PROPOSED 3D SEISMIC SURVEY
IN THE ORANGE BASIN
OFF THE WEST COAST OF SOUTH AFRICA

(Project: ZA24-010_Orange Basin MC3D MSS)

Biodiversity and Ecosystem Services Assessment

Prepared for:

Searcher Geodata UK Ltd

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PISCES ENVIRONMENTAL SERVICES (PTY) LTD

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NOTE

The information contained herein was the most up-to-date at the time of writing. The author cannot be held accountable for the omission of any publications that became available or changes to features such as EBSAs and CBA that occurred subsequent to finalisation and submission of the report.

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EXECUTIVE SUMMARY

Searcher Geodata UK Ltd proposes to undertake 3D seismic acquisition in the Orange Basin off the West Coast of South Africa. The survey will comprise the acquisition of up to ~29 900 km^2 of 3D seismic data over a period of ~130 days, during the best available window of opportunity in either 2025 or 2026, subject to granting of the Reconnaissance Permit and vessel availability.

The Reconnaissance Permit Area, which is approximately 30 000 km^2 in size, is located in water depths ranging from ~1 500 m to over 3 600 m off the South African West Coast between Alexander Bay and Cape Columbine. The seabed sediments comprise sandy muds. Although influenced by the Benguela Current the Reconnaissance Permit area is located on the western extent 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 study area is South Atlantic Central Water characterised by low oxygen concentrations, especially at depth. Surface waters in the Reconnaissance Permit Application area will primarily be nutrient poor and clear, being beyond the influence of coastal upwelling, with seasonal nutrient peaks expected on the eastern edge of the Reconnaissance Permit Area during periods of upwelling.

The proposed 3D survey area falls into the Southeast Atlantic Deep Ocean Ecoregions. Although there is a lack of knowledge of the community structure and diversity of benthic macrofauna off the shelf edge, the South Atlantic bathyal and 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). Only sections along the shelf edge and in the Cape Canyon are rated as 'Vulnerable' and 'Endangered'. Geological features of note in and adjacent to the proposed survey area are Child's Bank situated at about 31°50'S, 15°53'E and Tripp Seamount situated at about 29°40'S; 14°19'E. Two canyons, the Cape Canyon and Cape Valley also occur to the south of the Reconnaissance Permit Area. 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 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. There are six offshore Marine Protected Areas (MPAs) in the general project area, but none fall within the Reconnaissance Permit Area. The proposed 3D survey area lies well offshore of these MPAs. Although there is no overlap of the 3D survey area with Ecologically and Biologically Significant Areas (EBSAs), critical biodiversity areas (CBAs) within the Reconnaissance Permit and 3D survey areas include both CBA1: natural and CBA2: natural areas.

Potential impacts to the marine fauna as a result of the proposed 3D seismic acquisition include:

- Physiological injury and/or mortality;
- Behavioural avoidance;
- Reduced reproductive success/spawning;
- Masking of environmental sounds and communication;

- Collision of turtles/marine mammals with the survey and support vessels or entanglement in towed acoustic apparatus; and
- Indirect impacts on piscivorous predators due to seismic effects on prey species.

The highest sensitivities in response to the proposed 3D survey are:

- Humpback whales, which migrate through the area between June and November (inclusive);
- Sperm whales, beaked whales and other odontocetes that frequent offshore waters;
- Large migratory pelagic fish and shark species that show seasonal association with Child's Bank and Tripp Seamount;
- Leatherback turtles which frequent offshore waters in low numbers and aggregate around seamounts to feed on jellyfish; and
- Various pelagic Albatross, Petrel, Storm Petrel and Shearwater species.

The impacts before and after mitigation on marine habitats and communities associated with seismic noise are summarised below:

Impact	Significance (before mitigation)	Significance (after mitigation)
Whales and dolphins		
Baleen whale	Medium	Low
Toothed whales and dolphins	Medium	Low
Seals	Low	Low
Turtles	Medium	Low
Diving Seabirds	Low	Low
Pelagic fish	Medium	Low
Marine invertebrates	Low	Low
Plankton and ichthyoplankton	Low	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 – vessel and aircraft	Low	Low
Vessel lighting	Low	Low
Hull fouling and ballast water discharge	Low	Low
Waste Discharges to sea	Low	Low
Ship strikes and entanglement in gear	Low	Low
Accidental loss of equipment	Low	Low
Operational spills and vessel accidents	Medium	Low

The mitigation measures proposed for seismic surveys are as provided below for each phase of a seismic survey operation:

No.	Mitigation measure	Classification
1. Survey Planning		
1.1	Plan seismic surveys to avoid the most sensitive periods within the survey area for some marine fauna, notably: • Movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters from early June to early December, • Aggregation of migratory cetaceans on the summer feeding grounds between St Helena Bay and Dassen Island from late October to late December. If data acquisition commences before late December then Passive Acoustic Monitoring (PAM) technology must be in place at all times.	Avoid
1.2	Plan the survey, as far as possible, so that the first commencement of airgun firing in a new area (including gun tests) are undertaken during daylight hours.	Abate on site
1.3	Prohibit airgun use (including airgun tests) outside of the Reconnaissance Permit Area.	Avoid
1.4	Although a seismic vessel and its gear may transit, including passing through a declared Marine Protected Area, acoustic sources (airguns) must not be operational during this transit.	Avoid
1.5	A 5 km buffer zone where no airgun operation is permitted is recommended around all MPAs	Avoid
2. Key Equipment		
2.1	**Passive Acoustic Monitoring (PAM)**	
2.1.1	Ensure the seismic vessel is fitted with Passive Acoustic Monitoring (PAM) technology, which detects some animals through their vocalisations. The PAM technology must have enough bandwidth to be sensitive to the whole frequency range of sensitive marine life expected in the area.	Abate on site
2.1.2	As the survey area would largely be in waters deeper than 1 000 m where sperm whales and other deep-diving odontocetes are likely to be encountered, implement the use of PAM 24-hr a day when the airgun is in operation.	Abate on site
2.1.3	Ensure that the PAM hydrophone streamer is towed in such a way that the interference of vessel noise is minimised.	Abate on site
2.1.4	Ensure the PAM streamer is fitted with at least four hydrophones, of which two are HF and two LF, to allow directional detection of cetaceans.	Abate on site
2.1.5	Ensure spare PAM hydrophone streamers (e.g. 4 heavy tow cables and 6 hydrophone cables) are readily available in the event that PAM breaks down, in order to ensure timeous redeployment.	Abate on site
2.2	**Acoustic Source**	
2.2.1	Define and enforce the use of the lowest practicable airgun volume for production. Design arrays to maximise downward propagation, minimise horizontal propagation and adopting suitable array configurations and pulse synchronization and eliminating unnecessary high frequencies.	Abate on site
2.2.2	Ensure a display screen for the acoustic source operations is provided to the marine observers. All information relating to the activation of the acoustic source and the power output levels must be readily available to support the observers in real time via the display screen and to ensure that operational capacity is not exceeded.	Abate on site
2.2.3	Ensure the ramp-up noise volumes do not exceed the production volume.	Abate on site

No.	Mitigation measure	Classification
2.2	**Streamers**	
2.2.1	Ensure that ‘turtle-friendly’ tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Abate on site
2.2.2	Ensure that solid streamers rather than fluid-filled streamers are used to avoid leaks.	Avoid
3. Key Personnel		
3.1	• Make provision for the placing of at least two qualified MMOs on board the seismic vessel. As a minimum, one must be on watch during daylight hours for the pre-shoot observations and when the acoustic source is active. • The duties of the MMO would be to: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Record airgun activities, including sound levels, ‘soft-start’ procedures and pre-firing regimes; – Observe and record responses of marine fauna to seismic shooting from optimum vantage points, including seabird, large pelagic fish (e.g. shoaling tuna, sunfish, sharks), turtle, seal and cetacean incidence and behaviour and any mortality or injuries of marine fauna as a result of the seismic survey. Data captured should include species identification, position (latitude/longitude), distance/bearing from the vessel, swimming speed and direction (if applicable) and any obvious changes in behaviour (e.g. startle responses or changes in surfacing/diving frequencies, breathing patterns) as a result of the seismic activities. Both the identification and the behaviour of the animals must be recorded accurately along with current seismic sound levels. Any attraction of predatory seabirds, large pelagic fish or cetaceans (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should also be recorded; – Record sightings of any injured or dead marine mammals, large pelagic fish (e.g. sharks), seabirds and sea turtles, regardless of whether the injury or death was caused by the seismic vessel itself. If the injury or death was caused by a collision with the seismic vessel, the date and location (latitude/longitude) of the strike, and the species identification or a description of the animal should be recorded and included as part of the daily report; – Record meteorological conditions at the beginning and end of the observation period, and whenever the weather conditions change significantly; – Request the delay of start-up or temporary termination of the seismic survey or adjusting of seismic shooting, as appropriate. It is important that MMO decisions on the termination of firing are made confidently and expediently, and following dialogue between the observers on duty at the time. A log of all termination decisions must be kept (for inclusion in both daily and “close-out” reports); – Use a recording spreadsheet (e.g. JNCC 2017) in order to record all the above observations and decisions; and	Abate on site

No.	Mitigation measure	Classification
	– Prepare daily reports of all observations, to be forwarded to the necessary authorities as required, in order to ensure compliance with the mitigation measures.	
3.2	• Make provision for placing of a qualified PAM operator on board the seismic vessel. As a minimum, one must be on "watch" during the pre-shoot observations and when the acoustic source is active. • The duties of the PAM operator would be to: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Ensure that the hydrophone cable is optimally placed, deployed and tested for acoustic detections of marine mammals; – Confirm that there is no marine mammal activity within 500 m of the airgun array prior to commencing with the 'soft-start' procedures; – Record species identification, position (latitude/longitude), distance and bearing from the vessel and acoustic source, where possible; – Record general environmental conditions; – Record airgun activities, including sound levels, 'soft-start' procedures and pre-firing regimes; and – Request the delay of start-up and temporary termination of the seismic survey, as appropriate.	Abate on site
3.3.	Ensure MMOs and PAM operators are briefed on the area-specific sensitivities and on the seismic survey planning (including roles and responsibilities, and lines of communication).	Abate on site
4. Airgun Testing		
4.1	Maintain a pre-shoot watch of 60-minutes before any instances of airgun testing. If only a single lowest power airgun is tested, the pre-shoot watch period can be reduced to 30 minutes.	Avoid / Abate on site
4.2	Implement a 'soft-start' procedure if testing multiple airguns. • The 'soft-start' should be carried out over a time period proportional to the number of guns being tested and not exceed 20 minutes; airguns should be tested in order of increasing volume; • If testing all airguns at the same time, a 20 minute 'soft-start' is required; • If testing a single lowest power airgun a 'soft-start' is not required.	Avoid / Abate on site
5. Pre-Start Protocols		
5.1	Implement a dedicated MMO and PAM pre-shoot watch of at least 60 minutes (to accommodate deep-diving species in water depths greater than 200 m).	Avoid / Abate on site
5.2	Implement a 'soft-start' procedure of a **minimum of 20 minutes'** duration on initiation of the seismic source if: • **during daylight** hours it is confirmed: – visually by the MMO during the pre-shoot watch (60 minutes) that there are no penguins or feeding aggregations of diving seabirds, slow-swimming large pelagic fish, turtles, seals or cetaceans within 500 m of the seismic source, and – by PAM technology that there are no vocalising cetaceans detected in the 500 m mitigation zone.	Avoid / Abate on site

No.	Mitigation measure	Classification
	• **during times of poor visibility or darkness** it is confirmed by PAM technology that no vocalising cetaceans are present in the 500 m mitigation zone during the pre-shoot watch (60 minutes).	
5.3	Delay 'soft-starts' if penguins or feeding aggregations of diving seabirds, slow-swimming large pelagic fish, turtles, seals or cetaceans are observed within the mitigation zone. • A 'soft-start' should not begin until 30 minutes after cetaceans depart the 500 m mitigation zone or 30 minutes after they are last seen or acoustically detected by PAM in the mitigation zone. • In the case of penguins, diving seabirds, slow-swimming large pelagic fish and turtles, delay the 'soft-start' until animals are outside the 500 m mitigation zone. • In the case of fur seals, which may occur commonly around the vessel, delay 'soft-starts' for at least 10 minutes until it has been confirmed that the mitigation zone is clear of all seal activity. However, if after a period of 10 mins seals are still observed within 500 m of the airgun, the normal 'soft-start' procedure should be allowed to commence for at least a 20-minute duration. Seal activity should be carefully monitored during 'soft-starts' to determine if they display any obvious negative responses to the airgun and gear or if there are any signs of injury or mortality as a direct result of the seismic activities.	Avoid / Abate on site
5.4	As noted above for planning, when arriving at the survey area for the first time, survey activities should, as far as possible, only commence during daylight hours with good visibility and wind speeds below Beaufort 3. However, if this is not possible due to prolonged periods of high wind speeds, poor visibility (e.g. thick fog) or unforeseen technical issue which results in a night-time start, the initial acoustic source activation (including gun tests) may only be undertaken if the normal 60-minute PAM pre-watch and 'soft-start' procedures have been followed.	Avoid / Abate on site
5.5	Schedule 'soft-starts' so as to minimise, as far as possible, the interval between reaching full power operation and commencing a survey line. The period between the end of the soft start and commencing with a survey line must not exceed 20 minutes. If it does exceed 20 minutes, refer to breaks in firing below.	Abate on site
6. Line Turns		
6.1	If line changes are expected to take **longer** than 40 minutes: • Terminate airgun firing at the end of the survey line and implement a pre-shoot search (60 minutes) and 'soft-start' procedure (20 minutes) when approaching the next survey line. • If line turn is shorter than 80 minutes (i.e. shorter than a 60-minute pre-shoot watch and 20-minute 'soft-start' combined), the pre-shoot watch can commence before the end of the previous survey line.	Abate on site
6.2	If line changes are expected to take **less** than 40 minutes, airgun firing can continue during the line change if: • The power is reduced to 180 cubic inches (or as close as is practically feasible) at standard pressure. Airgun volumes of less than 180 cubic inches can continue to fire at their operational volume and pressure; • The Shot Point Interval (SPI) is increased to provide a longer duration between shots, with the SPI not to exceed 5 minutes; and	Abate on site

No.	Mitigation measure	Classification
	• The power is increased and the SPI is decreased in uniform stages during the final 10 minutes of the line change (or geophone repositioning), prior to data collection re-commencing (i.e. a form of mini soft start). • Normal MMO and PAM observations continue during this period when reduced power airgun is firing.	
7. Shut-Downs		
7.1	Terminate seismic shooting on: • observation and/or detection of penguins or feeding aggregations of diving seabirds, turtles, slow swimming large pelagic fish (including whale sharks, basking sharks, manta rays [and devil rays-Namibia only]) or cetaceans within the 500 m mitigation zone. • observation of any obvious mortality or injuries to cetaceans, turtles, seals or mass mortalities of squid and fish (specifically large shoals of tuna or surface shoaling small pelagic species such as sardine, anchovy and mackerel) when estimated by the MMO to be as a direct result of the survey.	Abate on site
7.2	Depending the species, specific mitigation will be implemented to continue the survey operations, as specified below: • For specific species such as turtles, penguins, diving seabirds and slow swimming large pelagic fish (including whale sharks, basking sharks, manta rays [and devil rays-Namibia only]), terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no soft-start required). • For cetaceans, terminate shooting until such time as there has been a 30 minute delay from the time the animal was last sighted within the mitigation zone before the commencement of the normal soft start procedure.	Abate on site
8. Breaks in Airgun Firing		
8.1	If after breaks in firing, the airgun can be restarted **within 5 minutes**, no soft-start is required and firing can recommence at the same power level **provided no marine mammals have been observed or detected** in the mitigation zone during the break-down period.	Abate on site
8.2	For all breaks in firing of **longer than 5 minutes, but less than 20 minutes**, implement a 'soft-start' of similar duration, assuming there is continuous observation by the MMO and PAM operator during the break.	Abate on site
8.3	For all breaks in firing of **20 minutes or longer**, implement a 60-minute pre-shoot watch and 20-minute 'soft-start' procedure prior to the survey operation continuing.	Abate on site
8.4	For planned breaks, ensure that there is good communication between the seismic contractor and MMOs and PAM operators in order for all parties to be aware of these breaks and that early commencement of pre-watch periods can be implemented to limit delays.	Abate on site
9. PAM Malfunctions		
9.1	If the PAM system malfunctions or becomes damaged during **night-time operations** or periods of low visibility, continue operations for 30 minutes without PAM if no marine mammals were detected by PAM in the mitigation zones in the previous 2 hours, while the PAM operator diagnoses the issue. If after 30 minutes the diagnosis indicates that the PAM gear must be repaired to solve the problem, reduce power to 180 cubic inches. Firing of the reduced power gun may continue for 30 minutes while PAM is being repaired, the last 10-minute of which is a 10-minute ramp up to full power (mini 'soft-start'). If the PAM repair will take longer than	Abate on site

No.	Mitigation measure	Classification
	60 minutes, stop surveying until such time as a functional PAM system can be redeployed and tested.	
9.2	If the PAM system breaks down during **daylight hours**, continue operations for 20 minutes without PAM, while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM gear must be repaired to solve the problem, operations may continue for an additional 2 hours without PAM monitoring as long as: • No marine mammals were detected by PAM in the mitigation zones in the previous 2 hours; • Two MMOs maintain watch at all times during operations when PAM is not operational; • The time and location in which operations began and stop without an active PAM system is recorded.	Abate on site

Vessel and Aircraft Operations

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 by ensuring that the flight path is perpendicular to the coast, as far as possible.	Avoid/ abate on site
3	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals.	Avoid
4	The lighting on the survey and support vessels should be reduced to a minimum compatible with safe operations whenever and wherever possible. Light sources should, if possible and consistent with safe working practices, be positioned in places where emissions to the surrounding environment can be minimised.	Reduce at Source
5	Keep disorientated, but otherwise unharmed, seabirds in dark containers (e.g. cardboard box) for subsequent release during daylight hours. Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring).	Repair or Restore
6	Avoid the unnecessary discharge of ballast water.	Reduce at source
7	Use filtration procedures during loading of ballast water in order to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms.	Avoid/reduce at source
8	Ensure that routine cleaning of ballast tanks to remove sediments 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
9	Ensure all equipment (e.g. arrays, streamers, tail buoys etc) that has been used in other regions is thoroughly cleaned prior to deployment	Avoid/Reduce at Source
10	Implement a waste management system that addresses all wastes generated at the various sites, shore-based and marine. This should include: – Separation of wastes at source; – Recycling and re-use of wastes where possible; – Treatment of wastes at source (maceration of food wastes, compaction, incineration, treatment of sewage and oily water separation).	Avoid/Reduce at Source
11	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
12	Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.	Reduce at Source

No.	Mitigation measure	Classification
13	The vessel operators should keep a constant watch for marine mammals and turtles in the path of the vessel.	Avoid
14	Keep watch for marine mammals behind the vessel when tension is lost on the towed equipment and either retrieve or regain tension on towed gear as rapidly as possible.	Avoid
15	Should a cetacean become entangled in towed gear, contact the South African Whale Disentanglement Network (SAWDN) formed under the auspices of DEA to provide verbal specialist assistance in releasing entangled animals where necessary.	Repair/restore
16	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Avoid
17	Ensure vessel transit speed between the survey area and port is a maximum of 12 knots (22 km/hr), except in the MPAs where it is reduced further to 10 knots (18 km/hr).	Avoid/reduce at source
18	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/restore
19	During ship-to-ship supply, ensure that loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system.	Avoid
20	Minimise the lifting path between vessels.	Avoid
21	Undertake frequent checks to ensure items and equipment are stored and secured safely on board each vessel.	Avoid
22	In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the Reconnaissance Permit Area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval.	Repair/restore
23	Following an accidental oil spill, use low toxicity dispersants cautiously and only with the permission of the Department of Forestry, Fisheries and Environment (DFFE).	Abate on and off site
24	As far as possible, and whenever the sea state permits, attempt to control and contain any spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill.	Abate on site
25	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
26	Ensure offshore bunkering is not undertake in the following circumstances: – Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; – During any workboat or mobilisation boat operations; – During helicopter operations; – During the transfer of in-sea equipment; and – At night or times of low visibility.	Avoid / Reduce at source

ACRONYMS, ABBREVIATIONS and UNITS

2D	Two-dimensional
3D	Three-dimensional
ALARP	as low as reasonably practicable
BAR	Basic Assessment Report
BAT	Best Available Techniques
BCC	Benguela Current Commission
BCLME	Benguela Current Large Marine Ecosystem
BEP	Best Environmental Practice
BOD	Biological Oxygen Demand
CBD	Convention of Biological Diversity
CCA	CCA Environmental (Pty) Ltd
cm	centimetres
cm/s	centimetres per second
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CMS	Centre for Marine Studies
CSIR	Council for Scientific and Industrial Research
dB	decibell
DEFRA	UK Department for Environment, Food & Rural Affairs
DFFE	Department of Forestry, Fisheries and Environment
EBSAs	Ecologically or Biologically Significant Areas
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
EMP	Environmental Management Programme
EOO	Extent of Occurrence
ENSO	El Niño Southern Oscillation
EPA	Environmental Protection Agency
ERA	Environmental Risk Analysis
ERP	Emergency Response Plan
FAO	Food and Agricultural Organisation
g/m^2	grams per square metre
$g\ C/m^2/day$	grams Carbon per square metre per day
h	hour
H_2S	hydrogen sulphide
HAB	Harmful Algal Bloom
kHz	Herz
IBA	Important Bird Area
IFC	International Finance Corporation
IMO	International Maritime Organisation
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
JNCC	Joint Nature Conservation Committee

kHz	kiloHerz
km	kilometre
km^2	square kilometre
km/h	kilometres per hour
kts	knots
LACS	Low-Level Acoustic Combination Source
m	metres
m^2	square metres
m^3	cubic metre
mm	millimetres
m/s	metres per second
mg/l	milligrams per litre
MBES	Multi Beam Echo Sounder
MMO	Marine Mammal Observer
MPA	Marine Protected Area
MPRDA	Minerals and Petroleum Development Act
MV	Marine Vibroseis
N	north
NBHF	narrow band, high frequency
NDP	Namibian Dolphin Project
NMFS	National Marine Fisheries Services
NNW	north-northwest
NW	north-west
PAM	Passive Acoustic Monitoring
PASA	Petroleum Association of South Africa
PIM	Particulate Inorganic Matter
Pk SPL	Peak Sound Pressure Level
POM	Particulate Organic Matter
ppm	parts per million
PRDW	Prestedge Retief Dresner Wijnberg Coastal Engineers
PTS	Permananet Threshold Shift
psi	pound-force per square inch
RMS SPL	root-mean-square sound pressure levels
RMU	Regional Management Unit
ROV	Remotely Operated Vehicle
S	south
SACW	South Atlantic Central Water
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SEL	Sound Exposure Level
SFRI	Sea Fisheries Research Institute, Department of Environmental Affairs
SLR	SLR Environmental Consulting (South Africa) (Pty) Ltd
SOPEP	Shipboard Oil Pollution Emergency Plan
SPRFMA	South Pacific Regional Fisheries Management Authority
SSW	South-southwest
SW	south-west

T	ton(s)
TBT	tributyltin
TSPM	Total Suspended Particulate Matter
TTS	Temporary Threshold Shift
VMEs	Vulnerable Marine Ecosystems
VOS	Voluntary Observing Ships
WBMs	Water-based muds
WWF	World Wildlife Fund
µg	micrograms
µm	micrometre
µg/l	micrograms per litre
µPa	micro Pascal
˚C	degrees Centigrade
%	percent
‰	parts per thousand
~	approximately
<	less than
>	greater than
"	inch

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 (Pr.Sci.Nat. No: 400327/06), South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist report was compiled for Searcher Geodata UK Ltd for the use of EIMS in preparing a Basic Assessment Report and Environmental Management Programme Report (EMPr) for proposed 3D seismic acquisition in the 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 Searcher Geodata UK Ltd and EIMS who are undertaking the Basic Assessment process, and has no vested interests in the proposed project or the study area.

Andrea Pulfrich

Dr Andrea Pulfrich

1 GENERAL INTRODUCTION

Hydrocarbon deposits occur in reservoirs in sedimentary rock layers. Being lighter than water they accumulate in traps where the sedimentary layers are arched or tilted by folding or faulting of the geological layers. Marine seismic surveys are the primary tool for locating such deposits and are thus an indispensable component of offshore oil or gas exploration.

Seismic survey programmes comprise data acquisition in either two-dimensional (2D) and/or three dimensional (3D) scales, depending on information requirements. 2D surveys are typically applied to obtain regional data from widely spaced survey grids and provide a vertical slice through the seafloor geology along the survey track-line. Infill surveys on closer grids subsequently provide more detail over specific areas of interest. In contrast, 3D seismic surveys are conducted on a very tight survey grid and provide a cube image of the seafloor geology along each survey track–line. Such surveys are typically applied to promising petroleum prospects to assist in fault line interpretation.

The nature of the sound impulses utilised during seismic surveys have resulted in concern over their potential impact on marine fauna, particularly marine mammals, seabirds and fish (McCauley *et al.* 2000). Consequently, it has been proposed that environmental management already be applied at the exploration stage of the life cycle of a hydrocarbon field project (Duff *et al.* 1997, in Salter & Ford 2001).

For this investigation Searcher Geodata UK Ltd (Searcher) is planning to continue undertaking 3D seismic acquisition in the Orange Basin off the West Coast of South Africa as it was not able to complete the intended survey during the 2023-2024 season, due to the viable acquisition windows and vessel availability. Searcher has consequently applied for a new Reconnaissance Permit over a similar area, but are proposing to exclude a section of the survey area from full power source data acquisition. The area of interest is located on the edge of the South African Exclusive Economic Zone (EEZ). The Reconnaissance Permit Area extends over a number of licence blocks between the South-African – Namibian border and Cape Columbine (Figure 1-1). Water depths in the Reconnaissance Permit area range from about 1 500 m to 3 700 m. Searcher 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 as part of the Reconnaissance Permit. EIMS in turn approached Pisces Environmental Services (Pty) Ltd to provide an updated specialist assessment of the specialist report submitted in October 2022 on potential impacts of the proposed exploration well-drilling operations on marine fauna and ecological processes in the area.

1.1 Scope of Work

This specialist report was compiled as a desktop study on behalf of Searcher, for their use in preparing an EMP as part of a Basic Assessment Report for the proposed 3D seismic survey in the Orange Basin, offshore of the West Coast of South Africa (Figure 1-1).

The terms of reference specifically for the Biodiversity and Ecosystem Services Assessment is to:

- Provide an update of the baseline environment and impact assessment for the proposed 3D acquisition offshore of the South African West Coast, based on current available literature.

1.2 Approach to the Study

This specialist report was compiled as a desktop study on behalf of Searcher; no new infield data were collected. All identified marine and coastal impacts are summarised, categorised and ranked in an appropriate impact assessment table, to be incorporated in the overall EIA.

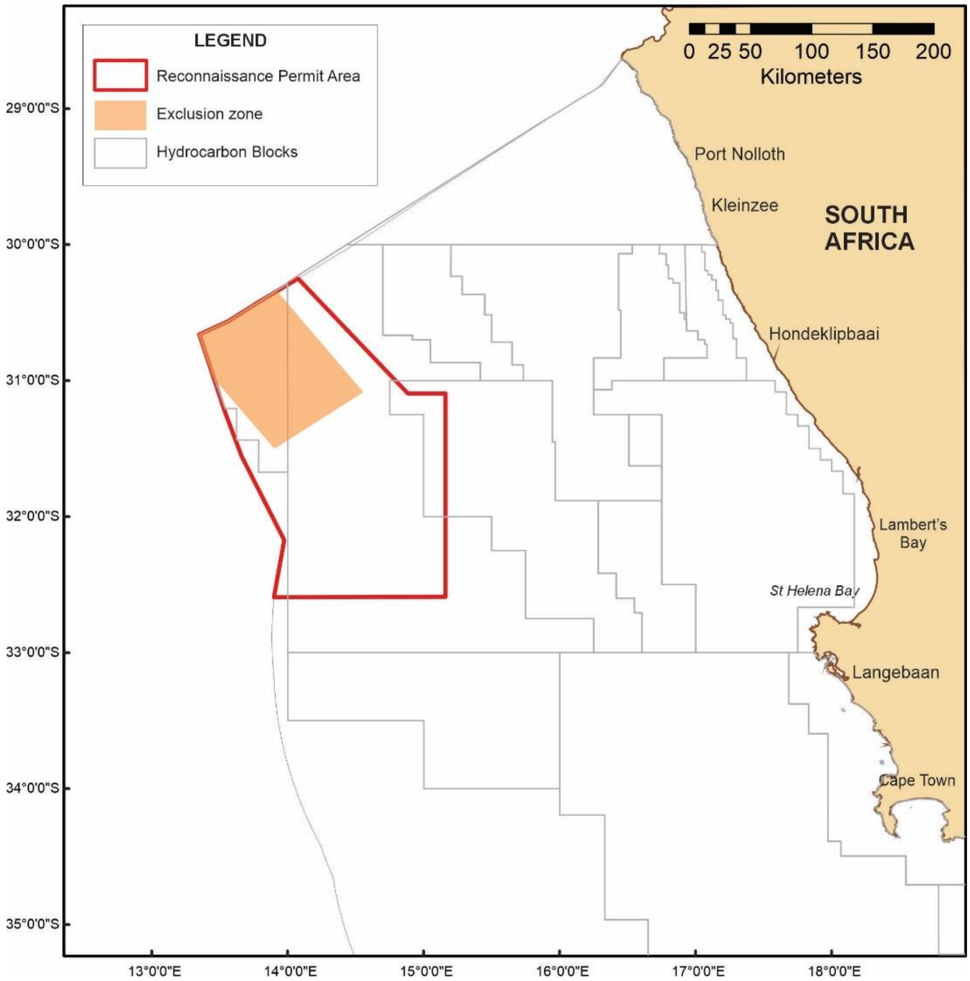


Figure 1-1: Map of the Reconnaissance Permit Area (red polygon) in relation to hydrocarbon blocks off the West Coast (grey polygons). The implemented exclusion zone is shaded orange.

1.3 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. The sources consulted are listed in the Reference chapter.

The assumptions made in this specialist assessment are:

- The study is based on the **project description made available to the specialist at the time of the commencement of the study**.
- Some important conclusions regarding the extent of the zones of impact of seismic sound and associated assessments on marine fauna are based on the results of the Underwater Acoustic Modelling Study (SLR Consulting Australia 2024).

- Potential changes in the marine environment such as sea-level rise and/or increases in the severity and frequency of storms related to climate change are not included in the terms of reference and therefore not dealt with in this report.

All identified marine impacts are summarised, categorised and ranked in appropriate impact assessment tables, to be incorporated in the overall EIA Report.

Information gaps include:

- details of the benthic macrofaunal communities beyond the shelf break;
- details on demersal fish communities beyond the shelf break;
- information specific to the marine communities of seamounts (Tripp Seamount, Child's Bank) and submarine canyons (Cape Canyon and Cape Point Canyon); and
- current information on the distribution, population sizes and trends of most cetacean species occurring in South African waters and the project area in particular.

Keeping these information gaps in mind, the assessment of impacts has adopted a strongly precautionary approach.

1.4 Assessment Procedure

The assessments presented in the impact assessment chapter below are based on the format used by Environmental Impact Management Services (Pty) Ltd (EIMS) (see Appendix 1).

2 DESCRIPTION OF THE PROPOSED PROJECT

Searcher Geodata UK Ltd is planning to conduct a seismic campaign over an area of interest in the Orange Basin during the best available window of opportunity in 2025 possibly extending to 2026, subject to vessel availability. The Reconnaissance Permit Area is approximately 29 900 km^2 in extent and is situated roughly between the Orange River mouth and Cape Columbine, approximately 220 km offshore at its closest points, in water depths beyond -2 000 m. Water depths in the Reconnaissance Permit area range from ~1 500 m to over 3 500 m (Figure 2-1). The total 3D survey duration would be in the order of up to four months during the survey window in the first quarter of 2025 with extension to 2026 if necessary.

The anticipated acoustic source (airgun) and hydrophone array would consist of 24 active guns with operating pressures of 2 000 pound-force per square inch (psi), situated some 50 m behind the vessel at a depth of 7 - 8 m below the surface. The 3D survey will involve multiple streamers (up to 12 streamers spaced 100 m apart) up to 12 000 m long, towed at a depth of approximately 8 m.

The seismic vessel would steam a series of predefined transects describing the survey grid, the headings of which would be fixed and reciprocal. During surveying the seismic vessel would travel at a speed of between four and six knots and the sound sources would be “fired” by the airgun array. As the seismic vessel would be restricted in manoeuvrability (a turn radius of approximately 5 km is expected), other vessels should remain clear of it. A support vessel usually assists in the operation of keeping other vessels at a safe distance.

Each triggering of a sound pulse is termed a seismic shot, and these are fired at intervals of 6 - 20 seconds (depending on water depth and other environmental characteristics) (Barger & Hamblen 1980). Each seismic shot is usually only between 5 and 30 milliseconds in duration, and despite peak levels within each shot being high, the total energy delivered into the water is low.

Airguns have most of their energy in the 5-300 Hz frequency range, with the optimal frequency required for deep penetration seismic work being 50-80 Hz.

Sound pressure levels (or pressure level peak to peak) from individual airguns use today in the seismic industry range from 200 to 232 dB re 1 µPa at 1 m, for small to large individual guns, respectively. For airgun arrays, sound levels range from 235 dB re 1 µPa at 1 m for a small array (500 cubic inches) to 260 dB re 1 µPa at 1 m for large arrays (7 900 cubic inches) (Bröcker 2019). The majority of the produced energy is below 250 Hz, with 90% of the energy between 70 to 140 Hz, although pulses do contain some higher frequencies up to 16 kHz (Bröcker 2019; Harding & Cousins 2022). It must be noted, however, that the sound level specifications for airgun arrays refer to sound levels in the vertical direction directly beneath the airgun array, generally near its centre, with nominal sound levels (but higher frequency components) in the horizontal direction being ~10-20 dB lower (Caldwell & Dragoset 2000; Dragoset 2000). If spread in a sound channel, sound signals from seismic airgun surveys can be received thousands of kilometres away from the source. The low-frequency energy can also travel long distances through seabed sediments, re-entering the water far from the source (Harding & Cousins 2022).

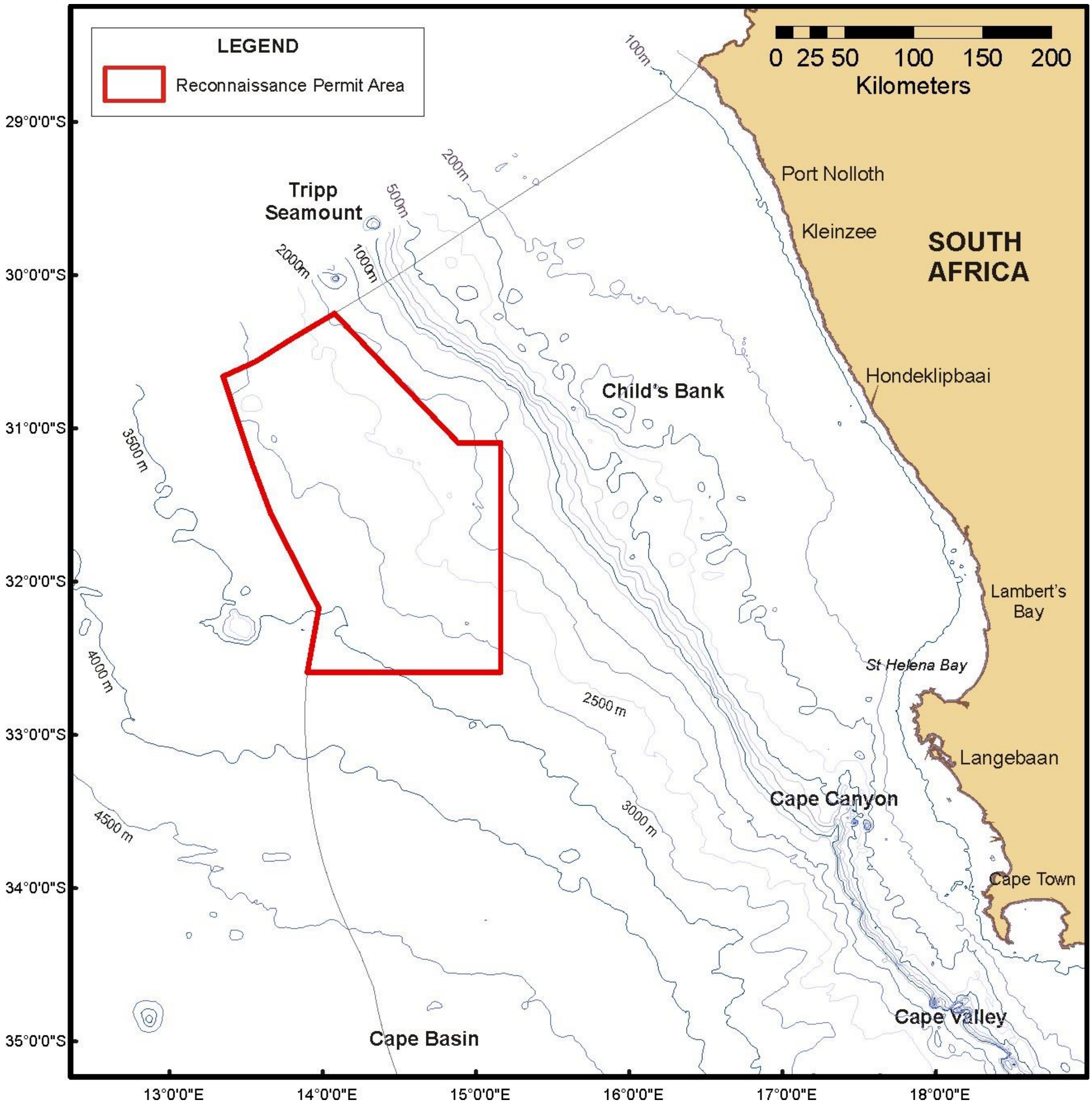


Figure 2-1: Map indicating location of the Reconnaissance Permit Area in relation to bathymetric features off the West Coast. Places mentioned in the text are also indicated.

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 seismic acquisition within the Orange Basin, which may be affected by seismic noise, whereas the area of indirect influence will vary in extent depending on the type of receptor potentially affected by more far-reaching impacts. 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 2-1). 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 within the northern portion of the project target area. 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 is a geological feature ~70 km to the north of the Reconnaissance Permit area, which 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.

Further underwater features in the vicinity of the Reconnaissance Permit Area include the Cape Canyon and Cape Valley, which lie over 200 km to the southeast of the southern boundary of the Reconnaissance Permit Area (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 3-1). 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 Reconnaissance Permit Area.

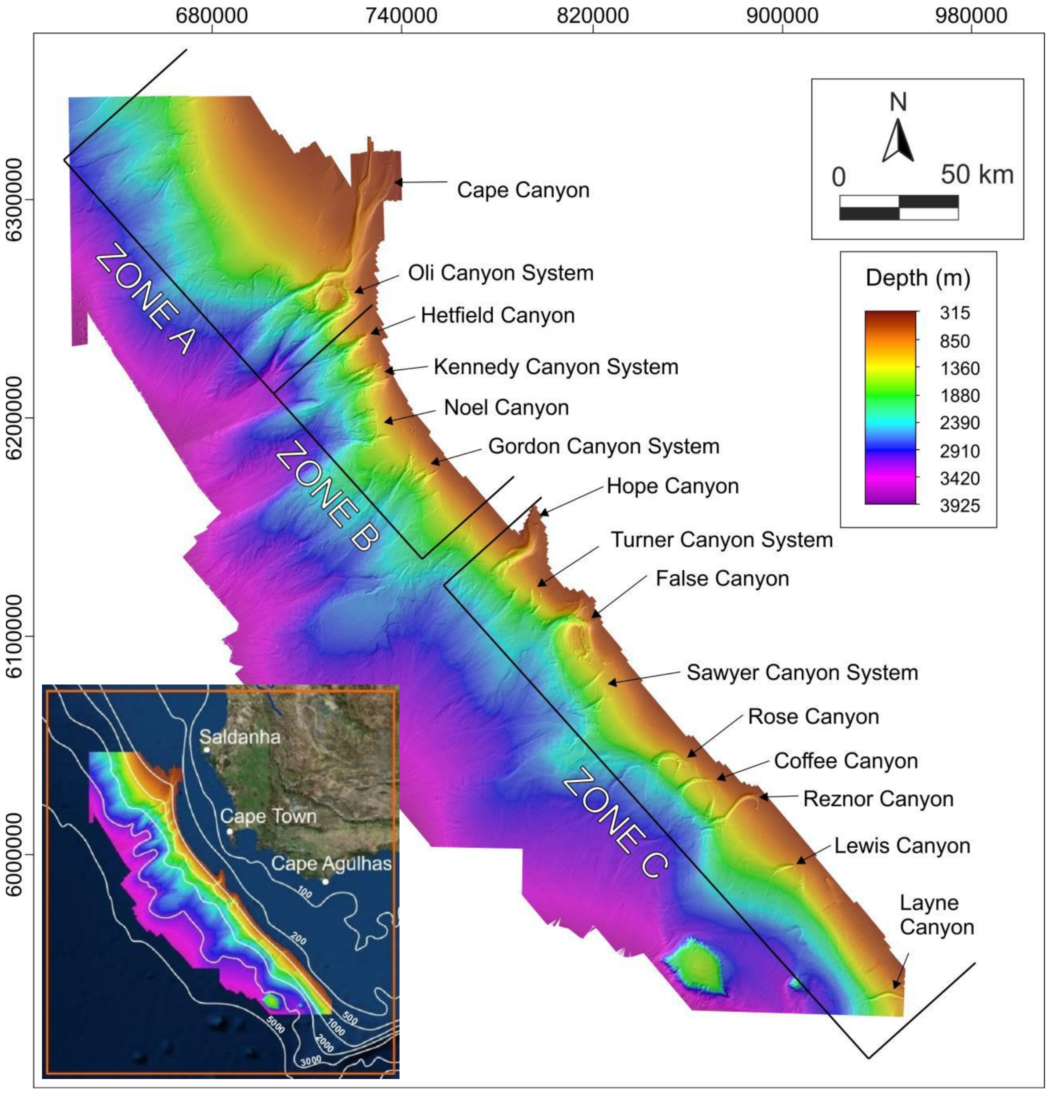


Figure 3-1: Submarine canyon domains of the southwestern Cape continental margin identified by Palan (2017). Insert shows the locality of the study area.

3.1.2 Coastal and Inner-shelf Geology and Seabed Geomorphology

Figure 3-2 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 Reconnaissance Permit Area, sediment is dominated by muds and sandy muds. 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.

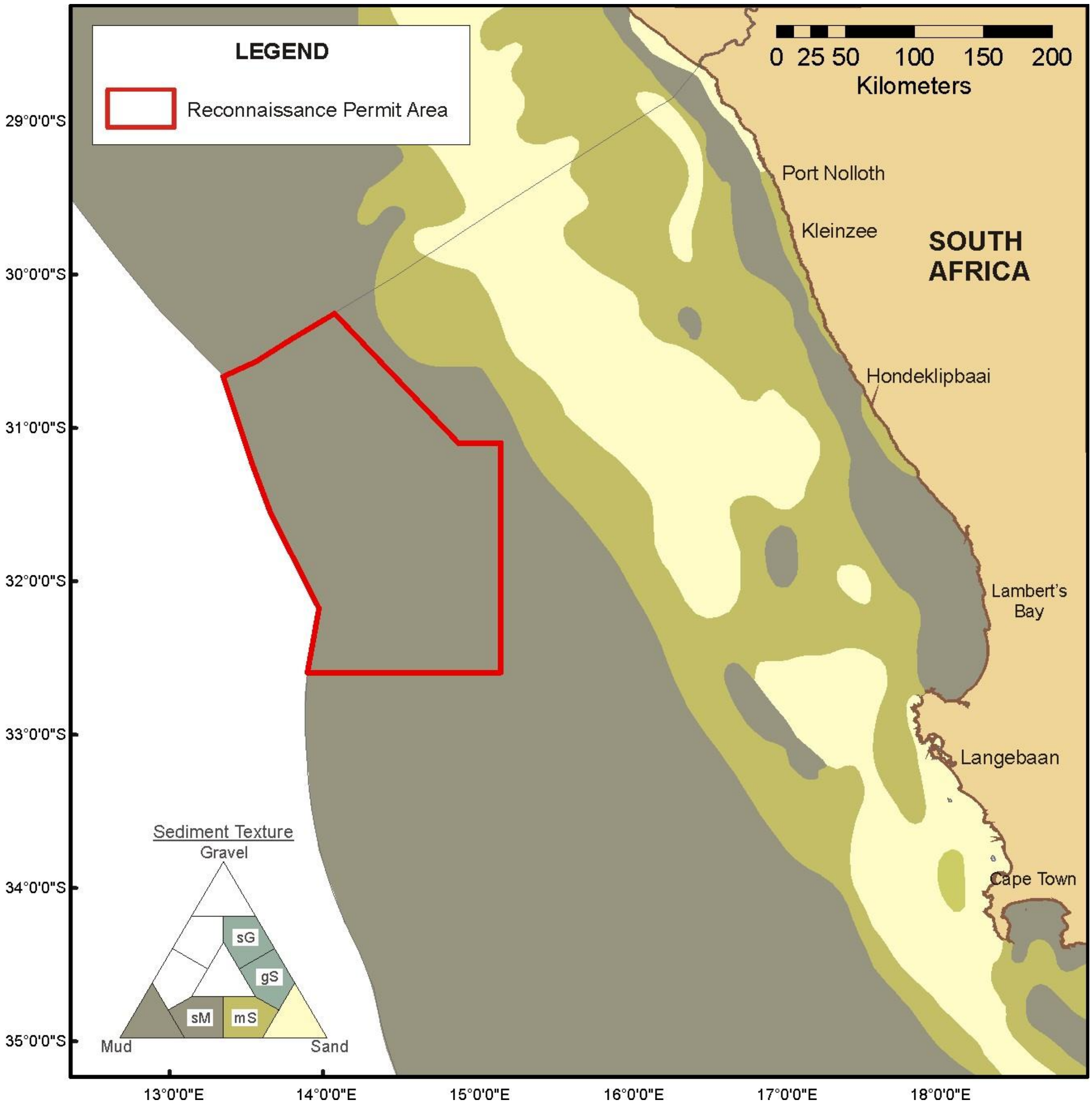


Figure 3-2: The Reconnaissance Permit Area in relation to sediment distribution on the continental shelf of the South African West Coast (Adapted from Rogers 1977). Based on information in Holness *et al.* (2014) and Sink *et al.* (2019), the mud/sandy mud sediments have been extended to the edge of 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 3-3).

In the Reconnaissance Permit Area the water depth ranges from approximately 1 000 m to over 3 500 m. The Southeast Atlantic Unclassified Slopes and Southeast Atlantic Unclassified Abyss substrata dominate across the area. The shelf inshore of the Reconnaissance Permit Area boasts a diversity of substrata (Sink *et al*. 2019).

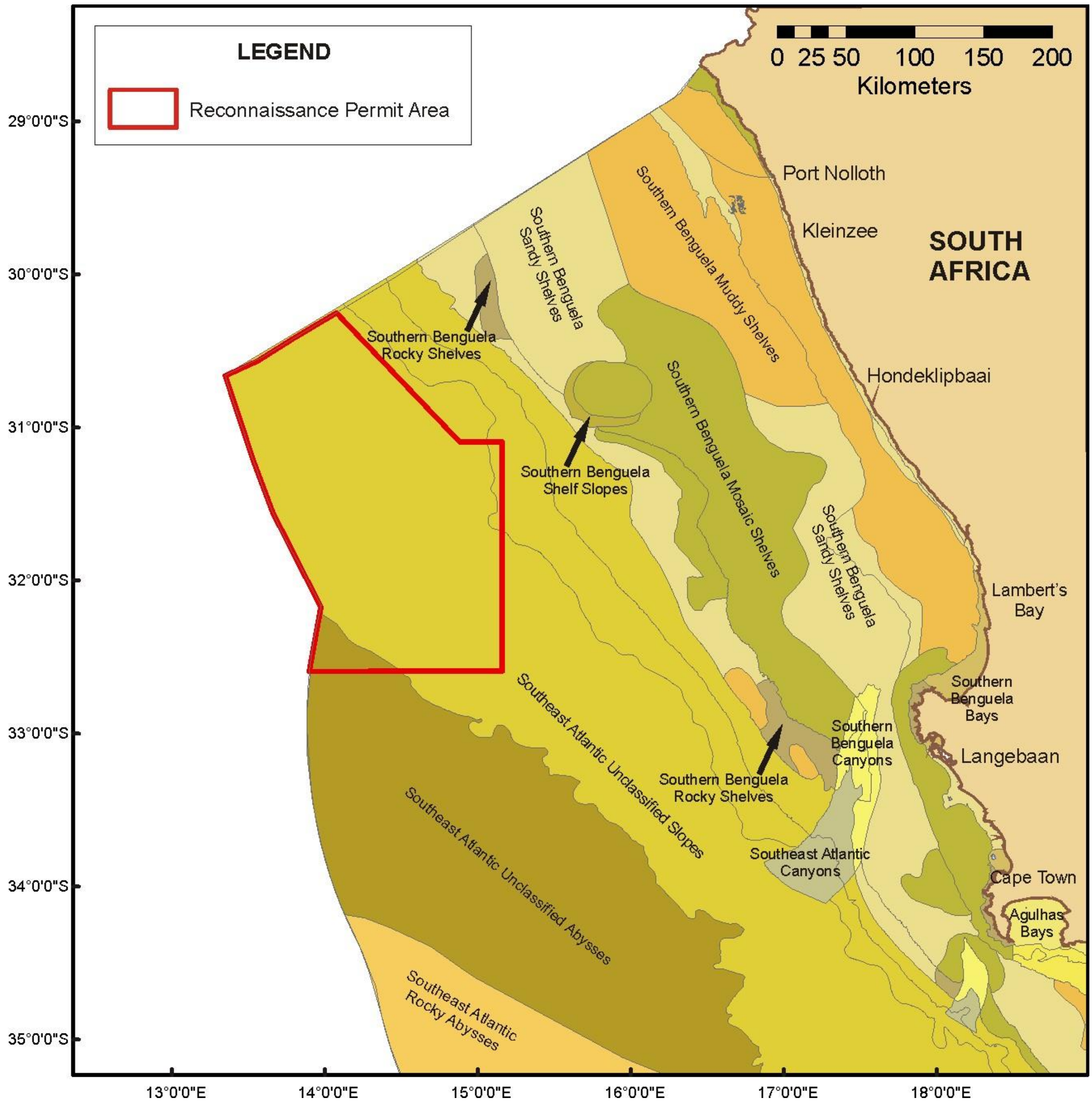


Figure 3-3: The Reconnaissance Permit Area in relation to the distribution of seabed substratum types along the West Coast (adapted from Sink *et al*. 2019).

In the Deep Water Orange Basin and over much of the Reconnaissance Permit Area, the seabed is homogenous and of low relief, dominated by soft, muddy sediments with indication of abundant bioturbation. The organic and nutrient content of the sediments was comparatively low. Three habitats were identified, namely 'deep-sea mud' (dominant), 'deep, muddy-sand' and 'Atlantic mid-abyssal sand' or mixed sediment. The EBS undertaken at depths of 2 960 m to 3 000 m in Namibian Block 2913B adjacent and to the north of the Reconnaissance Permit Area identified homogeneous habitat type of 'deep-sea sandy mud' with very limited bioturbation or evidence of faunal assemblages and insignificant organic enrichment (Benthic Solutions Ltd 2018) (Figure 3-4, left). Similarly, unconsolidated seabed at depths ranging from -350 m to 1 682 m in Namibian Block 2914A some 55 km north of the Reconnaissance Permit Area comprised 'sandy mud', 'sand' and 'muddy sand' sediments with was some depth-driven variation in sediment type (Fugro 2024) (Figure 3-4, right).


Figure 3-4: Homogenous seabed comprising deep-sea mud and muddy sand in adjacent Block 2913B (left) and Block 2914B (right) (Source: Benthic Solutions 2018; Fugro 2024).

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 3-5, 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 3-5, right). The Reconnaissance Permit Area 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).

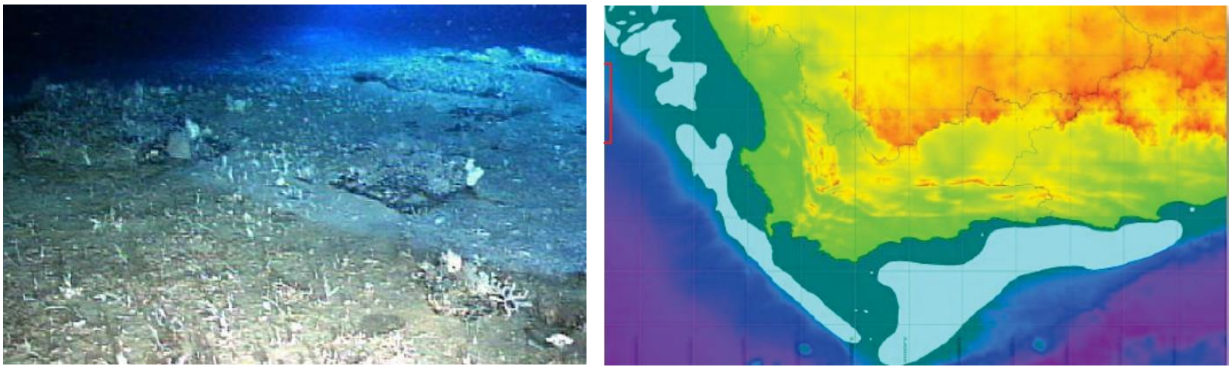


Figure 3-5: Phosphorite hard ground (left) and its distribution (cyan) on the South African continental shelf (right) in relation to the Reconnaissance Permit Area (red polygon) (adapted from Morant 2013).

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).

The Reconnaissance Permit Area lies offshore of the known phosphate-bearing hard grounds, and seismic acquisition 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 3-6). 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.

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 3-6). 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 3-7).

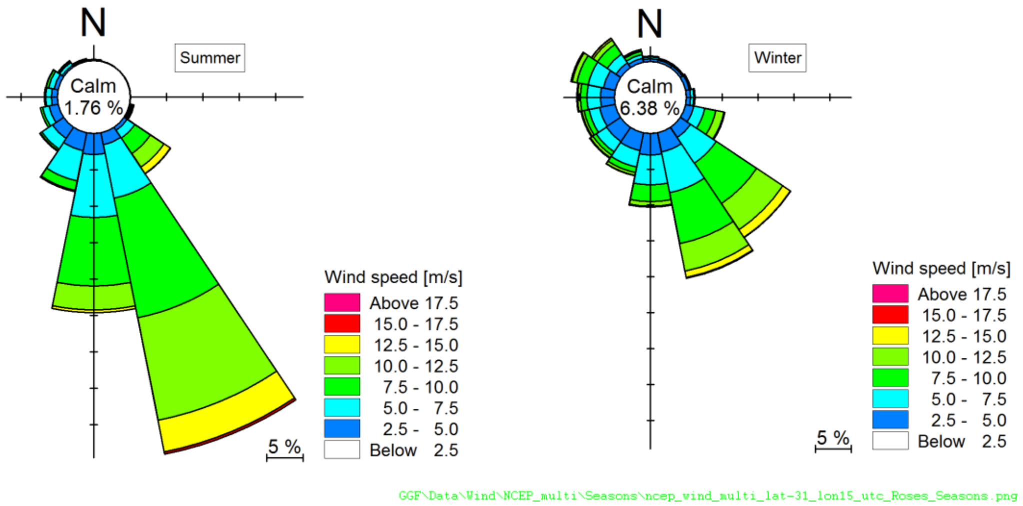


Figure 3-6: Wind Speed vs. Wind Direction for NCEP hind cast data at location 15°E, 31°S (From PRDW 2013).

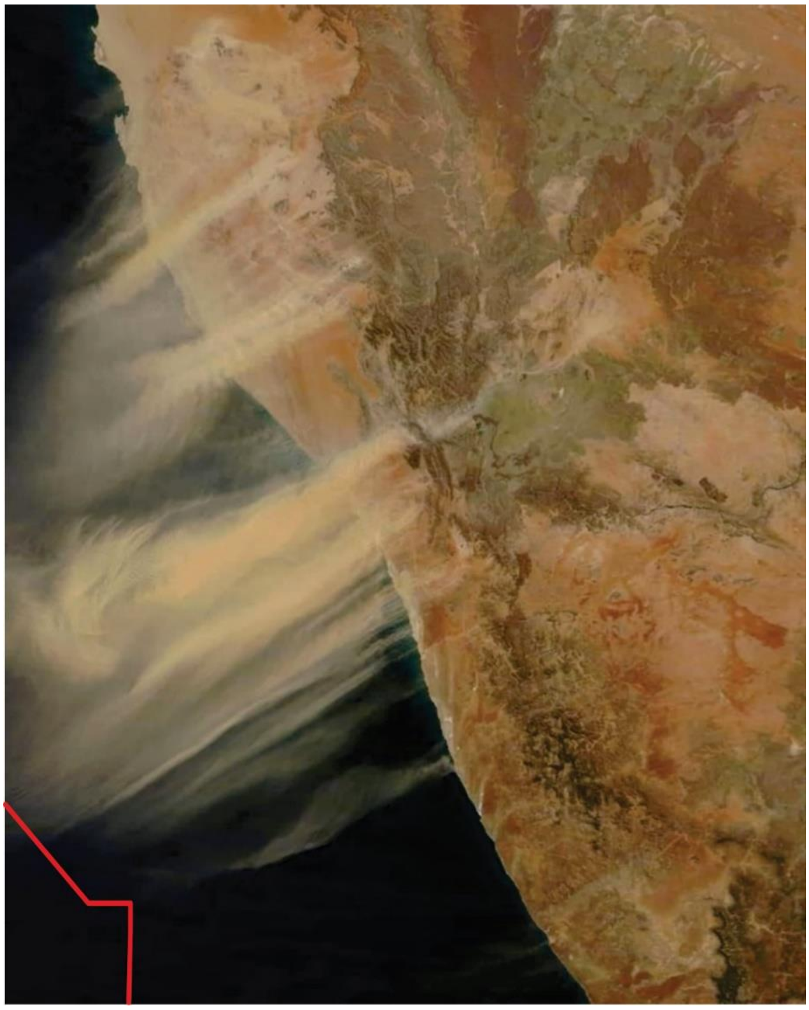


Figure 3-7: The Reconnaissance Permit Area (red polygon) in relation to aerosol plumes of sand and dust due to a 'berg' wind event on the southern African west coast in October 2019 (Image Source: LandWaterSA).

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 3-8b). 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.

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 3-8a). Upwelling in these cells is seasonal, with maximum upwelling occurring between September and March. The Reconnaissance Permit Area is located well offshore of these upwelling events.

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 3-8). 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 Reconnaissance Permit Area lies offshore of 15°E on the outer edge of these features.

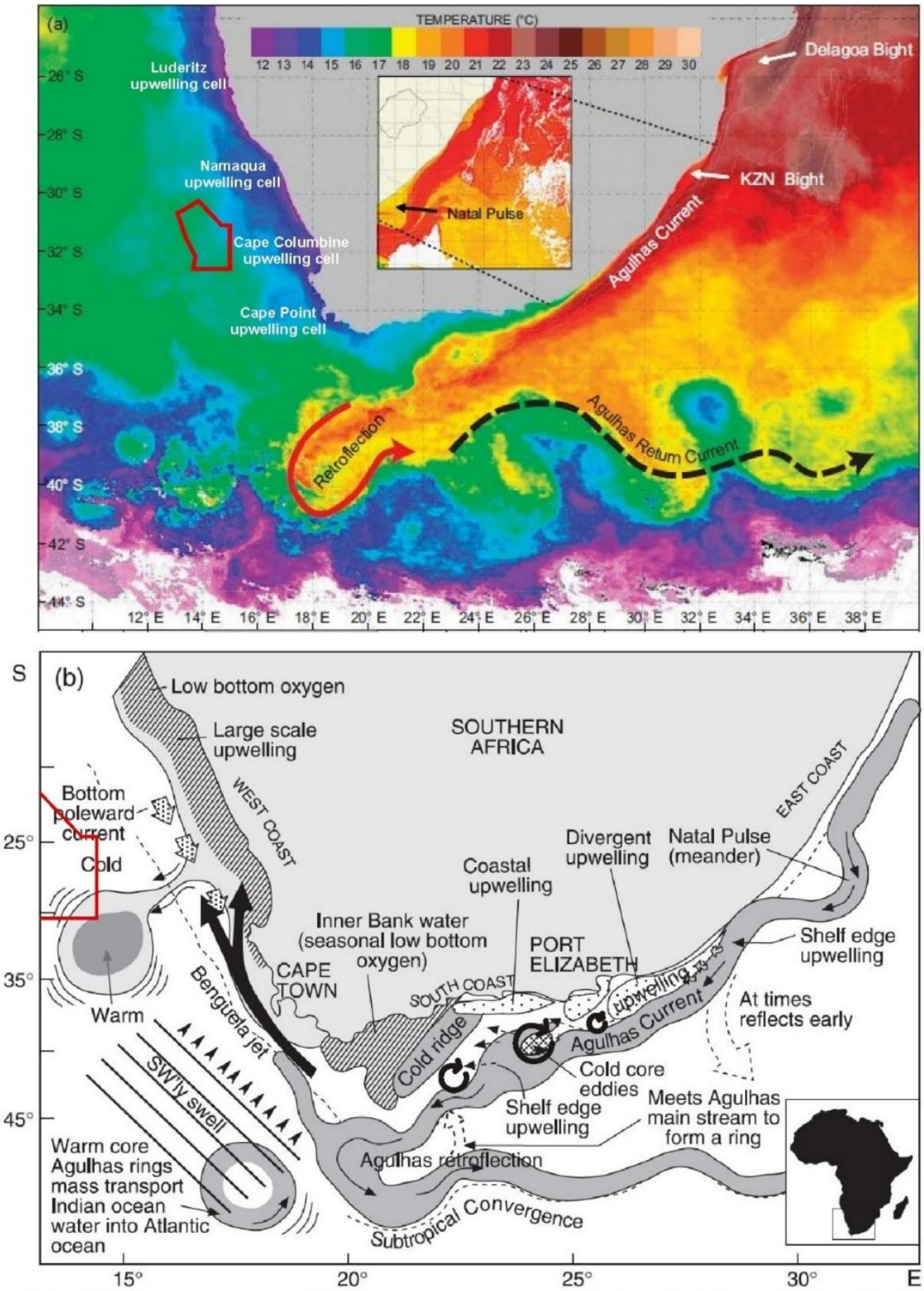


Figure 3-8: (a) Satellite sea-surface temperature image showing the predominance of the warm Agulhas Current along the South African south coast and the colder upwelled water on the west coast (adapted from Roberts *et al*. 2010), and (b) physical processes and features associated with the Southwest Coast (adapted from Roberts 2005) in relation to the Reconaissance Permit Area (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 3-9). The peak wave energy periods fall in the range 9.7 – 15.5 seconds.

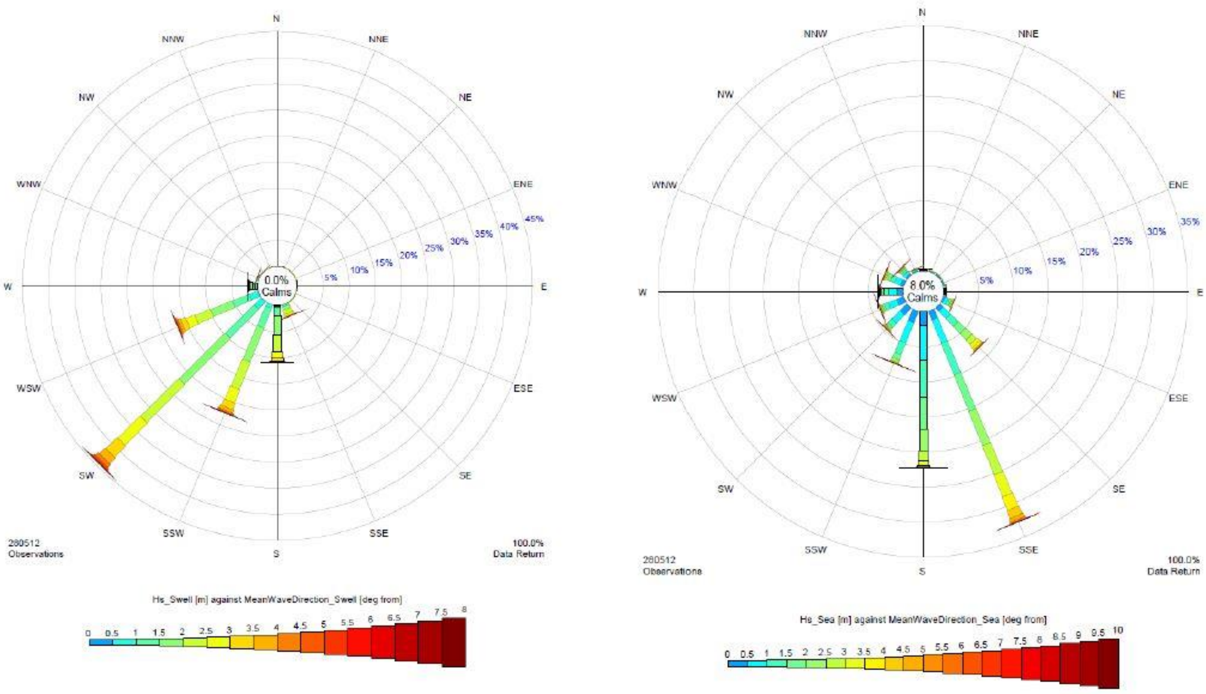


Figure 3-9: Annual roseplots of significant wave height partitions of swell (left) and wind-sea (right) for GROW1012 hind cast data at location 15°E, 31°S.

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 primary phytoplankton production. This, in turn, serves as the basis for a rich food chain up through zooplankton, pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (hake and snoek), mammals (primarily seals and dolphins) and seabirds (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. Figure 3-8 illustrates that the eastern boundary of the Reconnaissance Permit Area is located to the west of the offshore influence of these coastal upwelling events and although waters are expected to be comparatively warm and nutrient poor, seasonal upwelling inshore of the Reconnaissance Permit Area can be expected. Within the Reconnaissance Permit Area itself, however, surface chlorophyll concentrations are expected to be low due to the scarce phytoplankton community.

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.

An associated phenomenon ubiquitous in the Benguela system are red tides (dinoflagellate and/or ciliate blooms) (see Shannon & Pillar 1985; Pitcher 1998). Also referred to as Harmful Algal Blooms (HABs), these red tides can reach very large proportions, extending over several square kilometres of ocean (Figure 3-10, 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. Being associated primarily with upwelling cells, HABs may occur inshore of the Reconnaissance Permit Area, but are unlikely in the proposed 3D survey area.

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 3-2), 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.

Figure 3-10: 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).

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 most recent walkout occurred in early March 2022 at Elands Bay, when some 500 tons of rocklobster were reported stranded on the beach (Figure 3-10, right). The blooms develop over a period of unusually calm wind conditions when sea surface temperatures where high. Algal blooms usually occur during summer-autumn (February to April) but can also develop in winter during the 'berg' wind periods, when similar warm windless conditions occur for extended periods.

3.2.8 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 the Reconnaissance Permit Area 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). The Reconnaissance Permit Area falls into the Southeast Atlantic Deep Ocean Ecoregion (Sink *et al*. 2019) (Figure 3-11). 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.

The Southeast Atlantic Oceanic Ecoregion extends from the shelf edge of the Southern Benguela onto the slope and into the abyssal plain of the Cape Basin, which comprises a relatively monotonous plain, interrupted by sporadic seamounts. This deep ocean region extends into Namibia and is bounded in the north by the prominent Walvis Ridge. In the south it is separated from the Southwest Indian Deep Ocean by the Agulhas Ridge, a transverse ridge that forms part of the Agulhas Falklands Fracture Zone and acts as a divide between the Cape Basin and the Agulhas Basin. The biodiversity patterns in the deep ocean ecosystems are not well understood (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.

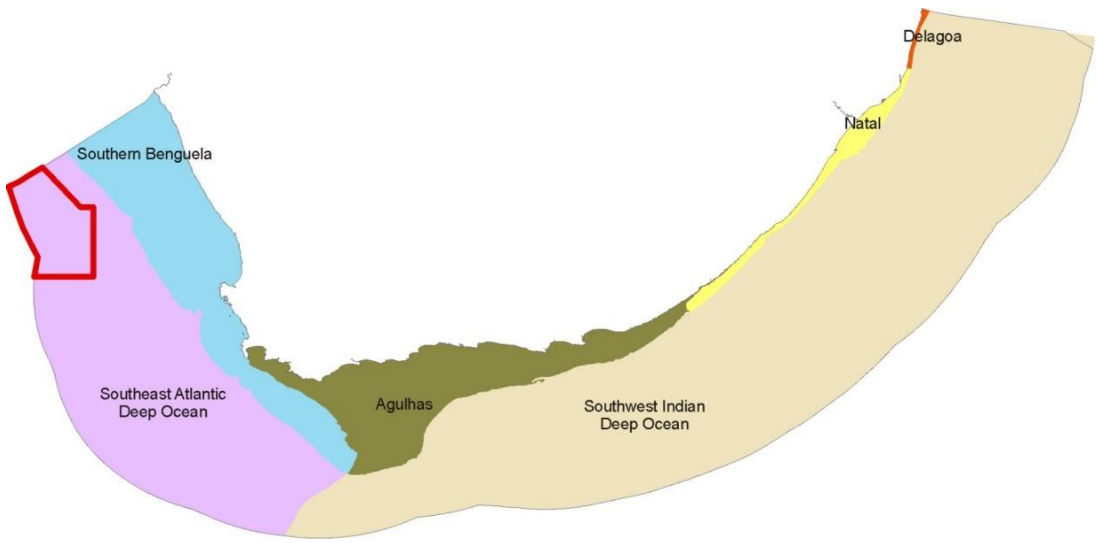


Figure 3-11: The Reconnaissance Permit Area (red polygon) in relation to the inshore and offshore ecoregions of the South African coast (adapted from Sink *et al*. 2019).

3.3.1 Demersal Communities

3.3.1.1 Benthic Invertebrate Macrofauna

The seabed communities in the Reconnaissance Permit Area lie within the Namaqua sub-photic and continental slope biozones, which extend from a 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 3-12) and assigned an ecosystem threat status based on their level of protection (Figure 3-13).

The Reconnaissance Permit Area coincides with three ecosystem types, namely:

- 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 Lower Slope - Unknown seabed type on the lower slope of Southeast Atlantic with a depth range of -1 800 m to -3 500 m.
- Cape Basin Abyss - Abyssal ecosystem in the Cape Basin, with a depth range of -3 500 m to -4 600 m.

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 2004; 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. 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).

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).

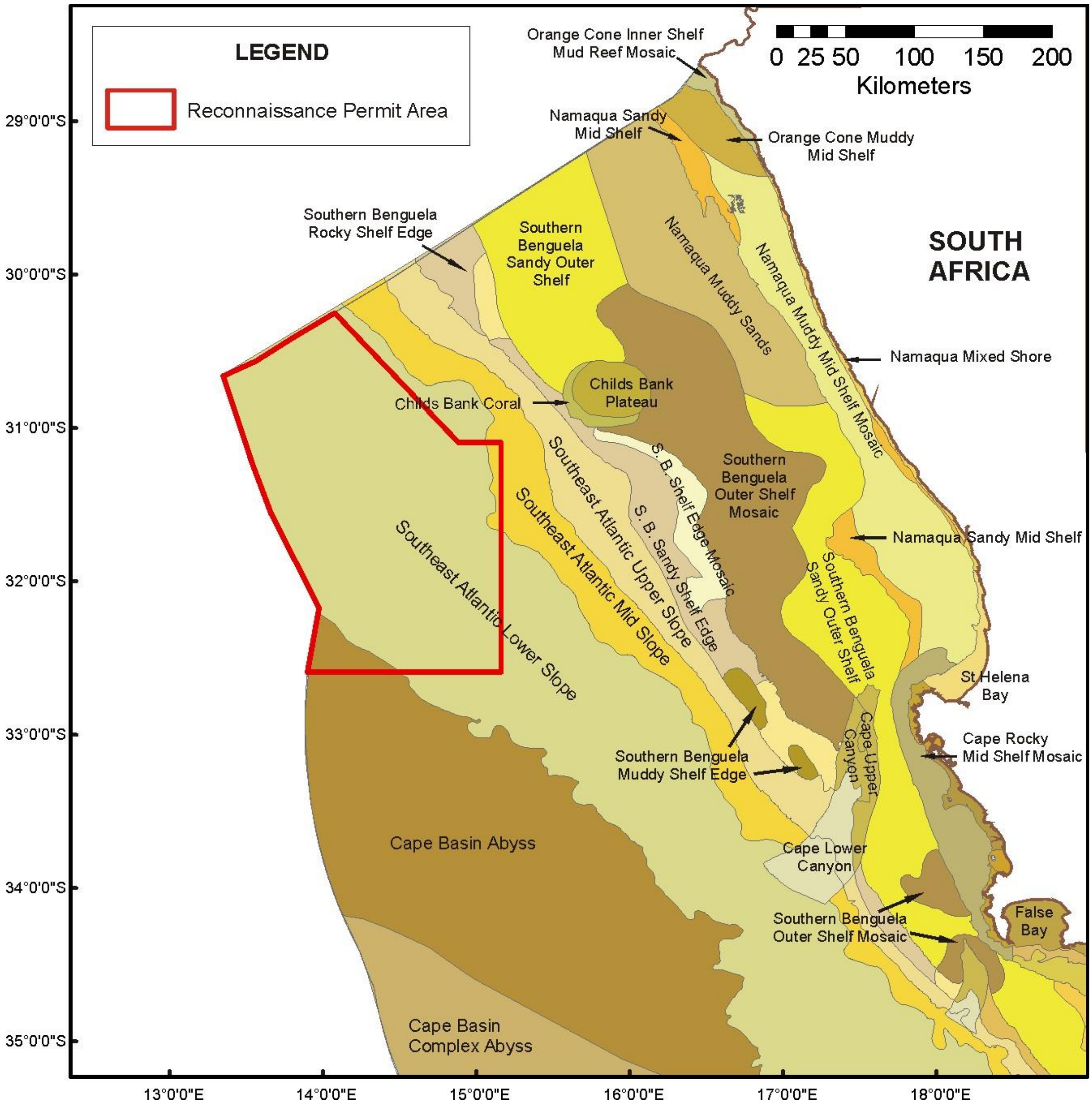


Figure 3-12: The Reconnaissance Permit Area in relation to the distribution of ecosystem types along the West Coast (adapted from Sink *et al.* 2019). Only those ecosystem types within the immediate vicinity of the Reconnaissance Permit Area are labelled.

Karenyi *et al.* (2016) found that off Namaqualand, species richness generally increased 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.

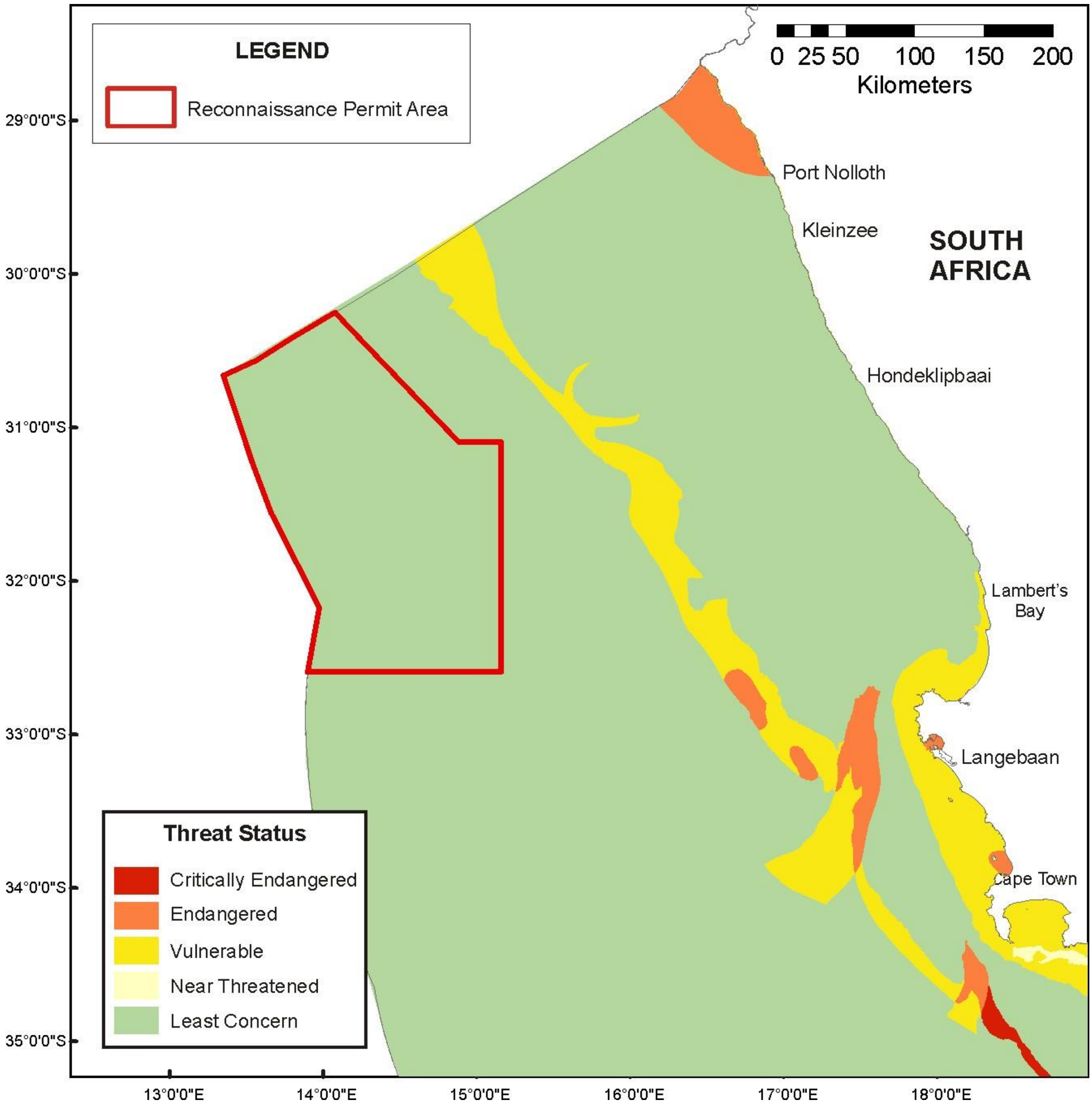


Figure 3-13: The Reconnaissance Permit Area in relation to the ecosystem threat status for coastal and offshore benthic and pelagic habitat types on the South African West Coast (adapted from Sink *et al*. 2019).

Nonetheless, there is limited knowledge on the benthic biodiversity of all three of the broad ecosystem groups in South African waters (Sink *et al*. 2019), and no studies exist examining connectivity between slope, plateau or abyssal ecosystems in South Africa and. The benthic fauna of the outer shelf and continental slope (beyond ~450 m depth) are very poorly known, due to limited opportunities for sampling as well as the lack of access to Remote Operated Vehicles (ROVs) for visual sampling of hard substrata. Consequently, very few areas on the continental slope off the West Coast have been biologically surveyed to date (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 3-2), 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). More recently, however, Environmental Baseline Surveys (EBS) conducted by various hydrocarbon companies holding exploration licences off the southern African west coast have confirmed the presence of homogenous unconsolidated sediments at depths beyond -500 m.

Due to the paucity of quantitative data describing bathyal (-1 000 m to 3 500 m) and abyssal (> -3 500 m) ecosystems in South Africa, there is limited understanding of ecosystem functioning and sensitivity of benthic macrofaunal communities beyond the shelf break (Sink *et al.* 2019; Anderson & Hulley 2000; Harris *et al.* 2022). Quantitative information on the benthic fauna of the lower continental slope and abyss is largely lacking due to limited opportunities for sampling. The description below is drawn from recent EBSs undertaken in Block 2913B (Benthic Solutions Ltd 2019) and Block 2914A (Fugro 2024) just to the north of the Reconnaissance Permit Area, and from the EBS undertaken in the Deep Water Orange Basin (Benthic Solutions & Creocean 2024). These surveys provided valuable information on the benthic infaunal communities of the lower continental slope. As conditions in such deep water habitats are comparatively uniform ((low temperatures and oligoxic conditions characterising the SACW that comprises the bulk of the water in the area), the description of the benthic fauna and demersal communities is considered applicable to the Reconnaissance Permit Area.

The macrofauna inhabiting unconsolidated sediments beyond 2 000 m depth are generally impoverished but fairly consistent, which is typical for deep water sediments. In Block 2913B, 105 species were recorded. The macrofauna, was 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 Block 2913B area adjacent and to the north of the Reconnaissance Permit Area are illustrated in Figure 3-14.

In the Deep Water Orange Basin, at depths ranging from -500 m to nearly -4 000 m (and covering much of the Reconnaissance Permit Area), the unconsolidated seabed was characterised by abundant small mounds, oblique burrows, large depressions, wavy casts, xenophyophores and worm casts, all indicative of abundant bioturbation. As reported in the adjacent Block 2913B, the infaunal benthic community had a low diversity and biomass, being dominated by polychaetes, crustaceans and molluscs. No infaunal species with particular protection status were detected.

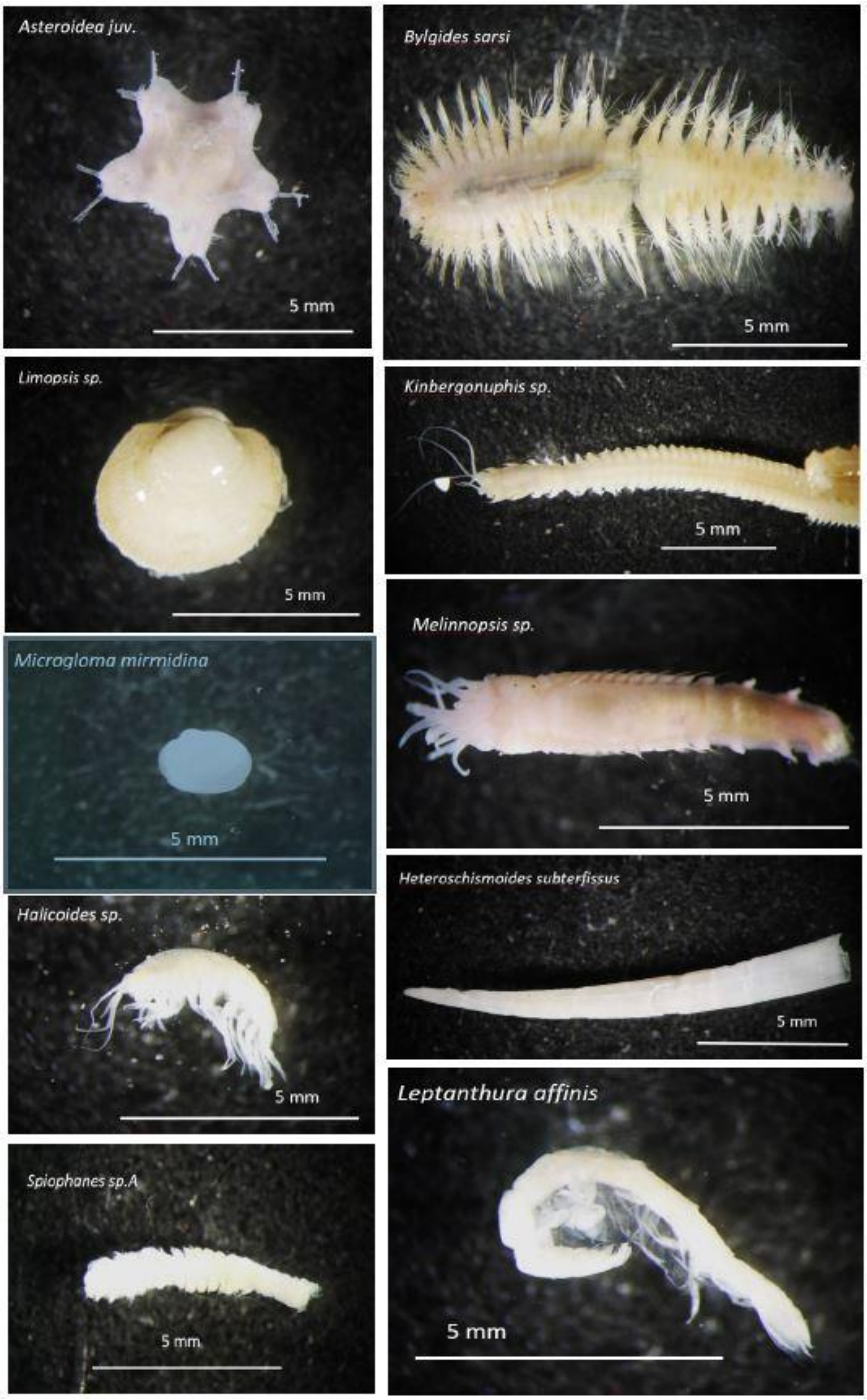


Figure 3-14: Examples of macroinvertebrates recorded in Block 2913B to the north of the Reconnaissance Permit Area (Source Benthic Solutions Ltd 2019).

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 shear bed 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 deep-water shelf areas of the West Coast that can over-ride the suitability 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. Amorim & Zettler (2023) provided a comprehensive study on the distribution of macrofaunal assemblages of the Oxygen Minimum Zone (OMZ) off Namibia, using samples collected along three transects to a maximum depth of 1 523 m. The deep assemblages displayed high diversity, intermediate abundance and low biomass. Thyasirid bivalves, and the polychaetes *Ceratocephale* sp. and *Spiophanes* sp were dominant in samples collected at the deepest stations. The authors note that slope communities are likely distributed along a much wider latitudinal range and deeper depths than were sampled and are similar to other upwelling slope areas.

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, 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. The continental shelf on the West Coast between depths of 100 m and 250 m, contains a single epifaunal community characterised by the hermit crabs *Sympagurus dimorphus* and *Parapaguris pilosimanus*, the prawn *Funchalia woodwardi* and the sea urchin *Brisaster capensis* (Lange 2012). Atkinson (2009) also reported numerous species of urchins and burrowing anemones beyond 300 m depth off the West Coast. 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).

In Namibian Block 2914A (55 km to the north of the reconnaissance Permit Area) three biotopes were identified within the survey area spanning depths of -350 m to 1 682 m and classified in accordance with the Coastal and Marine Ecological Classification Standard (CMECS): 'Burrowing fauna on Namibian continental slope', 'Soft sediment brittlestars on Namibian continental slope' and 'Pennatulid bed on

Namibian continental slope'. Bioturbation, in the form of burrows, was present within all biotopes indicating the presence of infaunal taxa, but no further details on infauna were provided other than mention of feather duster worms (? Sabellida). The dominant epifaunal taxa were brittlestars (Ophiuroidea), sea pens (Pennatuloidea, including ?*Umbellula* sp.), anemones (Actinaria, including Actinostoloidea and Metridioidea), and sea cucumbers (Holothuroidea, including ?*Benthothuria* sp., ?Benthodytes sp. and *Enypniastes eximia*). The sea pens and the sea whips/ black corals (Octocorallia/Antipatharia) observed in the survey area are considered indicator species of Vulnerable Marine Ecosystems (VME) (see later) within the SEAFO (South East Atlantic Fisheries Organisation) convention area. Other mobile epifauna included pelagic cnidarians (Cnidaria), sea urchins (?*Phormosoma placenta)*, shrimps (Caridea) and crabs (Brachyura), sea stars (Asteroidea inc. Solasteridae), vampire squid (?Vampyroteuthidae) (Fugro 2024).

In the Deep Water Orange Basin, phytodetritus deposits were common across the area, with epifauna represented by 92 taxa. Starfish, sea urchins and brittle stars dominated the invertebrate epifauna, with burrowing anemones, a variety of sea pens and sea whips, and crustaceans (shrimps, crabs, barnacles and hermit crabs) also being reported. Mobile epifauna included benthic and pelagic holothurians, larvaceans and cepahlopods (dumbo octopus).

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 3-13), with only those communities occurring along the shelf edge (-500 m) being considered 'Vulnerable'. This primarily reflects the great extent of these habitats in the South African Exclusive Economic Zone (EEZ).

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. Infauna and epifauna would, however, receive the sound in the far field only and no detrimental effects to the communities or to individual benthic species are expected.

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 in 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 and western boundary of the Reconnaissance Permit Area (see Figure 2-1). 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).

Details on demersal fish communities beyond the shelf break and in the Reconnaissance Permit Area are, however, lacking (see Harris *et al.* 2022). However, in the recent EBS undertaken in Namibian Block 2914A (55 km to the north of the reconnaissance Permit Area) fish observed included numerous rattails and grenadiers (Macrouridae, including *Coryphaenoides* sp.), lizard fish (*Bathysaurus* sp.), cutthroat eel (Synaphobranchidae), halosaurs (Halosauridae, including *Aldrovandia* sp.), hagfish (Myxinidae), possible lantern shark (?Squaliformes), anglerfish (?*Lophius* sp.), rockfish (Sebastidae), skates (Rajidae) and deep-water hake (?*Merluccius paradoxus*) (Fugro 2024). Fish reported from within the Deep Water Orange Basin included numerous species of rattails (Macrouridae), eels, halosaurs and tripod fish.

The diversity and distribution of demersal cartilagenous fishes on the continental shelf of 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 3-1. The shelf-associated[2] distribution of some of these species was provided in Harris *et al.* (2022)

[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.

(Figure 3-15a, 3-15b). Details on demersal cartilaginous species beyond the shelf break and in the Reconnaissance Permit Area are lacking, however. Demersal fish species would, however, receive the sound in the far field only and no detrimental effects to the communities or to individual benthic species are expected.

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 (200-2 000 m) include rattails (Macrouridae), greeneyes (*Chlorophthalmus* species), 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 3-1: 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
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

Common Name	Scientific name	Depth Range (m)	IUCN Conservation Status
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 spinacidermis*	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

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 influences the distribution of organisms on and around seamounts. Evidence of enrichment of bottom-associated communities and high abundances of demersal fishes has been regularly reported over such seabed features.

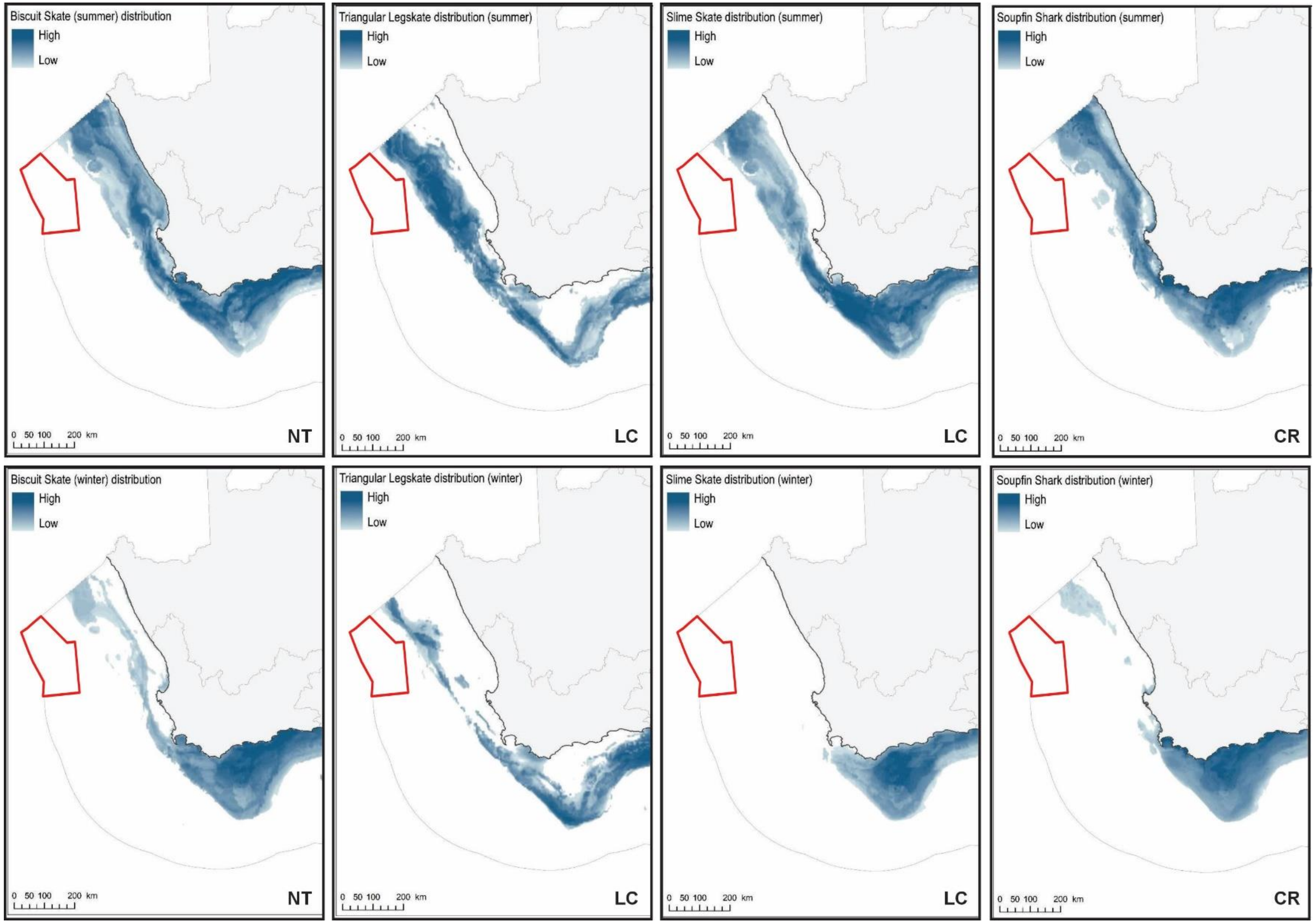


Figure 3-15a: The summer (top) and winter (bottom) distribution of biscuit skate, triangular legskate, slime skate and soupfin shark in relation to the Reconnaissance Permit Area (red polygon) (adapted from Harris *et al*. 2022). The IUCN conservation status is provided.

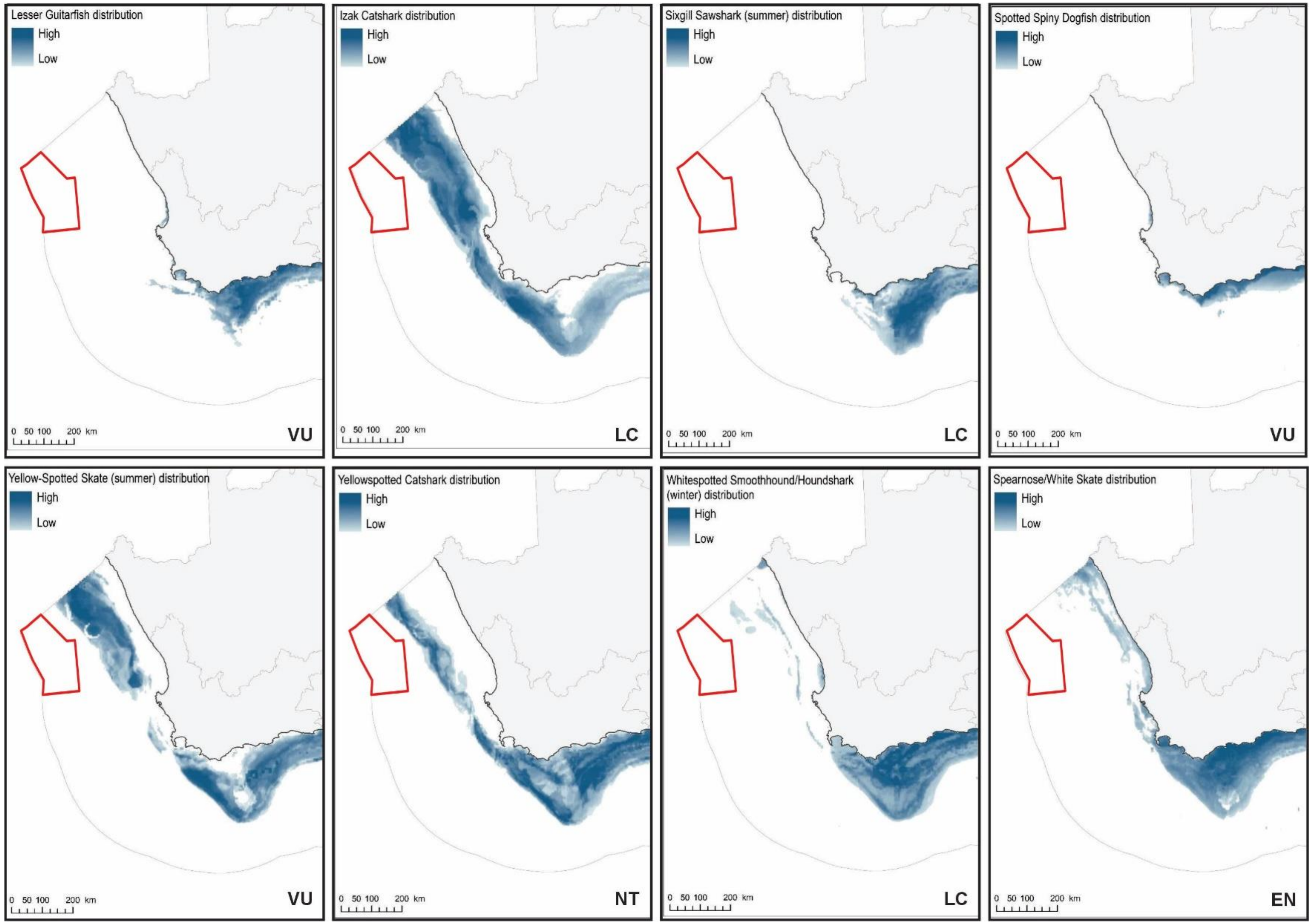


Figure 3-15b: The distribution of various cartilaginous species mentioned in Table 2 in relation to the Reconnaissance Permit Area (red polygon) (adapted from Harris *et al*. 2022). The IUCN conservation status is provided.

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 ~70 km north of the northern boundary of the survey area. 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 decapods 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), 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 Protea and Argentina Seamounts.

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 3-16). 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).

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).

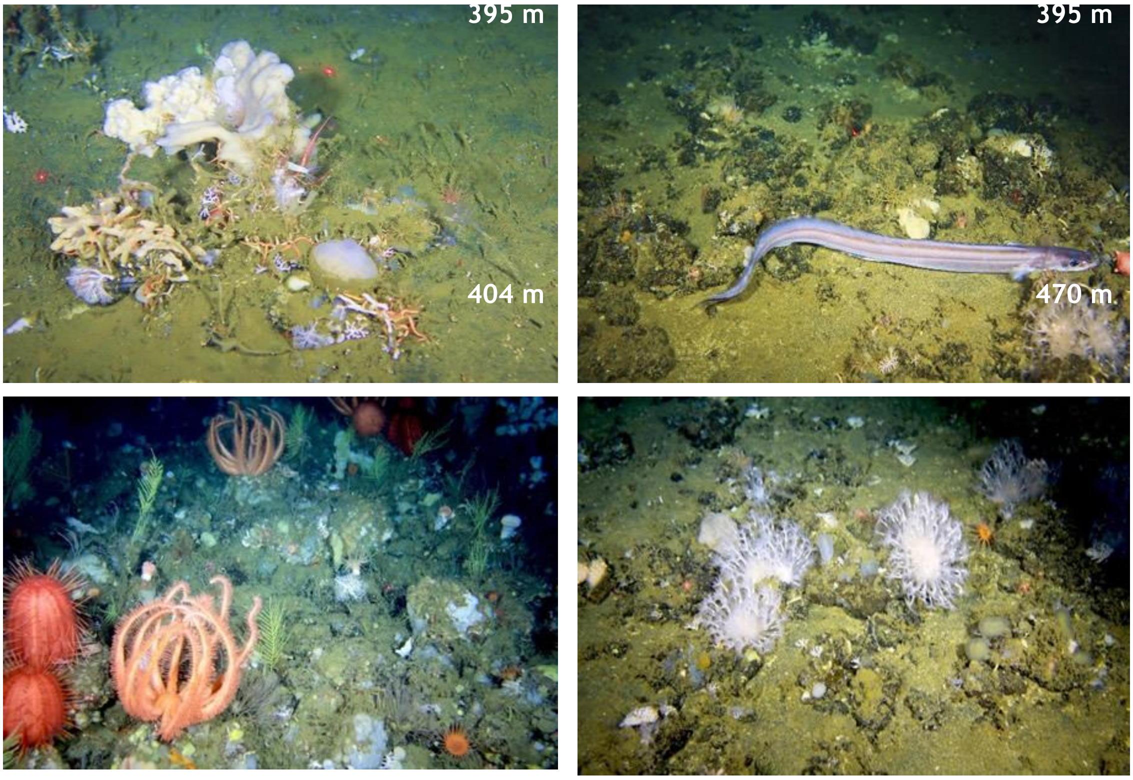


Figure 3-16: Deep water benthic macrofauna from various depths in the Cape Canyon (Source: www.environment.gov.za/dearesearchteamreturnfromdeepseaexpedition).

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 3-17), 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 3-2). 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 3-2 (Atkinson & Sink 2018; Sink *et al*. 2019).

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 the Reconnaissance Permit Area. Should they occur, however, they would receive the sound in the far field only and no detrimental effects to the communities or to individual benthic species are expected. 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 3-18). Some sites need more research to determine their status. The location of the Reconnaissance Permit Area is well offshore of these known and potential VMEs emphasising the gaps in our knowledge specific to the vulnerability of marine communities of bathyal and abyssal habitats.

Figure 3-17: Gorgonians and bryozoans communities recorded on deep-water reefs (100-120 m) off the southern African West Coast (Photos: De Beers Marine).

Table 3-2: 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

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 to the south of the Reconnaissance Permit Area by Palan (2017).

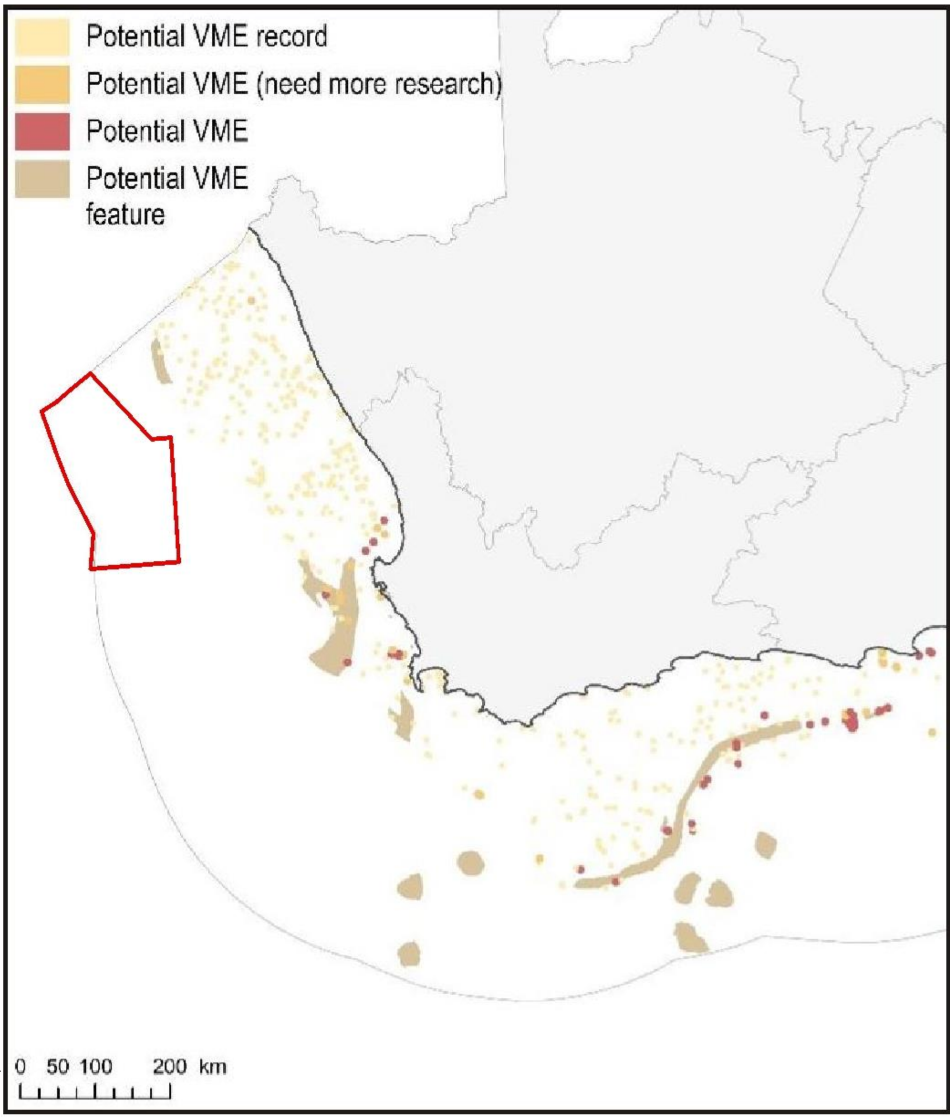


Figure 3-18: The Reconnaissance Permit Area (red polygon) in relation to the distribution of known and potential Vulnerable Marine Ecosystem habitat (adaptef from Harris *et al.* 2022).

3.3.3 Pelagic Communities

In contrast to demersal and benthic biota 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 3-19).

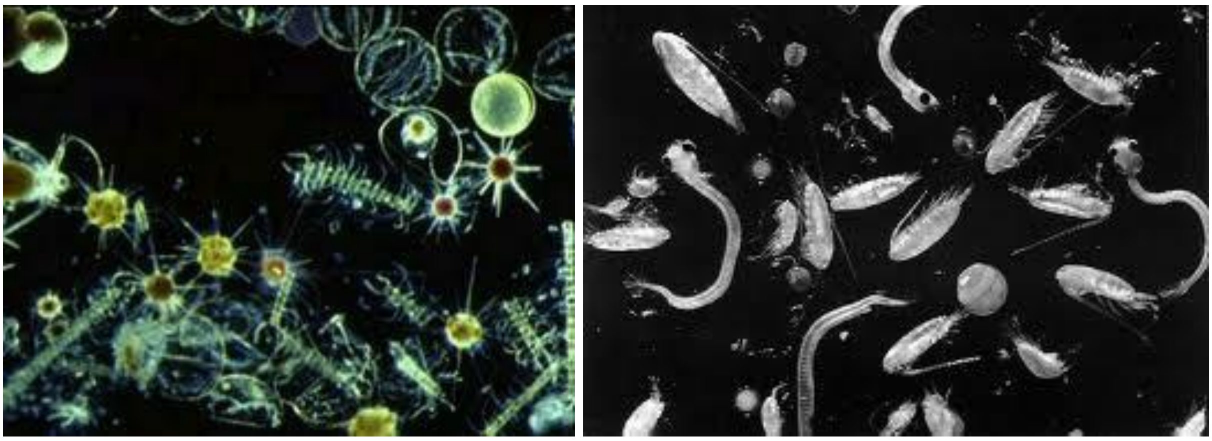


Figure 3-19: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

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.

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 the proposed 3D survey area.

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 3-20, Figure 3-21a and 3-21b, and Figure 3-22), 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 3-21a and 21b 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 3-22, 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 3-22, 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.

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 no overlap of the Reconnaissance Permit Area with the northward egg and larval drift of commercially important species, and the return migration of recruits (Figure 3-20). In the offshore oceanic waters of the proposed 3D survey area, ichthyoplankton abundance is, therefore, expected to be low.

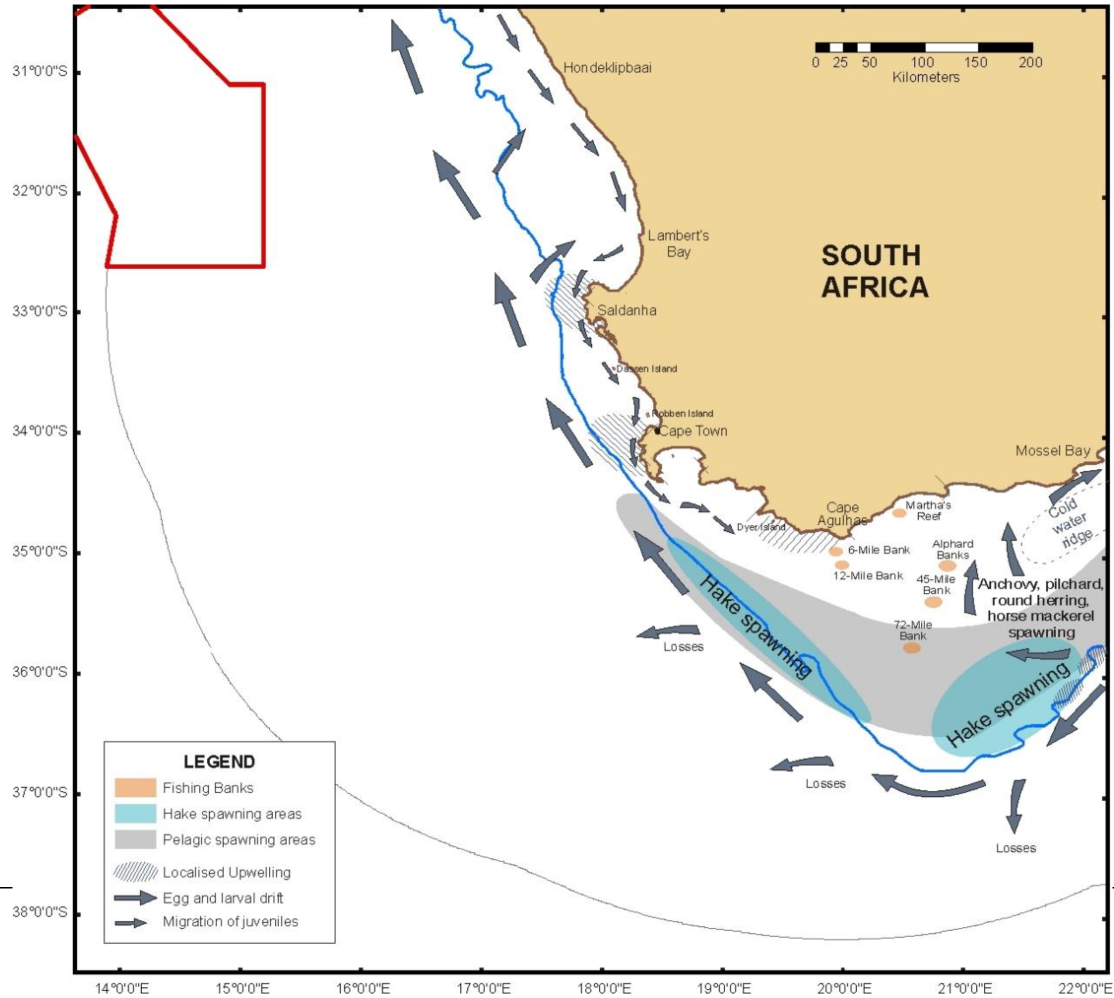


Figure 3-20: The Reconnaissance Permit Area (red polygon) in relation to major spawning, recruitment and nursery areas in the southern Benguela region (adapted from Crawford *et al*. 1987; Hutchings 1994; Hutchings *et al*. 2002).

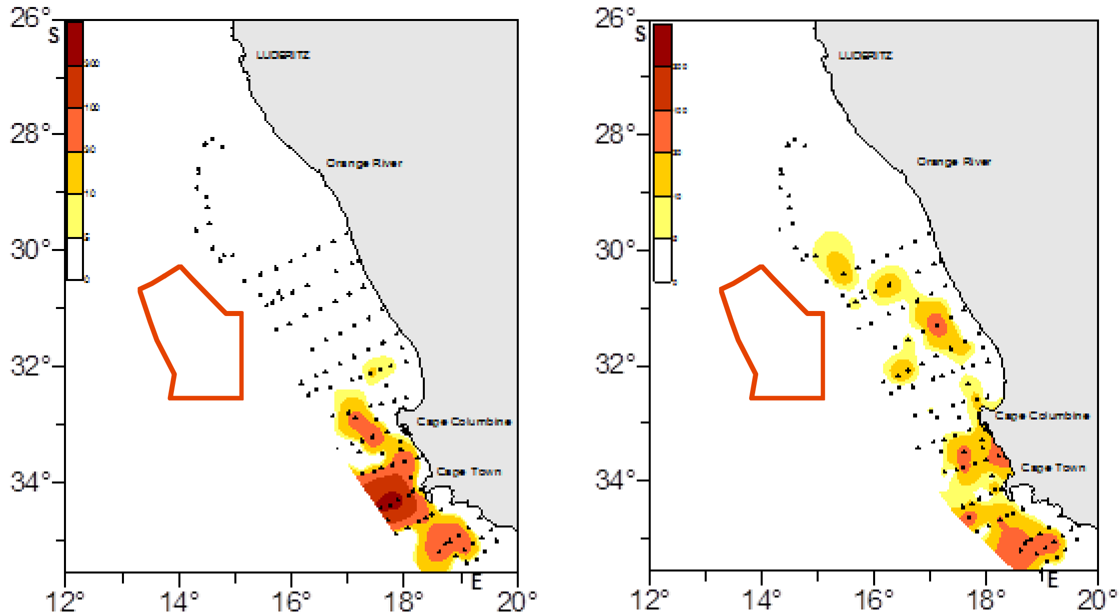


Figure 3-21a: Distribution of hake eggs (left) and larvae (right) off the West Coast of South Africa between September and October 2005 (adapted from Stenevik *et al*. 2008) in relation to the Reconnaissance Permit Area (red polygon).

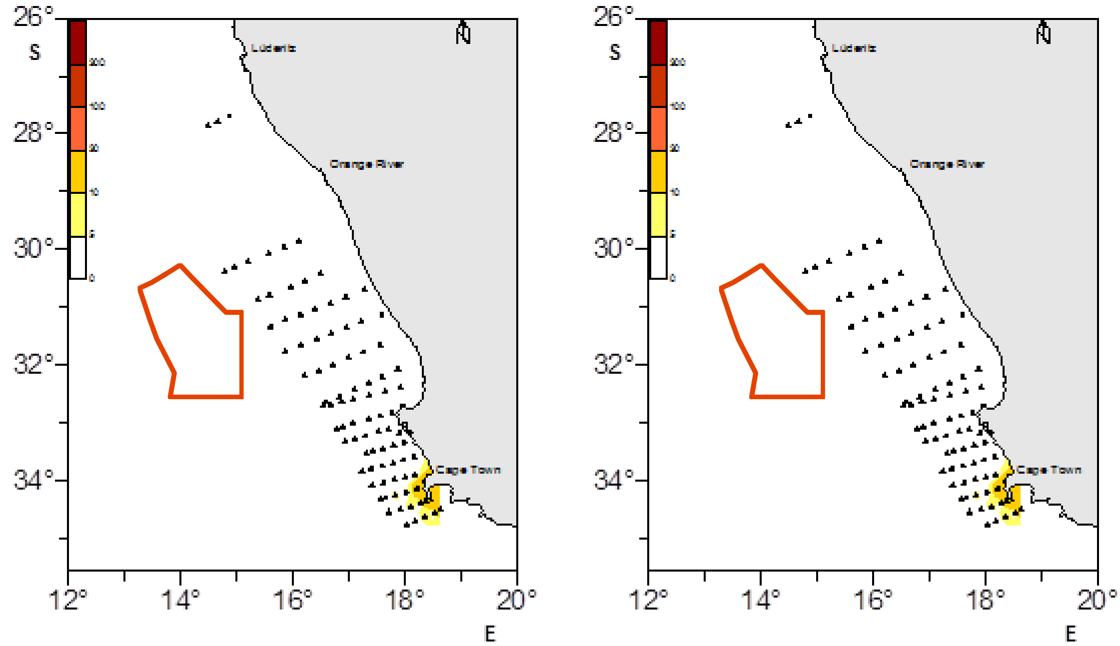
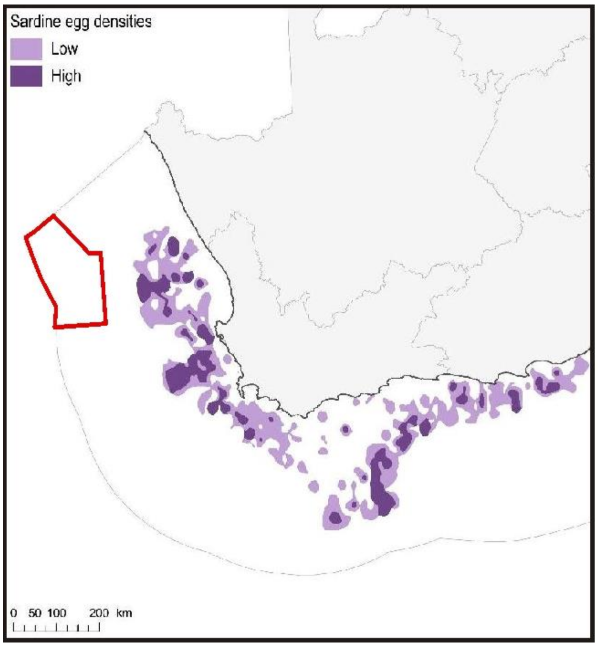


Figure 21b: Distribution of hake eggs (left) and larvae (right) off the West Coast of South Africa between March and April 2007 (adapted from Stenevik *et al*. 2008) in relation to the Reconnaissance Permit Area (red polygon).



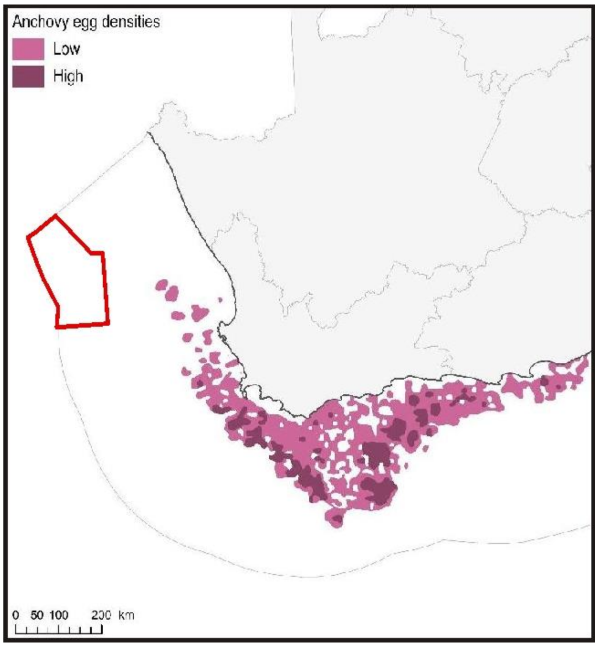


Figure 3-22: Distribution of sardine (left) and anchovy (right) spawning areas, as measured by egg densities, in relation to the Reconnaissance Permit Area (red polygon) (adapted from Harris *et al*. 2022).

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 3-23, top) while the giant squid is usually found near continental and island slopes all around the world's oceans (Figure 3-23, 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.

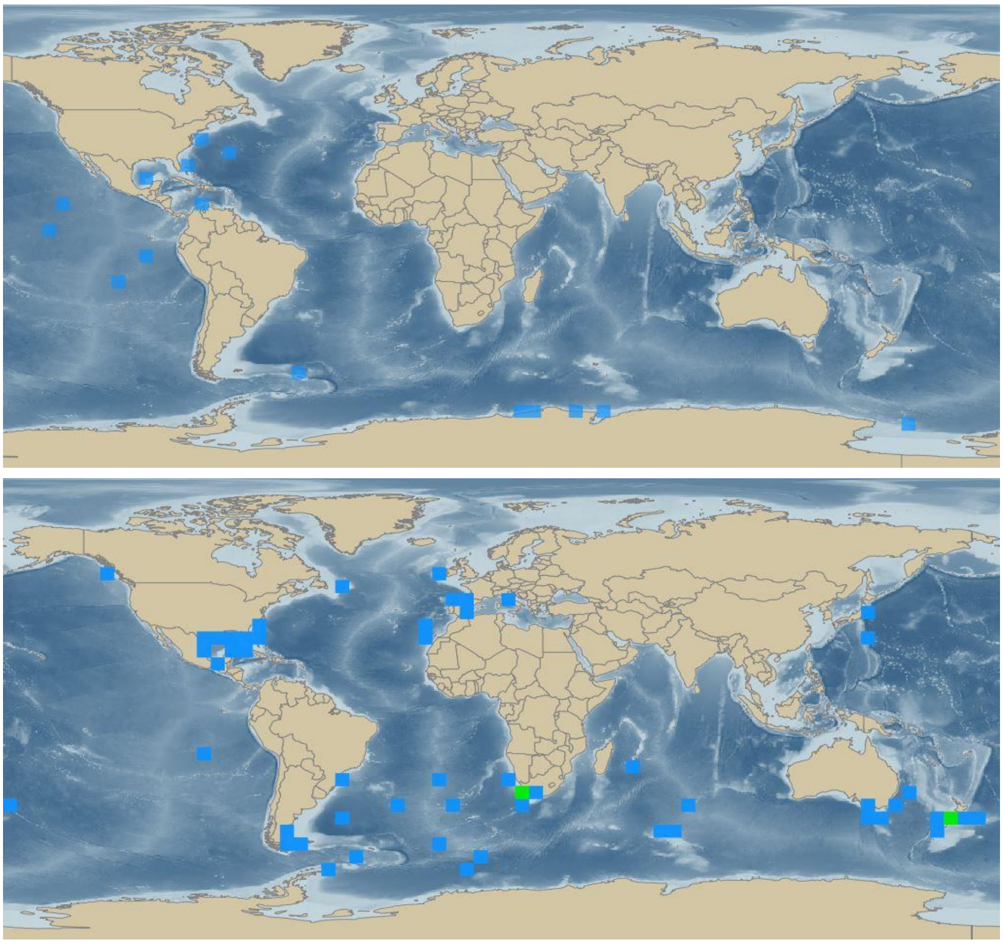


Figure 3-23: Distribution of the colossal squid (top) and the giant squid (bottom). Blue squares <5 records, green squares 5-10 records (Source: http://iobis.org).

3.3.3.3 Pelagic Fish

Small pelagic species include the sardine/pilchard (*Sadinops ocellatus*) (Figure 3-24, left), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) (Figure 3-24, 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 3-20). 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 3-24: 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 movement 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 3-25). 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 the Reconnaissance Permit Area.

The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of the proposed 3D survey areas 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 3-3). 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.

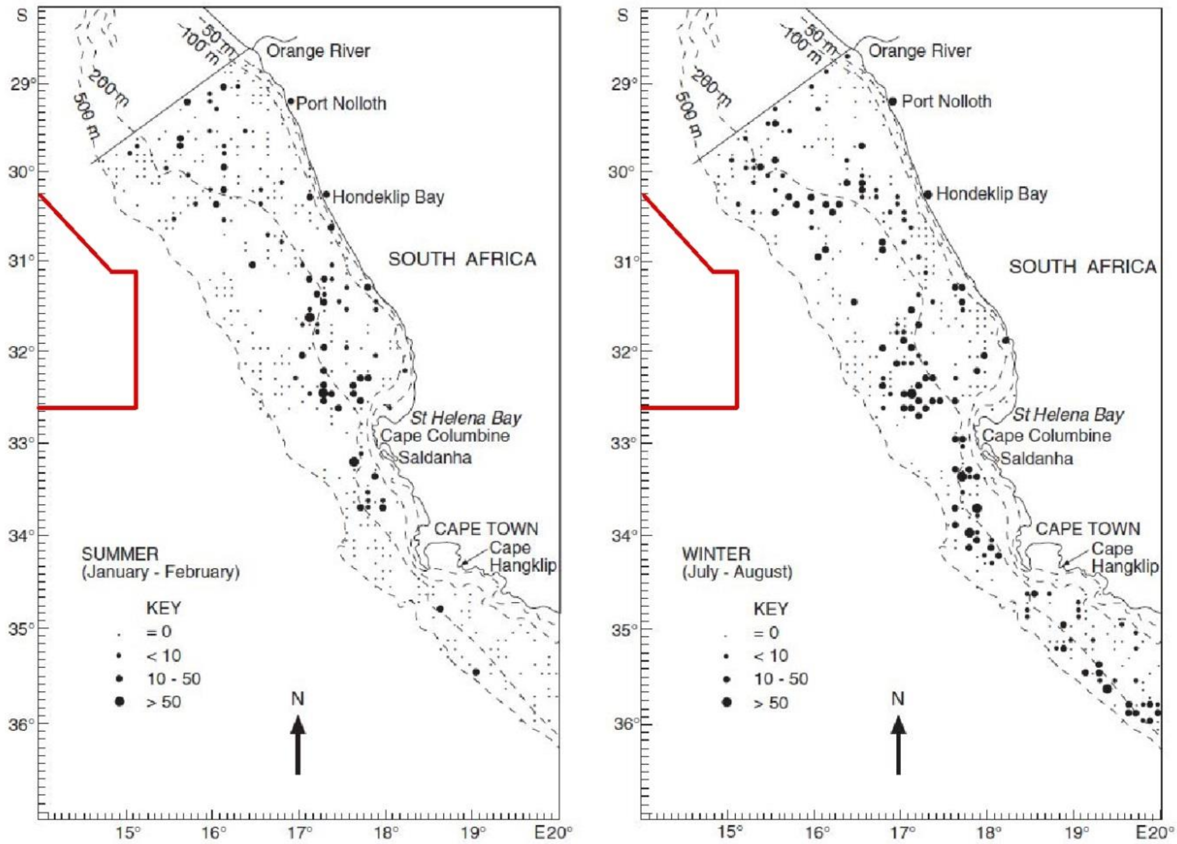


Figure 3-25: Mean number of snoek per demersal trawl per grid block (5 × 5 Nm) by season for (A) the west coast (July 1985–Jan 1991) and (B) the south coast in relation to the Reconnaissance Permit Area (red polygon) (adapted from Griffiths 2002).

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 3-26, right), yellowfin *T. albacares*, bigeye *T. obesus*, and skipjack *Katsuwonus pelamis tunas*, as well as the Atlantic blue marlin *Makaira nigricans* (Figure 3-26, 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 2022 – Fisheries Specialist Study).

A number of species of pelagic sharks are also known to occur on the West and South-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 the project area *en route* to South America (da Silva *et al.* 2010).

Table 3-3: 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.

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	Near Threatened
Sailfish	*Istiophorus platypterus*	Least concern	Least concern
Swordfish	*Xiphias gladius*	Data deficient	Least concern
Pelagic Sharks			
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Not Assessed	Vulnerable
Dusky Shark	*Carcharhinus obscurus*	Data deficient	Vulnerable
Bronze Whaler Shark	*Carcharhinus brachyurus*	Data deficient	Near Threatened
Great White Shark	*Carcharodon carcharias*	Least concern	Vulnerable
Shortfin Mako	*Isurus oxyrinchus*	Vulnerable	Endangered
Longfin Mako	*Isurus paucus*	Not Assessed	Vulnerable
Whale Shark	*Rhincodon typus*	Not Assessed	Endangered
Blue Shark	*Prionace glauca*	Least concern	Near Threatened

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-adult 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).

Figure 3-26: Large migratory pelagic fish such as blue marlin (left) and longfin tuna (right) occur in offshore waters (photos: www.samathatours.com; www.osfimages.com).

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) in the Greater St. Lucia Wetland Park (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 the Reconnaissance Permit Area is relatively low.

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 3-27).

[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.

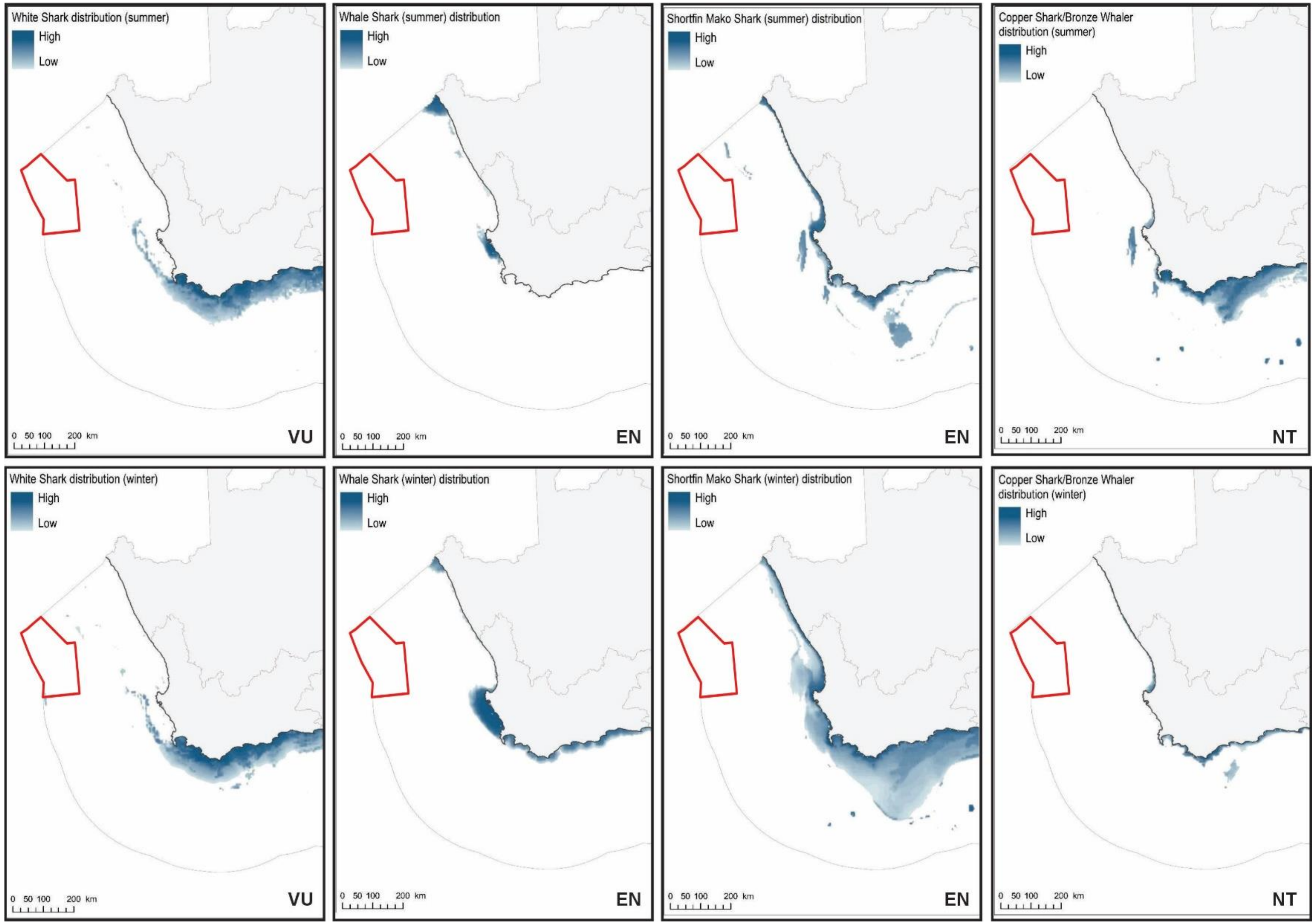


Figure 3-27: The summer (top) and winter (bottom) distribution of white shark, whale shark, shortfin mako and bronze whaler shark in relation to Block 3B/4B (red polygon) (adapted from Harris *et al*. 2022).

3.3.3.4 Turtles

Three species of turtle occur along the West Coast, namely the Leatherback (*Dermochelys coriacea*) (Figure 3-28, left), and occasionally the Loggerhead (*Caretta caretta*) (Figure 3-28, right) and the Green (*Chelonia mydas*) turtle. Loggerhead and Green turtles 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 the Reconnaissance Permit Area (Lauret-Stepler *et al*. 2007). The most recent conservation status, which assessed the species on a sub-regional scale, is provided in Table 3-4.

The Leatherback is the only turtle 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 southeast Indian Ocean (South Africa) (Lambardi *et al*. 2008, Elwen & Leeney 2011; SASTN 2011[4]). Leatherback turtles from the east South Africa population have been satellite tracked swimming around the west coast of South Africa and remaining in the warmer waters west of the Benguela ecosystem (Lambardi *et al*. 2008) (Figure 3-29).

Figure 3-28: Leatherback (left) and loggerhead turtles (right) occur along the West Coast of Southern Africa (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

Table 3-4: Global and Regional Conservation Status of the turtles occurring off the South 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

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

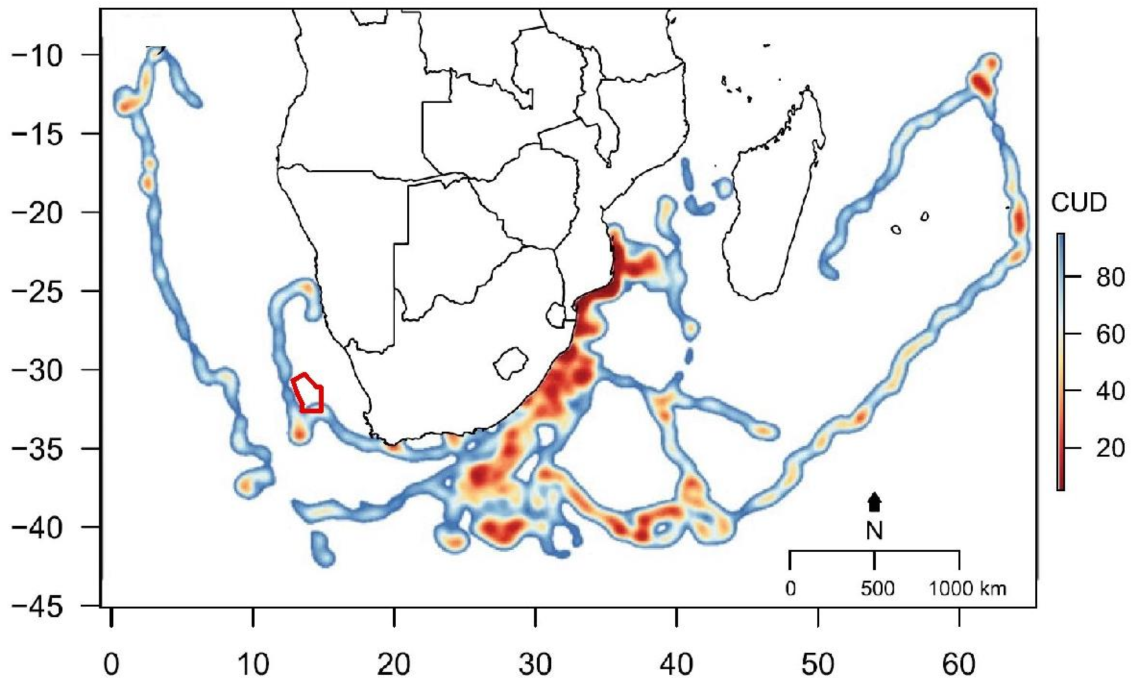


Figure 3-29: The Reconnaissance Permit Area (red polygon) in relation to the migration corridors of leatherback turtles in the south-western Indian Ocean. Relative use (CUD, cumulative utilization distribution) of corridors is shown through intensity of shading: light, low use; dark, high use (adapted from Harris *et al.* 2018).

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 sighting of a Loggerhead turtle in the Deep Water Orange Basin Area has, however, been reported by an MMO (CapFish 2013a). Furthermore, a green turtle and loggerhead turtle recently released on the Cape Peninsula by the Two Oceans Aquarium has 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) (Figure 3-30).

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[5]). Leatherback turtles inhabit deeper waters and are considered a pelagic species, travelling the ocean currents in

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

search of their prey (primarily jellyfish). While hunting they may dive to over 600 m and remain submerged for up to 54 minutes (Hays *et al.* 2004). Their abundance in the study area is unknown but expected to be low. Leatherbacks feed on jellyfish and are known to have mistaken plastic marine debris for their natural food. Ingesting this can obstruct the gut, lead to absorption of toxins and reduce the absorption of nutrients from their real food.

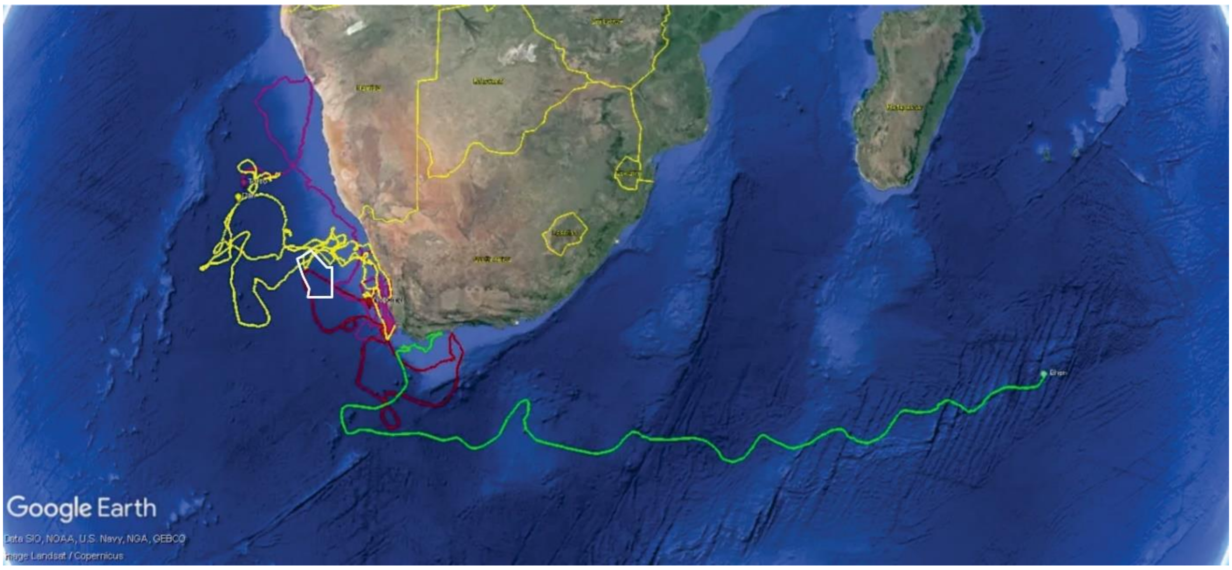


Figure 3-30: The Reconnaissance Permit Area (white polygon) in relation to to turtle telemetry data recorded by Two Oceans Aquarium. Green and purple lines = green turtles, red and yellow lines = loggerhead turtles (https://aquarium.evlink21.net/public/messages/view-online/sUxLeTchHn1pvYc9/f4ow0OckcO3B4rjT/VFS8EqhUDNyVyLW1 (accessed 9 April 2024)).

Loggerheads and leatherbacks nest along the sandy beaches of the northeast coast of KwaZulu-Natal, 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 the Reconnaissance Permit Area (Figure 3-31). Despite their extensive distributions and feeding ranges, the numbers of adult and neonate turtles encountered in the Reconnaissance Permit Area 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.

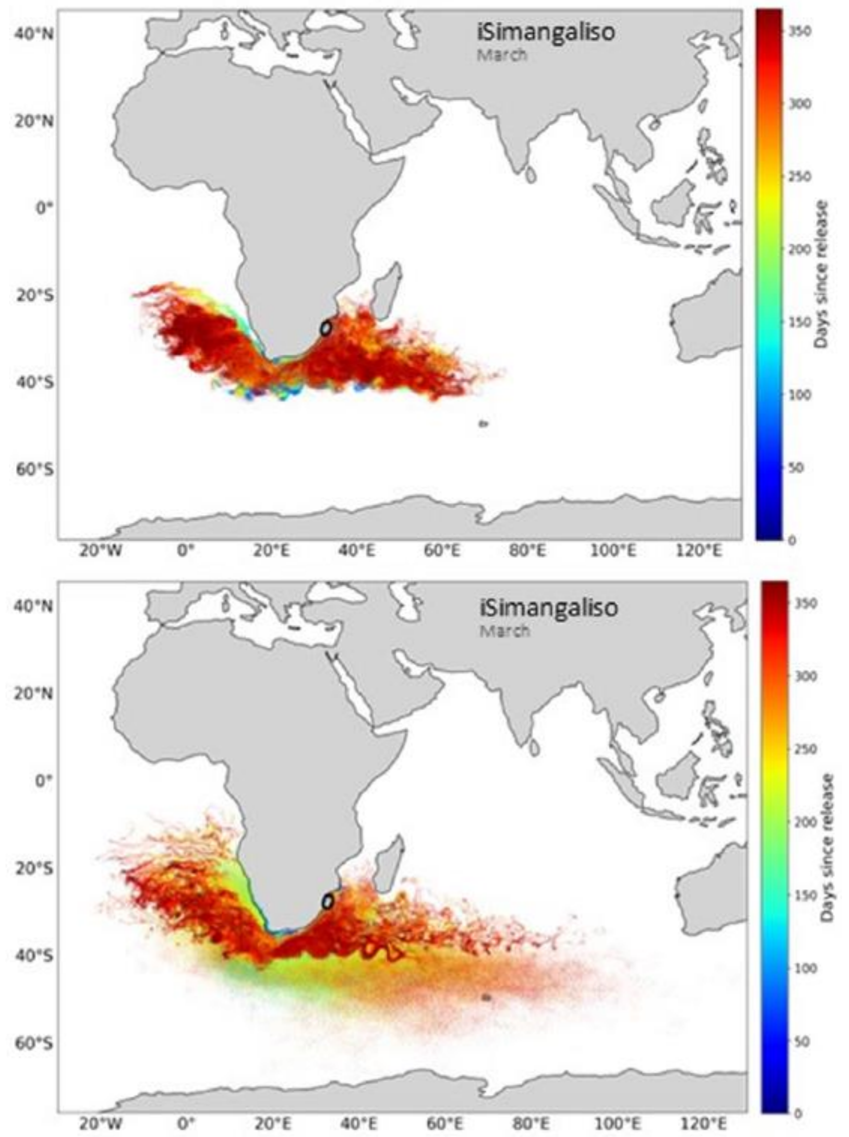


Figure 3-31: Dispersal maps showing trajectories of 5000 particles released from the respective nesting sites (white circles) in March 2018 for loggerheads (top) and leatherbacks (bottom). Colours (blue to red) indicate the number of days since release (adapted from Le Gouvelle *et al.* 2020b).

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 Southwestern 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) (see Figure 3-29) (Lambardi *et al.* 2008; de Wet 2013; Harris *et al.* 2018).

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, 14 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 are listed in Table 3-5. 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 species in the region reach highest densities offshore of the shelf break (200 – 500 m depth), with highest population levels during their non-breeding season (winter). Pintado petrels and Prion spp. show the most marked variation here. Pelagic seabird species are therefore likely to be relatively frequently encountered in the offshore waters of the Reconnaissance Permit Area.

Fifteen species of seabirds breed in southern Africa; Cape Gannet (Figure 3-32, left), African Penguin (Figure 3-32, right), four species of Cormorant, White Pelican, three Gull and four Tern species (Table 3-6). The breeding areas are distributed around the coast with islands being especially important. The closest breeding islands to the Reconnaissance Permit Area are Bird Island in Lambert's Bay, the Saldanha Bay Islands and Dassen Island, which lie approximately 295 km, 270 km and 290 km to the east and southeast of the eastern and southern boundary of the Reconnaissance Permit Area, 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. The proposed 3D survey area lies well offshore of the aggregate core home ranges of Cape Gannet and African Penguin (Figure 3-33) (BirdLife South Africa 2022). Aggregate core home ranges and foraging areas for Cape Cormorant and Bank Cormorant similarly lie well inshore of the Reconnaissance Permit Area (see Harris *et al.* 2022). There is, however, overlap of the foraging areas of Wandering Albatross, Atlantic Yellow-nosed Albatross (Figure 3-33) and utilisation distribution of Black-browed Albatross (Figure 3-34) with the Reconnaissance Permit Area (BirdLife South Africa 2022; Harris *et al.* 2022).

Table 3-5: 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 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

Common Name	Species name	Global IUCN	Regional Assessment
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 3-32: Cape Gannets *Morus capensis* (left) (Photo: NACOMA) and African Penguins *Spheniscus demersus* (right) (Photo: Klaus Jost) breed primarily on the offshore Islands.

Table 3-6: 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 the 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*	Near Threatened	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*	Near Threatened	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

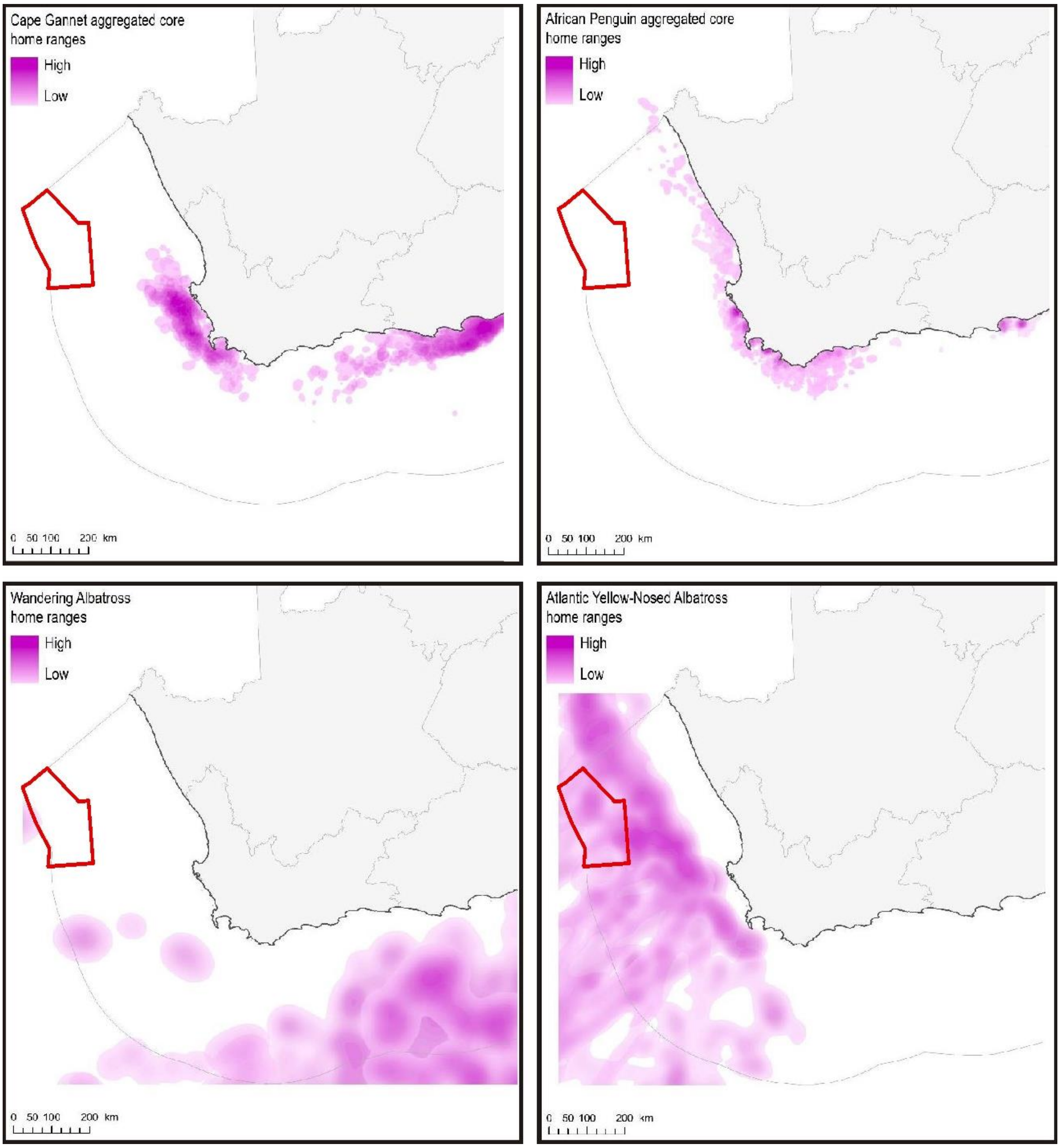


Figure 3-33: The Reconnaissance Permit Area (red polygon) in relation to aggregate core home ranges of Cape Gannet (top left), African Penguin (top right) for different colonies and life-history stages, and foraging areas of Wandering Albatross (bottom left) and Atlantic Yellow-nosed Albatross (bottom 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).

Interactions with commercial fishing operations, either through incidental bycatch or competition for food resources, are 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.

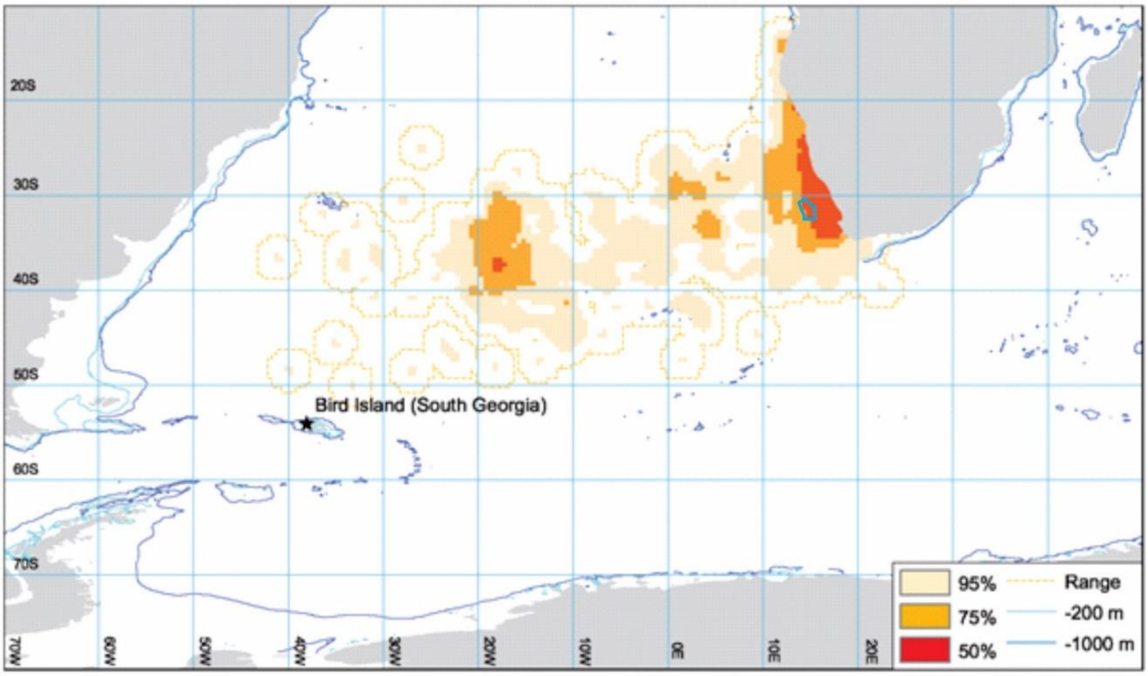


Figure 3-34: Utilisation distribution of incubating Black-browed Albatross from Bird Island, South Georgia (Birdlife Africa, 2004).

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 three species 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 these waters (Table 3-7). 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 *et al.* 2009; 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 MMOs 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.

The 3D acquisition area extends from the Namibian border to 32°27' offshore of St Helena Bay from roughly the 2 000 m isobath to 3 600 m water depth. Oceanographically this area lies largely outside 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, Risso's dolphin, common dolphin, sperm whale (winter distribution) and humpback whale (Figure 3-35) (Harris *et al.* 2022).

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.

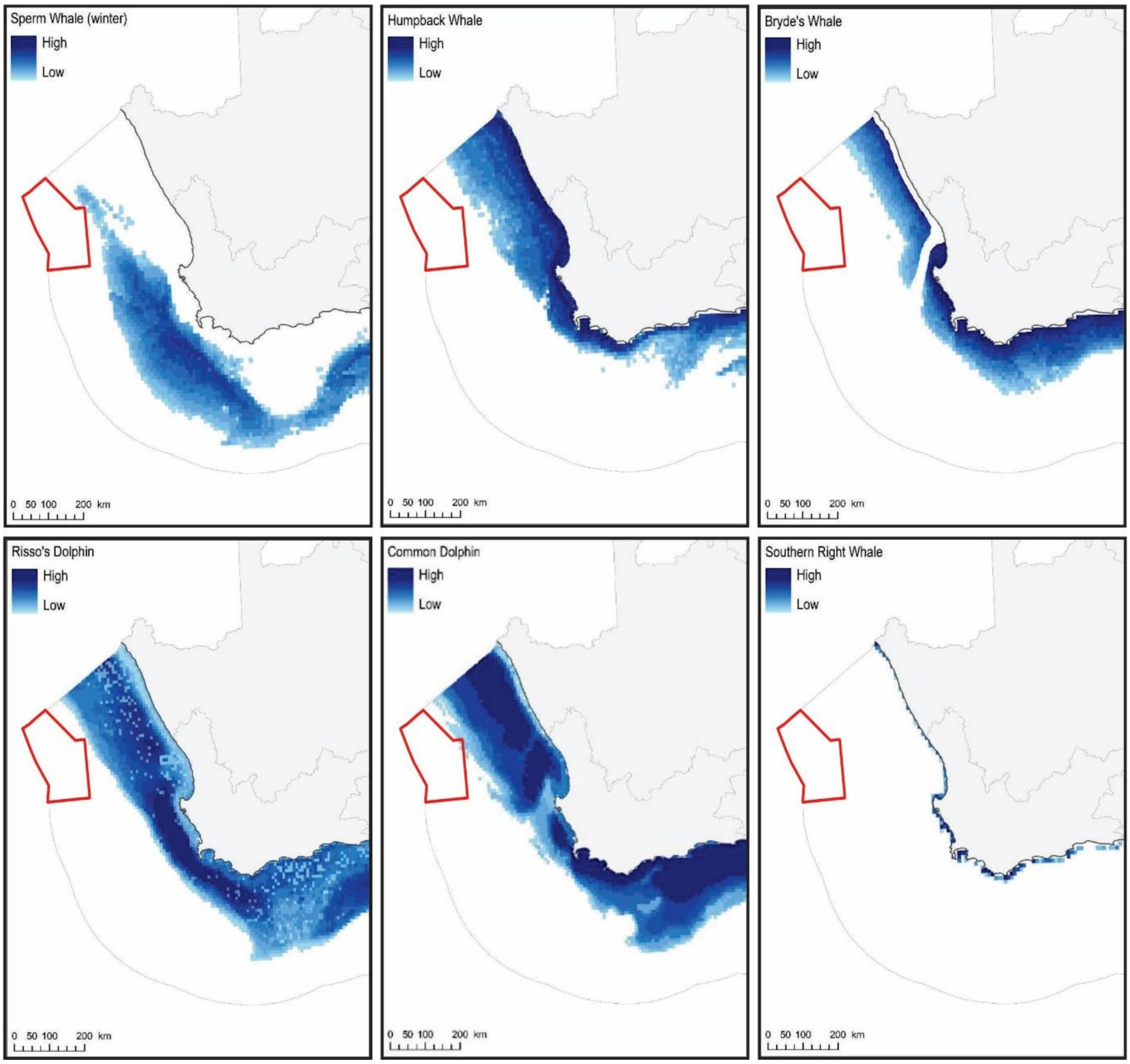


Figure 3-35: The Reconnaissance Permit Area (red polygon) in relation to the predicted distribution of sperm whales (winter distribution)(top left), humpback whale (top middle), Bryde's whale (top right), Risso's dolphin (bottom left), common dolphin (bottom middle) and southern right whale (bottom right) with darker shades of blue indicating highest likelihood of occurrence (adapted from Harris *et al.* 2022).

Table 3-7 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 3-36a – b; Figure 3-37). 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 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, or bimodal (e.g. May to July and October to November), reflecting a northward and southward migration through the area. 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 3-38, 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 summering grounds off western South Africa. Its seasonality on the West Coast is thus opposite to the majority of the balaenopterids with abundance likely to be highest in the area in January - March. The "inshore population" of Bryde's whale live mainly on the continental shelf and Agulhas Bank, and are 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' on the South 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 pelgic stocks around South Africa. The sighting of a Bryde's whale was reported by MMOs during an Environmental Baseline Survey (EBS) in the Deep Water Orange Basin Area. Encounters in the Reconnaissance Permit Area are thus possible.

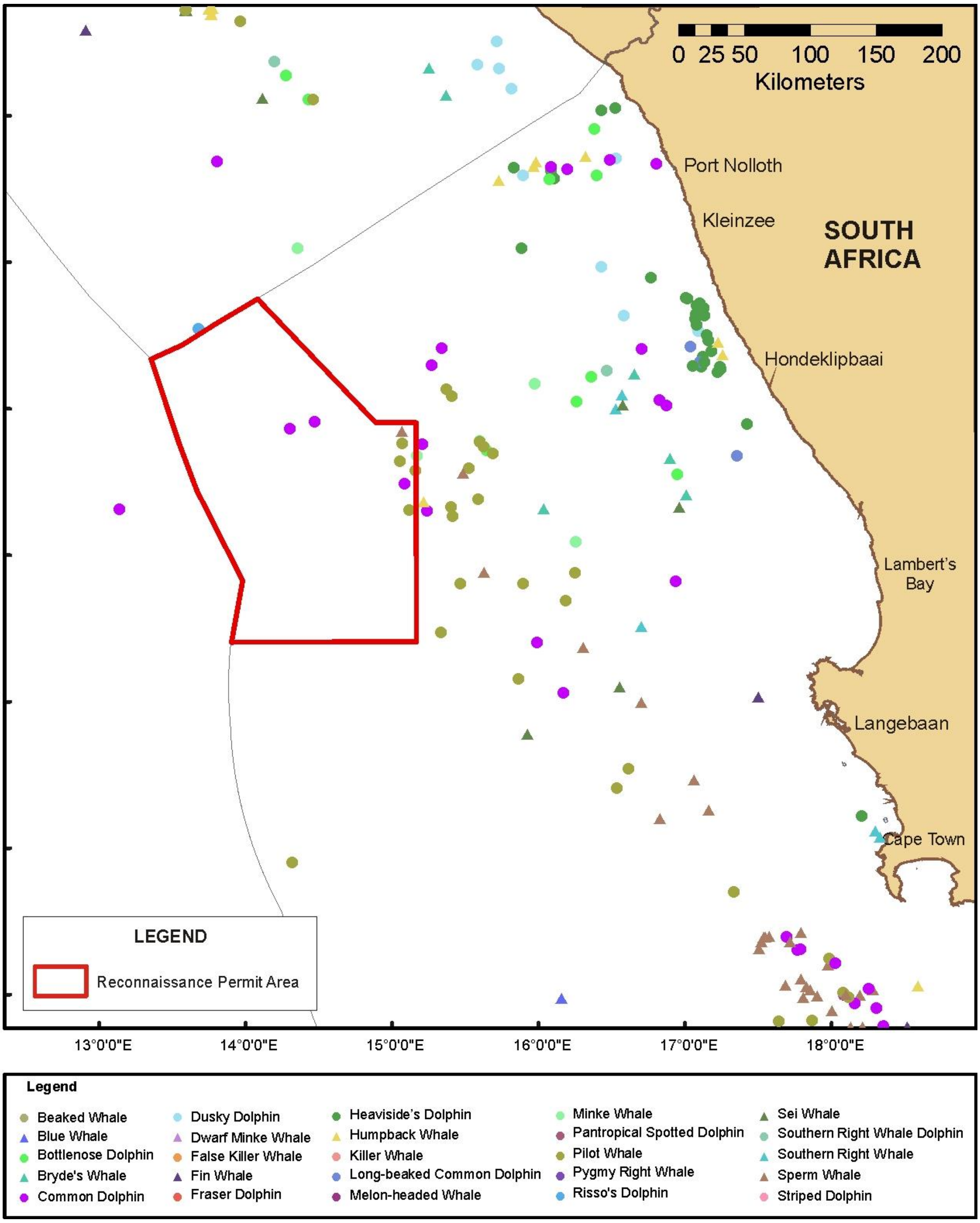


Figure 3-36a: The Reconnaissance Permit Area in relation to the distribution and movement of cetaceans along the West Coast collated between 2001 and 2020 (SLR MMO database).

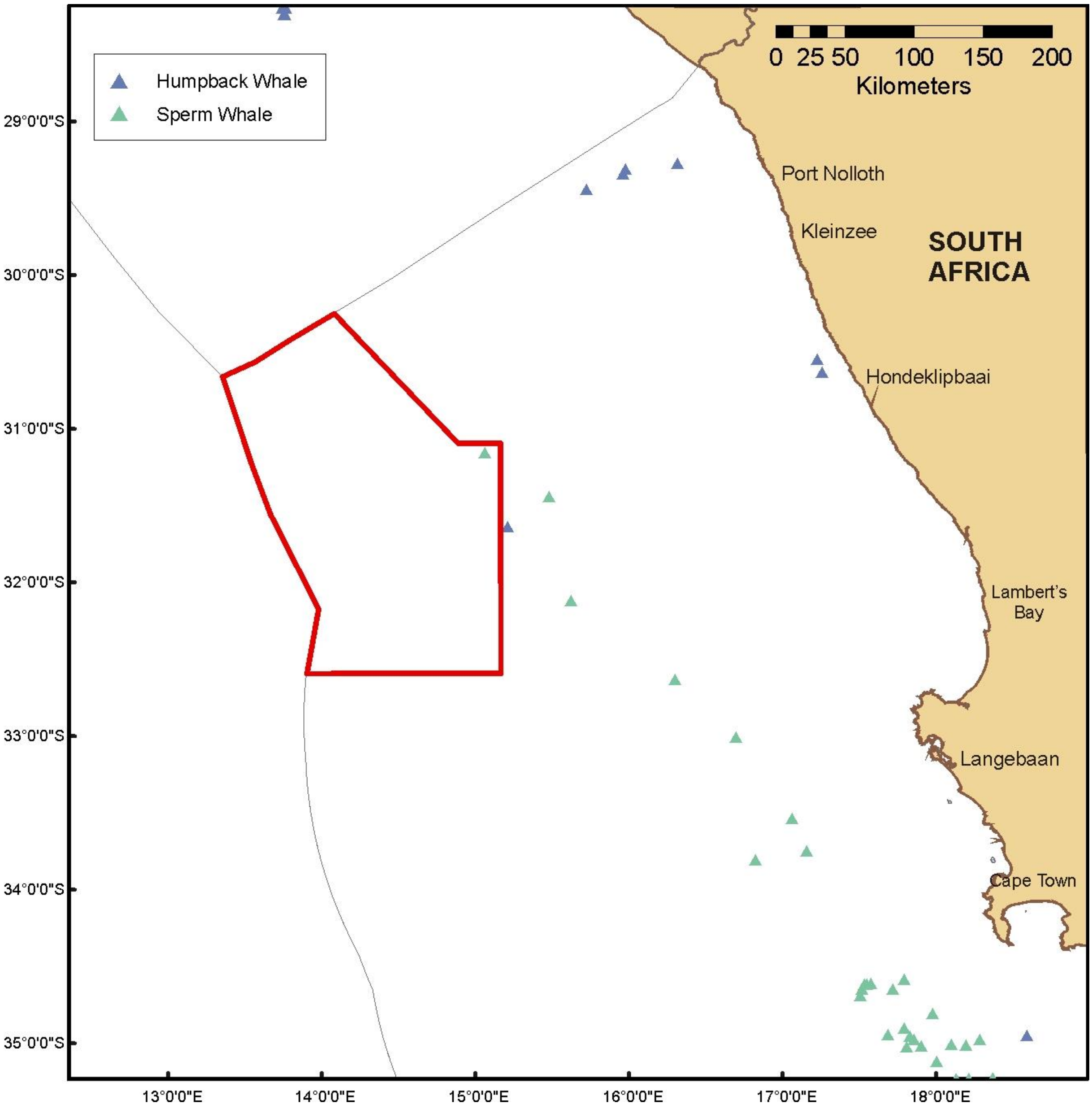


Figure 36b: The Reconnaissance Permit Area (red polygon) in relation to the distribution and movement of Humpback whales and Sperm whales along the West Coast collated between 2001 and 2020 (SLR MMO database).

Table 3-7: 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	Data Deficient
Dwarf sperm whale	*Kogia sima*	VHF	Edge	Yes	Year round	Data Deficient	Data Deficient
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	Data Deficient
Southern bottlenose	*Hyperoodon planifrons*	HF	No	Yes	Year round	Least Concern	Least Concern
Layard's	*Mesoplodon layardii*	HF	No	Yes	Year round	Data Deficient	Data Deficient
True's	*Mesoplodon mirus*	HF	No	Yes	Year round	Data Deficient	Data Deficient
Gray's	*Mesoplodon grayi*	HF	No	Yes	Year round	Data Deficient	Data Deficient
Blainville's	*Mesoplodon densirostris*	HF	No	Yes	Year round	Data Deficient	Data Deficient
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 3-8: 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 3-7.

	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

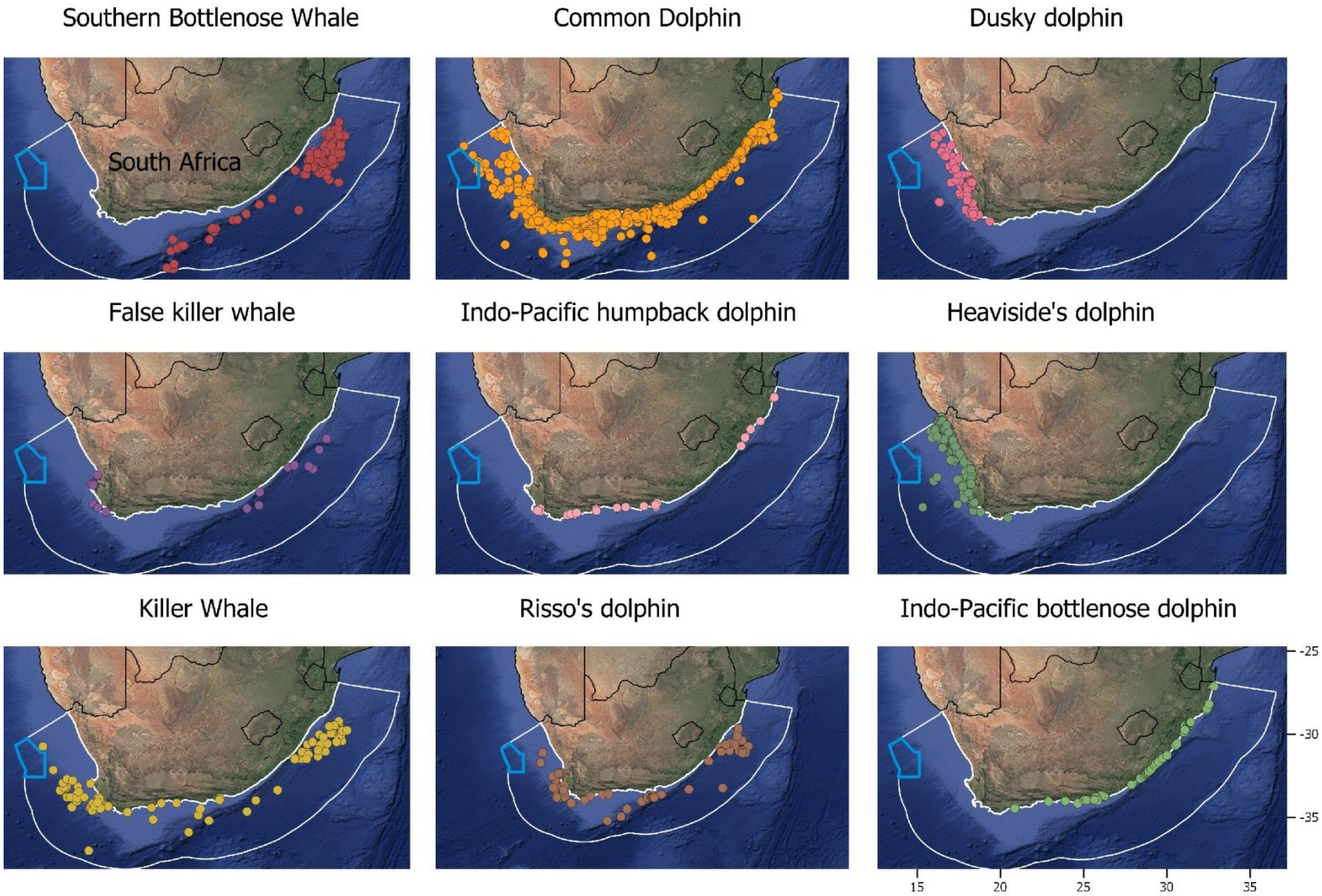


Figure 3-37: The Reconnaissance Permit area (cyan polygon) in relation to projections of predicted distributions for nine odontocete species off the West Coast of South Africa (adapted from: Purdon *et al*. 2020a).

Sei whales: Almost all information is based on whaling records 1958-1963, most from shore-based catchers operating within a few hundred kilometres 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 SA 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 deeper than 1 000 m (Best & Lockyer 2002). A recent survey to Vema Seamount ~1 000 km west of Cape Town during Oct-Nov 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 NW of the historic whaling grounds suggesting this region remains an important feeding area for the species. This region lies well within the impact area of the proposed 3D seismic survey and caution is recommended to reduce impacts on this endangered and poorly known species.

Figure 3-38: 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). Aggregations of up to eight animals have been seen on multiple occasions on the coast either side of Lüderitz in Apr-May of 2014 and January 2015 (Sea Search unpubl. Data), 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 (see above). 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 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 (CapFish 2013a). Encounters in the Reconnaissance Permit 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), off western South Africa (Shanbangu *et al.* 2019) and in northern Namibia between May and July (Thomisch 2017) supporting 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. 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 3-38, 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 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 the project area, although sightings have been reported in the general project area (SLR data).

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.

The most abundant baleen whales in the Benguela are southern right whales and humpback whales (Figure 3-39). 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 migrations (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).

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, three separate matches have been made between individuals off South Africa and Brazil by citizen scientist photo-identification (www.happywhale.com). 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).

Figure 3-39: 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).

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 29b), 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 Deep Water Orange Basin Area (CapFish 2013a) and encounters within the Reconnaisssance Permit Area 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.

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 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. 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, 2020; 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 the Reconnaissance Permit Area when migrating southwards from the feeding areas between April and June (Figure 3-40).

Figure 3-40: The Reconnaissance Permit Area (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).

Odontocetes (toothed) whales

The Odontoceti are a varied group of animals including the dolphins, porpoises, beaked whales and sperm whales. Species occurring within the broader project area display a diversity of features, for example their ranging patterns vary from extremely coastal and highly site specific to oceanic and wide ranging (see Figure 3-37). 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 3-41, left). They are considered to be relatively abundant globally (Whitehead 2002), although no estimates are available for South African waters. Seasonality of catches 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 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 MMOs working in this area (SLR data). 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 Deep Water Orange Basin Area (CapFish 2013a, 2013b).

Figure 3-41: 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, population trends and seasonality 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 are most frequently occur in pelagic and shelf edge waters, are thus likely to occur in the survey area at low levels; seasonality is unknown. Dwarf sperm whales are associated with warmer tropical and warm-temperate waters, being recorded from both the Benguela and Agulhas ecosystem (Best 2007) in waters deeper than ~1 000 m.

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 3-41) 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). 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 Reconnaissance Permit 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 survey area since 2010 (de Rock *et al*. 2019; Sea Search unpublished data, SLR data). Observed group sizes range from 8-100 individuals (Seakamela *et al*. 2022). Pilot whales are commonly sighting by MMOs and detected by PAM during a seismic surveys. 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 sightings, including those from MMOs, suggest sightings regularly out 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 Deep Water Orange Basin Area (CapFish 2013a). Encounters in the Reconnaissance Permit Area are thus likely to occur.

Dusky dolphin: In water <500 m deep, dusky dolphins (Figure 3-42, 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 near shore 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). Dusky dolphins are resident year round in the Benguela. Encounters in the offshore waters of the Reconnaissance Permit Area are unlikely.

Heaviside’s dolphins: Heaviside’s dolphins (Figure 3-42, 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 Lambert’s 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 only occur well inshore of the Reconnaissance Permit Area.

Figure 3-42: The dusky dolphin *Lagenorhynchus obscurus* (left) and endemic Heaviside's Dolphin *Cephalorhynchus heavisidii* (right) (Photos: Simon Elwen, Sea Search Research and Conservation).

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 Reconnaissance Permit Area 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 the inshore portions of the Reconnaissance Permit Area is possible (see Figure 3-35).

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 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). 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. Presence in the project area may fluctuate seasonally, but insufficient data exist to define this clearly. Sightings of beaked whales in the Reconnaissance Permit 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.

Seals (Pinnipeds)

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 3-43) 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 3-47). 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).

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 the Reconnaissance Permit Area are at Bucchu Twins, Cliff Point, Kleinzee, Strandfontein Point and Cape Columbine located over 200 km inshore of the Reconnaissance Permit Area.

Figure 3-43: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich).

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 the Reconnaissance Permit Area. There is no overlap of the Reconnaissance Permit Area with foraging areas.

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. Their diet varies with season and availability and includes pelagic species such as horse mackerel, pilchard, and hake, as well as squid and cuttlefish. Benthic feeding to depths of nearly 200 m for periods of up to 2 minutes has, however, also been recorded (Kirkman *et al*. 2015). Seals are unlikely to be encountered in the offshore waters of the Reconnaissance Permit Area (Figure 3-44).

The timing of the annual breeding cycle is very regular, occurring between November and January. Breeding success is highly dependent on the local abundance of food, territorial bulls and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen 1991).

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 Fisheries, Forestry 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).

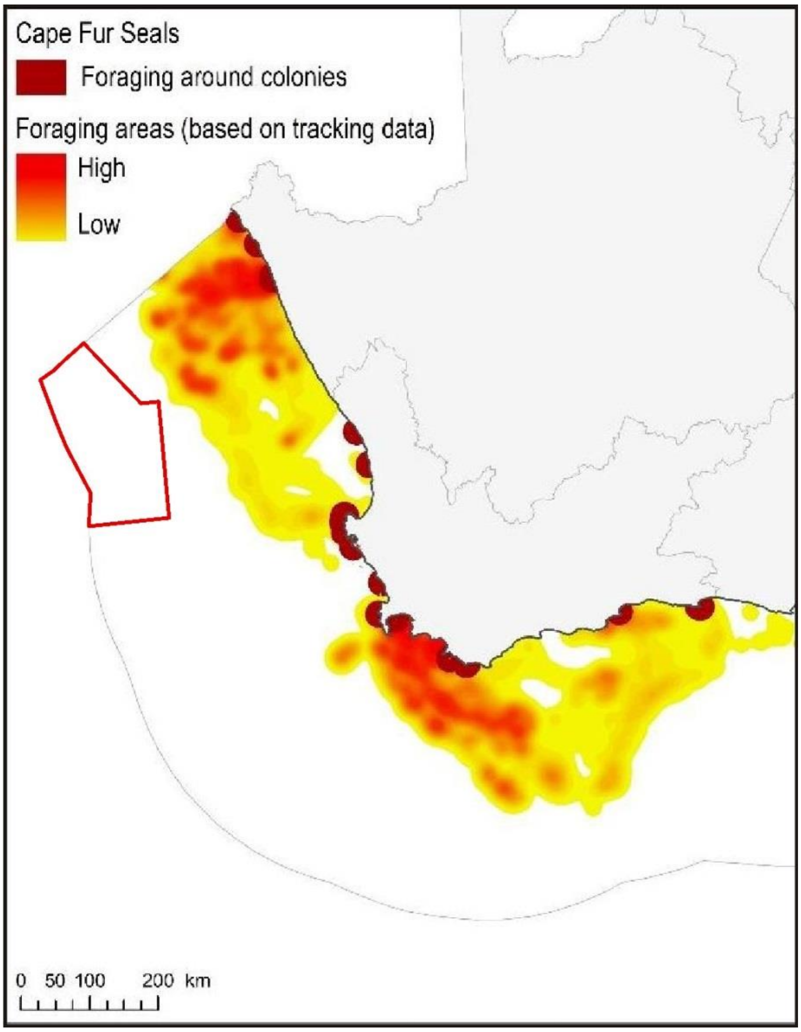


Figure 3-44: Reconnaissance Permit Area (red polygon) in relation to seal foraging areas on the West and South Coasts. Brown areas are generalised foraging areas around colonies, and areas in shades of red are foraging areas based on tracking data. Darker shades of red indicate areas of higher use.

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).

3.4 Other Uses of the Area

3.4.1 Beneficial Uses

The Reconnaissance Permit Area is located well offshore beyond the 1 000 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 well inshore of the eastern portion of the Reconnaissance Permit Area (Figure 3-45). Recreational activities along the coastline north of St Helena Bay are limited to the area around Lambert's Bay, Hondeklip Bay and Port Nolloth.

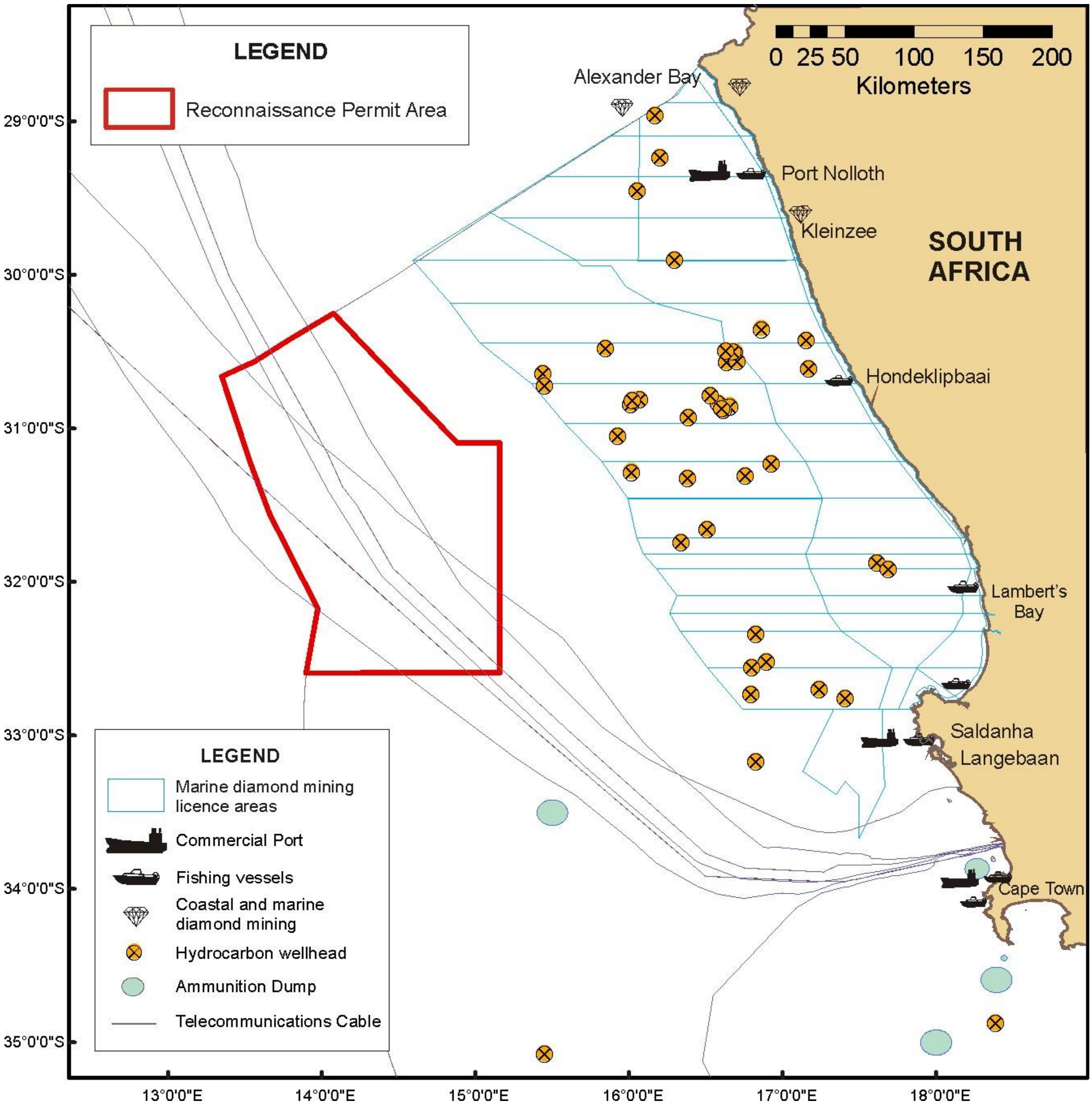


Figure 3-45: The Reconnaissance Permit Area in relation to project - environment interaction points on the West Coast, illustrating the location of marine diamond mining concessions and ports for commercial and fishing vessels. Existing hydrocarbon wellheads, telecommunications cables and ammunition dumps are also shown.

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, immediately to the northeast of the Reconnaissance Permit Area.

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 3-46). 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 (see Figure 3-45). None of these activities should in any way be affected by 3D seismic survey activities offshore.

Figure 3-46: Typical crawler-vessel (left) and drillship (right) operating in the Atlantic 1 Mining Licence Area (Photos: De Beers Marine).

3.4.2 Conservation Areas and Marine Protected Areas

Numerous sanctuaries, marine protected area (MPA) exist offshore and along the coastline of the Western Cape, although none of them overlap with the Reconnaissance Permit Area. For the sake of completeness, these are described in more detail below.

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 the Reconnaissance Permit Area.

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 3-47. There are six offshore Marine Protected Areas (MPAs) that fall within the broader project area, namely the Orange Shelf Edge MPA, Child's Bank MPA, Benguela Muds MPA, Cape Canyon MPA, Robben Island MPA and the Southeast Atlantic Seamounts MPA. These are described briefly below.

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 ~48 km inshore of the Reconnaissance Permit Area, 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.

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.

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 **Namaqua Fossil Forest MPA,** which lies ~210 km inshore of the Reconnaissance Permit Area, 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.

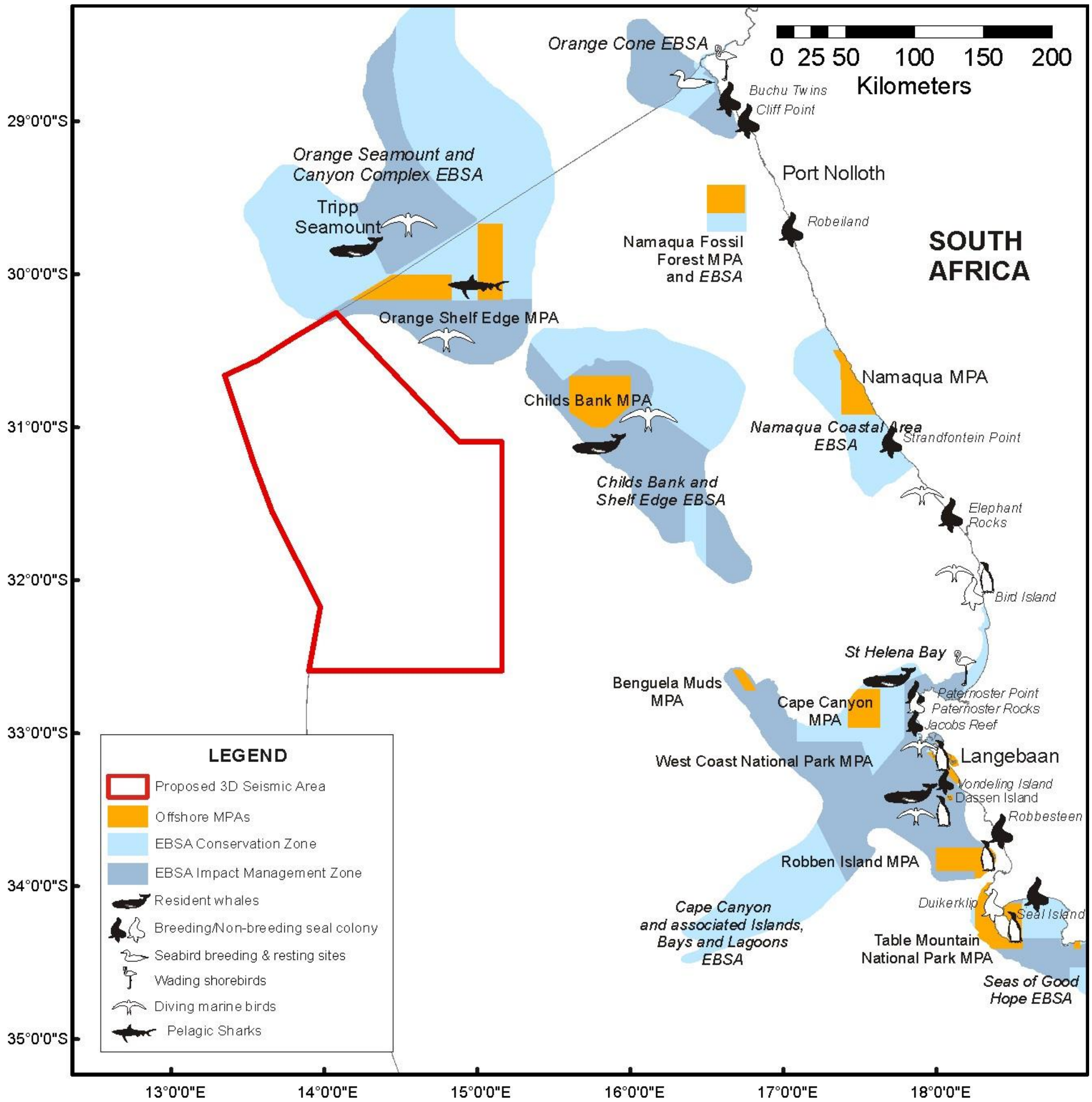


Figure 3-47: The Reconnaissance Permit Area in relation to project - environment interaction points on the West Coast, illustrating the location of seabird and seal colonies and resident whale populations, Marine Protected Areas (MPAs) and Ecologically and Biologically Significant Areas (EBSAs).

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

The **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.

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.

Sensitive Areas

Despite the development of the offshore MPA network a number of 'Endangered' and 'Vulnerable' ecosystem types (i.e. Orange Cone Inner Shelf Mud Reef Mosaic, Orange Cone Muddy mid Shelf, Namaqua Muddy Sands, Southern Benguela Outer Shelf Mosaic, Southern Benguela Shelf Edge Mosaic and Southeast Atlantic Lower Slope) are currently 'not well protected' and further effort is needed to improve protection of these threatened ecosystem types (Sink *et al.* 2019) (Figure 3-48). Ideally, all highly threatened ('Critically Endangered' and 'Endangered') ecosystem types should be well protected. Currently, however, most of the Southern Benguela Sandy Shelf Edge and 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. Most of the ecosystem types in the Reconnaissance Permit Area are either poorly protected or not protected.

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 (see Figure 3-47), with the intention of implementing improved conservation and protection measures within these sites. South Africa currently has 11 EBSAs solely within its national jurisdiction with a further four having recently been proposed. It also shares five trans-boundary EBSAs with Namibia (3) and Mozambique (2). 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.

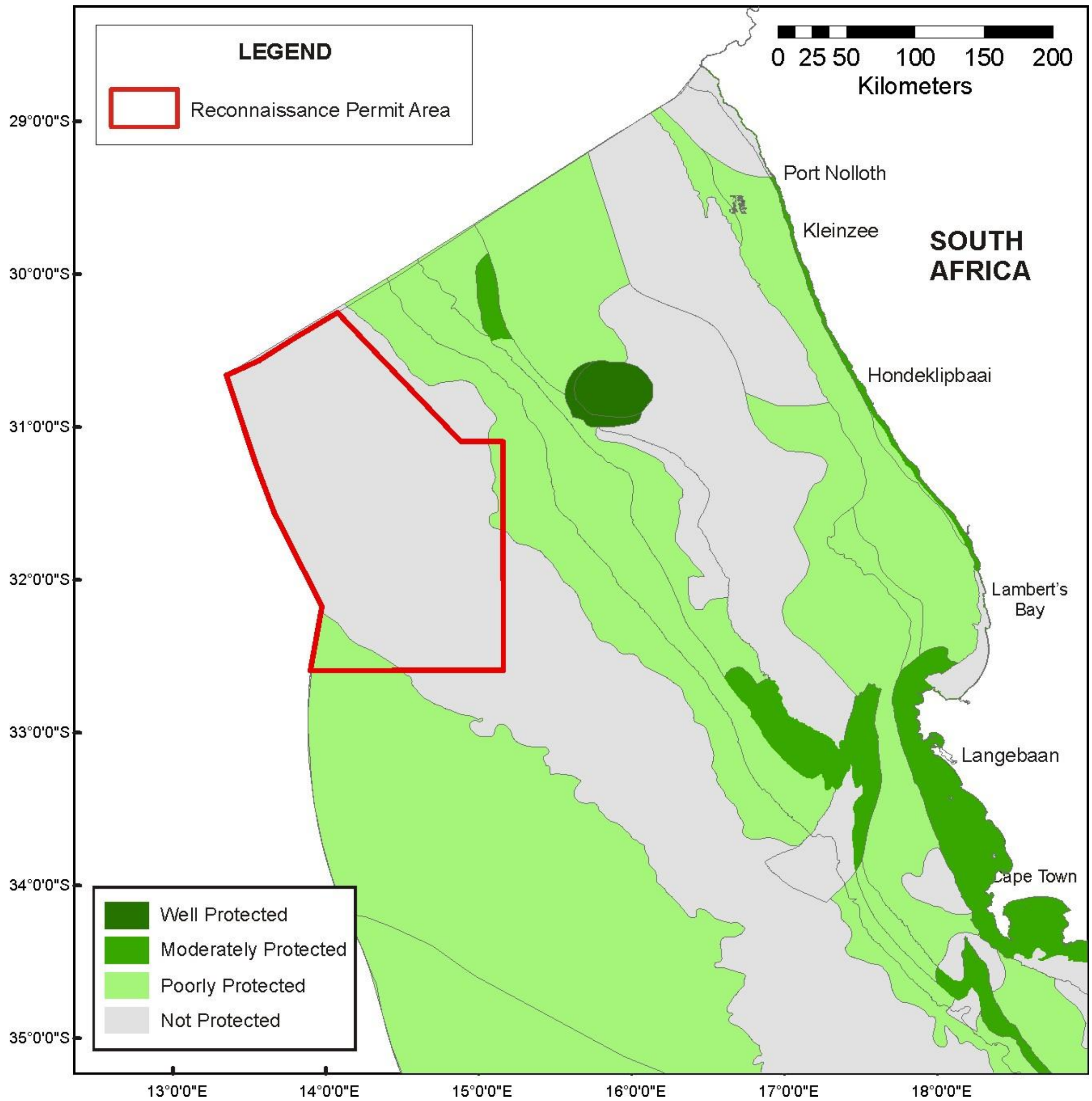


Figure 3-48: The Reconnaissance Permit Area in relation to protection levels of 150 marine ecosystem types as assessed by Sink *et al.* (2019).

The following summaries of the EBSAs in the Reconnaissance Permit area are adapted from http://cmr.mandela.ac.za/EBSA-Portal/Namibia/.

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

The **Orange Cone** transboundary EBSA lies inshore of the Reconnaissance Permit Area and spans the mouth of the Orange River. The estuary is biodiversity-rich but modified, and the coastal area includes many 'Critically endangered', 'Endangered' and 'Vulnerable' habitat types (with the area being particularly important for the 'Critically Endangered' Namaqua Sandy Inshore, Namaqua Inshore Reef and Hard Grounds and Namaqua Intermediate and Reflective Sandy Beach habitat types). The marine environment experiences slow, but variable currents and weaker winds, making it potentially favourable for reproduction of pelagic species. An ecological dependence for of river outflow for fish recruitment on the inshore Orange Cone is also likely. The Orange River Mouth is a transboundary Ramsar site and falls within the Tsau//Khaeb (Sperrgebiet) National Park. It is also under consideration as a protected area by South Africa, and is an Important Bird and Biodiversity Area.

The **Namaqua Fossil Forest** EBSA, which lies ~210 km inshore of the Reconnaissance Permit Area, is a small seabed outcrop composed of fossilized yellowwood trees at 136-140 m depth, approximately 30 km offshore on the west coast of South Africa. A portion of the EBSA comprised the Namaqua Fossil Forest MPA. The fossilized tree trunks form outcrops of laterally extensive slabs of rock have been colonized by fragile, habitat-forming scleractinian corals and a newly described habitat-forming sponge species. The EBSA thus encompasses a unique feature with substantial structural complexity that is highly vulnerable to benthic impacts.

The **Childs Bank and Shelf Edge** EBSA, which lies ~40 km inshore of the Reconnaissance Permit Area, is a unique submarine bank feature rising from 400 m to -180 m on the western continental margin on South Africa. This area includes five benthic habitat types, including the bank itself, the outer shelf and the shelf edge, supporting hard and unconsolidated habitat types. Childs Bank and associated habitats are known to support structurally complex cold-water corals, hydrocorals, gorgonians and glass sponges; species that are particularly fragile, sensitive and vulnerable to disturbance, and recover slowly.

The **Namaqua Coastal Area** EBSA, which lies ~190 km inshore of the Reconnaissance Permit Area and encompasses the Namaqua Coastal Area MPA, is characterized by high productivity and community biomass along its shores. 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.

The **Cape Canyon and Associated Islands** EBSA lies ~135 km east of the Reconnaissance Permit Area. The 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.

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.

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

Biodiversity Priority Areas

The National Coastal and Marine Spatial Biodiversity Plan[6] 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.

The Reconnaissance Permit Area overlaps with areas mapped as Critical Biodiversity Area 1 (CBA 1): Natural and Critical Biodiversity Area 2: (CBA 2) Natural. Approximately 36.4% of the Reconnaissance Permit Area is covered by CBA 1 and CBA 2: Natural (see Figure 3-49). ESA comprises 0.11% of the Reconnaissance Permit Area. 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

[6] 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.

CBA 2 are "best design sites" and there 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.

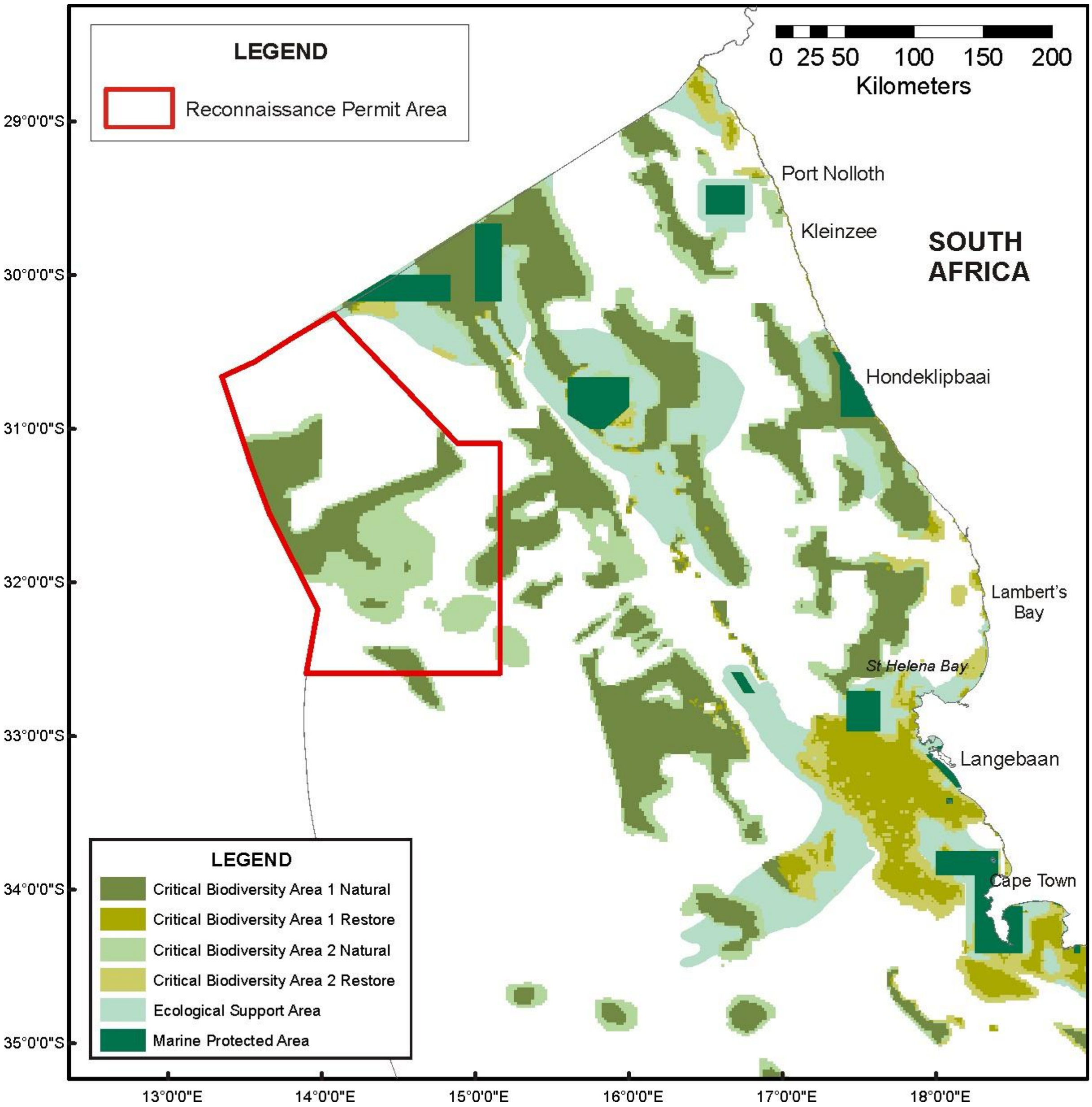


Figure 3-49: The Reconnaissance Permit Area in relation to Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) (Version 1.2 April 2021).

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)

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

Table 3-9) (www. http://datazone.birdlife.org/). These are all located well inshore of the Reconnaissance Permit Area and should in no way be directly affected by the proposed seismic surveys.

The Orange River Mouth wetland located ~230 km to the northeast of the Reconnaissance Permit Area provides an important habitat for large numbers of a great diversity of wetland birds and is listed as a Global IBA (www. http://datazone.birdlife.org/). The area was designated a Ramsar site in June 1991, and processes are underway to declare a jointly-managed transboundary Ramsar reserve. A Ramsar site is considered a 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 seismic acquisition in the Reconnaissance Permit Area.

Various marine IBAs have also been proposed in South African and Namibian territorial waters, with a candidate trans-boundary marine IBA suggested off the Orange River mouth and a further candidate marine IBA suggested in international waters west of the Cape Peninsula (Figure 3-50). There is no overlap of the Reconnaissance Permit Area with any of these Marine IBAs.

Table 3-9: List of Important Bird Areas (IBAs) and their criteria listings. 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. modeled on criterion 5 of the Ramsar Convention for identifying wetlands of international importance. The use of this criterion is discouraged where quantitative data are good enough to permit the application of A4i and A4ii.

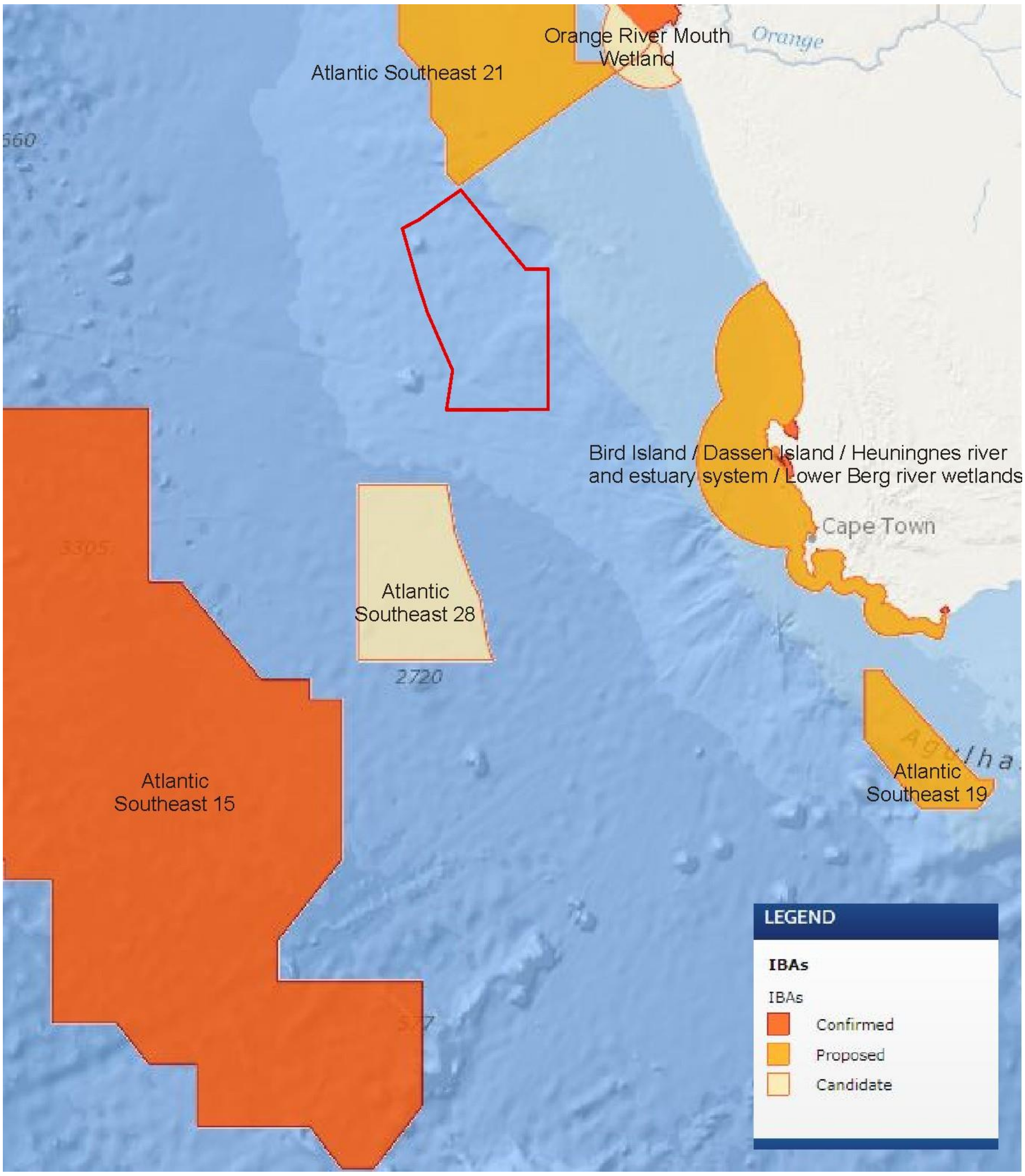


Figure 3-50: The Reconnaissance Permit Area (red polygon) in relation to coastal and marine IBAs in Namibia (Source: https://maps.birdlife.org/marineIBAs).

Important Marine Mammal Areas (IMMAs)

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

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

Criterion A – Species or Population Vulnerability

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

Criterion B – Distribution and Abundance

Sub-criterion B1 – Small and Resident Populations: Areas supporting at least one resident population, containing an important proportion of that species or population that are occupied consistently.
Sub-criterion B2 – Aggregations: Areas with underlying qualities that support important concentrations of a species or population.

Criterion C – Key Life Cycle Activities

Sub-criterion C1 – Reproductive Areas: Areas that are important for a species or population to mate, give birth, and/or care for young until weaning.
Sub-criterion C2 – Feeding Areas: Areas and conditions that provide an important nutritional base on which a species or population depends.
Sub-criterion C3 – Migration Routes: Areas used for important migration or other movements, often connecting distinct life-cycle areas or the different parts of the year-round range of a non-migratory population.

Criterion D – Special Attributes

Sub-criterion D1 – Distinctiveness: Areas which sustain populations with important genetic, behavioural or ecologically distinctive characteristics.
Sub-criterion D2 – Diversity: Areas containing habitat that supports an important diversity of marine mammal species.

Although much of the West Coast of 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 3-51) 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).

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.

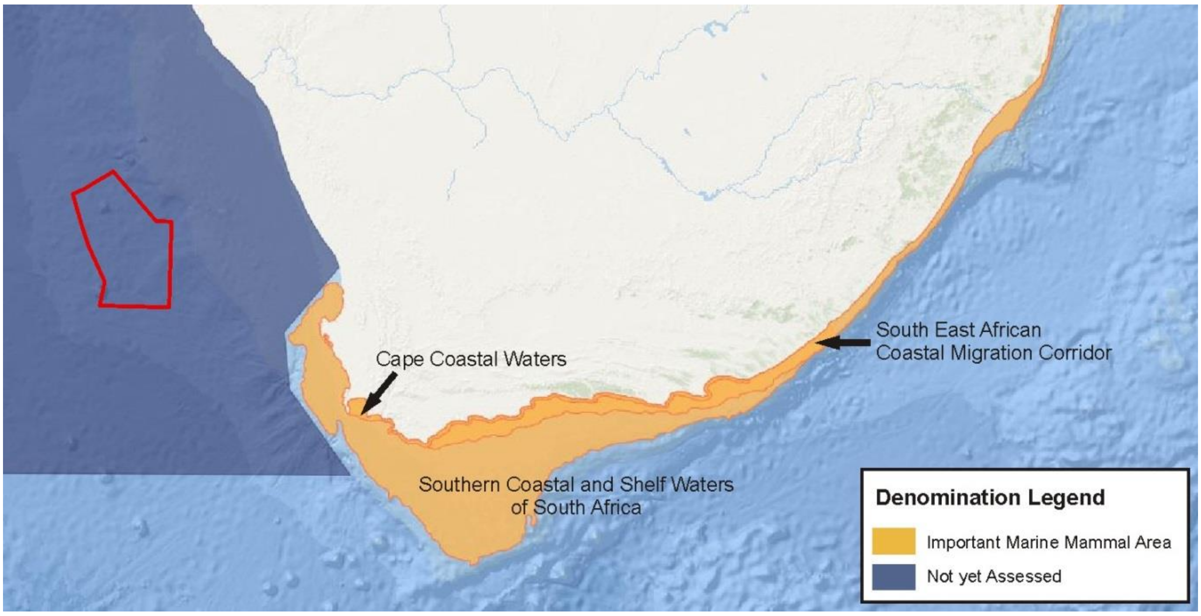


Figure 3-51: Reconnaissance Permit Area (red polygon) in relation to coastal and marine IMMAs (Source: www.marinemammalhabitat. org/imma-eatlas/).

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 the Reconnaissance Permit Area with these IMMAs as it falls within the area along the West Coast of South Africa that has not yet been assessed.

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 Table 4-1 for an outline of the activities in these phases) of the proposed seismic acquisition project, namely:

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

4.1 Identification of Impacts

Interaction of these activities with the receiving environment gives rise to a number of environmental aspects, which in turn may result in a single or a number of impacts. The identified aspects and their potential impacts are summarised below, providing also the project phases during which the aspects would occur:

- Increase in underwater and atmospheric noise levels by the seismic vessel, during seismic acquisition, and by support vessels and helicopters
  - Disturbance / behavioural changes of coastal and marine fauna
  - Avoidance of key feeding areas (e.g. Child's Bank, Tripp Seamount and Southeast Atlantic Seamounts)
  - Effects on key breeding areas (e.g. coastal birds and cetaceans)
  - Abandonment of nests (birds) and young (birds and seals)
- Introduction of invasive alien species in the ballast water of the seismic vessel
  - Threats to West Coast ecosystem biodiversity
- Discharge of waste to sea (e.g. deck and machinery space drainage, sewage and galley wastes) from seismic and vessels, and local reduction in water quality
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column
  - Increased food source for marine fauna
  - Fish aggregation and increased predator-prey interactions
- Increase in ambient lighting from seismic vessel and support vessels
  - Disorientation and mortality of marine birds
  - Physiological and behavioural effects on marine fauna
  - Fish aggregation and increased predator-prey interactions
- Localised reduction in water quality due to accidental release of fuel into the sea 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 vessels due to vessel accident/collision
  - Toxic effects on marine biota and reduced faunal health
  - Pollution and smothering of coastal habitats
- Accidental loss of equipment
  - Disturbance and damage to seabed habitats
  - Entanglement of marine fauna

4.2 Application of the Mitigation Hierarchy

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

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

4.3 Acoustic Impacts of Seismic Surveys on Marine Fauna

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).

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 4-1.

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 (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 hundreds of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al*. 2003; Duarte *et al*. 2021).

As the Reconnaissance Permit Area is located within the main offshore shipping routes that pass around southern Africa (Figure 4-2), the shipping noise component of the ambient noise environment is expected to be significant within and around the proposed 3D acquisition area (OceanMind Limited 2020). Given the significant local shipping traffic and relatively strong metocean conditions specific to the area, ambient noise levels are expected to be 90–130 dB re 1 µPa for the frequency range 10 Hz – 10 kHz (SLR Consulting Australia 2020, 2021).

Table 4-1: Aspects and impacts register relevant to marine fauna

Activity Phase		Activity	Aspect	Potential Impact
Seismic Surveying	**Mobilisation Phase**	Transit of survey vessels to survey area	Underwater noise levels	Disturbance to marine fauna
			Routine discharge 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
			Vesssel Lighting	Disorientation and mortality of marine birds
				Increased predator - prey interactions
			Discharge of ballast water and equipment fouling	Loss of biodiversity due to the introduction of invasive alien species
	Operation Phase	Operation of survey vessels	Increase in underwater noise levels	Disturbance to marine fauna
			Routine discharge of waste 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
			Increase in ambient lighting	Disorientation and mortality of marine birds
				Increased predator - prey interactions
		Seismic acquisition	Increase in underwater noise levels	Disturbance / behavioural changes to marine fauna
				Physiological effect on marine fauna
				Fish avoidance of key feeding areas
				Reduced fish catch and increased fishing effort
		Operation of helicopters	Increase in noise levels	Avoidance of key breeding areas (e.g. coastal birds and cetaceans)
				Abandonment of nests (birds) and young (birds and seals)
	Demobilisation Phase	Survey vessels leave survey area and transit to port or next destination	Increase in underwater noise levels during transit	Disturbance to marine fauna
			Routine discharge 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
			Increase in noise levels	Avoidance of key breeding areas (e.g. coastal birds and cetaceans)
				Abandonment of nests (birds) and young (birds and seals)
	Unplanned Activities	Collision with survey vessels and equipment	Collison and entanglement with marine fauna	Physiological effect on marine fauna
		Dropped objects / Lost equipment	Increased hard substrate on seafloor	Physical damage to and mortality of benthic species / habitats
				Obstruction to or damage of fishing gear
		Hydrocarbon spills	Release of fuel into sea during bunkering and localised reduction in water quality	Effect on faunal health (e.g. respiratory damage) or mortality (e.g. suffocation and poisoning)

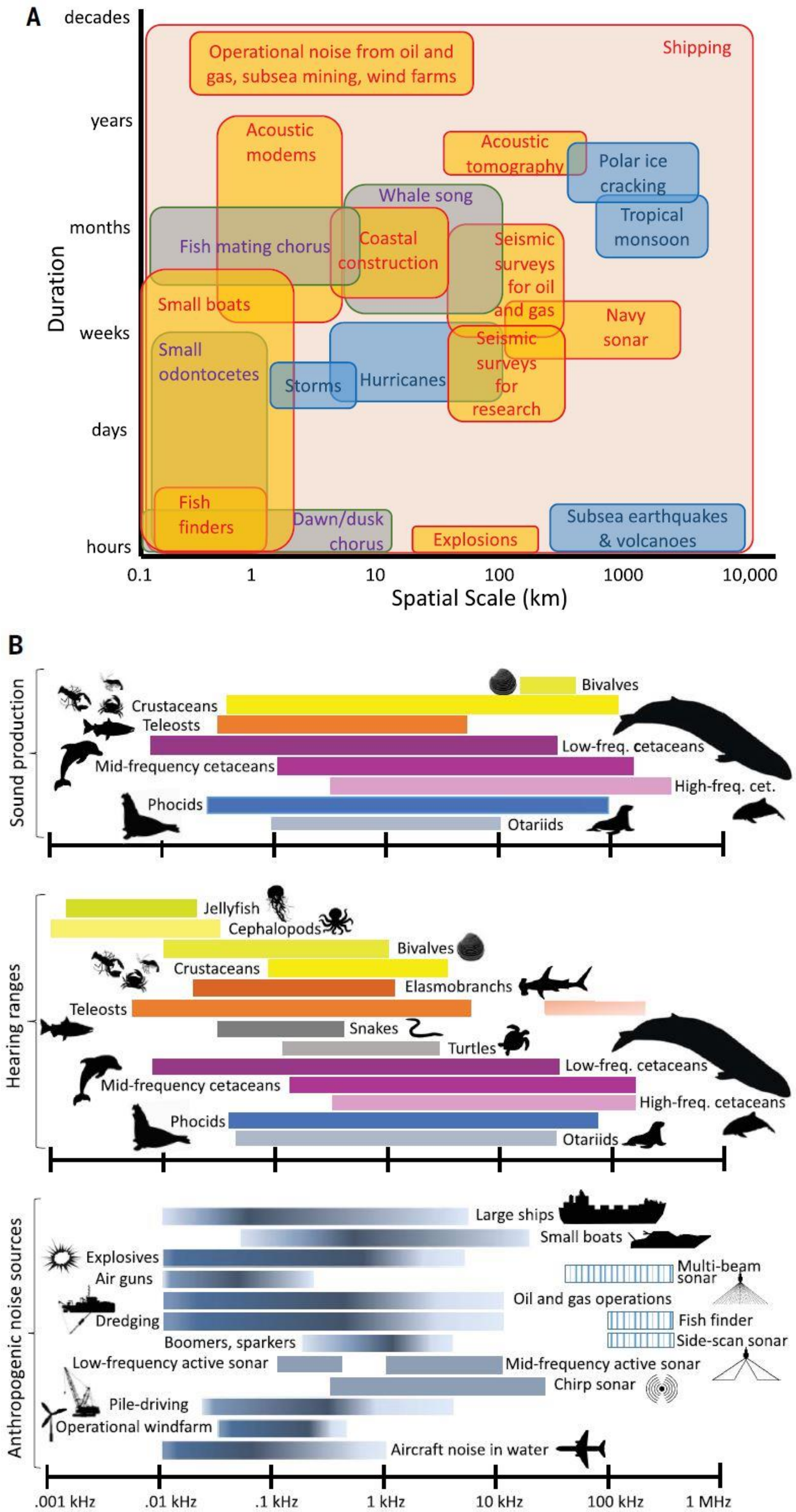


Figure 4-1: Sources and animal receivers of sound in the ocean. A) Spatial extent and duration of selected sound producing events, and B) Approximate sound production and hearing ranges of marine taxa and frequency ranges of selected anthropogenic sound sources. (Source: Duarte *et al*. 2021).

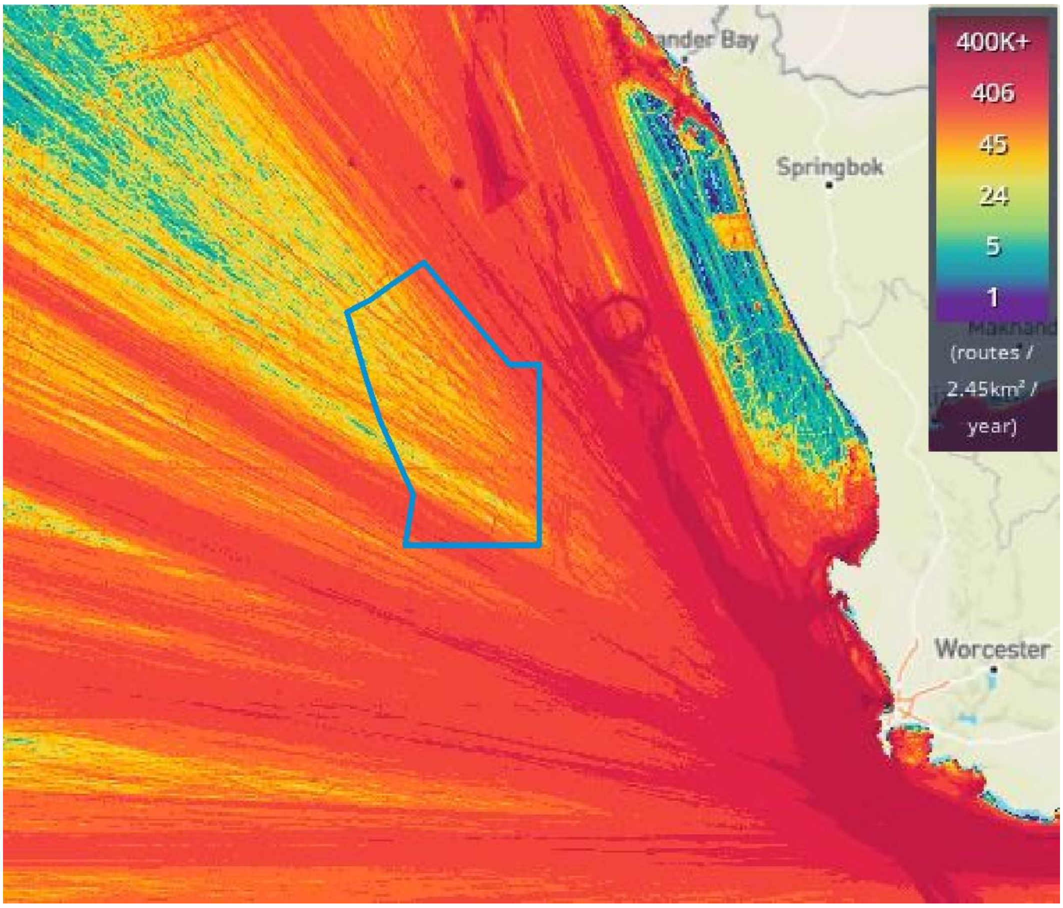


Figure 4-2: The Reconnaissance Permit Area (cyan polygon) in relation to offshore vessel traffic density (adapted from www.marinetraffic.com/en/ais/home).

The airguns used in modern seismic surveys produce some of the most intense non-explosive sound sources used by humans in the marine environment (Gordon *et al.* 2004) and are the second highest contributor of human-caused underwater noise in total energy output per year after nuclear explosions and ship-shock trials (explosions used by the Navy to test the structural integrity of their ships) (Weilgart 2013). Until the demand for petroleum resources is substantially diminished and renewable energy resources can be adopted on a global scale, or alternatives to seismic surveys are found, seismic surveys will remain a major source of noise in the ocean (Przeslawski *et al.* 2018). However, the transmission and attenuation of seismic sound is probably of equal or greater importance in the assessment of environmental impacts than the produced source levels themselves, as transmission losses and attenuation are very site specific, and are affected by propagation conditions, distance or range, water and receiver depth and bathymetrical aspect with respect to the source array. McCauley *et al.* (2016) reported high variability of received signal sound exposure level within a seismic survey and between shots, with different transmission regimes for open ocean, continental shelf and shelf-slope environments. Seismic source energy transmitted at longer ranges (> 1 km) was typically dominated by low frequency (< 500 Hz) energy, with high frequency energy observed only at short range (< 1 km). Furthermore, a considerable amount of air gun array energy may directly excite the seabed, couple into the seabed and travel horizontally, or by way of interface waves. Seabed type therefore also influences airgun transmission losses (McCauley *et al.* 2016; McCauley *et al.* 2021). In water depths of 25 - 50 m airgun arrays are often audible above ambient noise levels to ranges of 50 - 75 km, and with efficient propagation conditions such as experienced on the continental shelf or in deep oceanic water, detection ranges can exceed 100 km and 1 000 km[7], respectively (Bowles *et al.* 1991; Richardson *et al.* 1995; see also references in McCauley 1994; McCauley *et al.* 2016). On analysing 10 years of recordings from the Mid-Atlantic Ridge, Nieukirk *et al.* (2012), found that airguns could be heard at distances of 4 000 km from the seismic vessels, and were audible for 80-95% of the time for more than 12 consecutive months in some locations.

The signal character of seismic shots also changes considerably with propagation effects. Reflective boundaries include the sea surface, the sea floor and boundaries between water masses of different temperatures or salinities, with each of these preferentially scattering or absorbing different frequencies of the source signal. This results in the received signal having a different spectral makeup from the initial source signal. In shallow water (<50 m) at ranges exceeding 4 km from the source, signals tend to increase in length from <30 milliseconds, with a frequency peak between 10-100 Hz and a short rise time, to a longer signal of 0.25-0.75 seconds, with a downward frequency sweep of between 200 - 500 Hz and a longer rise time (McCauley 1994; McCauley *et al.* 2016; McCauley *et al.* 2000).

In contrast, in deep water received levels vary widely with range and depth of the exposed animals, and exposure levels cannot be adequately estimated using simple geometric spreading laws (Madsen *et al.* 2006). These authors found that the received levels fell to a minimum between 5 - 9 km from the source and then started increasing again at ranges between 9 – 13 km, so that absolute received levels were as high at 12 km as they were at 2 km, with the complex sound reception fields arising from multi-path sound transmission.

Acoustic pressure variation is usually considered the major physical stimulus in the hearing of marine mammals and some fish, but all fish are are sensitive to sound-driven particle motion. Marine invertebrate epifauna are predominantly sensitive to waterborne particle acceleration, while epifauna and infauna are sensitive to waterborne particle acceleration and ground acceleration (Turl 1993; McCauley *et al.* 2021). An important component of hearing is the ability to detect sounds over and above the ambient background noise. Auditory masking of a sound occurs when its' received level is at a similar level to background noise within the same frequencies. The signal to noise ratio required to detect a pure tone signal in the presence of background noise is referred to as the critical ratio.

The auditory thresholds of many species are affected by the ratio of the sound stimulus duration to the total time (duty cycle) of impulsive sounds of <200 millisecond duration. The lower the duty cycle the higher the hearing threshold usually is. Although seismic sound impulses are extremely short and have a low duty cycle at the source, received levels may be longer due to the transmission and attenuation of the sound (as discussed above).

Below follows a brief review of the impacts of seismic surveys on marine faunal communities. This information is largely drawn from McCauley (1994), McCauley *et al.* (2000), the Generic EMPR for Oil and Gas Prospecting off the Coast of South Africa (CCA & CMS 2001) and the very comprehensive review by Cetus Projects (2007), supplemented by more recent peer-reviewed literature available on the WWW (reviewed in Carroll *et al.* 2017; Elliott *et al.* 2019; Affatati 2020; Affatati & Camerlenghi 2023; Weilgart 2023). While the discussion and assessments focus primarily on marine mammals, the effects on pelagic and benthic invertebrates, fish, turtles and seabirds are also covered.

[7] Audibility above ambient, however, does not imply impacts resulting in PTS, TTS or behavioural changes.

The impact assessment table provided in each section provides a summary of the various impacts identified, with the significance rating for the pre-mitigation and residual impacts presenting the worst-case scenario.

4.3.1 Impacts of Seismic Noise on Whales and Dolphins

Source of Impact

The project activities that will result in impacts to marine cetaceans are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

The potential impact of seismic survey noise on whales and dolphins could include physiological injury to individuals, behavioural avoidance of individuals (and subsequent displacement from key habitat), masking of important environmental or biological sounds and indirect effects due to effects on predators or prey.

Project Controls

The operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

Thirty three 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 South African waters are baleen whales (mysticetes), while toothed whales (odontocetes) may be resident or migratory. Of the 33 species, the blue whale is listed as 'Critically endangered', the fin and sei whales are 'Endangered' and the sperm, Bryde's (inshore) and humpback (B2 ppopulation) whales are considered 'Vulnerable' (South African Red Data list Categories). Due to its location offshore and proximity to important seabed features such as Tripp Seamount, Child's Bank and the Cape Canyon, the sensitivity of migratory cetaceans is thus considered to be **HIGH**. However, the numbers of individuals encountered during the survey are likely to be low because of the extensive distributions of the various species concerned.

Impact Assessment

Reactions of cetaceans to anthropogenic sounds have been reviewed by McCauley (1994), Richardson *et al.* (1995), Gordon & Moscrop (1996) and Perry (1998). More recently reviews have focused specifically on the effects of sounds from seismic surveys on marine mammals (DFO 2004; NRC 2005; Nowacek *et al*. 2007; Southall *et al*. 2007; Abgrall *et al*. 2008; Stone & Tasker 2006; Stone *et al*. 2017, amongst others).

The factors that affect the response of marine mammals to sounds in their environment include the sound level and its prevailing acoustic characteristics, the ecological features of the environment in which the animal encounters the sound and the physical and behavioural state of the animal. When discussing the potential effects of seismic surveys on marine mammals we should bear in mind the lack of data (uncertainty) concerning the auditory capabilities and thresholds of impacts on the different species encountered and the individual variability in hearing thresholds and behavioural responses, which are likely to influence the degree of impact (Luke *et al*. 2009; Gedamke *et al*. 2011). Furthermore, 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). Depending on the duration and spatial scale of noise exposure, sub-lethal effects could be either acute (generally short-term and associated with a specific activity) or chronic (longer-term and associated with many overlapping activities). These authors point out that a lack of observed response 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.

This uncertainty and the variability in hearing thresholds and behavioural responses can have a large influence on how risk to marine mammals is assessed. Assessing the impact of seismic activity on populations off southern Africa is further hampered by a poor understanding of the abundance and distribution of many of the species found here.

Cetacean vocalisations

Cetacean are highly reliant on acoustic channels for orientation in their environment, feeding and social communication (Tyack & Clark 2000). Baleen whales produce a wide repertoire of sounds ranging in frequencies from 12 Hz to 8 kHz (Richardson *et al*. 1995; Erbe *et al*. 2017). Vocalisations may be produced throughout the year (Dunlop *et al*. 2007; Mussoline *et al*. 2012; Vu *et al*. 2012), with peaks in call rates during breeding seasons in some species, most notably humpback whales (Winn & Winn 1978).

Odontocetes produce a spectrum of vocalizations including whistles, pulsed sounds and echolocation clicks (Popper 1980; Erbe *et al*. 2017). Whistles play a key role in social communication, they are concentrated in the 1-30 kHz frequency range but may extend up to 75 kHz (Samarra *et al*. 2010) and contain high frequency harmonics (Lammers *et al*. 2003). The characteristics of burst pulsed sounds are highly variable, concentrated in the mid frequency for killer whales (Richardson *et al*. 1995), but extending well into the ultrasonic frequency range for other dolphin species (Lammers *et al*. 2003). Although most odontocete vocalizations are predominantly in mid and high frequency bands, there are recent descriptions of dolphins producing low frequency moans (150-240 Hz) and low frequency modulated tonal calls (990 Hz) (van der Woude 2009; Simrad *et al*. 2012; Erbe *et al*. 2017), the function of which remains unclear but may be related to social behaviours.

Clicks are high intensity, short sounds associated with orientation and feeding. The frequency composition of echolocation clicks varies with species (Erbe *et al*. 2017). Most delphinids produce broad band echolocation clicks with frequencies which extend well up into the ultra-sonic range > 100 kHz (Richardson *et al*. 1995). Sperm whales produce broadband echolocation clicks reaching up to 40 kHz in frequency (Backus & Schevill 1966; Madsen *et al.* 2002a, 2002b). Neonatal sperm whales produce lower frequency sounds at 300-1700 Hz (Madsen *et al.* 2003). Porpoise, Kogiids and dolphins in the genus *Cephalorhynchus* (including the Heaviside's dolphin) produce characteristic narrow band, high frequency (NBHF) echolocation clicks with a central frequency around 125 kHz (Madsen *et al.* 2005a; Morisaka *et al.* 2011). Beaked whales produce low frequency sounds (Richardson *et al.*, 1995) and mid frequency echolocation clicks, burst pulse vocalisations and frequency modulated pulses with energy concentrated at 10 kHz and above (Madsen *et al.* 2005b; Rankin *et al.* 2011).

Cetacean hearing

Cetacean hearing has received considerable attention in the international literature, and available information has been reviewed by several authors including Popper (1980), Fobes & Smock (1981), Schusterman (1981), Ridgway (1983), Watkins & Wartzok (1985), Johnson (1986), Moore & Schusterman (1987) and Au (1993).

Marine mammals as a group have wide variations in ear anatomy, frequency range and amplitude sensitivity. The hearing threshold is the amplitude necessary for detection of a sound and varies with frequency across the hearing range (Nowacek *et al.* 2007). Hearing thresholds differ between odontocetes and baleen whales, and between individuals, resulting in different levels of sensitivity to sounds at varying frequencies. For most species, hearing sensitivity corresponds closely to the frequencies at which they vocalise, however it is likely that hearing range is broader than vocalisation range (Bradley & Stern 2008). Consequently, baleen whale hearing is centred at below 1 kHz (Fleischer 1976, 1978; Norris & Leatherwood 1981), while toothed whale and dolphin hearing is centred at frequencies of between 10 and 100 kHz (Richardson *et al.*1995). The combined information strongly suggests that baleen whales are likely to be most sensitive to sounds from 10's of Hz to around 10 kHz (Southall *et al.* 2007), while toothed whale and dolphin hearing is centred at frequencies of between 10 and 100 kHz (Richardson *et al.*1995).

Behavioural and electrophysical audiograms are available for several species of small- to medium-sized toothed whales (killer whale: Hall & Johnson 1972; Bain *et al.* 1993, false killer whale: Thomas *et al.* 1988, bottlenose dolphins: Johnson 1967, beluga: White *et al.* 1978; Awbrey *et al.* 1988, Harbour porpoise: Andersen 1970, Chinese river dolphin: Ding Wang *et al.* 1992 and Amazon river dolphin: Jacobs & Hall 1972; Risso's dolphin: Nachtigall *et al.* 1995, 1996, Harbour porpoise: Lucke *et al.* 2009). In these species, hearing is centered at frequencies between 10 and 100 kHz (Richardson *et al.*1995). The high hearing thresholds at low frequency for those species tested implies that the low frequency component of seismic shots (10 - 300 Hz) will not be audible to the small to medium odontocetes at any great distance. However, the higher frequency of an airgun array shot, which can extend to 15 kHz and above (Madsen *et al.* 2006) may be audible from tens of kilometres away, due to the very low sensitivity thresholds of many toothed whales at frequencies exceeding 1 kHz. For example, Sarnocińska *et al.* (2020) reported a decrease in echolocation signals of harbour porpoise in response to airgun signals 8-12 km away, potentially indicating temporary displacement from the area or changes in foraging behaviour (but see also Pirotta *et al.* 2014; Thompson *et al.* 2013).

No psycho-acoustical or electrophysical work on the sensitivity of baleen whales to sound has been conducted (Richardson *et al.* 1995) and hypotheses regarding the effects of sound in baleen whales are extrapolations from what is known to affect odontocetes or other marine mammals and from observations of behavioural responses. A partial response "audiogram" exists for the gray whale based on the avoidance of migrating whales to a pure tone source (Dahlheim & Ljungblad 1990). Humpback whales in the wild have been reported to detect sounds ranging from 10 Hz to 10 kHz at levels of 102 to 106 dB re 1 µPa (Frankel *et al.* 1995, in Perry 1998; Frankel & Clark 2000). Blue whales and Blainville's beaked reduce calling in the presence of mid-frequency sonar (1-8 kHz) providing evidence that they are receptive to sound in this range (Melcón *et al.* 2012; McCarthy *et al.* 2011), and evidence exists for changes in humpback whale vocalisation in response to low-frequency sonar as much as 200 km away (Miller *et al.* 2000; Risch *et al.* 2012).). Based on the low frequency calls produced by larger toothed whales, and anatomical and paleaontological evidence for baleen whales, it is predicted that these whales hear best in the low frequencies (Fleischer 1976, 1978; McCauley 1994), with hearing likely to be most acute below 1 kHz (Fleischer 1976, 1978; Norris & Leatherwood 1981). The available information demonstrates that the larger toothed whales and baleen whales will be very receptive to the sound produced by seismic airgun arrays and consequently this group may be more affected by this type of disturbance than smaller toothed whales (Morton & Symonds 2002; Nowacek *et al.* 2007).

Overlap between the frequency spectra of seismic shots and the hearing threshold curve with frequency for some toothed whale species, suggests that these may react to seismic shots at long ranges, but that hearing damage from seismic shots is only likely to occur at close range. They will thus not be affected as severely as many fish, and possibly sea turtles and baleen whales that have their greatest hearing sensitivity at low frequencies (McCauley 1994).

Physiological injury and stress

Exposure to high sound levels can result in physiological injury to cetaceans through a number of avenues, including shifts of hearing thresholds (as either PTS or TTS) (Richardson *et al.* 1995; Au *et al.* 1999; Schlundt *et al.* 2000; Finneran *et al.* 2000, 2001, 2002, 2003), tissue damage (Lien *et al.* 1993; Ketten *et al.* 1993), acoustically induced decompression sickness particularly in beaked whales (Crum & Mao 1996; Cox *et al.* 2006; Hooker *et al.* 2019), and non-auditory physiological effects including elevated blood pressures, increased heart and respiration rates, and temporary increases in blood catecholamines and glucocorticoids (Bowles & Thompson 1996), which may have secondary impacts on reproduction. Most studies conducted on sound-related injuries in cetaceans, however, investigated the effects of explosive pulses (Bohne *et al.* 1985, 1986; Lien *et al.* 1993; Ketten *et al.* 1993) and mid-frequency sonar pulses (Simmonds & Lopez-Jurado 1991; Crum & Mao 1996; Frantzis 1998; Balcomb & Claridge 2001; Evans & England 2001; Jepson *et al.* 2003; Cox *et al.* 2006), and the results are thus not directly applicable to non-explosive seismic sources such as those from airgun arrays.

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 (Nowacek *et al.* 2007). Southall *et al.* (2007) propose a dual criterion for assessing injury from noise 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. For a pulsed sound source such as that generated during seismic seabed surveys, the maximum levels for PTS are 230 dB re:1 µPa (peak) and 203 re:1 µPa2-s for SPL and SEL respectively for the various marine mammal functional hearing groups (Table 4-2). For TTS these values are 226 dB re:1 µPa (peak) and 188 dB re:1 µPa2-s for SPL and SEL, respectively. There is thus a range at which permanent or temporary hearing damage might occur, although some hearing damage may already occur when received levels exceed 1 838 dB re:1 µPa2-s SEL. The behavioural disruptive threshold for impulsive noise for all functional groups is root-mean-square (RMS) SPL of 160 dB re 1µPa (NMFS 2013).

Table 4-2: The Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) levels for marine mammal functional hearing groups exposed to either single or multiple impulsive noise events within a 24-h period (Southall *et al.* 2019).

Marine mammal hearing group	PTS and TTS threshold levels - impulsive noise events			
	Injury (PTS) onset		TTS onset	
	Pk SPL, dB re 1μPa	Weighted SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$	Pk SPL, dB re 1μPa	Weighted SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$
Low-frequency cetaceans (mysticetes: southern right, humpback, sei, fin, blue, Bryde's, minke)	219	183	213	168
High-frequency cetaceans (odontocetes: dolphins, toothed, beaked, and bottle nose whales)	230	185	224	170
Very high-frequency cetaceans (Heaviside's dolphins, dwarf and pygmy sperm whales)	202	155	196	140
Sirenians (dugongs, manatees)*	226	203	220	175
Phocid carnivores in water (true seals)*	218	185	212	170
Other marine carnivores in water (sea lions, fur seals)	232	203	226	188

* do not occur in Orange Basin

Based on statistical simulations accounting for uncertainty in the available data and variability in individual hearing thresholds, Gedamke *et al.* (2011) conclude that the possibility of seismic activity leading to TTS in baleen whales must be considered at distances up to several kilometers. As cetaceans are highly reliant on sound, hearing damage leading to TTS and PTS is likely to result in a reduction in foraging efficiency, reproductive potential, social cohesion and ability to detect predators (Weilgart 2007). Results of the sound modelling study for the present survey are presented later.

Noise induced stress resulting from exposure to sources of marine sound can cause detrimental changes in blood hormones, including cortisol (Romano *et al.* 2004). The timing of the stressor relative to seasonal feeding and breeding cycles (such as those observed in migrating baleen whales) may influence the degree of stress induced by noise exposure (Tyack 2008). However, quantifying stress caused by noise in wild populations is difficult as it is not possible to determine the physiological responses of an animal to a noise stressor based on behavioural observations alone (Wright *et al.* 2007). It can, however, negatively affect reproduction, immune systems, growth, health, and other important life functions (Rolland *et al.* 2012; Lemos *et al.* 2021). One recent study was able to identify a reduction in stress-related faecal hormone metabolites (glucocorticoids) in North Atlantic right whales concurrent with a 6 dB reduction in shipping noise. This study provided the first evidence that exposure to low-frequency ship noise may be associated with chronic stress in whales (Rolland *et al.* 2012).

Behavioural disturbance

The factors that affect the response of marine mammals to sounds in their environment include the sound level and other properties of the sound, the physical and behavioural state of the animal and its prevailing acoustic characteristics, and the ecological features of the environment in which the animal encounters the sound. 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).

The speed of sound increases with increasing temperature, salinity and pressure (Richardson *et al.* 1995) and stratification in the water column affects the rate of propagation loss of sounds produced by an airgun array. As sound travels, acoustic shadow and convergence zones may be generated as sound is refracted towards areas of slower sound speed. These can lead to areas of high and low noise intensity (shadow zones) so that exposure to different pulse components at distances of 1-13 km from the seismic source does not necessarily lessen (attenuate) with increasing range. In some cases this can lead to received levels at 12 km being as high as those at 2 km (Madsen *et al.* 2006). Depending on the propagation conditions of the water column, animals may need to move closer to the sound source or apply vertical rather than horizontal displacement to reduce their exposure, thus making overall avoidance of the sound source difficult Although such movement may reduce received levels in the short-term it may prolong the overall exposure time and accumulated SEL (Madsen *et al.* 2006). Results of the sound modelling study for the present survey are presented later.

Typical behavioural response in cetaceans to seismic airgun noise include initial startle responses (Malme *et al.* 1985; Ljungblad *et al.* 1988; McCauley *et al.* 2000), changes in surfacing behaviour (Ljungblad *et al.* 1988; Richardson *et al.* 1985a; McCauley *et al.* 1996, 2000), shorter dives (Ljungblad *et al.* 1988; Robertson *et al.* 2013; Dunlop *et al.* 2015), changes in respiration rate (Ljungblad *et al.* 1988; Richardson *et al.* 1985a, 1985b; Malme *et al.* 1983, 1985,1986), slowing of travel (Malme *et al.* 1983, 1984; Dunlop *et al.* 2015, 2017a, 2017b), increase in swimming speed (Heide-Jørgensen *et al.* 2021) and changes in vocalisations (McDonald *et al.* 1993, 1995; Castellote *et al.* 2012; Sarnocińska *et al.* 2020) and call rate (Di Iorio & Clarke 2010; Blackwell *et al.* 2013, 2015). These subtle changes in behavioural measures are often the only observable reaction of whales to reception of anthropogenic stimuli, and there is no evidence that these changes are biologically significant for the animals (see for example McCauley 1994). Possible exceptions are impacts at individual (through reproductive success) and population level through disruption of feeding within preferred areas (Western gray whales: Weller *et al.* (2002); blue whales: Goldbogen *et al.* 2013; Friedlaender *et al.* 2016; sperm whales: Farmer *et al.* 2018; harbour porpoise: Sarnocińska *et al.* 2020). For continuous noise, whales begin to avoid sounds at exposure levels of 110 dB, and more than 80% of species observed show avoidance to sounds of 130 dB re:1µPa. For seismic noise, most whales show avoidance behaviour above 160 dB re:1µPa (Malme *et al.* 1983, 1984; Ljungblad *et al.* 1988; Pidcock *et al.* 2003), with displacement from the noise impacted area potentially persisting for an extended period (Yazvenko *et al.* 2007a, 2007b; Castellote *et al.* 2012). Behavioural responses are often evident beyond 5 km from the sound source (Ljungblad *et al.* 1988; Richardson *et al.* 1986, 1995; NMFS 2013; Kavanagh *et al.* 2019; Sarnocińska *et al.* 2020; Heide-Jørgensen *et al.* 2021), with the most marked avoidance response recorded by Kolski and Johnson (1987) who reported bowhead whales swimming rapidly away from an approaching seismic vessel at a 24 km distance. More recently, basin-wide effects of seismic surveys on cetacean sightings and calling behaviour have been reported (Blackwell *et al.* 2015; Kavanagh *et al.* 2019; Kyhn *et al.* 2019; see also Nieukirk *et al.* 2012).

In an analysis of marine mammal sightings recorded from seismic survey vessels in United Kingdom waters, Stone (2003) reported that responses to large gun seismic activity varied between species, with small odontocetes showing the strongest avoidance response (Stone 2003; Stone & Tasker 2006). Responses of medium and large odontocetes (killer whales, pilot whales and sperm whales) were less marked, with sperm whales showing no observable avoidance effects (see also Rankin & Evans 1998; Davis *et al.* 2000; Madsen *et al.* 2006) but may be affected at greater ranges than currently regulated due to subtle effects on their foraging behaviour (Miller *et al.* 2009; Farmer *et al.* 2018). Baleen whales showed fewer responses to seismic survey activity than small odontocetes, and although there were no effects observed for individual baleen whale species, fin and sei whales were less likely to remain submerged during firing activity. All baleen whales showed changes in behavioural responses further from the survey vessel (see also Ljungblad *et al.* 1988; McCauley 2000; Abgrall *et al.* 2008), and both orientated away from the vessel and altered course more often during shooting activity. The author suggests that different species adopt different strategies in response to seismic survey disturbance, with faster smaller odontocetes fleeing the survey area (e.g. Weir 2008; van Beest *et al.* 2018), while larger slower moving baleen whales orientate away from and move slowly from the firing guns, possibly remaining on the surface as they do so (see also Richardson *et al.* 1985a, 1985b, 1986, 1995). Responses to small airguns were less, and although no difference in distance to firing and non-firing small airguns were recorded, there were fewer sightings of small odontocetes in association with firing airguns. Other reports suggest that there is little effect of seismic surveys on small odontocetes such as dolphins (e.g. Pirotta *et al.* 2014; Thompson *et al.* 2013; van Beest *et al.* 2018), as these have been reported swimming near or riding the bow-waves of operating seismic vessels (Duncan 1985; Evans & Nice 1996; Abgrall *et al.* 2008; but see also Schlundt *et al.* 2000). Recent evidence has, however, shown that for small, localised odontocete populations exhibiting high site fidelity, displacement away from the ensonified area may itself pose a biological risk. Although the consequences of displacement are poorly understood, they likely include increased stress and reduce foraging success, with associated effects on survival and reproduction (Forney *et al.* 2017).

McCauley *et al.* (1996, 2000) found no obvious evidence that humpback whales were displaced by 2D and 3D seismic surveys and no apparent gross changes in the whale's migratory path could be linked to the seismic survey (but see Dunlop *et al.* 2016, 2017). Localised avoidance of the survey vessel during airgun operation was however noted within 4 km of the source at levels over 130 re 1 $\mu Pa^2\ s^{-1}$ (Dunlop *et al.* 2017a, 2018) as was a reduction in social interactions among whales (Dunlop *et al.* 2020). Whales which are not migrating but using the area as a calving or nursery ground may be more seriously affected through disturbance of suckling or resting. Potential avoidance ranges of 7-12 km by nursing animals and >4 km for migrating humpbacks have been suggested, although these might differ in different sound propagation conditions (McCauley *et al.* 2000; Dunlop *et al.* 2017a, 2017b; Ellison *et al.* 2018). Base on the noise exposure criteria of RMS SPL 160 dB re 1µPa provided by Popper *et al.* (2014), the sound transmission loss modelling study undertaken for the current project (SLR Consulting Australia 2024) identified that for 3D acquisition, the maximum horizontal threshold distance from the source to impact behavioural threshold levels for marine mammals was 4.0 km. Disturbance of mating behaviour (which could involve a high degree of acoustic selection) by seismic noise could be of consequence to breeding animals.

Masking of important environmental or biological sounds

Potential interference of seismic emissions with acoustic communication in cetaceans includes direct masking of the communication signal, temporary or permanent reduction in the hearing capability of the animal through exposure to high sound levels or limited communication due to behavioural changes in response to the seismic sound source. Masking can both reduce the range over which the signals can be heard and the quality of the signal's information (Weilgart *et al.* 2007). Marked differences occur in the hearing of baleen whales and toothed whales and dolphins. The vocalisation and estimated hearing range of baleen whales (centred at below 1 kHz) overlap the highest peaks of the power spectrum of airgun sounds and consequently these animals may be more affected by disturbance from seismic surveys (Nowacek *et al.* 2007). Whales may respond to masking by calling more frequently, calling louder, calling less frequently (Weilgart *et al.* 2007a, 2007b; Cholewiak *et al.* 2018) or showing no change in calling behaviour (Madsen *et al.* 2002). For example, it has been reported that blue whales called consistently more on days when seismic exploration was taking place, presumably to compensate for the elevated ambient noise levels (Di Iorio & Clarke 2010). More recently, Blackwell *et al.* (2013, 2015) determined that bowhead whales increased calling rates as soon as airgun pulses were detectable, with calling rates leveling off at a received cumulative SEL of ~94 dB re 1 μPa^2, but decreasing once $CSEL_{10\text{-}min}$ exceeded ~127 dB re 1 μPa^2 and ceasing altogether when $CSEL_{10\text{-}min}$ values were above ~160 dB re 1 μPa^2. Similarly, Cerchio *et al.* (2014) reported decreased singing activity in humpbacks off Northern Angola in response to increasing seismic noise, with possible implications on breeding displays by males, which in turn could result in decreased reproductive success).

The masking effect of seismic pulses might be reduced by their intermittent production. However, the length of seismic pulses increases with distance from the source, thereby increasing the potential to cause masking at range (Gordon *et al.* 2004). Toothed whales vocalise at much higher frequencies of between 10 and 100 kHz, and it is likely that clicks are not masked by seismic survey noise (Goold & Fish 1998). However, due to multi-path propagation, receivers (cetaceans) can be subject to several versions of each airgun pulse, which have very different temporal and spectral properties (Madsen *et al.* 2006). High frequency sound is released as a by-product of airgun firing and this can extend into the mid- and high-frequency range (up to and exceeding 15 kHz) so that the potential for masking of these sound sources should also be considered (Madsen *et al.* 2006).

Indirect effects on prey species

Exposure to seismic airguns can cause hearing damage to fish (reviewed in Popper & Schilt 2008) and several studies have linked seismic exploration with short-term reductions in fish abundance and changes in distribution away from the seismic survey area (Engås *et al.* 1995; Slotte *et al.* 2004). The majority of baleen whales will undertake little feeding within breeding ground waters and rely on blubber reserves during their migrations. Therefore, they may not be affected by changes in fish distribution. Although the fish and cephalopod prey of toothed whales and dolphins may be affected by seismic surveys, impacts will be highly localised and small in relation to the feeding ranges of cetacean species, but cumulative impacts within species ranges must be considered.

Environmental Risk

Marked differences occur in the hearing of baleen whales (mysticete cetaceans) and toothed whales and dolphins (odontocete cetaceans). The vocalisation and estimated hearing range of baleen whales (centred at below 1 kHz) overlap the highest peaks of the power spectrum of airgun sounds and consequently these animals may be more affected by disturbance from seismic surveys (Nowacek *et* *al*. 2007). In contrast, the hearing of toothed whales and dolphins is centred at frequencies of between 10 and 100 kHz, suggesting that these may react to seismic shots at long ranges, but that hearing damage from seismic shots is only likely to occur at close range. Mysticete and odontocete cetaceans are thus assessed separately below.

Physiological injury

There is little information available on the levels of noise that would potentially result in physiological injury to cetaceans, and no permanent threshold shifts have been recorded. Available information suggests that the animal would need to be in close proximity to operating airguns to suffer physiological injury, and being highly mobile it is assumed that they would avoid sound sources at distances well beyond those at which injury is likely to occur. Deep-diving cetacean species (e.g. sperm whales) may, however, be more susceptible to acoustic injury, particularly in the case of seafloor-focussed seismic surveys, where the downward focussed impulses could trap deep diving cetaceans within the survey pulse, as escaping towards the surface would result in exposure to higher sound level pulses.

Due to the high level of impulsive signal emissions from the array source, marine mammals are predicted to experience a PTS at close proximity to the source array due to the immediate exposure to individual pulses. The Underwater Noise Modelling Study undertaken for the proposed 3D survey area in the Orange Basin (SLR Consulting Australia 2024) identified that the low-frequency cetaceans expected to occur in the Reconnaissance Permit Area (e.g. southern right, humpback, fin, sei, blue, Bryde's, minke) were predicted to experience PTS effects within approximately 40 m from the 3D source array, at all assessed water depth scenarios, with the the zone of TTS due to a single pulse exposure predicted within approximately 80 m from the source array (

Table 4-3). High-frequency cetaceans (e.g. sperm, killer and beaked whales and the diversity of dolphins) and very high frequency cetaceans (e.g. pygmy sperm whale and dwarf sperm whale) were expected to experience PTS within approximately 10 m from the source array and 270 m from the source array, respectively (

Table 4-3). The maximum threshold distance for TTS onset for very-high frequency cetaceans occurs within 500 m from the array source.

Among marine mammals expected to occur in the Reconnaissance Permit area, low-frequency cetaceans have the highest zones of PTS and TTS impact from multiple pulses (i.e. the maximum horizontal perpendicular distances from assessed survey lines to cumulative impact threshold levels). The zones of PTS impact are predicted to range up to 800 m from the adjacent survey lines for the typical 24-hour survey operation scenario considered, with the maximum zones of TTS impact for low frequency cetaceans predicted to be around 8 000 m from the adjacent survey lines (

Table 4-3) (SLR Consulting Australia 2024). It must be kept in mind that the cumulative zones of impact are conservative, and that being highly mobile, whales and dolphins are thus likely to have moved considerable distances over the cumulative 24-hr period. Cumulative effects would only be expected where the animals do not move away from the area, e.g. from specific coastal areas used as calving sites or from mid-ocean focal sites such as Child's Bank and Tripp Seamount.

Although for high-frequency cetaceans it was predicted that the cumulative PTS criteria for the 24-hour survey operation scenario would not to be reached, the zones of TTS impact were predicted to be <10 m from the adjacent survey lines for the cumulative scenario considered. In the case of very high frequency cetaceans, the zones of PTS impact for the cumulative scenario are predicted to range up to 80 m from the adjacent 3D survey lines, for the typical 24-hour survey operation scenario considered, with the zones of TTS impact predicted to range to 2 500 m from the adjacent 3D survey lines (

Table 4-3).

The majority of baleen whales migrate to the southern African subcontinent to breed during winter months. Humpback whales migrating north strike the coast at varying places mostly north of St Helena Bay resulting in increasing whale density on shelf waters and into deeper pelagic waters as one moves northwards, but no clear migration 'corridor'. The northern migration would begin passing through the project area around April, continuing through to September/October when the southern migration begins and continues through to January/February. Southern right whales arrive in coastal waters in June, building up to a maximum in August/September and departing again in November. The Orange Basin thus lies within the migration paths of humpback and southern right whales, but well offshore of inshore coastal areas frequented by southern right whales for mating and breeding. As the survey is proposed for the summer months (December to May) encounters with migrating whales should be minimal, although some humpbacks on their return journey in November/December and those remaining on the summer feeding grounds off Cape Columbine may still be encountered. However, the survey is likely to frequently encounter resident odontocetes such as common dolphin, Risso's dolphin and pilot whales, which are present year-round, and may encounter sperm whales, particularly in winter.

Table 4-3: Zones of immediate and cumulative impact from single and multiple pulses for PTS and TTS for the marine mammal groups likely to occur in the Orange Basin area (from SLR Consulting Australia 2024).

Marine mammal hearing group	Zones of impact - maximum horizontal distances from source to impact threshold levels (from single 3D pulses)		Zones of impact - maximum horizontal perpendicular distances from assessed 3D survey lines to cumulative impact threshold levels	
	Injury (PTS) onset	TTS onset	Injury (PTS) onset	TTS onset
Low-frequency cetaceans (mysticetes: southern right, humpback, sei, fin, blue, Bryde's, minke)	40 m	80 m	800 m	8 000 m
High-frequency cetaceans (odontocetes: dolphins, toothed whales (e.g. sperm), beaked whales, bottle-nose whales)	10 m	25 m	-	< 10 m
Very High-Frequency cetaceans (Heaviside's dolphins, pygmy sperm and dwarf sperm whale	270 m	500 m	80 m	2 500 m

Other marine carnivores in water (sea lions, fur seals)	<10 m	20 m	-	< 10 m

Note: a dash indicates the threshold is not applicable.

Although the current distribution of the offshore population of Bryde's whales is located inshore of the proposed 3D survey area (Harris *et al*. 2022), it may be encountered in the inshore portions of the survey area in the Orange Basin during the summer survey period as its seasonality on the West Coast is opposite to the majority of the balaenopterids with abundance likely to be highest in the broader project area in January - March.

Assuming the survey is scheduled so as to avoid the key migration period (early June to late November), there would be a low likelihood of encountering migrating humpback and southern right whales, but a high likelihood of encountering offshore Bryde's whales. The impact of potential physiological injury to mysticete and odontocete cetaceans as a result of seismic sounds is thus deemed to be of HIGH intensity. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL), the potential for physiological injury is therefore considered to be of **MEDIUM** environmental risk for resident mysticetes and odontocetes.

Behavioural disturbance

Avoidance of seismic survey activity by cetaceans, particularly mysticete species, begins at distances where levels of approximately 150 to 180 dB are received. More subtle alterations in behaviour may occur at received levels of 120 dB. The Underwater Noise Modelling Study undertaken for the proposed 3D survey area (SLR Consulting Australia 2024) identified that the zones of behavioural disturbance for cetaceans caused by the immediate exposure to individual pulses was within 4.0 km from the 3D array source, assuming a SPL criteria of 160 dB re 1μPa. Although behavioural avoidance of seismic noise in the proposed survey area by baleen whales is highly likely, such avoidance is generally considered of minimal impact in relation to the distances of migrations of the majority of baleen whale species.

The timing of the survey relative to seasonal breeding cycles (such as those observed in migrating baleen whales) may influence the degree of stress induced by noise exposure (Tyack 2008). Displacement from critical habitat is particularly important if the sound source is located at an optimal feeding or breeding ground or areas where mating, calving or nursing occurs. For example, persistent disturbance of foraging behaviour in response to seismic noise can result in reductions in relative fitness of reproductive female Sperm whales leading to abortions and calf abandonment (Farmer *et al*. 2018), with mid-frequency sonars shown to reduced foraging efficiency in blue whales (Goldbogen *et al*. 2013). Species that feed intensively within a season and depend on dense prey concentrations can therefore experience significant population consequences, which in turn may pose significant risks to the recovery rates of endangered populations. Based on this knowledge, Norway has since 2019, recommended that seismic activity be restricted in areas and periods with intensive feeding of baleen whales (Sivle *et al*. 2021).

The survey area overlaps with the migration routes of humpback whales to and from their breeding grounds. The survey area is located well offshore of the coastal migration route for southern right whales. Although encounter rates peak in migration periods, humpback whales are found off the West Coast year-round. For other species, the paucity of fine scale data from offshore waters on the distribution and seasonal occurrence of most cetacean species prevents prediction where such critical habitat might be with any certainty. Other baleen whale species are also found year-round or have seasonal occurrences, although not well known, but existing data shows year-round presence of mysticetes. However, if the survey is scheduled to occur outside of the main winter northward and southward migration periods (June and November), interactions with migrating whales should be low.

Of greater concern than general avoidance of migrating whales is avoidance of critical breeding habitat or area where mating, calving or nursing occurs. The humpback whales have their winter breeding concentrations off tropical west Africa, between Angola and the Gulf of Guinea and therefore over 1 000 km to the north-east of the proposed 3D survey area in the Orange Basin. Southern right whales currently have their most significant winter concentrations on the South Coast of South Africa between Port Elizabeth and Cape Town but are seen regularly off the southern half of Namibia, and would therefore pass along the West Coast. However, as the survey area is located in excess of 200 km offshore, there should be no overlap with potential coastal nursery areas for this species.

Assuming the survey is scheduled so as to avoid the key northward and southward migration periods (early June and late November, respectively), there is a low likelihood of encountering migrating humpback whales. However, due to the increasing numbers of southern right and humpback whales year round off the southern African West Coast and the Bryde's whales with migration periods opposite to the typical winter migrations, the potential impact of behavioural avoidance of seismic survey areas by mysticete cetaceans is considered to be of HIGH intensity (resident species), across the Reconnaissance Permit Area (REGIONAL) and for the duration of the survey (SHORT - 4 months). Considering the distribution ranges of most species of cetaceans, the impact of seismic surveying in the Orange Basin is considered of **MEDIUM** environmental risk for both migrating mysticetes and for resident whales, or Bryde's whales that show seasonality opposite to most balaenopterids.

Information available on behavioural responses of toothed whales and dolphins to seismic surveys is more limited than that for baleen whales. No seasonal patterns of abundance are known for odontocetes occupying the proposed 3D survey area but several species are considered to be year-round residents. Furthermore, a number of toothed whale species have a more pelagic distribution thus occurring further offshore, with species diversity and encounter rates likely to be highest on the shelf slope. The impact of seismic survey noise on the behaviour of toothed whales is considered to be of HIGH intensity across the proposed survey area (REGIONAL) and for the duration of the survey (SHORT - 4 months). The overall environmental risk will however not vary between species, and will be **MEDIUM**.

Masking of important environmental or biological sounds

Baleen whales appear to vocalise almost exclusively within the frequency range of the maximum energy of seismic survey noise, while toothed whales vocalise at frequencies higher than these. As the by-product noise in the mid- and high frequency range (up to and exceeding 15 kHz) can travel far (at least 8 km), masking of communication sounds produced by whistling dolphins and blackfish[8] is likely (Madsen *et al*. 2006). In the migratory baleen whale species, vocalisation increases once they reach the breeding grounds and on the return journey in November/December when accompanied by calves. Although most mother-calf pairs tend to follow a coastal route southwards, there is no clear

[8] The term blackfish refers to the delphinids: melon-headed whale, killer whale, pygmy killer whale, false killer whale, long-finned pilot whale, short-finned pilot whale

migration corridor and humpbacks can be spread out widely across the shelf and into deeper pelagic waters. Vocalisation of southward migrating whales may thus potentially be regionally comparatively high on commencement of operations in December, reducing thereafter. However, masking of communication signals is likely to be limited by the low duty cycle of seismic pulses. Should the survey overlap with the key migration and breeding period when there is a high likelihood of encountering migrating Humpback whales (including possible mother-calf pairs) and no other mitigation measures are in place, the intensity of impacts on baleen whales is likely to be HIGH (mother-calf pairs) over the survey area (REGIONAL) and SHORT-TERM duration (4 months), and of MEDIUM intensity (species specific) in the case of toothed whales over the survey area (REGIONAL) and duration (SHORT - 4 months). The environmental risk for both mysticetes and odontocets would be **MEDIUM**.

Indirect impacts due to effects on prey

As with other vertebrates, the assessment of indirect effects of seismic surveys on resident odontocete cetaceans is limited by the complexity of trophic pathways in the marine environment. Although the fish and cephalopod prey of toothed whales and dolphins may be affected by seismic surveys, impacts will be highly localised and small in relation to the feeding ranges of cetacean species. Although the majority of baleen whales will undertake little feeding within breeding-ground waters along the southern African west coast and rely on blubber reserves during their migrations there is increasing evidence that some species (fin whales, southern rights and humpbacks) are using upwelling areas off the South African West Coast as summer feeding grounds. The upwelling zone off Cape Columbine has become an important summer feeding area, and baleen whales have been reported to feed inshore of the Reconnaissance Permit area between St Helena Bay and Cape Town. Any indirect effects on their food source would thus be of LOW intensity over the survey area (REGIONAL) and duration (SHORT - 4 months) and therefore of **LOW** environmental risk. In the case of odontocetes, the broad ranges of prey species (in relation to the avoidance patterns of seismic surveys of such prey species) suggest that indirect impacts due to effects on prey would similarly be of LOW intensity over the survey area (REGIONAL) and duration (SHORT - 4 months) and therefore of **LOW** environmental risk.

Impact Significance

Physiological injury and mortality

The potential impact of seismic noise on physiological injury of mysticetes and odontocetes, considering their high sensitivity, the high probability of the impact occurring and the medium environmental risk, is deemed to be of **MEDIUM** significance.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in mysticetes and odontocetes, considering their high sensitivity, the high probability of the impact occurring and the medium environmental risk, is deemed to be of **MEDIUM** significance.

Masking of Sounds and Communication

The potential impact of seismic noise on the masking of environmental sounds and communications in mysticetes and odontocetes, considering their high sensitivity, the high probability of the impact occurring and the medium environmental risk, is deemed to be of **MEDIUM** significance.

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources of mysticetes and odontocetes, considering their high sensitivity, the low likelihood of the impact occurring and the low environmental risk, is thus deemed to be of **LOW** significance.

Identification of Mitigation Measures

No.	Mitigation measure	Classification
1. Survey Planning		
1.1	Plan seismic surveys to avoid the most sensitive periods within the survey area for some marine fauna, notably: • Movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters from early June to early December, • Aggregation of migratory cetaceans on the summer feeding grounds between St Helena Bay and Dassen Island from late October to late December. If data acquisition commences before late December then Passive Acoustic Monitoring (PAM) technology must be in place at all times.	Avoid
1.2	Plan the survey, as far as possible, so that the first commencement of airgun firing in a new area (including gun tests) is undertaken during daylight hours.	Abate on site
1.3	Prohibit airgun use (including airgun tests) outside of the area of operation (which includes line turns undertaken outside the Reconnaissance Permit area).	Avoid
1.4	Although a seismic vessel and its gear may transit, including passing through a declared Marine Protected Area, acoustic sources (airguns) must not be operational during this transit.	Avoid
2. Key Equipment		
2.1	**Passive Acoustic Monitoring (PAM)**	
2.1.1	Ensure the seismic vessel is fitted with Passive Acoustic Monitoring (PAM) technology, which detects some animals through their vocalisations. The PAM technology must have enough bandwidth to be sensitive to the whole frequency range of sensitive marine life expected in the area.	Abate on site
2.1.2	As the survey area would largely be in waters deeper than 1 000 m where sperm whales and other deep-diving odontocetes are likely to be encountered, implement the use of PAM 24-hr a day when the sound source are in operation.	Abate on site
2.1.3	Ensure the PAM streamer is fitted with at least four hydrophones, of which two are HF and two LF, to allow directional detection of cetaceans.	Abate on site
2.1.4	Ensure the PAM hydrophone streamer is towed in such a way that the interference of vessel noise is minimised.	Abate on site
2.1.5	Ensure spare PAM hydrophone streamers are readily available in the event that PAM breaks down, in order to ensure timeous redeployment	Abate on site
2.2	**Acoustic Source**	
2.2.1	Define and enforce the use of the lowest practicable airgun volume for production, and design arrays to maximise downward propagation, minimise horizontal propagation and adopting suitable array configurations and pulse synchronization and eliminating unnecessary high frequencies.	Abate on site
2.2.2	Ensure a display screen for the acoustic source operations is provided to the marine observers. All information relating to the activation of the acoustic source and the power output levels must be readily available to support the observers in real time via the display screen and to ensure that operational capacity is not exceeded.	Abate on site
2.2.3	Ensure the ramp-up noise volumes do not exceed the production volume.	Abate on site

No.	Mitigation measure	Classification
2.3	**Streamers**	
2.3.1	Ensure that ‘turtle-friendly’ tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Abate on site
2.3.2	Ensure that solid streamers rather than fluid-filled streamers are used to avoid leaks.	Avoid
3. Key Personnel		
3.1	• Make provision for the placing of at least two qualified MMOs on board the seismic vessel. As a minimum, one must be on watch during daylight hours for the pre-shoot observations and when the acoustic source is active. • The duties of the MMO would be to: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Record airgun activities, including sound levels, ‘soft-start’ procedures and pre-firing regimes; – Observe and record responses of marine fauna to seismic shooting from optimum vantage points, including seabird, large pelagic fish (e.g. shoaling tuna, sunfish, sharks), turtle, seal and cetacean incidence and behaviour and any mortality or injuries of marine fauna as a result of the seismic survey. Data captured should include species identification, position (latitude/longitude), distance/bearing from the vessel, swimming speed and direction (if applicable) and any obvious changes in behaviour (e.g. startle responses or changes in surfacing/diving frequencies, breathing patterns) as a result of the seismic activities. Both the identification and the behaviour of the animals must be recorded accurately along with current seismic sound levels. Any attraction of predatory seabirds, large pelagic fish or cetaceans (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should also be recorded; – Record sightings of any injured or dead marine mammals, large pelagic fish (e.g. sharks), seabirds and sea turtles, regardless of whether the injury or death was caused by the seismic vessel itself. If the injury or death was caused by a collision with the seismic vessel, the date and location (latitude/longitude) of the strike, and the species identification or a description of the animal should be recorded and included as part of the daily report; – Record meteorological conditions at the beginning and end of the observation period, and whenever the weather conditions change significantly; – Request the delay of start-up or temporary termination of the seismic survey or adjusting of seismic shooting, as appropriate. It is important that MMO decisions on the termination of firing are made confidently and expediently, and following dialogue between the observers on duty at the time. A log of all termination decisions must be kept (for inclusion in both daily and close-out reports);	Abate on site

No.	Mitigation measure	Classification
	– Use a recording spreadsheet (e.g. JNCC 2017) in order to record all the above observations and decisions; and – Prepare daily reports of all observations, to be forwarded to the necessary authorities as required, in order to ensure compliance with the mitigation measures.	
3.2	• Make provision for placing of a qualified PAM operator on board the seismic vessel. As a minimum, one must be on "watch" during the pre-shoot observations and when the acoustic source is active. • The duties of the PAM operator would be to: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Ensure that the hydrophone cable is optimally placed, deployed and tested for acoustic detections of marine mammals; – Confirm that there is no marine mammal activity within 500 m of the airgun array prior to commencing with the 'soft-start' procedures; – Record species identification, position (latitude/longitude), distance and bearing from the vessel and acoustic source, where possible; – Record general environmental conditions; – Record airgun activities, including sound levels, 'soft-start' procedures and pre-firing regimes; and – Request the delay of start-up and temporary termination of the seismic survey, as appropriate.	Abate on site
3.3.	Ensure MMOs and PAM operators are briefed on the area-specific sensitivities and on the seismic survey planning (including roles and responsibilities, and lines of communication).	Abate on site
4. Airgin testing		
4.1	Maintain a pre-shoot watch of 60-minutes before any instances of airgun testing. If only a single lowest power airgun is tested, the pre-shoot watch period can be reduced to 30 minutes.	Avoid / Abate on site
4.2	Implement a 'soft-start' procedure if testing multiple higher powered airguns. • The 'soft-start' should be carried out over a time period proportional to the number of guns being tested and not exceed 20 minutes; airguns should be tested in order of increasing volume. • If testing all airguns at the same time, a 20 minute 'soft-start' is required. • If testing a single lowest power airgun a 'soft-start' is not required.	Avoid / Abate on site

No.	Mitigation measure	Classification
5. Pre-Start Protocols		
5.1	Implement a dedicated MMO and PAM pre-shoot watch of at least 60 minutes[9] (to accommodate deep-diving species in water depths greater than 200 m).	Avoid / Abate on site
5.2	Implement a 'soft-start' procedure of a **minimum of 20 minutes'** duration on initiation of the seismic source if: • **during daylight** hours it is confirmed: – visually by the MMO during the pre-shoot watch (60 minutes) that there are no cetaceans within 500 m of the seismic source, and – by PAM technology that there are no vocalising cetaceans detected in the 500 m mitigation zone. • **during times of poor visibility or darkness** it is confirmed by PAM technology that no vocalising cetaceans are present in the 500 m[10] mitigation zone during the pre-shoot watch (60 minutes).	Avoid / Abate on site
5.3	Delay 'soft-starts' if cetaceans are observed within the mitigation zone. • A 'soft-start' should not begin until 30 minutes after cetaceans depart the 500 m mitigation zone or 30 minutes after they are last seen or acoustically detected by PAM in the mitigation zone.	Avoid / Abate on site
5.4	As noted above for planning, when arriving at the survey area for the first time, survey activities should, as far as possible, only commence during daylight hours with good visibility and wind speeds below Beaufort 3. However, if this is not possible due to prolonged periods of high wind speeds, poor visibility (e.g. thick fog) or unforeseen technical issue which results in a night-time start, the initial acoustic source activation (including gun tests) may only be undertaken if the normal 60-minute PAM pre-watch and 'soft-start' procedures have been followed.	Avoid / Abate on site
5.5	Schedule 'soft-starts' so as to minimise, as far as possible, the interval between reaching full power operation and commencing a survey line. The period between the end of the soft start and commencing with a survey line must not exceed 20 minutes. If it does exceed 20 minutes, refer to breaks in firing below.	Abate on site

[9] Although Weilgart (2023) recommends that a pre-shoot watch of 120 minutes should be implemented, in this case the JNCC Guideline of 60 minutes is considered adequate.

[10] As noted in the text above, the cumulative effects would only be expected where the animals are known to congregate and do not move away from the area, e.g. from specific coastal areas used as calving sites or from mid-ocean focal sites such as Tripp Seamount. As Tripp Seamount is approximately 50 km to the north of the survey area cumulative effects from multiple pulses would not be expected. Thus, the discussion here focuses on the maximum zone of impact from a single seismic pulse. Although for the most sensitive hearing group (very high frequency cetaceans) the maximum zone of impact from a single seismic pulse is 270 m for PTS onset and 500 m for TTS onset, the recommended mitigation zone is 500 m. This is due to the VHF signal attenuating rapidly and the likelihood of picking up VHF on PAM at a distance of beyond 500 m is very low. Thus, although VHF cetaceans may experience TTS at a distance of up to 500 m at full power, this is unlikely when implementing the soft-start procedure, where the airgun source is under reduced operating pressure conditions, and consequently has lower noise emissions, thereby providing animals the opportunity to leave the area. As such, the zones of impact during the soft start process are predicted to be less than the full-power operation condition. As an example, under a reduced operating pressure of 1 000 PSI, the noise emissions from the airgun array source are approximately 6 dB lower than from the full-power operation, and the resulted zones of impact are estimated to be approximately half of those zones assessed under the full-power operation condition (SLR Consulting Australia 2024).

No.	Mitigation measure	Classification
6. Line turns		
6.1	If line changes are expected to take longer than 40 minutes: • Terminate airgun firing at the end of the survey line and implement a pre-shoot search (60 minutes) and 'soft-start' procedure (20 minutes) when approaching the next survey line. • If line turn is shorter than 80 minutes (i.e. shorter than a 60-minute pre-shoot watch and 20-minute 'soft-start' combined), the pre-shoot watch can commence before the end of the previous survey line.	Abate on site
6.2	If line changes are expected to take less than 40 minutes, airgun firing can continue during the line change if: • The power is reduced to 180 cubic inches (or as close as is practically feasible) at standard pressure. Airgun volumes of less than 180 cubic inches can continue to fire at their operational volume and pressure; • The Shot Point Interval (SPI) is increased to provide a longer duration between shots, with the SPI not to exceed 5 minutes; • The power is increased and the SPI is decreased in uniform stages during the final 10 minutes of the line change (or geophone repositioning), prior to data collection re-commencing (i.e. a form of mini soft start); and • Normal MMO and PAM observations continue during this period when reduced power airgun is firing.	Abate on site
7. Shut-Downs		
7.1	Terminate seismic shooting on: • observation and/or detection of cetaceans within the 500 m mitigation zone. • observation of any obvious mortality or injuries to cetaceans when estimated by the MMO to be as a direct result of the survey.	Abate on site
7.2	• For cetaceans, terminate shooting until such time as there has been a 30 minute delay from the time the animal was last sighted within the mitigation zone before the commencement of the normal soft start procedure.	Abate on site
8. Breaks in Airgun Firing		
8.1	If after breaks in firing, airguns can be restarted **within 5 minutes**, no soft-start is required and firing can recommence at the same power level **provided no marine mammals have been observed or detected** in the mitigation zone during the break-down period.	Abate on site
8.2	For all breaks in airgun firing of **longer than 5 minutes, but less than 20 minutes**, implement a 'soft-start' of similar duration, assuming there is continuous observation by the MMO and PAM operator during the break.	Abate on site
8.3	For all breaks in firing of **20 minutes or longer**, implement a 60-minute pre-shoot watch and 20-minute 'soft-start' procedure prior to the survey operation continuing.	Abate on site
8.4	For planned breaks, ensure that there is good communication between the seismic contractor and MMOs and PAM operators in order for all parties to be aware of these breaks and that early commencement of pre-watch periods can be implemented to limit delays.	Abate on site

No.	Mitigation measure	Classification
9. PAM malfunctions		
9.1	If the PAM system malfunctions or becomes damaged during night-time operations or periods of low visibility, continue operations for 30 minutes without PAM if no marine mammals were detected by PAM in the mitigation zones in the previous 2 hours, while the PAM operator diagnoses the issue. If after 30 minutes the diagnosis indicates that the PAM gear must be repaired to solve the problem, reduce power to 180 cubic inches. Firing of the reduced power gun may continue for 30 minutes while PAM is being repaired, the last 10 minutes of which is a ramp up to full power (mini 'soft-start'). If the PAM diagnosis and repair will take longer than 60 minutes, stop surveying until such time as a functional PAM system can be redeployed and tested.	Abate on site
9.2	If the PAM system breaks down during daylight hours, continue operations for 20 minutes without PAM, while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM gear must be repaired to solve the problem, operations may continue for an additional 2 hours without PAM monitoring as long as: • No marine mammals were detected by PAM in the mitigation zones in the previous 2 hours; • Two MMOs maintain watch at all times during operations when PAM is not operational; and • The time and location in which operations began and stop without an active PAM system is recorded.	Abate on site

Residual Impact Assessment

The potential impacts cannot be eliminated due to the nature of the seismic sound source required during surveying. The proposed mitigation measures, which are essentially designed to keep animals out of the immediate area of impact and thereby reduce the risk of deliberate injury to marine mammals would reduce the intensity of most impacts to medium, and the residual impacts will reduce to low environmental risk and **LOW** significance, except for the effects on prey which remains of **VERY LOW** significance.

Potential impact of seismic noise to mysticete and odontocete cetaceans

1	*Impacts of seismic noise on mysticetes and odontocetes*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**High**	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**LOW**
Intensity	HIGH	MODERATE
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	HIGH	MEDIUM
Significance	**MEDIUM**	**LOW**
Confidence	High	High
Loss of Resources	Medium	Medium
Mitigation Potential	-	Medium
Cumulative potential	Low	Low

4.3.2 Impacts of Seismic Noise on Seals

Source of Impact

The project activities that will result in impacts to seals are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

The potential impact of seismic survey noise on seals could include physiological injury to individuals, behavioural avoidance of individuals (and subsequent displacement from key habitat), masking of important environmental or biological sounds and indirect effects due to effects on predators or prey. The Cape fur seal that occurs off the West Coast forages over the continental shelf to depths of over 200 m and is thus unlikely to be encountered in the Reconnaissance Permit Area (see Figure 3-44).

Project Controls

The operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

Seals occur at numerous breeding and non-breeding sites on the mainland, namely at Buchu Twins and Cliff Point near Alexander Bay, Robeiland near Kleinzee, Strandfontein Point, Elephant Rocks, at various emergent reefs around Cape Columbine, Robbesteen near Duynefontein and at Duikerklip and Seal Island on the Cape Peninsula. Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles (~220 km) offshore, with bulls ranging further out to sea than females. Seals are therefore unlikely to be encountered in the proposed 3D survey area. Their sensitivity to the proposed seismic operations is considered to be **LOW**. However, considering the recent mass mortality of seals along much of the South and West Coasts, every precaution should be taken to avoid further stresses to these populations.

Environmental Risk

Physiological injury or mortality

Underwater behavioural audiograms have been obtained for two species of Otariidae (sea lions and fur seals), but no audiograms have been measured for Cape fur seals. Extrapolation of these audiograms to below 100 Hz would result in hearing thresholds of approximately 140-150 dB re 1 µPa for the California sea lion and well above 150 dB re 1 µPa for the Northern fur seal. The range of greatest sensitivity in fur seals lies between the frequencies of 2-32 kHz (McCauley 1994). Underwater critical ratios have been measured for two northern fur seals and averaged ranged from 19 dB at 4 kHz to 27 dB at 32 kHz. The audiograms available for otariid pinnipeds suggest they are less sensitive to low frequency sounds (<1 kHz) than to higher frequency sounds (>1 kHz). The range of low frequency sounds (30-100 Hz) typical of seismic airgun arrays thus falls below the range of greatest hearing sensitivity in fur seals. This generalisation should, however, be treated with caution as no critical ratios have been measured for Cape fur seals.

Seals produce underwater sounds over a wide frequency range, including low frequency components. Although no measurement of the underwater sounds have been made for the Cape fur seal, such measurements have been made for a con-generic species Arctocephalus philippii, which produced narrow-band underwater calls at 150 Hz. Aerial calls of seals range up to 6 Hz, with the dominant energy in the 2-4 kHz band. However, these calls have strong tonal components below 1 kHz, suggesting some low frequency hearing capability and therefore some susceptibility to disturbance from the higher frequency components of seismic airgun sources (Goold & Fish 1998; Madsen *et al.* 2006).

The physiological effects of loud low frequency sounds on seals are not well documented, but include cochlear lesions following rapid rise time explosive blasts (Bohne *et al.* 1985; 1986), TTS following exposure to octave-band noise (frequencies ranged from 100 Hz to 2000 Hz, octave-band exposure levels were approximately 60–75 dB, while noise-exposure periods lasted a total of 20–22 min) (Kastak *et al.* 1999), with recovery to baseline threshold levels within 24 h of noise exposure. Due to the high level of impulsive signal emissions from seismic arrays, seals are predicted to experience a PTS at close proximity to the sound source due to the immediate exposure to individual pulses.

Using measured discomfort and injury thresholds for humans, Greenlaw (1987) modelled the pain threshold for seals and sea lions and speculated that this pain threshold was in the region of 185 - 200 dB re 1 µPa. The impact of physiological injury to seals from seismic noise is deemed to be low as it is assumed that highly mobile creatures such as fur seals would avoid severe sound sources at levels below those at which discomfort occurs. However, noise of moderate intensity and duration may be sufficient to induce TTS under water in pinniped species (Kastak *et al.* 1999), as individuals did not appear to avoid the survey area. Reports of seals swimming within close proximity of firing airguns should thus be interpreted with caution in terms of the impacts on individuals as such individuals may well be experiencing hearing threshold shifts. Their tendency to swim at or near the surface will, however, expose them to reduced sound levels when in close proximity to an operating airgun array.

The Underwater Noise Modelling Study undertaken for the current project (SLR Consulting Australia 2024) identified that for seals (Other Marine Carnivores in water) PTS and TTS were predicted to occur within only <10 m and 20 m of the 3D array, respectively (Table 4-3). Maximum threshold distance for recoverable injury from multiple pulses was not reached, with the maximum threshold distance for TTS estimated at <10 m.

The potential impact of physiological injury to seals as a result of seismic noise is deemed to be of HIGH intensity and would be limited to the survey area (REGIONAL). As seals are known to forage up to 120 nautical miles (~220 km) offshore, the proposed 3D survey area falls well to the west of the foraging range of seals from all of the West Coast colonies. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4 months), the potential physiological injury is therefore considered to be of **MEDIUM** environmental risk.

Behavioural avoidance

Information on the behavioural response of fur seals to seismic exploration noise is lacking (Richardson *et al.* 1995; Gordon *et al.* 2004). Reports of studies conducted with Harbour and Grey seals include initial startle reaction to airgun arrays, and range from partial avoidance of the area close to the vessel (within 150 m) (Harris *et al.* 2001) to fright response (dramatic reduction in heart rate), followed by a clear change in behaviour, with shorter erratic dives, rapid movement away from the noise source and a complete disruption of foraging behaviour (Gordon *et al.* 2004). In most cases, however, individuals quickly reverted back to normal behaviour once the seismic shooting ceased and did not appear to avoid the survey area. Seals seem to show adaptive responses by moving away from airguns and reducing the risk of sustaining hearing damage. Potential for long-term habitat exclusion and foraging disruption over longer periods of exposure (i.e. during full-scale surveys conducted over extended periods) is however a concern.

Cape fur seals generally appear to be relatively tolerant to noise pulses from underwater explosives, which are probably more invasive than the slower rise-time seismic sound pulses. There are also reports of Cape fur seals approaching seismic survey operations and individuals biting hydrophone streamers (CSIR 1998). This may be related to their relative insensitivity to sound below 1 kHz and their tendency to swim at or near the surface, exposing them to reduced sound levels. It has also been suggested that this attraction is a learned response to towed fishing gear being an available food supply.

Although partial avoidance (to less than 250 m) of operating airguns has been recorded for some seal species, Cape fur seals appear to be relatively tolerant to loud noise pulses and, despite an initial startle reaction, individuals quickly reverted back to normal behaviour. The potential impact of seal foraging behaviour changing in response to seismic surveys is thus considered to be of MINOR intensity as they are known to show a tolerance to loud noises. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL), the potential for behavioural avoidance of seals is considered to be of **LOW** environmental risk.

Masking of environmental sounds and communication

The use of underwater sounds for environmental interpretation and communication by Cape fur seals is unknown, although masking is likely to be limited by the low duty cycle of seismic pulses (37.5 m interval between consecutive shot-points for 3D). The potential impact of masking of sounds and communication in seals due to seismic surveys is considered to be of MINOR intensity as they are known to show a tolerance to loud noises. As the duration of the impact would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL), the potential for masking of sounds is considered to be of **LOW** environmental risk.

Indirect effects due to the effects of seismic sounds on prey species

As with other vertebrates, the assessment of indirect effects of seismic surveys on Cape fur seals is limited by the complexity of trophic pathways in the marine environment. The impacts are difficult to determine, and would depend on the diet make-up of the species (and the flexibility of the diet), and the effect of seismic surveys on the diet species. Seals typically forage on small pelagic shoaling fish prey species that occur inshore of the 200 m depth contour or associated with oceanic features such as Child's Bank. Furthermore, the broad ranges of fish prey species (in relation to the avoidance patterns of seismic surveys of such prey species) and the extended foraging ranges of Cape fur seals suggest that indirect impacts due to effects on predators or prey would be of MINOR intensity, would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL). The potential for effects of seismic surveys on prey species is thus considered to be of **LOW** environmental risk.

Impact Significance

Physiological injury and mortality

The potential impact of seismic noise on physiological injury or mortality of seals, considering their low sensitivity, the very low likelihood of the impact occurring and the medium environmental risk, is deemed to be of **LOW** significance.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in seals, considering their low sensitivity, the very low likelihood of the impact occurring and the minor environmental risk, is deemed to be of **LOW** significance.

Masking of Sounds and Communication

The potential impact of seismic noise on the masking of environmental sounds and communications in seals, considering their low sensitivity, the very low likelihood of the impact occurring and the minor environmental risk, is deemed to be of **LOW** significance.

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources of seals, considering their low sensitivity, the very low likelihood of the impact occurring and the minor environmental risk, is thus deemed to be of **LOW** significance.

Identification of Mitigation Measures

In addition to the mitigation measures recommended for cetaceans, the following is recommended for seals:

No.	Mitigation measure	Classification
1	Implement a 'soft-start' procedure of a **minimum of 20 minutes'** duration on initiation of the seismic source if during daylight hours it is confirmed visually by the MMO during the pre-shoot watch (60 minutes) that there are no seals within 500 m of the seismic source.	Avoid / Abate on site
2	In the case of fur seals being observed within the mitigation zone, which may occur commonly around the vessel, delay 'soft-starts' for at least 10 minutes until it has been confirmed that the mitigation zone is clear of all seal activity. However, if after a period of 10 minutes seals are still observed within 500 m of the airguns, the normal 'soft-start' procedure should be allowed to commence for at least a 20-minute duration. Seal activity should be carefully monitored during 'soft-starts' to determine if they display any obvious negative responses to the airguns and gear or if there are any signs of injury or mortality as a direct result of the seismic activities.	Avoid / Abate on site
3	Terminate seismic shooting on observation of any obvious mortality or injuries to seals when estimated by the MMO to be as a direct result of the survey.	Abate on site

Residual Impact Assessment

With the implementation of the typical 'soft-start' procedures, the residual impacts of physiological Injury and mortality reduce to **(VERY) LOW** significance. All other impacts on seals would all remain **LOW**.

2	***Impacts of seismic noise on seals***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**Low**	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**LOW**
Intensity	HIGH	MODERATE
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	IMPROBABLE	IMPROBABLE
Significance	**LOW**	**LOW**

	Pre-Mitigation Impact	Residual Impact
Confidence	High	High
Loss of Resources	Low	Low
Mitigation Potential	-	Medium
Cumulative potential	Low	Low

4.3.3 Impacts of Seismic Noise on Turtles

Source of Impact

The project activities that will result in impacts to turtles are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition;

Impact Description

The potential effects of seismic surveys on turtles include:

- Physiological injury (including disorientation) or mortality from seismic noise;
- Behavioural avoidance of seismic survey areas;
- Masking of environmental sounds and communication; and
- Indirect impacts due to effects on predators or prey.

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The leatherback and loggerhead turtles that occur in offshore and coastal waters around southern Africa, and likely to be encountered in the Reconnaissance Permit area are considered regionally 'Critically Endangered' and 'Endangered', respectively, in the List of Marine Threatened or Protected Species (TOPS) as part of the NEMBA. Following nesting in December-January, loggerhead turtles migrate back to their foraging grounds along the East and South Coasts (Harris *et al*. 2018). Hatchlings of both species emerge from their nests from mid-January to mid-March with most dispersing south-westward within the Agulhas Current (Le Gouvelle *et al*. 2020). 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 (Figure 4-3). Despite their extensive distributions and feeding ranges, the numbers of adult and neonate turtles encountered in the

Reconnaissance Permit Area 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 on their migrations. Consequently, the sensitivity of turtles to seismic noise is considered to be **HIGH**, particularly neonates and juveniles as they are unable to actively avoid seismic sounds and consequently are more susceptible to seismic noise.

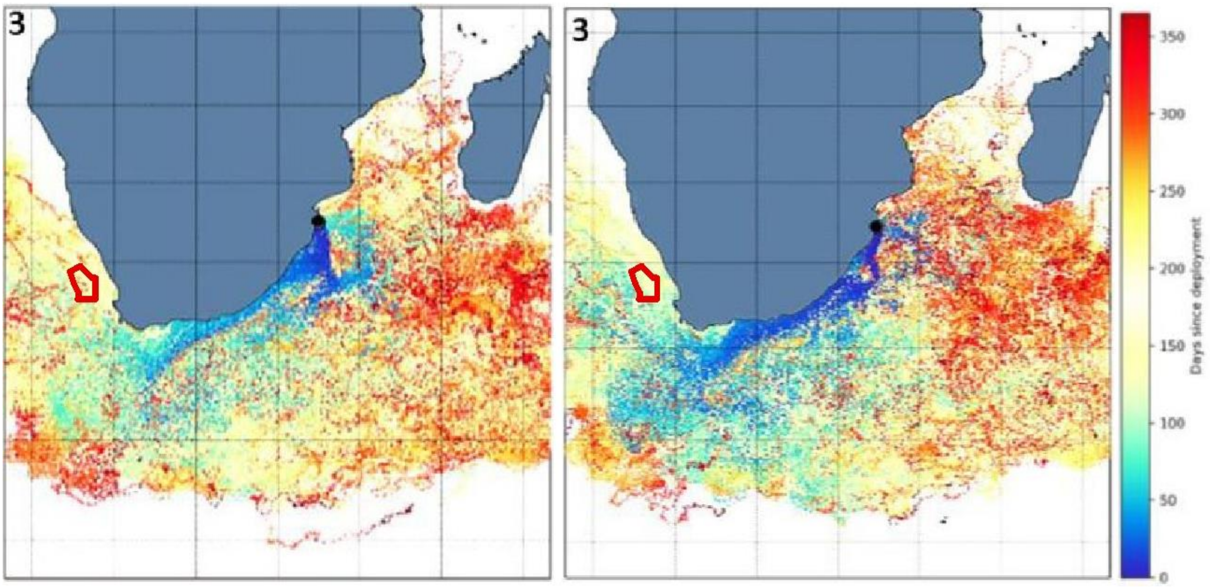


Figure 4-3: Virtual hatchling trajectories for loggerhead (left) and leatherback (right) turtles after 365 days (48 hr @0.15 m/s then no swim) in relation to Reconnaissance Permit Area (red polygon) (adapted from Le Gouvelle *et al.* 2020).

<u>**Environmental Risk**</u>

Available data on marine turtle hearing is limited but suggest highest auditory sensitivity at frequencies of 250 – 700 Hz, and some sensitivity to frequencies at least as low as 60 Hz (Ridgway *et al.* 1969; Wever *et al.* 1978, in McCauley 1994; O'Hara & Wilcox, 1990; Moein-Bartol *et al.* 1999). More recent studies using electrophysiological and behavioural techniques have found that turtles can detect frequencies between 50 Hz and 1 600 Hz (Bartol & Ketten 2006; Lavender *et al.* 2014; Martin *et al.* 2012; Dow-Piniak *et al.* 2012a, 2012b; Papale *et al.* 2020), indicating that their hearing ranges overlap with the peak amplitude, low frequency sound emitted by seismic airguns (10–500 Hz; DeRuiter & Larbi Doukara 2012; Parente *et al.* 2006). The overlap of this hearing sensitivity with the higher frequencies produced by airguns, suggest that turtles may be considerably affected by seismic noise (see review by Nelms *et al.* 2016), although what effect this may have on their fitness or survival is not known.

Physiological injury (including disorientation) or mortality

Due to a lack of research, it is not known what levels of sound exposure (or frequencies) would cause permanent or temporary hearing loss or what effect this may have on the fitness or survival of turtles (DeRuiter & Larbi Doukara 2012), although Eckert *et al.* (1998) assumed physiological effects at levels of 190 dB re 1 μPa ref 1 m, while Popper *et al.* (2014) have predicted that mortality or potential mortal injury will occur at peak sound pressure levels of over 207 dB re 1 μPa. Evidence, however, suggests that turtles only detect airguns at close range (<10 m) or are not sufficiently mobile to move away from approaching airgun arrays (particularly if basking). Initiation of a sound source at full power in the immediate vicinity of a diving, swimming or basking turtle would thus be expected to result in physiological injury. This applies particularly to hatchlings and juveniles as they are unable to avoid seismic sounds whilst being transported in the ocean currents, and consequently are more susceptible to seismic noise. For the first few months following emergence, hatchlings are reported to spend most of their time in the upper 5 m of the water column (Salmon *et al*. 2004; Howell *et al*. 2010; Mansfield *et al*. 2014). Juveniles in contract appear to spend most of their time diving to depths, spending only 43% of their time at the surface during the day and 29% of the time at the surface during the night (Freitas *et al*. 2018, 2019). Both hatchlings and juveniles would therefore be particularly susceptible to airguns at close range.

If subjected to seismic sounds at close range, temporary or permanent hearing impairment may result, but it is unlikely to cause death or life-threatening injury. As with other large mobile marine vertebrates, it is assumed that adult turtles will avoid seismic noise at levels/distances where the noise is a discomfort. Juvenile turtles may be unable to avoid seismic sounds in the open ocean, and consequently may be more susceptible to seismic noise.

The noise exposure criteria for turtles were established in 2004 under the ANSI-Accredited Standards Committee S3/SC 1: Animal Bioacoustics sponsored by the Acoustical Society of America. The criteria for seismic airguns were subsequently provided by Popper *et al*. (2014) (

Table 4-4).

Table 4-4: Noise exposure criteria in turtles for seismic airguns (after Popper *et al*. 2014).

Animal	Zones of impact - maximum horizontal distances from source to impact threshold levels (from single 3D pulses)		Zones of impact - maximum horizontal perpendicular distances from assessed 3D survey lines to cumulative impact threshold levels	
	Injury (PTS) onset Pk SPL re 1 μPa	TTS onset Pk SPL	Injury (PTS) onset Weighted SEL_{24hr} re 1 $\mu Pa^2 \cdot s$	TTS onset Weighted SEL_{24hr} re 1 $\mu Pa^2 \cdot s$
Sea turtles	232 m	226 m	204 m	189 m

Using the peak sound pressure level of 232 dB re 1 μPa, the Underwater Noise Modelling Study undertaken for the current project (SLR Consulting Australia 2024) identified that the maximum horizontal distance from the seismic source to impact threshold levels leading to mortality or potential mortal injury in turtles was 15 m and therefore highly localised at any one time. The maximum horizontal distance from the seismic source to impact threshold levels leading to recoverable injury (TTS) was 30 m. The zones of cumulative impact from multiple pulses (i.e. the maximum horizontal perpendicular distances from assessed survey lines to cumulative impact threshold levels), was estimated as <10 m for mortality and potential mortal injury. Maximum threshold distances for recoverable injury and TTS from multiple pulses was estimated at 50 m. It must be kept in mind that the cumulative zones of impact are conservative, as any turtles likely to be encountered in the Orange Basin area are the highly migratory, and are likely to have moved considerable distances over the cumulative 24-hr period.

As the breeding areas for Leatherback turtles in Gabon occur over 1 500 km to north of the proposed 3D survey area, and on the northeast coast of South Africa, turtles encountered during the survey are likely to be adults migrating to foraging grounds, and dispersing neonates and juveniles. Although turtles have extensive distributions and feeding ranges, the number of turtles encountered in the survey area is expected to be low. Despite their low numbers in the survey area, the intensity of potential physiological injury would be thus rated as HIGH. However, the duration of the impact on the population would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL). The potential physiological injury or mortality of turtles is considered to be of **MEDIUM** environmental risk.

Behavioural avoidance

Behavioural changes in response to anthropogenic sounds have been reported for some sea turtles. Controlled exposure experiments on captive turtles found an increase in swim speed and erratic behaviour indicative of avoidance, at received airgun sound levels of 160 – 176 dB re 1 μPa (O'Hara & Wilcox 1990; Eckert *et al.* 1998; McCauley *et al.* 2000). Sounds of frequency of 250 and 500 Hz resulted in a startle response from a loggerhead turtle (Lenhardt *et al.* 1983; Lenhardt 1994), and avoidance by 30 m of operating airguns where the received level would have been in the order of 175 - 176 dB re 1 μPa (O'Hara & Wilcox 1990). McCauley (1994), however, pointed out that these results may have been influenced by echo associated with the shallow environment in which the test was undertaken.

Further trials carried out on caged loggerhead and green turtles indicated that significant avoidance response occurred at received levels ranging between 172 and 176 dB re 1 μPa at 24 m, and repeated trials several days later suggest either temporary reduction in hearing capability or habituation with repeated exposure. Hearing however returned after two weeks (Moein *et al.* 1994; Lenhardt *et al.* 1994; McCauley *et al.* 2000). McCauley *et al.* (2000) reported that above levels of 166 dB re 1 μPa turtles increased their swimming activity compared to periods when airguns were inactive. Above 175 dB re 1 μPa turtle behaviour became more erratic possibly reflecting an agitated behavioural state at which unrestrained turtles would show avoidance response by fleeing an operating sound source. These would correspond to distances of 2 km and 1 km from a seismic vessel operating in 100 - 120 m of water, respectively. The behavioural threshold of 166 dB re 1 μPa for sea turtles as established by McCauley *et al.* (2000) was subsequently adopted by the National Marine Fisheries Services (NMFS) (NSF 2011).

Observations of marine turtles during a ten-month seismic survey in deep water (1 000-3 000 m) off Angola found that turtle sighting rate during guns-off (0.43 turtles/h) was double that of full-array seismic activity (0.20/h) (Weir 2007). These results should be treated with caution, however, since a large proportion of the sightings occurred during unusually calm conditions and during peak diurnal abundance of turtles when the airguns were inactive (Weir 2007). In contrast, Parente *et al.* (2006), working off Brazil found no significant differences in turtle sightings with airgun state. It is possible that during deep water surveys turtles only detect airguns at close range or are not sufficiently mobile to move away from approaching airgun arrays (particularly if basking for metabolic purposes when they may be slow to react) (Weir 2007). This is in marked contrast to previous assessments that assumed that the impact of seismic noise on behaviour of adult turtles in the open ocean environment is of low significance given the mobility of the animals (CSIR 1998; CCA & CMS 2001). In the study by

Weir (2007) a confident assessment of turtle behaviour in relation to seismic status was hindered, however, by the apparent reaction of individual animals to the survey vessel and towed equipment rather than specifically to airgun sound. As these reactions occurred at close range (usually <10 m) to approaching objects, they appeared to be based principally on visual detection.

Information on how individuals might respond behaviourally to seismic sounds thus remains inconclusive and may be species specific (Piniak *et al*. 2012, 2016; van der Wal *et al*. 2016). Acoustic disturbance could potentially lead to exclusion from key habitats, interruption of breeding, foraging or basking behaviours, or may incite responses which may compromise the turtle's energy budgets (e.g. changes to foraging duration, swim speed, dive depth and duration, and restricting access to the surface to breath) (DeRuiter & Larbi Doukara 2012). Such changes could lead to a reduction in individual fitness (through changes to reproductive outputs or foraging rates), potentially causing detrimental effects at a population level.

Using the RMS SPL criteria of 175 dB re 1 µPa, the Underwater Noise Modelling Study undertaken for the current project (SLR Consulting Australia 2024) identified that the maximum threshold distance for behavioural disturbance for turtles caused by the immediate exposure to individual pulses was predicted to be within 1 140 m from the 3D array. Turtles can therefore hear seismic sounds at a considerable distance and may respond by altering their swimming/basking behaviour or alter their migration route. However, as the number of turtles encountered during the proposed 3D survey is expected to be low, the impact of seismic sounds on turtle behaviour would be of LOW intensity, and would persist only for the duration of the survey (SHORT - 4 months), and be restricted to the survey area (REGIONAL). The impact of seismic noise on turtle behaviour is thus deemed to be of **LOW** environmental risk.

Masking of environmental sounds and communication

Breeding adults of sea turtles undertake large migrations between distant foraging areas and their nesting sites (within the summer months October to March, with peak nesting during December and January). Although Lenhardt *et al*. (1983) speculated that turtles may use acoustic cues for navigation during migrations, information on turtle communication is lacking. The effect of seismic noise in masking environmental cues such as surf noise (150-500 Hz), which overlaps the frequencies of optimal hearing in turtles (McCauley 1994), is unknown and speculative.

As the breeding areas for Leatherback turtles occur over 1 500 km to north of the survey area in Gabon, and on the north-east coast of South Africa, turtles encountered during the survey are likely to be migrating vagrants. Their low abundance in the survey area would suggest that the impact (should it occur) would be of MINOR intensity. As the impact would persist only for the duration of the survey (SHORT - 4 months), and be restricted to the survey area (REGIONAL), the impact is deemed to be of **LOW** environmental risk.

Indirect impacts due to effects on prey

As with other vertebrates, the assessment of indirect effects of seismic surveys on turtles is limited by the complexity of trophic pathways in the marine environment. The leatherback turtles eat pelagic prey, primarily jellyfish. The low numbers and the broad ranges of potential prey species and extensive ranges over which most turtles feed suggest that indirect impacts would be of MINOR intensity, persisting only for the duration of the survey (SHORT - 4 months), and restricted to the survey area (REGIONAL). The impact would therefore be of **LOW** environmental risk.

Impact Significance

Physiological injury and mortality

The potential impact of seismic noise on physiological injury or mortality of turtles, considering their high sensitivity and medium environmental risk, is deemed to be of **MEDIUM** significance. In the case of hatchlings and juveniles, the impact can be considered of **MEDIUM** significance due to their high sensitivity and the potentially high intensity of the impact.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in turtles, considering their medium sensitivity, the medium probability of the impact occurring and the low environmental risk, is deemed to be of **LOW** significance.

Masking of Sounds and Communication

The potential impact of seismic noise on the masking of environmental sounds and communications in turtles, considering their medium sensitivity, the medium probability of the impact occurring and the low environmental risk, is deemed to be of **LOW** significance.

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources of turtles, considering their medium sensitivity, the very low likelihood of the impact occurring and the low environmental risk, is thus deemed to be of **LOW** significance.

Identification of Mitigation Measures

Van der Wal *et al*. (2016) report on innovative measures for mitigating potential impacts on turtles during seismic surveys. They point out that the standard mitigation measures developed for marine mammals ('soft-starts', MMOs) may be less effective for sea turtles as these have a shorter surface presence per unit time and a much lower surfacing profile than do marine mammals. This makes turtles increasingly difficult to detect by MMOs in sea states greater than Beaufort 2. The following mitigation measures are recommended for sea turtles:

No.	Mitigation measure	Classification
1	Implement a 'soft-start' procedure of a **minimum of 20 minutes'** duration on initiation of the seismic source if during daylight hours it is confirmed visually by the MMO during the pre-shoot watch (60 minutes) that there are no turtles within 500 m of the seismic source.	Avoid / Abate on site
2	In the case of turtles being observed within the mitigation zone, delay the 'soft-start' until animals are outside the 500 m mitigation zone.	Avoid / Abate on site
3	Terminate seismic shooting on: – Observation of turtles within the 500 m mitigation zone. – observation of any obvious mortality or injuries to turtles when estimated by the MMO to be as a direct result of the survey. For turtles, terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no 'soft-start' required).	Abate on site
4	Avoid surveying within 100 m of critical foraging habitats (e.g. seamounts)	Avoid

Residual Impact Assessment

With the implementation of the mitigation measures above, the residual impact on potential physiological injury would reduce to **LOW**. The other impacts would remain of **VERY LOW** significance.

3	*Impacts of seismic noise on turtles*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**LOW**
Intensity	HIGH	MODERATE
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	HIGH	MEDIUM
Significance	**MEDIUM**	**LOW**
Confidence	**High**	**High**
Loss of Resources	**High**	**High**
Mitigation Potential	**-**	**Medium**
Cumulative potential	**Low**	**Low**

4.3.4 Impacts of Seismic Noise on Seabirds

Source of Impact

The project activities that will result in impacts to seabirds are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

Potential impacts of seismic pulses to diving birds could include physiological injury, behavioural avoidance of seismic survey areas and indirect impacts due to effects on prey. The seabird species are all highly mobile and would be expected to flee from approaching seismic noise sources at distances well beyond those that could cause physiological injury, but initiation of a sound source at full power in the immediate vicinity of diving seabirds could result in injury or mortality where feeding behaviour override a flight response to seismic survey sounds. The potential for physiological injury or behavioural avoidance in non-diving seabird species, being above the water and thus not coming in direct contact with the seismic pulses, is considered NEGLIGIBLE and will not be discussed further here.

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

Among the marine avifauna occurring along the West Coast of South Africa, it is only the diving birds, or birds which rest on the water surface, that may be affected by the underwater noise of seismic surveys. The African Penguin (S*pheniscus demersus*), which is flightless and occurs along the southwestern Cape coastline, would be particularly susceptible to impacts from underwater seismic noise. Similarly, Cape Gannets dive for their pelagic prey and would be susceptible to seismic noise. Penguins from the Robben Island colony have been tracked feeding up to 70 km offshore of the island (Campbell 2016), and Cape Gannets are known to forage within 200 km offshore (Dundee 2006; Ludynia 2007; Grémillet *et al.* 2008) and both species therefore unlikely to be encountered in the proposed 3D survey area. Both species are considered 'Endangered' on a national and global scale. Of the pelagic seabirds likely to occur in the offshore regions characterising the Orange Basin, many are considered regionally 'Vulnerable' (e.g. White-chinned Petrel), 'Endangered' (e.g. Black-browed Albatross, Atlantic Yellow-nosed Albatross, Subantarctic Skua) and 'Critically Endangered' (Leach's Storm Petrel). Pelagic seabirds spend a significant proportion of their lives on the open ocean diving or skimming the surface for food and resting on the water surface, returning to Southern Ocean Islands only to breed. Tripp Seamount is located approximately 50 km to the north of the proposed 3D survey area, which is an important feature because it attracts an abundance of marine life and is a productive fishing ground. Despite their extensive distributions and feeding ranges, the proposed survey area overlaps with core usage areas for Yellow-nosed Albatross and Wandering Albatross (see Figure 3-33). The numbers of individuals encountered during the survey may thus not be insignificant, particularly in the vicinity of the Child's Bank and Orange Shelf Edge MPAs and associated with Tripp Seamount. Consequently, the sensitivity for both coastal and pelagic seabirds is considered to be **MEDIUM**.

Environmental Risk

Birds are well known for their acoustic communication and hearing abilities, but psychophysical or behavioural data on how birds hear or react to sound underwater is currently lacking (Dooling 2012).

Recent studies on the in-air and underwater hearing in the great cormorant (*Phalacrocorax carbo sinensis*) identified that their greatest sensitivity was at 2 kHz, with an underwater hearing threshold of between 71 – 79 dB re 1 µPa rms (Johansen *et al.* 2016; Hansen *et al.* 2017; Larsen *et al.* 2020) suggesting that the species is better at hearing underwater than in air, with hearing thresholds in the frequency band 1–4 kHz comparable to those of seals and toothed whales. This opens up the possibility of cormorants and other aquatic birds having special adaptations for underwater hearing and making use of underwater acoustic cues from conspecifics, their surroundings, as well as prey and predators.

In African Penguins the best hearing is in the 600 Hz to 4 kHz range with the upper limit of hearing at 15 kHz and the lower limit at 100 Hz (Wever *et al.* 1969). Compared to other birds (Necker 2000), African Penguins were considered to be relatively insensitive to sounds both in terms of frequency and intensity (Wever *et al.* 1969). No critical ratios have, however, been measured. Principal energy of vocalisation of African penguins was found at <2 kHz, although some energy was measured at up to 6 kHz (Wever *et al.* 1969). Penguins are known to respond to underwater vocalisations of predators (Frost *et al.* 1975). Recently underwater vocalisations have been recorded in King, Gentoo and Macaroni penguins with a frequency of maximum amplitude averaging 998 Hz, 1097 Hz and 680 Hz, respectively (Thiebault *et al.* 2019).

Physiological injury

The continuous nature of the intermittent seismic survey pulses suggest that diving birds would hear the sound sources at distances where levels would not induce mortality or injury, and consequently be able to flee an approaching sound source. Available evidence, although scant, therefore suggests that most diving seabirds would be able to hear seismic sounds at considerable distances, and consequently be able to flee an approaching sound source at distances where levels would not induce injury or mortality. The potential for physiological injury to seabirds from seismic surveys in the open ocean is thus deemed to be low (see also Stemp 1985, in Turnpenny & Nedwell 1994), particularly given the extensive feeding range of the potentially affected seabird species.

Of the plunge diving species that occur along the West Coast, the Cape Gannet regularly feeds as far offshore as 100 km, the rest foraging in nearshore areas up to 40 km from the coast, although Cape Cormorants have been reported up to 80 km from their colonies. The nearest Cape Gannet nesting grounds are at Lambert's Bay and Malgas Island, 300 km and 285 km inshore and to the southeast of the eastern boundary of the Reconnaissance Permit area, respectively. The nearest African Penguin nesting sites are similarly at Lambert's Bay, on the Saldanha Bay Islands and at Robben Island. This species forages at sea with most birds being found within 20 km of the coast, although individuals have been recorded as far as 70 km offshore. As the survey area is situated well beyond the foraging ranges of these coastal species, encounters with both Cape Gannets and African penguins are unlikely during 3D seismic acquisition in offshore waters. In the offshore environment, pelagic seabirds that dive for their prey may, however, be encountered, particularly in the portions of the survey area closest to Tripp Seamount.

Should an encounter with diving pelagic seabirds occur, the potential physiological impact on individual pelagic and coastal diving birds would be of HIGH intensity, but as the likelihood of encountering large numbers of diving seabirds is low, due to their extensive distributions and feeding ranges the intensity is considered MODERATE. Furthermore, the duration of the impact on the population would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL). The potential for physiological injury is therefore considered to be of **LOW** environmental risk.

Behavioural avoidance

Diving birds would be expected to hear seismic sounds at considerable distances as they have good hearing at low frequencies (which coincide with seismic shots). Response distances are speculative, however, as no empirical evidence is available. Evidence from studies at Bird and St Croix Islands in Algoa Bay, South Africa on the behavioural response of African Penguins to seismic operations within 100 km of their colonies found that they showed a strong avoidance of their preferred foraging areas during seismic activities. Birds were reported to forage significantly further from the survey vessel when in operation, while increasing their overall foraging effort. Although maximum foraging distance to the colony increased during seismic activity, this increase was not significant relative to outside of seismic activity, with mean maximum distances in the order of 28 km. The birds reverted to normal foraging behaviour when the seismic operations ceased (Pichegru *et al.* 2017). For penguins who spend considerable time underwater while hunting, the impact zone for behavioural disturbance may, however, be larger than for plunge diving species that undertake short dives only before returning to the sea surface.

Due to the extensive distribution and feeding ranges of pelagic seabirds, the impact for pelagic seabirds would thus be of LOW intensity within the survey area (REGIONAL) over the duration of the survey period (SHORT - 4 months). For African Penguins and Cape Gannets, the impact for would thus be of HIGH intensity, but as the likelihood of encountering large numbers in offshore areas is low, the intensity is considered MODERATE. Similarly, for pelagic seabirds the impact would be of HIGH intensity, but due to their extensive distributions and feeding ranges, the likelihood of encountering significant numbers is low, and the intensity is therefore considered MODERATE. The duration of the impact on the population would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL). The behavioural avoidance of feeding areas by coastal diving seabirds and diving pelagic seabirds is thus considered to be of **LOW** environmental risk.

Indirect impacts due to effects on prey

As with other vertebrates, the assessment of indirect effects of seismic surveys on diving seabirds is limited by the complexity of trophic pathways in the marine environment. The impacts are difficult to determine, and would depend on the diet make-up of the bird species concerned and the effect of seismic surveys on the diet species. With few exceptions, most plunge-diving birds forage on small shoaling fish prey species that typically occur relatively close to the shore (<200 m depth) or associated with oceanic features such as the Child's Bank and Tripp Seamount. Cape Gannets vocalise regularly while at sea to maintain group cohesion and avoid collision, and rely on visual observation of other (diving) gannets as a cue to find food (Thiebault *et al.* 2014, 2016), while African Penguins have been reported to hunt cooperatively larger groups (25 165) to corral shoaling fish to the surface, where they subsequently become more accessible to other avian predators such as Cape gannets and cormorants (McInnes *et al.* 2017).

Other than the report of Pichgru *et al.* (2017) for penguins at the Algoa Bay Islands no information is available on the feeding success of seabirds in association with seismic survey noise. Although seismic surveys have been reported to affect fish catches up to 30 km from the sound source, with effects persisting for a duration of up to 10 days, for the current project relatively low behavioural risks are expected for fish species at far-field distances (1 000s of metres) (SLR Consulting Australia 2024). This could have implications for plunge-diving seabirds such as African Penguins that forage in restricted areas within a given radius of their breeding sites. Similarly, pelagic seabirds that feed around seamounts may also be affected. As the survey area is located beyond the foraging range of African penguins and Cape gannets, and Tripp Seamount is located ~50 km north of the proposed survey area, seismic effects on the prey species of coastal seabirds, or pelagic seabirds that feed around seamounts is not expected. The impact on potential food sources for pelagic and coastal diving seabirds would thus be of MINOR intensity within the survey area (REGIONAL) over the duration of the survey period (SHORT - 4 months). The broad ranges of potential fish prey species (in relation to potential avoidance patterns of seismic surveys of such prey species) and extensive ranges over which most seabirds feed suggest that indirect impacts would be of **LOW** environmental risk.

The impact on potential food sources for pelagic seabirds would thus be of MINOR intensity within the survey area (LOCAL) over the duration of the survey period (4 months). The broad ranges of potential fish prey species (in relation to potential avoidance patterns of seismic surveys of such prey species) and extensive ranges over which most seabirds feed suggest that indirect impacts would be of **LOW** environmental risk.

Impact Significance

Physiological injury and mortality

The potential impact of seismic noise on physiological injury or mortality of pelagic seabirds, considering their medium sensitivity, the medium likelihood of the impact occurring and low environmental risk, is deemed to be of **LOW** significance.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in pelagic seabirds, considering their medium sensitivity the medium likelihood of the impact occurring and low environmental risk, is deemed to be of **LOW** significance.

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources for pelagic seabirds, considering their medium sensitivity, the very low likelihood of the impact occurring and the low environmental risk, is thus deemed to be of **LOW** significance.

Identification of Mitigation Measures

As the proposed survey area is located far offshore, it is not deemed necessary to implement mitigation measures to avoid the pre- and postmoult periods for African penguins. In addition to the mitigation measures recommended for cetaceans, the following is recommended for feeding aggregations of diving seabirds:

No.	Mitigation measure	Classification
1	Implement a 'soft-start' procedure of a **minimum of 20 minutes'** duration on initiation of the seismic source if during daylight hours it is confirmed visually by the MMO during the pre-shoot watch (60 minutes) that there are no penguins or feeding aggregations of diving seabirds within 500 m of the seismic source.	Avoid / Abate on site
2	In the case of penguins or feeding aggregations of diving seabirds being observed within the mitigation zone, delay the 'soft-start' until animals are outside the 500 m mitigation zone.	Avoid / Abate on site
3	Terminate seismic shooting on observation of penguins and feeding aggregations of diving seabirds within the 500 m mitigation zone. For penguins and feeding aggregations of diving seabirds, terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no 'soft-start' required).	Abate on site

Residual Impact Assessment

With the implementation of the mitigation measures above, the residual impact on potential physiological injury or behavioural avoidance by seabirds, masking of sounds and indirect impacts on food sources would remain **LOW**.

4	*Impacts of seismic noise on diving seabirds*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**LOW**	**VERY LOW**
Intensity	MODERATE	LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	MEDIUM	MEDIUM
Significance	**LOW**	**LOW**
Confidence	High	High
Loss of Resources	Medium	Medium
Mitigation Potential	-	Medium
Cumulative potential	Low	Low

4.3.5 Impacts of Seismic Noise on Fish

Source of Impact

The project activities that will result in impacts to fish are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

Fish hearing has been reviewed by numerous authors including Popper and Fay (1973), Hawkins (1973), Atema *et al*. (1988), Hawkins & Popper (2018) and Slabbekoorn *et al*. (2019) (amongst others). Fish have two different systems to detect sounds namely 1) the ear (and the otolith organ of their inner ear) that is sensitive to sound pressure and 2) the lateral line organ that is sensitive to particle motion.

Certain species utilise separate inner ear and lateral line mechanisms for detecting sound; each system having its own hearing threshold (Tavolga & Wodinsky 1963), and it has been suggested that fish can shift from particle velocity sensitivity to pressure sensitivity as frequency increases (Cahn *et al*. 1970, in Turl 1993). More recently, Popper & Hawkins (2018) determined that most fish (and all elasmobranchs) primarily detect particle motion.

In fish, the proximity of the swim-bladder to the inner ear is an important component in the hearing as it acts as the pressure receiver and vibrates in phase with the sound wave. Vibrations of the otoliths, however, result from both the particle velocity component of the sound as well as stimulus from the swim-bladder. The resonant frequency of the swim-bladder is important in the assessment of impacts of sounds as species with swim-bladders of a resonant frequency similar to the sound frequency would be expected to be most susceptible to injury. Although the higher frequency energy of received seismic impulses needs to be taken into consideration, the low frequency sounds of seismic surveys would be most damaging to swim-bladders of larger fish. The lateral line is sensitive to low frequency (between 20 and 500 Hz) stimuli through the particle velocity component of sound and would thus be sensitive to the low frequencies of airguns, which most energy at 20-150 Hz.

The sound waves produced during seismic surveys are low frequency, with most energy at 20-150 Hz (although significant contributions may extend up to 500 Hz) (Hirst & Rodhouse 2000), and overlap with the range at which fish hear well (Dalen & Mæsted 2008). A review of the available literature suggests that potential impacts of seismic pulses to fish (including sharks) species could include physiological injury and mortality, behavioural avoidance of seismic survey areas, reduced reproductive success and spawning, masking of environmental sounds and communication, and indirect impacts due to effects on predators or prey (Popper & Hawkins 2018).

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

Most species of fish and elasmobranchs are able to detect sounds from well below 50 Hz (some as low as 10 or 15 Hz) to upward of 500 – 1 000 Hz (Popper & Fay 1999; Popper 2003; Popper *et al*. 2003), with hearing specialists able to detect sounds to 4 000 Hz (Ladich & Fay 2013). Consequently, fish can detect sounds within the frequency range of most widely occurring anthropogenic noises. Within the frequency range of 100 – 1 000 Hz at which most fish hear best, hearing thresholds vary considerably (50 and 110 dB re 1 μPa). They are able to discriminate between sounds, determine the direction of a sound, and detect biologically relevant sounds in the presence of noise (Popper & Hawkins 2019). In addition, some clupeid fish can detect ultrasonic sounds to over 200 kHz (Popper & Fay 1999; Mann *et al*. 2001; Popper *et al*. 2004). Fish that possess a coupling between the ear and swim-bladder have probably the best hearing of fish species (McCauley 1994). Consequently, there is a wide range of susceptibility among fish to seismic sounds, with those with a swim-bladder will be more susceptible to anthropogenic sounds than those without this organ (Popper & Hawkins 2019). Such species may suffer physiological injury or severe hearing damage and adverse effect may intensify and last for a considerable time after the termination of the sound source. Fish without swim bladders include jawless fishes, elasmobranchs (sharks, skates and rays), some flatfishes, some gobies, and some tuna and other pelagic and deep-sea species (Popper *et al.* 2014). As hearing thresholds differ greatly among species, the impacts of seismic sounds are therefore species specific.

The greatest risk of physiological injury from seismic sound sources is for species that establish home ranges on shallow- or deep-water reefs or congregate in areas to spawn or feed, and those displaying an instinctive alarm response to hide on the seabed or in the reef rather than flee. Such species would be associated with the seabed (at >1 500 m) or with Child's Bank or Tripp Seamount. The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of the proposed 3D survey area are the large migratory pelagic species. In many of the large pelagic species, the swim-bladders are either underdeveloped or absent, and the risk of physiological injury through damage of this organ is therefore lower. However, many of the large pelagic fish and shark species likely to occur in the offshore regions characterising the Orange Basin are considered globally 'Vulnerable' (e.g. bigeye tuna, blue marlin, Oceanic Whitetip shark, dusky shark, great white shark, longfin mako), 'Endangered' (e.g. shortfin mako, whale shark) and 'Critically Endangered' (Southern bluefin tuna). However, the numbers of individuals encountered during the survey are likely to be low, even when these species are *en route* to or from recognised feeding grounds associated with Tripp Seamount or Child's Bank where greater concentrations of pelagic fish can be expected. The sensitivity of fish to seismic noise is considered to be HIGH sensitivity.

Environmental Risk

The physiological effects of seismic sounds from airgun arrays will mainly affect the younger life stages of fish such as eggs, larvae and fry, many of which form a component of the meroplankton and thus have limited ability to escape from their original areas in the event of various influences. These have been dealt with under section 4.3.7 below.

Physiological injury and mortality

Studies have shown that fish can be exposed directly to the sound of seismic survey without lethal effects, outside of a very localised range of physiological effects. Exposure of fishes to very high intensity low and mid-frequency sonars resulted in no mortality (Halvorsen *et al.* 2013; Popper *et al.* 2007), nor did exposure to seismic airguns (Popper *et al.* 2005; Popper *et al.* 2016). Physiological effects of impulsive airgun sounds on fish species include swim-bladder damage (Falk & Lawrence 1973), transient stunning (Hastings 1990, in Turnpenney & Nedwell 1994), short-term biochemical variations in different tissues typical of primary and secondary stress response (Santulli *et al.* 1999; Smith *et al.* 2004; Nedelec *et al.* 2015; Sierra-Flores *et al.* 2015), and temporary hearing loss (TTS) due to destruction of the hair cells in the hearing maculae (Enger 1981; Lombarte *et al.* 1993; Hastings *et al.* 1996; McCauley *et al.* 2000; Scholik & Yan 2001, 2002; McCauley *et al.* 2003; Popper *et al.* 2005; Smith *et al.* 2006; Smith & Monroe 2016) and haemorrhaging, eye damage and blindness (Hirst & Rodhouse 2000; Halvorsen *et al.* 2012). Although TTS has been demonstrated in a number of species from a diverse array of sounds (Smith & Monroe 2016), in all cases it only occurred after multiple exposures to intense sounds (<190 dB re 1 µPa rms) or as a result of long-term exposure to less intense sounds (Popper & Hawkins 2019).

Physical damage may lead to delayed mortality as reduced fitness is associated with higher vulnerability to predators and decreased ability to locate prey (Hirst & Rodhouse 2000; McCauley *et al.* 2003; Popper *et al.* 2005). Reduced heart rate (bradycardia) in response to the particle motion component of the sound from the airgun, indicative of an initial flight response has also been reported (Davidsen *et al.* 2019). Popper (2008) concludes that as the vast majority of fish exposed to seismic sounds will in all likelihood be some distance from the source, where the sound level has attenuated considerably, only a very small number of animals in a large population will ever be directly killed or damaged by sounds from seismic airgun arrays. Consequently, direct physical damage from exposure to high level sound from airguns was not considered an issue that required special mitigation (Gausland 2003).

The noise exposure criteria for fish were established in 2004 under the ANSI-Accredited Standards Committee S3/SC 1: Animal Bioacoustics sponsored by the Acoustical Society of America. The exposure criteria for seismic airguns were subsequently provided by Popper *et al.* (2014) (

Table 4-5).

Child's Bank and Tripp Seamount lie ~80 km east and ~50 km north of the proposed 3D survey area, and any demersal species associated with these important fishing banks would receive the seismic noise within the far-field range, and outside of distances at which physiological injury or avoidance would be expected. Impacts on demersal species are thus deemed of MINOR intensity across the survey area (REGIONAL) and for the survey duration (SHORT) and are considered to be of **LOW** environmental risk.

Table 4-5: Noise exposure criteria in fish for seismic airguns (after Popper *et al.* 2014).

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recovery injury	TTS	Masking	
Fish: no swim bladder (particle motion detection)	>219 dB SEL_{24hr}, or >213 dB Pk SPL	>216 dB SEL_{24hr} or >213 dB Pk SPL	>>186 dB SEL_{24hr}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (particle motion detection)	210 dB SEL_{24hr} or >207 dB Pk SPL	203 dB SEL_{24hr} or >207 dB Pk SPL	>>186 dB SEL_{24hr}	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing (primarily pressure detection)	207 dB SEL_{24hr} or >207 dB Pk SPL	203 dB SEL_{24hr} or >207 dB Pk SPL	186 dB SEL_{24hr}	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Fish eggs and fish larvae	>210 dB SEL_{24hr} or >207 dB Pk SPL	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Notes: peak sound pressure levels (Pk SPL) dB re 1 μPa; Cumulative sound exposure level (SEL_{24hr}) dB re 1 $\mu Pa^2 \cdot s$. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Given the high mobility of most fish that occur offshore of the 200 m isobath, particularly the highly migratory pelagic species likely to be encountered in deeper water, it is assumed that the majority of fish species would avoid seismic noise at levels below those where physiological injury or mortality would result. Possible injury or mortality in pelagic species could occur on initiation of a sound source at full pressure in the immediate vicinity of fish, or where reproductive or feeding behaviour override a flight response to seismic survey sounds. Many of the pelagic sharks and tunas likely to be encountered in offshore waters also do not have a swim bladder and are thus less susceptible to seismic sounds than those species that do have swim bladders.

The underwater noise modelling study undertaken for the current survey (SLR Consulting Australia 2024) identified that the maximum horizontal distance from 3D seismic source to impact threshold levels leading to mortality or potential mortal injury was 80 m, for fish lacking swim bladders (e.g. some tunas, sharks and most mesopelagic species) and 160 m for fish with swim bladders. Zones of immediate impact from single pulses for recovery injury were the same. The zones of potential mortal injuries for fish species without a swim bladder, were predicted to be within 10 m from the adjacent survey lines for the cumulative 24-hour survey operation scenario considered, whereas for fish with swim bladders this distance is 60 m for 3D sound sources. For recoverable injury, the zones of cumulative impact from multiple pulses are predicted to be within 20 m from the adjacent survey lines for fish without a swim bladder, and within 200 m for fish with a swim bladder. The zones of TTS effect for fish species with and without swim bladders are predicted to be within 3 500 m for the cumulative scenario. It must be kept in mind that the cumulative zones of impact are conservative as most fish likely to be encountered in the Orange Basin are the highly migratory pelagic sharks, tunas and billfish, and are likely to have moved considerable distances over the cumulative 24-hr period.

Should an encounter occur, the potential physiological impact on individual migratory pelagic fish, would be of HIGH intensity. Furthermore, the duration of the impact on the population would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL). The impact is therefore considered to be of **MEDIUM** environmental risk.

Behavioural avoidance

When interpreting the results of the many studies on potential behavioural effects of sounds on fish one must be cautious of results obtained in tanks or large enclosures and keep in mind that that the responses of fishes may vary with their age and condition, under different environmental conditions and when the level of the sound received by the animal differs (Popper & Hawkins 2019). Behavioural responses to impulsive sounds are varied and include leaving the area of the noise source (Suzuki *et al.* 1980; Dalen & Rakness 1985; Dalen & Knutsen 1987; Løkkeborg 1991; Skalski *et al.* 1992; Løkkeborg & Soldal 1993; Engås *et al.* 1996; Wardle *et al.* 2001; Engås & Løkkeborg 2002; Hassel *et al.* 2004), changes in vertical and horizontal distribution (Chapman & Hawkins 1969; Dalen 1973; Pearson *et al.* 1992; Slotte *et al.* 2004; Løkkeborg *et al.* 2012; Davidsen *et al.* 2019), spatial changes in schooling behaviour (Slotte *et al.* 2004), and startle response to short range start up or high level sounds (Pearson *et al.* 1992; Wardle *et al.* 2001; Paxton *et al.* 2017). Behavioural responses such as avoidance of seismic survey areas and changes in feeding behaviours of some fish to seismic sounds have been documented at received levels of a between 130 and 180 dB re 1 μPa, with disturbance ceasing at noise levels below this (Slabbekoorn *et al.* 2019). In some cases, behavioural responses were observed at up to 5 km distance from the firing airgun array (Santulli *et al.* 1999; Hassel *et al.* 2004; Dalen *et al.* 2007; Fewtrell & McCauley 2012, but see also Rogers *et al.* 2021), with Paxton *et al.* (2017) demonstrating a 78% decline in multispecies presence at a site 7.9 km away from the survey path during active seismic surveying. In contrast, Miller & Cripps (2013) found no effect of seismic survey on the fish species composition of a coral reef in northern Australia, and Meekan *et al.* (2020, 2021) reported no short-term (days) or long-term (months) effects of seismic exposure on the composition, abundance, size structure, behaviour, or movement of demersal fish fauna on the North West Shelf of Western Australia.

Based on the noise exposure criteria provided by Popper *et al.* (2014), relatively high to moderate behavioural risks are expected at near to intermediate distances (tens to hundreds of meters) from the source location. Relatively low behavioural risks are expected for fish species at far field distances (thousands of meters) from the source location. Behavioural effects are generally short-term, however, with duration of the effect being less than or equal to the duration of exposure, although these vary between species and individuals, and are dependent on the properties of the received sound. Although changes in fish distribution have been reported during and after airgun operations, they generally returned to the original site within hours or days after the end of the seismic operation (Engås *et al.* 1996; Engås & Løkkeborg 2002). In some cases, behaviour patterns returned to normal within minutes of commencement of surveying indicating habituation to the noise (Davidsen *et al.* 2019) or showed little to no reaction at all (Peña *et al.* 2013; Miller & Crisp 2013; Meekan *et al.* 2021; McQueen *et al.* 2023). Disturbance of fish is believed to cease at noise levels below 160 dB re 1µPa. The ecological significance of such effects is therefore expected to be low, except in cases where they influence reproductive activity, interfere with foraging or feeding, disruption of migrations and habitat selection or result in delayed mortality (Hirst & Rodhouse 2000; Popper & Hawkins 2019; Soudijn *et al.* 2020). Sub-lethal impacts of acoustic disturbance such as changes in activity patterns and energy budgets can result in altered food intake and growth rates, indirectly affecting the age at sexual maturity, survival and fecundity, thereby ultimately leading to population level consequences (Bruce *et al.* 2018; Cox *et al.* 2018; Slabbekoorn *et al.* 2019; Soudijn *et al.* 2020; van der Knaap *et al.* 2021). As hearing sensitivity can vary with life-cycle stage, season, locality and duration of shooting (Hirst & Rodhouse 2000), it is difficult to determine with accuracy the impact of seismic sound on the behaviour of fish (Gausland 2003).

As spawning is considered a particularly sensitive period in the life-cycle of fish, the potential for anthropogenic noise interferring with successful reproduction is of particular concern (Slabbekoorn *et al.* 2010; de Jong *et al.* 2020). Changes in spawning, migration and feeding behaviour of fishes in response to seismic shooting could indirectly affect fisheries through reduced catches resulting from changes in feeding behaviour, abundance and vertical distribution (Skalski *et al.* 1992; Hirst & Rodhouse 2000; Gausland 2003). Such behavioural changes could lead to changes in commercial catch rates if fish move into or out of important fishing grounds (Engås *et al.* 1996; Hirst & Rodhouse 2000; Dalen & Mæsted 2008; Streever *et al.* 2016; Bruce *et al.* 2018). Reports on observed declines in catch rates differ considerably between studies, between target species and gear types used, ranging from no apparent reduction to an 83% reduction in bycatch in a shrimp trawl (Løkkeborg & Soldal 1993) and typically persisting for a relatively short duration only (12 hours to up to 10 days). More recently, McQueen *et al.* (2022, 2023) investigated the behavioural responses of wild, spawning Atlantic cod to seismic airgun exposure and found no changes in swimming acceleration, displacement, or area use. They concluded that at received sound exposure levels varying between 115 and 145 dB re 1 µPa2s over a 5-d period, there was no substantial alteration in cod behaviour during the spawning period.

The distance from the seismic sound source at which reductions in catch rates were measured also varied substantially between studies ranging from no significant effects in trawl, trammel net and hydraulic dredging fisheries (La Bella *et al.* 1996), through approximately 8 km to as much as 36 km (Hirst & Rodhouse 2000; see also Cochrane & Wilkinson 2015). The potential effects of seismic surveys on fisheries are discussed in more detail in the Commercial Fisheries Impact Assessment (Japp & Wilkinson 2022). Airgun noise related changes to prey and predator species of commercially important species could also play a role in affecting catch rates (Hirst & Rodhouse 2000). Information on feeding success of fish (or larger predators) in association with seismic survey noise is lacking.

Seismic activities have been predicted to possibly affect the migration patterns of tuna leading to substantially reduced catches of albacore and southern bluefin tuna in southern Namibia and the Great Australian Bight, respectively. In the Benguela region it has been suggested that the seasonal movement of longfin tuna northwards from the west coast of South Africa into southern Namibia may be disrupted by the noise associated with seismic surveys. Longfin and other tuna species migrations are known to be highly variable from year to year and are associated with prey availability and also favourable oceanographic conditions. While the potential exists to disrupt the movement of longfin tuna in the Benguela, this disruption, if it occurs, would be localised spatially and temporarily and would be compounded by environmental variability. Similar uncertainty has been expressed for southern bluefin tuna in the Great Australian Bight, and there too there is much uncertainty and any changes in movement and or availability of bluefin tuna was compounded by inter-annual variability and no direct cause and effect could yet be attributed to seismic surveys (Evans *et al*. 2018). As there is currently a dearth of information on the impacts of seismic noise on truly pelagic species such as swordfish and tuna (Evans *et al*. 2018; Webster *et al*. 2018), links between changes in migration patterns and subsequent catches thus remains speculative.

Behavioural responses such as deflection from migration paths or avoidance of seismic survey areas and changes in feeding behaviours of some fish to seismic sounds have been documented at received levels of about 130 - 180 dB re 1 μPa. Behavioural effects are generally short-term, however, with duration of the effect being less than or equal to the duration of exposure, although these vary between species and individuals, and are dependent on the properties of the received sound. The potential impact on individual fish behaviour could therefore be of HIGH intensity (particularly in the near-field of the airgun array). Impacts to behavioural responses would be limited to the survey duration (SHORT), and the survey area (REGIONAL). Consequently, it is considered to be of **MEDIUM** environmental risk.

Reproductive success / spawning

Although the effects of airgun noise on spawning behaviour of fish have not been quantified to date, it is predicted that if fish are exposed to powerful external forces on their migration paths or spawning grounds, they may be disturbed or even cease spawning altogether (de Jong *et al*. 2020). The deflection from migration paths may be sufficient to disperse spawning aggregations and displace spawning geographically and temporally, thereby affecting recruitment to fish stocks. The magnitude of effect in these cases will depend on the biology of the species and the extent of the dispersion or deflection. Depending on the physical characteristics of the area, the range of the impact may extend beyond 30 km (Dalen *et al*. 2007), and could thus potentially affect subsequent recruitment to fish stocks if spawning is displaced geographically or temporally. Dalen *et al*. (1996), however, recommended that in areas with concentrated spawning or spawning migration seismic shooting be avoided at a distance of ~50 km from these areas, particularly areas subjected to repeated, high intensity surveys (see also Gausland 2003). In Norway, legislation has now been put in place ensuring that areas supporting high densities of spawning fish are sometimes closed to seismic surveys as a measure both to avoid scaring away the spawning adults and to avoid direct mortality of early life stages (Boertmann *et al*. 2009; Sivle *et al*. 2021). A buffer of 20 nautical miles around Norwegian spawning grounds has now been recommended to be closed for 3D seismic surveys (Sivle *et al*. 2021). To effectively protect spawning areas, however, thorough knowledge of the actual spawning areas and periods of the species involved is crucial.

The spawning areas of the small pelagic shoaling species are distributed on the continental shelf and along the shelf edge from Lambert's Bay to Mossel Bay, with the major spawning grounds for most species (anchovy, round herring, horse mackerel, chub mackerel) located east of Cape Point and hake spawning occurring on the western Agulhas Bank. There is therefore no overlap of the proposed 3D survey area with the migration routes and spawning areas of these commercially important species (see Figure 3-20). If behavioural responses to seismic noise result in deflection from coastal migration routes or disturbance of spawning, further impacts may occur that may affect recruitment to fish stocks. The intensity of effect in these cases will depend on the biology of the species and the extent of the dispersion or deflection. Despite the current low biomass of sardine, particularly west of Cape Agulhas, recent successive years of low recruitment and the dependence of future recruitment on successful West Coast spawning (Shabangu *et al.* 2019b) the intensity of the potential impact of the 3D survey can be considered MINOR for the duration of the survey (SHORT) as the survey area lies well offshore of these West Coast spawning areas and is not known to be a spawning area for large pelagic species. The impact is thus considered to be of **LOW** environmental risk.

Masking of environmental sounds and communication

While some nearshore reef species are known to produce isolated sounds or to call in choruses, communication and the use of environmental sounds by fish off the South African West Coast are unknown. Demersal species in abyssal and continental slope habitats or associated with Child's Bank or Tripp Seamount would receive the seismic noise in the far field and vocalisation, should it occur, is unlikely to be masked. Impacts arising from masking of sounds are thus expected to be of MINOR intensity due to the duty cycle of seismic surveys in relation to the more continuous biological noise. Such impacts would occur across the survey area (REGIONAL) and for the duration of the survey (4 months). The impact is thus considered to be of **LOW** environmental risk.

Indirect impacts due to effects on predators or prey

The assessment of indirect effects of seismic surveys on fish is limited by the complexity of trophic pathways in the marine environment. The impacts are difficult to determine, and would depend on the diet make-up of the fish species concerned and the effect of seismic surveys on the diet species. Indirect impacts of seismic surveying could include attraction of predatory species such as sharks, tunas or diving seabirds to pelagic shoaling fish species stunned by seismic noise. In such cases, where feeding behaviour overrides a flight response to seismic survey sounds, injury or mortality could result if the seismic sound source is initiated at full power in the immediate vicinity of the feeding predators. Little information is available on the feeding success of large migratory fish species in association with seismic survey noise. The pelagic shoaling species that constitute the main prey item of migratory pelagic species typically occur inshore of the 200 m depth contour. Although large pelagic species are known to aggregate around seamounts to feed, considering the extensive range over which large pelagic fish species can potentially feed in relation to the survey area, and the low abundance of pelagic shoaling species that constitute their main prey across most of the 3D survey area the intensity of the impact would be LOW, restricted to the survey area (REGIONAL) and persisting over the SHORT-TERM only (4 months). The impact would thus be of **LOW** environmental risk.

<u>Impact Significance</u>

Physiological injury and mortality

The potential impact of seismic noise on physiological injury or mortality of fish, considering their high sensitivity and medium environmental risk, is thus deemed to be of **MEDIUM** significance.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in large migratory pelagic fish, considering the high sensitivity, the low to medium likelihood of the impact occurring and medium environmental risk, is deemed to be of **MEDIUM** significance.

Reproductive success / spawning

The potential impact of seismic noise on the reproductive success and spawning of nearshore commercial fish species, considering their high sensitivity, the low to medium likelihood of the impact occurring and the very low environmental risk, is deemed to be of **LOW** significance.

Masking of environmental sounds and communication

The potential impact of seismic noise on the masking of sounds of fish, considering the high sensitivity, the low likelihood of the impact occurring and the very low environmental risk is thus deemed to be of **LOW** significance.

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources for fish, considering their high sensitivity, the low likelihood of the impact occurring and the very low environmental risk, is thus deemed to be of **LOW** significance.

Identification of Mitigation Measures

As the proposed survey area is located far offshore, it is not deemed necessary to implement mitigation measures to avoid the key spring spawning periods for most commercially important fish species. Furthermore, Searcher has agreed to avoid the key "ring fenced" fishing and spawning areas identified during previous consultation with the commercial fishing sector. In addition to the mitigation measures recommended for cetaceans, the following is recommended for fish:

No.	Mitigation measure	Classification
1	Implement a 'soft-start' procedure of a **minimum of 20 minutes'** duration on initiation of the seismic source if during daylight hours it is confirmed visually by the MMO during the pre-shoot watch (60 minutes) that there are no slow swimming large pelagic fish within 500 m of the seismic source.	Avoid / Abate on site
2	In the case of slow swimming large pelagic fish being observed within the mitigation zone, delay the 'soft-start' until animals are outside the 500 m mitigation zone.	Avoid / Abate on site
3	Terminate seismic shooting on – Observation of slow-swimming large pelagic fish (including whale sharks, basking sharks, manta rays and devil rays) within the 500 m mitigation zone. – Observation of any obvious mass mortalities of fish (specifically large shoals of tuna or surface shoaling small pelagic species such as sardine, anchovy and mackerel) when estimated by the MMO to be as a direct result of the survey. For slow swimming large pelagic fish, terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no 'soft-start' required).	Abate on site

<u>**Residual Impact Assessment**</u>

The potential impacts cannot be eliminated due to the nature of the seismic sound source required during surveying. The location of the proposed survey area well to the west of the 'ring-fenced' area and proposed mitigation measures, which are essentially designed to keep animals out of the immediate area of impact and thereby reduce the risk of deliberate injury to fish, reduces the intensity of the impacts relating to physiological injury / mortality to medium, the residual impact will reduce to low environmental risk and be of **LOW** significance. All other impacts on fish remain of **LOW** significance.

5	***Impacts of seismic noise to pelagic fish***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**LOW**
Intensity	HIGH	MODERATE
	LOW: demersal & small pelagic species; HIGH: large pelagic species	LOW: demersal & small pelagic species; MEDIUM: large pelagic species
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	HIGH (large pelagic) LOW (demersal & small pelagic species)	LOW
Significance	**MEDIUM**	**LOW**
Confidence	High	High
Loss of Resources	Low	Low
Mitigation Potential	-	Medium
Cumulative potential	Low	Low

4.3.6 Impacts of Seismic Noise on Marine Invertebrates

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

The project activities that will result in impacts to marine invertebrates are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

Many marine invertebrates have tactile organs or hairs (termed mechanoreceptors), which are sensitive to hydro-acoustic near-field disturbances, and some have highly sophisticated statocysts, which have some resemblance to the ears of fishes (Offutt 1970; Hawkins & Myrberg 1983; Budelmann 1988, 1992; Packard *et al.* 1990; Popper *et al.* 2001) and are thought to be sensitive to the particle acceleration component of a sound wave in the far-field. Solé *et al.* (2023) provide a detailed review of invertebrate bioacoustics and the detection and production of sound by invertebrates. Potential impacts of seismic pulses on invertebrates would include physiological injury or mortality in the immediate vicinity of the airgun sound source, and behavioural avoidance. Masking of environmental sounds and indirect impacts due to effects on predators or prey have not been documented and are highly unlikely and are thus not discussed further here.

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The proposed 3D survey area lies well offshore where the ecosystem threat status is considered of 'Least concern'. The proposed 3D acquisition area lies well offshore where the deepwater habitat types are comparatively uniform and cover large areas. The benthic fauna of the abyss, lower and upper continental slope and outer shelf (beyond ~450 m depth) are very poorly known and there are no species of commercial value occurring that far offshore. Sensitive deep-water coral communities would be expected with topographic features such as Tripp Seamount and Childs Bank, which lie ~50 km to the north and 80 km east of the survey area, respectively, but are unlikely to occur in the survey area. Furthermore, most ecosystem types outside the offshore MPAs are either poorly protected or not protected at all (see Figure 3-48). Pelagic invertebrates that may occur in the Orange Basin are the giant squid, which is a deep dwelling species confined to the continental slopes. This species could thus potentially occur in the survey area, although the likelihood of encounter is extremely low.

The sensitivity of benthic invertebrates is considered to be VERY LOW, whereas for neritic and pelagic invertebrates the sensitivity can be considered LOW. Following the precautionary principle, the LOW sensitivity will be assumed in determining the significance.

Environmental Risk

Information on hearing by invertebrates, and noise impacts on them is sparse (reviewed in Moriyasu *et al.* 2004; Carroll *et al.* 2017; Solé *et al.* 2023). Although many invertebrates cannot sense the pressure of a sound wave or the lower amplitude component of high frequency sounds, low frequency high amplitude sounds may be detected *via* the mechanoreceptors, particularly in the near-field of such sound sources (McCauley 1994). Sensitivity to near-field low-frequency sounds or hydroacoustic disturbances has been recorded for the lobster *Homarus americanus* (Offut 1970; Day *et al.* 2016a; Fitzgibbon *et al.* 2017), cephalopods (Kaifu *et al.* 2008; Hu *et al.* 2009; Mooney *et al.* 2010, 2012; André *et al.* 2011; Fewtrell & McCauley 2012; Samson *et al.* 2014; Mooney *et al.* 2016), scallops (Day *et al.* 2016; Day *et al.* 2017), and various other invertebrate species (Horridge 1965, 1966; Horridge

& Boulton 1967; Moore & Cobb 1986; Packard *et al.* 1990; Turnpenney & Nedwell 1994; reviewed in Solé *et al.* 2023).

Physiological injury

Recent field-based methods on scallop beds (*Pecten fumatus* and *Mimachlamys asperrima*) in the Bass Strait, Australia, showed no evidence of scallop mortality attributable to seismic surveying, although sub-lethal effects could not be excluded (Przeslawski *et al.* 2016, 2018; see also Parry *et al.* 2002; Harrington *et al.* 2010). Another study on exposure of scallops from transplanted populations to an airgun operated in shallow water (<12 m), however, found evidence of seismic impacts (increased mortality, inability to maintain homeostasis, reflex changes, depressed immune response) (Day *et al.* 2016, 2017).

No other quantitative records of invertebrate mortality from seismic sound exposure under field operating conditions have been reported, although lethal and sub-lethal effects have been observed under experimental conditions where invertebrates were exposed to airguns at close range (reviewed by Carroll *et al.* 2017). These include reduced growth and reproduction rates, compromised nutritional condition and immunological capacity, and behavioural changes in crustaceans (DFO 2004; McCauley 1994; McCauley *et al.* 2000; Day *et al.* 2016; Fitzgibbon *et al.* 2017). The effects of seismic survey energy on snow crab (*Chionoecetes opilo*) on the Atlantic coast of Canada, for example ranged from no physiological damage (Lee-Dadswell 2009), but effects on developing fertilized eggs at 2 m range (Christian *et al.* 2003) to possible bruising of the heptopancreas and ovaries, delayed embryo development, smaller larvae, and indications of greater leg loss but no acute or longer term mortality and no changes in embryo survival or post hatch larval mobility (DFO 2004). In contrast, Day *et al.* (2016a; 2016b, 2019, 2021, 2022) demonstrated delayed righting time, which was correlated to damage to statocysts in adult rock lobster (*Jasus edwardsii*) persisting up to a year after exposure to airgun sounds, despite larval stages showing no adverse effects (Day *et al.* 2017, 2019). Impairments in righting behaviour were found to extend to at least 500 m form the airgun discharge, with those closest to the source demonstrating both persistent righting impairment and an increased intermoult duration (Day *et al.* 2019, 2021, 2022). The ecological significance of sub-lethal or physiological effects could thus range from trivial to important depending on their nature. It must be kept in mind, however, that assessing seismic impacts using experimental cages or tanks is challenging due to experimental artefacts (Gray *et al.* 2016; Rogers *et al.* 2016) that may lead to misinterpretation of impact in field settings (e.g. DeSoto *et al.* 2013) who reported developmental delays in scallop (*Pecten novaezelandiae*) larvae exposed to playbacks of seismic pulses).

Other field-based studies on adult invertebrate populations revealed no evidence of increased mortality in response to airgun exposure in scallops, clams or lobsters, a variety of reef-associated invertebrates, snowcrabs and shrimp (reviewed in Carroll *et al.* 2017). Day *et al.* (2016a), however, reported dose-dependent increased mortality in transplanted scallops reared in suspended lantern nets four months after exposure to an airgun.

Some studies have also been undertaken on invertebrates that lack statocysts to determine potential non-auditory impacts. Hastings (2008) suggested that at high levels (~260 dB re 1 µPa) hydroacoustic force could potentially cause skeletal and tissue damage in corals. Direct mortality of invertebrates from hydroacoustic force has been considered unlikely (Department of Fisheries and Oceans Canada 2004; Massey & Forde 2015). In a structured infield before-after/control-impact study, no measurable effects on skeletal integrity, physiological damage or stress, and no evidence of a behavioural response in adult scleractinian corals in 30 – 70 m depth at Scott Reef, northwest Australia, were detected immediately after and up to four months following a 3D seismic survey (maximum SEL of 204dB re 1μPa^2) (Battershill *et al.* 2007, 2008; Heyward *et al.* 2018). Heyward *et al.* (2018) point out that the study did not, however, consider sub-lethal or incipient damage to corals or their habitat, such as reduced reproduction, behavioural or physiological changes and slower growth.

Although causative links to seismic surveys have not been established with certainty, giant squid strandings coincident with seismic surveys have been reported (Guerra *et al.* 2004; Leite *et al.* 2016). The animals examined by Guerra *et al.* (2004) following two incidents of multiple strandings in the Bay of Biscay showed no external damage, but all had severe internal injuries (including disintegrated muscles and unrecognisable organs) indicative of having ascended from depth too quickly. Similarly, exposure of various species of caged Mediterranean cephalopods to low frequency sounds revealed lesions in the statocysts, consistent with a massive acoustic trauma (André *et al.* 2011; Solé *et al.* 2013a, 2013b).

Behavioural avoidance

Behavioural responses of invertebrates to particle motion of low frequency stimulation have been measured by numerous researchers (reviewed in McCauley 1994). Again a wide range of responses are reported ranging from no avoidance by free ranging invertebrates (crustaceans, echinoderms and molluscs) of reef areas subjected to pneumatic airgun fire (Wardle *et al.* 2001), and no reduction in catch rates of shrimp (Webb & Kempf 1998; Andriguetto-Filho *et al.* 2005), prawns (Steffe & Murphy 1992, in McCauley, 1994) or rock lobsters (Parry & Gasson 2006) or snow crab (Courtenay *et al.* 2009; Morris *et al.* 2018; Cote *et al.* 2020; Morris *et al.* 2020a, 2020b) in the near-field during or after seismic surveys. Startle responses and alarm behaviour in decapods occurred only when the animals were <0.10 m away from the sound source (Goodall *et al.* 1990). Day *et al.* (2017), however, demonstrated a reduction in classic behaviours and the development of a nonclassic velar 'flinch' of scallops in response to airgun signals. Branscomb & Rittschof (1984), however, reported that low frequency noise was successful in deterring barnacle larvae from settling on ship hulls. Changes in predator avoidance behaviours may, however, have population-level implications if predation rates increase due to sound-induced behavioural changes in prey (reviewed in Carroll *et al.* 2017; see also Day *et al.* 2019). Solan *et al.* (2016) showed that exposure to underwater broadband sound fields altered sediment-dwelling invertebrate contributions to fluid and particle transport. Thus, despite the effects of the sound not being lethal, it could have significant functional, fitness and ecological consequences by affecting key processes in benthic nutrient cycling).

Cephalopods, in contrast, may be receptive to the far-field sounds of seismic airguns, with reported responses to frequencies under 400Hz including alarm response (e.g. jetting of ink), changes in behaviour (aggression and spawning), position in the water column and swimming speeds (Kaifu *et al.* 2008; Hu *et al.* 2009; Mooney *et al.* 2010, 2012; Fewtrell & McCauley 2012; Samson *et al.* 2014; Mooney *et al.* 2016). Squid responded to sounds from 80 to 1 000 Hz pure tone and at sound levels above 140 dB re. 1 μPa rms, with response rates diminishing at the higher and lower end of this range (Samson *et al.* 2014; Mooney *et al.* 2016). In contrast Maniwa (1976) reported attraction and increased capture of *Todarodes pacificus* at 600 Hz pure tone. Behavioural responses, however, typically involved startle responses at received levels of 174 dB re 1 μPa, to increase levels of alarm responses once levels had reached 156 – 161 dB re 1 μPa (McCauley *et al.* 2000; Fewtrell & McCauley 2012), which is well below the maximum range of 230-255 dB re 1μPa at 1 m for airgun arrays. The results of caged experiments suggest that squid would significantly alter their behaviour at an estimated 2 - 5 km from an approaching large seismic source, although recent research has shown that gradual increase in signal intensity and prior exposure to air gun noise would decrease the severity of the alarm responses, suggesting that animals became accustomed to the noise at low levels (McCauley *et al*. 2000; Fewtrell & McCauley 2012; Samson *et al*. 2014). Limited avoidance of airgun sounds by mobile neritic and pelagic invertebrates can, however, therefore be expected.

As the proposed 3D survey area is located in waters in excess of 1 500 m depth, the received noise by benthic invertebrates at the seabed would be within the far-field range, and outside of distances at which physiological injury would be expected. The impact is therefore deemed of MINOR intensity across the survey area (REGIONAL) and for the four-month survey duration (SHORT) and is therefore considered to be of **LOW** environmental risk.

The potential impact of seismic noise on physiological injury or mortality and behavioural avoidance of pelagic cephalopods could potentially be of high intensity to individuals, but as distribution of mobile neritic and pelagic squid is naturally spatially highly variable and the numbers of giant squid likely to be encountered is low, the intensity would be considered LOW across the survey area (REGIONAL) and for the survey duration (SHORT - 4 months) resulting in a **LOW** environmental risk.

Impact Significance

The potential impact of 3D seismic noise on benthic, and neritic and pelagic invertebrates, considering the low sensitivity, the low likelihood of the impact occurring is thus deemed to be of **LOW** significance.

Identification of Mitigation Measures

The following mitigation measure is however recommended:

No.	Mitigation measure	Classification
1	Terminate seismic shooting on observation of any obvious mass mortalities of squid when estimated by the MMO to be as a direct result of the survey.	Abate on site

Residual Impact Assessment

With the implementation of the typical 'soft-starts', the residual impact on potential behavioural avoidance by cephalopods would remain of **LOW** significance.

6	***Impacts of seismic noise to marine invertebrates***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**VERY LOW**	**VERY LOW**
Intensity	LOW	MINOR
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW – MEDIUM (SQUID)	LOW
Significance	**LOW**	**LOW**
Confidence	Medium	Medium
Loss of Resources	Low	Low
Mitigation Potential	-	Low
Cumulative potential	Low	Low

4.3.7 Impacts of Seismic Noise on Plankton (including ichthyoplankton)

Source of Impact

The project activities that will result in impacts to plankton are listed below.

Project phase	Activity
Mobilisation	N/A
Operation	Seismic acquisition/ firing of airguns
Demobilisation	N/A

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

As the movement of phytoplankton, zooplankton and ichthyoplankton is largely limited by currents, they are not able to actively avoid the seismic vessel and thus are likely to come into close contact with the sound sources, potentially experiencing multiple exposures during acquisition of adjacent lines. Potential impacts of seismic pulses on plankton would include physiological injury or mortality in the immediate vicinity of the airgun sound source.

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The proposed 3D survey area lies offshore of the the Namaqua and Cape Columbine upwelling cells (see Figure 3-8a), in the warmer oceanic waters. Phytoplankton and zooplankton abundance in the clear offshore waters of the Benguela Current are thus expected to be low, although seasonal peaks may occur associated with Child's Bank and Tripp Seamount.

The major spawning areas of the small pelagic shoaling species are on the continental shelf and along the shelf edge from Lambert's Bay to Mossel Bay. Hake, snoek and round herring also move to the western Agulhas Bank and southern west coast to spawn, generally in late winter and early spring, although hake are reported to spawn year round. The eggs and larvae are carried around Cape Point and up the West Coast in northward flowing surface waters, except hake whose eggs rise slowly through the water column, remain entrained in the upwelling circulation and are drawn shorewards at depth until just before hatching. 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. There is therefore no overlap of the proposed 3D survey area with the northward egg and larval drift of commercially important species, and the return migration of recruits (see Figure 3-20).

Phytoplankton are not known to be affected by seismic surveys and are unlikely to show any significant effects of exposure to airgun impulses outside of a 1 m distance (Kosheleva 1992; McCauley 1994). Although subject to nutrient availability, the regeneration time of phytoplankton is rapid so that an area vacated by mortality through exposure to airgun blasts would be rapidly recolonized. Furthermore, the fast current speeds would ensure rapid displacement and replacement of damaged or dead plankton within the survey area.

Zooplankton comprises meroplankton (organisms which spend a portion of their life cycle as plankton, such as fish and invertebrate larvae and eggs) and holoplankton (organisms that remain planktonic for their entire life cycle, such as siphonophores, nudibranchs and barnacles). The abundance and spatial distribution of zooplankton is highly variable and dependent on factors such as fecundity, seasonality in production, tolerances to temperature, length of time spent in the water column, hydrodynamic processes and natural mortality. Zooplankton densities are therefore generally patchily distributed.

Invertebrate members of the plankton that have a gas-filled flotation aid, may be more receptive to the sounds produced by seismic airgun arrays, and the range of effects may extend further for these species than for other plankton.

Phytoplankton, zooplankton and ichthyoplankton abundances across most of the survey area are thus expected to be comparatively low, and (if they occur) have a highly patchy distribution and seasonally high abundances. Although plankton distribution is naturally temporally and spatially variable and natural mortality rates are high, the overall sensitivity is considered **MEDIUM** due to the potentially reduced reproductive success in some of the small pelagic species.

Environmental Risk

The amount of exposure that plankton can withstand due to the influence of seismic sound is dependent on a wide range of variables namely 1) the presence of gas-filled flotation aids, 2) temporal and spatial variability in occurrence, and 3) proximity to the sound source. Potential impacts of seismic pulses on plankton, and fish eggs and larvae would include mortality or physiological injury in the immediate vicinity of the airgun sound source.

Due to their importance in commercial fisheries, numerous studies have been undertaken experimentally exposing the eggs and larvae of various zooplankton and ichthyoplankton species to airgun sources (Kostyuchenko 1971; Dalen & Knutsen 1987; Holliday *et al.* 1987; Booman *et al.* 1992; Kosheleva 1992; McCauley 1994; Popper *et al.* 2005; and reviewed in Carroll *et al.* 2017 and Sivle *et al.* 2021). These studies generally identified that for a large seismic array, mortalities and physiological injuries occurred at very close range (<5 m) only. For example, increased mortality rates for fish eggs were proven out to ~5 m distance from the air guns. A mortality rate of 40-50% was recorded for yolk sac larvae (particularly for turbot) at a distance of 2-3 m (Booman *et al.* 1996), although mortality figures for yolk sac larvae of anchovies at the same distances were lower (Holliday *et al.* 1987). Yolk sac larvae of cod experienced significant eye injuries (retinal stratification) at a distance of 1 m from an air gun array (Matishov 1992), and Booman *et al.* (1996) report damage to brain cells and lateral line organs at <2 m distance from an airgun array. Increased mortality rates (10-20%) at later stages (larvae, post-larvae and fry) were proven for several species at distances of 1-2 m. Changes have also been observed in the buoyancy of the organisms, in their ability to avoid predators and effects that affect the general condition of larvae, their growth rate and thus their ability to survive. Temporary disorientation juvenile fry was recorded for some species (McCauley 1994). McCauley (1994) concluded that when compared with total population sizes or natural mortality rates of planktonic organisms, the relative influence of seismic sound sources on these populations can be considered insignificant. The wash from ships propellers and bow waves can be expected to have a similar, if not greater, volumetric effect on plankton than the sounds generated by airgun arrays.

More recently, however, McCauley *et al.* (2017) demonstrated significant declines in zooplankton abundance within a maximum range of 1.2 km of the airguns' passage (see also Tollefson 2017) and suggested that seismic surveys may result in significant and unacknowledged impacts on ocean ecosystem function and productivity. A follow-up publication by Richardson *et al.* (2017), however, queried the robustness of the McCauley *et al.* (2017) study on the grounds of insufficient sample size. Richardson *et al.* (2017) estimated that while zooplankton populations declined 22% within the survey area and 14% within 15 km of the survey area, biomass recovery occurred within 3 days following survey completion and any effects on zooplankton by seismic noise would endure in the very short term only. The time required for recolonisation of the water column by zooplankton (and ichthyoplankton) would depend on a number of variables, including seasonality of zooplankton spawning, water movement, vertical migration of plankton species and proximity of breeding adult populations. The authors stressed that impacts in areas of dynamic ocean circulation (as would be the case in the offshore reaches of the Benguela Current, are likely to be even less. A more recent study by Fields *et al.* (2019) reported that there was significantly higher immediate mortality of the copepod *Calanus finmarchicus* at distances of 5 m from the airguns compared to controls, but that increased mortality did not exceed 30% at any distance from airgun blasts. Whether it was the sound pulse itself, the large-scale fluid motion generated by the airgun blasts, or other effects such as the bubble cloud that caused the higher mortality in the copepods, however, remains unknown. In contrast, Vereide *et al.* (2023) reported an immediate 14% mortality in the nauplii of the copepod *Acartia tonsa* exposed to the output of two small 40 cubic inch airguns (HGS sleve guns) passing at distances of between 50 – 1 200 m. Nauplii exposed to the airguns discharge showed reduced growth rates with nearly 100% mortality four days post-exposure.

From a fish resource perspective, these effects may potentially contribute to a certain diminished net production in fish populations, both directly through mortality of ichthyoplankton, as well as indirectly through reduction in plankton that serves as a food source. However, Sætre & Ona (1996) calculated that under the "worst case" scenario, the number of larvae killed during a typical seismic survey was 0.45% of the total larvae population. When more realistic "expected values" were applied to each parameter of the calculation model, the estimated value for killed larvae during one run was equal to 0.03% of the larvae population. If the same larval population was exposed to multiple seismic runs, the effect would add up for each run. For species such as cod, herring and capelin, the natural mortality is estimated at 5-15% per day of the total population for eggs and larvae. This declined to 1-3% per day once the species reach the 0-group stage *i.e.* at approximately 6 months (Sætre & Ona 1996). Consequently, Dalen *et al.* (1996) concluded that seismic-created mortality is so low that it can be considered to have an inconsequential impact on recruitment to the populations. Furthermore, due to the rate at which airguns are discharged, and the fact that the vessel is continuously moving, it is highly unlikely that eggs and larvae will be repeatedly exposed to harmful sound waves (Dalen & Mæsted 2008). In Norway, where until 1996 recommendations limiting seismic surveys in areas with drifting eggs and larvae had been in place, these were reviewed to allow surveying in areas of high ichthyoplankton abundance. However, restrictions for spawning areas and areas with spawning migrations, remained in place (Sivle *et al.* 2021).

A peak SPL of >207 dB has been established for mortality and potential mortal injury of fish eggs and larvae (see Table 4-5). Based on the noise exposure criteria provided by Popper *et al.* (2014), the Underwater Noise Modelling Study undertaken for the survey (SLR Consulting Australia 2024) identified that the maximum horizontal distance from the seismic source to impact threshold levels for fish eggs and larvae leading to mortality or potential mortal injury was 160 m. The zones of cumulative impact from multiple pulses (i.e. the maximum horizontal perpendicular distances from assessed survey lines to cumulative impact threshold levels), was estimated 30 m. Maximum threshold distances for recoverable injury and temporary threshold shifts (TTS) for fish eggs and larvae were not reached. Impacts will thus be of high intensity at close range.

As the 3D survey is scheduled for the summer survey window (start December to end May), there will be some temporal overlap with the peak spawning products of commercially important species. However, as plankton distribution is naturally temporally and spatially variable and natural mortality rates are high, and the survey area lies well offshore of the West Coast northward egg and larval drift and return migration of recruits, any impacts would be of LOW intensity for phytoplankton and zooplankton, but of MODERATE intensity for ichthyoplankton. Although the impact is restricted to within a few hundred metres of the airguns, it would extend over the entire survey area (REGIONAL) during the course of the survey. Should impacts occur, they would persist over the SHORT-TERM (days) in the case of phytoplankton and zooplankton only due to the rapid natural turn-over rate of these plankton communities, but would persist over the SHORT-term in the case of ichthyoplankton (particularly the sardine stock, which is experiencing successive years of low recruitment). The environmental risk would therefore be **LOW** for phytoplankton and zooplankton but **MEDIUM** for ichthyoplankton. As plankton abundances in the offshore waters of the proposed 3D survey area will be negligible, the environmental risk of the impact would be **LOW**.

Impact Significance

The potential impact of seismic noise on phytoplankton and zooplankton, considering the medium sensitivity and very low environmental risk, is thus deemed to be of **LOW** significance both with and without mitigation. Due to the medium environmental risk and medium sensitivity of ichthyoplankton, but the low likelihood of the impact occurring in offshore waters, the impacts are deemed to be of **LOW** significance.

Identification of Mitigation Measures

As the proposed survey area is located far offshore, it is not deemed necessary to implement mitigation measures to avoid the key spring spawning periods thereby mitigating potential impacts on plankton to some degree. In addition, Searcher has agreed to avoid the key "ring fenced" fishing and spawning areas in the south-east of the reconnaissance permit area identified during previous consultation with the commercial fishing sector. No other direct mitigation measures for potential impacts on plankton and fish egg and larval stages are feasible or deemed necessary.

Residual Impact Assessment

This potential impact cannot be eliminated due to the nature of the seismic sound source required during surveying. With the implementation of the above mitigation measure, the residual impact would remain of **LOW** significance.

7	***Impacts of seismic noise to plankton and ichthyoplankton***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**Medium**	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**VERY LOW**
Intensity	MODERATE	MODERATE
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	High	High
Loss of Resources	Medium	Medium
Mitigation Potential		Low
Cumulative potential	Unlikely	Unlikely

4.3.8 Impacts of Seismic Noise at Ecosystem Level

Figure 4-4 provides a simplified conceptual model for the nearshore and offshore receiving environment on the West and South-West Coasts illustrating key variables, processes, linkages, relationships, dependencies and feed-back-loops.

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 tons 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, 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.

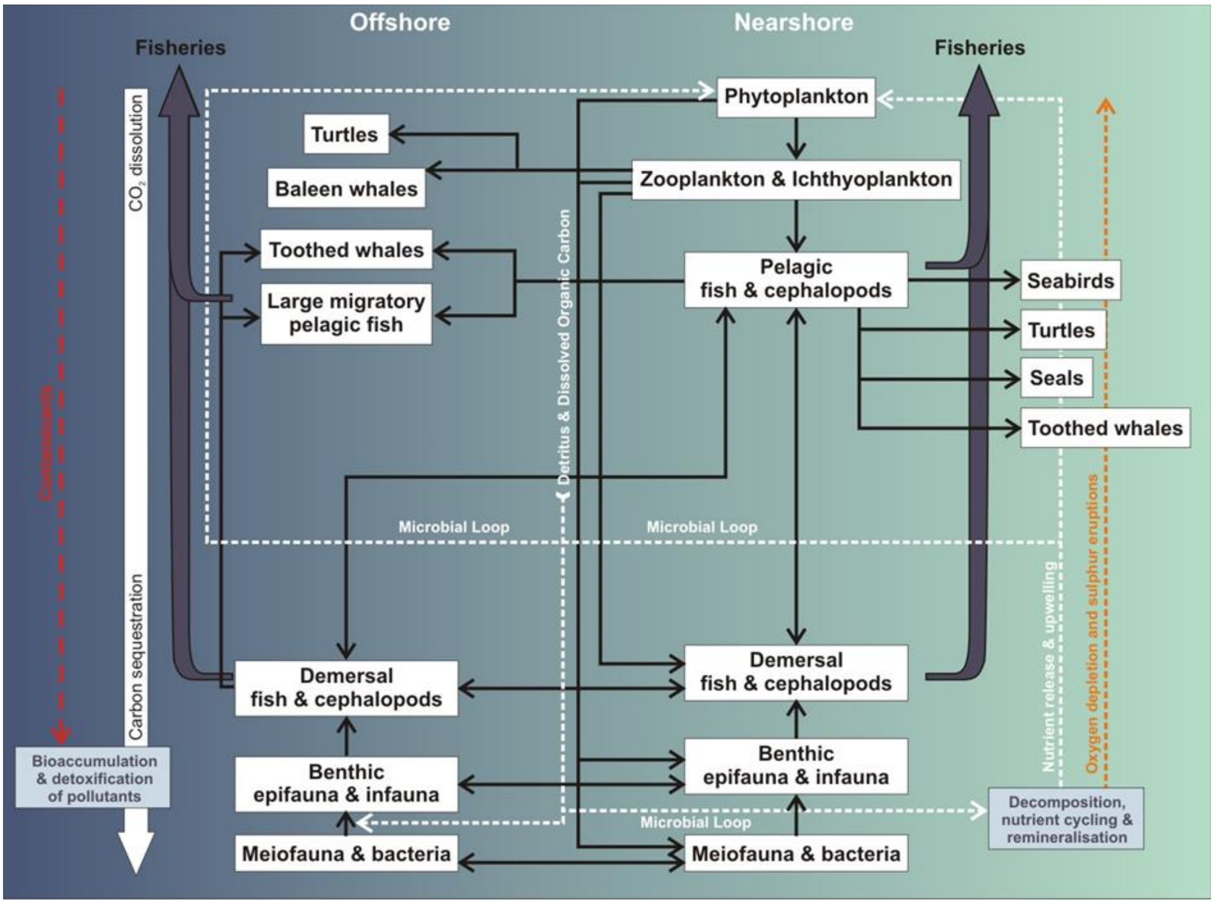


Figure 4-4: Simplified network diagram indicating the interaction between the key ecosystem components off the West Coast.

Ecosystem functions of the offshore deep water 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. The review provided in the impact assessment illustrates that the impacts of anthropogenic noise, at various scales surrounding the stressor, have been recorded in a diverse range of faunal groups. Studies on acoustic impacts, however, largely deal with effects upon individual animals or species, with impacts across large spatial scales, cumulative effects (both of ocean noise and factors other than sound pollution) or multiple species and/or food web levels having rarely been considered.

Below follows 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 (also referred to as 'aggregate' or the combined effects of different types of sound sources) impacts of multiple pressures on multiple ecosystem components.

With growing evidence of the ecosystem-wide effects of seismic noise (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 (CMS 2017; IWC 2018; Risch *et al.* 2020; Harding & Cousins 2022). 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; Claridge 2013), but can have effects that go beyond a single species and 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/dearesearchteamreturnfromdeepseaexpedition). 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 (see also 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 and pelagic and coastal seabirds (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 stabilizing 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 (either directly on individuals or indirectly through loss of prey) 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; de Jong *et al*. 2020) and invertebrates (Hubert *et al*. 2018). The PCAD/PCoD models use and synthesize data from behavioural monitoring programs, 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).

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 tradeoffs. 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 synthesize existing knowledge, potentially extending the reach of explicitly quantitative methods to data-poor situations.

4.4 Other Impacts of Seismic Surveys on Marine Fauna

4.4.1 Impact of Vessel and Helicopter Noise on Marine Fauna

Source of Impact

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

Project phase	Activity
Mobilisation	Transit of vessels to survey area
Operation	Operation of survey vessels
	Operation of helicopters
Demobilisation	Survey vessels leave survey area and transit to port or next destination

These activities and their associated aspects are described below:

- The presence and operation of the seismic vessel and support vessels during transit to the survey area, during the proposed survey 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.
- Crew transfers by helicopter from Cape Town or a suitable location nearby to the survey vessel, if required (preferred alternative is *via* the support vessel) will generate noise in the atmosphere that may disturb coastal species such as seabirds and seals. Noise source levels from helicopters are expected to be around 109 dB re 1μPa at the most noise-affected point (SLR Consulting Australia 2019).

Impact Description

Elevated underwater and aerial noise can affect marine fauna, including cetaceans, by:

- causing direct physical injury to hearing;
- masking or interfering with other biologically important sounds (e.g. communication, echolocation, signals and sounds produced by predators or prey);
- causing disturbance to the receptor resulting in behavioural changes or displacement from important feeding or breeding areas.

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The vessel and aircraft noise described above would primarily take place in the survey area and along the route taken by the support vessels and helicopters between the survey area and Cape Town, which has both a commercial port and airport with existing high daily levels of ambient noise. Depending on the location of the seismic vessel at the time of the crew transfer, the flight path between the survey area and Cape Town would potentially cross over offshore and 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). In addition, migratory pelagic species transiting through the survey area may also be directly affected. Tripp Seamount, which is located approximately 50 km to the north of the survey area in Namibian waters, is also an important feature because it attracts an abundance of marine life and is a productive fishing ground. Tripp Seamount falls outside of any possible flight path or vessel route.

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 survey 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, Subantarctic Skua, 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 survey area, due to their extensive distributions their numbers are expected to be low. Based on the low numbers of listed species, the sensitivity is considered to be **MEDIUM**.

Environmental Risk

Vessel 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). 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). Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping (Erbe *et al*. 2018, 2019), with the largest contributors being containerships, dry bulk and liquid tanker vessels, which emit 75% of the underwater shipping noise source energy (Jalkanen *et al*. 2022). Depending on size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 μPa at 1 m (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). In the South African EEZ shipping stressors and climate-related stressors are increasing more rapidly than other stressors (Purdon *et al*. 2020b), however, despite these stressors being more pronounced along the shelf and shelf edge of the West Coast, this area boasts the highest cetacean species richness in the oceans around South Africa (Purdon *et al*. 2020b). Consequently, shipping impacts need to be appropriately managed to avoid effects on the population growth rates of the species concerned.

As the proposed survey area falls within with the main offshore shipping routes that pass around southern Africa (see Figure 4-2), the shipping noise component of the ambient noise environment is expected to be the dominant component within and around the survey area (OceanMind Limited 2020). Shabangu *et al*. (2022) determined that the noise of vessel traffic dominates the soundscape below 500 Hz off the West Coast, while wind-generated noise increased with wind speed above 5 m/s and dominates the soundscape above 500 Hz. Given the significant local shipping traffic and relatively strong metocean conditions specific to the area, ambient noise levels are expected to be 90 - 130 dB re 1 µPa for the frequency range 10 Hz – 10 kHz (SLR Consulting Australia 2019). The noise generated by the survey vessel, 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, unlike the noise generated by the sound source, underwater noise from vessels is not considered to be of sufficient amplitude to cause direct harm to marine life, even at close range. Due to their extensive distributions, the numbers of pelagic species (large pelagic fish, turtles and cetaceans) encountered during the proposed seismic surveys is expected to be low and consequently the intensity of potential physiological injury or behavioural disturbance as a result of vessel noise would be rated as LOW. Furthermore, the duration of the impact on the populations would be limited to the SHORT-TERM (4 months) and extend REGIONALLY between the survey area and the logistics base. The potential physiological injury or behavioural disturbance as a result of vessel noise would thus be of **LOW** environmental risk.

Aircraft Noise

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. 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 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 reaction of pinnipeds to aircraft noise was 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, except for cases where commercial airports are located close to the coast and overflights are frequent (Erbe *et al.* 2018), and isolated occurrences around the survey vessel 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.

During the northern migration, animals 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, but no clear migration 'corridor. Humpbacks could therefore potentially transit through the entire Orange Basin area on their northwards migration. 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 Cape Columbine in summer. Humpback whales are thus likely to be the most frequently encountered baleen whale in the project area, ranging from the coast out beyond the shelf, with year round presence but numbers peaking in July – 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. 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 West Coast extending northwards into southern Namibia. Southern right whales have been recorded off the West Coast in all months of the year, but with numbers peaking in winter (June - September). While in local waters, Southern Rights are found in groups of 1-10 individuals, with cow-calf pairs predominating in inshore nursery areas. Smaller cetaceans in the area include the common dolphin and Heaviside's dolphin, which tend to occur further inshore on the shelf but may be encountered in the shallower portions of the proposed survey area. 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 the logistics base and the survey vessel could affect seabirds and seals in breeding colonies and roosts on the mainland coast. The nearest seabird colonies to Saldanha airport are on the Saldanha Bay Islands and on the emergent reefs off Cape Columbine. These colonies would fall within the potential flight path between the Saldanha Bay airport and the centre of the proposed 3D survey area. The seal colonies falling within the potential flight paths would similarly be at Cape Columbine. If Cape Town International Airport is used as the logistics base for crew transfers, the flight path would not cross any seabird or seal colonies.

Indiscriminate low altitude flights over whales, seals, seabird colonies and turtles by helicopters used to support the seismic vessel could thus have an impact on behaviour and breeding success. The intensity of disturbance would depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions and could range from low to high intensity for individuals but of LOW intensity for the populations as a whole.

As such impacts would be REGIONAL (although temporary in nature - a few minutes while the helicopter passes overhead) to the flight path and SHORT-TERM (4 months), impacts would be of **LOW** environmental risk.

Impact Significance

Vessel Noise

The potential impact of vessel noise causing physiological injury to, or behavioural avoidance by, pelagic and coastal sensitive species, is deemed to be of **LOW** significance.

Aircraft Noise

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.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over coastal seal colonies and seabird nesting areas	Avoid / abate on site
2	Avoid extensive low-altitude coastal flights by ensuring that the flight path is perpendicular to the coast, as far as possible	Avoid/ abate on site
3	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. Similarly the generation of vessel noise cannot be eliminated. The proposed mitigation, specifically maintaining the regulated altitude over the coastal zone and MPAs and flying perpendicular to the coast would reduce the intensity of the impact to very low, but the residual impact will remain of very low environmental risk and of **LOW** significance. Without mitigation measures for vessel noise, the residual impact of vessel noise would remain of **LOW** significance.

Aircraft and vessel 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.

8	*Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to vessel 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	**LOW**	**LOW**
Intensity	LOW	LOW
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	LOW
Significance	**LOW**	**LOW**
Confidence	High	High
Loss of Resources	Low	Low
Mitigation Potential	-	Low
Cumulative potential	Medium	Medium

9	*Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to 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	LOW	MINOR
Extent	REGIONAL	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	IMPROBABLE
Significance	**LOW**	**LOW**
Confidence	**High**	**High**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Low**
Cumulative potential	**Low**	**Low**

4.4.2 Impact of Survey Vessel Lighting on Pelagic Fauna

Source of Impact

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

Project phase	Activity
Mobilisation	Transit of vessels to survey area
Operation	Operation of survey vessel and support vessel
Demobilisation	Survey vessels leave survey area and transit to port or next destination

These activities and their associated aspects are described further below.

- Transit and operation of the survey vessel and support vessels. The operational lighting of survey/support vessels during transit and seismic acquisition can be a significant source of artificial light in the offshore environment increasing the ambient lighting in offshore areas.

Impact Description

The survey activities would be undertaken in the offshore marine environment, more than 100 km offshore, far removed from any sensitive coastal receptors (e.g. bird or seal colonies), but could still directly affect migratory pelagic species (pelagic seabirds, turtles, marine mammals and fish) transiting through the Reconnaissance Permit Area. The strong operational lighting used to illuminate the survey vessel at night may disturb and disorientate pelagic seabirds feeding in the area. Operational lights may also result in physiological and behavioural effects of fish and cephalopods 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

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles (particularly hatchlings and neonates), large migratory pelagic fish, and both migratory and resident cetaceans transiting through the survey area may also be attracted by the lights. Some of the species potentially occurring in the survey 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 survey area, due to their extensive distributions their numbers are expected to be low. Based on the low numbers of listed species, the 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 vessels or drilling units 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 Reconnaissance Permit Area would become accustomed to the presence of the seismic vessel within a few days. Since the survey area is located within the main traffic routes that pass around southern Africa (see Figure 4-2), 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 survey vessel to prevent seabird collisions, reports of collisions or death of seabirds on vessels are rare (TEEPSA, pers. comm.). Should they occur, the light impacts would primarily take place in the survey area and along the route taken by the support vessels between the survey area and Saldanha Bay/Cape Town. Most of the seabird species breeding along the West Coast feed relatively close inshore (10-30 km), with African Penguins recorded as far as 60 km offshore and Cape Gannets up to 140 km offshore. Pelagic species occurring further offshore would be unfamiliar with artificial lighting and may be attracted to the survey vessel. Fish and squid may also be attracted to the light sources potentially resulting in increased predation on these species by higher order consumers. It is expected, however, that seabirds and marine mammals in the area would become accustomed to the presence of the survey vessel within a few days. Since the survey 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.

Operational lights may also result in physiological and behavioural effects of turtles 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. The dispersal of turtle hatchlings is reported to be disrupted by light, causing them to linger, become disoriented in the nearshore and expend energy swimming against ocean currents (Wilson *et al*. 2018). Although seals are known to forage up to 120 nautical miles (~220 km) offshore, the offshore location of the proposed survey area fall to the west of the foraging range of seals from the West Coast colonies. Odontocetes are also highly mobile, supporting the notion that various species are likely to occur in the Reconnaissance Permit Area and thus potentially attracted to the area.

Due to their extensive distributions, the numbers of pelagic species (large pelagic fish, turtles and cetaceans) encountered during the proposed 3D survey is expected to be low. Due to anticipated numbers and the proximity of survey area to the main traffic routes, the increase in ambient lighting in the offshore environment would be of LOW intensity and REGIONAL in extent (although limited to the area in the immediate vicinity of the vessel) over the SHORT-TERM (4 months). For support vessels travelling from Saldanha Bay/Cape Town increase in ambient lighting would likewise be restricted to the immediate vicinity of the vessel over the short-term. The potential for behavioural disturbance as a result of vessel lighting would thus be of **LOW** environmental risk.

Impact Significance

The potential for collision of birds with the survey vessel due to lighting or behavioural disturbance by vessel lighting is deemed to be of **LOW** significance, due to the medium sensitivity of the receptors, the low likelihood of the impact occurring and the very low environmental risk.

Identification of Mitigation Measures

The use of lighting on the seismic vessel cannot be eliminated due to safety, navigational and operational requirements. Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	The lighting on the survey and support vessels should be reduced to a minimum compatible with safe operations whenever and wherever possible. Light sources should, if possible and consistent with safe working practices, be positioned in places where emissions to the surrounding environment can be minimised	Reduce at Source
2	Keep disorientated, but otherwise unharmed, seabirds in dark containers for subsequent release during daylight hours. Ringed/banded birds should be reported 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 **LOW**.

10	*Disturbance and behavioural changes in pelagic fauna due to vessel lighting*	
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	MINOR
Extent	LOCAL - REGIONAL	LOCAL - REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	LOW	IMPROBABLE
Significance	**LOW**	**LOW**
Confidence	High	High
Loss of Resources	Low	Low
Mitigation Potential	-	Low
Cumulative potential	Low	Low

4.4.3 Impact of Hull Fouling and Ballast Water Discharge

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 vessels to survey area
	Discharge of ballast water by seismic vessel and/or support vessels
Operation	n/a
Demobilisation	n/a

These activities and their associated aspects are described further below:

- Larvae, cysts, eggs and adult marine organisms are frequently firmly attached to artificial structures such as vessel hulls and infrastructure that have been in the sea for any length of time. Vessels and the transportation of infrastructure from one place to another in the ocean also provide the potential for translocation of introduced or alien species.
- De-ballasting of the survey vessel once at the survey area could introduce non-native species into the area.

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 equipment from one part of the ocean to another would therefore also facilitate the transfer of the associated marine organisms. Survey vessels, seismic equipment and support vessels are used and relocated all around the world. Similarly, the ballasting and de-ballasting of these vessels may lead to the introduction of exotic species and harmful aquatic pathogens to the marine ecosystems (Bax *et al.* 2003).

The marine invertebrates that colonize the surface of vessels 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. Once established, an invasive species is likely to remain in perpetuity (Bax *et al.* 2003).

Project Controls

Ballast water is discharged subject to the requirements of the International Maritime Organisation's (IMO) 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments. The Convention aims to prevent the spread of harmful aquatic organisms from one region to another, by establishing standards and procedures for the management and control 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 from nearest land in waters of at least 200 m deep; the absolute minimum being 50 nautical miles from the nearest land. Project vessels would be required to comply with this requirement.

Sensitivity of Receptors

The discharge of ballast water from the survey and support vessels would take place in the vicinity of the survey area, which is located more than 40 km offshore, 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 survey area (~1 000 m up to 3 600 m), colonisation by invasive species on the seabed is considered unlikely. Thus, the sensitivity of benthic receptors in the offshore waters of the Orange Basin is therefore 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 group, 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 survey vessel, and possibly the support / escort vessels, will more than likely have spent time outside of South Africa's EEZ prior to surveying. 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 due by the implementation of ballast water management measures in accordance with the IMO guidelines. The risk is further reduced due to the far offshore location of the survey area. Since the survey area is far removed from the coast, which together with the dominant wind and current direction, will ensure that any invasive species drift mainly in a north-westerly direction away from the coast. In addition, the water depths in the survey area (~1 000 m up to 3 600 m) will ensure that colonisation of invasive species on the seabed is unlikely. De-ballasting in the survey area will thus not pose an additional risk to the introduction of invasive species.

In terms of hull fouling, the survey area is located along one of the main traffic routes that pass around southern Africa. Thus, the introduction of invasive species into South African 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, through and inshore of the survey area, on a daily basis.

Considering the location of the survey area and compliance with the IMO guidelines for ballast water, the impact related to the introduction of alien invasive marine species is considered to be of MODERATE intensity (due to it having a minimal effect on receptors) in the LONG-TERM (should invasive species be able to establish) and of REGIONAL extent. Thus, the environmental risk is, therefore, considered to be **LOW**.

Impact Significance

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

Identification of Mitigation Measures

This potential impact cannot be eliminated due to the necessity of bringing survey vessels and seismic equipment to the survey area from other parts of the world, and the need for de-ballasting these once on site. In addition to the Project Controls, recommendations for mitigation include:

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 to remove sediments 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 infrastructure (e.g. arrays, streamers, tail buoys etc) that has been used in other regions is thoroughly cleaned prior to deployment	Avoid/Reduce at Source

Residual Impact Assessment

With the implementation of the mitigation measures above, the residual impact would reduce to **NEGLIGIBLE**.

11	*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	MODERATE	LOW
Extent	REGIONAL	REGIONAL
Duration	LONG	LONG
Reversibility	IRREVERSIBLE	IRREVERSIBLE
Probability	LOW	IMPROBABLE
Significance	**LOW**	**LOW**
Confidence	Medium	Medium
Loss of Resources	Low	Low
Mitigation Potential	-	Very Low
Cumulative potential	Medium	Medium

4.4.4 Impacts of Waste Discharges to Sea

<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 vessels to survey area
Operation	Operation of survey vessels and transit of support vessels between the survey area and the logistics base
Demobilisation	Survey vessels leave survey area and transit to port or next destination

These activities and their associated aspects are described further below:

- **Deck drainage**: all deck drainage from work spaces is collected and piped into a sump tank on board the seismic vessel 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 and disinfected. In accordance with MARPOL Annex IV, the effluent must not produce visible floating solids in, nor causes discolouration of, the surrounding water. The treatment system must provide primary settling, chlorination and dechlorination before the treated effluent can be discharged into the sea. The treated sanitary effluents discharged into the sea are estimated at around 10 000 litres per day for the duration of the seismic study based on 140-150 litres

per 70-80 persons. The discharge depth is variable, depending upon the draught of the seismic vessel / support vessel at the time, but would be in accordance with MARPOL Annex IV.

- **Vessel machinery spaces, mud pit wash residue and ballast water**: the concentration of oil in discharge water from vessel machinery space or ballast tanks may not exceed 15 ppm oil in water (MARPOL Annex I). If the vessel intends to discharge bilge or ballast water at sea, this is achieved through use of an oily-water separation system. Oily waste substances must be shipped to land for treatment and disposal.
- **Food (galley) wastes**: food wastes may be discharged after they have been passed through a comminuter or grinder, and when the seismic vessel is located more than 3 nautical miles from land. Discharge of food wastes not comminuted is permitted beyond 12 nautical miles. The ground wastes must be capable of passing through a screen with openings <25 mm. The daily volume of discharge from a standard seismic vessel is expected to be <0.2 m^3.
- **Cooling Water and drinking water surplus:** The cooling water and surplus generated by the drinking water supply system are likely to contain a residual concentration of chlorine (generally less than 0.5 mg/l for drinking water supply systems. seismic vesselSuch water would be tested prior to discharge and would comply with relevant Water Quality Guidelines.

Impact Description

The discharge of wastes to sea could create local reductions in water quality, both during transit to and within the survey area. 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 gallery 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 in a number of different ways:

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

Project Controls

The operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and in compliance with the applicable requirements in MARPOL 73/78, as summarised below.

- The discharge of biodegradable wastes 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 when the vessel is sailing.

- 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.
- 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.
  - Vessels must have an onboard sewage treatment plant providing primary settling, chlorination and dechlorination before discharge of treated effluent.
  - The discharge depth is variable, depending upon the draught of the seismic vessel / support vessel at the time, but will be in accordance with MARPOL 73/78 Annex IV.
  - Discharge of sewage beyond 12 nm requires no treatment. However, sewage effluent must not produce visible floating solids in, nor cause the discolouration of, the surrounding water.
  - Sewage must be comminuted and disinfected for discharges between 3 nm (± 6 km) and 12 nm (± 22 km) from the coast. This will require an onboard sewage treatment plant or a sewage comminuting and disinfecting system.
  - Disposal of sewage originating from holding tanks must be discharged at a moderate rate while the ship is proceeding on route at a speed not less than 4 knots.
- Sewage will be treated using a marine sanitation device to produce an effluent with:
  - A biological oxygen demand (BOD) of <25 mg/l (if the treatment plant was installed after 1/1/2010) or <50 mg/l (if installed before this date).
  - Minimal residual chlorine concentration of 0.5 mg/l.
  - No visible floating solids or oil and grease.

The project will also comply with industry best practices with regard to waste management, including:

- Waste management will follow key principles: Avoidance of Waste Generation, adopting the Waste Management Hierarchy (reduce, reuse, recycle, recover, residue disposal), and use of Best Available Technology.
- An inventory will be established of all the potential waste generated, clarifying its classification (hazardous, non-hazardous or inert) and quantity, as well as identifying the adequate treatment and disposal methods.
- Waste collection and temporary storage shall be designed to minimise the risk of escape to the environment (for example by particulates, infiltration, runoff or odours).
- On-site waste storage should be limited in time and volume.
- Dedicated, clearly labelled, containers (bins, skips, etc.) will be provided in quantities adapted to anticipated waste streams and removal frequency.

Sensitivity of Receptors

The operational waste discharges from the activities described above would primarily take place in the survey area and along the route taken by the support vessels between the survey area and the logistics base in Saldanha Bay/Cape Town. The 3D survey area is located in the offshore marine environment, 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 survey area. Vessel discharges *en route* to the onshore supply base could result in discharges closer to shore, thereby potentially having an environmental effect on the sensitive coastal environment.

The taxa most vulnerable to waste discharges are pelagic seabirds, turtles, and large migratory pelagic fish and marine mammals. Some of of the species potentially occurring in the survey 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 survey area, due to their extensive distributions their numbers are expected to be low. Based on the low numbers of listed species, the sensitivity is considered to be **MEDIUM**.

Environmental Risk

The contracted survey / support vessels will have the necessary sewage treatment systems in place, and the vessel will have oil/water separators and food waste macerators to ensure compliance with MARPOL 73/78 standards. MARPOL compliant discharges would therefore 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 survey area is suitably far removed from sensitive coastal receptors and the dominant wind and current direction will ensure that any discharges are rapidly dispersed north-westwards and away from the coast. There is no potential for accumulation of wastes 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 the survey vessels 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 be segregated, duly identified transported to shore for ultimate valorisation and/or disposal at a licensed waste management facility. 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 survey / support vessels will be of MINOR intensity, SHORT duration and REGIONAL in extent (although localised at any one time around the project vessels). The environmental risk is therefore considered **LOW**.

Impact Significance

The impacts associated with normal waste discharges from the survey vessel is deemed to be of **LOW** significance, due to the medium sensitivity of the offshore receptors, the high probability of the impact occurring and the low environmental risk.

Identification of Mitigation Measures

In addition to compliance with MARPOL 73/78 regulations regarding waste discharges mentioned above, the following measures will be implemented to reduce wastes at the source:

No.	Mitigation measure	Classification
1	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
2	Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.	Reduce at Source

Residual Impact Assessment

This potential impact cannot be eliminated because the seismic / support vessels are needed to undertake the survey 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.

12	*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	REGIONAL
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE	FULLY REVERSIBLE
Probability	HIGH	HIGH
Significance	**LOW**	**LOW**
Confidence	High	High
Loss of Resources	Low	Low
Mitigation Potential	-	Medium
Cumulative potential	Low	Low

4.5 Unplanned Events

4.5.1 Faunal Strikes with Project Vessels and Equipment

Source of Impact

The project activities that will result in potential collision impacts with marine fauna are listed below.

Project phase	Activity
Mobilisation	Ship strikes during transit of vessels to survey area
Operation	Ship strikes during Operation of survey vessels
	Strikes and entanglement of marine fauna during seismic and/or acquisition
Demobilisation	Ship strikes during transit to port or next destination

These activities and their associated aspects are described below:

- Passage of the seismic vessel and chase vessels - Ship strikes.
- Towing of seismic equipment - Collision with or entanglement in towed seismic apparatus.

Impact Description

The potential effects of vessel presence and towed equipment on turtles and cetaceans include physiological injury or mortality.

Project Controls

The operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The leatherback and loggerhead turtles that occur in offshore waters around southern Africa, and likely to be encountered in the proposed survey area 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 survey are likely to be low. Consequently, the sensitivity of turtles is considered to be **MEDIUM**.

Thirty three 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 South African waters are baleen whales (mysticetes), while toothed whales (odontocetes) may be resident or migratory. Of the 33 species, the blue whale is listed as 'Critically Endangered', the fin and sei whales are 'Endangered' and the sperm, Bryde's (offshore) and humpback whales are considered 'Vulnerable' (South African Red Data list Categories). Although the survey area is far removed from the coast, overlap with Child's Bank and the proximity to Tripp Seamount, where a greater number of individuals can be expected, the sensitivity of cetaceans to strikes 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 proposed 3D survey area is located in a region of very high vessel traffic (see Figure 4-2), potential collisions between marine fauna and vessels would not be limited to project-specific vessels. Given the slow speed (about 4 - 6 kts) of the vessel while towing the seismic array, ship strikes whilst surveying are unlikely, but may occur during the transit of the vessel to or from the survey area. Ship strikes by the chase vessel may also occur.

The physical presence of the survey vessel and increased vessel traffic west of the main transport routes could increase the likelihood of animal-vessel collisions. 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.

The potential for ship strikes of cetaceans is dependent on the abundance and behaviour of cetaceans in the area and vessel speed. For example, Keen *et al*. (2019) modeled 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. 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.

The large amount of equipment towed astern of survey vessels also increases the potential for collision with or entrapped in seismic equipment and towed surface floats. Entanglement of cetaceans in gear is possible in situations where tension is lost on the towed array.

Basking turtles are particularly slow to react to approaching objects and may not be able to move rapidly away from approaching airguns. In the past, almost all reported turtle entrapments were associated with the subsurface structures ('undercarriage') of the tail buoys attached to the end of each seismic cable. Towing points are located on the leading edge of each side of the undercarriage, and these are attached by chains to a swivel leading to the end of the seismic cable (Ketos Ecology 2009). Entrapment occurs either as a result of 'startle diving' in front of towed equipment or following foraging on barnacles and other organisms growing along seismic cables and surfacing to breathe immediately in front of the tail buoy (primarily loggerhead and Olive Ridley turtles). In the first case the turtle becomes stuck within the angled gap between the chains and the underside of the buoy, lying on their sides across the top of the chains and underneath the float with their ventral surface facing the oncoming water thereby causing the turtle to be held firmly in position (Figure 4-5, left). Depending on the size of the turtle, they can also become stuck within the gap below a tail buoy, which extends to 0.8 m below water level and is ~0.6 m wide. The animal would need to be small enough to enter the gap, but too big to pass all the way through the undercarriage. Furthermore, the presence of the propeller in the undercarriage of some buoy-designs prohibits turtles that have entered the undercarriage from travelling out of the trailing end of the buoy (Figure 4-5, right). Once stuck inside or in front of a tail buoy, the water pressure generated by the 4–6 knot towing speed, would hold the animal against/inside the buoy with little chance of escape due to the angle of its body in relation to the forward movement of the buoy. For a trapped turtle this situation will be fatal, as it will be unable to reach the surface to breathe (Ketos Ecology 2009). To prevent entrapment, the seismic industry has implemented the use of "turtle guards" on all tailbuoys.

The potential for collision between adult turtles and the seismic vessel, or entanglement of turtles in the towed seismic equipment and surface floats, is highly dependent on the abundance and behaviour of turtles in the survey area at the time of the survey. Due to their extensive distributions and feeding ranges, and the extended distance from their nesting sites, the number of turtles encountered during the proposed seismic surveys is expected to be low. Should collisions or entanglements occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL), the potential for collision and entanglement in seismic equipment is therefore considered to be of **LOW** environmental risk.

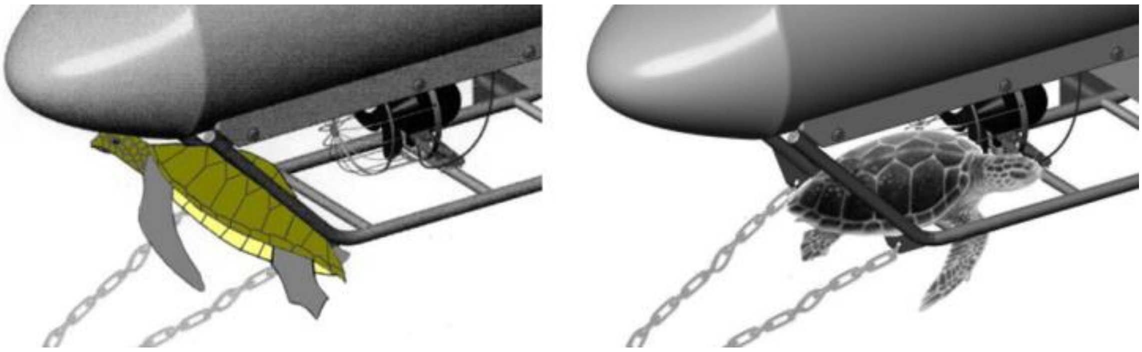


Figure 4-5: Turtles commonly become trapped in front of the undercarriage of the tail buoy in the area between the buoy and the towing chains (left), and inside the 'twin-fin' undercarriage structure (right) (Ketos Ecology 2009).

The potential for strikes and entanglement of cetaceans in the towed seismic equipment, is similarly highly dependent on the abundance and behaviour of cetaceans in the survey area at the time of the survey. Due to their extensive distributions and feeding ranges, the number of cetaceans encountered during the proposed seismic surveys is expected to be low. Should entanglements occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4 months) and be restricted to the survey area (REGIONAL), the potential for entanglement in seismic equipment is therefore considered to be of **LOW** environmental risk.

<u>Impact Significance</u>

The potential for collision with or entanglement by turtles and cetaceans during the seismic survey or the transit of the vessel to or from the survey area is deemed to be of **LOW** significance, due to the high sensitivity of the receptors, but very low likelihood of the impact occurring and the low environmental risk.

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	The vessel operators should keep a constant watch for marine mammals and turtles in the path of the vessel.	Avoid
2	Keep watch for marine mammals behind the vessel when tension is lost on the towed equipment and either retrieve or regain tension on towed gear as rapidly as possible.	Avoid
3	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Abate on site
4	Ensure vessel transit speed between the survey area and port is a maximum of 12 knots (22 km/hr), except in MPAs where it is reduced further to 10 knots (18 km/hr) as well as when they are present in the vicinity.	Avoid/reduce at source
5	Should a cetacean become entangled in towed gear, contact the South African Whale Disentanglement Network (SAWDN) formed under the auspices of DEA to provide verbal specialist assistance in releasing entangled animals where necessary.	Repair/restore
6	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/restore

Monitoring

Should a collision with a large whale occur, the event must be reported to the 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).

Residual Impact Assessment

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

13	*Impacts on turtles and cetaceans due to ship strikes, collision and entanglement with towed equipment*	
Project Phase:	**Mobilisation, Operation & Decommissioning**	
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	SHORT
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**

4.5.2 Accidental Loss of Equipment

Source of Impact

The project activities that will result in the accidental loss of equipment are listed below.

Project phase	Activity
Mobilisation	n/a
Operation	Accidental loss of equipment to the water column or seabed during operation
Demobilisation	n/a

These activities and their associated aspects are described further below:

- Irretrievable loss of equipment to the seabed during vessel transfer with crane.
- Accidental loss of paravanes, streamers, arrays and tail buoys during seismic acquisition.

During seismic acquisition, the survey vessel tows a substantial amount of equipment; the deflectors or paravanes, which keep the streamers equally spread are towed by heavy-duty rope, and the streamers themselves are towed by lead-in cables. Each streamer is fitted with a dilt float at the head of the streamer, numerous streamer mounts (birds and fins) to control streamer depth and lateral positioning, and a tail buoy to mark the end of the streamer. Streamers are neutrally buoyant at the required depth (5-10 m) but have buoyancy bags embedded within them that inflate at a depth of 40 m. If streamers are accidentally lost they would therefore float in the water column for some time before sinking. Dilt floats and tail buoys would ultimately be dragged down under the weight of the streamer.

Airguns are suspended under floats by a network of ropes, cables and chains, with each float configuration towed by an umbilical. Should both the float and umbilical fail, the airguns would sink to the seabed.

In the unlikely event of complete failure of buoyancy and tow systems, the seismic equipment and the attached ropes, cables and chains could pose an entanglement hazard to turtles and marine mammals.

If equipment falls to the seabed, it would crush benthic fauna in its footprint, but ultimately provide a hard surface for colonisation.

Impact Description

The potential impacts associated with lost equipment include:

- Potential disturbance and damage to seabed habitats and crushing of epifauna and infauna within the equipment footprint;
- Potential physiological injury or mortality to pelagic and neritic marine fauna due to entanglement in streamers, arrays and tail buoys drifting on the surface or in the water column.

Project Controls

The seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

Loss of equipment would likely take place during seismic acquisition within the survey area, which is located in the offshore marine environment, more than 40 km offshore at its closest point, far removed from any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks) The survey area lies well offshore where the pelagic and benthic ecosystem threat status is mainly considered as 'Least threatened', and where the deepwater habitat types are comparatively uniform and cover large areas. The benthic fauna beyond ~450 m depth are very poorly known and there are no species of commercial value occurring that far offshore. Sensitive deep-water coral communities would be expected with topographic features such as Tripp Seamount and Child's Bank. The sensitivity of benthic fauna is considered to be LOW.

Lost equipment could also pose an entanglement risk to migratory turtles and cetaceans transiting through the survey area. The taxa most vulnerable to entanglement in lost equipment are turtles and marine mammals. Some of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. leatherback turtles and blue whales), 'Endangered' (e.g. whale shark, fin and sei whales), or 'Vulnerable' (e.g. loggerhead turtles and sperm, Bryde's and humpback whales). Although species listed as 'Critically Endangered' or 'Endangered' may potentially occur in the survey area, entanglement is highly unlikely. In addition, due to their extensive distributions their numbers are expected to be low. Based on the low numbers of listed species, the sensitivity is considered to be MEDIUM.

Overall, considering the precautionary principle, the sensitivity of marine fauna for collision or entanglement is considered to be MEDIUM.

Environmental Risk

The accidental loss of equipment onto the seafloor would provide a localised area of hard substrate in an area of otherwise unconsolidated sediments. The availability of hard substrata on the seabed provides opportunity for colonisation by sessile benthic organisms and could provide shelter for demersal fish and mobile invertebrates thereby potentially increasing the benthic biodiversity and biomass in the continental slope and abyssal regions. The benthic fauna inhabiting islands of hard substrata in otherwise unconsolidated sediments of the outer shelf and continental slope are, however, very poorly known but would likely be different from those of the surrounding unconsolidated sediments. In the unlikely event of equipment loss, associated impacts would be of LOW intensity and be highly localised and limited to the SITE over the SHORT-term (any lost object, depending on its size, will likely sink into the sediments and be buried over time). The environmental risk for equipment lost to the seabed is therefore considered **LOW**.

The loss of streamers and floats would result in entanglement hazards in the water column before the streamers sink under their own weight. In the unlikely event of streamer loss, associated impacts would similarly be of LOW intensity and be highly localised and limited to the SITE (although would potentially float around regionally) over the SHORT-term. The environmental risk for equipment lost to the water column is therefore considered **LOW**.

Impact Significance

The impacts associated with the accidental loss of equipment are deemed to be of **LOW** significance, due to the medium sensitivity of the offshore receptors, the very low likelihood of the impact occurring and the very low environmental risk.

Identification of Mitigation Measures

The following measures will be implemented to manage accidental loss of equipment:

No.	Mitigation measure	Classification
1	Ensuring that 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	Undertake frequent checks to ensure items and equipment are stored and secured safely on board each vessel.	Avoid
4	In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the Reconnaissance Permit Area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval	Repair/restore

Residual Impact Assessment

With the implementation of the project controls and mitigation measures, the residual impact will remain of **VERY LOW** significance.

14	*Impacts on benthic and pelagic fauna due to accidental loss of equipment to the seabed or the water column*	
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	VERY LOW
Extent	SITE	SITE
Duration	SHORT	SHORT
Reversibility	FULLY REVERSIBLE to PARTIALLY REVERSIBLE	FULLY REVERSIBLE to PARTIALLY REVERSIBLE
Probability	LOW	IMPROBABLE
Significance	**LOW**	**LOW**

	Pre-Mitigation Impact	Residual Impact
Confidence	High	High
Loss of Resources	Low	Low
Mitigation Potential	-	Low
Cumulative potential	Low	Low

4.5.3 Release of diesel to sea during bunkering or due to vessel accident

Source of Impact

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

Project phase	Activity
Mobilisation	Loss of fuel from vessel accident
Operation	Loss of fuel from vessel accident
	Bunkering of fuel
Demobilisation	Loss of fuel from vessel accident

These activities and their associated aspects are described further below:

- Instantaneous spills of marine diesel at the surface of the sea can potentially occur during operation, and Such spills are usually of a low volume.
- Larger volume spills of marine diesel would occur in the event of a vessel collision or vessel accident.

Impact Description

Marine diesel spilled in the marine environment would have an immediate detrimental effect on water quality, with the toxic effects potentially resulting in mortality (e.g. suffocation and poisoning) of marine fauna or affecting faunal health (e.g. respiratory damage). If the spill reaches the coast, it can result in the smothering of sensitive coastal habitats.

Project Controls

The operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques. The purpose of the Operator's performance standards is to reduce the risk of pollution and oil spills for projects to As Low As Reasonably Practicable (ALARP). The objectives of the Operator's policies and procedures are to:

- Apply the hazard management process;
- Careful HSSE management by all parties;
- Design and install equipment and/or implement Procedures to reduce the impact of discharges to the environment;
- Assess the Maritime Safety Risks and put controls in place to manage these risks to ALARP;
- Establish and maintain procedures for managing the risk of maritime operations that comply with the Operator's Maritime Safety Requirements for Design, Engineering and Operation..

Escort vessels with appropriate radar and communications will be used during the survey operation to warn vessels that are in danger of breaching the safety/exclusion zone.

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) / Evacuation Plan will be prepared and put in place. A Medical Evacuation Plan (Medevac Plan) will form part of the ERP.

Project vessels will be equipped with appropriate spill containment and clean-up equipment, e.g. booms, dispersants and absorbent materials. All relevant vessel crews will be trained in spill clean-up equipment use and routine spill clean-up exercises.

Sensitivity of Receptors

Accidental spills and loss of marine diesel during bunkering or in the event of a vessel collision could take place in the survey area and along the route taken by the survey and support vessels between the survey area and the logistics base at Saldanha Bay or Cape Town. The survey area is located in the offshore marine environment, more than 200 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 survey area. Diesel spills or accidents en route to the onshore supply base could result in fuel loss closer to shore, thereby potentially having Oil or diesel spilled in the marine environment will have an immediate detrimental effect on water quality. Being highly toxic, marine diesel released during an operational spill would negatively affect any marine fauna it comes into contact with. The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. Tristan Albatross, Cape Gannet) or 'Endangered' (e.g. Black-Browed and Yellow-Nosed Albatross, African Penguin, Bank and Cape Cormorant) or 'Vulnerable' (e.g. Hartlaub's Gull, Swift Tern). As Tripp Seamount is located ~50 km to the north of the proposed 3D the survey area, the sensitivity of marine fauna to diesel spill is considered to be HIGH.

Environmental Risk

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, distillation characteristics, viscosity and pour point, all of which are dependent on the oils chemical composition (e.g. the amount of asphaltenes, resins and waxes). Spilled oil undergoes physical and chemical changes (collectively termed 'weathering'), 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.

As soon as oil is spilled, various weathering processes come into play. Although the individual processes may act simultaneously, their relative importance varies with time. 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.

As a general rule, oils with a volatile nature, low specific gravity and low viscosity (e.g. marine diesel) are less persistent and tend to disappear rapidly from the sea surface. In contrast, high viscosity oils containing bituminous, waxy or asphaltenic residues, dissipate more slowly and are more persistent, usually requiring a clean-up response.

Oil spilled in the marine environment will have an immediate detrimental effect on water quality. Any release of liquid hydrocarbons thus has the potential for direct, indirect and cumulative effects on the marine environment. These effects include physical oiling and toxicity impacts to marine fauna and flora, localised mortality of plankton (particularly copepods), pelagic eggs and fish larvae, and habitat loss or contamination (CSIR 1998; Perry 2005).

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 it adheres to fine-grained suspended sediments, which can subsequently settle out on the seafloor. As it is not very sticky or viscous, diesel tends to penetrate porous sediments quickly, but also to be washed off quickly by waves and tidal flushing. In the case of a coastal spill, shoreline cleanup is thus usually not needed. Diesel oil is degraded by naturally occurring microbes within one to two months. Nonetheless, in terms of toxicity to marine organisms, diesel is considered to be one of the most acutely toxic oil types. Many of the compounds in petroleum products are known to smother organisms, lower fertility and cause disease. Intertidal invertebrates and seaweed that come in direct contact with a diesel spill may be killed. 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 are 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 is 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 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 vessel collision, the magnitude 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. Based on the results of the oil spill modelling undertaken in the Orange Basin (PRDW 2013) a diesel slick in the survey area would be blown in a north-westerly direction due to the dominant winds and currents in the survey area. The diesel would most likely remain at the surface for <36 hours with no probability of reaching sensitive coastal habitats. In offshore environments, impacts associated with a spill or vessel collision would thus be of LOW intensity, REGIONAL (depending on the nature of the spill) over the SHORT-term (<5 days). The environmental risk for a marine diesel spill is therefore considered **LOW**.

However, in the case of a spill or vessel collision *en route* to the survey area, the spill may extend into coastal MPAs and reach the shore affecting intertidal and shallow subtidal benthos and sensitive coastal bird species, in which case the intensity would be considered HIGH, but still remaining REGIONAL over the SHORT-TERM. The environmental risk would be **MEDIUM**.

Impact Significance

The impact methodology used to assess the impact significance calculates an overall LOW pre-mitigation significance. However, considering the high sensitivity of receptors and the low (offshore) and medium environmental risk (nearshore), the potential impact on the marine fauna is in reality considered to range from **LOW** significance (offshore) to **MEDIUM** significance (nearshore) without mitigation. The likelihood of the impact occurring is, however, low.

Identification of Mitigation Measures

In addition to compliance with MARPOL 73/78 regulations regarding waste discharges mentioned above, the following measures will be implemented:

No.	Mitigation measure	Classification
1	Use low toxicity dispersants cautiously and only with the permission of DFFE.	Abate on and off site
2	As far as possible, and whenever the sea state permits, attempt to control and contain any spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill	Abate on site
3	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
4	Ensure offshore bunkering is not undertake in the following circumstances: – Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; – During any workboat or mobilisation boat operations; – During helicopter operations; – During the transfer of in-sea equipment; and – At night or times of low visibility.	Avoid / Reduce at source

Residual Impact Assessment

With the implementation of the project controls and mitigation measures, the residual impact will reduce to **LOW** significance for nearshore spills, and remain **LOW** for offshore spills.

15	***Impacts of an operational spill or vessel collision on marine fauna***	
Project Phase:	**Seismic Exploration**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Environmental Risk	**MEDIUM**	**LOW**
Intensity	LOW to HIGH*	LOW
Extent	REGIONAL	LOCAL
Duration	SHORT	SHORT
Reversibility	REVERSIBLE	REVERSIBLE
Probability	MEDIUM (operational spills) LOW (vessel collisions)	LOW
Significance	**MEDIUM**	**LOW**
Confidence	High	High
Loss of Resources	Low to Medium*	Low
Mitigation Potential		Medium
Cumulative potential	Low	Low

* if the spill occurs near the coast and/or in proximity to sensitive coastal or offshore receptors.

4.6 Confounding Effects and Cumulative Impacts

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 makers and stakeholders should focus on those that can be meaningfully interpreted (DEAT 2004).

While it is foreseeable that further exploration and future production activities could arise if the current Environmental Authorisation 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 information, which the proposed exploration process aims to address. There are many other rights holders in the South African and adjacent Namibian offshore environment, but most of these are not undertaking any exploration activities at present or would be concurrently with the proposed 3D survey, particularly not in the far offshore environment. 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 EIA 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).

The most reliable guage of cumulative pressures 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 4-6, left). Based on the severity of modification across the marine realm, a map of ecological condition was generated (Figure 4-6, right). From this it can be determined that the Reconnaissance Permit Area is located in an area experiencing very low cumulative impacts and that the ecological condition is therefore still natural or near-natural.

The assessments of impacts of seismic sounds provided in the scientific literature usually consider short-term responses at the level of individual animals only, as our understanding of how such short-term effects relate to adverse residual effects at the population level are limited. Data on behavioural reactions to seismic noise 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 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 seismic surveys.

Similarly, potential cumulative impacts on individuals and populations as a result of other seismic surveys undertaken previously, concurrently or subsequently 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. Historic survey data for the West Coast is illustrated in

Figure 4-7, which shows the 2D survey lines shot between 2001 and 2018, and indicates 3D survey areas on the West Coast. Despite the density of seismic survey coverage over the past 17 years, the southern right whale population is reported to be increasing by 6.5% per year (Brandaõ *et al.* 2017), and the humpback whale by at least 5% per annum (IWC 2012) over a time when seismic surveying frequency has increased, suggesting that, for these population at least, there is no evidence of long-term negative change to population size as a direct result of seismic survey activities. Similar 2D and 3D data for southern Namibia (up to August 2017) is presented in Figure 4-8.

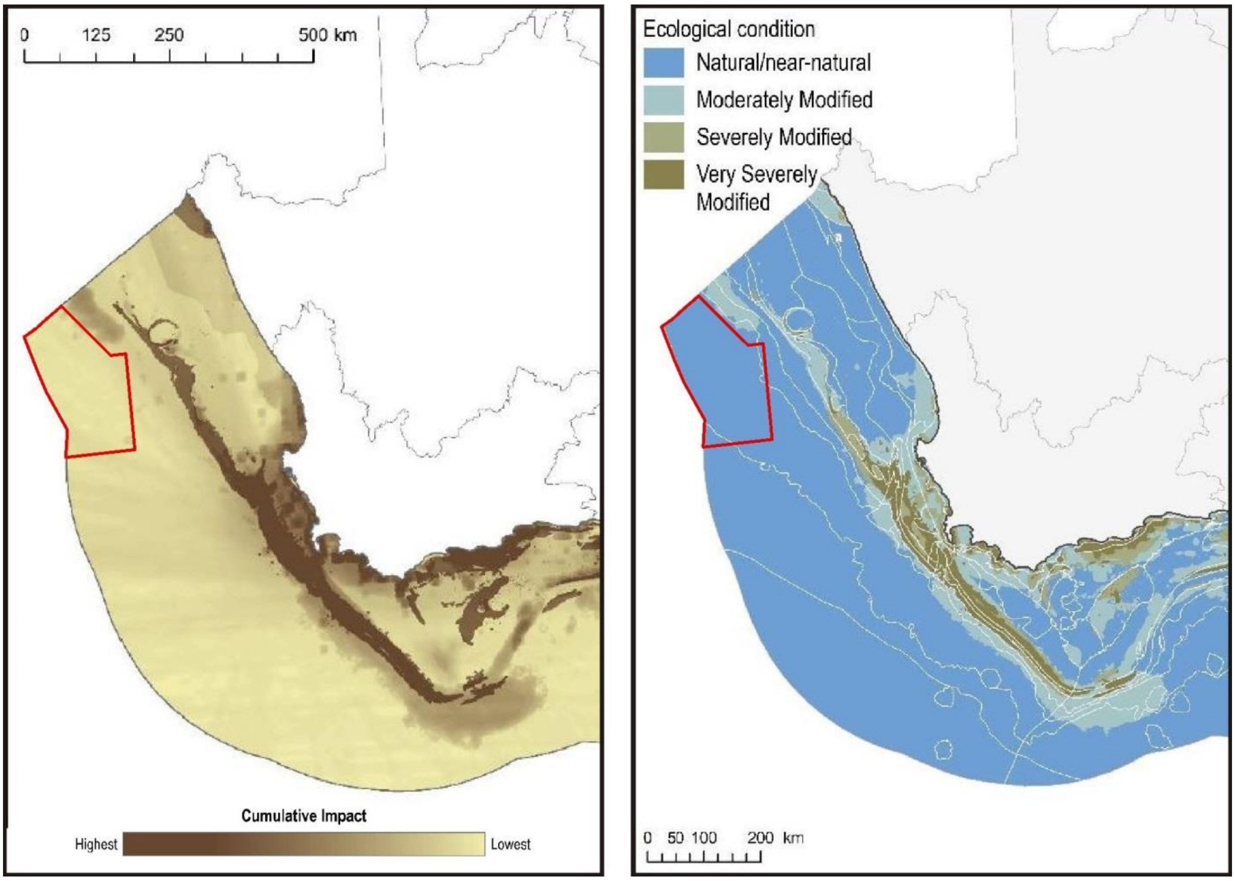


Figure 4-6: The Reconnaissance Permit Area (red polygon) in relation to cumulative impact on marine biodiversity, based the intensity of all cumulative pressures and the sensitivity of the underlying ecosystem types to each of those pressures (left) and the ecological condition of the marine realm based on the severity of modification as a result of the cumulative impacts (adapted from Sink *et al.* 2019 and Harris *et al.* 2022).

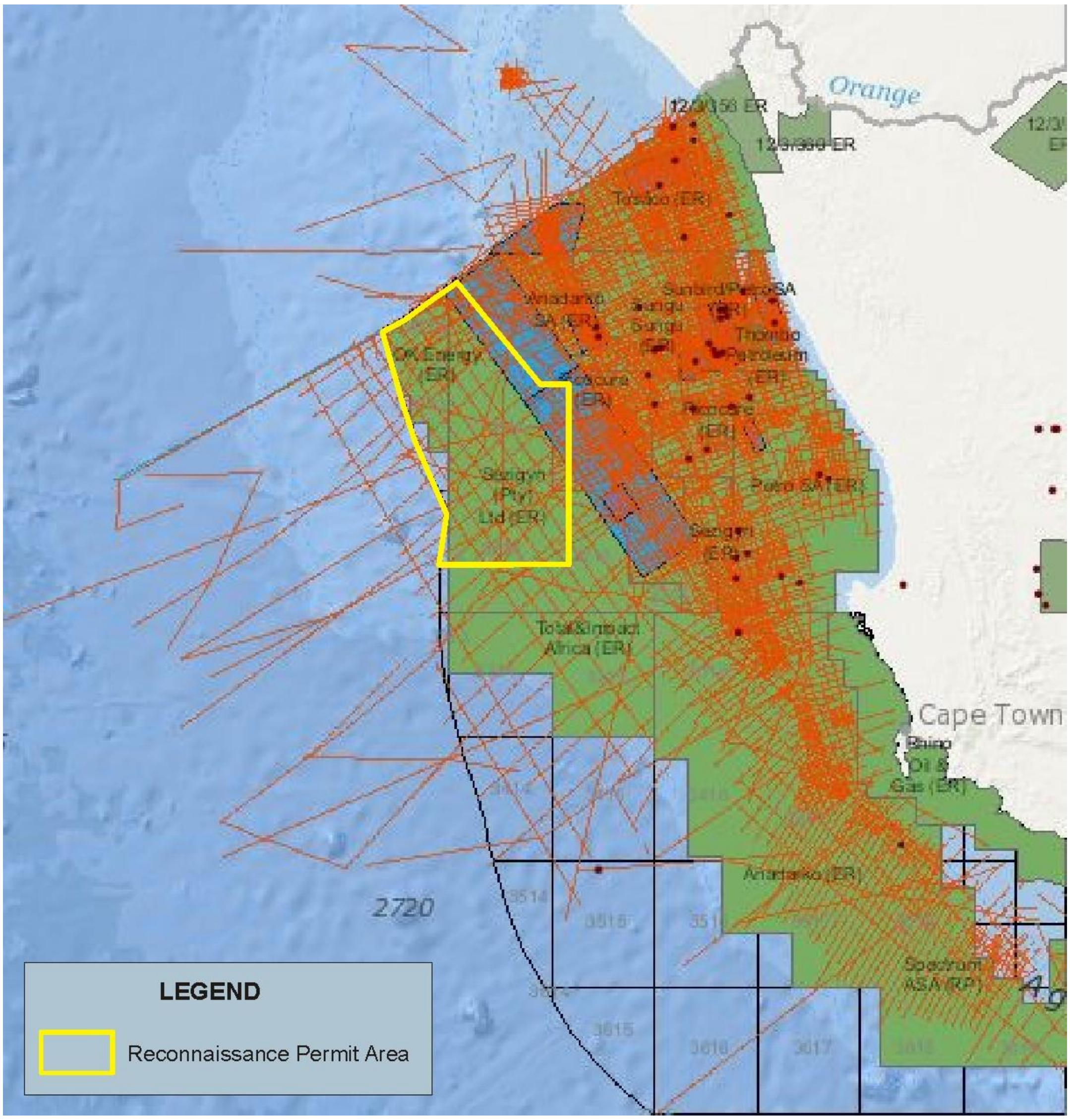


Figure 4-7: The Reconnaissance Permit Area in relation to historical 2D (red lines) and 3D (blue and purple polygons) surveys conducted on the West Coast between 2001 and 2018 (Source: PASA).

Reactions to sound 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 an underwater sound 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 sound source displaces a species from an important feeding or breeding area for a prolonged period, impacts at the population level could be significant. The increasing numbers of southern right and humpback whales around the Southern African coast, and their lingering on West Coast feeding grounds long into the summer, suggest that those surveys conducted over the past 17 years have not negatively influenced the distribution patterns of these two migratory species at least. Information on the population trends of resident species of baleen and toothed whales is unfortunately lacking, and the potential effects of seismic surveys on such populations remains unknown.

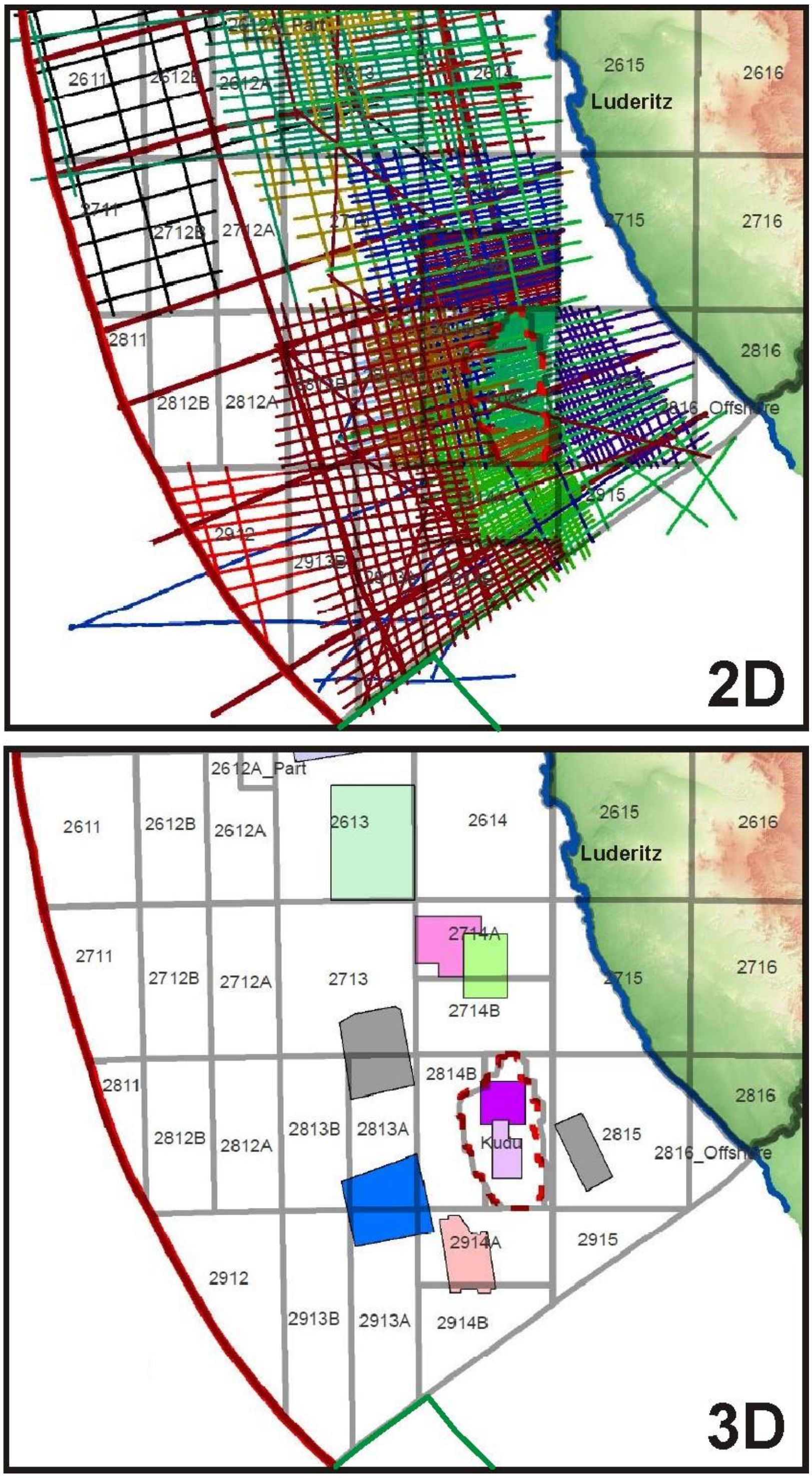


Figure 4-8: The Reconnaissance Permit Area (green polygon) in relation to historical 2D (top) and 3D (bottom) surveys conducted in southern Namibia up to August 2017 (Source: Namibian MME).

Consequently, suitable mitigation measures must be implemented during seismic data acquisition to ensure the least possible disturbance of marine fauna in an environment where the cumulative impact of increased background anthropogenic noise levels has been recognised as an ongoing and widespread issue of concern that can have chronic effects on marine fauna (Koper & Plön 2012; Simmonds *et al.* 2014; Williams *et al.* 2015; CMS 2017; IWC 2018; Risch *et al.* 2020; Chahouri *et al.* 2021; Harding & Cousins 2022). Should other concurrent seismic exploration activities be undertaken in the Orange Basin or in adjacent Namibian waters, cumulative impacts can be expected.

Despite the difficultly in undertaking a reliable assessment of the potential cumulative environmental impacts of future seismic acquisition in the Deep Water Orange Basin due to likely variation in the scope, extent and duration of proposed surveys, the cumulative impacts of potential surveys occurring concurrently needs to be considered.

The cumulative assessment table below assumes the worst case scenario of surveys occurring simultaneously during the summer survey window in 2025 and/or 2026.

In the unlikely event that multiple surveys would be undertaken concurrently within the Deep Water Orange Basin Area, associated impacts to marine fauna would be of HIGH intensity and extend REGIONALLY, over the SHORT-term (assuming they take place over the same summer survey window). The environmental risk for cumulative surveys is therefore considered **MEDIUM**.

Impact Significance

The impacts to marine fauna associated with concurrent surveys are deemed to be of **MEDIUM** significance, due to the high sensitivity of the offshore receptors, the very high likelihood of cumulative effects of acoustic impacts on marine fauna.

In applying the EIMS assessment methodology, the numerical approach similarly results in the cumulative impact having a **MEDIUM** significance.

16	***Impacts to marine fauna of concurrent seismic acquisition by multiple operators***
Project Phase:	**Mobilisation, Operation & Decommissioning**
Type of Impact	**Direct - Cumulative**
Nature of Impact	**Negative**
Sensitivity of Receptor	High
Environmental Risk	**MEDIUM**
Intensity	HIGH
Extent	PROVINCIAL
Duration	SHORT
Reversibility	PARTIALLY REVERSIBLE
Probability	DEFINITE
Significance	**MEDIUM**
Confidence	Medium
Loss of Resources	Medium

Identification of Mitigation Measures

The following measures should be considered:

No.	Mitigation measure	Classification
1	Should surveys be run simultaneously, ensure that a distance of at least 40 km is maintained between survey vessels[11] until sufficient objective evidence is obtained that a reduced buffer distance is acceptable.	Abate on site

Residual Impact Assessment

With the implementation of the above-mentioned controls and mitigation measures, the intensity of the impact would reduce to MEDIUM and the probability of the impact would reduce to LIKELY, but the overall significance would remain **MEDIUM**.

[11] This 40 km buffer maintained by any other survey vessels aligns to advice by the US Department of Interior (2014) and is considered sufficient on the basis that it provides a corridor between vessels where airgun noise approaches ambient levels such that animals may pass between, and/or the potential cumulative effect beyond this distance is considered to be negligible.

5 FINDINGS AND RECOMMENDATIONS

5.1 Key Findings

The proposed exploration activities to be undertaken by Searcher are expected to result in impacts on marine invertebrate fauna in the Orange Basin, ranging from negligible to very low significance. Only in the case of potential impacts to turtles and marine mammals are impacts of low significance expected.

A summary of impacts and mitigation measures of seismic noise on marine fauna is provided in Table 5-1. Other impacts that may occur during seismic surveys are summarised in

Table 5-2.

Table 5-1: Summary of the impacts and mitigation of seismic noise.

Impact	Significance (before mitigation)	Significance (after mitigation)
Whales and dolphins		
Baleen whale	Medium	Low
Toothed whales and dolphins	Medium	Low
Seals	Low	Low
Turtles	Medium	Low
Diving Seabirds	Low	Low
Pelagic fish	Medium	Low
Marine invertebrates	Low	Low
Plankton and ichthyoplankton	Low	Low

Table 5-2: Summary of other impacts and mitigation of seismic surveys.

Impact	Significance (before mitigation)	Significance (after mitigation)
Non-seismic noise – vessel and aircraft	Low	Low
Vessel lighting	Low	Low
Hull fouling and ballast water discharge	Low	Low
Waste Discharges to sea	Low	Low
Ship strikes and entanglement in gear	Low	Low
Accidental loss of equipment	Low	Low
Operational spills and vessel accidents	Medium	Low

5.2 Environmental Acceptability

If all environmental guidelines, and appropriate mitigation measures recommended in this report are implemented, there is no reason why the proposed seismic survey programme should not proceed. It should also be kept in mind that some of the migratory species are now present year-round off the West Coast, and that certain baleen and toothed whales are resident and/or show seasonality opposite to the majority of the baleen whales. Data collected by independent onboard observers should form part of a survey close-out report to be forwarded to the necessary authorities, and any incidence data and seismic source output data arising from surveys should be made available for analyses of survey impacts in Southern African waters.

5.3 Consideration of Alternative Technologies

It is by now widely recognised that noise reduction at the source is the most effective approach to reducing acoustic impacts from both continuous (e.g. shipping) and impulsive noise (e.g. pile driving, construction, explosions, and seismic survey) in the ocean. Seismic operators typically use a source level that applies to the most difficult conditions expected during a survey, which may be higher than required for the majority of the time. Given that geophysicists do not record or make use of any energy over about 200 Hz, a lot of energy is wasted and needlessly impacts marine fauna (Weilgart 2023). The high-frequency energy, in the tens of kHz and extending to over 100 kHz (Goold & Coats 2006) to which the MF and HF cetaceans are sensitive to, is a by-product of generating low frequency and can be suppressed. Weilgart (2023) suggests that "seismic operators should be required to develop a detailed plan describing how they will minimize sound levels, including calculations of the minimum required levels to meet the survey objectives, how these will change within the survey area and with different weather conditions, and how the survey equipment will be configured to ensure only the minimum sound level is generated".

Continued development and prioritised use of noise-reducing technologies is being recommended (Simmonds *et al*. 2014; Rische *et al*. 2020; Lee *et al*. 2023; Weilgart 2023) together with the establishment and enforcement of noise limits to encourage technological development for source level reduction of noise-producing activities. Alternative acoustic source technologies are those that have the potential to replace existing commonly used technologies under certain conditions. Some of the alternative technologies described by Weilgart (2023) are summarised below.

The alternative pneumatic marine seismic sources under development, which are however not yet commercially viable, aim to limit bandwidth, increasing low-frequency content, while reducing the higher frequency output by controlling and slowing the release of air. This also slows the rise time and lowers the SEL. Arrays of pneumatic sources are generally 'tuned', by either separating or clustering source elements to produce a larger low-frequency output. Such methods can result in significant reductions in the signal strength at high frequencies (Weilgart 2023 and references therein).

There has also been evolution in the way in which seismic sources are configured and activated. Although most airgun arrays are designed to direct low-frequency energy downwards, they can produce sidelobes that project higher frequencies at more horizontal angles. Arrays can be designed to minimize more horizontal propagation, which would reduce environmental impacts. Techniques to reduce lateral noise emissions from airguns include the use of bubble curtains, parabolic reflectors, and airgun silencers. After initial evaluation, however, these noise abatement techniques were regarded as impractical and ineffective (Harding & Cousins 2022).

Seismic sources are traditionally made up of dual arrays, activated alternately ('flip-flop'), with an acoustic signal every ~10-12 seconds. There is, however, a shift toward using triple (3) and quintuple (5) sources, and the coded activation of multiple individual source elements in a randomised activation pattern. Such 'blended' or 'simultaneous' acquisition provides greater spatial resolution in the subsurface image and can increase efficiency through facilitating the deployment of larger receiver spreads, resulting in less line kilometres being sailed per square kilometre of data acquired. The use of multiple smaller sources reduces peak sound pressure levels and sound exposure levels, with reduced time between each acoustic signal. The effectiveness of these modifications, however, needs to be evaluated in terms of the reduction in SPL and possible extended pulse times (Weilgart 2023).

High-frequency output can also be reduced without affecting the low frequencies by desynchronizing or staggering airgun activation to reduce peak pressure and SEL. A small millisecond scatter in activation times acts like a high cut filter, reducing frequencies above a frequency defined by the distribution in firing times. A large scatter in firing times produces a continuous wavefield, sounding like white noise, with a decrease of 20 dB in peak amplitude but an increase in duty cycle (Weilgart 2023).

Many of the technologies under development and not yet commercially viable, are however, proprietary to individual companies, and therefore not commercially available to all survey contractors, thereby presenting a problem for regulators.

Perhaps the most promising alternative technology under development but not yet commercially viable are marine vibrator (MV) systems, which replace the short, high amplitude, wide frequency-bandwidth signal produced by an airgun array with a much longer, lower-amplitude signal, with the same acoustic energy in the frequency band required for the seismic survey (below 200 Hz and sometimes below 120 Hz). The frequency bands required for effective imaging have the same energy spread over a longer duration, thereby allowing for a lower source level and less wasted energy at frequencies that are not used. Such a quieter signal should reduce the risk of damage to an animal's hearing at short range. Being a scalable source, MV output level can be adjusted in real time to environmental and operational conditions, by 1) altering the number of vibrators used in the array, 2) changing the output level, and 3) changing the length of the sweep. The emitted frequency band, phase, amplitude (SPL), or energy over time (SEL) can be selected, which is largely impossible for airgun surveys (Weilgart 2023). Modelling studies have concluded that due to reduced SPLs and lower SELs potential injury to marine mammals was less likely from MV arrays, with benefits even at long ranges and even for animals with good low-frequency hearing (Duncan *et al*. 2017). MV surveys would be expected to cause less of an impact (behavioral, physiological, auditory) than airgun surveys in all habitats and environments regardless of water depth or environmental conditions (LGL & MAI 2011). A drawback of MV compared with airguns is the greater potential for masking, due to the longer duration, and higher duty cycle. This would impact mainly low-frequency hearing specialists (mysticetes and some fish). Slight masking effects could extend to a few tens of kilometers from the MV source. MV thus shows potential in providing an environmentally safer alternative to airguns without compromising effectiveness for seismic exploration and could at some stage in the future replace at least some, and perhaps eventually all, airguns. However, this change will need to be driven by regulation. Unfortunately, MV systems are not yet commercially widely available, although their development and pilot projects are being sponsored by numerous industry role players (Weilgart 2023).

From the above it is evident that the recommendations of the CMS and IWC to take action to reduce ocean noise is being addressed not only at policy level through the international standardisation of mitigation measures (see below), but also at technological levels through research and development into alternative technologies for seismic acquisition as well as abatement measures to reduce the noise generated during surveys. Merchant *et al*. (2022), however, point out that "while quieter alternative to seismic airgun surveys have been developed and tested successfully, none are available at commercial scale due to a lack of regulatory incentive to encourage their use".

Specifically, marine vibrator systems are expensive; if industry professionals were compensated for the switch, the switch would be more likely. Pneumatic alternatives to conventional airguns are available commercially, but their deployment would involve capital and operational expenses that are smaller than those of marine vibrators. Increased costs in implementing alternative seismic technologies are significant and in effect impede their deployment as replacements for conventional airguns (Harding & Cousins 2022).

5.4 Recommendations

The use of Best Available Techniques/Technologies (BAT) and Best Environmental Practice (BEP) is a requirement recognised and promoted in several international agreements and conventions (e.g. CMS and CBD), and several of these BATs and BEPs exist for noise sources already and should be made use of to reduce the effect of noise on marine fauna (Weilgart 2019; 2023). Those regularly applied as risk reduction measures for seismic surveys are discussed briefly below.

The **detection of cetaceans by real-time visual observation** is a standard measure for seismic surveys. Weir *et al*. (2006) point out that while *not* a mitigation measure per se, it is an essential component of marine mammal mitigation during seismic surveys. As many marine mammals and turtles are cryptic, elusive, and often underwater, and since survey activities continue during the night or during limited-visibility conditions, the use of MMOs results in only a limited risk reduction, particularly for deep-diving species (Barlow & Gisiner 2006; Parsons *et al*. 2009; Leaper *et al*. 2015). Given these constraints, the use of dedicated and experienced MMOs (as opposed to Fisheries Liaison Officers and/or ship's crew) is critical in achieving the most reliable results.

Real-time **Passive Acoustic Monitoring (PAM)** should be used as an additional mitigation measure in conjunction with visual observation, to maximize the probability of detection. Not only does PAM detect vocalising diving animals, it can also detect vocalising animals at night and in rough weather conditions (Gordon & Tyack, 2002). However, while having great potential for detecting cetacean species that vocalise frequently, those species that do not vocalise, or cease vocalising for some reason will remain undetected by PAM.

Other measures that attempt to reduce noise impacts associated with physical injuries rather than masking or disturbance include **increasing loud noises slowly** (e.g. 'soft-start' or 'ramp-up' procedures) **or shutting down the noise sources** when vulnerable species come within a specified range of the source.

Regulators remain heavily reliant on the use of **safety zones (exclusion zones)** as the primary means of noise mitigation. Although the extent of these exclusion zones has more recently been based on the impact zones for different faunal species as predicted by sound transmission loss modelling studies, their limitations are widely acknowledged (e.g. Weir & Dolman 2007; Lubchenco 2010; Wright 2014).

The most frequently implemented mitigation measure is **time-area closures**, which provide a way of keeping noise sources away from vulnerable (e.g. migrating) species. This, however, relies on sufficiently detailed temporal and spatial knowledge of the distribution patterns of the vulnerable species, but does not cater for resident species that are present year-round.

Detailed mitigation measures for seismic surveys in other parts of the world are provided by Weir *et al*. (2006), Weir & Dolman (2007), Compton *et al*. (2007), US Department of Interior (2007), Reyes Reyes *et al*. (2016), Vilardo & Barbosa (2018), Bröker *et al*. (2015), Bröker (2019) and Harding & Cousins (2022), with the most recent and comprehensive mitigation measures provided in Weilgart (2023). Many of the international guidelines presented in these documents are extremely conservative as they are designed for areas experiencing repeated, high intensity surveys and harbouring particularly sensitive species, or species with high conservation status. A number of countries have updated their guidelines, most of which are based on the JNCC (2010, 2017) recommendations but adapted for specific areas of operation. A review and comparison of these is provided in MaMa CoCo SEA (2015). The guidelines currently applied to seismic surveying in South African waters are those proposed in the Generic EMPR (CCA & CMS 2001) and by Purdon (2018). Purdon (2018) highlights the importance of developing mitigation guidelines both locally and regionally and points out that if South Africa is to maintain environmental integrity, mitigation guidelines for seismic surveys specific to the country, and based on the most recent scientific data, need to be implemented.

These have been updated as necessary to include salient points from recognised international guidelines, particularly the JNCC (2010, 2017) Guidelines, the 2013 New Zealand Code of Conduct for seismic operations (New Zealand Dept. of Conservation 2013) and recommendations made by Weilgart (2023). The proposed mitigation is thus comprehensive and in-line with, and in certain instances more comprehensive than, international good-practice industry standards.

Elliott *et al*. (2019) point out that in most cases the mitigation standards adopted are designed to mitigate impacts on marine mammals (e.g. Nowacek *et al*. 2013), with no set of standards or guidelines for sea turtles and fish. Even less in known about the efficacy of mitigation in protecting marine vertebrates from acoustic impacts (Parsons *et al*. 2009). The authors argue that without baseline information on species before surveys (see for example Fossati *et al*. 2018), it is difficult to assess the efficacy of existing guidelines and standards during or after surveys.

Adopting as far as possible the principles outlined in Nowacek & Southall (2016) and Nowacek *et al*. (2013, 2015), the mitigation measures proposed for seismic surveys are as provided below for each phase of a seismic survey operation:

No.	Mitigation measure	Classification
1. Survey Planning		
1.1	Plan seismic surveys to avoid the most sensitive periods for some marine fauna, notably: • Movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters from early June to early December, • Aggregation of migratory cetaceans on the summer feeding grounds between St Helena Bay and Dassen Island from late October to late December. If data acquisition commences before late December then Passive Acoustic Monitoring (PAM) technology must be in place at all times.	Avoid
1.2	Plan survey, as far as possible, so that the first commencement of airgun firing in a new area (including gun tests) are undertaken during daylight hours.	Abate on site
1.3	Prohibit airgun use (including airgun tests) outside of the Reconnaissance Permit Area.	Avoid

No.	Mitigation measure	Classification
1.4	Although a seismic vessel and its gear may transit, including passing through a declared Marine Protected Area, acoustic sources (airguns) must not be operational during this transit.	Avoid
1.5	A 5 km buffer zone where no airgun operation is permitted is recommended around all MPAs	Avoid
2. Key Equipment		
2.1	**Passive Acoustic Monitoring (PAM)**	
2.1.1	Ensure the seismic vessel is fitted with Passive Acoustic Monitoring (PAM) technology, which detects some animals through their vocalisations. The PAM technology must have enough bandwidth to be sensitive to the whole frequency range of sensitive marine life expected in the area.	Abate on site
2.1.2	As the survey area would largely be in waters deeper than 1 000 m where sperm whales and other deep-diving odontocetes are likely to be encountered, implement the use of PAM 24-hr a day when the airgun is in operation.	Abate on site
2.1.3	Ensure that the PAM hydrophone streamer is towed in such a way that the interference of vessel noise is minimised.	Abate on site
2.1.4	Ensure the PAM streamer is fitted with at least four hydrophones, of which two are HF and two LF, to allow directional detection of cetaceans.	Abate on site
2.1.5	Ensure spare PAM hydrophone streamers are readily available in the event that PAM breaks down, in order to ensure timeous redeployment.	Abate on site
2.2	**Acoustic Source**	
2.2.1	Define and enforce the use of the lowest practicable airgun volume for production, and design arrays to maximise downward propagation, minimise horizontal propagation and adopting suitable array configurations and pulse synchronization and eliminating unnecessary high frequencies.	Abate on site
2.2.2	Ensure a display screen for the acoustic source operations is provided to the marine observers. All information relating to the activation of the acoustic source and the power output levels must be readily available to support the observers in real time via the display screen and to ensure that operational capacity is not exceeded.	Abate on site
2.2.3	Ensure the ramp-up noise volumes do not exceed the production volume.	Abate on site
2.2	**Streamers**	
2.2.1	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Abate on site
2.2.2	Ensure that solid streamers rather than fluid-filled streamers are used to avoid leaks.	Avoid
3. Key Personnel		
3.1	• Make provision for the placing of at least two qualified MMOs on board the seismic vessel. As a minimum, one must be on watch during daylight hours for the pre-shoot observations and when the acoustic source is active. • The duties of the MMO would be to: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Record airgun activities, including sound levels, 'soft-start' procedures and pre-firing regimes;	Abate on site

No.	Mitigation measure	Classification
	– Observe and record responses of marine fauna to seismic shooting from optimum vantage points, including seabird, large pelagic fish (e.g. shoaling tuna, sunfish, sharks), turtle, seal and cetacean incidence and behaviour and any mortality or injuries of marine fauna as a result of the seismic survey. Data captured should include species identification, position (latitude/longitude), distance/bearing from the vessel, swimming speed and direction (if applicable) and any obvious changes in behaviour (e.g. startle responses or changes in surfacing/diving frequencies, breathing patterns) as a result of the seismic activities. Both the identification and the behaviour of the animals must be recorded accurately along with current seismic sound levels. Any attraction of predatory seabirds, large pelagic fish or cetaceans (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should also be recorded; – Record sightings of any injured or dead marine mammals, large pelagic fish (e.g. sharks), seabirds and sea turtles, regardless of whether the injury or death was caused by the seismic vessel itself. If the injury or death was caused by a collision with the seismic vessel, the date and location (latitude/longitude) of the strike, and the species identification or a description of the animal should be recorded and included as part of the daily report; – Record meteorological conditions at the beginning and end of the observation period, and whenever the weather conditions change significantly; – Request the delay of start-up or temporary termination of the seismic survey or adjusting of seismic shooting, as appropriate. It is important that MMO decisions on the termination of firing are made confidently and expediently, and following dialogue between the observers on duty at the time. A log of all termination decisions must be kept (for inclusion in both daily and “close-out” reports); – Use a recording spreadsheet (e.g. JNCC 2017) in order to record all the above observations and decisions; and – Prepare daily reports of all observations, to be forwarded to the necessary authorities as required, to ensure compliance with the mitigation measures.	
3.2	• Make provision for placing of a qualified PAM operator on board the seismic vessel. As a minimum, one must be on "watch" during the pre-shoot observations and when the acoustic source is active. • The duties of the PAM operator would be to: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Ensure that the hydrophone cable is optimally placed, deployed and tested for acoustic detections of marine mammals; – Confirm that there is no marine mammal activity within 500 m of the airgun array prior to commencing with the ‘soft-start’ procedures;	Abate on site

<table>
<tr><th>No.</th><th>Mitigation measure</th><th>Classification</th></tr>
<tr><td></td><td>– Record species identification, position (latitude/longitude), distance and bearing from the vessel and acoustic source, where possible;
– Record general environmental conditions;
– Record airgun activities, including sound levels, 'soft-start' procedures and pre-firing regimes; and
– Request the delay of start-up and temporary termination of the seismic survey, as appropriate.</td><td></td></tr>
<tr><td>3.3.</td><td>Ensure MMOs and PAM operators are briefed on the area-specific sensitivities and on the seismic survey planning (including roles and responsibilities, and lines of communication).</td><td>Abate on site</td></tr>
<tr><td colspan="3">4. Airgun Testing</td></tr>
<tr><td>4.1</td><td>Maintain a pre-shoot watch of 60-minutes before any instances of airgun testing. If only a single lowest power airgun is tested, the pre-shoot watch period can be reduced to 30 minutes.</td><td>Avoid / Abate on site</td></tr>
<tr><td>4.2</td><td>Implement a 'soft-start' procedure if testing multiple airguns.
• The 'soft-start' should be carried out over a time period proportional to the number of guns being tested and not exceed 20 minutes; airguns should be tested in order of increasing volume;
• If testing all airguns at the same time, a 20 minute 'soft-start' is required;
• If testing a single lowest power airgun a 'soft-start' is not required.</td><td>Avoid / Abate on site</td></tr>
<tr><td colspan="3">5. Pre-Start Protocols</td></tr>
<tr><td>5.1</td><td>Implement a dedicated MMO and PAM pre-shoot watch of at least 60 minutes (to accommodate deep-diving species in water depths greater than 200 m).</td><td>Avoid / Abate on site</td></tr>
<tr><td>5.2</td><td>Implement a 'soft-start' procedure of a minimum of 20 minutes' duration on initiation of the seismic source if:
• during daylight hours it is confirmed:
– visually by the MMO during the pre-shoot watch (60 minutes) that there are no penguins or feeding aggregations of diving seabirds, slow-swimming large pelagic fish, turtles, seals or cetaceans within 500 m of the seismic source, and
– by PAM technology that there are no vocalising cetaceans detected in the 500 m mitigation zone.
• during times of poor visibility or darkness it is confirmed by PAM technology that no vocalising cetaceans are present in the 500 m mitigation zone during the pre-shoot watch (60 minutes).</td><td>Avoid / Abate on site</td></tr>
<tr><td>5.3</td><td>Delay 'soft-starts' if penguins or feeding aggregations of diving seabirds, slow-swimming large pelagic fish, turtles, seals or cetaceans are observed within the mitigation zone.
• A 'soft-start' should not begin until 30 minutes after cetaceans depart the 500 m mitigation zone or 30 minutes after they are last seen or acoustically detected by PAM in the mitigation zone.
• In the case of penguins, diving seabirds, slow-swimming large pelagic fish and turtles, delay the 'soft-start' until animals are outside the 500 m mitigation zone.
• In the case of fur seals, which may occur commonly around the vessel, delay 'soft-starts' for at least 10 minutes until it has been confirmed that the mitigation zone is clear of all seal activity. However, if after a period of 10 mins seals are still observed within 500 m of the airgun, the normal 'soft-start' procedure should be</td><td>Avoid / Abate on site</td></tr>
</table>

No.	Mitigation measure	Classification
	allowed to commence for at least a 20-minute duration. Seal activity should be carefully monitored during 'soft-starts' to determine if they display any obvious negative responses to the airgun and gear or if there are any signs of injury or mortality as a direct result of the seismic activities.	
5.4	As noted above for planning, when arriving at the survey area for the first time, survey activities should, as far as possible, only commence during daylight hours with good visibility and wind speeds below Beaufort 3. However, if this is not possible due to prolonged periods of high wind speeds, poor visibility (e.g. thick fog) or unforeseen technical issue which results in a night-time start, the initial acoustic source activation (including gun tests) may only be undertaken if the normal 60-minute PAM pre-watch and 'soft-start' procedures have been followed.	Avoid / Abate on site
5.5	Schedule 'soft-starts' so as to minimise, as far as possible, the interval between reaching full power operation and commencing a survey line. The period between the end of the soft start and commencing with a survey line must not exceed 20 minutes. If it does exceed 20 minutes, refer to breaks in firing below.	Abate on site
6. Line Turns		
6.1	If line changes are expected to take **longer** than 40 minutes: • Terminate airgun firing at the end of the survey line and implement a pre-shoot search (60 minutes) and 'soft-start' procedure (20 minutes) when approaching the next survey line. • If line turn is shorter than 80 minutes (i.e. shorter than a 60-minute pre-shoot watch and 20-minute 'soft-start' combined), the pre-shoot watch can commence before the end of the previous survey line.	Abate on site
6.2	If line changes are expected to take **less** than 40 minutes, airgun firing can continue during the line change if: • The power is reduced to 180 cubic inches (or as close as is practically feasible) at standard pressure. Airgun volumes of less than 180 cubic inches can continue to fire at their operational volume and pressure; • The Shot Point Interval (SPI) is increased to provide a longer duration between shots, with the SPI not to exceed 5 minutes; and • The power is increased and the SPI is decreased in uniform stages during the final 10 minutes of the line change (or geophone repositioning), prior to data collection re-commencing (i.e. a form of mini soft start). • Normal MMO and PAM observations continue during this period when reduced power airgun is firing.	Abate on site
7. Shut-Downs		
7.1	Terminate seismic shooting on: • observation and/or detection of penguins or feeding aggregations of diving seabirds, turtles, slow swimming large pelagic fish (including whale sharks, basking sharks, manta rays [and devil rays-Namibia only]) or cetaceans within the 500 m mitigation zone. • observation of any obvious mortality or injuries to cetaceans, turtles, seals or mass mortalities of squid and fish (specifically large shoals of tuna or surface shoaling small pelagic species such as sardine, anchovy and mackerel) when estimated by the MMO to be as a direct result of the survey.	Abate on site

No.	Mitigation measure	Classification
7.2	Depending the species, specific mitigation will be implemented to continue the survey operations, as specified below: • For specific species such as turtles, penguins, diving seabirds and slow swimming large pelagic fish (including whale sharks, basking sharks, manta rays [and devil rays-Namibia only]), terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no soft-start required). • For cetaceans, terminate shooting until such time as there has been a 30 minute delay from the time the animal was last sighted within the mitigation zone before the commencement of the normal soft start procedure.	Abate on site
8. Breaks in Airgun Firing		
8.1	If after breaks in firing, the airgun can be restarted **within 5 minutes**, no soft-start is required and firing can recommence at the same power level **provided no marine mammals have been observed or detected** in the mitigation zone during the break-down period.	Abate on site
8.2	For all breaks in firing of **longer than 5 minutes, but less than 20 minutes**, implement a 'soft-start' of similar duration, assuming there is continuous observation by the MMO and PAM operator during the break.	Abate on site
8.3	For all breaks in firing of **20 minutes or longer**, implement a 60-minute pre-shoot watch and 20-minute 'soft-start' procedure prior to the survey operation continuing.	Abate on site
8.4	For planned breaks, ensure that there is good communication between the seismic contractor and MMOs and PAM operators in order for all parties to be aware of these breaks and that early commencement of pre-watch periods can be implemented to limit delays.	Abate on site
9. PAM Malfunctions		
9.1	If the PAM system malfunctions or becomes damaged during night-time operations or periods of low visibility, continue operations for 30 minutes without PAM if no marine mammals were detected by PAM in the mitigation zones in the previous 2 hours, while the PAM operator diagnoses the issue. If after 30 minutes the diagnosis indicates that the PAM gear must be repaired to solve the problem, reduce power to 180 cubic inches. Firing of the reduced power gun may continue for 30 minutes while PAM is being repaired, the last 10-minute of which is a 10-minute ramp up to full power (mini 'soft-start'). If the PAM repair will take longer than 60 minutes, stop surveying until such time as a functional PAM system can be redeployed and tested.	Abate on site
9.2	If the PAM system breaks down during **daylight hours**, continue operations for 20 minutes without PAM, while the PAM operator diagnoses the issue. If the diagnosis indicates that the PAM gear must be repaired to solve the problem, operations may continue for an additional 2 hours without PAM monitoring as long as: • No marine mammals were detected by PAM in the mitigation zones in the previous 2 hours; • Two MMOs maintain watch at all times during operations when PAM is not operational; • The time and location in which operations began and stop without an active PAM system is recorded.	Abate on site

Vessel and Aircraft Operations

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over seabird and seal colonies and offshore islands by at least 1 852 m (i.e. 1 nm)	Avoid / abate on site
2	Avoid extensive low-altitude coastal flights by ensuring that the flight path is perpendicular to the coast, as far as possible	Avoid/ abate on site
3	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Avoid
4	The lighting on the survey and support vessels should be reduced to a minimum compatible with safe operations whenever and wherever possible. Light sources should, if possible and consistent with safe working practices, be positioned in places where emissions to the surrounding environment can be minimised	Reduce at Source
5	Keep disorientated, but otherwise unharmed, seabirds in dark containers for subsequent release during daylight hours. Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring)	Repair or Restore
6	Avoid the unnecessary discharge of ballast water.	Reduce at source
7	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
8	Ensure that routine cleaning of ballast tanks to remove sediments 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
9	Ensure all equipment (e.g. arrays, streamers, tail buoys etc) that has been used in other regions is thoroughly cleaned prior to deployment	Avoid/Reduce at Source
10	Implement a waste management system that addresses all wastes generated at the various sites, shore-based and marine. This should include: – Separation of wastes at source; – Recycling and re-use of wastes where possible; – Treatment of wastes at source (maceration of food wastes, compaction, incineration, treatment of sewage and oily water separation).	Avoid/Reduce at Source
11	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
12	Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.	Reduce at Source
13	The vessel operators should keep a constant watch for marine mammals and turtles in the path of the vessel.	Avoid
14	Keep watch for marine mammals behind the vessel when tension is lost on the towed equipment and either retrieve or regain tension on towed gear as rapidly as possible.	Avoid
15	Should a cetacean become entangled in towed gear, contact the South African Whale Disentanglement Network (SAWDN) formed under the auspices of DEA to provide verbal specialist assistance in releasing entangled animals where necessary.	Repair/restore
16	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Avoid

No.	Mitigation measure	Classification
17	Ensure vessel transit speed between the survey area and port is a maximum of 12 knots (22 km/hr), except in the MPAs where it is reduced further to 10 knots (18 km/hr) as well as when they are present in the vicinity.	Avoid/reduce at source
18	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/restore
19	Ensuring that loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system.	Avoid
20	Minimise the lifting path between vessels	Avoid
21	Undertake frequent checks to ensure items and equipment are stored and secured safely on board each vessel.	Avoid
22	In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the Reconnaissance Permit Area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval	Repair/restore
23	Use low toxicity dispersants cautiously and only with the permission of DFFE.	Abate on and off site
24	As far as possible, and whenever the sea state permits, attempt to control and contain any spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill	Abate on site
25	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
26	Ensure offshore bunkering is not undertake in the following circumstances: – Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; – During any workboat or mobilisation boat operations; – During helicopter operations; – During the transfer of in-sea equipment; and – At night or times of low visibility.	Avoid / Reduce at source

- In addition to the mitigation measures provided above it is recommended that operators give consideration to the proposals made by Weilgart (2023) in meeting international Best Environmental Practice (BEP) for seismic surveys, namely:Encourage data sharing among seismic operators to minimize duplicate surveying. Duplicated surveys need to be justified.
- Encourage re-analysis of old seismic data using new signal processing or analysis techniques
- "Baseline studies of biological abundance and distribution of sensitive species, including turtles, fish, and invertebrates, must occur at least a year, preferably two, in advance of seismic surveys. These must be of sufficient quality and statistical power to meaningfully mitigate impacts". The proposed monitoring technology includes fixed acoustic detectors (buoys, bottom recorders, etc.) or mobile gliders, which can be used both for vocal marine mammals and fish species.
- Monitoring should be statistically powerful enough to detect subtle impacts. BDA (Before During After) or BACI (Before After Control Impact) studies to examine impacts must contain power analyses to show whether possible impacts would be detectable or not. Impact and

biological baseline studies should include fish, turtles, and invertebrates. All biological and impact data collected for mitigation should be publicly available.
- Results of sound propagation modelling studies should be verified in the field.
- Seismic surveys should not be allowed to proceed without some proof of efficacy of the mitigation measures used and for all sensitive species.

In striving to achieve these BEPs in southern Africa, it is recommended that seismic operators and holders of hydrocarbon exploration licences give consideration to contributing to a centrally managed research fund. Collaboration across the industry to collectively fund pro-active research would provide opportunity for the development and implementation of a structured and experimentally sound acoustic study to quantitatively inform the authorities and stakeholders of acoustic impacts to the various faunal groups in southern African waters.

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APPENDIX 1: METHOD FOR ASSESSING IMPACT SIGNIFICANCE

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 3.

Table 3: 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 4.

Table 4: 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 5: 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 6.

Table 6: 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[12] or which meet the definition of migratory and congregatory species[13], but which do not qualify as Critical Habitat based on IUCN Key Biodiversity Area thresholds[14]. 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[15], 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.

[12] 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)

[13] 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.

[14] IUCN, A Global Standard for the Identification of Key Biodiversity Areas, 2016.

[15] 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 7: 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 7. 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 8).

Table 8: 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 9: 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).
≥ -20	High negative (i.e., where the impact must have an influence on the decision process to develop in the area).

Value	Description
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: C*urriculum Vitae* Dr Andrea Pulfrich

Personal Details

Born:	Pretoria, South Africa on 11 August 1961
Nationality and Citizenship:	South African and German
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Academic Qualifications

- BSc (Zoology and Botany), University of Natal, Pietermaritzburg, 1982
- BSc (Hons) (Zoology), University of Cape Town, 1983
- MSc (Zoology), University of Cape Town, 1987
- PhD, Department of Fisheries Biology of the Institute for Marine Science at the Christian-Albrechts University, Kiel, Germany, 1995

Membership in Professional Societies

- South African Council for Natural Scientific Professions (Pr.Sci.Nat. No: 400327/06)
- South African Institute of Ecologists and Environmental Scientists
- International Association of Impact Assessment (South Africa)

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.