seep related? *Marine Geology* 137: 159-164.

HOVLAND, M., VASSHUS, S., INDREEIDE, A., AUSTDAL, L. & Ø. NILSEN, 2002. Mapping and imaging deep-sea coral reefs off Norway, 1982-2000. *Hydrobiol.* **471**: 13-17.

HOVLAND, M., MORTENSEN, P.B., BRATTEGARD, T., STRASS, P. & K. ROKOENGEN, 1998. Ahermatypic coral banks off mid-Norway: Evidence for a link with seepage of light hydrocarbons. Palaios 13: 189-200.

HOWARD, J.A.E., JARRE, A., CLARK, A.E. & C.L. MOLONEY, 2007. Application of the sequential t-test algorithm or analyzing regime shifts to the southern Benguela ecosystem. *African Journal of Marine Science* 29(3): 437-451.

HUBERT, J., CAMPBELL, J., VAN DER BEEK, J. G., DEN HAAN, M. F., VERHAVE, R., VERKADE, L. S. & H. SLABBEKOORN, 2018. Effects of broadband sound exposure on the interaction between foraging crab and shrimp – A field study. *Environmental Pollution*, 243: 1923–1929.

HUGHES, G. R. 1974. *The sea turtles of south east Africa.* PhD, University of Natal.

HUGHES, G. & R. NEL, 2014[a]. Family Cheloniidae. In: BATES, M.F., BRANCH, W.R., BAUER, A.M., BURGER, M., MARAIS, J., ALEXANDER, G.J., DE VILLIERS, M.S. (eds) Atlas and Red List of the Reptiles of South Africa, Lesotho and Swaziland. Suricata 1, SANBI, Pretoria.

HUGHES, G. & R. NEL, 2014b. Family Dermochelyidae. In: BATES, M.F., BRANCH, W.R., BAUER, A.M., BURGER, M., MARAIS, J., ALEXANDER, G.J., DE VILLIERS, M.S. (eds) Atlas and Red List of the Reptiles of South Africa, Lesotho and Swaziland. Suricata 1, SANBI, Pretoria.

HUGHES, G.R., LUSCHI, P., MENCACCI, R. & F. PAPI, 1998. The 7000 km journey of a leatherback turtle tracked by satellite. *Journal of Experimental Marine Biology and Ecology*, **229**: 209 - 217.

HUGHES, S.J.M., JONES,D.O.B., HAUTON,C., GATES,A.R. & L.E. HAWKINS, 2010. Anassessment of drilling disturbance on *Echinusacutus* var. *norvegicus* based on *in-situ* observations and experiments using a remotely operated vehicle(ROV). *J. Exp. Mar. Biol. Ecol.*, 395: 37–47.

HUI, C,A., 1985. Undersea topography and the comparative distributions of two pelagic cetaceans. *Fishery Bulletin*, **83(3)**: 472-475.

HÜPPOP, O., HÜPPOP, K., DIERSCHKE, J. & R. HILL, 2016. Bird collisions at an offshore platform in the North Sea. Bird Study, 63: 73-82.

HURLEY, G. & J. ELLIS, 2004. Environmental Effects of Exploratory Drilling Offshore Canada: Environmental Effects Monitoring Data and Literature Review - Final Report. Prepared for the Canadian Environmental Assessment Agency - Regulatory Advisory Committee.

HUSEBØ, Å., NØTTESTAD, L., FOSSÅ, J.H., FUREVIK, D.M. & S.B. JØRGENSEN, 2002. Distribution and abundance of fish in deep-sea coral habitats. Hydrobiologia 471: 91–99.

HUSKY OIL OPERATIONS LIMITED, 2000. White Rose Oilfield Comprehensive Study. Submitted by Husky Oil Operations Limited as Operator, St. John's, NL.

HUSKY OIL OPERATIONS LIMITED, 2001a. White Rose Oilfield Comprehensive Study Supplemental Report Responses to Comments from Canada-Newfoundland Offshore Petroleum Board, Department of Fisheries and Oceans, Environment Canada, Natural Resources Canada and Canadian Environmental Assessment Agency. Submitted by Husky Oil Operations Limited (Operator). 265 pp. + Appendices.

HUSKY OIL OPERATIONS LIMITED, 2001b. White Rose baseline characterization data report June 2001. Prepared by Jacques Whitford Environment Limited for Husky Oil Operations Limited. St. John's. NL. 109 p. — App.

HUTCHINGS, L. 1994. The Agulhas Bank: a synthesis of available information and a brief comparison with other east-coast shelf regions. S. Afr. J. Sci., 90: 179-185.

HUTCHINGS L., NELSON G., HORSTMANN D.A. & R. TARR, 1983. Interactions between coastal plankton and sand mussels along the Cape coast, South Africa. *In: Sandy Beaches as Ecosystems*. Mclachlan, A. & T. E. Erasmus (eds). Junk, The Hague. pp 481-500.

HUTCHINGS L., BECKLEY L. E., GRIFFITHS M.H., ROBERTS M. J. SUNDBY S. & VAN DER LINGEN C. 2002. Spawning on the edge: spawning grounds and nursery areas around the southern African coastline. *Marine and Freshwater Research* **53**:307-318.

HYLAND, J., HARDIN, D., STEINHAUER, M., COATS, D., GREEN, R.H., & J. NEFF, 1994. Environmental impact of offshore oil development on the outer continental shelf and slope off Point Arguello, California. *Marine Environmental Research*, **37**: 195-229.

HYLLEBERG, J., NATEEWATHANA, A. & B. CHATANANTHAWEJ, 1985. Temporal changes in the macrobenthos on the west coast of Phuket Island, with emphasis on the effects of offshore tin mining. *Research Bulletin of the Phuket Marine Biological Center*, **38**: 32 pp.

INTEGRAL CONSULTING INC., 2006. Exxon Valdez Oil Spill Restoration Project Final Report – 2005. Assessment of Lingering Oil and Resource Injuries from the Exxon Valdez Oil Spill. Report to Exxon Valdez Oil Spill Trustee Council, June 2006. 193pp.

IOGP (International Association of Oil and Gas Producers), 2003. Environmental Aspects of use and disposal of non-aqueaous drilling fluids associated with offshore oil & gas operations. IOGP Report 342, IOGP, London, UK, pp114.

IOGP (International Association of Oil and Gas Producers), 2016. Environmental fates and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations. IOGP Report 543, pp144.

ITOPF (International Tanker Owners Pollution Federation) 2014. Effects of Oil Pollution on Fisheries and Mariculture. Technical Informaption Paper (TIPS) 11: pp12.

ITOPF (International Tanker Owners Pollution Federation) 2014. Oil tanker spill statistics 2014. Available at www.itopf.com

IMO, 2001. International convention on the control of harmful anti-fouling systems on ships. London: International Maritime Organisation. Available at http://www.imo.org.

IMO 2004. *International Convention for the control and management of ships ballast water and sediments.*

INCARDONA, J.P., GARDNER, K.D., LINBO, T.L., SWARTS, T.L., ESBAUGH, A.J., MAGER, E.M., STIEGLITZ, J.D., FRENCH, B.L., LABENIA, J.S., LAETZ, C.A. *et al.* 2014. Deepwater Horizon crude oil cardiotoxicity to the developing hearts of large predatory pelagic fish. Proceedings of the National Academy of Sciences of the United States of America 111(15): E1505–E1508.

INTERNATIONAL WHALING COMMISSION (IWC), 2012. Report of the Scientific Committee. Annex H: Other Southern Hemisphere Whale Stocks Committee 11–23.

IWAMOTO, T. & M.E. ANDERSON, 1994. Review of the grenadiers (Teleostei: Gadiformes) of southern Africa, with descriptions of four new species. Ichthyological Bulletin 61: 1–18.

JACKSON, L.F. ad S. McGIBBON, 1991. Human activities and factors affecting the distribution of macro-benthic fauna in Saldanha Bay. *S. Afr. J. Aquat. Sci.*, **17**: 89-102.

JACOB, B.A, MCEACHRAN, J.D. & P.L. LYONS, 1994. Electric organs in skates: Variation and phylogenetic significance (Chondrichthyes: Rajoidei). *Journal of Morphology* **221**: 45-63.

JANUARY, D.K., 2018. Mapping Break-Back Thrust Sequence Developments of the Orange Basin (offshore) South Africa. Unpublished MSc Thesis, University of the Western Cape, pp121.

JARAMILLO, E., MCLACHLAN, A. & J. DUGAN, 1995. Total sample area and estimates of species richness in exposed sandy beaches. *Marine Ecology Progress Series* **119**: 311-314.

JARMAN N.G. & R.A. CARTER, 1981. The primary producers of the inshore regions of the Benguela. *Trans. Roy. Soc. S. Afr.*, **44(3)**: 321-325.

JENSEN, T., PALERUD, R., OLSGARD, F. & S.M. BAKKE, 1999. Dispersion and effects of synthetic drilling fluids in the Environment. Technical Report to the Ministry of Oil and Energy. Report no. 99-3507. 49pp.

JENSEN, A.S. & G.K. SILBER, 2003. Large Whale Ship Strike Database. NOAA Technical Memorandum NMFS-OPR. Silver Spring, MD: US Department of Commerce.

JEPSON, P.D., DEAVILLE, R., ACEVEDO-WHITEHOUSE, K., BARNETT, J., BROWNLOW, A., JR BROWNELL, R.L., CLARE F.C., DAVISON, N., LAW, R.J., LOVERIDGE, J., PENROSE, R., PERKINS, M.W., MACGREGOR, S.K., MORRIS, S., TREGENZA, N.J.C., CUNNINGHAM, A.A., & A. FERNA, 2013. What Caused the UK' s Largest Common Dolphin (*Delphinus delphis*) Mass Stranding Event? PLoS ONE 8(4): e60953. https://doi.org/10.1371/journal.pone.0060953.

JØDESTØL, K. & E. FURUHOLT, 2010. Will Drill Cuttings And Drilling Mud Harm Cold Water Corals? International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, 12-14 April 2010, Rio de Janeiro, Brazil. Pp11.

JOHNSSON, A. & S. RAMSTAD, 2004. Seabed Logging Environmental Study: Possible Biological Effects of Electromagnetic Fields on Marine Life. Report to EMGS, Norwegian University of Science and Technology. pp 34

JOHNSON, C., REISINGER, R., PALACIOS, D., FRIEDLAENDER, A., ZERBINI, A., WILLSON, A., LANCASTER, M. , BATTLE, J., GRAHAM, A., COSANDEY-GODIN, A., JACOB T., FELIX, F., GRILLY, E., SHAHID, U., HOUTMAN, N., ALBERINI, A., MONTECINOS, Y., NAJERA, E. & S. KELEZ, 2022. Protecting Blue Corridors, Challenges and Solutions for Migratory Whales Navigating International and National Seas. WWF, Oregon State University, University of California, Santa Cruz, Publisher: WWF International, Switzerland.

JONES, D. 2014. Brulpadda-1AX Megafaunal Report. Survey report for TOTAL E & P South Africa BV. Global Marine Research Ltd. pp.46.

JONES, D.O.B., GATES, A.R. & B. LAUSEN, 2012. Recovery of deep-water megafaunal assemblages from hydrocarbon drilling disturbance in the Faroe–Shetland Channel. Marine Ecology Progress Series, 461: 71-82.

JONES, D.O.B., WIGHAM, B.D., HUDSON, I.R. & B.J. BETT, 2007. Anthropogenic disturbance of deep-sea megabenthic assemblages: a study with Remotely- operated vehicles in the Faroe-Shetland Chanel, NE Atlantic. *Mar.Biol*., 151: 1731–1741.

JONSSON, P.R., HAMMAR, L., WÅHLSTRÖM, I., *et al*. 2021. Combining seascape connectivity with cumulative impact assessment in support of ecosystem-based marine spatial planning. *J Appl Ecol*., 58: 576–586.

KANWISHER, J.W. & S.H. RIDGWAY, 1983. The physiological ecology of whales and porpoises. *Scientific American*, 248: 110–120.

KARENYI, N., 2014. Patterns and drivers of benthic macrofauna to support systematic conservation planning for marine unconsolidated sediment ecosystems. PhD Thesis, Nelson Mandela Metropolitan University, South Africa.

KARENYI, N., SINK, K. & R. NEL, 2016. Defining seascapes for marine unconsolidated shelf sediments in an eastern boundary upwelling region: The southern Benguela as a case study. *Estuarine, Coastal and Shelf Science* 169: 195–206.

KATSANEVAKIS, S., WALLENTINUS, I., ZENETOS, A., LEPPÄKOSKI, E., ÇINAR, M.E., OZTÜRK, B., GRABOWSKI, M., GOLANI, D. & A.C. CARDOSO, 2014, 'Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review', *Aquatic Invasions* 9(4), pp. 391–423.

KAVANAGH, A.S., NYKÄNEN, M., HUNT, W., RICHARDSON, N. & M.J. JESSOPP, 2019. Seismic surveys reduce cetacean sightings across a large marine ecosystem. *Scientific Reports*, 9(1): 1-10.

KEEN, E.M., SCALES, K.L., RONE, B.K., HAZEN, E.L., FALCONE, E.A. & G.S. SCHORR, 2019. Night and day: diel differences in ship strike risk for fin whales (*Balaenoptera physalus*) in the California current system. *Front. Mar. Sci.*, 6: 730.

KEEN, K., BELTRAN, R., & PIROTTA, E. & D. COSTA, 2021. Emerging themes in Population Consequences of Disturbance models. *Proceedings of the Royal Society B: Biological Sciences*. 288. 20210325. 10.1098/rspb.2021.0325.

KENDALL, M.A. & S. WIDDICOMBE, 1999. Small scale patterns in the structure of macrofaunal assemblages of shallow soft sediments. *Journal of Experimental Marine Biology and Ecology*, **237**:127-140.

KENNY, A.J., REES, H.L., GREENING, J. & S. CAMPBELL, 1998. The effects of marine gravel extraction on the macrobenthos at an experimental dredge site off north Norfolk, U.K. (Results 3 years post-dredging). *ICES CM 1998/V*:14, pp. 1-8.

KENSLEY, B., 1980. Decapod and Isopod Crustaceans From the West Coast of Southern Africa, Including Seamounts Vema and Tripp. *Annals of the South African Museum*, 83(2): 13-32.

KENSLEY, B., 1981. On the Zoogeography of Southern African Decapod Crustacea, With a Distributional Checklist. *Smithsonian Contributions to Zoology*, 338: 1-64.

KENYON, N.H., AKHMETZHANOV, A.M, WHEELER, A.J., VAN WEERING, T.C.E., DE HAAS, H. & M.K. IVANOV, 2003. Giant carbonate mud mounds in the southern Rockall Trough. *Marine Geology* 195: 5-30.

KERSHAW, J.L., RAMP, C.A., SEARS, R., PLOURDE, S., BROSSET, P., MILLER, P.J.O., *et al.*, 2021. Declining reproductive success in the Gulf of St. Lawrence's humpback whales (*Megaptera novaeangliae*) reflects ecosystem shifts on their feeding grounds. *Glob. Change Biol.*, 27: 1027–1041.

KETOS ECOLOGY, 2009. 'Turtle Guards': A method to reduce the marine turtle mortality occurring in certain seismic survey equipment. www.ketosecology.co.uk.

KETTEN, D.R., 1998. Marine Mammal Auditory Systems: A summary of audiometric and anatomical data and its implications for underwater acoustic impacts. NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-256.

KHELIFA, A., STOFFYN-EGLI, P., HILL, P.S. & K. LEE, 2005. Effects of salinity and clay type on oil–mineral aggregation. Mar. Environ. Res., 59(3): 235–254.

KINGSTON, P.F., 1987. Field effects of platform discharges on benthic macrofauna. *Philosophical Transactions of the Royal Society of London*, Series B 317, 545–565.

KINGSTON, P.F., 1992. Impact of offshore oil production installations on the benthos of the North Sea. *ICES J. Mar. Sci.*, **49**: 45-53.

KIRK, J.T.O., 1985. Effects of suspensoids on penetration of solar radiation in aquatic ecosystems. *Hydrobiologia*, **125**: 195-208.

KIRKMAN, S.P., YEMANE, D., OOSTHUIZEN, W.H., MEYER, M.A., KOTZE, P.G.H., SKRYPZECK, H., VAZ VELHO, F., UNDERHILL, L.G., 2013. Spatio-temporal shifts of the dynamic Cape fur seal population in southern Africa, based on aerial censuses (1972-2009). *Marine Mammal Science* **29**: 497-524.

KIRKMAN, S.P., KOTZE, D., MCCUE, S., SEAKAMELA, M., MEŸER, M., HLATI, K. & H. OOSTHUIZEN, 2015. Cape fur seal foraging behaviour. In: VERHEYE, H., HUGGETT, J. & R. CRAWFORS (Eds) State of the Oceans and Coasts Around South Africa - 2015 Report Card.

KIRKMAN, S. P., COSTA, D. P., HARRISON, A., KOTZE, P. G. H., OOSTHUIZEN, W.H., WEISE, M., BOTHA, J. A., & ARNOULD, J. P. Y., 2019. Dive behaviour and foraging effort of female Cape fur seals Arctocephalus pusillus pusillus. Royal Society Open Science, 6, 191369.

KOPASKA-MERKEL D.C. & D.W. HAYWICK, 2001. Carbonate mounds: sedimentation, organismal response, and diagenesis. *Sedimentary Geology,* **145**: 157-159.

KOPER, R.P & S. PLÖN, 2012. *The potential impacts of anthropogenic noise on marine animals and recommendations for research in South Africa.* EWT Research & Technical Paper No. 1. Endangered Wildlife Trust, South Africa.

KOSLOW, J.A., 1996. Energetic and life history patterns of deep-sea benthic, benthopelagic and seamount associated fish. *Journal of Fish Biology*, **49A**: 54-74.

KOSTKA, J.E., PRAKASH, O., OVERHOLT, W.A., GREEN, S.J., FREYER, G., CANION, A., DELGARDIO, J., NORTON, N., HAZEN, T.C. & M. HUETTEL, 2011. Hydrocarbon-Degrading Bacteria and the Bacterial Community

Response in Gulf of Mexico Beach Sands Impacted by the Deepwater Horizon Oil Spill. Appl. Environ. Microbiol., 77: 7962–7974.

KOTTA, J., MARTIN, G. & R. APS, 2007. Sensitivity of benthic vegetation and invertebrate functional guilds to oil spills and its use in oil contingency management related negotiation processes. Proc. Estonian Acad. Sci. Biol. Ecol., 56: 255-269.

KOZAK, N.V. & I.A. SHPARKOVSKI, 1991. Testing Drilling Muds and their Components with the Use of Fish from the Barents Sea. In Theses of the Second. *All-Union Conference on Fisheries Toxicology*, **1**: 272-273

KRANZ, P.M., 1974. The anastrophic burial of bivalves and its paleoecological significance. *Journal of Geology*, **82**:29

KRIEGER, K.J. & B.L. WING, 2002. Megafauna associations with deepwater corals (*Primnoa* spp.) in the Gulf of Alaska. Hydrobiologia 471: 83–90.

KUJAWINSKI, E.B., SOULE, M.C.K., VALENTINE, D.L., BOYSEN, A.K., LONGNECKER, K.& M.C. REDMOND, 2011. Fate of Dispersants Associated with the Deepwater Horizon Oil Spill. Environ. Sci. Technol. 45, 1298–1306.

KYHN, L.A., WISNIEWSKA, D.M., BEEDHOLM, K., TOUGAARD, J., SIMON, M., MOSBECH, A., *et al*. 2019. Basin-wide contributions to the underwater soundscape by multiple seismic surveys with implications for marine mammals in Baffin Bay, Greenland. *Mar. Pollut. Bull.*, 138: 474–490.

LACOURSIÈRE-ROUSSEL, A., BOCK, D.G., CRISTESCU, M.E., GUICHARD, F., GIRARD, P., LEGENDRE, P. & C.W. MCKINDSEY 2012. Disentangling invasion processes in a dynamic shipping–boating network. *Molecular Ecology* 21: 4227–4241.

LAGABRIELLE, E. 2009. Preliminary report: National Pelagic Bioregionalisation of South Africa. Cape Town: South African National Biodiversity Institute.

LAIRD, M. & C.L. GRIFFITHS, 2008. Present distribution and abundance of the introduced barnacle Balanus glandula Darwin in South Africa. *African Journal of Marine Science* **30**: 93-100.

LAMBARDI, P., LUTJEHARMS, J.R.E., MENACCI, R., HAYS, G.C. & P. LUSCHI, 2008. Influence of ocean currents on long-distance movement of leatherback sea turtles in the Southwest Indian Ocean. Marine Ecology Progress Series, 353: 289–301.

LANE, S.B. & R.A. CARTER, 1999. *Generic Environmental Management Programme for Marine Diamond Mining off the West Coast of South Africa.* Marine Diamond Mines Association, Cape Town, South Africa. 6 Volumes.

LANGANGEN, Ø., OLSEN, E., STIGE, L.C., OHLBERGER, J., YARAGINA, N.A., VIKEBØ, F.B., BOGSTAD, B., STENSETH, N.C. & D.Ø. HJERMANN, 1017. The effects of oil spills on marine fish: Implications of spatial variation in natural mortality. Marine Pollution Bulletin, 119: 102-109.

LANGE, L., 2012. Use of demersal bycatch data to determine the distribution of soft-bottom assemblages off the West and South Coasts of South Africa. PhD thesis, University of Cape Town

LARGE, S.I., FAY, G., FRIEDLAND, K.D. & J.S. LINK, 2015. Quantifying Patterns of Change in Marine Ecosystem Response to Multiple Pressures. PLoS ONE 10(3): e0119922. doi:10.1371/journal.

LARSSON, A.I., VAN OEVELEN, D., PURSER, A. & L. THOMSEN, 2013. Tolerance to long-term exposure of suspended benthic sediments and drill cuttings in thecold-water coral *Lophelia pertusa*. *Mar.Pollut.Bull.,* 70: 176–188.

LARSSON, A.I. & A. PURSER, 2011. Sedimentation on the cold-water coral *Lophelia pertusa*: cleaning efficiency from natural sediments and drill cuttings. *Mar. Pollut. Bull.,* 62: 1159−1168.

LAURET-STEPLER, M., BOURJEA, J., ROOS, D., PELLETIER, D., RYAN, P., CICCIONE, S. and H. GRIZEL, 2007. Reproductive seasonality and trend of *Chelonia mydas* in the SW Indian Ocean: a 20 yr study based on track counts. *Endangered Species Research*, 3, 217-227.

LAWS, R.M. (Ed.), 2009. Antarctic Seals: Research Methods and Techniques. Cambridge University Press, Cambridge. 390pp.

LEATHERWOOD, S., AWBREY, F.T. & J.A. THOMAS, 1982. Minke whale response to a transiting survey vessel. *Report of the International Whaling Commission* **32**: 795-802.

LEENEY, R.H., POST, K., HAZEVOET, C.J. AND S.H. ELWEN, 2013. Pygmy right whale records from Namibia. *African Journal of Marine Science* **35(1)**: 133-139.

LEES, D.C. & J.P. HOUGHTON, 1980. Effects of drilling fluids on benthic communities at the Lower Cook Inlet C.O.S.T. well. pp309-350. In: Proceedings of Symposium, Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, Vol. I, January 21-24, 1980, Lake Buena Vista, Florida. American Petroleum Institute, Washington, DC.

LE GOUVELLO, D.Z.M., NEL, R. & A.E. CLOETE, 2020. The influence of individual size on clutch size and hatchling fitness traits in sea turtles. J. Exp. Mar. Biol. Ecol., 527: 151372.

LE GOUVELLO, D.Z.M., HEYE, S., HARRIS, L.R., TEMPLE-BOYER, J., GASPAR, P., HART-DAVIS, M.G., LOURO, C. & R. NEL, 2024. Dispersal corridors of neonate sea turtles from dominant rookeries in the Western Indian Ocean. *Ecological Modelling*, 487, p.110542.

LEMOS, L.S., HAXEL, J.H., OLSEN, A., BURNETT, J.D., SMITH, A., CHANDLER, T.E., NIEUKIRK, S.L., LARSON, S.E., HUNT, K.E. & L.G. TORRES, 2021. Sounds of stress: Assessment of relationships between ambient noise, vessel traffic, and gray whale stress hormones. *Proc R Soc B Biol Sci:* (in press).

LEPLAND, A. & P.B. MORTENSEN, 2008. Barite and barium in sediments and coral skeletons around the hydrocarbon exploration drilling site in the Traena Deep, Norwegian Sea. *Environ. Geol.*, **56**: 119–129.

LEUNG-NG, S. & S. LEUNG, 2003. Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. Mar. Env. Res., 56: 555-567.

LEVIN, P.S., FOGARTY, M.J., MURAWSKI, S.A. & D. FLUHARTY, 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. *PLoS Biology*, 7: e1000014.

LEVIN, P.S., *et al*. 2014. Guidance for implementation of integrated ecosystem assessments: a US perspective. *ICES Journal of Marine Science*, 71:1198–1204.

LEVITT, G.J., ANDERSON, R.J., BOOTHROYD, C.J.T. & F.A. KEMP, 2002. The effects of kelp harvesting on its regrowth and the understorey benthic community at Danger Point, South Africa, and a new method of harvesting kelp fronds. *South African Journal of Marine Science* **24**: 71-85.

LIPINSKI, M.R., 1992. Cephalopods and the Benguela ecosystem: trophic relationships and impacts. S. Afr. J. Mar. Sci., 12 : 791-802.

LIU, Y., & E.B. KUJAWINSKI, 2015. Chemical Composition and Potential Environmental Impacts of Water-Soluble Polar Crude Oil Components Inferred from ESI FT-ICR MS. PLoS ONE 10(9): e0136376.

LIVAS, B., 2023a. Well Drilling in Block 3B-4B – Drilling Discharge Modelling Technical Report. Report by HES Expertise Services to Africa Energy Co South Africa. October 2023, 42pp.

LIVAS, B., 2023b. Well Drilling in Block 3B-4B – Oil Spill Drift Modelling Technical Report. Report by HES Expertise Services to Africa Energy Co South Africa. October 2023, 42pp.

LIVERSIDGE, R. & LE GRAS, G.M. 1981. Observations of seabirds off the eastern Cape, South Africa, 1953-1963. In: *Proceedings of the symposium on birds of the sea and shore, 1979*. COOPER, J. (Ed.). 149-167.

LGL LIMITED, 2009. *Orphan Basin controlled source electromagnetic survey program environmental assessment: Supplement 2009*. LGL Rep. SA1038. Rep. by LGL Limited, St. John's, NL, for ExxonMobil Canada Ltd., St. John's, NL. 19 p. + appendices.

LOEFER, J.K., SEDBERRY, G.R. & J.C. MCGOVERN, 2005. Vertical movements of a shortfin mako in the Western North Atlantic as determined by pop-up satellite tagging. *Southeastern Naturalist* 4, 237-246.

LOMBARD, A.T., STRAUSS, T., HARRIS, J., SINK, K., ATTWOOD, C. & L. HUTCHINGS, 2004. National Spatial Biodiversity Assessment 2004: South African Technical Report Volume 4: Marine Component

LOVE, M.S. & A. YORK, 2006. The relationships between fish assemblages and the amount of bottom horizontal beam exposed at California oil platforms: fish habitat preferences at man-made platforms and (by inference) at natural reefs. *Fisheries Bulletin,* **104**: 542-549.

LOVE, M.S., SCHROEDER, D.M. & W.H. LENARZ, 2005. Distribution of bocaccio (*Sebastes paucispinis*) and cowcod (*Sebastes levis*) around oil platforms and natural outcrops off California with implications for larval production. *Bulletin of Marine Science,* **77(3)**: 397-408.

LUDYNIA, K., 2007. *Identification and characterisation of foraging areas of seabirds in upwelling systems: biological and hydrographic implications for foraging at sea*. PhD thesis, University of Kiel, Germany.

LUSCHI, P., HAYS, G. C. & F. PAPI, 2003a. A review of long-distance movements by marine turtles, and the possible role of ocean currents. *Oikos,* 103, 293 – 302.

LUSCHI, P., LUTJEHARMS, J.R.E., LAMBARDI, P., MENCACCI, R., HUGHES, G.R. & G.C. HAYS, 2006. A review of migratory behaviour of sea turtles off southeastern Africa. *South African Journal of Science*, 102, 51 - 57.

LUSCHI, P., SALE, A., MENCACCI, R., HUGHES, G. R., LUTJEHARMS, J. R. E. & F. PAPI, 2003b. Current transport of leatherback sea turtles (*Dermochelys coriacea*) in the ocean. *Proceedings of the Royal Society: Biolgical Sciences,* 270, 129 - 132.

LUSSEAU, D., 2004. The hidden cost of tourism: Effects of interactions with tour boats on the behavioral budget of two populations of bottlenose dolphins in Fiordland, New Zealand. Ecology and Society 9 (1): Part. 2.

LUSSEAU, D., 2005. Residency pattern of bottlenose dolphins *Tursiops* spp. in Milford Sound, New Zealand, is related to boat traffic. Marine Ecology Progress Series 295: 265-272.

LUSSEAU, D., BAIN, D.E., WILLIAMS, R. & J.C. SMITH, 2009. Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*. *Endangered Species Research* 6: 211-221.

LUTJEHARMS, J.R.E., 2006. *The Agulhas Current*. Springer Verlag, 314pp.

LUTJEHARMS, J.R.E., COOPER, J. & M. ROBERTS, 2000. Upwelling at the inshore edge of the Agulhas Current. *Continental Shelf Research*, 20: 737 – 761.

MACDONALD, J.M., SHIELDS, J.D., & R.K. ZIMMER-FAUST, 1988. Acute toxicities of eleven metals to early lift-history stages of the yellow crab *Cancer anthonyi*. *Mar. Biol.*, **98**: 201-207.

MacISSAC, K., BOURBONNAIS, C., KENCHINGTON, E.D., GORDON JR. & S. GASS, 2001. Observations on the occurrence and habitat preference of corals in Atlantic Canada. *In:* (eds.) J.H.M. WILLISON, J. HALL, S.E. GASS, E.L.R. KENCHINGTON, M. BUTLER, AND P. DOHERTY. Proceedings of the First International Symposium on Deep-Sea Corals. Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia.

MacLEOD, C.D. & A. D'AMICO, 2006. A review of beaked whale behaviour and ecology in relation to assessing and mitigating impacts of anthropogenic noise. *Journal of Cetacean Research and Management* 7(3): 211–221.

MacPHERSON, E. & A. GORDOA, 1992. Trends in the demersal fish community off Namibia from 1983 to 1990. *South African Journal of Marine Science* **12**: 635-649.

MAJIEDT, P., HOLNESS, S., SINK, K., OOSTHUIZEN, A. & P. CHADWICK, 2013. Systematic Marine Biodiversity Plan for the West Coast of South Africa. South African National Biodiversity Institute, Cape Town. Pp 46.

MALME, C.I., MILES, P.R., TYACK, P., CLARK, C.W. & J.E. BIRD, 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. BBN Report 5851, OCS Study MMS 85-0019. Report from BBN Laboratories Inc., Cambridge, MA, for U.S. Minerals Management Service, NTIS PB86-218385. Bolt, Beranek, and Newman, Anchorage, AK.

MARTIN, M.J., GRIDLEY, T., ROUX, J.P. & S.H. ELWEN, 2020. First Abundance Estimates of Heaviside's (*Cephalorhynchus heavisidii*) and Dusky (*Lagenorhynchus obscurus*) Dolphins Off Namibia Using a Novel Visual and Acoustic Line Transect Survey. Front Mar Sci., 7: 1–20.

MATE, B.R., BEST, P.B., LAGERQUIST, B.A. & , M.H. WINSOR, 2011. Coastal, offshore and migratory movements of South African right whales revealed by satellite telemetry. *Marine Mammal Science*, 27(3): 455-476.

MATE, B.R., LAGERQUIST, B.A., WINDSOR, M., GERACI, J. & J.H. PRESCOTT, 2005. Movements and dive habits of a satellite-monitoring longfinned pilot whales (*Globicephala melas*) in the northwest Atlantic. *Marine Mammal Science* 21(10): 136-144.

MATKIN, C.O., SAULITIS, E.L., ELLIS, G.M., OLESIUK, P. & S.D. RICE, 2008. Ongoing population-level impacts on killer whales Orcinus orca following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. *Mar. Ecol. Prog. Ser.,* **356**: 269– 281.

MATTHEWS, S.G. & G.C. PITCHER, 1996. Worst recorded marine mortality on the South African coast. In: YASUMOTO, T, OSHIMA, Y. & Y. FUKUYO (Eds), *Harmful and Toxic Algal Blooms*. Intergovernmental Oceanographic Commission of UNESCO, pp 89-92.

MAURER, D., KECK, R.T., TINSMAN, J.C. & W.A. LEATHEM, 1981a. Vertical migration and mortality of benthos in dredged material: Part I – Mollusca. *Marine Environmental Research*, **4**: 299-319.

MAURER, D., KECK, R.T., TINSMAN, J.C. & W.A. LEATHEM, 1981b. Vertical migration and mortality of benthos in dredged material: Part II – Crustacea. *Marine Environmental Research*, **5**: 301.317.

MAURER, D., KECK, R.T., TINSMAN, J.C. & W.A. LEATHEM, 1982. Vertical migration and mortality of benthos in dredged material: Part III – Polychaeta. *Marine Environmental Research*, **6**: 49-68.

MAURER, D.L., LEATHEM, W., KINNER, P. & J. TINSMAN, 1979. Seasonal fluctuations in coastal benthic invertebrate assemblages. *Estuarine and Coastal Shelf Science*, 8: 181-193.

MAURER, D., KECK, R.T., TINSMAN, J.C. & W.A. LEATHAM, 1986. Vertical migration and mortality of marine benthos in dredged material: A synthesis. *Int. Revue Ges. Hydrobiol*ogia, **71**: 49-63.

MAYFIELD, S., 1998. Assessment of predation by the West Coast rock lobster (*Jasus lalandii*): relationships among growth rate, diet and benthic community composition, with implications for the survival of juvenile abalone (*Haliotis midae*) Unpusblished PhD Thesis, University of Cape Town

MAYFIELD, S., BRANCH, G.M. & A.C. COCKCROFT, 2000. Relationships among diet, growth rate and food availability for the South African rock lobster, *Jasus lalandii*. *Crustaceana* **73(7)**: 815–834.

MAYFIELD, S., BRANCH, G.M. & A.C. COCKCROFT, 2005. Role and efficacy of marine protected areas for the South African rock lobster, *Jasus lalandii*. *Marine and Freshwater Research*, 56: 913-924.

McALPINE, D.F., 2018. Pygmy and Dwarf Sperm Whales: *Kogia breviceps* and *K. sima*. In *Encyclopedia of Marine Mammals* (3rd ed., Issue June 2018, p936–938).

McCAULEY, R.D. 1994. Seismic surveys. In: Swan, J.M., Neff, J.M., Young, P.C. (Eds.). Environmental implications of offshore oil and gas development in Australia - The findings of an Independent Scientific Review. APEA, Sydney, Australia, 695 pp.

McCAULEY, R.D., FEWTRELL, J., DUNCAN, A.J., JENNER, C., JENNER, M.N., PENROS, J.D., PRINCE, R.I.T., ADHITYA, A., MURDOCH, J. & K. McCABE, 2000. Marine Seismic Surveys: Analysis and Propagation of Air Gun Signals, and Effects of Exposure on Humpback Whales, Sea Turtles, Fishes and Squid. Prepared for the APPEA. CMST, Curtin University.

McCLAIN, C.R., NUNNALLY, C. & M.C. BENFIELD, 2019. Persistent and substantial impacts of the Deepwater Horizon oil spill on deep-sea megafauna. R. Soc. open sci. 6: 191164. http://dx.doi.org/10.1098/rsos.191164

McDONALD,M.A., CALAMBOKIDIS, J., TERANISHI, A.M. & J.A. HILDEBRAND, 2001. The acoustic calls of blue whales off California with gender data. *J.Acoust. Soc. Am.*, 109(4): 1728–1735.

McDONALD, M.A., HILDEBRAND, J.A., WIGGINS, S.M., THIELE, D., GLASGOW, D. & S.E. MOORE, 2005. Sei whale sounds recorded in the Antarctic. *J. Acoust. Soc. Am.*, 118(6): 3941–3945. doi:10. 1121/1.2130944.

McDONALD, M.A., MESNICK, S.L. & J.A. HILDEBRAND, 2006. Biogeographic characterisation of blue whale song worldwide: using song to identify populations. *J. Cetacean Res. Manag.*, 8(1): 55–65.

McHURON, E.A., SCHWARZ, L.K., COSTA, D.P. & M. MANGEL, 2018. A state-dependent model for assessing the population consequences of disturbance on income-breeding mammals. *Ecological Modelling*, 385: 133-144.

McLACHLAN, A., 1980. The definition of sandy beaches in relation to exposure: a simple rating system. *S. Afr. J. Sci.*, **76**: 137-138.

McLACHLAN, A., JARAMILLO, E., DONN, T.E. & F. WESSELS. 1993. Sandy beach macrofauna communities and their control by the physical environment: a geographical comparison. *Journal of coastal Research, Special Issue*, **15**: 27-38.

McNUTT,M.K., CAMILLI,R., CRONE,T.J., GUTHRIE,G.D., HSIEH,P.A., RYERSON,T.B., SAVAS,O. & F. SHAFFER, 2012. Review of flow rate estimates of the Deepwater Horizon oilspill. Proceedings of the National Academy of Sciences, 109: 20260- 20267.

McQUAID, C.D. & G.M. BRANCH, 1985. Trophic structure of rocky intertidal communities: response to wave action and implications for energy flow. *Mar. Ecol. Prog. Ser.,* **22**: 153-161.

MEAD, A., CARLTON, J.T., GRIFFITHS, C.L. & M. RIUS, 2011. Revealing the scale of marine bioinvasions in developing regions: a South African re-assessment. *Biological Invasions* 13: 1991–2008.

MENN, I., 2002. Ecological comparison of two sandy shores with different wave energy and morphodynamics in the North Sea. *Berliner Polarforschung und Meeresforschung*, **417**: 1-174.

MEŸER, M.A., BEST, P.B., ANDERSON-READE, M.D., CLIFF, G., DUDLEY, S.F.J. & S.P. KIRKMAN, 2011. Trends and interventions in large whale entanglement along the South African coast, African Journal of Marine Science, 33(3): 429-439

MEYER, C.G., HOLLAND, K.N. & Y.P. PAPASTAMATIOU, 2004. Sharks can detect changes in the geomagnetic field. *Journal of the Royal Society Interface*. Published online.

MEYNECKE, J.-O., SEYBOTH, E., DE BIE, J., MENZEL BARRAQUETA, J.-L., CHAMA, A., PRAKASH DEY, S., *et al.*, 2020. Responses of humpback whales to a changing climate in the Southern Hemisphere: priorities for research efforts. *Mar. Ecol.*, 41: e12616.

MEYNECKE, J.-.O, DE BIE, J., BARRAQUETA, J.-L.M., SEYBOTH, E., DEY, S.P., LEE, S.B., SAMANTA, S., VICHI, M., FINDLAY, K., ROYCHOUDHURY, A. & B. MACKEY, 2021. The Role of Environmental Drivers in Humpback Whale Distribution, Movement and Behavior: A Review. *Front. Mar. Sci.*, 8: 720774.

MITCHELL-INNES, B.A. & D.R. WALKER. 1991. Short-term variability during an Anchor Station study in the southern Benguela upwelling system. Phytoplankton production and biomass in relation to species changes. *Prog. Oceanogr.*, **28**: 65-89.

MOLDAN, A.G.S., 1978. A study of the effects of dredging on the benthic macrofauna in Saldanha Bay. *South African Journal of Science*, **74**: 106-108.

MONTAGNA, P.A., & D.E. HARPER, JR., 1996. Benthic infaunal long-term response to offshore production platforms in the Gulf of Mexico. Can. J. Fish. Aquat. Sci., 53: 2567–2588.

MONTAGNA, P.A., J.G. BAGULEY, C. COOKSEY, I. HARTWELL, L.J. HYDE, J.L. HYLAND, R.D. KALKE, L.M. KRACKER, M. REUSCHER & A.C.E. RHODES, 2013. Deep-sea benthic footprint of the Deepwater Horizon blowout. PLoS ONE 8:e70540

MONTEALEGRE-QUIJANO, S. & C.M. VOOREN, 2010. Distribution and abundance of the life stages of the blue shark *Prionace glauca* in the Southwest Atlantic. *Fisheries Research* 101: 168–179.

MONTEIRO, P.M.S., 1998. Assessment of sediment biogeochemical characteristics in the Espirito Santo Estuary-Maputo, Bay system in order to devise a low risk dredging-disposal management plan linked to the proposed MOZAL Matola Terminal. CSIR Report No: ENV/s-C98131 A. pp 39.

MONTEIRO, P.M.S., VAN DER PLAS, A., MOHRHOLZ, V., MABILLE, E., PASCAL, A. & W. JOUBERT, 2006. Variability of natural hypoxia and methane in a coastal upwelling system: Oceanic physics or shelf biology? *Geophys. Res. Lett.*, 33, L16614, doi:10.1029/2006GL026234.

MONTEIRO, P.M.S. & A.K. VAN DER PLAS, 2006. Low Oxygen Water (LOW) variability in the Benguela System: Key processes and forcing scales relevant to forecasting. In: SHANNON, V., HEMPEL, G., MALANOTTE-RIZZOLI, P., MOLONEY, C. & J. WOODS (Eds). *Large Marine Ecosystems*, Vol. 15, pp 91-109.

MONTGOMERY, J. & N. PENKHURST, 1997. Sensory physiology. pp. 325-349. *In:* RANDALL D.J. & A.P. FARRELL (eds) Deep Sea Fishes. Academic Press, N.Y.

MONTGOMERY, J.C. & M.M. WALKER, 2001. Orientation and navigation in elasmobranchs: which way forward? *Environmental Biology of Fishes* **60**: 109-116.

MOORE, A., FREAKE S.M. & I.M. THOMAS, 1990. Magnetic particles in the lateral line of the Atlantic salmon (*Salmo salar* L.). *Philosophical Transaction of the Royal Society of London B* **329**: 11-15.

MORANT, P.D., 1999. Synthesis and assessment of information on the BCLME. BCLME Thematic Report 4: Integrated overview of the offshore oil and gas industry in the Benguela Current Region. CSIR Report. ENV-S-C 99057.

MORANT, P.D., 2006. Environmental Management Programme Report for Exploration/Appraisal Drilling in the Kudu Gas Production Licence No 001 on the Continental Shelf of Namibia. Prepared for Energy Africa Kudu Limited. CSIR Report CSIR/NRE/ECO/2006/0085/C.

MORANT, P.D., 2013. Environmental Management Plan for the proposed marine phosphate prospecting in the Outeniqua West Licence Area on the eastern Agulhas Bank, offshore Mossel Bay. Prepared for Diamond Fields International Ltd. CSIR/CAS/EMS/ER/2013/0000/A, pp266.

MORTAZAVI, B., HOREL, A., BEAZLEY, M.J. & P.A. SOBECKY, 2013. Intrinsic rates of petroleum hydrocarbon biodegradation in Gulf of Mexico intertidal sandy sediments and its enhancement by organic substrates. J. Hazard. Mater., 244: 537-544.

MORTENSEN, P.B., HOVLAND, T., FOSSÅ, J.H. & D.M. FUREVIK, 2001. Distribution, abundance and size of *Lophelia perusa* coral reefs in mid-Norway in relation to seabed characteristics. *Journal of the Marine Biological Association of the UK* 81(4): 581-597.

MOSTERT, B.P., BICCARD, A., DUNA, O. & B.M. CLARK, 2016. Baseline survey of the benthic marine environment in the South African diamond mining Concession areas 1B and 1C. Report prepared for Alexkor and Placer Resource Management by Anchor Environmental Consultants, Report No. 1696/1

MOURA, J.F., ACEVEDO-TREJOS, E., TAVARES, D.C., MEIRELLES, A.C.O., SILVA, C.P.N., OLIVEIRA, L.R., SANTOS, R.A., WICKERT, J.C., MACHADO, R., SICILIANO, S. & A. MERICO, 2016. Stranding events of Kogia whales along the Brazilian coast. *PLoS ONE*, *11*(1): 1–15.

MUEHLENBACHS, L., COHEN, M.A. & T. GERARDEN, 2013. The impact of water depth on safety and environmental performance in offshore oil and gas production. Energy Policy, 55: 699-705.

MULLIN, K., HOGGARD, W., RODEN, C., LOHOEFENER, R., ROGERS, C. & B. TAGGART, 1991. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. OCS Study MMS 91-0027. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, USA.

MUNRO, P., CROCE, B., MOFFIT, C., BROWN, N., McINTOSH, A., HIRD, S. & R. STAGG, 1997. Solid-Phase Test for Comparison of Degradation Rates of Synthetic Mud Base Fluids Used in the Off-Shore Drilling Industry. *Environmental Toxicology and Chemistry,* **17(10)**: 1951-1959.

MUNRO, P.D., CROCE, B., MOFFAT, C.F., BROWN, N.A., MCINTOSH, A.D., HIRD, S.J. & R.M. STAGG, 1998. Solid-phase test for comparison of degradation rates of synthetic mud base fluids used in the off-shore drilling industry. *Environmental Toxicology and Chemistry*, **17(10)**: 1951-1959.

MURRAY, R.W., 1960. Electrical sensitivity of the ampullae of Lorenzini. *Nature* **187**: 957.

MURRAY, R.W., 1962. The response of the ampullae of Lorenzini of elasmobranchs to electrical stimulation. *Journal of Experimental Biology* **39**: 119-128.

MUSCHENHEIM, D.K. & T.G. MILLIGAN, 1996. Flocculation and accummulation of fine drilling waste particulates on the Scotian Shelf (Canada). *Marine Pollution Bulletin* 32 (10): 740-745.

NATIONAL MARINE FISHERIES SERVICES (NMFS), 2013. Marine mammals: Interim Sound Threshold Guidance (webpage), National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

NATIONAL PROTECTED AREAS REGISTER 2020, https://portal.environment.gov.za/portal/apps/webappviewer/index.html?id=54487a82babf4a7e9ab3a42aacabdf84.

NATIONAL RESEARCH COUNCIL (NRC), 2003a. Oil in the Sea III: Inputs, Fates, and Effects. The National Academies Press.

NCEP, 2012. National Weather Service Environmental Modeling Centre. [Online] Available at: http://polar.ncep.noaa.gov

NEFF, J.N., 1991. *Water Quality in Prince William Sound and the Gulf of Alaska*. Arthur D Little, Cambridge, Massachusetts.

NEFF, J.M., RABALAIS, N.N. & D.F. BOESCH, 1987. Offshore oil and gas development activities potentially causing long-term environmental effects. pp 149-174. In: BOESCH D.F. & N.N. RABALAIS, Eds., Long Term Effects of Offshore Oil and Gas Development. Elsevier Applied Science Publishers, London.

NEFF, J.M., BOTHNER, M.H., MACIOLEK, N.J. & J.F. GRASSLE, 1989. Impacts of exploratory drilling for oil and gas on the benthic environment of Georges Bank. *Marine Environmental Research*, **27**: 77-114.

NEFF, J.M., SAUER, T.C. & N. MACIOLEK, 1992. Composition, fate and effects of produced water discharges to nearshore waters. pp371-386. In: RAY, J.P. & F.R. ENGELHARDT, Eds., Produced Water: Technological/Environmental Issues. Plenum Publishing Co., New York.

NEFF, J.M., McKELVIE, S. & R.C. AYERS, Jr., 2000. Environmental Impacts of Synthetic Based Drilling Fluids. OCS Study MMS 2000-64. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Program, New Orleans, LA. 118 pp.

NEFF, J.M., 2005. Composition, Environmental Fates, and Biological Effects of Water Based Drilling Muds and Cuttings Discharged to the Marine Environment: A Synthesis and Annotated Bibliography. Prepared fro Petroleum Environmental Research Forum (PERF) and American Petroleum Institute. 83pp.

NEFF, J.M., 2008. Estimation of bioavailability of metals from drilling mud barite. Integr. Environ. Assess. Manag., 4: 184-193.

NEL, P., 2001. Physical and biological factors structuring sandy beach macrofauna communities. PhD Thesis, University of Cape Town, Cape Town, South Africa: pp 202

NEL, R., PULFRICH, A. & A.J. PENNEY, 2003. Impacts of Beach Mining Operations on Sandy Beach Macrofaunal Communities on the Beaches of Geelwal Karoo. Pisces Environmental Services (Pty) Ltd. Report to Trans Hex Operations (Pty) Ltd. October 2003, 54pp.

NELSON, G., 1989. Poleward motion in the Benguela area. In: Poleward Flows along Eastern Ocean Boundaries. NESHYBA *et al.* (eds) New York; Springer: 110-130 (Coastal and Estuarine Studies 34).

NELSON G. & L. HUTCHINGS, 1983. The Benguela upwelling area. *Prog. Oceanogr.*, 12: 333-356.

NETTO, S.A., FONSECA, G. & F., GALLUCCI, 2010. Effects of drill cuttings discharge on meiofauna communities of the shelf break in the southwest Atlantic. Environ. Monit. Assess., 167:49–63.

NEWMAN, G.G. & D.E. POLLOCK, 1971. Biology and migration of rock lobster *Jasus lalandii* and their effect on availability at Elands Bay, South Africa. *Investl. Rep. Div. Sea Fish. S. Afr.*, 94: 1-24.

NICHOLS, W.J, RESENDIZ, A., SEMINOFF, J.A. & B. RESENDIZ, 2000. Transpacific migration of a loggerhead turtle monitored by satellite telemetry. *Bulletin of Marine Science* **67**: 937-947.

NICOL, S., BOWIE, A., JARMON, S., LANNUZEL, D., MEINERS, K.M., *et al*. 2010. Southern Ocean iron fertilization by baleen whales and Antarctic krill. *Fish and Fisheries*, 11: 203–209.

NIEUKIRK, S.L., MELLINGER, D.K., MOORE, S.E., KLINCK, K., DZIAK, R.P. & J. GOSLIN, 2012. Sounds from airguns and fin whales recorded in the mid-Atlantic Ocean, 1999–2009. *Journal of the Acoustical Society of America*, 131: 1102–1112.

NIU, H., LI, Z., LEE, K., KEPKAY, P. & J.V. MULLIN, 2011. Modeling the transport of oil-mineral-aggregates (OMAs) in the marine environment and assessment of their potential risks. Environ. Model Assess.,16: 61–75.

NOAA, 1998. Fact Sheet: Small Diesel Spills (500-5000 gallons) Available at: http://response.restoration.noaa.gov/oilaids/diesel.pdf

NOAA, 2010 (ed. Shigenaka). *Oil and Sea Turtles Biology, Planning, and Response*. Retrieved from http://response. restoration.noaa.gov/sites/default/files/Oil_Sea_Turtles.pdf

NRC, 2003. Ocean noise and marine mammals. National Academy Press, Washington, DC.

NRC, 2005. Marine mammal populations and ocean noise, determining when noise causes biologically significant effects. The National Academy Press, Washington, DC.

OCEANMIND LIMITED, 2020. A Geospatial Analysis of Vessel Traffic in Important Marine Mammal Areas. Using the Automatic Identification System to Monitor the Important Marine Mammal Areas (01Sep2018 – 01Sep2019). Report by WWF-IUCN-IWC-OceanMind, pp409.

OGP, 2003. Environmental aspects of the use and disposal of non aqueous drilling fluids associated with offshore oil and gas operations. Report prepared by the International Association of Oil and Gas Producers No. 342 pp.103.

OLSGARD, F. & J.S. GRAY, 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. *Marine Ecology Progress Series,* **122**: 277–306.

OOSTHUIZEN W.H., 1991. General movements of South African (Cape) fur seals Arctocephalus pusillus pusillus from analysis of recoveries of tagged animals. S. Afr. J. Mar. Sci., 11: 21-30.

OSPAR, 2008. OSPAR List of Substances / Preparations Used and Discharged Offshore which Are Considered to Pose Little or No Risk to the Environment (PLONOR).

O'TOOLE, M.J., 1997. A baseline environmental assessment and possible impacts of exploration and mining of diamond deposits (Prospecting Grants Areas M46/3/1946, 1950) off the coast of Namibia. In: LANE, S & CMS, 1996. Environmental Assessment and Management Plan report for deep sea diamond mining in Namibia by Arena Mining (Pty) Ltd.

OZHAN, K., PARSONS, M.L. & S. BARGU, 2014. How Were Phytoplankton Affected by the Deepwater Horizon Oil Spill? *BioScience* 64: 829–836.

PABORTSAVA, K., PURSER, A., WAGNER, H.a dn L. THOMSEN, 2011. The influence of drill cuttings on physical characteristics of phytodetritus. *Marine Pollution Bulletin* 62, 2170-2180.

PAINE, M.D., SKINNER, M.A., KILGOUR, B.W., DEBLOIS, E.M. & E. TRACY, 2014. Repeated-measures Regression Designs and Analysis for Environmental Effects Monitoring Programs, 110: 84–91.

PALAN, K.J., 2017. *Submarine canyon evolution of the Southwest Cape continental margin*. MSc Thesis, University of KwaZulu-Natal, South Africa.

PANIGADA, S., PESANTE, G., ZANARDELLI, M., CAPOULADE, F., GANNIER, A. & M.T. WEINRICH, 2006. Mediterranean fin whales at risk from fatal ship strikes. *Marine Pollution Bulletin* 52 (10): 1287-98.

PAPI, F., CHEW, H.C., LUSCHI, P. & E.H. CHAN, 1995. Long-range migratory travel of a green turtle tracked by satellite: evidence for navigational ability. *Marine Biology* 122: 171-175.

PAPI, F., LUSCHI, P., AKESSON, S., CAPOGROSSI, S. & G.C. HAYS, 2000. Open-sea migration of magnetically disturbed sea turtles. *The Journal of Experimental Biology* 203: 3435-3443.

PARKER, S.J., PENNEY, A.J. & M.R. CLARK, 2009. Detection criteria for managing trawl impacts on vulnerable marine ecosystems in high seas fisheries of the South Pacific Ocean. Marine Ecology Progress Series 397: 309–317.

PARKINS, C.A. & J.G.FIELD, 1998. The effects of deep sea diamond mining on the benthic community structure of the Atlantic 1 Mining Licence Area. Annual Monitoring Report – 1997. Prepared for De Beers Marine (Pty) Ltd by Marine Biology Research Institute, Zoology Department, University of Cape Town. pp. 44.

PARRY, D.M., KENDALL, M.A., PILGRIM, D.A. & M.B. JONES, 2003. Identification of patch structure within marine benthic landscapes using a remotely operated vehicle. J. Exp. Mar. Biol. Ecol., 285– 286: 497–511.

PARSONS, T.R., KESSLER T.A. & L. GUANGUO, 1986a. An ecosystem model analysis of the effect of mine tailings on the euphotic zone of a pelagic ecosystem. *Acta Oceanol. Sin.*, **5**: 425-436.

PARSONS, T.R., THOMPSON, P., WU YONG, LALLI, C.M., HOU SHUMIN & XU HUAISHU, 1986b. The effect of mine tailings on the production of plankton. *Acta Oceanol. Sin.*, **5**: 417-423.

PASSOW, U., 2016. Formation of rapidly-sinking, oil-associated marine snow. Deep-Sea Res. II, 129: 232-240.

PASSOW, U., ZIERVOGEL, K., ASPER, V. & A. DIERCKS, 2012. Marine snow formation in the aftermath of the Deepwater Horizon oil spill in the Gulf of Mexico. Environ. Res. Lett. 7.

PATENAUDE, N.J., RICHARDSON, W.J., SMULTEA, M.A., KOSKI, W.R., MILLER, G.W., WÜRSIG, B. & C.R. GREENE, JR., 2002. Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. *Marine Mammal Science* **18**: 309-335.

PAYNE, A.I.L. & R.J.M. CRAWFORD, 1989. *Oceans of Life off Southern Africa.* Vlaeberg, Cape Town, 380 pp.

PAYNE, J.R.& W.B. DRISKELL, 2015. 2010 DWH offshore water column samples — forensic assessments and oil exposures. U.S. Dept. of Interior, Deepwater Horizon Response & Restoration, Admin. Record (www.doi.gov/deepwaterhorizon/adminrecord, DWHAR0039121, 37 p).

PAULIN, M.G., 1995. Electroreception and the compass sense of sharks. *Journal of Theoretical Biology* **174**: 325-339.

PEARSON, T.H. & R. ROSENBERG. 1978. Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanogr. Mar. Biol. Ann. Rev. 16: 229-311.

PEARSON, W.H., 2014. Comment on "multitissue molecular, genomic, and developmental effects of the Deepwater Horizon oil spill on resident gulf killifish (Fundulus grandis)". Environ. Sci. Technol., 48: 7677–7678.

PEETERS, F.J., ACHESON, R., BRUMMER, G-JA., DE RUIJTER, W.P., SCHNEIDER, R.R., GANSSEN, G.M., UFKES, E. & D. KROON, 2004. Vigorous exchange between the Indian and Atlantic oceans at the end of the past five glacial periods. *Nature* 430: 661.

PENNEY, A.J., KROHN, R.G. & C.G. WILKE. 1992. A description of the South African tuna fishery in the southern Atlantic Ocean. *ICCAT Col. Vol. Sci. Pap.* XXIX(1) : 247-253.

PENNEY, A.J., PULFRICH, A., ROGERS, J., STEFFANI, N. & V. MABILLE, 2007. *Project: BEHP/CEA/03/02: Data Gathering and Gap Analysis for Assessment of Cumulative Effects of Marine Diamond Mining Activities on the BCLME Region.* Final Report to the BCLME mining and petroleum activities task group. December 2007. 410pp.

PENRY, G.S., 2010. Biology of South African Bryde's whales. PhD Thesis. University of St Andrews, Scotland, UK.

PERRY, J., 2005. Environmental Impact Assessment for Offshore Drilling the Falkland Islands to Desire Petroleum Plc. 186pp

PETERS, I.T, BEST, P.B. & M. THORNTON, 2005. Abundance Estimates of Right Whales on a Feeding Ground off the West Coast of South Africa. Paper SC/S11/RW11. Submitted to the International Whaling Commission.

PETERSON, C.H., LANEY, W. & T. RICE, 2001. Biological impacts of beach nourishment. Workshop on the Science of Beach Renourishment, May 7-8, 2001. Pine Knoll Shores, North Carolina.

PHAM, C.K., VANDEPERRE, F., MENEZES, G., PORTEIRO, F., ISIDRO, E. & T. MORATO, 2015. The importance of deep-sea vulnerable marine ecosystems for demersal fish in the Azores. Deep-Sea Research Part I: Oceanographic Research Papers 96: 80–88.

PIDCOCK, S., BURTON, C. & M. LUNNEY, 2003. The potential sensitivity of marine mammals to mining and exploration in the Great Australian Bight Marine Park Marine Mammal Protection Zone. An independent review and risk assessment report to Environment Australia. Marine Conservation Branch. Environment Australia, Cranberra, Australia. pp. 85.

PILE, A.J. & C.M. YOUNG, 2006. The natural diet of a hexactinellid sponge: benthic--pelagic coupling in a deep-sea microbial food web. Deep Sea Research Part I: Oceanographic Research Papers 53: 1148-1156.

PILLAR, S.C., 1986. Temporal and spatial variations in copepod and euphausid biomass off the southern and and south-western coasts of South Africa in 1977/78. *S. Afr. J. mar. Sci.*, **4**: 219-229.

PILLAR, S.C., BARANGE, M. & L. HUTCHINGS, 1991. Influence of the frontal sydtem on the cross-shelf distribution of Euphausia lucens and Euphausia recurva (Euphausiacea) in the Southern Benguela System. *S. Afr. J. mar. Sci.*, **11** : 475-481.

PIROTTA, E., BOOTH, C.G., COSTA, D.P., *et al.* 2018. Understanding the population consequences of disturbance. *Ecol Evol.*, 8: 9934–9946. https://doi.org/10.1002/ece3.4458.

PIROTTA, V., GRECH, A., JONSEN, I.D., LAURANCE, W.F. & R.G. HARCOURT, 2019. Consequences of global shipping traffic for marine giants. *Frontiers in Ecology and the Environment*, 17(1): 39-47.

PITCHER, G.C., 1998. *Harmful algal blooms of the Benguela Current*. IOC, World Bank and Sea Fisheries Research Institute Publication. 20 pp.

PITCHER ,G.C. & D. CALDER, 2000. Harmful algal blooms of the southern Benguela current: a review and appraisal of monitoring from 1989–1997. *South African Journal of Marine Science*, **22**: 255–271.

PLÖN, S., 2004. The status and natural history of pygmy (*Kogia breviceps*) and dwarf (*K. sima*) sperm whales off Southern Africa. PhD Thesis. Department of Zoology & Entomology (Rhodes University), p. 551.

POMILLA, C. & H.C. ROSENBAUM, 2005. Against the current: an inter-oceanic whale migration event. *Biol. Lett.*, 1: 476-479.

POOPETCH, T. 1982. Potential effects of offshore tin mining on marine ecology. Proceedings of the Working Group Meeting on environmental management in mineral resource development, *Mineral Resource Development Series*, **49**: 70-73.

POST, A.L., WASSENBERG, T.J.& V. PASSLOW, 2006. Physical surrogates for macrofaunal distributions and abundance in a tropical gulf. *Marine and Freshwater Research*, **57**: 469-483.

POWELL, S.M., SNAPE, T.I., BOWMAN, J.P., THOMPSON, B.A.W., STARK, J.S., MCCAMMON, S. A.& M.J. RIDDLE, 2005. A comparison of the short term effects of diesel fuel and lubricant oils on Antarctic benthic microbial communities. J. Exp. Mar. Biol. Ecol. 322, 53–65

PRDW, 2013. Impact Assessment for Proposed Exploration Drilling in the Orange Basin Deep Water Licence Area off the West Coast of South Africa. Drill Cuttings and Oil Spill Modelling Specialist Study, November 2013. 126pp.

PRZESLAWSKI, R., BYRNE, M., MELLIN, C., 2015. A review and meta-analysis of the effects of multiple abiotic stressors on marine embryos and larvae. *Glob. Chang. Biol.* **21**: 2122–2140.

PROUTY, N.G., FISHER, C.R., DEMOPOULOS, A.W.J. & E.R.M.DRUFFEL, 2014. Growth rates and ages of deep-sea corals impacted by the Deepwater Horizon oil spill. Deep-Sea Res. II Top. Stud. Oceanogr. http://dx.doi.org/10.1016/j.dsr2.2014.10.021 (Published online 8 November2014, 17 pp.).

PULFRICH, A., 2013. Intertidal Rocky-Shore Communities of the Sperrgebiet Coastline: Consolidated Rocky-shores Monitoring Report – 2013. *Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia*. 126pp.

PULFRICH, A. & A.J. PENNEY, 1999. The effects of deep-sea diamond mining on the benthic community structure of the Atlantic 1 Mining Licence Area. Annual Monitoring Report – 1998. Prepared for De Beers Marine (Pty) Ltd by Marine Biology Research Institute, Zoology Department, University of Cape Town and Pisces Research and Management Consultants CC. pp 49.

PULFRICH, A., PENNEY, A.J., BRANDÃO, A., BUTTERWORTH, D.S. & M. NOFFKE, 2006. Marine Dredging Project: FIMS Final Report. Monitoring of Rock Lobster Abundance, Recruitment and Migration on the Southern Namibian Coast. *Prepared for De Beers Marine Namibia, July 2006*. 149pp.

PULFRICH, A., 2011. Environmental Management Programme for Proposed Seismic and Controlled Source Electromagnetic Surveys in Licence Block 5/6, South-West Coast, South Africa - Marine Faunal Assessment. Prepared for CCA Environmental (Pty) Ltd. on behalf of PetroSA. August 2011. 128pp.

PULFRICH, A., 2013. Environmental Management Programme for a proposed Seafloor Geochemical Sampling Programme in Licence Blocks 5/6 (Er #224) and 7 (Er #228), South-West Coast, South Africa - Marine Faunal Assessment Prepared for CCA Environmental (Pty) Ltd. on behalf of Impact Africa Limited. May 2013. 67pp.

PULFRICH, A., 2018a. Environmental Management Plan for Proposed Speculative 2D and 3D Seismic Surveys off the South and West Coasts of South Africa. Marine Faunal Assessment. Prepared for SLR Environmental Consulting (Pty) Ltd. on behalf of PGS. October 2018, 153pp.

PULFRICH, A., 2018b. Environmental Management Plan for Proposed Speculative 2D Seismic Survey off the South Coast of South Africa. Marine Faunal Specialist Assessment. Prepared for SLR Environmental Consulting (Pty) Ltd. on behalf of Spectrum. 146pp.

PULFRICH, A., 2019. Environmental Impact Asessment for an offshore2D Seismic Survey in Licence Blocks 5/6 (Er #224) and 7 (Er #228), South-West Coast, South Africa - Marine Faunal Assessment Prepared for CCA Environmental (Pty) Ltd. on behalf of Anadarko South Africa (Pty) Ltd. March 2019. 150pp.

PULSTER, E.L., GRACIA, A., ARMENTEROS, M., TORO-FARMER, G., SNYDER, S.M., CARR, B., SCHWABB, M.R., NICHOLSON, T.J., MROWICKI, J. & S.A. MURAWSKI, 2020. A first comprehensive baseline of hydrocarbon pollution in Gulf of Mexico fishes. Nature/Scientific reports, 10: 6437.

PURDON, J., SHABANGU, F., PIENAAR, M., SOMERS, M.J. & K.P. FINDLAY, 2020a. South Africa's newly approved marine protected areas have increased the protected modelled habitat of nine odontocete species SUPPLEMENT 2. *Mar Ecol Prog Ser* 633:1–21.

PURDON, J., SHABANGU, F., PIENAAR, M., SOMERS, M.J. & K.P. FINDLAY, 2020b. Cetacean species richness in relation to anthropogenic impacts and areas of protection in South Africa's mainland Exclusive Economic Zone. Ocean Coast Manag., 197: 105292

PURDON, J., SHABANGU, F.W., YEMANE, D., PIENAAR, M., SOMERS, M.J. & K. FINDLAY, 2020c. Species distribution modelling of Bryde's whales, humpback whales, southern right whales, and sperm whales in the southern African region to inform their conservation in expanding economies. PeerJ. 8:e9997. doi: 10.7717/peerj.9997. PMID: 33024637; PMCID: PMC7518163.

PURSER, A., 2015. A time series study of Lophelia pertusa and reef megafauna responses to drill cuttings exposure on the Norwegian margin. PLoSONE 10:e0134076.doi:10.1371/journal.pone.0134076.

PURSER, A & L. THOMSEN, 2012. Monitoring Strategies for drill cutting discharge in the vicinity of cold-water coral ecosystems. *Mar. Pollut. Bull.*, 64: 2309-2316

PUTMAN, N.F. & K.L. MANSFIELD, 2015. Direct Evidence of Swimming Demonstrates Active Dispersal in the Sea Turtle "Lost Years". *Curr. Biol.*, 25: 1221–1227.

PUTMAN, N.F., ABREU-GROBOIS, F.A., ITURBE-DARKISTADE, I., PUTMAN, E.M., RICHARDS, P.M. & P. VERLEY, 2015. Deepwater Horizon oil spill impacts on sea turtles could span the Atlantic. Biol. Lett. 11: 20150596.

PUTMAN, N.F., VERLEY, P., SHAY, T.J. & K.J. LOHMANN, 2012. Simulating transoceanic migrations of young loggerhead sea turtles: merging magnetic navigation with an ocean circulation model. *J. Exp. Biol.*, 215: 1863–1870.

PUTMAN, N.F. & E. NARO-MACIEL, 2013. Finding the 'lost years' in green turtles: insights from ocean circulation models and genetic analysis. *Proc. R. Soc. Biol.*, 280.

PUTMAN, N.F., SENEY, E.E., VERLEY, P., SHAVER, D.J., LOPEZ-CASTRO, M.C., COOK, M., *et al.*, 2020. Predicted distributions and abundances of the sea turtle 'lost years' in the western North Atlantic Ocean. *Ecography*, 43: 506-517.

QU, F., NUNNALLY, C.C., LEMANSKI, J.R., WADE, T.L., AMON, A.M.W., ROWE, G.T., 2016. Polychaete annelid (segmented worms) abundance and species composition in the proximity (6–9 km) of the Deepwater Horizon (DWH) oil spill in the deep Gulf of Mexico. Deep-Sea Research Part II: 129: 130-136.

QUEIROS, A.M., BIRCHENOUGH, S.N.R., BREMNER, J., GODBOLD, J.A., PARKER, R.E., ROMERO- RODRIGUES, A., REISS, H., SOLAN, M., SOMERFIELD, P.J., COLEN, C.V., HOEY, G.V., WIDDICOMBE, S., 2013. A bioturbation classification of European marine infaunal invertebrates. Ecol. Evol. 3 (11), 3958–3985.

RAES, M & A. VANREUSEL, 2005. The metazoan meiofauna associated with a cold-water coral degradation zone in the Porcupine Seabight (NE Atlantic). Cold-water corals and ecosystems. Springer. pp 821–847.

RAMOS, E., CHEESEMAN, T., MARCONDES, M., OLIO, M., VOGEL, A., ELWEN, S., MELO, T., FACCHOLA, C., CIPOLOTTI, S., SOUTHERLAND, K., FINDLAY, K., SEYBOTH, E., McCUE, S., KOTZE, P. & M. SEAKAMELA, 2023. Interchange of Southern Hemisphere humpback whales across the South Atlantic Ocean. Scientific Reports. 13. 10.1038/s41598-023-31358-5.

RAND, A.M., 2006. Using Geographic Information Systems and Remote Sensing to improve the management of kelp resources in South Africa. MSc Thesis, University of Cape Town.

RANGER, 1993. Exploration Drilling Phase Environmental ImpactAssessment; Licence Area 2213, Namibia. Ranger Oil Limited.

REDDY, C.M., AREY, J.S., JEFFREY, S.S., SEAN, P.S., KARIN, L.L., *et al*. 2012. Composition and fate of gas and oil released to the water column during the Deepwater Horizon oil spill. Proc Natl Acad Sci USA 109: 20229-20234.

RICHARDSON, W.J., GREENE, C.R., JR., KOSKI, W.R. & M.A. SMULTEA, 1991. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska-1990 phase: Sound propagation and whale responses to playbacks of continuous drilling noise from an ice platform, as studied in pack ice conditions. Unpublished report to U.S. Minerals Management Service, Procurement Operations, Herndon, Virginia: Contract 14-12-0001-30412 (LGL Report TA848-)

RICHARDSON, W.J., GREENE, C.R., MALME, C.I. & THOMSON, D.H. 1995. Marine Mammals and Noise. Academic Press, San Diego, CA.

RICHARDSON, W.J. & B. WÜRSIG, 1997. Influences of man-made noise and other human actions on cetacean behaviour. *Marine and Freshwater Behaviour and Physiology* **29**: 183-209.

RICHTER, C.F., DAWSON, S.M. & E. SLOOTEN, 2003. Sperm whale watching off Kaikoura, New Zealand: Effects of current activities on surfacing and vocalisation patterns. Science for Conservation Report No. 219. Department of Conservation, Wellington, New Zealand.

RICHTER, C., DAWSON, S. & E. SLOOTEN, 2006. Impacts of commercial whale watching on male sperm whales at Kaikoura, New Zealand. *Marine Mammal Science* **22**: 46-63.

RIPPLE, W.J., ESTES, J.A., SCHMITZ, O.J., CONSTANT, V., KAYLOR, M.J., LENZ, A., MOTLEY, J.L., SELF, K.E., TAYLOR, D.S. & C. WOLF, 2016. What is a trophic cascade?. Trends in ecology & evolution, 31(11):.842-849.

RITZ, T., ADEM, S. & K. SCHULTEN, 2000. A model for photoreceptor-based magnetoreception in birds. *Biophysical Journal*, **78**: 707-718.

ROBERSON, L.A., LAGABRIELLE, E., LOMBARD, A.T., SINK, K., LIVINGSTONE, T., GRANTHAM, H. & J.M. HARRIS, 2017. Pelagic bioregionalisation using open-access data for better planning of marine protected area networks. Ocean and Coastal Management 148: 214–230.

ROBERTS, J.M. & J.D. GAGE, 2003. Scottish Association for Marine Science Work Package 3 of ACES project: To describe the deep-water coral ecosystem, its dynamics and functioning; investigate coral biology and behaviour and assess coral sensitivity to natural and anthropogenic stressors. Final Report to the Atlantic Coral Ecosystem Study," Internal SAMS Report, 2003.

ROBERTS, J.M., WHEELER, A.J. & A. FREIWALD, 2006. Reefs of the deep: the biology and geology of cold-water coral ecosystems. *Science* 312: 543–547.

ROBERTS, R.D., MURRAY, S., GREGORY, R. & B.A. FOSTER, 1998. Developing an efficient macrofauna monitoring index from an impact study - A dredge spoil example. *Mar. Pollut. Bull.*, **36**: 231-235.

ROBINSON, N., ANDERS, D., BACHOO, S., HARRIS, L., HUGHES, G., KOTZE, D., MADURAY, S., MCCUE, S., MEYER, M., OOSTHUIZEN, H., PALADINO, F. & P. LUSCHI, 2019. Satellite tracking of leatherback and loggerhead sea turtles on the southeast African coastline. Indian Ocean Turtle Newsletter, 28: 5pp.

ROBINSON, T., GRIFFITHS, C., McQUAID, C. & M. RIUS, 2005. Marine alien species of South Africa - status and impacts. *African Journal of Marine Science* **27**: 297-306.

ROEL, B.A., 1987. Demersal communities off the west coast of South Africa. *South African Journal of Marine Science* **5**: 575-584.

ROGAN, E, BAKER, J.R., JEPSON, P.D., BERROW, S. & O. KIELY, 1997. A mass stranding of white-side dolphins (*Lagenorhynchus acutus*) in Ireland: biological and pathological studies. *Journal of Zoology* **242**: 217-227.

ROGERS, A.D., 1999. The biology of *Lophelia pertusa* (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. *International Review of Hydrobiology,* **84 (4)**: 315-406.

ROGERS, A.D., 1994. The biology of seamounts. *Advances in Marine Biology*, **30**: 305–350.

ROGERS, A.D., 2004. The biology, ecology and vulnerability of seamount communities. IUCN, Gland, Switzerland. Available at: www.iucn.org/themes/ marine/pubs/pubs.htm 12 pp.

ROGERS, A.D., CLARK, M.R., HALL-SPENCER, J.M. & K.M. GJERDE, 2008. The Science behind the Guidelines: A Scientific Guide to the FAO Draft International Guidelines (December 2007) For the Management of Deep-Sea Fisheries in the High Seas and Examples of How the Guidelines May Be Practically Implemented. IUCN, Switzerland, 2008.

ROGERS, J., 1977. *Sedimentation on the continental margin off the Orange River and the Namib Desert*. Unpubl. Ph.D. Thesis, Geol. Dept., Univ. Cape Town. 212 pp.

ROGERS, J., 1979. Dispersal of sediment from the Orange River along the Namib Desert coast. *S. Afr. J. Sci.*, **75**: 567 (abstract).

ROGERS, J., 1986. Seismic, bathymetric and photographic evidence of widespread erosion and a manganese-nodule pavement along the continental rise of the southeast Cape Basin. Technical Report. *Joint Geological Survey/University of Cape Town Marine Geoscience Unit* 7: 1–212.

ROGERS, J. & J.M. BREMNER, 1991. The Benguela Ecosystem. Part VII. Marine-geological aspects. *Oceanogr. Mar. Biol. Ann. Rev.*, **29**: 1-85.

ROLLAND, R.M., PARKS, S.E. HUNT, K.E., CASTELLOTE, M., CORKERON, P.J., NOWACEK, D.P., WASSER, S.K. &S.D. KRAUS, 2012. Evidence that ship noise increases stress in right whales. *Proceedings of the Royal Society B: Biological Sciences*, 279 (1737): 2363-2368.

ROLLINSON, D., WANLESS, R. & P. RYAN, 2017. Patterns and trends in seabird bycatch in the pelagic longline fishery off South Africa. *African Journal of Marine Science* 39: 9–25.

ROMAN, J. & J.J. McCARTHY, 2010. The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin. *PLoS ONE* 5(10): e13255. doi:10.1371/

ROSENBAUM, H.C., POMILLA, C., MENDEZ, M., LESLIE, M.S., BEST, P.B., FINDLAY, K.P., MINTON, G., ERSTS, P.J., COLLINS, T., ENGEL, M.H., BONATTO, S., KOTZE, P.G.H., MEŸER, M., BARENDSE, J., THORNTON, M., RAZAFINDRAKOTO, Y., NGOUESSONO, S., VELY, M. & J. KISZKA, 2009. Population structure of humpback whales from their breeding grounds in the South Atlantic and Indian Oceans. PLoS One, 4 (10): 1-11.

ROSENBAUM, H.C., MAXWELL, S., KERSHAW, F. & B.R. MATE, 2014. Long-range movement of Humpback Whales and Their Overlap with Anthropogenic Activities in the South Atlantic Ocean. *Conservation Biology*, 28(2): 604-615.

ROSS, G.J.B., 1979. Records of pygmy and dwarf sperm whales, genus *Kogia*, from southern Africa, with biological notes and some comparisons. *Annals of the Cape Province Museum (Natural History)* 11: 259-327.

ROTHMAN, M.D., ANDERSON, R.J. & A.J. SMITH, 2006. The effects of harvesting of the South African kelp (*Ecklonia maxima*) on kelp population structure, growth rate and recruitment. *Journal of Applied Phycology* **18**: 1-7.

ROUX, J-P., BEST, P.B. & P.E. STANDER. 2001. Sightings of southern right whales (*Eubalaena australis*) in Namibian waters, 1971-1999. *J. Cetacean Res. Manage.* (Special Issue). 2: 181–185.

ROUX, J-P., BRADY, R. & P.B. BEST, 2011. Southern right whales off Namibian and their relationship with those off South Africa. Paper SC/S11/RW16 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

ROUX, J-P., BRADY, R. & P.B. BEST, 2015. Does disappearance mean extirpation? The case of right whales off Namibia. Marine Mammal Science 31(3): 1132-1152.

ROWAT, D., 2007. Occurrence of the whale shark (*Rhincodon typus*) in the Indian Ocean: a case for regional conservation. *Fisheries Research*, **84**: 96-101.

ROWAT, D. & M. GORE, 2007. Regional scale horizontal and local scale vertical movements of whale sharks in the Indian Ocean off Seychelles. *Fisheries Research* **84**: 32–40.

ROYAL HASKONING DHV, 2016. Breede River Estuarine Management Plan. Western Cape Government Department of Environmental Affairs and Development Planning.

ROYAL HASKONING DHV, 2017. Knysna River Estuarine Management Plan. Western Cape Government Department of Environmental Affairs and Development Planning.

RUIZ, G.M. & J.T. CARLTON, 2003. Invasion vectors: a conceptual framework for management. In: RUIZ, G.M. & J.T. CARLTON (eds), Invasive species: vectors and management strategies. Washington, DC: Island Press. pp 459–504.

RUIZ, G.M., FOFONOFF, P.W., CALTON, J.T., WONHAM, M.J. & A.H. HINES, 2000. Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. *Annual Review of Ecology and Systematics* 31: 481–531.

RYAN, P.G. & ROSE, B. 1989. Migrant seabirds. In: Oceans of life off southern Africa. PAYNE, A.I.L. & CRAWFORD, R.J.M. (Eds.). Cape Town. Vlaeberg Publishers, pp. 274-287.

SAADOUN, I.M.K, 2015. Impacts of Oil on Marine Life. In: Larramendy, M.L. & S. Soloneski (Eds.), Emerging Pollutants in the Environment - Current and Further Implications. http://dx.doi.org/10.5772/60455

SALAS, F., MARCOS, C., NETO, J.M., PATRICIO, J., PÉREZ-RUZAFA, A. & J.C. MARQUES, 2006. User-friendly guide for using benthic ecological indicators in coastal and marine quality assessment. *Ocean and Coastal management* **49**: 308-331.

SALCEDO, D.L., SOTO, L.A., ESTRADAS-ROMERO, A. & A.V. BOTELLO, 2017. Interannual variability of soft-bottom macrobenthic communities of the NW Gulf of Mexico in relationship to the Deepwater Horizon oil spill. *Marine Pollution Bulletin* **114**:987-994

SAMSON, J.E., MOONEY, T.A., GUSSEKLOO, S.W.S. & R.T. HANLON, 2014. Graded behavioural responses and habituation to sound in the common cuttlefish *Sepia officianalis*. *Journal of Experimental Biology*, 217: 4347-4355.

SANBI, 2018, Using CBA maps to support land-use planning and decision making. South African National Biodiversity Institute, Pretoria.

SANDRINI-NETO, L., MARTINS, C.C. & P.C. LANA, 2016. Are intertidal soft sediment assemblages affected by repeated oil spill events? A field-based experimental approach. Environ. Pollut., 213: 151–159.

SAVAGE, C., FIELD, J.G. & R.M. WARWICK, 2001. Comparative meta-analysis of the impact of offshore marine mining on macrobenthic communities versus organic pollution studies. *Mar Ecol Prog Ser.*, **221**: 265-275.

SCHAANNING, M.T., TRANNUM, H.C., OXNEVAD, S., CARROLL, J. & T. BAKKE, 2008. Effects of drill cuttings on biogeochemical fluxes and macrobenthos of marine sediments. *Journal of Experimental Marine Biology and Ecology,* **361**: 49–57.

SCHAFFNER, L.C., 1993. *Baltimore Harbor and channels aquatic benthos investigations at the Wolf Alternate Disposal Site in lower Chesapeake Bay.* Final report prepared by the College of William and Mary and the Virginia Institute of Marine Science for the US Army Corps of Engineers, Baltimore District: pp. 120.

SCHALL, E., THOMISCH, K., BOEBEL, O. *et al.* 2021. Humpback whale song recordings suggest common feeding ground occupation by multiple populations. *Sci. Rep.*, 11, 18806. https://doi.org/10.1038/s41598-021-98295-z

SCHOEMAN, R.P., PATTERSON-ABROLAT, C. & S. PLÖN, 2020. A Global Review of Vessel Collisions With Marine Animals. Frontiers in Marine Science, 7: doi.org/10.3389/fmars.2020.00292

SCHOLZ, D., MICHEL, J., SHIGENAKA, G. & R. HOFF, 1992. Biological resources. In: An Introduction to Coastal habitats and Biological Resources for Oil Spill Response. Report HMRAD 92-4 pp (4)-1-66. NOAA Hazardous Materials Response and Assessment Division, Seattle.

SCHRATZBERGER, M., REES, H.L. & S.E. BOYD, 2000a. Effects of simulated deposition of dredged material on structure of nematode assemblages - the role of burial. *Mar. Biol.*, **136**: 519-530.

SCHRATZBERGER, M., REES, H.L. & S.E. BOYD, 2000b. Effects of simulated deposition of dredged material on structure of nematode assemblages - the role of contamination. *Mar. Biol.*, **137**: 613-622.

SCHUMANN, E.H. 1998. The coastal ocean off southeast Africa, including Madagascar coastal segment (15, W). In: The Sea, Vol.11. Robinson, A.R. & Brink, K. (eds). John Wiley & Sons, Inc.

SCHUT, E.W., UENZELMANN-NEBEN, G. & R. GERSONDE, 2002. Seismic evidence for bottom current activity at the Agulhas Ridge. *Global and Planetary Change* 34: 185–198.

SCOTT, R., BIASTOCH, A., RODER, C., STIEBENS, V.A. & C. EIZAGUIRRE, 2014. Nano-tags for neonates and ocean-mediated swimming behaviours linked to rapid dispersal of hatchling sea turtles. *Proc. R. Soc. B*, 281: 20141209.

SEAKAMELA, S.M., MEŸER, M.A., KOTZE, P.G.H., MCCUE, S. & S.P. KIRKMAN, 2015. Humpback whale (*Megaptera novaeangliae*): Suspended migration or confused individuals off the east coast? In: VERHEYE, H., HUGGETT, J. & R. CRAWFORS (Eds) State of ohe Oceans and Coasts Around South Africa - 2015 Report Card.

SEAKAMELA, S.M., KOTZE, P.H.G., MCCUE, S.A. & S. BENJAMIN, 2022. 23. The first satellite tracking of movements of long-finned pilot whales in South Africa. In: KIRKMAN, S.P., HUGGETT, J.A., LAMONT, T. & T. HAUPT (Eds.) Oceans and Coasts Annual Science Report 2021. Department of Forestry, Fisheries and the Environment, p26.

SEAKAMELA, S.M., McCUE, S.A. & P.G.H. KOTZE, 2020. Unusual mortality events of whales of the genus *Kogia* along the South Afrcan coastline. Top Predator Research Programme, Report for External Distribution, July 2020, Department of Environment, Forestry and Fisheries, pp15.

SEAKAMELA, S.M., KOTZE, P.G.H. & S.A. McCUE, 2021. 18. Unusual Mortality level of Kogiid whales in 2020. In: KIRKMAN, S.P., HUGGETT, J.A., LAMONT, T. & M.C. PFAFF (Eds.) Oceans and Coasts Annual Science Report 2020. Department of Forestry, Fisheries and the Environment, p23.

SEAKAMELA, S.M., KOTZE, P.H.G., McCUE, S.A., DE GOEDE, J., LAMONT, T., PIETERSE, J., SMITH, M. & T. ANTHONY, 2022. 25. Mortality event of Cape fur seals in South Africa during 2021. In: KIRKMAN, S.P., HUGGETT, J.A., LAMONT, T. & T. HAUPT (Eds.) Oceans and Coasts Annual Science Report 2021. Department of Forestry, Fisheries and the Environment, p28.

SEAKAMELA, S.M., KOTZE, P.G.H., GUMEDE, N.C., SIBIYA, N., SHABANGU, F.W. & S.A. McCUE, 2022. Finally sean: a rare sighting of Antractic blue whale cow-calf pair off the west coast of South Africa. Polar Biology, 45: 1715-1721

SELL, D., CONWAY, L., CLARK, T., PICKEN, G.B., BAKER, J.M., DUNNET, G.M., MCINTYRE, A.D. & R.B. CLARK, 1995. Scientific criteria to optimize oil spill Cleanup. In: Proceedings of the 1995 International Oil Spill Conference. American Petroleum Institute, Washington, DC, pp595-610.

SERRANO, R. de la H., LASTRA, M. & J. LOPEZ. Oil Spills. In: Encyclopedia of Environmental Health. Elsevier

SHABANGU, F.W. & R.K. ANDREW, 2020. Clicking throughout the year: sperm whale clicks in relation to environmental conditions off the west coast of South Africa. Endanger Species Res., 43:475–494

SHABANGU, F.W., FINDLAY, K.P., YEMANE, D., STAFFORD, K.M., VAN DEN BERG, M., BLOWS, B. & R.K. ANDREW, 2019. Seasonal occurrence and diel calling behaviour of Antarctic blue whales and fin whales in relation to environmental conditions off the west coast of South Africa. J. Mar. Syst., 190: 25–39.

SHANNON, L.J., C.L. MOLONEY, A. JARRE & J.G. FIELD, 2003. Trophic flows in the southern Benguela during the 1980s and 1990s. *Journal of Marine Systems*, **39**: 83 - 116.

SHANNON, L.V. & F.P. ANDERSON, 1982. Application of satellite ocean colour imagery in the study of the Benguela Current system. *S. Afr. J. Photogrammetry, Remote Sensing and Cartography*, **13(3)**: 153-169.

SHANNON, L.V. & J.G. FIELD, 1985. Are fish stocks food-limited in the southern Benguela pelagic ecosystem ? *Mar. Ecol. Prog. Ser.*, **22(1)** : 7-19.

SHANNON L.V. & S. PILLAR, 1985. The Benguela Ecosystem III. Plankton. *Oceanography and Marine Biology: An Annual Review*, **24**: 65-170.

SHANNON, L.V. & M.J. O'TOOLE, 1998. BCLME Thematic Report 2: Integrated overview of the oceanography and environmental variability of the Benguela Current region. Unpublished BCLME Report, 58pp

SHANNON, L., VAN DER ELST, R. & R. CRAWFORD, 1989. Tunas, bonitos, spanish mackerels and billfish. In: PAYNE, A. & R. CRAWFORD (eds), *Oceans of Life off southern Africa*. Cape Town, South Africa: Vlaeberg Publishers. pp 188–197.

SHAUGHNESSY, P.D. 1977. Flock size in Sabine's Gull. *Cormorant*. **3**: 17.

SHAUGHNESSY P.D., 1979. Cape (South African) fur seal. In: Mammals in the Seas. *F.A.O. Fish. Ser.*, 5, **2**: 37-40.

SHILLINGTON, F. A., PETERSON, W. T., HUTCHINGS, L., PROBYN, T. A., WALDRON, H. N. & J. J. AGENBAG, 1990. A cool upwelling filament off Namibia, South West Africa: Preliminary measurements of physical and biological properties. *Deep-Sea Res.*, **37 (11A)**: 1753-1772.

SHINE, K., 2006. Biogeographic patterns and diversity in demersal fish off the south and west coasts of south Africa: Implications for conservation. MSc thesis, Universty of Cape Town.

SHINE, K.H., 2008. Biogeographic Patterns and Assemblages of Demersal Fishes on the south and west coasts of South Africa. BCLME Project BEHP/BAC/03/03 Report. Cape Town, South Africa: Benguela Current Large Marine Ecosystem Programme.

SHORT, A.D. & P.A. HESP, 1985. Wave, beach and dune interactions in southern Australia. *Marine Geology*, **48**: 259-284.

SHPARKOVSKI, I.A., PETROV, V.S. & N.V. KOZAK, 1989. Physiological Criteria [for] Assessment of the Ecological Situation During Drilling on the Shelf. In: *Theses of the First All-Union Conference on Fisheries Toxicology*, **2**:199-200 Riga.

SIESSER, W.G., SCRUTTON, R.A. & E.S.W. SIMPSON, 1974 . Atlantic and Indian Ocean margins of southern Africa. In: Burk CA, Drake CL (eds), *The Geology of Continental Margins*. New York: Springer-Verlag. pp 641–654.

SIMMONS, R.E., 2005. Declining coastal avifauna at a diamond mining site in Namibia: comparisons and causes. *Ostrich*, **76**: 97-103.

SIMON-BLECHER, N., GRANEVITZE, Z. & Y. ACHITUV, 2008. *Balanus glandula*: from North-West America to the west coast of South Africa. *African Journal of Marine Science* **30**: 85-92.

SIMPSON, E.S.W. & E. FORDER, 1968. The Cape Submarine Canyon. *Fisheries Bulletin South Africa*. 5: 35–38.

SINK, K.J., BOSHOFF, W., SAMAAI, T., TIMM, P.G. & S.E. KERWATH, 2006. Observations of the habitats and biodiversity of the submarine canyons at Sodwana Bay. *South African Journal of Science* 102: 466-474.

SINK, K., HOLNESS, S., HARRIS, L., MAJIEDT, P., ATKINSON, L., ROBINSON, T., KIRKMAN, S., HUTCHINGS, L., LESLIE, R., LAMBERTH, S., KERWATH, S., VON DER HEYDEN, S., LOMBARD, A., ATTWOOD, C., BRANCH, G., FAIRWEATHER, T., TALJAARD, S., WEERTS, S., COWLEY, P., AWAD, A., HALPERN, B., GRANTHAM, H. & T. WOLF, 2012a. National Biodiversity Assessment 2011: Technical Report. Volume 4: Marine and Coastal Component. South African National Biodiversity Institute, Pretoria.

SINK, K. & C. LAWRENCE, 2008. Threatened Marine and Coastal Species in Southern Africa. SANBI Report, pp16.

SINK, K. & T. SAMAAI, 2009. Identifying Offshore Vulnerable Marine Ecosystems in South Africa. Unpublished Report for South African National Biodiversity Institute, 29 pp.

SINK, K.J, WILKINSON, S., ATKINSON, L.J, SIMS, P.F, LESLIE, R.W. & C.G. ATTWOOD, 2012b. The potential impacts of South Africa's demersal hake trawl fishery on benthic habitats: historical perspectives, spatial analyses, current review and potential management actions. Unpublished report, South African National Biodiversity Institute.

SINK, K.J., VAN DER BANK, M.G., MAJIEDT, P.A., HARRIS, L.R., ATKINSON, L.J., KIRKMAN, S.P. & N. KARENYI (eds), 2019. South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria. South Africa.

SIVLE, L.D., VEREIDE, E.H., DE JONG, K., FORLAND, T.N., DALEN, J. & H. WEHDE, 2021. Effects of Sound from Seismic Surveys on Fish Reproduction, the Management Case from Norway. *J. Mar. Sci. Eng.*, 9: 436. https://doi.org/10.3390/jmse9040436

SLABBEKOORN, H., DALEN, J., DE HAAN, D., WINTER, H.V., RADFORD, C., AINSLIE, M.A., HEANEY, K.D., VAN KOOTEN, T., THOMAS, L. & J. HARWOOD, 2019. Population-level consequences of seismic surveys on fishes: An interdisciplinary challenge. *Fish and Fisheries* 20(4): 653-685.

SLABBEKOORN, H. & W. HALFWERK, 2009. Behavioural ecology: Noise annoys at community level. *Current Biology*, 19: R693–R695.

SLR CONSULTING CANADA, 2023. Proposed Offshore Exploration Drilling Campaign in Block 3B/4B. Underwater Sound Transmission Loss Modelling. Prepared for EIMS. October 2023. 87pp.

SMALE, M.J., ROEL, B.A., BADENHORST, A. & J.G. FIELD, 1993. Analysis of the demersal community of fish and cephalopods on the Agulhas Bank, South Africa. *J Fish Biol.*, 43: 169–191.

SMIT, M.G.D., HOLTHAUS, K.I.E., TAMIS, J.E., JAK, R.G., KARMAN, C.C., KJEILEN-EILERTSEN, G., TRANNUM, H. & J. NEFF, 2006. *Threshold levels and risk functions for non-toxic sediment stressors: burial, grain size changes, and hypoxia - summary report – TNO.*

SMIT, M.G.D., HOLTHAUS, K.I.E., TRANNUM, H.C., NEFF, J.M., KJEILEN-EILERTSEN, G., JAK, R.G., SINGSAAS, I., HUIJBREGTS, M.A.J. & A.J. HENDRIKS, 2008. Species sensitivity distributions for suspended clays, sediment burial, and grain size change in the marine environment. *Environmental Toxicology and Chemistry*, **27**: 1006-1012.

SMITH, M.M. & P.C. HEEMSTRA, 2003. Smiths' Sea Fishes. Penguin Random House South Africa.

SMITH, G.G & G.P. MOCKE, 2002. Interaction between breaking/broken waves and infragravity-scale phenomena to control sediment sediment suspension and transport in the surf zone. *Marine Geology*, **187**: 320-345.

SMITH, S.D.A. & M.J. RULE, 2001. The effects of dredge-spoil dumping on a shallow water soft-sediment community in the Solitary Islands Marine Park, NSW, Australia. *Mar. Pollut. Bull.*, **42**: 1040-1048.

SMULTEA, M.A., KIECKHEFER, T.R. & A.E. BOWLES, 1995. Response of humpback whales to an observation aircraft as observed from shore near Kauai, Hawaii, 1994. Final Report for the 1994 Marine Mammal Research Program of the Acoustic Thermometry of Ocean Climate (ATOC) study. Prepared by the Bioacoustics Research Program of the Cornell Laboratory of Ornithology, Cornell University, Ithaca, NY, USA. 46 p.

SMULTEA, M.A., MOBLEY, J.R., FERTL, D. & G.L. FULLING, 2008. An unusual reaction and other observations of sperm whales near fixed-wing aircraft. *Gulf and Caribbean Research* **20**: 75-80.

SMULTEA, M.A. & B. WÜRSIG, 1995. Behavioral reactions of bottlenose dolphins to the Mega Borg oil spill, Gulf of Mexico 1990. Aquat. Mamm., 21: 171–181.

SOARES, A.G., 2003. Sandy beach morphodynamics and macrobenthic communities in temperate, subtropical and tropical regions - a macroecological approach. PhD, University of Port Elizabeth

SOARES, A.G., McLACHLAN, A. & T.A. SCHLACHER, 1996. Disturbance effects of stranded kelp on populations of the sandy beach bivalve *Donax serra* (Röding). *Journal of Experimental Marine Biology and Ecology* **205**: 165-186.

SOARES, A.G., SCHLACHER, T.A. & A. McLACHLAN, 1997. Carbon and nitrogen exchange between sandy beach clams. *Marine Biology* **127**: 657-664.

SOLAN, M., HAUTON, C., GODBOLD, J.A., WOOD, C.L., LEIGHTON, T.G. & P. WHITE, 2016. Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. *Sci. Rep.*, 6: 20540.

SOUTHALL, B.L., A.E. BOWLES, W.T. ELLISON, J.J. FINNERAN, R.L. GENTRY, C.R. GREENE, JR., D. KASTAK, D.R. KETTEN, J.H., MILLER, P.E. NACHTIGALL, W.J. RICHARDSON, J.A. THOMAS & P.L. TYACK, 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals, 33(4): 411-522.

SOUTHALL, B.L., ROWLES, T., GULLAND, F., BAIRD, R.W. & P.D. JEPSON, 2008. Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (*Peponocephala electra*) in Antsohihy, Madagascar.

SOUTHALL, B.L., FINNERAN, J.J., REICHMUTH, C., NACHTIGALL, P.E., KETTEN, D.R., BOWLES, A.E., ELLISON, W.T., NOWACEK, D.P. & P.L. TYACK, 2019. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals 2019, 45(2), 125-232,

SPOONER, E., KARNAUSKAS, M., HARVEY, C.J., KELBLE, C., ROSELLON-DRUKER, J., KASPERSKI, S., LUCEY, S.M., ANDREWS, K.S., GITTINGS, S.R., MOSS, J.H., GOVE, J.M., SAMHOURI, J.F., ALLEE, R.J., BOGRAD, S.J., MONACO, M.E., CLAY, P.M., ROGERS, L.A., MARSHAK, A., WONGBUSARAKUM, S., BROUGHTON, K. & P.D. LYNCH, 2021. Using Integrated Ecosystem Assessments to Build Resilient Ecosystems, Communities, and Economies, Coastal Management, 49:1, 26-45, DOI: 10.1080/08920753.2021.1846152

SPRAGUE, J.B. & W.J. LOGAN, 1979. Separate and joint toxicity to rainbow trout of substances use in drilling fluid for oil exploration. *Environ. Pollut.*, **19**: 269-281.

SPRFMA, 2007. Information describing seamount habitat relevant to the South Pacific Regional Fisheries Management Organisation.

STARCZAK, V.R., FULLER, C.M. & C.A. BUTMAN, 1992. Effects of barite on aspects of ecology of the polychaete *Mediomastus ambiseta*. *Marine Ecology Progress Series,* **85**: 269-282.

STEFFANI, N., 2007a. Biological Baseline Survey of the Benthic Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area off Pomona for the Marine Dredging Project. *Prepared for De Beers Marine Namibia (Pty) Ltd.* pp. 42 + Appendices.

STEFFANI, N., 2007b. Biological Monitoring Survey of the Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area between Kerbehuk and Bogenfels. 2005 Survey. *Prepared for De Beers Marine Namibia (Pty) Ltd.* pp. 51 + Appendices.

STEFFANI, N., 2009a. Biological monitoring surveys of the benthic macrofaunal communities in the Atlantic 1 Mining Licence Area and the inshore area - 2006/2007. Prepared for De Beers Marine Namibia (Pty) Ltd. pp. 81 + Appendices.

STEFFANI, C.N., 2009b. *Assessment of Mining Impacts on Macrofaunal Benthic Communities in the Northern Inshore Area of the De Beers ML3 Mining Licence Area - 18 Months Post-mining.* Prepared for De Beers Marine (South Africa), 47pp.

STEFFANI, C.N., 2010a. Biological monitoring surveys of the benthic macrofaunal communities in the Atlantic 1 Mining Licence Area - 2008. Prepared for De Beers Marine Namibia (Pty) Ltd. pp. 40 + Appendices.

STEFFANI, C.N., 2010b. Benthic grab monitoring survey in the Atlantic 1 Mining Licence Area -2009- sediment composition. Prepared for De Beers Marine Namibia (Pty) Ltd. pp. 19 + Appendix.

STEFFANI, C.N., 2010c. *Assessment of mining impacts on macrofaunal benthic communities in the northern inshore area of the De Beers Mining Licence Area 3 – 2010* . Prepared for De Beers Marine (South Africa). pp 30 + Appendices.

STEFFANI, C.N., 2012a. *Assessment of Mining Impacts on Macrofaunal Benthic Communities in the Northern Inshore Area of the ML3 Mining Licence Area - 2011.* Prepared for De Beers Marine (South Africa), July 2012, 54pp.

STEFFANI, C.N., 2012b. Assessment of mining impacts on macrofaunal benthic communities in the northern inshore area of mining licence area 3.

STEFFANI, C.N., 2014. Assessment of mining impacts on macrofaunal benthic communities in the northern inshore area of mining licence area MPT 25-2011.

STEFFANI, C.N. & G.M. BRANCH, 2003a. Spatial comparisons of populations of an indigenous limpet *Scutellastra argenvillei* and an alien mussel *Mytilus galloprovincialis* along a gradient of wave energy. *African Journal of Marine Science* **25**: 195-212.

STEFFANI, C.N. & G.M. BRANCH, 2003b. Temporal changes in an interaction between an indigenous limpet *Scutellastra argenvillei* and an alien mussel *Mytilus galloprovincialis*: effects of wave exposure. *African Journal of Marine Science* **25**: 213-229.

STEFFANI, C.N. & G.M. BRANCH, 2005. Mechanisms and consequences of competition between an alien mussel, *Mytilus galloprovincialis*, and an indigenous limpet, *Scutellastra argenvillei*. *Journal of Experimental Marine Biology and Ecology* **317**: 127-142.

STEFFANI, C.N. & A. PULFRICH, 2004. The potential impacts of marine dredging operations on benthic communities in unconsolidated sediments. Specialist Study Report. In: PISCES ENVIRONMENTAL SERVICES (PTY) LTD, 2004. *Marine Dredging Project Pre-Feasibility Study, Environmental Impact Assessment, Volume II: Specialist Studies & Appendices.* Prepared for De Beers Marine (Pty) Ltd. and Namdeb Diamond Corporation (Pty) Ltd. 46pp.

STEFFANI, C.N. & A. PULFRICH, 2007. Biological Survey of the Macrofaunal Communities in the Atlantic 1 Mining Licence Area and the Inshore Area between Kerbehuk and Lüderitz 2001 – 2004 Surveys. *Prepared for De Beers Marine Namibia, March 2007*, 288pp.

STEFFANI, N., SEDICK, S., ROGERS, J. & M.J. GIBBONS, 2015. Infaunal benthic communities from the inner shelf off Southwestern Africa are characterised by generalist species. PLoS ONE 10(11): e0143637. doi:10.1371/journal.pone.0143637.

STEGENGA, H., BOLTON, J.J. & R.J. ANDERSON, 1997. Seaweeds of the South African West Coast. *Contributions from the Bolus Herbarium, No. 18.* Creda Press, Cape Town. 655 pp.

STEINHAUER, M., CRECELIUS, E. & W. STEINHAUER, 1994. Temporal and spatial changes in the concentrations of hydrocarbons and trace metals in the vicinity of an offshore oil-production platform. *Marine Environmental Research*, **37**: 129-163.

STENEVIK, E.K., VERHEYE, H.M., LIPINSKI, M.R., OSTROWSKI, M. & T. STRØMME, 2008. Drift routes of Cape hake eggs and larvae in the southern Benguela Current system. Journal of Plankton Research Vol. 30:10. Pp. 1147 – 1156.

STEWART, B.S., EVANS, W.E. & F.T. AWBREY, 1982. Effects of man-made waterborne noise on behaviour of belukha whales (*Delphinapterus leucas*) in Bristol Bay, Alaska. Unpublished report for National Oceanic and Atmospheric Administration, Juneau, Alaska, by Hubbs/Sea World Research Institute, San Deigo, California. HSWRI Technical Report 82-145.

STOUT, S. A., ROUHANI, S., LIU, B., OEHRIG, J., RICKER, R. W., BAKER, G., *et al.* (2017). Assessing the footprint and volume of oil deposited in deep-sea sediments following the Deepwater Horizon oil spill. *Mar. Pollut. Bull.* 114: 327–342.

STRØMME, T., LIPINSKI, M.R. & P. KAINGE, 2015. Life cycle of hake and likely management implications. Rev. Fish. Biol. Fisheries, DOI 10.1007/s11160-015-9415-9

TAGATZ, M.E. & M. TOBIA, 1978. Effect of barite (BaSO4) on development of estuarine communities. *Estuarine and Coastal Marine Science,* **7**: 401-407.

TAIT, R.D., MAXON, C.L., PARR, T.D. & F.C. NEWTON III, 2016. Benthos response following petroleum exploration in the southern Caspian Sea: Relating effects of nonaqueous drilling fluid, water depth, and dissolved oxygen. Marine Pollution Bulletin, 110: 520-527.

TANG, D., SUN, J., ZHOU, L., WANG, S., SINGH, R.P. & G. PAN, 2019. Ecological response of phytoplankton to the oil spills in the oceans, Geomatics, Natural Hazards and Risk, 10(1): 853-872

TAUNTON-CLARK, J., 1985. The formation, growth and decay of upwelling tongues in response to the mesoscale windfield during summer. *In*: South African Ocean Colour and Upwelling Experiment. Shannon L.V. (ed.). Sea Fisheries Research Institute, Cape Town. pp 47-62.

TAYLOR, P.B., 1987. Experimental evidence for juvenile Chinook salmon, *Oncorhynchus tshawytscha* Walbaum, orientation at night and in sunlight after a 7º change in latitude. *Journal of Fish Biology* **31**: 89-111.

TEAL, J.M. & R.W. HOWARTH, 1984. Oil spill studies: a review of ecological effects. *Environmental Management*, **8**: 27-44.

THOMISCH, K., 2017. Distribution patterns and migratory behavior of Antarctic blue whales. *Reports on Polar and Marine Research* **707**: pp194. doi:10.2312/BzPM_0707_2017

THOMISCH, K., BOEBEL, O., BACHMANN, J., FILUN, D., NEUMANN, S., SPIESECKE, S. & I. VAN OPZEELAND, 2019. Temporal patterns in the acoustic presence of baleen whale species in a presumed breeding area off Namibia. Mar Ecol Prog Ser 620:201–214.

THOMISCH, K., BOEBEL, O., CLARK, C.W., HAGEN, W., SPIESECKE, S., ZITTERBART, D.P. & I. VAN OPZEELAND, 2016. Spatio-temporal patterns in acoustic presence and distribution of Antarctic blue whales Balaenoptera musculus intermedia in the Weddell Sea. Endanger Species Res 30:239–253.

THOMSON, D.R., DAVIS, R.A., BELLORE, R., GONZALEZ, E., CHRISTIAN, J., MOULTON, V. & K HARRIS, 2000. Environmental assessment of exploration drilling off Nova Scotia. Report by LGL Limited for Canada-Nova Scotia Offshore Petroleum Board. Mobil Oil Canada Properties Ltd.. Shell Canada Ltd.. Imperial Oil Resources Ltd.. Gulf Canada Resources Ltd.. Chevron Canada Resources, PanCanadian Petroleum. Murphy Oil Ltd.. and Norsk Hydro. 278 p.

THRESHER, R.E., 1999. Diversity, impacts and options for managing invasive marine species in Australian waters. *Australian Journal of Environmental Management* 6: 164–74.

TISSOT, B.N., YOKLAVICH, M.M., LOVE, M.S., YORK, K. & M. AMEND, 2006. Benthic invertebrates that form habitat on deep banks off southern California, with special reference to deep sea coral. *Fishery Bulletin*, 104: 167–181.

TOWNER, A.V., WATSON, R.G.A., KOCK, A.A., PAPASTAMATIOU, Y., STURUP, M., GENNARI, E., BAKER, K., BOOTH, T., DICKEN, M., CHIVELL, W., ELWEN, S, KASCHKE, T., EDWARDS, D. & M.J. SMALE, 2022. Fear at the top: killer whale predation drives white shark absence at South Africa's largest aggregation site, *African Journal of Marine Science*, 44(2): 139-152.

TRANNUM, H.C., NILSSON, H.C., SCHAANNING, M.T. & S. ØXNEVAD, 2010. Effects of sedimentation from water-based drill cuttings and natural sediment on benthic macrofaunal community structure and ecosystem processes. *Journal of Experimental Marine Biology and Ecology,* **383**: 111-121.

TRANNUM, H.C., SETVIK, A., NORLING, K. AND H.C. NILSSON, 2011. Rapid macrofaunal colonization of water-based drill cuttings on different sediments. *Mar. Pollut. Bull.*, 62: 2145-2156.

TREFRY, J.H., DUNTON, K.H., TROCINE, R.P, SCHONBERG, S.V., MCTIGUE, N.D., HERSH E.S. & T.J. McDONALD, 2013. Chemical and biological assessment of two offshore drilling sites in the Alaskan Arctic. *Marine Environmental Research*, **86**: 35-45.

TRICUS, T.C., 2001. The neuroecology of the elasmobranch electrosensory world: why peripheral morphology shapes behavior. *Environmental Biology of Fishes* **60**: 77-92.

TURK, T.R. & M.J. RISK, 1981. Effects of sedimentation of infaunal invertebrate populations in Cobequid Bay, Bay of Fundy. *Can. J. Fish. Aquat. Sci.*, **38**: 642-648.

TURPIE, J.K., WILSON, G. & L. VAN NIEKERK, 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting, Cape Town, Report produced for the Council for Scientific and Industrial Research and the South African National Biodiversity Institute.

TYACK, P.L., ZIMMER, W.M.X., MORETTI, D., SOUTHALL, B.L., CLARIDGE, D.E., DURBAN, J.W., CLARK, C.W., *et al.*, 2011. Beaked Whales Respond to Simulated and Actual Navy Sonar, 6(3). doi:10.1371/journal.pone.0017009

TYARKS, S.C., ANICETO, A.S., AHONEN, H., PEDERSEN, G. & U. LINDSTRØM, 2021. Humpback Whale (*Megaptera novaeangliae*) Song on a Subarctic Feeding Ground. F*rontiers in Marine Science*, https://doi.org/10.3389/fmars.2021.669748.

U.S. DEPARTMENT OF THE INTERIOR. MMS GULF OF MEXICO OCS REGION. 2000. Press Release: Deepwater Production in the Gulf of Mexico Jumps Dramatically. 26 June, 2000. <http://www.gomr.mms.gov/homepg/whatsnew/newsreal/000626s.html>.

UENZELMANN-NEBEN, G., & K. GOHL, 2004. The Agulhas Ridge, South Atlantic: The Peculiar Structure of a Fracture Zone. *Marine Geophysical Researches* 25: 305–319.

VALENTINE, M.M. & M.C. BENFIELD, 2013. Characterization of epibenthic and demersal megafauna at Mississippi Canyon 252 shortly after the Deepwater Horizon oil spill. *Marine Pollution Bulletin* 77: 196–209.

VAN DALFSEN, J.A., ESSINK, K., TOXVIG MADSEN, H., BIRKLUND, J., ROMERO, J. & M. MANZANERA, 2000. Differential response of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. *ICES J. Mar. Sci.,* **57**: 1439–1445.

VAN NIEKERK, L., ADAMS, J.B., LAMBERTH, S.J., MACKAY, C.F., TALJAARD, S., TURPIE, J.K., WEERTS S.P. & RAIMONDO, D.C., 2019 (eds). South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. CSIR report number CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A. http://hdl.handle.net/20.500.12143/6373.

VAN WEELDEN, C., TOWERS, J.R. & T. BOSKER, 2021. Impacts of climate change on cetacean distribution, habitat and migration. *Clim. Change Ecol.*, 1: 100009.

VELIMIROV, B., FIELD, J.G., GRIFFITHS, C.L. & P. ZOUTENDYK, 1977. The ecology of kelp bed communities in the Benguela upwelling system. *Helgoländer Meeresunters*, **30**: 495-518.

VENN-WATSON, S., COLEGROVE, K.M., LITZ, J., KINSEL, M., TERIO, K., SALIKI, J., FIRE, S., CARMICHAEL, R., CHEVIS, C., HATCHETT, W., PITCHFORD, J., TUMLIN, M., FIELD, C., SMITH, S., EWING, R., FAUQUIER, D., LOVEWELL, G., WHITEHEAD, H., ROTSTEIN, D., MCFEE, W., FOUGERES, E., ROWLES, T., 2015. Adrenal gland and lung lesions in Gulf of Mexico common bottlenose dolphins (*Tursiops truncatus*) found dead following the Deepwater Horizon oil spill. Plos One 10 (23 pp.).

VERMEULEN, E., WILKINSON, C., & G. VAN DEN BERG, 2020. Report of the 2019 South African southern right whale aerial survey. Report to IWC. 10.13140/RG.2.2.29556.37766.

VERMEULEN, E., JOUVE, E., BEST, P., CLIFF, G., DICKEN, M., KOTZE D, *et al*. 2022. Mortalities of southern right whales (*Eubalaena australis*) and related anthropogenic factors in South African waters, 1999–2019 . *Journal of Cetacean Research and Management*, 23(1): 149-169.

VILLEGAS-AMTMANN, S., SCHWARZ, L.K., GAILEY, G., SYCHENKO, O. & D.P. COSTA, 2017. East or west: the energetic cost of being a gray whale and the consequence of losing energy to disturbance. *Endangered Species Research*, 34: 167-183.

VILLEGAS-AMTMANN, S., SCHWARZ, L.K., SUMICH, J.L. & D.P. COSTA, 2015. A bioenergetics model to evaluate demographic consequences of disturbance in marine mammals applied to gray whales. *Ecosphere,* 6(10): art183.

VISSER, G.A., 1969. Analysis of Atlantic waters off the coast of southern Africa. *Investigational Report Division of Sea Fisheries, South Africa*, 75: 26 pp.

VOLKMAN, J.K., MILLER, G.J., REVILL, A.T. & D.W. CONNELL, 1994. Environmental implications of offshore oil and gas development in Australia – oil spills. In: SWAN, J.M., NEFF, J.M. & P.C. YOUNG (eds), Environmental implications of offshore oil and gas development in Australia. The findings of an independent scientific review. Australian Exploration Association, Sydney. pp 509-695.

WALKER, D.R & W.T. PETERSON, 1991. Relationships between hydrography, phytoplankton production, biomass, cell size and species composition, and copepod production in the southern Benguela upwelling system in April 1988. *S. Afr. J. mar. Sci.*, **11**: 289-306

WALLACE, B., RISSING, M., CACELA, D., GARRISON, L., SCHROEDER, B., MCDONALD, T., MCLAMB, D., WITHERINGTON, B. & B. STACY, 2016. *Estimating degree of oiling of sea turtles and surface habitat during the Deepwater Horizon oil spill: implications for injury quantification.* NOAA report. https://www.doi.gov/deepwaterhorizon/adminrecord

WANG, F. & P.M. CHAPMAN, 1999. Biological implications of sulfide in sediment—a review focusing on sediment toxicity. *Environ. Toxicol. Chem.*, **18**: 2526-2532.

WARD, L.G., 1985. The influence of wind waves and tidal currents on sediment resuspension in Middle Chesapeake Bay. *Geo-Mar. Letters,* **5**: 1-75.

WARTZOK, D., A.N. POPPER, J. GORDON, & J. MERRILL, 2004. Factors affecting the responses of marine mammals to acoustic disturbance. Mar. Technology Soc. J., 37(4): 6-15.

WARWICK, R.M., 1993. Environmental impact studies on marine communities: Pragmatical considerations. *Australian Journal of Ecology,* **18**: 63-80.

WASSON, K., ZABIN, C.J., BEDINGER, L., CRISTINA DIAZ, M. & J.S. PEARSE, 2001. Biological invasions of estuaries without international shipping: the importance of intraregional transport. *Biological Conservation* 102: 143–153.

WATKINS, W.A., 1981. Activities and underwater sounds of fin whales. *Scientific Reports of the Whales Research Institute* **33**: 83-117.

WATKINS, W.A. 1986. Whale reactions to human activities in Cape Cod waters. Mar. Mamm. Sci., 2(4): 251-262.

WATKINS, W.A. & W.E. SCHEVILL, 1977. Sperm whale codas. *Journal of the Acoustical Society of America* **62**: 1485-90 + disk in pocket.

WEIR, C.R., 2011. Distribution and seasonality of cetaceans in tropical waters between Angola and the Gulf of Guinea. *African Journal of Marine Science* 33(1): 1-15.

WEIR, C.R., COLLINS, T., CARVALHO, I. & H.C. ROSENBAUM, 2010. Killer whales (*Orcinus orca*) in Angolan and Gulf of Guinea waters, tropical West Africa. *Journal of the Marine Biological Association of the U.K.* **90**: 1601– 1611.

WEISBERG, R.H., ZHENG, L., Liu, Y., MURAWSKI, S., Hu, C. & J.P. CHUANMIN HU, 2016. Did Deepwater Horizon hydrocarbons transit to the west Florida continental shelf? Deep-Sea Research II, 129: 259-272.

WHEELER, A.J., KOZACHENKO, M., BEYER, A., FOUBERT, A., HUVENNE, V.A.I., KLAGES, M., MASSON, D.G., OLU-LE ROY, K. & J. THIEDE, 2005. Sedimentary processes and carbonate mounds in the Belgica Mound province, Porcupine Seabight, NE Atlantic. In: *Cold-water Corals and Ecosystems*, FREIWALD, A & J.M. ROBERTS, (eds). Springer-Verlag Berlin Heidelberg pp. 571-603.

WHITE, R.W., GILLON, K.W., BLACK, A.D. & J.B. REID, 2001. Vulnerable concentrations of seabirds in Falkland Islands waters.. JNCC, Peterborough.

WHITE, H.K., P.Y. HSING, W. CHO, T.M. SHANK, E.E. CORDES, A.M. QUATTRINI, R.K. NELSON, R. CAMILLI, A.W.J. DEMOPOULOS, C.R. GERMAN, *et al.*, 2012. Impact of the Deepwater Horizon oil spill on a deep-water coral community in the Gulf of Mexico. Proceedings of the National Academy of Sciences of the United States of America 109: 20303–20308.

WHITE, H.K., LYONS, S.L., HARRISON, S.J., FINDLEY, D.M., LIU, Y. & E.B. KUJAWINSKI, 2014. Long- Term Persistence of Dispersants following the Deepwater Horizon Oil Spill. Environ. Sci. Technol. Lett. 1, 295–299.

WHITEHEAD, H., 2002. Estimates of the current global population size and historical trajectory for sperm whales. *Marine Ecology Progress Series*, 242: 295-304.

WHITT, A., WARDE, A., BLAIR, L., DESLARZES, K., & C. CHAINEAU, 2023. Recent occurrence of marine mammals and sea turtles off Angola and first report of right whales since the whaling era. *Journal of the Marine Biological Association of the United Kingdom*, 103, E9. doi:10.1017/S0025315422001084.

WICKENS, P., 1994. Interactions between South African Fur Seals and the Purse-Seine Fishery. *Marine Mammal Science*, **10**: 442–457.

WIESE, F.K., MONTEVECCHI, W.A., DAVOREN, G.K., HUETTMANN, F., DIAMOND, A.W. & J. LINKE, 2001. Seabirds at risk around offshore oil platforms in the north-west Atlantic. *Mar. Pollut. Bull.* 42: 1285–1290.

WIGLEY, R.A., 2004. *Sedimentary facies from the head of the Cape Canyon: Insights into the Cenozoic evolution of the western margin of South Africa.* PhD Thesis, University of Cape Town, South Africa.

WIGLEY, R.A. & J.S. COMPTON, 2006. Late Cenozoic evolution of the outer continental shelf at the head of the Cape Canyon, South Africa. *Marine Geolog*y, 226: 1–23.

WILKINSON, C., 2021. Estimating population changes in humpback whales (*Megaptera novaeangliae*) migrating past Cape Vidal, South Africa. MSc Thesis, Cape Peninsula University of Technology, pp108.

WILKINSON, S. & D. JAPP, 2005. Description and Evaluation of Hake-directed Trawling Intensity on benthic habitat in South Africa. Prepared for the South African Deepsea Trawling Industry Association in fulfilment of the Marine Stewardship Council certification of the South African Hake-Directed Trawl Fishery : Condition 4. pp75.

WISE, C.F.,WISE, J.T.F.,WISE, S.S., THOMPSON,W.D.,WISE JR., J.P.,WISE SR., J.P., 2014a. Chemical dispersants used in the Gulf of Mexico oil crisis are cytotoxic and genotoxic to sperm whale skin cells. Aquat. Toxicol., 152: 335–340.

WISE JR., J.P., WISE, J.T.F., WISE, C.F., WISE, S.S., GIANIOS JR., C., XIE, H., THOMPSON, W.D., PERKINS, C., FALANK, C., WISE SR., J.P., 2014b. Concentrations of the genotoxic metals, chromium and nickel, in whales, tar balls, oil slicks, and released oil from the Gulf of Mexico in the immediate aftermath of the Deepwater Horizon oil crisis: Is genotoxic metal exposure part of the Deepwater Horizon legacy? Environ. Sci. Technol., 48: 2997–3006.

WITHROW, D.E., 1983. Gray whale research in Scammon's Lagoon (Laguna Ojo de Liebre). *Cetus* **5(1)**: 8-13.

WOLFSON, A., VAN BLARICOM, G., DAVIS, N. & G.S. LEWBE, 1979. The marine life of an offshore oil platform. *Marine Ecology Progress Series,* **1**: 81-89.

WU, R.S.S., 2002. Hypoxia: from molecular responses to ecosystem responses. *Mar. Pollut. Bull.*, **45**: 35-45.

WÜRSIG, B., LYNN, S.K., JEFFERSON, T.A. & K.D. MULLIN, 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. *Aquatic Mammals* **24**: 41-50.

YANG, T., NIGRO, L.M., GUTIERREZ, T., D'AMBROSIO, L., JOYE, S.B., HIGHSMITH, R. & A. TESKE, 2016, Pulsed blooms and persistent oil-degrading bacterial populations in the water column during and after the Deepwater Horizon blowout, *Deep Sea Res., Part II, 129:* 282–291,

YEMANE, D., MAFWILA, S.K., KATHENA, J., NSIANGANGO, S.E. & S.P. KIRKMAN, 2015. Spatio-temporal trends in diversity of demersal fish species in the Benguela current large marine ecosystem region. *Fisheries Oceanography*, 24(S1): 102-121.

ZAJAC, R.N., LEWIS, R.S., POPPE, L.J., TWICHELL, D.C., VOZARIK, J., & M.L. DIGIACOMO-COHEN, 2000. Relationships among sea-floor structure and benthic communities in Long Island Sound at regional and benthoscape scales. *J. Coast. Res.,* **16**: 627– 640.

ZETTLER, M.L., BOCHERT, R. & F. POLLEHNE. 2009. Macrozoobenthos diversity in an oxygen minimum zone off northern Namibia. Marine Biology **156**:1949-1961.

ZETTLER, M.L., BOCHERT, R. & F. POLLEHNE. 2013. Macrozoobenthic biodiversity patterns in the northern province of the Benguela upwelling system. African Journal of Marine Science, 35(2): 283-290.

ZHOU, L., TANG, D.L. & J. SUN, 2013. Investigation of marine phytoplankton blooms after the oil spills in the seas. Ecol. Sci., 32: 692–702.

ZHOU, Z., LI, X., CHEN, L., LI, B., WANG, C., GUO, J., SHI, P., YANG, L., LIU, B. & B. SONG, 2019. Effects of diesel oil spill on macrobenthic assemblages at the intertidal zone: A mesocosm experiment *in situ*. Marine Environmental Research **152**: 104823.

ZONFRILLO, B., 1992. The menace of low-flying aircraft to Ailsa Craig. *Scottish Bird News*, 28 :4.

ZOUTENDYK, P., 1992. Turbid water in the Elizabeth Bay region: A review of the relevant literature. CSIR Report EMAS-I 92004.

ZOUTENDYK, P., 1995. Turbid water literature review: a supplement to the 1992 Elizabeth Bay Study. CSIR Report EMAS-I 95008.

APPENDIX 1

The Impact Assessment Methodology

The impact significance rating methodology, as provided by EIMS, is guided by the requirements of the NEMA EIA Regulations, 2014. The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/ likelihood (P) of the impact occurring. This determines the environmental risk. Additionally, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$\boldsymbol{C} = \frac{(\boldsymbol{E} + \boldsymbol{D} + \boldsymbol{M} + \boldsymbol{R}) * \boldsymbol{N}}{\boldsymbol{4}}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 17.

Table 17: Criteria for determination of impact consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e., limited to the area applicable to the specific activity)
	2	Site (i.e., within the block)
	3	Local (i.e., the area within 5 km of the site)
	4	Regional (i.e., extends between 5 and 50 km from the site
	5	Provincial / National (i.e., extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years)
	3	Medium term (6-15 years)
	4	Long term (the impact will cease after the operational life span of the project)

	5	Permanent (no mitigation measure of natural process will reduce the impact after construction)
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected)
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way)
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease)
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease)
Reversibility	1	Impact is reversible without any time and cost
	2	Impact is reversible without incurring significant time and cost
	3	Impact is reversible only by incurring significant time and cost
	4	Impact is reversible only by incurring prohibitively high time and cost
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table 18.

Table 18: Probability scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or

	5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table 19: Determination of environmental risk

Consequence						
	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in

Table 20.

Table 20: Significance classes

Risk Score	Description
< 10	Low (i.e., where this impact is unlikely to be a significant environmental risk),
≥ 10; < 20	Medium (i.e., where the impact could have a significant environmental risk),
≥ 20	High (i.e., where the impact will have a significant environmental risk).

Also taken into account, but not included in the calculations is **Determination of Sensitivity**

Sensitivity is a term that covers the ‘importance’ (e.g. value of an ecological receptor) or ‘vulnerability’ (e.g. ability of a receptor to cope with change) of a receptor to a project-induced change. It takes into account ‘Irreplaceability’ - measure of the value of, and level of dependence on, impacted resources, as well as of consistency with policy (e.g. conservation) targets or thresholds.

Broad definitions of sensitivity ratings for ecological and physical/abiotic receptors are defined below. These are not exhaustive and may be modified on a case by case basis, as appropriate.

Sensitivity Rating	Definition
Ecological Receptor	Species, habitats or ecosystems including processes necessary to maintain ecosystem functions
Very Low	Species or habitats with negligible importance for biodiversity including habitats that are largely transformed or highly modified.
Low	Species or habitats listed as Least Concern (LC) on the International Union for Conservation of Nature (IUCN) Red List or on regional or national Red Lists and/or habitats or species which are common and widespread, of low conservation interest, or habitats which are degraded and qualify as 'modified habitat' under international definitions (e.g. IFC or World Bank standards).
Medium	Species, habitats or ecosystems listed as globally Vulnerable (VU) or Near Threatened (NT) on IUCN Red List; or listed as VU or NT on national or regional Red Lists, or which meet the IUCN criteria based on expert-driven biodiversity planning processes. It includes habitats that meet definitions of 'natural habitat'; or ecosystems with important functional value in maintaining the biotic integrity of these habitats or VU or NT species.
High	Species, habitats or ecosystems listed as globally Endangered (EN) or Critically Endangered (CR) by IUCN, or listed as EN/CR on national or regional Red Lists; or which meet IUCN criteria for range-restricted species[17] or which meet the definition of migratory and congregatory species[18], but which do not qualify as Critical Habitat based on IUCN Key Biodiversity Area thresholds[19]. It includes habitats or ecosystems which are important for meeting national conservation targets based on expert-driven national or regional systematic conservation planning processes, but which do not meet global IUCN thresholds. It can also include protected areas such as national parks, marine protected areas or ecological support areas designated for biodiversity protection containing species that are nationally or globally listed as EN or CR, or other designated areas important for the persistence of EN/CR species or habitats.
Very High	Species, habitats or ecosystems listed as globally Endangered (EN) or Critically Endangered (CR) by IUCN, or listed as EN/CR on expert-verified national or regional Red Lists; or which meet IUCN criteria for range-restricted or migratory /congregatory species and which meet IUCN thresholds for Key Biodiversity Areas. It includes habitats or ecosystems which are of high importance for maintaining the persistence of species or habitats that meet critical habitat thresholds. Habitats of high sensitivity may typically include legally protected areas that meet IUCN categories 1, 1a and 1b[20], or KBAs or Important Bird Areas (IBAs) with biodiversity features that meet the IUCN KBA criteria and thresholds.
Physical Abiotic Receptors	**Water quality, sediment quality, air quality, noise levels**
Very Low	Receptors are highly resilient to project-induced change and changes remain undetectable and within any applicable thresholds.
Low	Receptors are resilient to project-induced change and changes, while detectable, are within the range of natural variation and remain within any applicable thresholds.

[17] Restricted range species are those with limited Extent Of Occurrence (EOO) (GN74):

- For terrestrial vertebrates and plants, a restricted-range species is defined as those species that have an EOO less than 50,000 square kilometres (km2).
- For marine systems, restricted-range species are provisionally being considered those with an EOO of less than 100,000 km2.
- For coastal, riverine, and other aquatic species in habitats that do not exceed 200 km width at any point (for example, rivers), restricted range is defined as having a global range of less than or equal to 500 km linear geographic span (i.e., the distance between occupied locations furthest apart)

[18] Migratory species are defined as any species of which a significant proportion of its members cyclically and predictably move from one geographical area to another (including within the same ecosystem) (GN76). Congregatory species are defined as species whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis.

[19] IUCN, A Global Standard for the Identification of Key Biodiversity Areas, 2016.

[20] IUCN, "Protected Areas Category", https://www.iucn.org/theme/protected-areas/about/protected-area-categories

Sensitivity Rating	Definition
Medium	Receptors are moderately resilient to project-induced changes, but these changes are easily detectable, exceed the limit of the normal range of variation on an intermittent basis and / or periodically exceed applicable thresholds.
High	Receptors are vulnerable to project-induced change and changes are readily detectable, well outside the range of natural variation or occurrence, and regularly exceed any applicable thresholds.
Very High	Receptors are highly vulnerable to project-induced change and changes are easily detectable, fall well outside the range of natural variation or occurrence, and will continually exceed any applicable thresholds.

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/ mitigated.

Further to the assessment criteria presented above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority / significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/ mitigation impacts are implemented.

Table 21: Criteria for the determination of prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.

	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in

Table 21. The impact priority is therefore determined as follows:

Priority = CI + LR

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 1.5 (refer to

Table 22).

Table 22: Determination of prioritisation factor

Priority	Prioritisation Factor
2	1
3	1.125
4	1.25
5	1.375
6	1.5

In order to determine the final impact significance, the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a factor of 0.5, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 23: Environmental Significance Rating

Value	Description
< -10	Low negative (i.e., where this impact would not have a direct influence on the decision to develop in the area).
≥ -10 < -20	Medium negative (i.e., where the impact could influence the decision to develop in the area).

Value	Description
≥ -20	High negative (i.e., where the impact must have an influence on the decision process to develop in the area).
0	No impact
< 10	Low positive (i.e, where this impact would not have a direct influence on the decision to develop in the area).
≥ 10 < 20	Medium positive (i.e,. where the impact could influence the decision to develop in the area).
≥ 20	High positive (i.e., where the impact must have an influence on the decision process to develop in the area).

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.

APPENDIX 2

Curriculum Vitae Dr Andrea Pulfrich

Personal Details

Born:	Pretoria, South Africa on 11 August 1961
Nationality and Citizenship:	South African and German
Languages:	English, German, Afrikaans
ID No:	610811 0179 087

Address:	62 Mill Street, McGregor, 6708, South Africa PO Box 302, McGregor, 6708, South Africa
Cell :	082 781 8152
E-mail:	apulfrich@pisces.co.za

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.

EIMS ENVIRONMENTAL IMPACT MANAGEMENT SERVICES	**SPECIALIST DECLARATION**

EIMS Ref	1570	Project Name	PROPOSED AFRICA OIL SOUTH AFRICA CORP BLOCK 3B/4B EXPLORATION RIGHT

Project Details

Project Name	Proposed Africa Oil South Africa Corp Block 3b/4b Exploration Right
Applicant	Africa Oil SA Corp, Ricocure (Pty) Ltd and Azinam Limited (a wholly owned subsidiary of Eco Atlantic) (the Joint Venture (JV) Partners)
Competent Authority	Department of Mineral Resources

Specialist Details

Specialist Company	Pisces Environmental Services (Pty) Ltd			
Specialist Name	Dr Andrea Pulfrich			
Contact details	Tel		Cell	082 7818152
	E-mail	apulfrich@pisces.co.za		
	Postal Address	n/a		
	Physical Address	62 Mill Street, McGregor 67-8		

General Declaration

By signing this form, I hereby declare that:

- I act as an independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting undertaking the specialist work as required, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations, and all other applicable legislation.
- I have not, and will not engage in, conflicting interest in the undertaking of the activity.
- I understand to disclose to the applicant and competent authority all material information in my possession that reasonably has or may have the potential of influencing- any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- I have taken into account, to the extent possible, the matters referred to in Regulation 18 when preparing the report, plan or document.
- I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.
- All the particulars furnished by me this form are true and correct.

EIMS ENVIRONMENTAL IMPACT MANAGEMENT SERVICES	SPECIALIST DECLARATION		
EIMS Ref	1570	Project Name	PROPOSED AFRICA OIL SOUTH AFRICA CORP BLOCK 3B/4B EXPLORATION RIGHT

- I will perform all other obligations as expected from an environmental assessment practitioner in terms of the Regulations.
- I am aware of what constitutes an offence in terms of Regulation 48 and that a person convicted of an offence in terms of Regulation 48(1) is liable to the penalties as contemplated in Section 49B of the Act.

Disclosure of Vested Interest

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remunerative for work performed in terms of the Regulations.

Undertaking Under Oath/Affirmation

By signing this form, I swear under oath/affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signatures

Specialist					
Name	Andrea Pulfrich	Signature		Date	20 March 2024
Commissioner of Oaths					
Name	W/O AFRICA	Signature		Date	2024.03.22.
Commissioner of Oaths Official Stamp					

SOUTH AFRICAN POLICE SERVICE
COMMUNITY SERVICE CENTRE MCGREGOR

22 MAR 2024

GEMEENSKAPDIENS SENTRUM MCGREGOR
SUID-AFRIKAANSE POLISIEDIENS

A 8 Dalmeny Road, Pine Park, Randburg | E mail@eims.co.za | W www.eims.co.za | F (086) 571- 9047 | T (011) 789-7170
P PO Box 2083, Pinegowrie 2123, South Africa

Mr G P Kriel
Environmental Impact
Management Services (Pty)
Ltd
gp@eims.co.za

5/4/2024

Dear Mr Kriel

Updated Review of Marine Biodiversity Specialist Assessment for AOSAC's proposed exploration drilling in Block 3B/4B

Introduction

I was commissioned by Dr Andrea Pulfrich, the author of the marine biodiversity assessment (MBA) for AOSAC's planned exploration drilling in Blocks 3B/4B offshore of RSA's west coast to provide a peer review of the assessment and supporting documents. The focus of the review is on the completeness of the provided information and interpretations of it in identifying risks posed by the proposed exploration to marine biodiversity.

The reports provided for the review were:

- AOSAC Drilling – Marine Biodiversity Specialist Assessment Report November 2023, updated on 3/4/2024 (Pisces), hereafter referred to as the MBA, along with the subsidiary supporting reports of:
- Oil spill and Drilling Discharge Reports (Livas 2023), and
- Draft AOSAC: Exploration Drilling Campaign in Block 3B/4B, Underwater Sound Transmission Loss Modelling (SLR October 25, 2023)

Review

Review comments are provided for each of the above reports.

Marine biodiversity assessment (MBA)

The review is set out below broadly following the structure of the report's table of contents.

Report layout

The report is logically structured, and the provided illustrations are clear and not too complex. The Abstract is complete and clear statements are made on the adopted desk top study approach, the limitations thereof and the response of being ultra-cautious in identifying and interpreting marine biodiversity risks.

Specialist Consultant in Applied Marine Sciences
8 Francolin St, Somerset West, 7130 South Africa
Email: robinc@cybersmart.co.za
Mobile +27 (0)82 922 3504

Project description

The project description provides information on activities within the preparation, operation, and demobilisation phases. Each of these are disaggregated into the important components in the respective phases. The details provided are complete in identifying the linked environmental stressors including sound, seabed disturbance and modification, water quality impairment. Where appropriate quantitative information is given such as durations of activities, volumes of sediment left on the seabed in riserless drilling and that discharged in cuttings from risered drilling, sound intensity, etc. This is essential information for defining marine biodiversity risks.

Marine environment baseline

As in the project description the baseline description is complete with granular detail in the information provided. Covered topics are expected seabed features, metocean conditions, and regional features of low oxygen events and turbidity. The biological environment is fully described, or as fully as it can be from the available information. GIS maps are used to show the spatial relationships between the project area of interest, i.e., where the proposed exploration drilling is to take place, and *inter alia* known distributions/localities of features of conservation importance (e.g., Child's Bank, Tripp Seamount, continental shelf edge canyons, major ecoregions and ecosystem types), phosphorite hard grounds, fish and fisheries, marine mammal distributions, seal colonies, seabird distributions, shipping lanes. The spatial relationships with known distributions of IUCN conservation status listed fish, whales, dolphins, and turtles along with the main fishery species' spawning areas and egg and larvae areas are important for the risk assessment. These show the separations, or not, between the proposed operations and possibly sensitive receptors.

Cetacean occurrences in the overall west coast region are well mapped with recent observations on movements of populations through the area and their seasonality. As cetaceans are important in terms of probabilities of exposures to underwater noise generated by the proposed drilling operations this level of detail contributes to identification of possible mitigation actions.

No information gaps are apparent in the baseline description.

Assessment of impacts

As stated above the identified impacts are assessed across mobilisation, operations, and demobilisation phases. Consequences of unplanned activities, e.g., equipment loss, well blowouts, are included. Impacts are defined according to the aspect, e.g., noise transmission, of a specific activity. The benefit is that this enables directed mitigation where needed. Impacts are generally specifically defined which facilitates monitoring, e.g., underwater noise modifies behaviour in cetaceans which is observable. In cases where mitigation is applied the results are thus also observable; in the example given 'normal' behaviour returns. This allows validation, or not, of the mitigation applied which is beneficial for the project proponent and the wider scientific community.

Identified impacts are fully defined and receptors and their sensitivity to the effects of the impact explained. Project controls are described, e.g., compliance with MARPOL for ship discharges, and the residual risks evaluated in terms of intensity, duration, scale, reversibility of effects or not and probability. Environmental significance is then assessed according to the risk level and the sensitivity of the identified receptors. The process is logical and is consistently applied across the listed impacts. In some instances, it is acknowledged that the given impact ratings are precautionary to a high degree, e.g., section 4.4.2.1.1, and, in the reviewer's opinion, would be practically impossible to verify. The benefits of applying any mitigation in such instances would be moot.

The major environmental risk of hydrocarbon drilling at sea is a well blowout and the unconstrained release of product into the receiving environment. The results of modelling are used to define the environmental risks of such blowouts for mixtures of natural gas with condensate, and crude oil. The modelling is considered robust (see review below) as it employs established algorithms and supporting data relevant to the region. The modelled outcomes indicate low risks of shoreline oiling and that, if capping is successfully applied, most released oil would be held midwater and be dispersed by ambient currents (stochastic results). The impact assessment takes account of such detail and uses such to define mitigation/control measures. This adds to the robustness of the impact assessment.

The assessment methodology has been consistently applied and the impacts generally associated with exploration drilling have been well addressed along with mitigations that should be applied. There are no apparent gaps or inconsistencies in this section.

Supporting information

Oil spill modelling technical reports (Livas 2023a)[1]

This oil spill modelling report provides predictions on the fate of condensate released through well blowout in a 'worst case' scenario according to distance offshore and proximity to marine protected areas. The updated Livas (2023b) report includes a 'worst case' crude oil blowout scenario for modelling. In both cases the well tested and applied near field blowout module of the OSCAR modelling tool was employed. Environmental data used as input to the modelling included that extracted from international data bases, as is common in these applications. The scenarios modelled included proxy condensate and crude oil profiles of SKARV 13 DEG-2014 and OSEBERG BLEND 2006 respectively. These are equivalents of the hydrocarbon reserves expected to be found in the region. One release point was modelled for condensates and two for crude oil. The predicted release characteristics for crude oil are that natural gas would be included contributing to buoyancy. Stochastic and deterministic model outcomes were provided with consequences of interventions.

Given that models are indicative of spilled oil behaviour and essentially simplify the structure and behaviour of the receiving environment confidence in the outcomes is mainly dependent on the applicability of the input data and proven application of the modelling platform and modules used.

The modelling of condensates and crude oil is considered sufficient in both of these aspects and the use of model outcomes in the biodiversity risk assessment is justified with reasonable confidence that likely outcomes are provided.

Drilling discharge modelling technical report (Livas 2023b[2])

The ParTrack module within the three-dimensional DREAM model from the Marine Environmental Modelling Workbench software (v 14.1) was used to simulate the behaviour for drill cuttings discharges from the exploration drilling. This enables tracking of particles with predefined properties within the density and currents field of the receiving environment and has a wide application in simulating spreading and deposition of drilling discharged sediment. Release volumes and densities were based on drilling fluid characteristics, bore hole diameter and depth with currents and density

[1] LIVAS, B., 2023a. Well Drilling in Block 3B-4B – Drilling Discharge Modelling Technical Report. Report by HES Expertise Services to Africa Energy Co South Africa. October 2023, 42pp.

[2] LIVAS, B., 2023b. Well Drilling in Block 3B-4B – Drilling Discharge Modelling Technical Report. Report by HES Expertise Services to Africa Energy Co South Africa. October 2023, 42pp.

profiles extracted from international data bases. Environmental risks were estimated from dose/response measurements of drilling fluid constituents available in the OSPAR data bases.

Toxicity effects in the water column and seabed were determined according to ratios of the predicted environmental concentration of the individual constituents divided by the predicted no effect concentration. A ratio equal or greater than one is indicative of the environmental risk to 5% of species that may be exposed to the stressor. This is a widely accepted threshold for adverse effects. The applied modelling allowed estimations of recovery time in affected sediments based on bioturbation, biodegradation, recolonisation and natural deposition (= dilution of stressors). Information, e.g., direct field observations, on biological community recoveries following sublethal stressor exposures is limited, Accordingly, the modelling used default values for this that are inherently precautionary.

The outcomes of the modelling in terms of maximum risk of effect distributions indicate distance scales in the upper water column of <1 km and confinement to the upper 200 m water column. On the seabed this is reduced to ~100 m radius. Most of the effect is physical being burial and change in sediment particle size.

The wide use internationally of the modelling approach and conservative nature of effect predictions indicate that the modelling results have a reasonable level of confidence that they are indicative of the scales of effects of the discharges.

Underwater sound transmission loss modelling (SLR 2023)[3]

By any yardstick the SLR report is of high quality and detailed. It provides sound transmission loss patterns for each of the noise generating activities and predicted risks to receptors including whales, dolphins, turtles and fish, the latter according to currently accepted thresholds. All results in this report can be confidently applied in the marine biodiversity risk assessment.

Conclusions

The marine biodiversity risk assessment is comprehensive, detailed, logically constructed, and consistent in its approach to the analyses. It is well supported by specialist reports on oil spills, discharged sediment behaviour and risks, and sound transmission loss modelling.

No gaps have been identified in this review and it is considered fit for purpose.

Robin Carter.

Dr Robin Carter

[3] SLR CONSULTING CANADA, 2023. Proposed Offshore Exploration Drilling Campaign in Block 3B/4B. Underwater Sound Transmission Loss Modelling. Prepared for EIMS. October 2023. 87pp.