PROPOSED 3D SEISMIC EXPLORATION IN BLOCK 1 OFF THE WEST COAST OF SOUTH AFRICA

Marine Faunal Specialist Assessment

Prepared for:

On behalf of

EIMS ENVIRONMENTAL IMPACT MANAGEMENT SERVICES

Tosaco Energy (Pty) Ltd

TOSACO Energy

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EXECUTIVE SUMMARY

Tosaco has applied for an Exploration Right for offshore oil and gas in Block 1, on the West Coast of South Africa. The Licence Block, which is 21,000 km^2 in extent, is situated roughly between the South African – Namibian maritime border and Hondeklipbaai. Water depths range from 20 m to 750 m. The commencement of the 3D surveys will depend on an Exploration Right award date and availability of seismic contractors. It is anticipated that the 3D survey would take approximately four months to complete.

The seabed sediments comprise sands, sandy muds and muddy sands. Influenced by the Benguela Current the licence block overlaps with the Namaqua upwelling cells. Winds come primarily from the south and southeast, whereas virtually all swells throughout the year come from the SW 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 licence area will be seasonally nutrient rich being within the influence of coastal upwelling.

The proposed 3D survey area falls into the Southern Benguela Ecoregion. Benthic invertebrate communities in the area have been relatively well studied and comprise primarily polychaetes, crustaceans and molluscs. The ecosystem types in the proposed survey area 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 around the Orange River mouth are rated as ‘Vulnerable’ and ‘Endangered’, respectively. A geological feature of note adjacent to the proposed survey area is the Namaqua Fossil Forest comprising trunks of fossilized yellowwood trees covered in delicate corals. These unique features stand out against surrounding mud, silt and gravel habitats.

Due to its overlap with the Namaqua upwelling cell, plankton abundance is expected to be seasonally high. Major fish spawning and migration routes occurring inshore on the shelf are situated primarily south of the proposed survey area. 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. Although the closest breeding areas for African Penguins and Cape Gannets are well to the south at Lambert’s Bay, these species may be encountered in the inshore portions of the survey area. Migrating turtles in the area would include the leatherback and loggerhead turtles. Marine mammals likely to occur include a variety of baleen whales including humpbacks, Antarctic minke, fin and sei whales. Toothed whales will include sperm and killer whales, as well as a variety of beaked whales and dolphins. The survey area has avoided overlap with the Namaqua Fossil Forest Marine Protected Ares, but does overlap with the Namaqua Fossil Forest Ecologically and Biologically Significant Area (EBSAs) and numerous critical biodiversity areas (CBAs).

Potential impacts to the marine fauna as a result of the proposed 2D 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);
- Offshore population of Bryde's whales whose seasonality on the West Coast is opposite to the majority of the balaenopterids;
- 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 of Residual Impact
Plankton and ichthyoplankton	
Mortality and/or pathological injury	Very Low
Marine invertebrates	
Mortality and/or pathological injury in benthic and pelagic/neritic invertebrates	Very Low
Behavioural avoidance	Very Low
Fish	
Mortality and/or pathological injury in demersal species	Very Low
Mortality and/or pathological injury in pelagic species	Very Low
Avoidance behaviour	Very Low
Reproductive success / spawning	Very Low
Masking of sounds	Very Low
Indirect impacts on food sources	Very Low
Seabirds	
Pathological injury	Very Low
Avoidance behaviour	Very Low
Indirect impacts on food sources	Very Low
Turtles	
Pathological injury, collision and entanglement	Very Low
Avoidance behaviour	Very Low
Masking of sounds	Very Low
Indirect impacts on food sources	Very Low
Seals	
Pathological injury	Very Low
Avoidance behaviour	Very Low
Masking of sounds	Very Low
Indirect impacts on food sources	Very Low

Impact	Significance of Residual Impact
Whales and dolphins	
Baleen whales	
Pathological injury	Low
Avoidance behaviour	Low
Masking of sounds and indirect impacts on food sources	Low
Indirect impacts on food sources	Very Low
Toothed whales and dolphins	
Pathological injury	Low
Avoidance behaviour	Low
Masking of sounds and indirect impacts on food sources	Low
Indirect impacts on food sources	Very 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	Very Low	Very Low
Vessel lighting	Very Low	Very Low
Hull fouling and ballast water discharge	Negligible	Negligible
Waste Discharges to sea	Very Low	Very Low
Geophysical Surveys (Sonar)	Negligible	Negligible
Ship strikes and entanglement in gear	Very Low	Very Low
Accidental loss of equipment	Very Low	Very Low
Operational spills and vessel collision	Very Low	Very 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 movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters (June to November inclusive) and ensure that migration paths are not blocked by seismic operations. Surveying should, therefore, be undertaken from December to May (inclusive). This would also avoid the period when juvenile penguins feed in inshore waters along the West Coast.	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 area of operation (which includes line turns undertaken outside the licence area).	Avoid

No.	Mitigation measure	Classification
1.4	Although a seismic vessel and its gear may pass 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.	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 (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.	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
2.3	**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	• Ensure that at least two qualified independent MMOs are on board at all times. 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, in order to ensure compliance with the mitigation measures.	
3.2	• Ensure that at least two qualified, independent PAM operators are on board at all times. 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:	Abate on site

No.	Mitigation measure	Classification
	– 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.	
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 sound sources. • The "soft-start" should be carried out over a time period proportional to the number of guns being tested and not exceed 20 minutes; sound sources should be tested in order of increasing volume. • If testing all sound sources 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 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 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. However, if this is not possible due to prolonged periods of poor visibility (e.g. thick fog) or unforeseen technical issue which results in a night-time start, 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; • 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

No.	Mitigation measure	Classification
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, the sound source 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
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	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;	Abate on site

No.	Mitigation measure	Classification
	• 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.	

Vessel and Aircraft Operations

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over seal colonies and bird breeding 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	A flight altitude >1 000 m to be maintained over MPAs and a cruising altitude of greater than 300 m, except when taking off and landing or in a medical emergency.	Avoid/ abate on site
4	Contractors should comply fully with aviation and authority guidelines and rule	Avoid
5	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Avoid
6	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
7	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
8	Avoid the unnecessary discharge of ballast water.	Reduce at source
9	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
10	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
11	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
12	The vessel operators should keep a constant watch for marine mammals and turtles in the path of the vessel.	Avoid
13	Ensure vessel transit speed between the survey area and port is a maximum of 12 knots (22 km/hr), except MPAs where it is reduced further to 10 knots (18 km/hr)	Avoid/reduce at source

No.	Mitigation measure	Classification
14	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
15	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
16	Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.	Reduce at Source
17	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
18	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
19	In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the licence area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval	Repair/restore
20	Use low toxicity dispersants cautiously and only with the permission of MET/MFMR.	Abate on and off site
21	As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill	Abate on site
22	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
23	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
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
DEA	Department of Environmental Affairs
DEFRA	UK Department for Environment, Food & Rural Affairs
EBSAs	Ecologically or Biologically Significant Areas
EEZ	Exclusive Economoc Zone
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
EOO	Extent of Occurrence
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
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
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
SANBI	South African National Biodiversity Institute
SEL	Sound Exposure Level
SFRI	Sea Fisheries Research Institute, Department of Environmental Affairs
SLR	SLR Environmental Consulting (Namibia) (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
TEPSA	
TSPM	Total Exploration & Production South Africa BV 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, South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist report was compiled for EIMS (Pty) Ltd for their use in preparing an Environmental and Social Impact Assessment (ESIA) and Environmental Management Programme Report (EMPr) for proposed 3D seismic acquisition by Tosaco Energy in Block 1 off the West Coast of South Africa. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of Tosaco and EIMS.

Andrea Pulfrich

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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 Tosaco Energy (Pty) Ltd is planning to undertake the reprocessing of approximately 5,000 km of existing 2D seismic lines previously acquired in Block 1 off the West Coast of South Africa, as well as approximately 750 km^2 of 3D seismic data previously undertaken in the block. If subsequent analysis of existing data determines that acquisition of a seismic dataset utilising 3D seismic techniques might be beneficial, then an additional 3D seismic survey might be conducted over an area of ~1,000 km^2.

The Licence Block is situated roughly between the South African – Namibian maritime border and Hondeklipbaai. It is 21,000 km^2 in extent, with water depths ranging from 20 m to 750 m. Environmental Impact Management Services (EIMS) has been appointed by Tosaco to conduct the Scoping and Environmental Impact Assessment (EIA) process and compile the Environmental Management Programme report (EMPr) for the proposed seismic acquisition. EIMS in turn has approached Pisces Environmental Services (Pty) Ltd to provide a specialist report on potential impacts of the proposed seismic operations on marine fauna in the area.

1.1 Scope of Work

This specialist report was compiled as a desktop study on behalf of EIMS, for their use in undertaking a scoping and EIA process associated with the application for an exploration right in Block 1 off the South African West Coast.

The terms of reference for this study, as specified by EIMS, are:

- Provide a general description of the benthic environment on the West Coast of South Africa, based on current available literature;
- Describe the habitats that are likely to be affected by seismic survey. Due to the distance offshore of the proposed 3D survey area, the coastal habitats will be described at a higher level compared to the offshore habitats;

- Identify sensitive habitats and species that may be potentially affected by the proposed seismic exploration activities;
- Describe seasonal and migratory occurrences of key marine fauna;
- Identify, describe and assess the significance of potential impacts of the proposed seismic survey on the local marine fauna, focussing particularly on marine mammals, turtles, fish and penguins, but including generic effects on fish eggs and larvae, and pelagic and benthic invertebrates; and
- Identify practicable mitigation measures to reduce the significance of any negative impacts and indicate how these can be implemented during surveying.

1.2 Approach to the Study

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 largely on the baseline description provided in the Marine Faunal Assessment compiled in 2012 as part of the EIA for the Addendum to PetroSA's EMPr for 2D and 3D seismic surveying in Block 1, and the subsequent Marine Faunal Assessment compiled in 2012 as part of the EIA for well drilling by Cairn South Africa (Pty) Ltd. These reports in turn was based on a review and collation of existing information and data from the scientific literature, internal reports and the Generic Environmental Management Programme (EMPr) compiled for oil and gas exploration in South Africa (CCA and CMS 2001). Information on the baseline environment had been updated where appropriate. The information for the identification of potential impacts of seismic activities on marine fauna was drawn from various scientific publications, the Generic EMPR, information sourced from the Internet as well as Marine Mammal Observer close-out Reports. The sources consulted are listed in the Reference chapter.

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

1.3 Assumptions, Limitations and Information Gaps

The assumptions made in this specialist assessment are:

- The study is based on the **project description made available to the specialists at the time of the commencement of the study**.

Information gaps include:

- details of the benthic macrofaunal communities and potentially vulnerable species on deep water reef habitats;
- current information on the distribution, population sizes and trends of most pelagic seabird, turtle and cetacean species occurring in South African waters and the project area in particular.

1.4 Assessment Procedure

The following convention was used to determine significance ratings in the assessment. For further details the reader is referred to Chapter 3 and Appendix 8 of the EA Amendment Report.

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. In addition 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 1.

Table 1: 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 development property boundary),
	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).

Aspect	Score	Definition
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), or
	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 2.

Table 2: 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 3: Determination of environmental risk

Consequence	Probability 1	Probability 2	Probability 3	Probability 4	Probability 5
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

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 4.

Table 4: Significance classes

Risk Score	Description
1	Negligible (i.e. where impact has an insignificant environmental risk)
>1; 3	Very Low (i.e. where the impact has a very low environmental risk)
>3; < 10	Low (i.e. where the 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).

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 5: 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 5. 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 6).

Table 6: 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 7: Environmental Significance Rating

Value	Description
0	No impact
-1	Impact occurs but is negligible
> -1 ≤ 3	Very Low negative
< -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).

2 DESCRIPTION OF THE PROPOSED PROJECT

Tosaco has applied for an Exploration Right for offshore oil and gas in Block 1, on the West Coast of South Africa. The Licence Block is situated roughly between the South African – Namibian maritime border and Hondeklipbaai (Figure 1). It is 21,000 km^2 in extent, with water depths ranging from 20 m to 750 m.

In accordance with the Exploration Works Programme the project will adopt a phased approach:

Year 1

- Review of all available technical data.
- Reprocessing of existing geological/geophysical data.
- Preliminary estimation of contingent resources.
- Prepare conceptual design and programme of future geophysical and geological exploration and appraisal.

Year 2

- Planning and preparation of possible seismic survey.

Year 3

- Possible 2D and/ or 3D seismic survey over an area of approximately 1,000 km^2.
- Processing and interpretation of seismic data.
- Evaluation and estimation of contingent resources based on new data.

The commencement of the 3D surveys will depend on an Exploration Right award date and availability of seismic contractors. It is anticipated that the 3D survey would take approximately four months to complete. In the event that the survey cannot be completed during the months when offshore seismic surveys are allowed, the survey will be completed in the following year.

The anticipated acoustic source (airgun) and hydrophone array would have an operating pressures of between 2,000 and 2,500 pound-force per square inch (psi) and a volume of 3,000 to 5,000 cubic inches. The airgun array will be towed some 80 - 150 m behind the vessel at a depth of 5 - 25 m below the surface. A 2D survey typically involves a single streamer, which would be up to 10,000 m long. The streamer would be towed at a depth of between 19 - 10 m below the surface and would not be visible, except for the tail-buoy at the far end of the cable.

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.

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 4.5 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.

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. The maximum sound pressure levels at the acoustic source in use today in the seismic industry are in the range 230-255 dB re 1 µPa at 1 m, with the majority of their produced energy being of low frequency between 10-100 Hz (McCauley 1994; NRC 2003). The location where this level of sound is attained is directly beneath the airgun array, generally near its centre, but the exact location and depth beneath the array are dependent on the detailed makeup of the array, the water depth, and the physical properties of the seafloor (Dragoset 2000). Based on analogue sound sources, sound levels for the seismic survey can notionally be expected to attenuate below 160 dB less than 1,325 m from the source array.

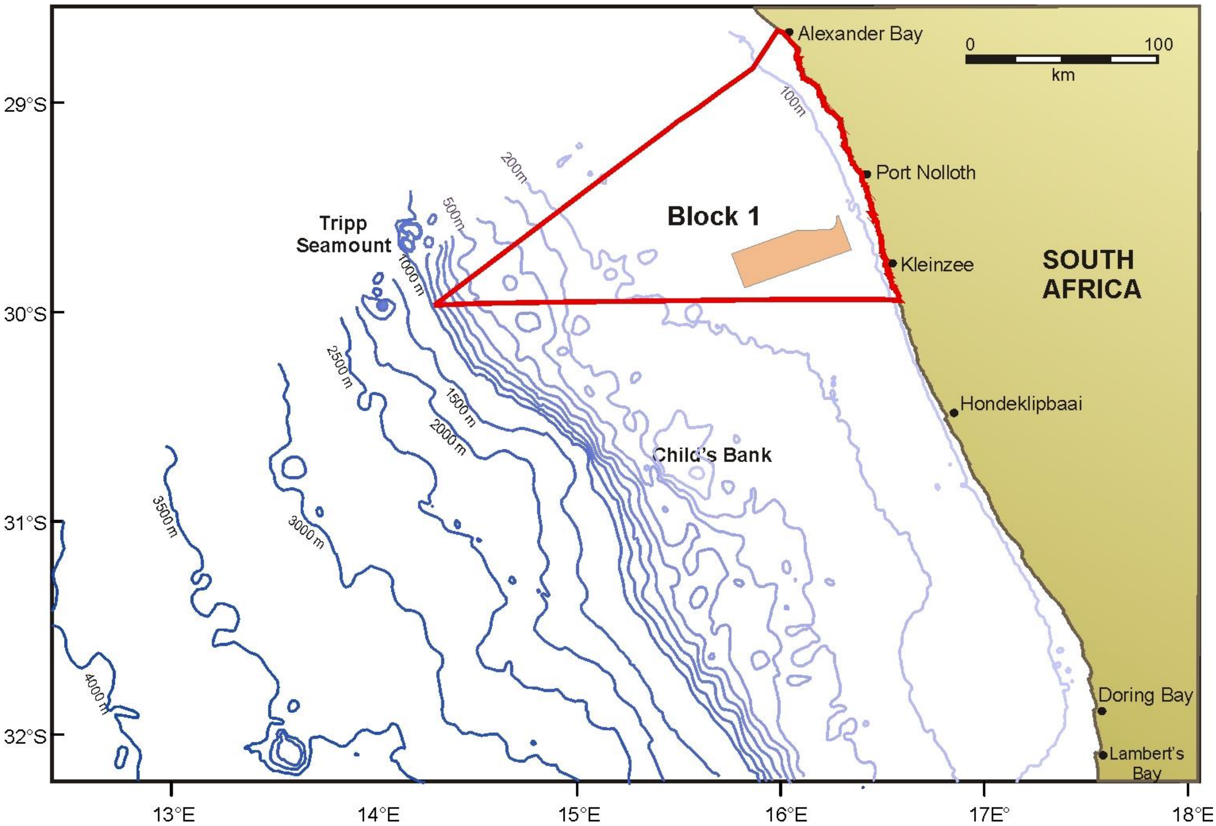

Figure 1: Map indicating location of the Block 1 and the proposed 3D survey area (orange polygon) in relation to bathymetric features off the West Coast. Places mentioned in the text are also indicated.

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 Lamberts Bay. The description of the marine environment includes the various biophysical receptors that may be affected both directly and indirectly by the project activities. The purpose of this environmental description is to provide the marine baseline environmental context within which the proposed exploration activities would take place. The summaries presented below are based on information gleaned from Lane & Carter (1999), Morant (2006), and Penney *et al.* (2007). The description of benthic macrofaunal communities was provided by Natasha Karenyi of the South African National Biodiversity Institute, and the section on marine mammals was provided by Dr Simon Elwen of the Namibian Dolphin Project and Mammal Research Institute (University of Pretoria) for other projects undertaken previously in the region. Information has been updated where necessary.

3.1 Geophysical Characteristics

3.1.1 Bathymetry

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

Banks on the continental shelf include the Orange Bank (Shelf or Cone), a shallow (160 - 190 m) zone that reaches maximal widths (180 km) offshore of the Orange River, and Child's Bank, situated ~150 km offshore at about 31°S, and ~75 km south of the Licence Block. Child's Bank is a major feature on the West Coast margin and is the only known submarine bank within South Africa's Exclusive Economic Zone (EEZ), rising from a depth of 350 - 400 m water to less than -200 m at its shallowest point. It is a rounded, flat topped, sandy plateau, which lies at the edge of the continental shelf. The bank has a gentle northern, eastern and southern margin but a steep, slump-generated outer face (Birch & Rogers 1973; Dingle *et al.* 1983; de Wet 2013). At its southwestern edge, the continental slope drops down steeply from -350 to -1 500 m over a distance of less than 60 km (de Wet 2013) creating precipitous cliffs at least 150 m high (Birch & Rogers 1973). The bank consists of resistant, horizontal beds of Pliocene sediments, similar to that of the Orange Banks, and 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 ~25 km to the west of the western point of the

[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.

Licence Block, 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.

3.1.2 Coastal and Inner-shelf Geology and Seabed Geomorphology

Figure 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 Licence Area, sediment is dominated by muddy sands and sand. The continental slope, seaward of the shelf break, has a smooth seafloor, underlain by calcareous ooze.

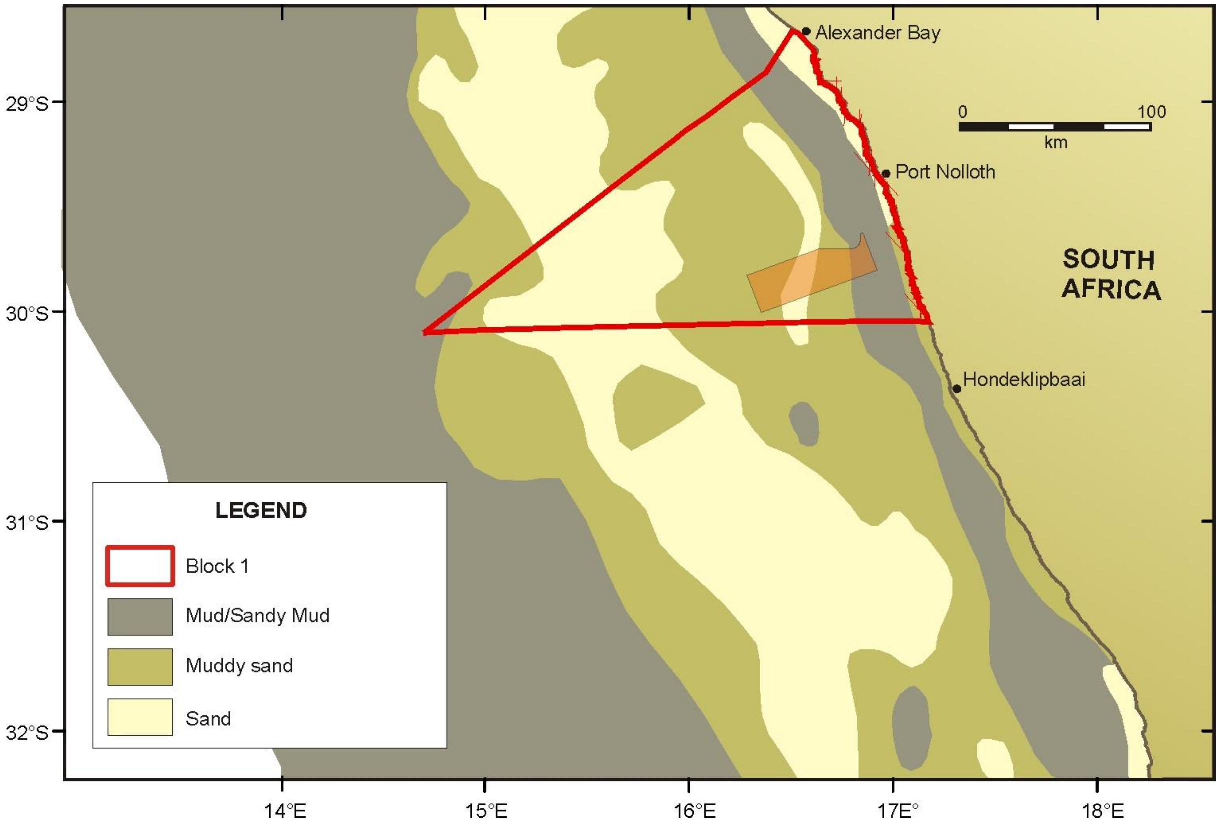

Figure 2: Sediment distribution on the continental shelf of the South African West Coast (Adapted from Rogers 1977). Based on information in Holness *et al*. (2014) and Sink *et al*. (2019), the mud/sandy mud sediments have been extended to the edge of the EEZ beyond that shown in Rogers (1977). The proposed 3D survey area is shaded orange.

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.

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).

In Block 1 the water depth ranges from approximately 20 m up to ~750 m. The Southern Benguela Muddy and Sandy Shelves substrata dominate across the block, with the deepest portions in the west being characterised by Southeat Atlantic Unclassified Slopes and a small portion of Southern Benguela Rocky Shelves. Namaqua Sandy Mid-Shelf substratum is present as a narrow band in the eastern third of the concession area and with Namaqua Mid-Shelf Fossils present in the Namaqua Fossil Forest Marine Protected Area (MPA).

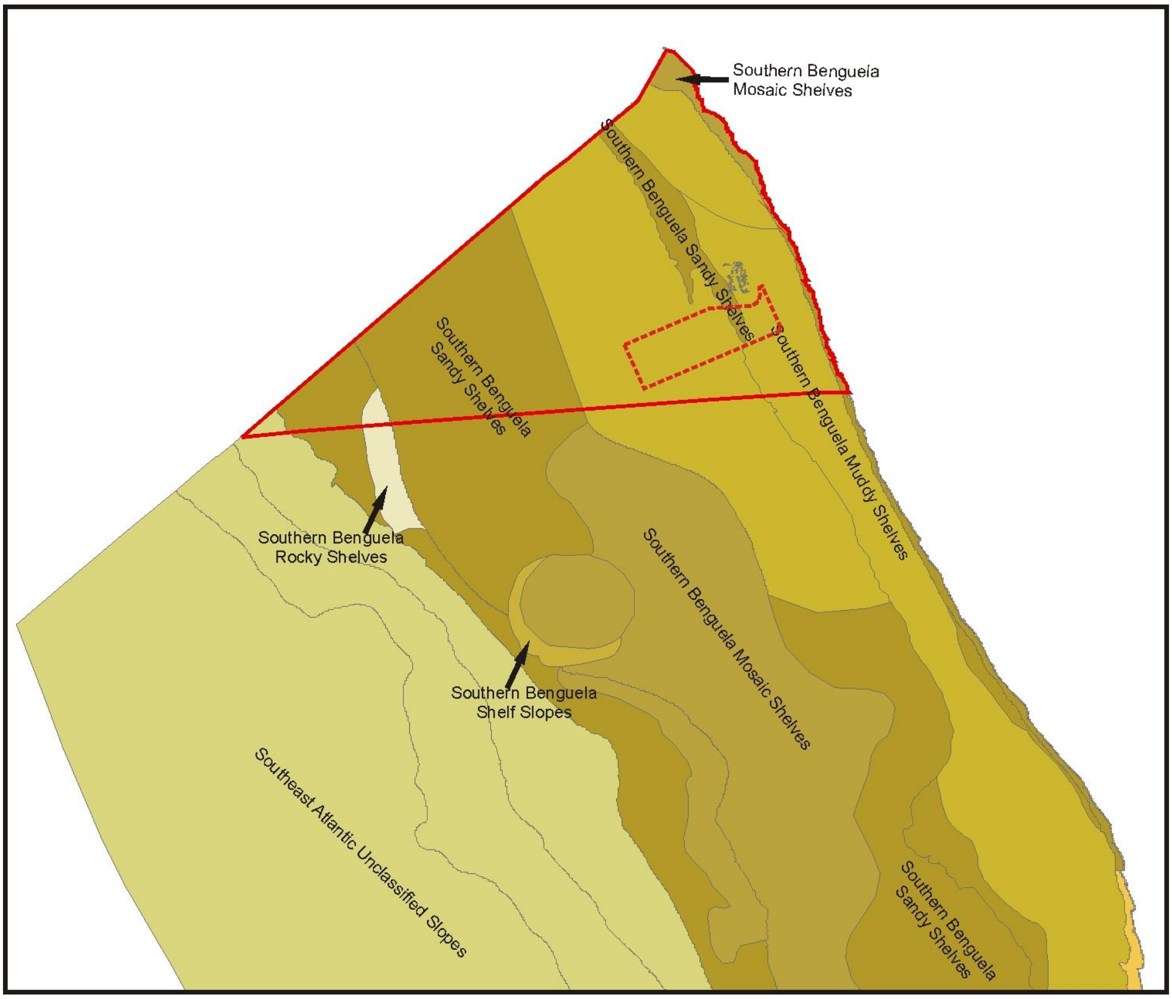

Figure 3: Block 1 (red polygon) and the proposed 3D survey area (dotted line) in relation to the distribution of seabed substratum types along the West Coast (adapted from Sink *et al*. 2019).

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 4). These southerlies occur over 40% of the time, averaging 20 – 30 kts and reaching speeds in excess of 60 kts, bringing cool, moist air into the coastal region and driving the massive offshore movements of surface water, and the resultant strong upwelling of nutrient-rich bottom waters, which characterise this region in summer. The winds also play an important role in the loss of sediment from beaches. These strong equatorwards winds are interrupted by the passing of coastal lows with which are associated periods of calm or north or northwest wind conditions. These northerlies occur throughout the year, but are more frequent in winter.

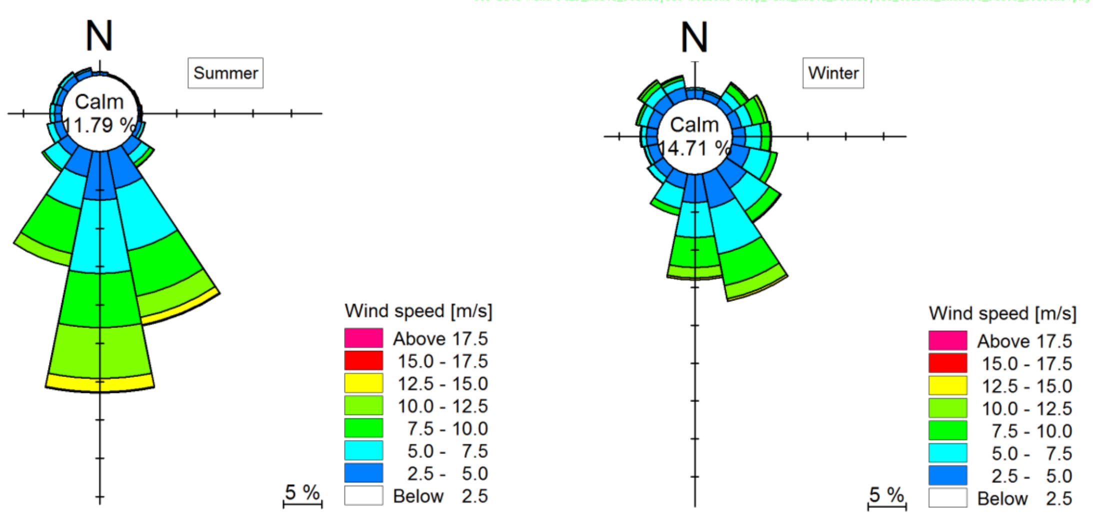

Figure 4: Wind Speed vs. Wind Direction for NCEP hind cast data at location 16.5°E, 29°S (From PRDW 2014).

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 4). 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 5).

Figure 5: Block 1 (red polygon) and proposed 3D survey area (white 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 2014). 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 2014). 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 6). 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 2014). The poleward flow becomes more consistent in the southern Benguela.

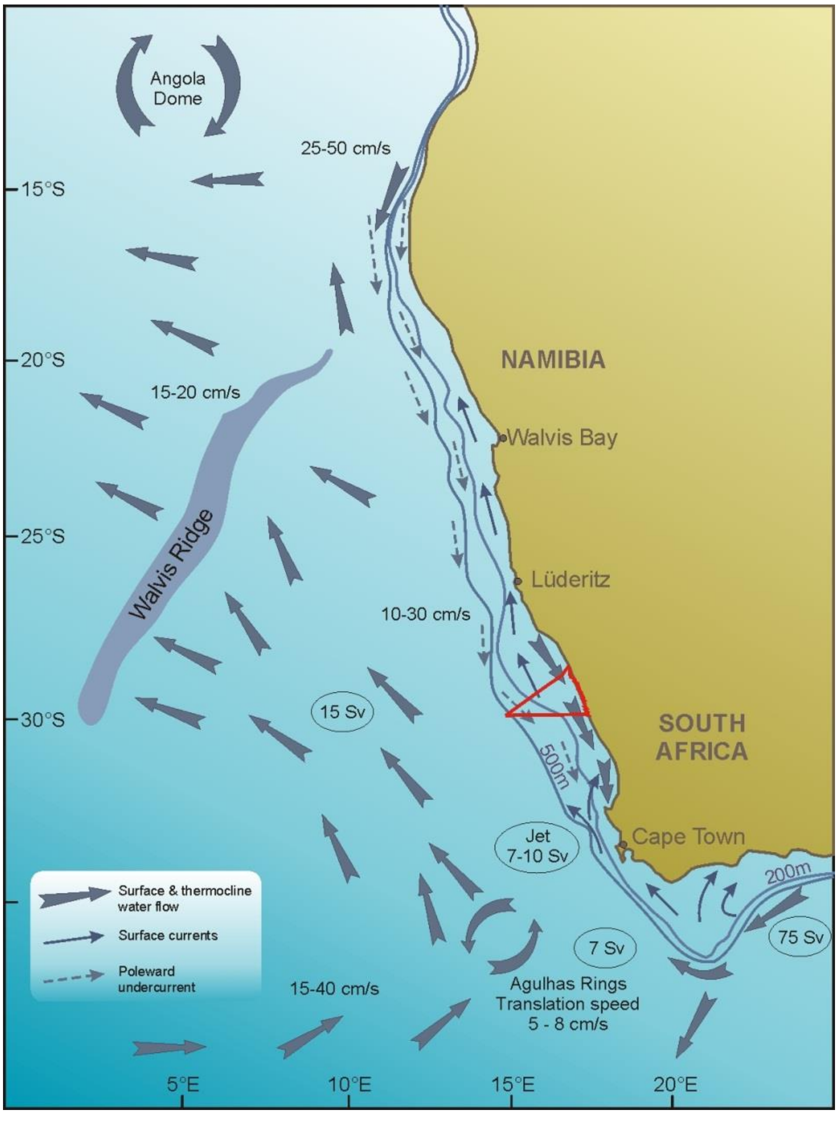

Figure 6: Major features of the predominant circulation patterns and volume flows in the Benguela System, along the southern Namibian and South African west coasts (re-drawn from Shannon & Nelson 1996).

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 7; left). Upwelling in these cells is seasonal, with maximum upwelling occurring between September and March. An example of one such strong upwelling event in December 1996, followed by relaxation of upwelling and intrusion of warm Agulhas waters from the south, is shown in the satellite images in Figure 7. The Block 1 area overlaps with the Namaqua Cell, and seasonal upwelling events can be expected.

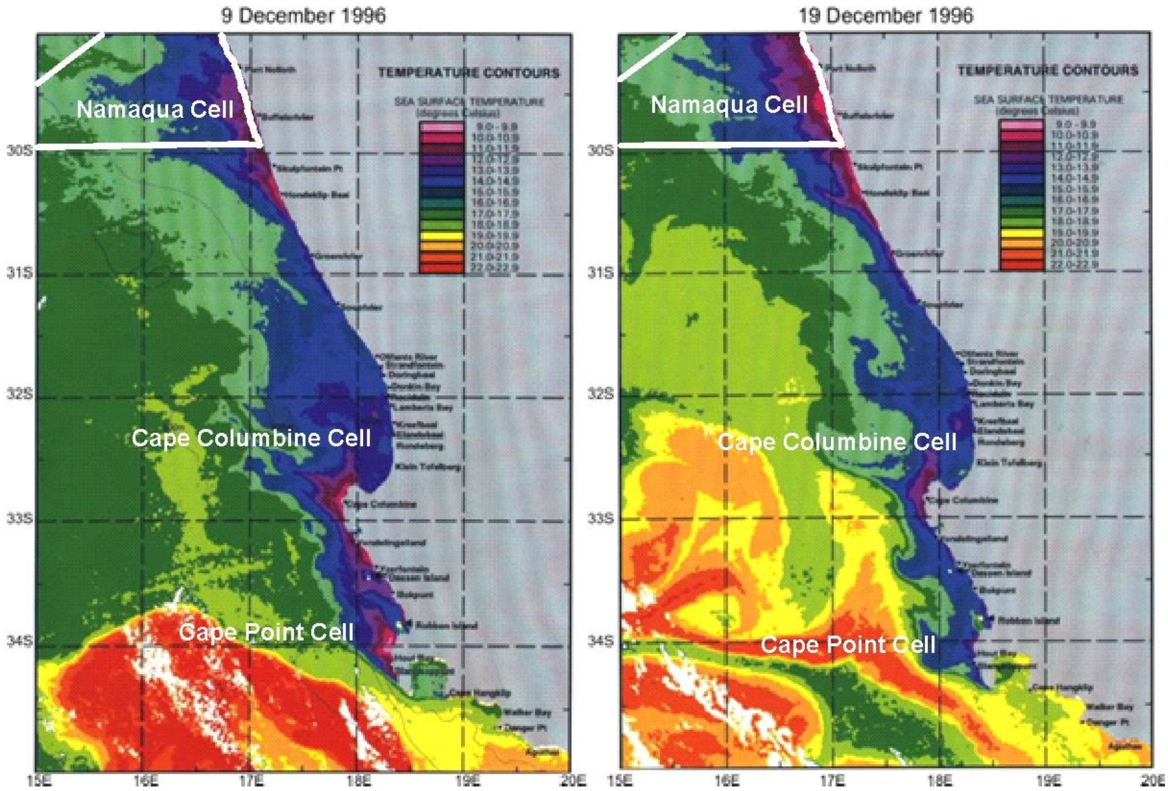

Figure 7: Satellite sea-surface temperature images showing upwelling intensity along the South African west coast on four days in December 1996 (from Lane & Carter 1999), in relation to Block 1 (white polygon).

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 7, right). 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).

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 8). The peak wave energy periods fall in the range 9.7 – 15.5 seconds.

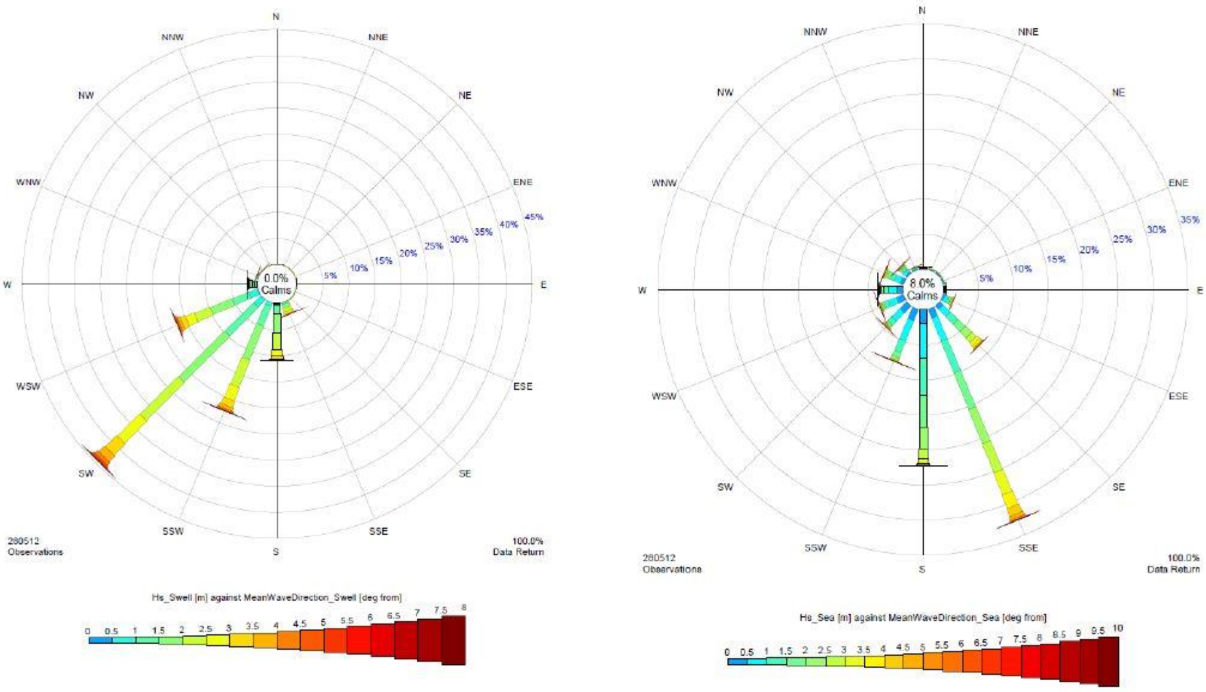

Figure 8: Annual roseplots of significant wave height partitions of swell (left) and wind-sea (right) for GROW1012 hind cast data at location 15°E, 31°S.

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.

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

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. Block 1 is located within the Namaqua upwelling cell and waters are expected to be cold and nutrient rich (see Figure 7).

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 to the Benguela system are red tides (dinoflagellate and/or ciliate blooms) (see Shannon & Pillar 1985; Pitcher 1998). Also referred to as Harmful Algal Blooms (HABs), these red tides can reach very large proportions, extending over several square kilometres of ocean (Figure 9, left). Toxic dinoflagellate species can cause extensive mortalities of fish and shellfish through direct poisoning, while degradation of organic-rich material derived from both toxic and non-toxic blooms results in oxygen depletion of subsurface water (Figure 9, right). Being associated primarily with upwelling cells, HABs could occur in Block 1.

Figure 9: 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 February 2002 (Right, Photo: www.waterencyclopedia.com)

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 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.

Periodic low oxygen events in the nearshore region can have catastrophic effects on the marine communities leading to large-scale stranding of rock lobsters, and mass mortalities of marine biota and fish (Newman & Pollock 1974; Matthews & Pitcher 1996; Pitcher 1998; Cockcroft *et al.* 2000). The development of anoxic conditions as a result of the decomposition of huge amounts of organic matter generated by phytoplankton blooms is the main cause for these mortalities and walkouts. The blooms develop over a period of unusually calm wind conditions when sea surface temperatures 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 (see Figure 5). 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 offshore portions of Block 1 are thus expected to be comparatively clear.

3.3 The Biological Environment

Biogeographically, the study area falls into the cold temperate Namaqua Bioregion, which extend from Sylvia Hill, north of Lüderitz in Namibia to Cape Columbine (Emanuel *et al.* 1992; Lombard *et al.* 2004).. Block 1 fall within the Southern Benguela Ecoregion (Sink *et al.* 2019) (

Figure 10), which extends from Namibia to the southern tip of the Agulhas Bank. 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.

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 10: Block 1 (red outline) and proposed 3D survey area (white polygon) in relation to the inshore and offshore ecoregions of the South African West Coast (adapted from Sink *et al*. 2019).

3.3.1 Demersal Communities

3.3.1.1 Benthic Invertebrate Macrofauna

The seabed communities in Block 1 lie within the Namaqua sub-photic and continental slope biozones, which extend from a 30 m depth to the shelf edge. 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 11) and assigned an ecosystem threat status based on their level of protection (Figure 12). Block 1 is characterised by numerous ecosystem types, namely, Orange Cone Inner Shelf Mud Reef Mosaic, Orange Cone Muddy Mid-Shelf, Namaqua Muddy Mid-Shelf Mosaic, Namaqua Sandy Mid-Shelf, Namaqua Muddy Sands, Southern Benguela Sandy Outer Shelf and Southern Benguela Rocky and Sandy Shelf Edge (Sink *et al.* 2019).

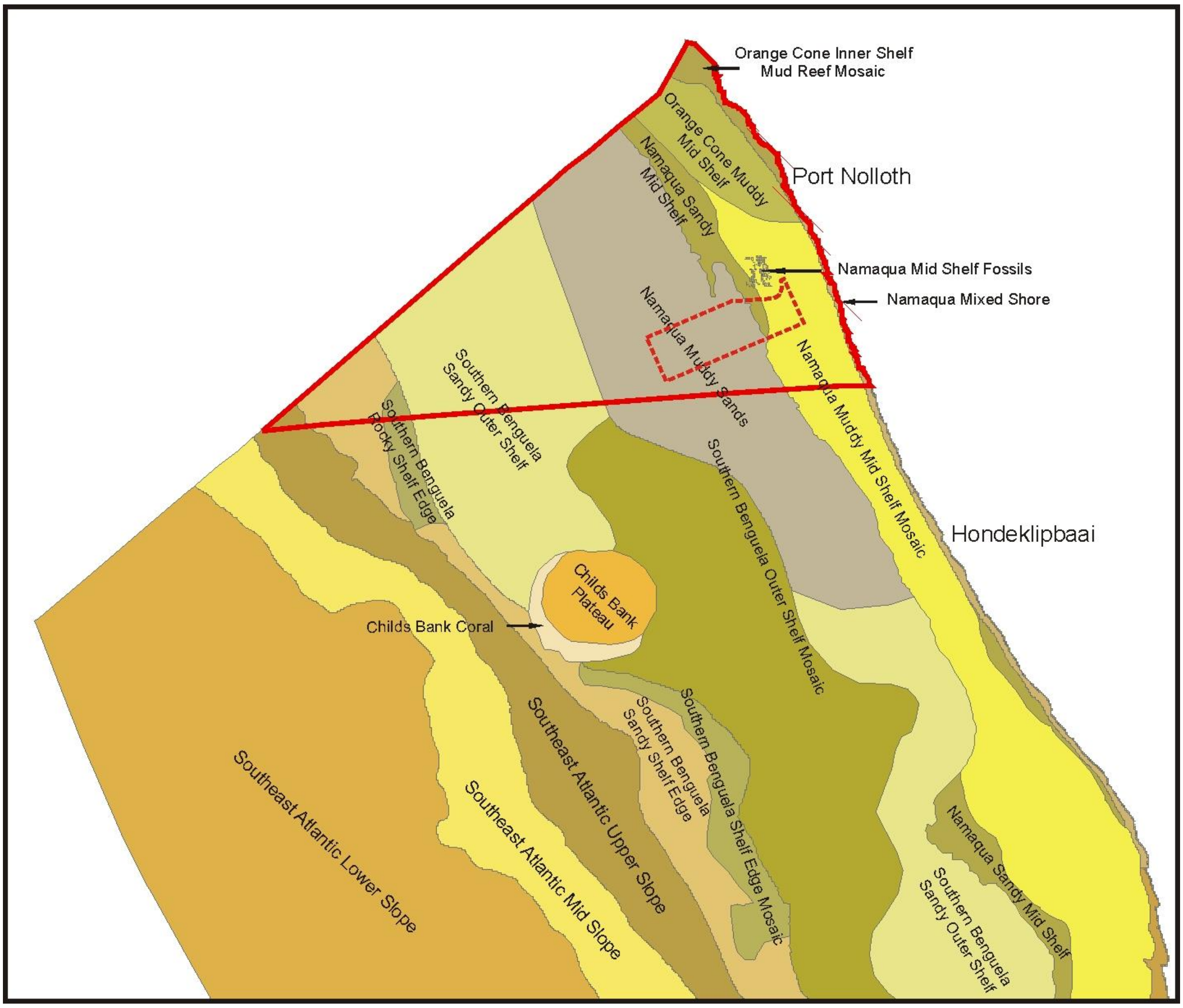

Figure 11: Block 1 (red polygon) and proposed 3D survey area (dotted line) in relation to the distribution of ecosystem types along the West Coast (adapted from Sink *et al.* 2019).

The benthic biota of unconsolidated marine sediments constitute invertebrates that live on (epifauna) or burrow within (infauna) the sediments, and are generally divided into macrofauna (animals >1 mm) and meiofauna (<1 mm). Numerous studies have been conducted on southern African West Coast continental shelf benthos, mostly focused on mining, pollution or demersal trawling impacts (Christie & Moldan 1977; Moldan 1978; Jackson & McGibbon 1991; Field *et al.* 1996; Field & Parkins 1997; Parkins & Field 1998; Pulfrich & Penney 1999; Goosen *et al.* 2000; Savage *et al.* 2001; Steffani & Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b; Atkinson 2009; Steffani 2009a, 2009b, 2010a, 2010b, 2010c; Atkinson *et al.* 2011; Steffani 2012a, 2012b, 2014; Karenyi 2014; Steffani *et al.* 2015; Biccard & Clark 2016; Biccard *et al.* 2016; Duna *et al.* 2016; Karenyi *et al.* 2016; Biccard *et al.* 2017, 2018; Gihwala *et al.* 2018; Biccard *et al.*2019; Giwhala *et al.* 2019). These studies, however, concentrated on the continental shelf and nearshore regions, and consequently the benthic fauna of the outer shelf and continental slope (beyond ~450 m depth) are very poorly known. This is primarily due to limited opportunities for sampling as well as the lack of access to Remote Operated Vehicles (ROVs) for visual sampling of hard substrata.

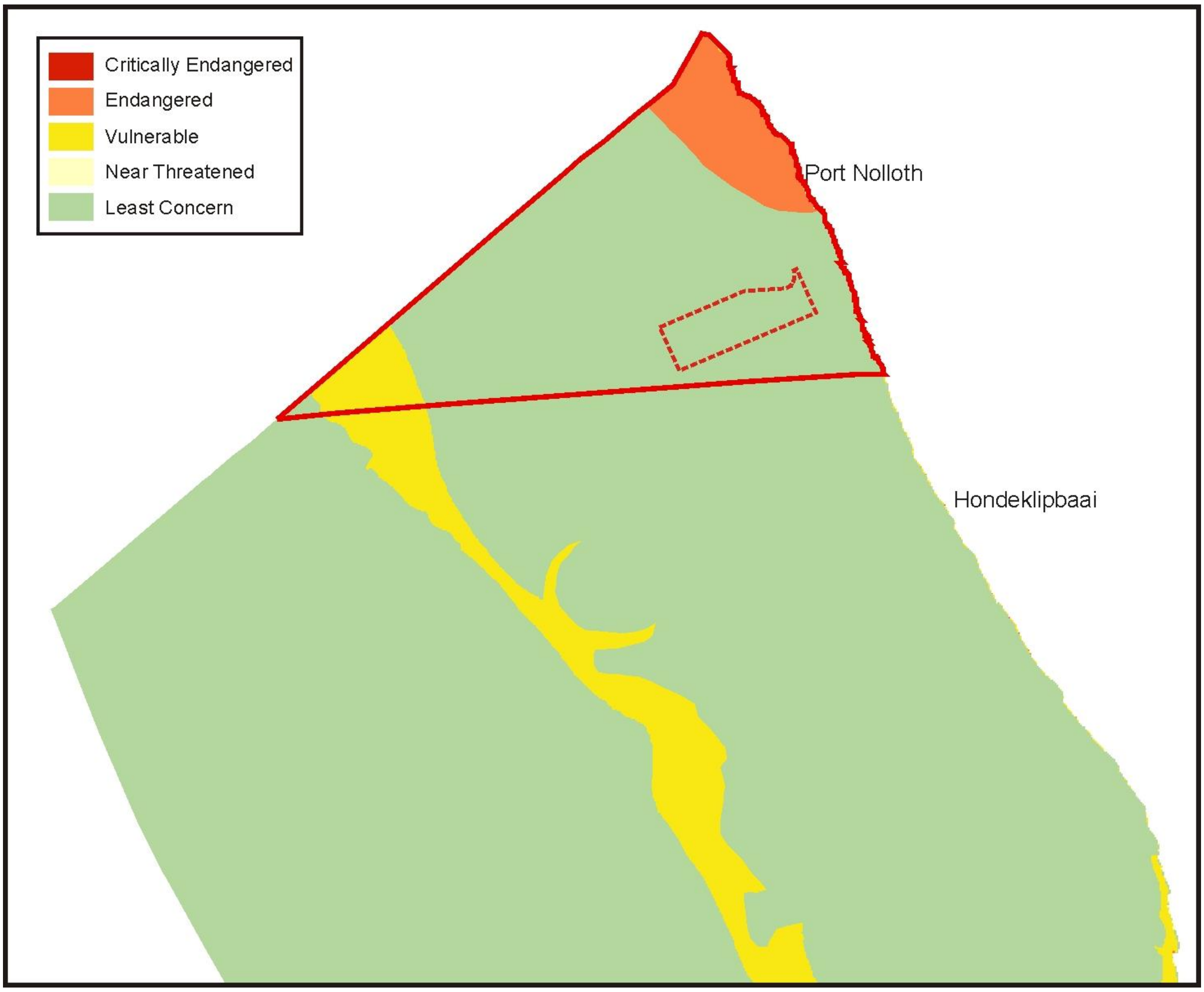

Figure 12: Block 1 (red outline) and proposed 3D survey area (dotted line) in relation to the ecosystem threat status for coastal and offshore benthic and pelagic habitat types on the South African West Coast (adapted from Sink *et al.* 2019).

To date very few areas on the continental slope off the West Coast have been biologically surveyed. Although sediment distribution studies (Rogers & Bremner 1991) suggest that the outer shelf is characterised by unconsolidated sediments (see Figure 2), recent surveys conducted between 180 m and 480 m depth revealed high proportions of hard ground rather than unconsolidated sediment, although this requires further verification (Karenyi unpublished data).

The description below from the continental shelf of the project area 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).

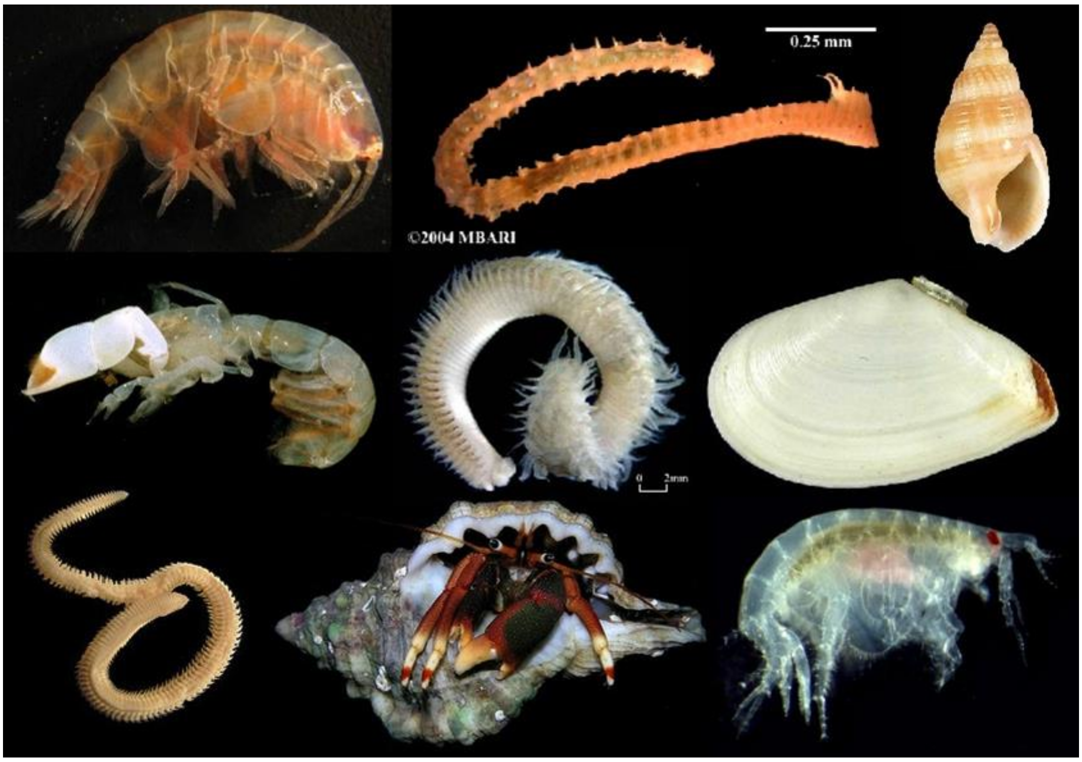

Figure 13: Benthic macrofaunal genera commonly found in nearshore sediments include: (top: left to right) *Ampelisca*, *Prionospio*, *Nassarius*; (middle: left to right) *Callianassa*, *Orbinia*, *Tellina*; (bottom: left to right) *Nephtys*, hermit crab, *Bathyporeia*.

Despite the current lack of knowledge of the community structure and endemicity of South African macro-infauna on the continental shelf, the marine component of the 2018 National Biodiversity Assessment (Sink *et al.* 2019), rated the habitat types that characterise most of Block 1 as being of 'Least concern' (Figure 12). The proposed 3D seismic survey area lies within habitat types considered of 'Least Concern'. This primarily reflects the great extent of these habitats in the South African Exclusive Economic Zone (EEZ). However, those communities occurring along the shelf edge (-500 m) in the western extreme of the Block have been rated as 'Vulnerable', and the Orange Cone Muddy Mid-Shelf and Inner Shelf Mud Reef Mosaic, which lie in the northern corner of the Block are considered 'Endangered' (Sink *et al.* 2019).

Generally species richness increases from the inner-shelf across the mid-shelf and is influenced by sediment type. The highest total abundance and species diversity was measured in sandy sediments of the mid-shelf. Biomass is highest in the inshore (± 50 g/m^2 wet weight) and decreases across the mid-shelf averaging around 30 g/m^2 wet weight. This is contrary to Christie (1974) who found that biomass was greatest in the mudbelt at 80 m depth off Lamberts Bay, where the sediment characteristics and the impact of environmental stressors (such as low oxygen events) are likely to differ from those off the northern Namaqualand coast.

Benthic communities are structured by the complex interplay of a large array of environmental factors. Water depth and sediment grain size are considered the two major factors that determine benthic community structure and distribution on the South African west coast (Christie 1974, 1976; Steffani & Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b) and elsewhere in the world (e.g. Gray 1981; Ellingsen 2002; Bergen *et al*. 2001; Post *et al*. 2006). However, studies have shown that 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.

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

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.

3.3.1.2 Deep-water coral communities

There has been increasing interest in deep-water corals in recent years because of their likely sensitivity to disturbance and their long generation times. These benthic filter-feeders generally occur at depths below 150 m with some species being recorded from as deep as 3,000 m. Some species form reefs while others are smaller and remain solitary. Corals add structural complexity to otherwise uniform seabed habitats thereby creating areas of high biological diversity (Breeze *et al*.

1997; MacIssac *et al.* 2001). Deep water corals establish themselves below the thermocline where there is a continuous and regular supply of concentrated particulate organic matter, caused by the flow of a relatively strong current over special topographical formations which cause eddies to form. Nutrient seepage from the substratum might also promote a location for settlement (Hovland *et al.* 2002). Corals have been discovered associated with the Namaqua Fossil Forest and other rocky outcrop areas in 100 - 120 m depth off southern Namibia and to the south-east of Child's Bank (De Beers Marine, unpublished data) (see Section 3.3.2 below). 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.

3.3.1.3 Demersal Fish Species

Demersal fish are those species that live and feed on or near the seabed. As many as 110 species of bony and cartilaginous fish have been identified in the demersal communities on the continental shelf of the West Coast (Roel 1987). Changes in fish communities occur both latitudinally (Shine 2006, 2008; Yemane *et al.* 2015) and with increasing depth (Roel 1987; Smale *et al.* 1993; Macpherson & Gordoa 1992; Bianchi *et al.* 2001; Atkinson 2009; Yemane *et al.* 2015), with the most substantial change in species composition occurring in the shelf break region between 300 m and 400 m depth (Roel 1987; Atkinson 2009). The shelf community (<380 m) is dominated by the Cape hake *M. capensis*, and includes jacopever *Helicolenus dactylopterus*, Izak catshark *Holohalaelurus regain*, soupfin shark *Galeorhinus galeus* and whitespotted houndshark *Mustelus palumbes*. The more diverse deeper water community is dominated by the deepwater hake *Merluccius paradoxus*, monkfish *Lophius vomerinus*, kingklip *Genypterus capensis*, bronze whiptail *Lucigadus ori* and hairy conger *Bassanago albescens* and various squalid shark species. There is some degree of species overlap between the depth zones.

Roel (1987) showed seasonal variations in the distribution ranges shelf communities, with species such as the pelagic goby *Sufflogobius bibarbatus*, and West Coast sole *Austroglossus microlepis* occurring in shallow water north of Cape Point during summer only. The deep-sea community was found to be homogenous both spatially and temporally. In a more recent study, however, Atkinson (2009) identified two long-term community shifts in demersal fish communities; the first (early to mid-1990s) being associated with an overall increase in density of many species, whilst many species decreased in density during the second shift (mid-2000s). These community shifts correspond temporally with regime shifts detected in environmental forcing variables (Sea Surface Temperatures and upwelling anomalies) (Howard *et al.* 2007) and with the eastward shifts observed in small pelagic fish species and rock lobster populations (Coetzee *et al.* 2008, Cockcroft *et al.* 2008).

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

Table 8.

Table 8: 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).

Common Name	Scientific name	Depth Range (m)
Frilled shark	*Chlamydoselachus anguineus*	200-1 000
Six gill cowshark	*Hexanchus griseus*	150-600
Gulper shark	*Centrophorus granulosus*	480
Leafscale gulper shark	*Centrophorus squamosus*	370-800
Bramble shark	*Echinorhinus brucus*	55-285
Black dogfish	*Centroscyllium fabricii*	>700
Portuguese shark	*Centroscymnus coelolepis*	>700
Longnose velvet dogfish	*Centroscymnus crepidater*	400-700
Birdbeak dogfish	*Deania calcea*	400-800
Arrowhead dogfish	*Deania profundorum*	200-500
Longsnout dogfish	*Deania quadrispinosum*	200-650
Sculpted lanternshark	*Etmopterus brachyurus*	450-900
Brown lanternshark	*Etmopterus compagnoi*	450-925
Giant lanternshark	*Etmopterus granulosus*	>700
Smooth lanternshark	*Etmopterus pusillus*	400-500
Spotted spiny dogfish	*Squalus acanthias*	100-400
Shortnose spiny dogfish	*Squalus megalops*	75-460
Shortspine spiny dogfish	*Squalus mitsukurii*	150-600
Sixgill sawshark	*Pliotrema warreni*	60-500
Goblin shark	*Mitsukurina owstoni*	270-960
Smalleye catshark	*Apristurus microps*	700-1 000
Saldanha catshark	*Apristurus saldanha*	450-765
"grey/black wonder" catsharks	*Apristurus* spp.	670-1 005
Tigar catshark	*Halaelurus natalensis*	50-100
Izak catshark	*Holohalaelurus regani*	100-500
Yellowspotted catshark	*Scyliorhinus capensis*	150-500
Soupfin shark/Vaalhaai	*Galeorhinus galeus*	<10-300
Houndshark	*Mustelus mustelus*	<100
Whitespotted houndshark	*Mustelus palumbes*	>350
Little guitarfish	*Rhinobatos annulatus*	>100
Atlantic electric ray	*Torpedo nobiliana*	120-450
African softnose skate	*Bathyraja smithii*	400-1 020
Smoothnose legskate	*Cruriraja durbanensis*	>1 000
Roughnose legskate	*Crurirajaparcomaculata*	150-620
African dwarf skate	*Neoraja stehmanni*	290-1 025
Thorny skate	*Raja radiata*	50-600
Bigmouth skate	*Raja robertsi*	>1 000
Slime skate	*Raja pullopunctatus*	15-460
Rough-belly skate	*Raja springeri*	85-500
Yellowspot skate	*Raja wallacei*	70-500
Roughskin skate	*Raja spinacidermis*	1 000-1 350
Biscuit skate	*Raja clavata*	25-500

Common Name	Scientific name	Depth Range (m)
Munchkin skate	*Raja caudaspinosa*	300-520
Bigthorn skate	*Raja confundens*	100-800
Ghost skate	*Raja dissimilis*	420-1 005
Leopard skate	*Raja leopardus*	300-1 000
Smoothback skate	*Raja ravidula*	500-1 000
Spearnose skate	*Raja alba*	75-260
St Joseph	*Callorhinchus capensis*	30-380
Cape chimaera	*Chimaera* sp.	680-1 000
Brown chimaera	*Hydrolagus* sp.	420-850
Spearnose chimaera	Rhinochimaera atlantica	650-960

3.3.2 Seamount Communities

Two geological features of note in the vicinity of Block 1 are Child's Bank, situated ~75 km south of the southern boundary of Block 1 at about 31°S, and Tripp Seamount situated at about 29°40'S, ~25 km west of the western tip of Block 1. Child's Bank 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). 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.

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

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

Enhanced currents, steep slopes and volcanic rocky substrata, in combination with locally generated detritus, favour the development of suspension feeders in the benthic communities characterising seamounts (Rogers 1994). Deep- and cold-water corals (including stony corals, black corals and soft corals) (Figure 14, left) 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).

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 (Figure 14, right) 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).

Figure 14: Seamounts are characterised by a diversity of deep-water corals that add structural complexity to seabed habitats and offer refugia for a variety of invertebrates and fish (Photos: www.dfo-mpo.gc.ca/science/Publications/article/2007/21-05-2007-eng.htm, Ifremer & AWI 2003).

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

VME frameworks are typically elevated from the seabed, increasing turbulence and raising supply of suspended particles to suspension feeders (Krieger & Wing 2002; Buhl-Mortensen & Mortensen 2005; Buhl-Mortensen *et al.* 2010). Poriferans and cold-water corals further 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. South Africa's seamounts and their associated benthic communities have not been extensively sampled by either geologists or biologists (Sink & Samaai 2009). 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 15), 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 do occur on the continental shelf.

Figure 15: Gorgonians and bryozoans communities recorded on deep-water reefs (100-120 m) off the southern African West Coast (Photos: De Beers Marine).

The deep water habitats on the West Coast are thought to be characterised by a number of Vulnerable Marine Ecosystem (VME) indicator species such as sponges, soft corals and hard corals (Table 9). The distribution of 22 potential VME indicator taxa for the South African EEZ were recently mapped, with those from the northern West Coast listed in
Table 9 (Atkinson & Sink 2018; Sink *et al*. 2019).

Table 9: Table of Potential VME species from 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

3.3.3 Pelagic Communities

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

3.3.3.1 Plankton

Plankton is particularly abundant in the shelf waters off the West Coast, being associated with the upwelling characteristic of the area. Plankton range from single-celled bacteria to jellyfish of 2-m diameter, and include bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton (Figure 16).

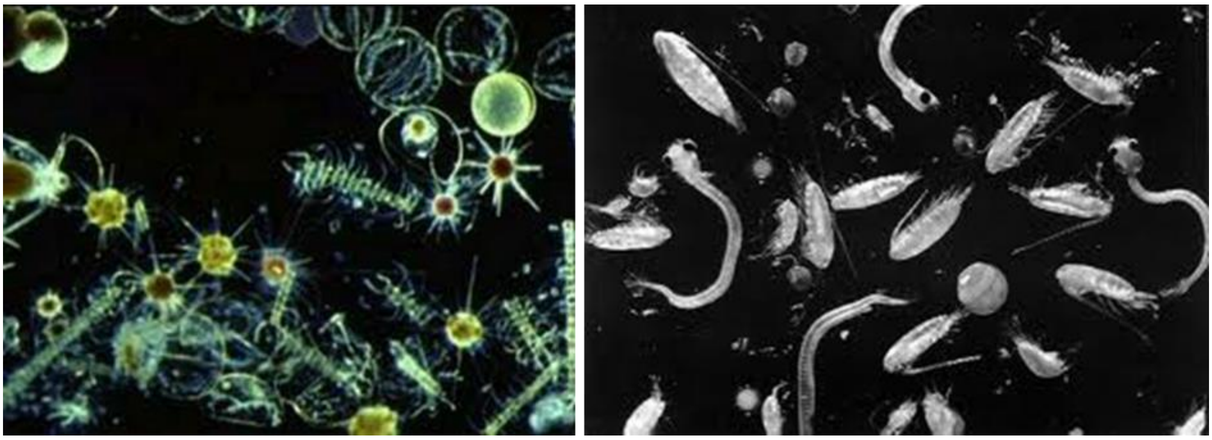

Figure 16: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

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.

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 17), and their eggs and larvae form an important contribution to the ichthyoplankton in the region. Hake, snoek and round herring move to the western Agulhas Bank and southern west coast to spawn in late winter and early spring, when offshore Ekman losses are at a minimum and their eggs and larvae drift northwards and inshore to the west coast nursery grounds. Ichthyoplankton abundance in the waters of the proposed survey area may therefore be seasonally high.

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 18, top) while the giant squid is usually found near continental and island slopes all around the world's oceans (Figure 18, bottom). Both species could thus potentially occur in the pelagic habitats of the project area, although the likelihood of encounter is extremely low.

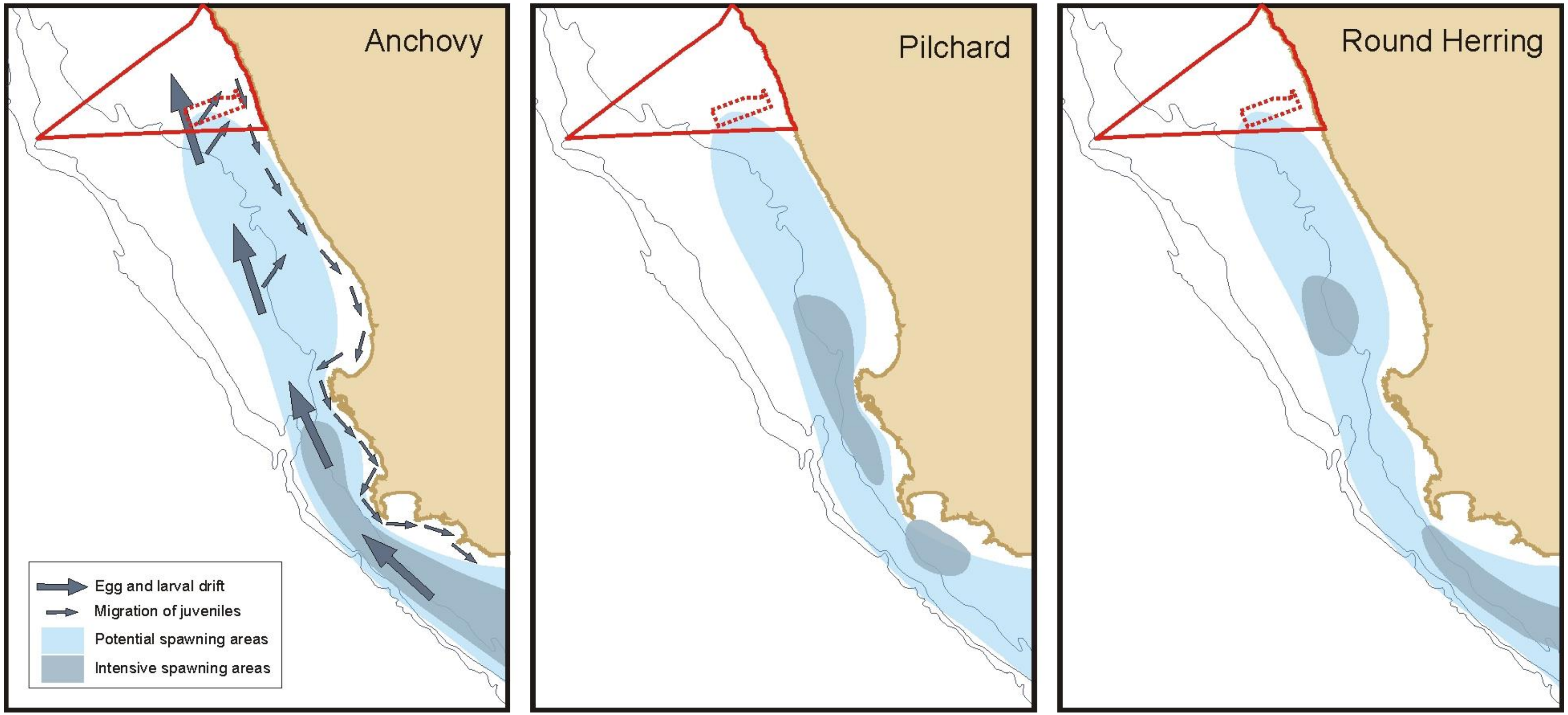

Figure 17: Block 1 (red polygon) and the proposed 3D survey area (dotted line) in relation to major spawning areas in the southern Benguela region (adapted from Cruikshank 1990).

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.

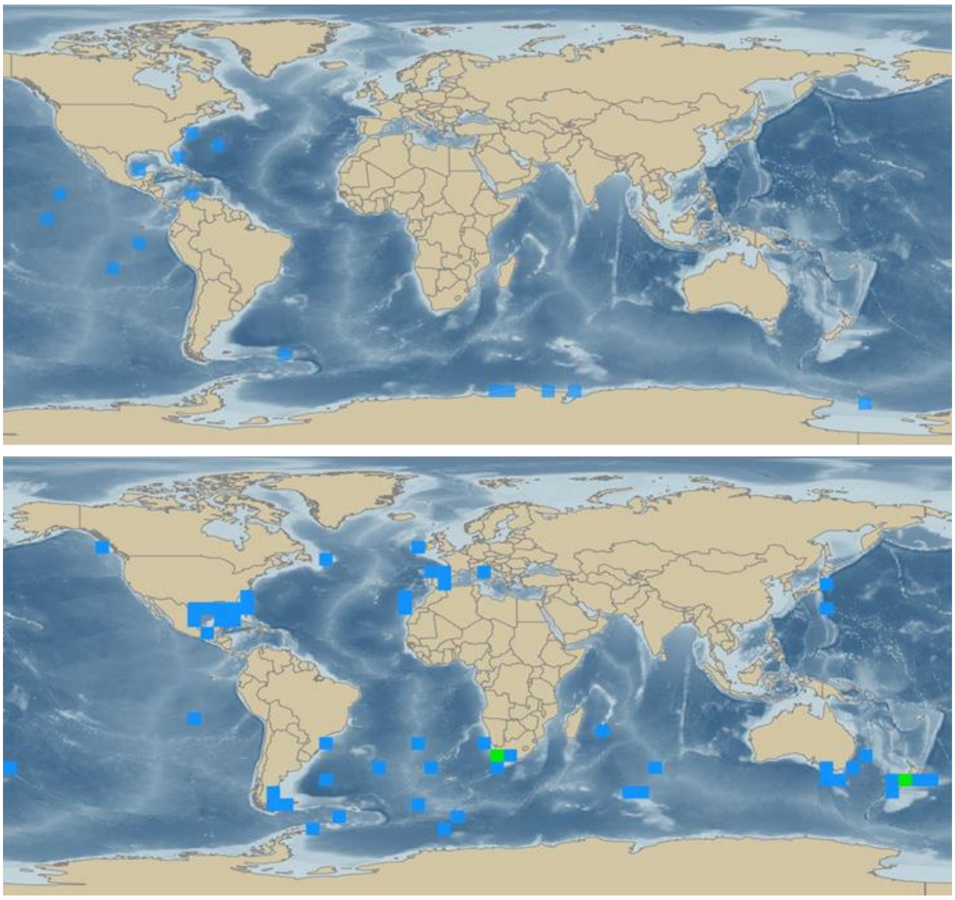

Figure 18: Distribution of the colossal squid (top) and the giant squid (bottom). Blue squares <5 records, green squares 5-10 records (Source: http://iobis.org).

3.3.3.3 Pelagic Fish

Small pelagic species include the sardine/pilchard (*Sadinops ocellatus*) (Figure 19, left), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) (Figure 19, 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. 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 17). 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 19: 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). Their appearance along the West and South-West coasts are highly seasonal. Snoek migrating along the southern African West Coast reach the area between St Helena Bay and the Cape Peninsula between May and August. They spawn in these waters between July and October before moving offshore and commencing their return northward migration (Payne & Crawford 1989). They are voracious predators occurring throughout the water column, feeding on both demersal and pelagic invertebrates and fish. Chub mackerel similarly migrate along the southern African West Coast reaching South-Western Cape waters between April and August. They move inshore in June and July to spawn before starting the return northwards offshore migration later in the year. Their abundance and seasonal migrations are thought to be related to the availability of their shoaling prey species (Payne & Crawford 1989).

The fish most likely to be encountered on the shelf and in the offshore waters of Block 1 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 10). 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.

Table 10: Some of the more important large migratory pelagic fish likely to occur in the offshore regions of the West Coast. The National and Global IUCN Conservation Status are also provided.

Common Name	Species	National Assessment	IUCN Conservation Status
Tunas			
Southern Bluefin Tuna	*Thunnus maccoyii*		Critically Endangered
Bigeye Tuna	*Thunnus obesus*	Vulnerable	Vulnerable
Longfin Tuna/Albacore	*Thunnus alalunga*	Near Threatened	Near Threatened
Yellowfin Tuna	*Thunnus albacares*	Near Threatened	Near Threatened
Frigate Tuna	*Auxis thazard*		Least concern
Eastern Little Tuna	*Euthynnus affinis*	Least concern	Least concern
Skipjack Tuna	*Katsuwonus pelamis*	Least concern	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*		Vulnerable
Dusky Shark	*Carcharhinus obscurus*	Data deficient	Vulnerable
Great White Shark	*Carcharodon carcharias*	Least concern	Vulnerable
Shortfin Mako	*Isurus oxyrinchus*	Vulnerable	Endangered
Longfin Mako	*Isurus paucus*		Vulnerable
Whale Shark	*Rhincodon typus*		Endangered
Blue Shark	*Prionace glauca*	Least concern	Near Threatened

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 20, right), yellowfin *T. albacares*, bigeye *T. obesus*, and skipjack *Katsuwonus pelamis tunas*, as well as the Atlantic blue marlin *Makaira nigricans* (Figure 20, left), the white marlin *Tetrapturus albidus* and the broadbill swordfish *Xiphias gladius* (Payne & Crawford 1989). The distributions 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 (Penney *et al.* 1992).

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.

Figure 20: Large migratory pelagic fish such as blue marlin (left) and longfin tuna (right) occur in offshore waters (photos: www.samathatours.com; www.osfimages.com).

3.3.3.4 Turtles

Three species of turtle occur along the West Coast, namely the Leatherback (*Dermochelys coriacea*) (Figure 21, left), and occasionally the Loggerhead (*Caretta caretta*) (Figure 21, right) and the Green (*Chelonia mydas*) turtle. Loggerhead and Green turtles are expected to occur only as occasional visitors along the West Coast. The most recent conservation status, which assessed the species on a sub-regional scale, is provided in Table 11.

Figure 21: Leatherback (left) and loggerhead turtles (right) occur along the West Coast of Southern Africa (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

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 south east Indian Ocean (South Africa) (Lambardi *et al*. 2008, Elwen & Leeney 2011; SASTN 2011[2]). Leatherback turtles from the east South Africa population have been satellite tracked swimming

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

around the west coast of South Africa and remaining in the warmer waters west of the Benguela ecosystem (Lambardi *et al*. 2008) (Figure 22).

Table 11: 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

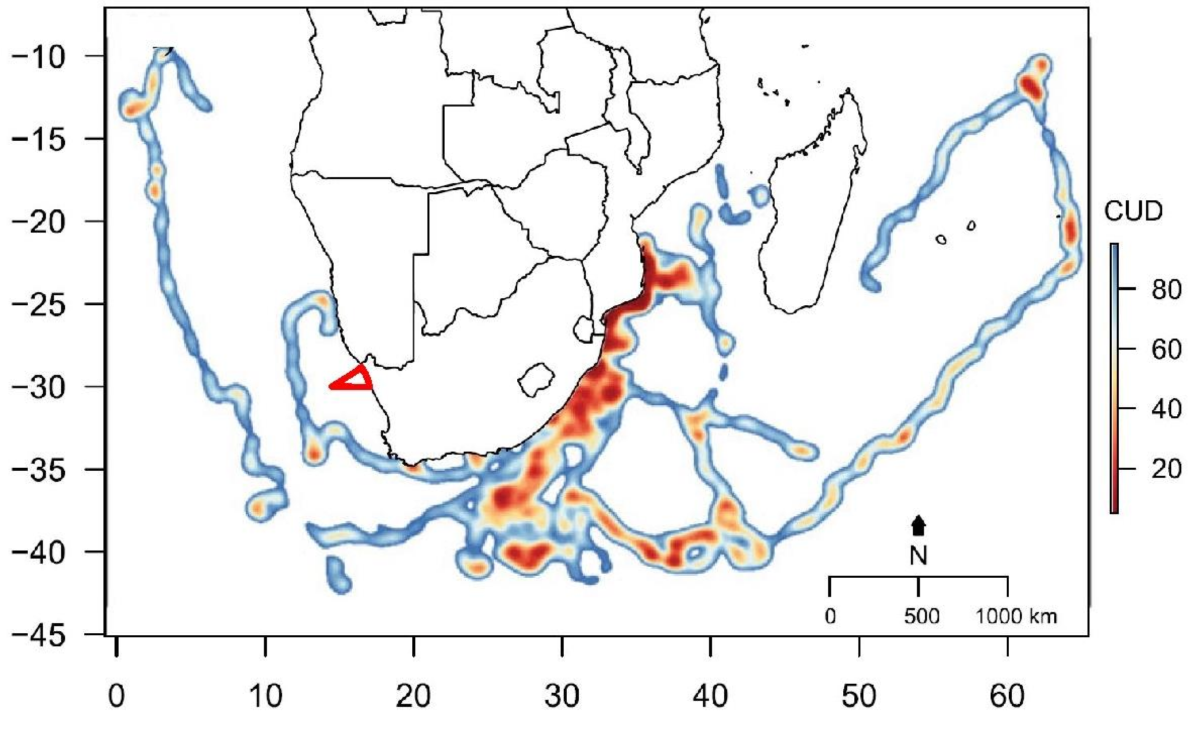

Figure 22: Block 1 (red polygon) in relation to the migration corridors of leatherback turtles in the south-western Indian Ocean. Relative use (CUD, cumulative utilization distribution) of corridors is shown through intensity of shading: light, low use; dark, high use (adapted from Harris *et al*. 2018).

Leatherback turtles inhabit deeper waters and are considered a pelagic species, travelling the ocean currents in 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. 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 12. 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), well inshore of the proposed area of interest, with highest population levels during their non-breeding season (winter). Pintado petrels and Prion spp. show the most marked variation here.

14 species of seabirds breed in southern Africa; Cape Gannet (Figure 23, left), African Penguin (Figure 23, right), four species of Cormorant, White Pelican, three Gull and four Tern species (Table 13). The breeding areas are distributed around the coast with islands being especially important. The closest breeding islands to the project area are Bird Island at Lambert's Bay (Cape Gannets) and Dassen Island (Penguins), ~255 km and 390 km south of the southern boundary of the Block, respectively, and Sinclair Island (Penguins) over 300 km to the north in Namibia. 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). The core usage areas and general distribution of post-moult African Penguins from Dassen Island extend up the West Coast to just north of the Sout River to as far as 60 km offshore (BirdLife South Africa 2021), but not as far north of Block 1. Postnatal penguins from the Southern Cape colonies have, however, been found dispersing up the West Coast north of St Helena Bay in late winter and early spring to the nursey areas of small pelagic fish (sardines and anchovies) that constitute their main prey (Sherley *et al*. 2017). Encounters with juvenile penguins could thus occur in the inshore portions of Block 1. Cape Gannets are known to forage within 200 km offshore (Dundee 2006; Ludynia 2007; Grémillet *et al*. 2008). Block 1 lies well to the north of South African West Coast gannet foraging areas and encounters are unlikely (Figure 24).

Numerous wide-ranging pelagic seabird species (Atlantic Yellow-Nosed Albatross, Great Shearwater and Northern Giant Petrel) are also known to traverse the project area (BirdLife South Africa 2021), but due to their wide distributions, numbers are likely to be low and encounters infrequent.

Figure 23: Cape Gannets *Morus capensis* (left) (Photo: NACOMA) and African Penguins *Spheniscus demersus* (right) (Photo: Klaus Jost) breed primarily on the offshore Islands.

Table 12: Pelagic seabirds common in the southern Benguela region (Crawford *et al*. 1991). IUCN Red List and Regional Assessment status are provided (Sink *et al*. 2019).

Common Name	Species name	Regional Assessment	Global IUCN
Shy Albatross	*Thalassarche cauta*	Near Threatened	Near Threatened
Wandering Albatross	*Diomedea exulans*	Vulnerable	Vulnerable
Northern Royal Albatross	*Diomedea sanfordi*	Endangered	Endangered
Black browed Albatross	*Thalassarche melanophrys*	Endangered	Least concern
Yellow-nosed Albatross	*Thalassarche chlororhynchos*	Endangered	Endangered
Grey-headed Albatross	*Thalassarche chrysostoma*	Endangered	Endangered
Giant Petrel sp.	*Macronectes halli/giganteus*	Near Threatened	Least concern
Pintado Petrel	*Daption capense*	Least concern	Least concern
Greatwinged Petrel	*Pterodroma macroptera*	Near Threatened	Least concern
Soft-plumaged Petrel	*Pterodroma mollis*	Near Threatened	Least concern
Spectacled Petrel	*Procellaria conspicillata*	Vulnerable	Vulnerable
Antarctic Prion	*Pachyptila desolata*	Least concern	Least concern
Broad-billed Prion	*Pachyptila vittata*	Least concern	Least concern
Southern Fulmar	*Fulmarus glacialoides*	Least concern	Least concern
White-chinned Petrel	*Procellaria aequinoctialis*	Vulnerable	Vulnerable
Cory's Shearwater	*Calonectris diomedea*	Least concern	Least concern
Great Shearwater	*Ardenna gravis*	Least concern	Least concern
Little Shearwater	*Puffinus assimilis*	Least concern	Least concern
Manx Shearwater	*Puffinus puffinus*	Least concern	Least concern
Sooty Shearwater	*Ardenna griseus*	Near Threatened	Near Threatened
European Storm Petrel	*Hydrobates pelagicus*	Least concern	Least concern
Leach's Storm Petrel	*Oceanodroma leucorhoa*	Critically Endangered	Vulnerable
Wilson's Storm Petrel	*Oceanites oceanicus*	Least concern	Least concern
Blackbellied Storm Petrel	*Fregetta tropica*	Near Threatened	Least concern
Subantarctic Skua	*Catharacta antarctica*	Endangered	Least concern
Sabine's Gull	*Larus sabini*	Least concern	Least concern

Table 13: Breeding resident seabirds present along the South Coast (adapted from CCA & CMS 2001). IUCN Red List and National Assessment status are provided (Sink *et al*. 2019).

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

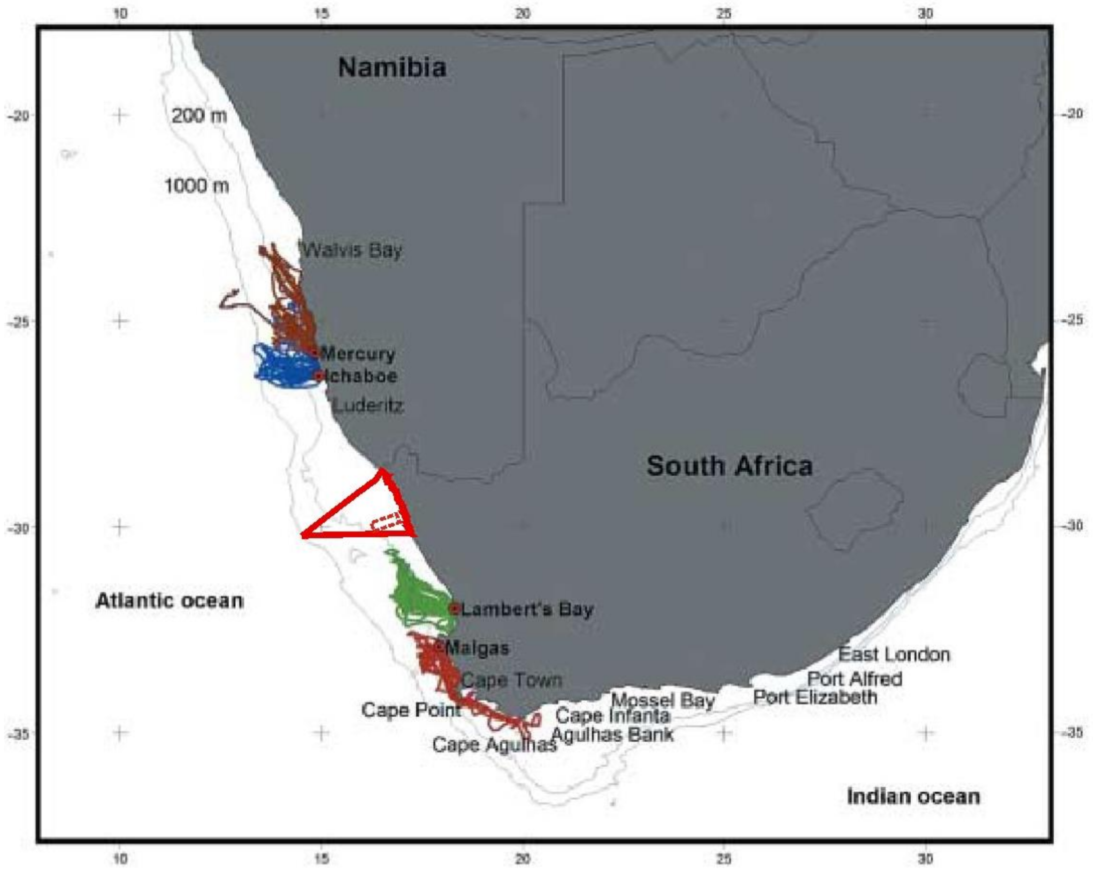

Figure 24: Block 1 (red polygon) in relation to GPS tracks recorded for 93 Cape Gannets foraging off four breeding colonies in South Africa and Namibia (adapted from Grémillet *et al*. 2008).

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 14), and their known seasonality (Table 15). 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 almost all available information from deeper waters (>200 m) arising from historic whaling records prior to 1970. Current information on the distribution, population sizes and trends of most cetacean species occurring on the west coast of southern Africa is lacking. Information on smaller cetaceans in deeper waters is particularly poor and the precautionary principal must be used when considering possible encounters with cetaceans in this 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, as well as those more commonly associated with colder waters of the west coast (e.g. dusky dolphins and long finned pilot whales) and those of the warmer east coast (e.g. striped and Risso's dolphins) (Findlay *et al.* 1992). The project area lies north of this transition zone and can be considered to be truly on the 'west coast'. However, the warmer waters that occur offshore of the Benguela ecosystem (more than ~100 km offshore) provide an entirely different habitat, that despite the relatively high latitude may host some species associated with the more tropical and temperate parts of the Atlantic such as rough toothed dolphins, Pan-tropical spotted dolphins and short finned pilot whales. 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. 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. As Block 1 is located on the continental shelf, cetacean diversity in the area can be expected to be comparatively high, with abundances also high compared to further offshore beyond the shelf. The most common species within the project area (in terms of likely encounter rate not total population sizes) are likely to be humpback whales and Heaviside's dolphins.

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

Table 14 lists the cetaceans likely to be found within the project area, based on data sourced from: Findlay *et al.* (1992), Best (2007), Weir (2011), Dr J-P. Roux, (MFMR pers. comm.) and unpublished records held by Sea Search. The majority of data available on the seasonality and distribution of

Table 14: Cetaceans occurrence off the South 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	Shelf (<200 m)	Offshore (>200 m)	Seasonality	RSA Regional Assessment	IUCN Global Assessment
Delphinids						
Dusky dolphin	*Lagenorhynchus obscurus*	Yes (0- 800 m)	No	Year round	Least Concern	Data Deficient
Heaviside's dolphin	*Cephalorhynchus heavisidii*	Yes (0-200 m)	No	Year round	Least Concern	Near Threatened
Common bottlenose dolphin	*Tursiops truncatus*	Yes	Yes	Year round	Least Concern	Least Concern
Common dolphin	*Delphinus delphis*	Yes	Yes	Year round	Least Concern	Least Concern
Southern right whale dolphin	*Lissodelphis peronii*	Yes	Yes	Year round	Least Concern	Least Concern
Striped dolphin	*Stenella coeruleoalba*	No	?	?	Least Concern	Least Concern
Pantropical spotted dolphin	*Stenella attenuata*	Edge	Yes	Year round	Least Concern	Least Concern
Long-finned pilot whale	*Globicephala melas*	Edge	Yes	Year round	Least Concern	Least Concern
Short-finned pilot whale	*Globicephala macrorhynchus*	?	?	?	Least Concern	Least Concern
Rough-toothed dolphin	*Steno bredanensis*	?	?	?		Least Concern
Killer whale	*Orcinus orca*	Occasional	Yes	Year round	Least Concern	Data deficient
False killer whale	*Pseudorca crassidens*	Occasional	Yes	Year round	Least Concern	Near Threatened
Pygmy killer whale	*Feresa attenuata*	?	Yes	?	Least Concern	Least Concern
Risso's dolphin	*Grampus griseus*	Yes (edge)	Yes	?	Data Deficient	Least Concern
Sperm whales						
Pygmy sperm whale	*Kogia breviceps*	Edge	Yes	Year round	Data Deficient	Data Deficient
Dwarf sperm whale	*Kogia sima*	Edge	?	?	Data Deficient	Data Deficient
Sperm whale	*Physeter macrocephalus*	Edge	Yes	Year round	Vulnerable	Vulnerable

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

Table 15: 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 14.

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

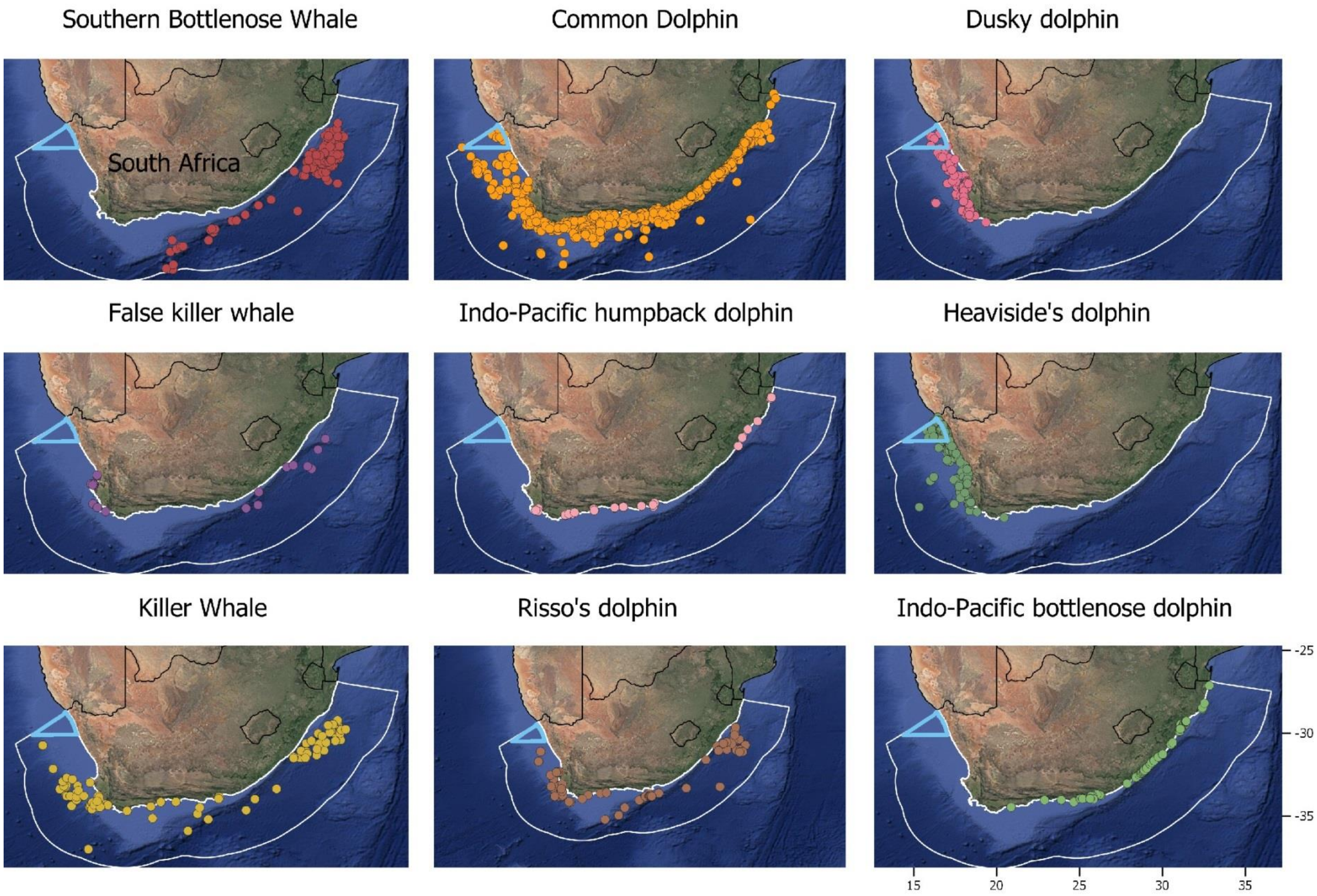

Figure 25: Block 1 (cyan polygon) in relation to projections of predicted distributions for nine odontocete species off the West Coast of South Africa (adapted from: Purdon *et al*. 2020).

large whales in the project area is the result of commercial whaling activities mostly dating from the 1960s. Changes in the timing and distribution of migration may have occurred since these data were collected due to extirpation of populations or behaviours (e.g. migration routes may be learnt behaviours). The large whale species for which there are current data available are the humpback and southern right whale, although almost all data is limited to that collected on the continental shelf close to shore.

A review of the distribution and seasonality of the key cetacean species likely to be found within the project area is provided below.

Mysticete (Baleen) whales

The majority of mysticetes whales fall into the family Balaenopeteridae. Those occurring in the area include the blue, fin, sei, Antarctic minke, dwarf minke, humpback and Bryde's whales. The southern right whale (Family Balaenidae) and pygmy right whale (Family Neobalaenidae) are from taxonomically separate groups. The majority of mysticete species occur in pelagic waters with only occasional visits to shelf waters. All of these species show some degree of migration either to or through the latitudes encompassed by the broader project area when *en route* between higher latitude (Antarctic or Subantarctic) feeding grounds and lower latitude breeding grounds. Depending on the ultimate location of these feeding and breeding grounds, seasonality may be either unimodal, usually in winter months, or bimodal (e.g. May to July and October to November), reflecting a northward and southward migration through the area. Northward and southward migrations may take place at different distances from the coast due to whales following geographic or oceanographic features, thereby influencing the seasonality of occurrence at different locations. Because of the complexities of the migration patterns, each species is discussed separately below.

Bryde's whales: Two genetically and morphologically distinct populations of Bryde's whales (Figure 26, 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 broader project area in January - March. Several strandings of adult offshore Bryde's whales in central Namibia confirm that the species passes through the project area. The "inshore population" of Bryde's, which lives on the continental shelf and Agulhas Bank, is unique amongst baleen whales in the region by being non-migratory. The published range of the population is the continental shelf and Agulhas Bank of South Africa ranging from Durban in the east to at least St Helena Bay off the west coast with possible movements further north up the West Coast and into Namibia during the winter months (Best 2007).

Sei whales: Sei whales spend time at high altitudes (40-50˚S) during summer months and migrate north through South African waters (where they were historically hunted in relatively high numbers) to unknown breeding grounds further north (Best 2007). Their migration pattern thus shows a bimodal peak with numbers west of Cape Columbine 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). Almost all information is based on whaling records 1958-1963 and there is no current information on abundance or distribution patterns in the region.

Figure 26: 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). There are no recent data on abundance or distribution of fin whales off western South Africa.

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 had been only two confirmed sightings of the species in the area since 1973 (Branch *et al*. 2007), evidence of blue whale presence off Namibia is increasing. Recent acoustic detections of blue whales in the Antarctic peak between December and January (Tomisch *et al*. 2016) and 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 in water >1 000 m deep confirm their existence in the area and occurrence in Autumn months. The chance of encountering the species in the proposed survey area is considered low.

Minke whales: Two forms of minke whale (Figure 26, 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.

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).

The most abundant baleen whales in the Benguela are southern right whales and humpback whales (Figure 27). In the last decade, both species have been increasingly observed to remain on the west coast of South Africa well after the 'traditional' South African whale season (June – November) into spring and early summer (October – February) where they have been observed feeding in upwelling zones, especially off Saldanha and St Helena Bay (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) and will therefore occur in or pass through the project area.


Figure 27: The Humpback whale *Megaptera novaeangliae* (left) and the Southern Right whale *Eubalaena australis* (right) are the most abundant large cetaceans occurring along the southern African West Coast (Photos: www.divephotoguide.com; www.aad.gov.au).

Humpback whales: The majority of humpback whales passing through the Benguela are migrating to breeding grounds off tropical west Africa, between Angola and the Gulf of Guinea (Rosenbaum *et al.* 2009; Barendse *et al.* 2010). In 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, but no clear migration 'corridor. 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). Recent abundance estimates put the number of animals in the west African breeding population to be in excess of 9 000 individuals in 2005 (IWC 2012) and it is likely to have increased since this time at about 5% per annum (IWC 2012). Since ~2011, 'supergroups' of up to 200 individual whales have been observed feeding within 10 km from shore off Dassen Island and Cape Columbine (Findlay *et al*. 2017) with many hundred more passing through the area. 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.

In the first half of 2017 (when seasonal numbers are expected to be at their lowest) more than 10 humpback whales were reported stranded along the Namibian and west South African coasts. The cause of these deaths is not known, but a similar event off Brazil in 2010 was linked to possible infectious disease or malnutrition (Siciliano *et al*. 2013), which suggests the West African population may be undergoing similar stresses and caution should be taken in increasing stress through human activities.

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). Southern right whales are seen regularly in the nearshore waters of the West Coast (<3 km from shore), extending north into southern Namibia (Roux *et al*. 2001, 2011). Southern right whales have been recorded off the West Coast in all months of the year, but with numbers peaking in winter (June - September).

In the last decade, deviations from the predictable and seasonal migration patterns of these two species have been reported from the Cape Columbine – Yzerfontein area (Best 2007; Barendse *et al*. 2010). High abundances of both southern right and humpback whales in this area during spring and summer (September-February), indicates that the upwelling zones off Saldanha and St Helena Bay may serve as an important summer feeding area (Barendse *et al*. 2011, Mate *et al*. 2011). It was previously thought that whales feed only rarely while migrating (Best *et al*. 1995), but these localised summer concentrations suggest that these whales may in fact have more flexible foraging habits.

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 25). Those in the region can range in size from 1.6-m long (Heaviside's dolphin) to 17 m (bull sperm whale).

Sperm whales: All information about sperm whales in the southern African sub-region results from data collected during commercial whaling activities prior to 1985 (Best 2007). Sperm whales are the largest of the toothed whales and have a complex, structured social system with adult males behaving differently to younger males and female groups. They live in deep ocean waters, usually greater than 1 000 m depth, although they occasionally come onto the shelf in water 500 - 200 m deep (Best 2007) (

Figure 28, 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). Sperm whales are thus likely to be encountered in relatively high numbers in deeper waters (>500 m), predominantly in the winter months (April - October). 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).

Figure 28: 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).

There are almost no data available on the abundance, distribution or seasonality of the smaller odontocetes (including the beaked whales and dolphins) known to occur in oceanic waters (>200 m) off the shelf of the southern African West Coast. Beaked whales are all considered to be true deep water species usually being seen in waters in excess of 1 000 – 2 000 m deep (see various species accounts in Best 2007). Presence in the project area may fluctuate seasonally, but insufficient data exist to define this clearly. Beaked whales seem to be particularly susceptible to man-made sounds and several strandings and deaths at sea, often *en masse,* have been recorded in association with naval mid-frequency sonar (Cox *et al*. 2006; MacLeod & D'Amico 2006) and a seismic survey for hydrocarbons also running a multi-beam echo-sounder and sub bottom profiler (Cox *et al*. 2006). Although the exact reason that beaked whales seem particularly vulnerable to man-made noise is not yet fully understood, the existing evidence clearly shows that animals change their dive behaviour in response to acoustic disturbance (Tyack *et al*. 2011), and all possible precautions should be taken to avoid causing any harm. Sightings of beaked whales in the project area are expected to be very low.

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 most frequently occur in pelagic and shelf edge waters, although their seasonality is unknown. 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. The majority of what is known about Kogiid whales in the southern African subregion results from studies of stranded specimens (e.g. Ross 1979; Findlay *et al*. 1992; Plön 2004; Elwen *et al*. 2013). *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. Abundance in Block 1 is likely to be very low.

Killer whales: Killer whales (

Figure 28, right) have a circum-global distribution being found in all oceans from the equator to the ice edge (Best 2007). Killer whales occur year round in low densities off western South Africa (Best *et al*. 2010), Namibia (Elwen & Leeney 2011) and in the Eastern Tropical Atlantic (Weir *et al*. 2010). Killer whales 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 (Best *et al*. 2014). 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.

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 melon-headed or pygmy killer whales 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).

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 (Mate *et al*. 2005; Findlay *et al*. 1992; Weir 2011). They are regularly seen associated with the shelf edge by marine mammal observers (MMOs) and 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 (Best 2007), it is likely that the vast majority of pilot whales encountered in the project area will be long-finned.

Common dolphin: The common dolphin is known to occur offshore in West Coast waters (Findlay *et al*. 1992; Best 2007), although the extent to which they occur in the project area is unknown, but likely to be low. Group sizes of common dolphins can be large, averaging 267 (± *SD* 287) for the South Africa region (Findlay *et al*. 1992). They are more frequently seen in the warmer waters offshore and to the north of the country, seasonality is not known.

Dusky dolphin: In water <500 m deep, dusky dolphins (Figure 29, 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). Although no information is available on the size of the population, they are regularly encountered in near shore waters between Cape Town and Lamberts Bay (Elwen *et al*. 2010; NDP unpubl. data) with group sizes of up to 800 having been reported (Findlay *et al*. 1992). A hiatus in sightings (or low density area) is reported between ~27°S and 30°S, associated with the Lüderitz upwelling cell (Findlay *et al*. 1992). Dusky dolphins are resident year round in the Benguela.

Heaviside's dolphins: Heaviside's dolphins (Figure 29, left) are relatively abundant in the Benguela ecosystem region with 10 000 animals estimated to live in the 400 km of coast between Cape Town and Lamberts Bay (Elwen *et al*. 2009). This species occupies waters from the coast to at least 200 m depth, (Elwen *et al*. 2006; Best 2007), and may show a diurnal onshore-offshore movement pattern (Elwen *et al*. 2010a, 2010b), but this varies throughout the species range. Heaviside's dolphins are resident year round.

Figure 29: The endemic Heaviside's Dolphin *Cephalorhynchus heavisidii* (left) (Photo: De Beers Marine Namibia), and Dusky dolphin *Lagenorhynchus obscurus* (right) (Photo: scottelowitzphotography.com).

Several other species of dolphins that might occur in deeper waters at low levels include the pygmy killer whale, Risso's dolphin, rough toothed dolphin, pan tropical 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 were never targeted commercially and their pelagic distribution makes them the most poorly studied group of cetaceans. With recorded dives of well over an hour and in excess of 2 km deep, beaked whales are amongst the most extreme divers of any air breathing animals (Tyack *et al*. 2011). They also appear to be particularly vulnerable to certain types of anthropogenic noise, although reasons are not yet fully understood. 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).

In summary, the humpback and southern right whale are likely to be encountered year-round, with numbers in the Cape Columbine area highest between September and February, and not during winter as is common on the South Coast breeding grounds. Several other large whale species are also most abundant on the West Coast during winter: fin whales peak in May-July and October-November; sei whale numbers peak in May-June and again in August-October and offshore Bryde's whale numbers are likely to be highest in January-February. Whale numbers on the shelf and in offshore waters are thus likely to be highest between October and February.

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

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 30) 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 35). Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* subantarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989).

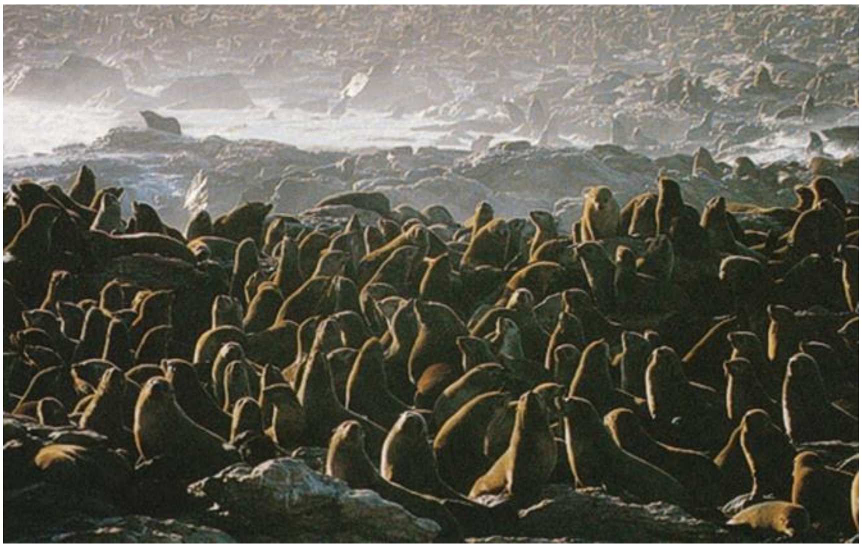

Figure 30: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich).

There are a number of Cape fur seal colonies within the study area: at Boegoeberg and Cliff Point near Alexander Bay, at Kleinzee (incorporating Robeiland), and at Strandfontein Point (south of Hondeklipbaai). The colony at Kleinzee has the highest seal population and produces the highest seal pup numbers on the South African Coast (Wickens 1994). The colony at Boegoeberg, formerly a non-breeding colony, has also attained breeding status (M. Meÿer, SFRI, pers. comm.). Non-breeding colonies and haul-out sites occur at Doringbaai south of Cliff Point, Rooiklippies, Swartduin and Noup between Kleinzee and Hondeklipbaai, and at Spoeg River and Langklip south of Hondeklip Bay. All have important conservation value since they are largely undisturbed at present. Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles offshore (Shaughnessy 1979), with bulls ranging further out to sea than females. The timing of the annual breeding cycle is very regular, occurring between November and January. Breeding success is highly dependent on the local abundance of food, territorial bulls and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen 1991).

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.

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 Environment, Forestry and Fisheries (DEFF) (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).

3.4 Other Uses of the Area

3.4.1 Beneficial Uses

3.4.1.1 Diamond Mining

The coastal area onshore of Block 1 falls within the Alexkor and West Coast Resources coastal diamond mining areas and as public access is restricted, recreational activities along the coastline between Hondeklipbaai and Alexander Bay is limited to the area around Port Nolloth.

The marine diamond mining concession areas are split into four or five zones (Surf zone and (a) to (c) or (d)-concessions), which together extend from the high water mark out to approximately 500 m depth (Figure 31). Off Namaqualand, marine diamond mining activity is primarily restricted to the surf-zone and (a)-concessions. Nearshore shallow-water mining is conducted by divers using small-scale suction hoses operating either directly from the shore in small bays or from converted fishing vessels out to ~30 m depth. However, over the past few years there has been a substantial decline in small-scale diamond mining operations due to the global recession and depressed diamond prices, although some vessels do still operate out of Alexander Bay and Port Nolloth.

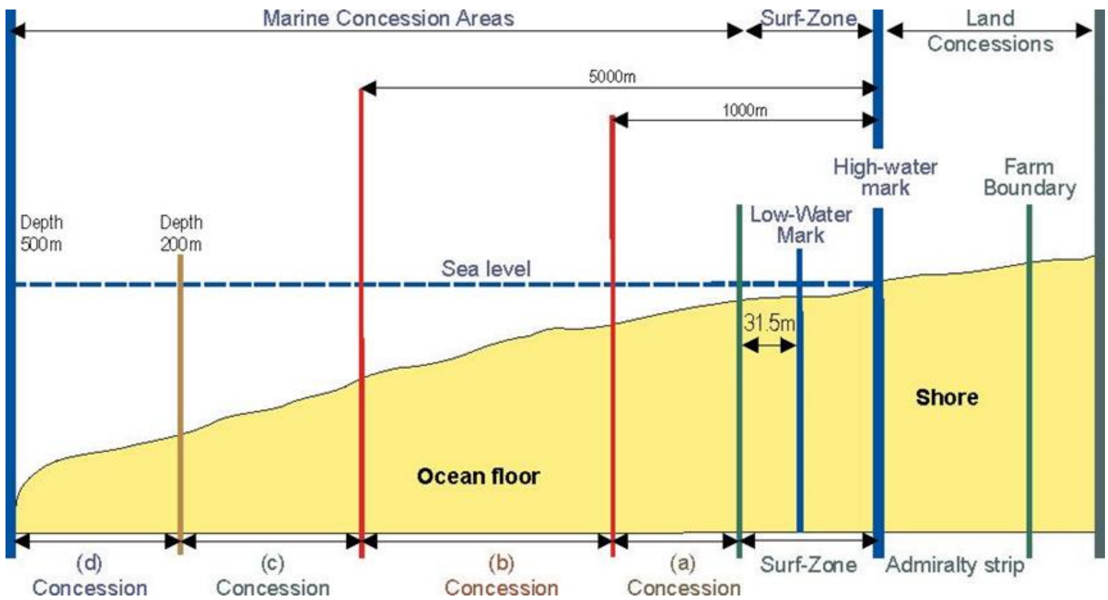

Figure 31: Diagram of the onshore and offshore boundaries of the South African (a) to (d) marine diamond mining concession areas.

Block 1 overlaps with a number of marine diamond mining concession areas (Figure 32). Deep-water diamond mining and exploration is, however, currently limited to operations by Belton Park Trading 127 (Pty) Ltd in concession 2C for mining and 3C -5C for exploration. De Beers Consolidated Mines (Pty) Ltd hold prospecting rights for diamonds, gold platinum group elements and other specific minerals in Concessions 6C – 10C and for gold and other specific minerals in Concessions 2C – 5C. There are also a number of proposed prospecting areas for glauconite and phosphorite/phosphate, all of which are located south of Block 1. In Namibia, deep-water diamond mining by De Beers Marine Namibia is currently operational in the Atlantic 1 Mining Licence Area.

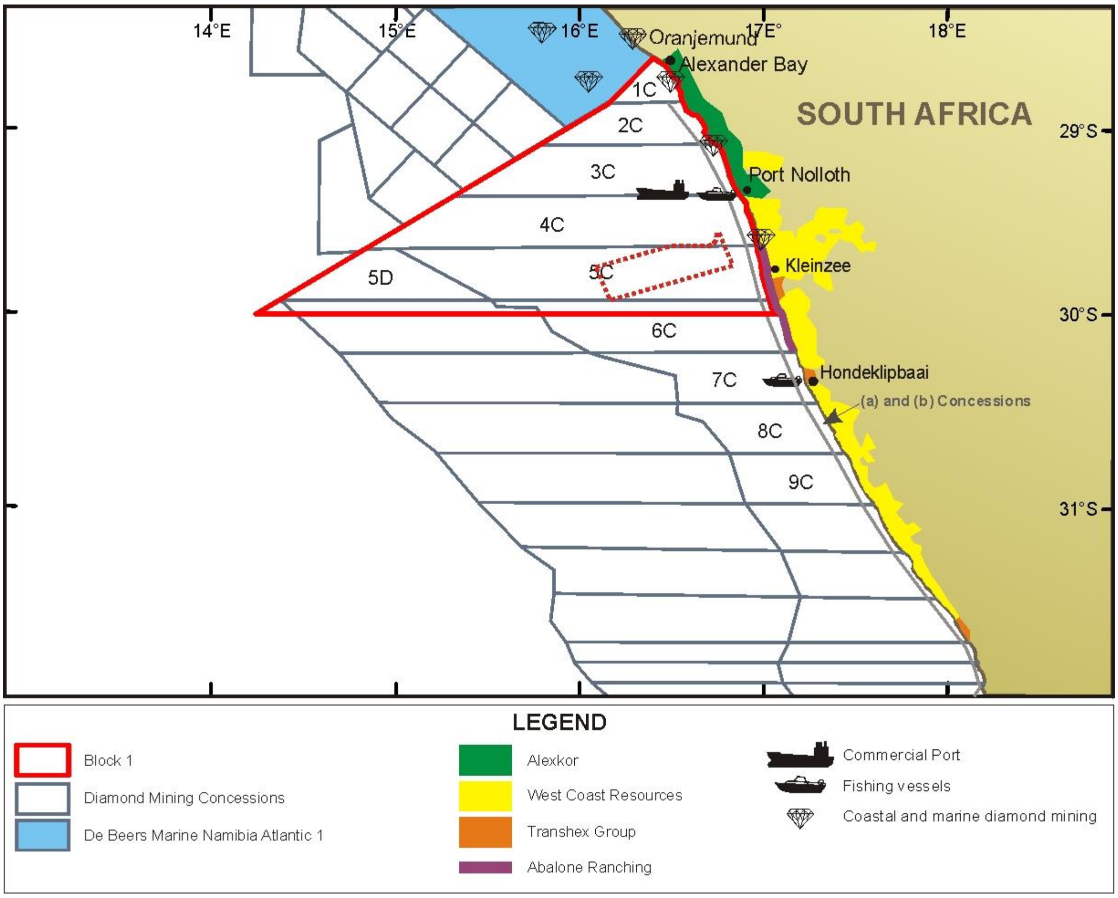

Figure 32: Project - environment interaction points on the West Coast, illustrating the location of Block 1 and the proposed 3D survey area in relation to marine diamond mining concessions and ports for commercial and fishing vessels.

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 33). 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. None of these activities should in any way be affected by exploration drilling activities offshore.

Figure 33: Typical crawler-vessel (left) and drillship (right) operating in the Atlantic 1 Mining Licence Area (Photos: De Beers Marine).

3.4.1.2 Development Potential of the Marine Environment in the Project Area

The economy of the Namaqualand region is dominated by mining. However, with the decline in the mining industry and the closure of many of the coastal mines, the economy of the region is declining and jobs are being lost with potential devastating socio-economic impacts on the region. The Northern Cape provincial government has recognized the need to investigate alternative economic activities to reduce the impact of minerals downscaling and has commissioned a series of baseline studies of the regional economy (Britz & Hecht 1997, Britz *et al*. 1999, 2000, Mather 1999). These assessments concluded that fishing and specifically mariculture offer a significant opportunity for long term (10+ years) sustainable economic development along the Namaqualand coast. The major opportunities cited in these studies include hake and lobster fishing (although the current trend in quota reduction is likely to limit development potentials), seaweed harvesting and aquaculture of

abalone, seaweeds, oysters and finfish. The Northern Cape provincial government is facilitating the development of the fishing and mariculture sectors by means of a holistic sector planning approach and has in partnership with a representative community and industry based Fishing and Mariculture Development Association (FAMDA), developed the Northern Cape Province Fishing and Mariculture Sector Plan. This plan forms part of the 'Northern Cape - Fishing and Mariculture Sector Development Strategy' (www.northern-cape.gov.za, accessed December 2013) whereby implementation of the plan will be coordinated and driven by FAMDA.

Abalone ranching (i.e. the release of abalone seeds into the wild for harvesting purposes after a growth period) has been identified as one of the key opportunities to develop in the short- to medium-term and consequently the creation of abalone ranching enterprises around Hondeklip Bay and Port Nolloth forms part of the sector plan's development targets (www.northern-cape.gov.za). In the past, experimental abalone ranching concessions have been granted to Port Nolloth Sea

Farms (PNSF) in Sea Concession areas 5 and 6, effectively a 60 km strip of coastline (see Figure 32), and to Ritztrade in the Port Nolloth area (www.northern-cape.co.za). These experimental operations have shown that although abalone survival is highly variable depending on the site characteristics and sea conditions, abalone ranching on the Namaqualand coast has the potential for a lucrative commercial business venture (Sweijd *et al.* 1998, de Waal 2004). As a result, the government publication 'Guidelines and potential areas for marine ranching and stock enhancement of abalone *Haliotis midae* in South Africa' (GG No. 33470, Schedule 2, April 2010) identified broad areas along the South African coastline that might be suitable for abalone ranching. Along the Northern Cape coast, four specific zones were marked, separated by 6-13 km wide buffer zones. Currently, applications for abalone ranching projects have been submitted and permits for pilot projects for some of the zones have been granted.

Besides abalone sea-ranching, several other potential projects were identified in the sector plan. Most of these are land-based aquaculture projects (e.g. abalone and oyster hatcheries in Port Nolloth and abalone grow-out facility in Hondeklip Bay), but included was a pilot project to harvest natural populations of mussels and limpets in the intertidal coastal zone along the entire Northern Cape coast. The objective of the project was to determine the stock levels and to ascertain what percentage of the biomass of each species can be sustainably harvested, as well as the economic viability of harvesting the resource.

Other industrial uses of the marine environment include the intake of feed-water for mariculture, or diamond-gravel treatment. None of these activities should in any way be affected by offshore exploration activities.

3.4.2 Conservation Areas and Marine Protected Areas

Conservation Areas

Numerous conservation areas and a marine protected area (MPA) exist along the coastline of the Western Cape, although none fall within Block 1. The only conservation area in the vicinity of the project area in which restrictions apply is the McDougall's Bay rock lobster sanctuary near Port Nolloth, which is closed to commercial exploitation of rock lobsters.

The Orange River Mouth wetland located ~75 km to the north of the project area provides an important habitat for large numbers of a great diversity of wetland birds and is listed as a Global Important Bird Area (IBA) (ZA023/NA 019)(BirdLife International 2005). The area was designated a Ramsar site in June 1991, and processes are underway to declare a jointly-managed transboundary Ramsar reserve.

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 (Figure 34). Block 1 lies south of the Atlantic Southeast 21 marine IBA and overlaps with the candidate Orange River Mouth Wetland IBA.

Marine Protected Areas

'No-take' MPAs offering protection of the Namaqua biozones (sub-photic, deep-photic, shallow-photic, intertidal and supratidal zones) were 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

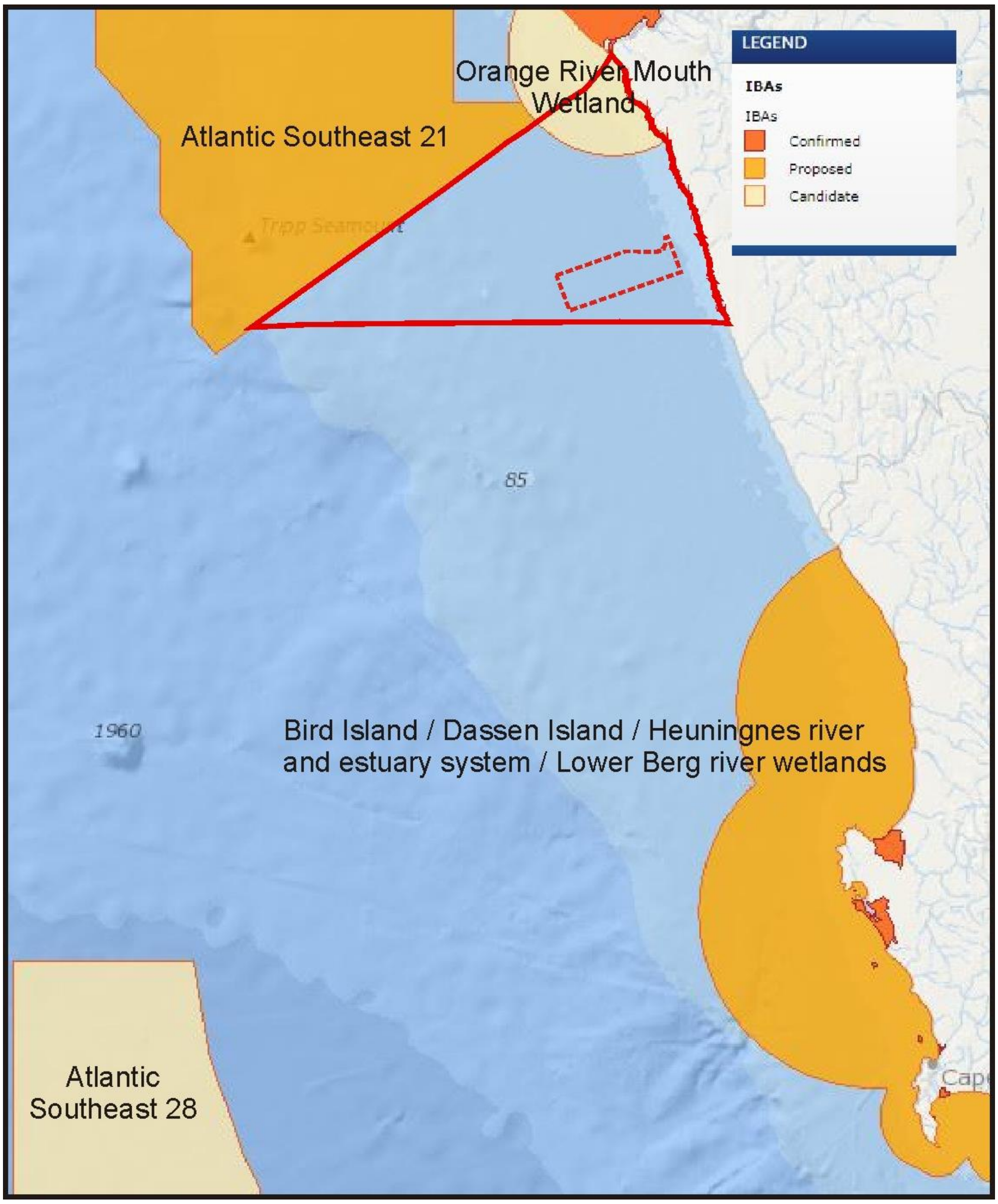

Figure 34: Block 1 in relation to coastal and marine IBAs in Namibia (Source: https://maps.birdlife.org/marineIBAs).

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 35. Block 1 overlap with the **Orange Shelf Edge and Namaqua Fossil Forest MPA** (Figure 35). The **Namaqua Fossil Forest MPA** 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.

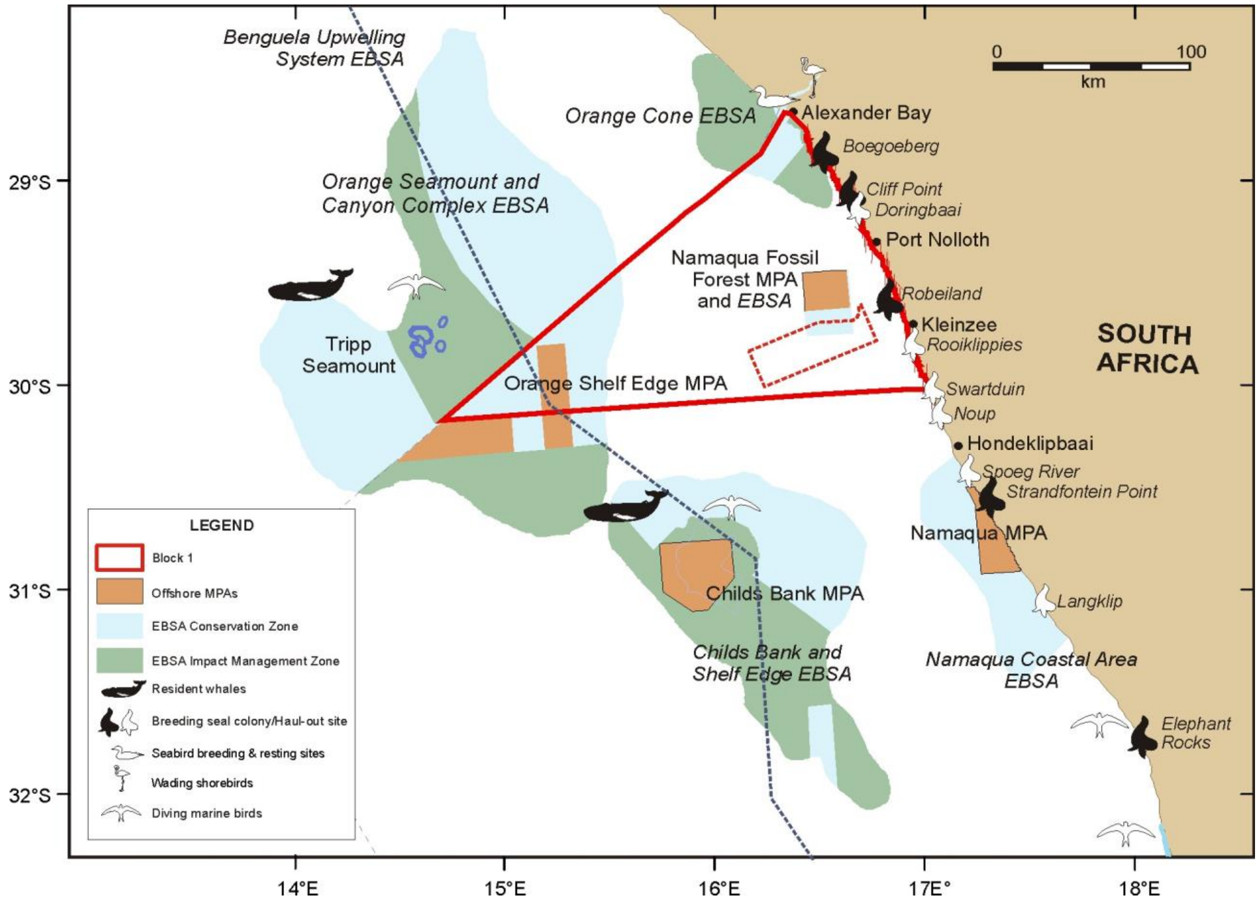

Figure 35: Block 1 (red polygon) and the proposed 3D survey area (dotted line) in relation to project - environment interaction points on the West Coast, illustrating the location of seabird and seal colonies and resident whale populations, Marine Protected Areas, and Ecologically and Biologically Significant Areas (EBSAs) and the marine spatial planning zones within these.

Other MPAs in the area are described briefly below (www.marineprotectedareas.org.za/offshore-mpas):

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 covers an area of importance for migratory species and 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 to the south of Block 1, 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 **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.

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 36). 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 Sea Concessions 4C and 5C 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, 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. Although no specific management actions have as yet been formulated for the EBSAs, they have been considered as part of the National Coastal and Marine Spatial Biodiversity Plan and the development of the Critical Biodiversity Map (CBA), which is addressed in the next section.

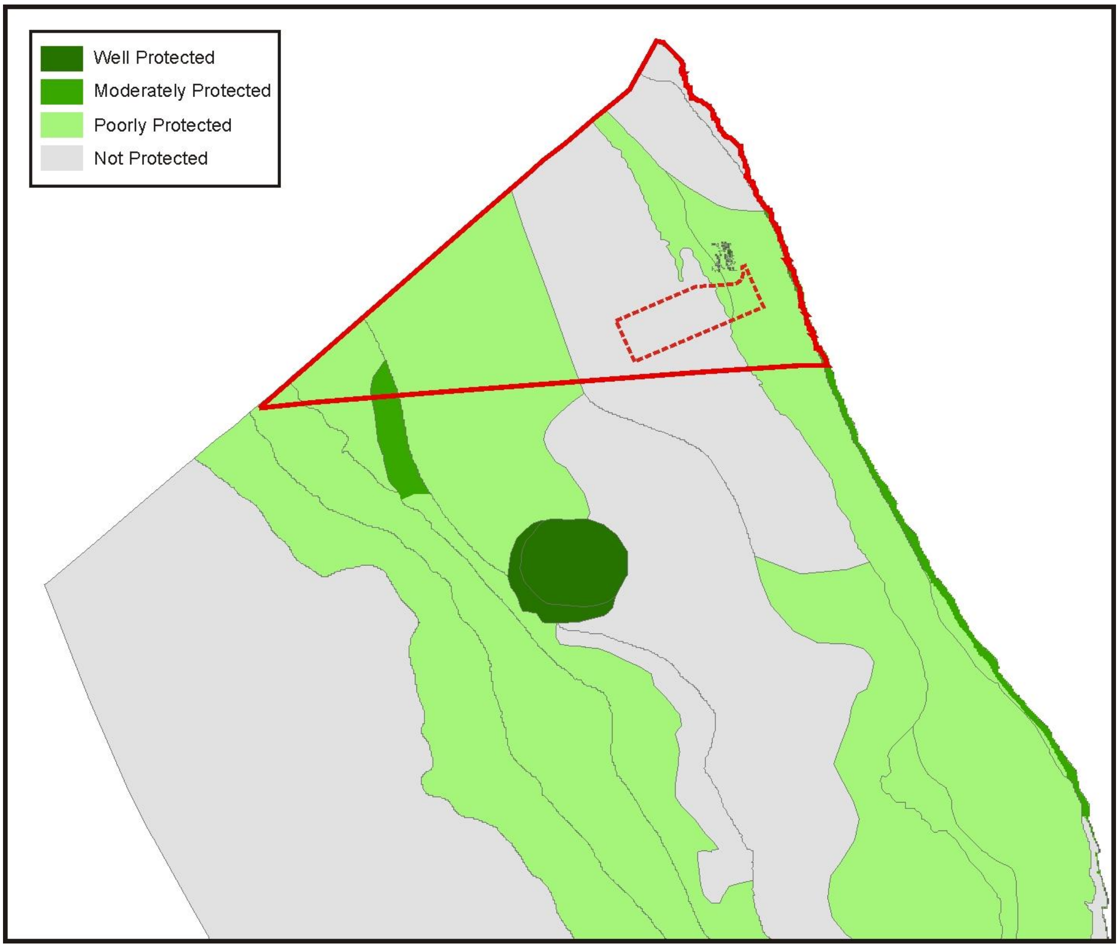

Figure 36: Protection levels of 150 marine ecosystem types as assessed by Sink *et al.* (2019) in relation to Block 1 (red polygon) and the proposed 3D survey area (dotted line).

The following summaries of the EBSAs in the general area of Block 1 (see Figure 35) are adapted from http://cmr.mandela.ac.za/EBSA-Portal/South-Africa/.

The **Namaqua Fossil Forest** EBSA, which lies within Block 1, 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 **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 in the northern corner of Block 1 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 **Childs Bank and Shelf Edge** EBSA, which lies to the south of Block 1, 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 to the south of Block 1 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 **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 latest version of National Coastal and Marine Spatial Biodiversity Plan (v1.1 released June 2021) (Harris *et al.* (2020)). This National Coastal and Marine Spatial Biodiversity 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.

The biodiversity priority areas and management objectives of each category have been defined and mapped as part of the marine spatial planning process. CBA Map categories are as follows: Protected Area, Critical Biodiversity Area 1 (CBA 1), Critical Biodiversity Area 2 (CBA 2), and Ecological Support Area (ESA). Sea-use guidelines are then proposed, with the Conservation Zones likely to comprise a Strict Biodiversity Conservation Zone (including Marine Protected Areas, and Other Effective Area-Based Conservation Measures (OECMs) as two separate types), and an Environmental Impact Management Zone. Protected areas will be managed according to their gazetted regulations. The intention is that the CBA Map (CBAs and ESAs) and sea-use guidelines inform the MSP Conservation Zones and management regulations, respectively.

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

Non-destructive petroleum exploration is compatible in ESAs and may be compatible, subject to certain conditions, in CBAs. Destructive exploration activities with localised impact, e.g. exploration wells, may be compatible, subject to certain conditions, in CBAs and ESAs. Petroleum production is classified as incompatible in CBAs but may be compatible, subject to certain conditions, in ESAs (Harris *et.al*. 2020).

These zones have been incorporated into the most recent iteration of the national Coastal and Marine Critical Biodiverity Area (CBA) Map (v1.1 released June 2021) (Harris *et al*. 2020) (**Error! Reference source not found.**). This indicates that CBA1 and CBA2 regions extend across some of the proposed 3D seismic survey 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 CBA 2 indicates optimal sites that generally can be adjusted to meet targets in other areas. Ecological Support Areas (ESAs) represent EBSAs outside of MPAs and not already selected as CBAs. Sea-use within the CBAs and ESAs reflect those specified by the EBSA biodiversity conservation and management zones described above.

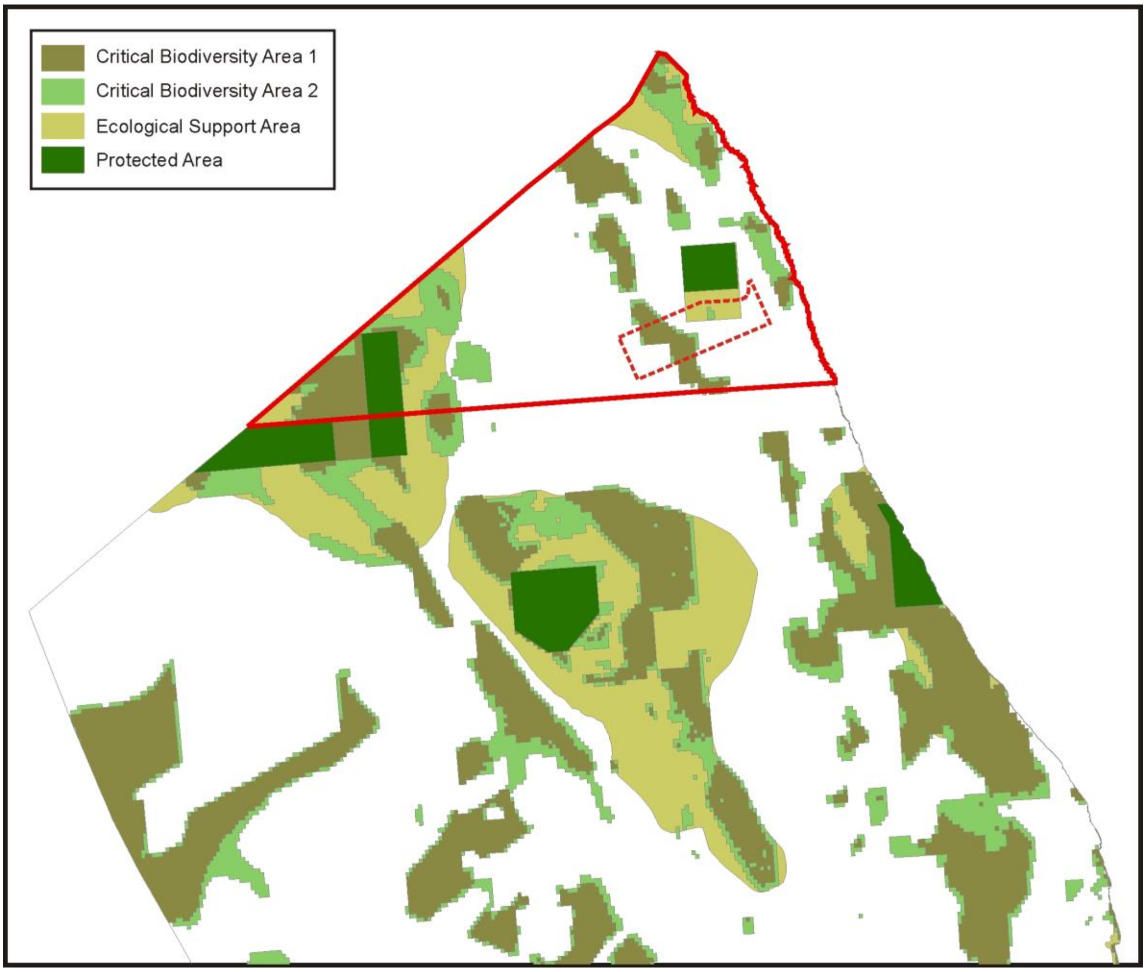

Figure 37: Block 1 (red polygon) and the proposed 3D survey area (dotted line) in relation to the National Coastal and Marine Critical Biodiversity Areas (adapted from Harris *et al.* (2020)).

4. ASSESSMENT OF IMPACTS

The sounds generated by the airgun arrays used during 3D surveys are no different to those produced during a 2D survey, the only difference being the number or airgun arrays and the size of the towed streamer array. However, as 3D seismic surveys are conducted on a very tight survey grid, typically over a smaller area within which promising petroleum prospects are suspected, the acoustic impact within the localised area persists for longer relative to that experienced within a particular location during a widely spaced 2D survey. Although the overall duration of a 3D survey is not necessarily longer than for a 2D survey, the impact of seismic noise will be locally somewhat higher for a 3D survey compared to a 2D survey. 2D surveys in contrast tend to be conducted over a larger area, and the spatial extent of the impact may thus be higher for 2D surveys. The overall impact, and the significance rating assigned using the prescribed impact rating methodology, is thus similar or the same for a 3D survey as for a 2D survey.

For this project, the identification and assessment of impacts relating specifically to the marine ecology cover the four main activity phases (see Table 16 for an outline of the activities in these phases) of the proposed well-drilling project, namely:

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

4.1 Identification of Impacts

Interaction of these activities with the receiving environment gives rise to a number of environmental aspects, which in turn may result in a single or a number of impacts. The identified aspects and their potential impacts are summarised below and in Table 16, 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 and Tripp Seamount)
  - 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, discharge of fuel during bunkering and discharge of hydraulic fluid due to pipe rupture
  - Toxic effects on marine biota and reduced faunal health
- Uncontrolled release of oil/gas from the 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

4.2 Application of the Mitigation Hierarchy

A key component of this EIA 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. With few exceptions, however, identified impacts were of low significance with very low or zero potential for further mitigation. In such cases the appropriate project Standards will be used and additional best management practices are proposed.

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).

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). Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping. 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 hundreds of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al.* 2003). Typical natural ambient noise levels in the study area are estimated to have overall root-mean-square sound pressure levels (RMS SPLs) in the range of 80 – 120 dB re 1 µPa, for the frequency range 10 – 10k Hz with a median level around 100 dB re 1µPa upon calm to strong sea state conditions (Croft & Li 2017; Li & Lewis 2020). A comparison of the various noise sources in the ocean is shown in Figure 38.

Table 16: 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	Increase in underwater noise levels during transit	Disturbance of behaviour (foraging and anti-predator) and physiology of 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
		Discharge of ballast water	Introduction of invasive alien species	Loss of biodiversity
	Operation Phase	Operation of survey vessels	Increase in underwater noise levels	Disturbance / behavioural changes to marine fauna
				Fish avoidance of key feeding areas
				Reduced fish catch and increased fishing effort
			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
	Unplanned Activities	Transit of survey vessels	Marine mammal collisions	Injury or mortality of marine mammals or turtles
		Loss of fuel from vessel accident	Release of fuel into the sea and localised reduction in water quality	Effect on faunal health (e.g. respiratory damage) or mortality (e.g. suffocation and poisoning)
		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
		Small spills	Discharge 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)

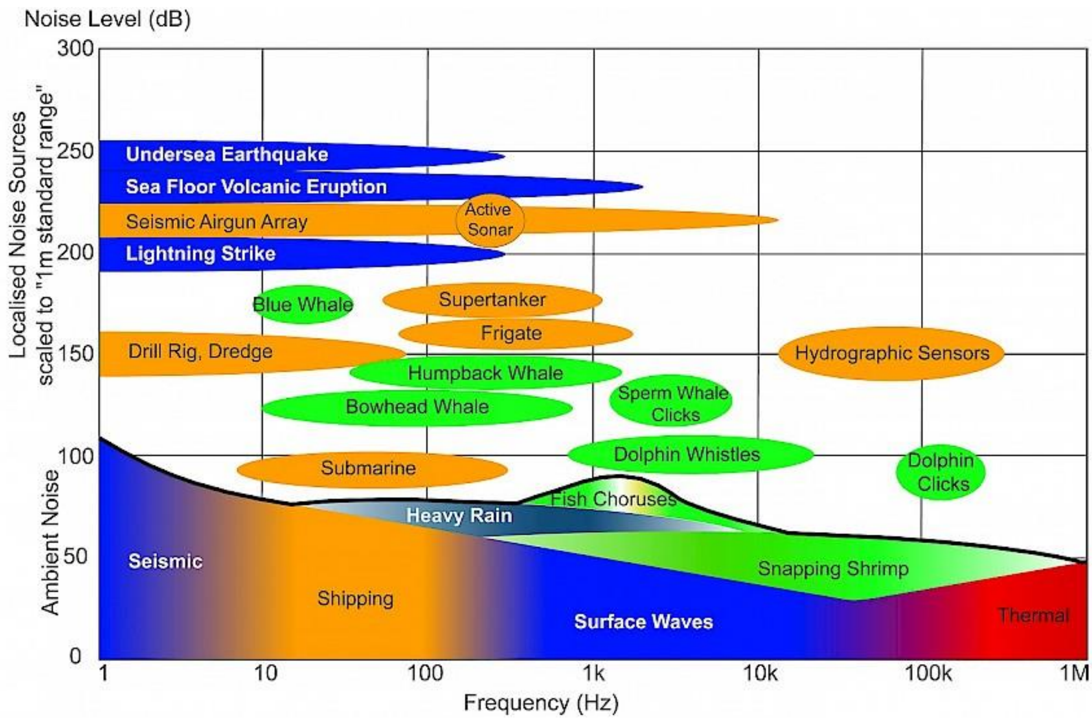

Figure 38: Comparison of noise sources in the ocean (Goold & Coates 2001).

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). 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. 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[3], respectively (Bowles *et al*. 1991; Richardson *et al*. 1995; see also references in McCauley 1994). 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*. 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

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

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 animal hearing, but certain taxa are capable of detecting either or both the pressure and particle velocity components of a sound (Turl 1993). 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).

The sounds generated by the airgun arrays used during 3D surveys are no different to those produced during a 2D survey, the only difference being the number or airgun arrays and the size of the towed streamer array. However, as 3D seismic surveys are conducted on a very tight survey grid, typically over a smaller area within which promising petroleum prospects are suspected, the acoustic impact within the localised area persists for longer relative to that experienced within a particular location during a widely spaced 2D survey. Although the overall duration of a 3D survey is not necessarily longer than for a 2D survey, the impact of seismic noise will be locally somewhat higher for a 3D survey compared to a 2D survey. 2D surveys in contrast tend to be conducted over a larger area, and the spatial extent of the impact may thus be higher for 2D surveys.

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). While the effects on pelagic and benthic invertebrates, fish, turtles and seabirds are covered briefly, the discussion and assessments focus primarily on marine mammals.

4.3.1 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 and zooplankton 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 shooting 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 operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT), and in compliance with the applicable requirements in the Minerals and Petroleum Resources Development Act (MPRDA) regulations.

Sensitivity of Receptors

The proposed 3D survey area within Block 1 lies well offshore where the ecosystem threat status is considered of 'Least concern', but where most ecosystem types outside the offshore MPAs are either poorly protected or not protected at all. Block 1 lies within the Namaqua upwelling cell and phytoplankton and zooplankton abundance can thus be expected to be seasonally high. There is also very limited overlap of the Block with the West Coast spawning areas and the northward egg and larval drift of commercially important species (see Figure 17). Ichthyoplankton abundance in the Licence Area is thus likely to be relatively low. As plankton distribution is naturally temporally and spatially variable and natural mortality rates are high, the sensitivity is considered to be **LOW**.

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).

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 in the survey area are expected to have a highly patchy distribution and have seasonally high abundances. The sensitivity is therefore considered to be **LOW**.

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). 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, 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 authors stressed that impacts in areas of dynamic ocean circulation (as would be the case around the nearby Mallory Seamount Cluster) are likely to be even less.

From a fish resource perspective, these effects may potentially contribute to a certain diminished net production in fish populations. 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 declines 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).

A peak SPL of >207 dB has been established for mortality and potential mortal injury of fish eggs and larvae (see Child's Bank and Tripp Seamount lie ~50 km south and ~30 km north of the southern and western boundaries of Block 1, respectively, and any demersal species associated with these important fishing banks would receive the seismic noise within the far-field range. As the 3D surveys will be undertaken in water depths in excess of 100 m, the received noise by demersal species at the seabed within Block 1 would similarly be within the far-field range, and outside of distances at which physiological injury or avoidance would be expected, it is deemed of MINOR intensity across the survey area (SITE) and for the survey duration (IMMEDIATE) and is considered to be of **LOW (NEGLIGIBLE)** environmental risk, both with and without mitigation, and of **LOW (NEGLIGIBLE)** significance.

Table 17). Based on the noise exposure criteria provided by Popper *et al.* (2014), the sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) 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 300 m[4]. 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 20 m. It must be kept in mind that the cumulative zones of impact are conservative, and the highly spatially and temporally variable plankton patches would drift with the currents and are thus likely to have moved considerable distances over the cumulative period between adjacent survey lines. Impacts will thus be of high intensity at close range.

As the 3D survey would most likely be scheduled for the summer survey window (start December to end May) over a four month period, there will be some temporal overlap with the spawning periods of commercially important species. However, as plankton distribution is naturally temporally and spatially variable and natural mortality rates are high, and the proposed survey area is located offshore of the West Coast spawning areas, any impacts on the plankton stocks would be of LOW intensity. Although the impact is restricted to within a few hundred metres of the airguns, it would extend over the entire survey area (SITE). Should impacts occur, they would persist over the immediate-term (days) only due to the rapid natural turn-over rate of plankton communities. The environmental risk would therefore be **(VERY) LOW** both with and without mitigation.

Identification of Mitigation Measures

[4] It is recognised that the accuracy of airgun array sound field modelling depends on the site specific parameters defining the sound propagation environment, including bathymetry, seafloor geo-acoustics and sound speed profiles. Nonetheless, using the modelling results from another study undertaken at similar depths will provide some indication of the expected maximum horizontal distance from the seismic source to impact threshold levels for different faunal groups.

No direct mitigation measures for potential impacts on plankton and fish egg and larval stages are feasible or deemed necessary.

Residual Impact Significance

This potential impact cannot be eliminated due to the nature of the seismic sound source required during surveying. Considering the very low sensitivity and (very) low environmental risk, the impact is thus deemed to have a **(VERY) LOW** Significance.

1	*Impacts of seismic noise to plankton and ichthyoplankton*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**Low**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	**Low**	**Low**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

4.3.2 Impacts of Seismic Noise on Marine Invertebrates

Source of Impact

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. 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 operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

Sensitivity of Receptors

The proposed 3D survey area within Block 1 lies offshore where the ecosystem threat status is considered of 'Least concern'. Pelagic invertebrates that may occur in the licence block 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**.

Environmental Risk

Information on hearing by invertebrates, and noise impacts on them is sparse. 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), and various other invertebrate species (Horridge 1965, 1966; Horridge & Boulton 1967; Moore & Cobb 1986; Packard *et al.* 1990; Turnpenney & Nedwell 1994).

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 (<10 m), however, found evidence of seismic impacts (increased mortality, inability to maintain homeostasis, reflex changes, depressed immune response) (Day *et al.* 2016; Day *et al.* 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 and behavioural changes in crustaceans (DFO 2004; McCauley 1994; McCauley *et al.* 2000; Day *et al.* 2016). The effects of seismic survey energy on snow crab (*Chionoecetes opilo*) on the Atlantic coast of Canada, for example ranged from no physiological damage 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) reported 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.* 2016b). 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.

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 has 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) 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). Branscomb and 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).

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; Fewtrell & McCauley 2012; Mooney *et al.* 2016). Squid responded to sounds from 80 to 1 000 Hz pure tone, with response rates diminishing at the higher and lower ends of this range (Mooney *et al.* 2016). In contrast Maniwa (1976) reported attraction 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). Limited avoidance of airgun sounds by mobile neritic and pelagic invertebrates can, however, therefore be expected.

As the proposed 3D survey area within Block 1 is located in waters in excess of 100 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 (SITE) for benthic invertebrates for the four-month survey duration (IMMEDIATE) and is therefore considered to be of **(VERY) LOW** environmental risk, both without and with mitigation.

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 Licence Area (SITE) and for the survey duration (4 months) resulting in a **(VERY) LOW** environmental risk, both without and with mitigation.

<u>Identification of Mitigation Measures</u>

The following mitigation measure is recommended:

No.	Mitigation measure	Classification
1	All initiation of airgun firing be carried out as “soft-starts” of at least 20 minutes duration, allowing neritic and pelagic cephalopods to move out of the survey area.	Avoid / Abate on site

<u>Residual Impact Assessment</u>

With the implementation of the typical ‘soft-starts’, the residual impact of 2D and 3D seismic noise on benthic, and neritic and pelagic invertebrates, and on potential behavioural avoidance by cephalopods, is thus deemed to have a **(VERY) LOW** significance.

2	*Impacts of seismic noise to marine invertebrates resulting in physiological injury*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**Very Low - Low (squid)**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	**Minor (benthic) - Low (neritic)**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low - Low (squid)**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Low**	

3	*Impacts of seismic noise to marine invertebrates resulting in behavioural avoidance*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Minor - Low (squid)**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low - Low (squid)**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Low**	

4.3.3 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), Tavolga *et al.* (1981), Lewis (1983), Atema *et al.* (1988), and Fay (1988) (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).

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.

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 (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

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), and consequently 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. 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. 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 >100 m) or with the Namaqua Fossil Forest reefs and other hard grounds in the survey area. The fish most likely to be encountered on the shelf, and in the offshore waters of Block 1 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 Block 1 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(s) are likely to be low, even when these species are *en route* to or from recognised feeding grounds associated with Tripp Seamount. Consequently, the sensitivity is considered to be **LOW** to **MEDIUM**.

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 4.3.1 above.

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. 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), and temporary hearing loss 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) and haemorrhaging, eye damage and blindness (Hirst & Rodhouse 2000). 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). 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 is not an issue that requires 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) (Child's Bank and Tripp Seamount lie ~50 km south and ~30 km north of the southern and western boundaries of Block 1, respectively, and any demersal species associated with these important fishing banks would receive the seismic noise within the far-field range. As the 3D surveys will be undertaken in water depths in excess of 100 m, the received noise by demersal species at the seabed within Block 1 would similarly be within the far-field range, and outside of distances at which physiological injury or avoidance would be expected, it is deemed of MINOR intensity across the survey area (SITE) and for the survey duration (IMMEDIATE) and is considered to be of **LOW (NEGLIGIBLE)** environmental risk, both with and without mitigation, and of **LOW (NEGLIGIBLE)** significance.

Table 17).

The sound transmission loss modelling undertaken for a licence block on the Agulhas Bank (Li & Lewis 2020a), where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 identified that the maximum horizontal distance from the seismic source to impact threshold levels leading to mortality or potential mortal injury was 150 m for fish lacking swim bladders (e.g. some tunas, sharks and most mesopelagic species) and 300 m for fish with swim bladders. Zones of immediate impact from single pulses for recovery injury were the same. 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 20 m. The zones of potential mortal injuries for fish species without a swim bladder, are predicted to be within 10 m from the adjacent survey lines for the cumulative (24-hour) survey operation, whereas for fish with swim bladders this distance is 20 m. For recoverable injury, the zones of cumulative impact from multiple pulses are predicted to be within 10 m from the adjacent survey lines for fish without a swim bladder, and within 40 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 1,000 m from the adjacent survey lines 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 Block 1 are the highly migratory pelagic species, which are likely to have moved considerable distances over the cumulative period.

Child's Bank and Tripp Seamount lie ~50 km south and ~30 km north of the southern and western boundaries of Block 1, respectively, and any demersal species associated with these important fishing banks would receive the seismic noise within the far-field range. As the 3D surveys will be undertaken in water depths in excess of 100 m, the received noise by demersal species at the seabed within Block 1 would similarly be within the far-field range, and outside of distances at which physiological injury or avoidance would be expected, it is deemed of MINOR intensity across the survey area (SITE) and for the survey duration (IMMEDIATE) and is considered to be of **LOW (NEGLIGIBLE)** environmental risk, both with and without mitigation, and of **LOW (NEGLIGIBLE)** significance.

Table 17: 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 100 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 likelihood of encountering feeding aggregations of large pelagic species is dependent on the locality of oceanic fronts and is considered to be low. Should an encounter occur, the potential physiological impact on individual migratory pelagic fish, would be of high intensity, but as the likelihood of encountering feeding aggregations of large pelagic species is low and dependent on the locality of oceanic fronts, the intensity is considered MODERATE. Furthermore, the duration of the impact on the population would be limited to the IMMEDIATE (4 months) and be restricted to the survey area (SITE). The impact is therefore considered to be of **LOW** environmental risk.

Behavioural avoidance

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 depth distribution (Chapman & Hawkins 1969; Dalen 1973; Pearson *et al.* 1992; Slotte *et al.* 2004), 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). 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 about 160 dB re 1 μPa, with disturbance ceasing at noise levels below this. 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). 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 immediate-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. In some cases behaviour patterns returned to normal within minutes of commencement of surveying indicating habituation to the noise. 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 or result in delayed mortality (Hirst & Rodhouse 2000). 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).

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 decreased commercial catch rates if fish move out of important fishing grounds (Engås *et al.* 1996; Hirst & Rodhouse 2000; Dalen & Mæsted 2008). 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).

The distance from the seismic sound source at which reductions in catch rates were measured also varied substantially between studies ranging from 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 is discussed in more detail in the Commercial Fisheries Impact Assessment (Japp*

&Wilkinson 2020). 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 160 dB re 1 μPa. Behavioural effects are generally immediate, 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 moderate to high intensity (particularly in the near-field of the airgun array) for individuals but of MODERATE intensity for the population due to the low likelihood of encounters in the offshore environment. Impacts to behavioural responses would be limited to the survey duration (IMMEDIATE), and the survey area (SITE). Consequently it is considered to be of **LOW** 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. 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, 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).

If behavioural responses 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, but can be considered of MINOR intensity overall . Considering the wide range over which the potentially affected species occur, the relatively short duration of the proposed survey (IMMEDIATE), the location of the 3D survey areas being offshore of the main migration routes of West Coast fish species and that the migration routes do not constitute narrow restricted paths, the impact is considered to be of **(VERY) 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 on the continental shelf 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 (SITE) and for the duration of the survey (4 months). The impact is thus considered to be of **(VERY) 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 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 likely low abundance of pelagic shoaling species that constitute their main prey, the intensity of the impact would be MINOR, restricted to the survey area (SITE) and persisting over the IMMEDIATE-term only (4 months). The impact would thus be of **(VERY) LOW** environmental risk.

<u>Identification of Mitigation Measures</u>

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	All initiation of airgun firing be carried out as "soft-starts" of at least 20 minutes duration, allowing fish to move out of the survey area and thus avoid potential physiological injury or behavioural avoidance as a result of seismic noise.	Avoid / Abate on site
2	All breaks in airgun firing of longer than 5 minutes but less than 20 minutes should be followed by a "soft-start" of similar duration. All breaks in firing	Avoid

No.	Mitigation measure	Classification
	of 20 minutes or longer must be followed by a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing.	
3	Any attraction of predatory fish (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should be recorded by an onboard Independent Observer or or Marine Mammal Observer (MMO).	Abate on site
4	Airgun firing should be terminated if, in the unlikely event, mass mortality of fish is observed as a direct result of shooting.	Avoid / Abate on site

Residual Impact Assessment

The potential impacts cannot be eliminated due to the nature of the seismic sound source required during surveying. With the implementation of the mitigation measures, the intensity of the impact for the impacts relating to physiological injury / mortality and behavioural avoidance would reduce from low to minor, the residual impacts will remain of very low environmental risk and of **(VERY) LOW** significance

4	*Impacts of seismic noise to large pelagic fish resulting in physiological injury*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	**Low**	**Minor**
	Minor for demersal fish; Moderate for large pelagic species	Minor for demersal fish; Low for large pelagic species
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low - Low (pelagic species)**	**Very Low**
Environmental Risk	LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Medium**	

5	*Impacts of seismic noise on fish resulting in behavioural avoidance*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	**Low**	**Low**
	See 4 above	See 4 above
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low - Low (pelagic species)**	**Very Low**
Environmental Risk	LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

6	*Impacts of seismic noise on reproductive success and spawning*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	**Minor**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Partially Reversible**	**Partially Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

7	*Impacts of seismic noise on fish resulting in masking of sounds*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude	**Minor**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

8	*Impacts of seismic noise on fish resulting in indirect impacts on food sources*	
Project Phase:	Operation	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Minor**
	See 4 above	See 4 above
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**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 operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

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. However, many of the pelagic seabirds likely to occur in the offshore regions characterising Block 1 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). However, the numbers of individuals encountered during the survey are likely to be low, even in the Child's Bank and Orange Shelf Edge MPAs and associated with Tripp Seamount and the Orange Seamount and Canyon Complex transboundary EBSA. Consequently, the sensitivity 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 sources 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, over 200 km south-southeast of Block !. The likelihood of encountering Cape Gannets is therefore low. The nearest African Penguin nesting sites are similarly at Lambert's Bay and on the Saldanha Bay Islands all >200 km south of the Licence Block. This species forages at sea with most birds being found within 20 km of the coast. As the Licence Block is situated well north of Bird Island in Lambert's Bay, encounters with penguins are unlikely. In the offshore environment, pelagic seabirds that dive for their prey may, however, be encountered, particularly in the portions of the Block closest to Tripp Seamount and Child's Bank.

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

For coastal diving seabirds such as African Penguins and Gannets the environmental risk is considered **NEGLIGIBLE** as they are highly unlikely to be encountered in the survey area.

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 of the behavioural response of African Penguins to seismic surveys within 100 km of their colonies at Bird and St Croix Islands in Algoa Bay, reported a strong avoidance of their preferred foraging areas during seismic activities in which the centroid was situated inshore of the 200 m depth contour off Cape Recife. Birds foraged significantly further from the survey vessel when in operation, while increasing their overall foraging effort. The birds reverted to normal foraging behaviour when the seismic operations ceased (Pichegru *et al.* 2017). Behavioural avoidance by diving seabirds would be restricted to the vicinity of the operating airguns within the survey area over the duration of the survey period.

Due to the unlikely probability of encountering African Penguins or Cape Gannets in the survey area, and the extensive distribution and feeding ranges of pelagic seabirds, the impact for pelagic seabirds would thus be of LOW intensity within the survey area (SITE) over the duration of the survey period (4 months). The behavioural avoidance of feeding areas by diving seabirds is thus considered to be of **(VERY) 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 or Tripp Seamount. 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) (see for example Li & Lewis 2020b). 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, or juvenile penguins that forage on small pelagic species along the West Coast north of St Helena Bay in late winter and early spring. Similarly, pelagic seabirds that feed around seamounts may also be affected. The impact on potential food sources for pelagic seabirds would thus be of MINOR intensity within the survey area (SITE) 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 **(VERY) LOW** environmental risk.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	All initiation of airgun firing be carried out as "soft-starts" of at least 20 minutes duration, allowing pelagic seabirds to move out of the survey area and thus avoid potential physiological injury or behavioural avoidance as a result of seismic noise.	Avoid/ Abate on site
2	An area of radius of 500 m from the centre of the airgun array be scanned (visually during the day) by an independent observer for the presence of diving seabirds (and in particular feeding aggregations of diving seabirds) prior to the commencement of "soft starts" and that these be delayed until such time as this area is clear of seabirds.	Avoid
3	Seabird incidence and behaviour should be recorded by an onboard Independent Observer. – Any obvious mortality or injuries to seabirds as a direct result of the survey should result in temporary termination of operations. – Any attraction of predatory seabirds (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should be recorded by an onboard Independent Observer.	Abate on site
4	All breaks in airgun firing of longer than 5 minutes but less than 20 minutes should be followed by a "soft-start" of similar duration. All breaks in firing of 20 minutes or longer must be followed by a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing.	Avoid
5	Any attraction of predatory fish (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should be recorded by an onboard Independent Observer.	Abate on site
4	Airgun firing should be terminated if, in the unlikely event, mass mortality of seabirds is observed as a direct result of shooting.	Avoid / Abate on site
5	Avoid surveying during late winter and early spring when juvenile penguins forage in inshore waters north of St Helena Bay	Avoid

Residual Impact Assessment

With the implementation of the mitigation measures above, the magnitude of the impacts for physiological injury and behavioural avoidance will reduce to MINOR. Considering their medium sensitivity and very low environmental risk, the residual impacts of seismic sounds on diving seabirds is thus deemed to be of **(VERY) LOW** significance.

9	*Impacts of seismic noise on diving seabirds resulting in physiological injury*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Low**
Environmental Risk	**LOW**	**(VERY) LOW**
Reversibility	**Partially Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Medium**	

10	*Impacts of seismic noise on diving seabirds resulting in behavioural avoidance*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

11	*Impacts of seismic noise on diving seabirds resulting in indirect impacts on food sources*	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Low**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Low**
Environmental Risk	**LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

4.3.5 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 operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

Sensitivity of Receptors

The leatherback and loggerhead turtles that occur in offshore waters around southern Africa, and likely to be encountered in the offshore portions of Block 1 are considered regionally 'critically endangered' and 'endangered', respectively, in the List of Marine Threatened or Protectes Species (TOPS) as part of the NEMBA. However, the numbers of individuals encountered during the survey are likely to be low, even 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 is considered to be **MEDIUM**.

Environmental Risk

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; Piniak *et al*. 2012a), 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 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 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. However, considering the relatively low abundance of adult turtles in relation to the extent of the survey area, the potential impact is considered to be of low intensity, but remain within the immediate-term.

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 sea 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 18).

Using the peak sound pressure level of over 207 dB re 1 μPa as determined by Popper *et al.* (2014), the sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) identified that the maximum horizontal distance from the seismic source to impact threshold levels leading to mortality or potential mortal injury in turtles was 300 m and therefore highly localised at any one time. 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 20 m for mortality and potential mortal injury. Maximum threshold distances for recoverable injury and TTS from multiple pulses were not reached. It must be kept in mind that the cumulative zones of impact are conservative, as any turtles likely to be encountered in Block 1 are the highly migratory, and are likely to have moved considerable distances over the cumulative period.

Table 18: Noise exposure criteria in turtles for seismic airguns (after Popper *et al.* 2014).

Type of animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recovery injury	TTS	Masking	
Sea turtles	210 dB SEL_{24hr} or >207 dB Pk SPL	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (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. 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).

As the breeding areas for Leatherback turtles occur over 1,000 km to north of the survey area in Gabon, and on the northeast coast of South Africa, turtles encountered during the survey(s) are likely to be migrating vagrants. Due to their extensive distributions and feeding ranges, the number of turtles encountered in the survey area is expected to be low and consequently the intensity of potential physiological injury would be rated as LOW. Furthermore, the duration of the impact on the population would be limited to the immediate-term (4 months) and be restricted to the survey area (LOCAL). The potential physiological injury or mortality of turtles is considered to be of **LOW** 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 166 – 176 dB re 1 μPa (O'Hara & Wilcox 1990; 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, in McCauley 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 and 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 trails 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.

The sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) identified that the zones of behavioural disturbance for turtles caused by the immediate exposure to individual pulses was predicted to be within 3.5 km from the array source. 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 surveys 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 (4 months), and be restricted to the survey area (SITE). The impact of seismic noise on turtle behaviour is thus deemed to be of **LOW** environmental risk.

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.

Reproductive success

Although three species of turtles occur along the West Coast, it is only the Leatherback turtle that is likely to be encountered in deeper waters. As the breeding areas for Leatherback turtles occur over 1,000 km to north of the survey area in Gabon, and on the northeast coast of South Africa, abundances of turtles encountered in the Licence Block during the survey are likely to be low, comprising occasional migrating vagrants. Effects on recruitment success would thus be both indirect, through entanglement and mortality of adults, as well as direct through seismic impacts to hatchlings. As hatchlings from Gabon would be dispersed eastwards in the South Equatorial Current, no hatchlings would be expected in the Benguela Current. The effect of seismic surveys on recruitment success will be of MINOR intensity and the consequently the impact of seismic noise on hatchling survival would be of **NEGLIGIBLE** environmental risk, and will not be assessed further.

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 1,000 km to north of the survey area in Gabon, 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 (4 months), and be restricted to the survey area (SITE), the impact is deemed to be of **(VERY) 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 (4 months), and restricted to the survey area (SITE). The impact would therefore be of **(VERY) LOW** environmental risk.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	All initiation of airgun firing be carried out as "soft-starts" of at least 20 minutes duration, allowing turtles to move out of the survey area and thus avoid potential physiological injury or behavioural avoidance as a result of seismic noise.	Avoid / Abate on site

No.	Mitigation measure	Classification
2	An area of radius of 500 m from the centre of the airgun array be scanned (visually during the day) by an independent observer for the presence of turtles prior to the commencement of "soft starts" and that these be delayed until such time as this area is clear of turtles.	Avoid
3	Turtle incidence and behaviour should be recorded by an onboard Independent Observer. – Any negative changes to turtle behaviour observed from the survey vessel must be recorded, or if animals are observed within the immediate vicinity (within 500 m) of operating airguns or appear to be approaching firing airguns. – Any obvious mortality or injuries to turtles as a direct result of the survey should result in temporary termination of operations.	Avoid / Abate on site
4	All breaks in airgun firing of longer than 5 minutes but less than 20 minutes should be followed by a "soft-start" of similar duration. All breaks in firing of 20 minutes or longer must be followed by a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing.	Avoid

Residual Impact Assessment

With the implementation of the mitigation measures above, the magnitude of the impacts for physiological injury and behavioural avoidance will reduce. Considering their medium sensitivity and very low environmental risk, the residual impacts of seismic sounds on turtles is thus deemed to be of **(VERY) LOW** significance.

12	*Impacts of seismic noise on turtles resulting in physiological injury*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Medium**	**Low**
Environmental Risk	**LOW**	**(VERY) LOW**
Reversibility	**Partially Reversible**	**Partially Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Medium**	

13	*Impacts of seismic noise on turtles resulting in behavioural avoidance*	
Project Phase:	Operation	
Type of Impact	Direct	
Nature of Impact	Negative	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	Residual Impact
Intensity	Low	Minor
Extent	Site	Site
Duration	Immediate	Immediate
Probability	Low	Very Low
Environmental Risk	LOW	(VERY) LOW
Reversibility	Fully Reversible	Fully Reversible
Confidence	High	
Cumulative potential	Low	
Loss of Resources	Low	
Priority Factor	1	
Significance	(VERY) LOW	
Mitigation Potential	None	

14	*Impacts of seismic noise on turtles resulting in masking of sounds*	
Project Phase:	Operation	
Type of Impact	Direct	
Nature of Impact	Negative	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	Residual Impact
Intensity	Minor	Minor
Extent	Site	Site
Duration	Immediate	Immediate
Probability	Very Low	Very Low
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	Fully Reversible	Fully Reversible
Confidence	Medium	
Cumulative potential	Low	
Loss of Resources	Low	
Priority Factor	1	
Significance	(VERY) LOW	
Mitigation Potential	None	

15	*Impacts of seismic noise on turtles resulting in indirect impacts on food sources*	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Minor**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Low**	

4.3.6 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 highly likely to be encountered in the proposed 3D survey area.

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 (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

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, and at Elephant Rocks. 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. Consequently, the sensitivity of seals is considered to be **LOW**.

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 sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) identified that PTS and TTS for seals were predicted to occur within only 15 m and 30 m of the array, respectively (see Table 19). Maximum threshold distances for recoverable injury and TTS from multiple pulses were not reached.

The potential impact of physiological injury to seals as a result of seismic noise is deemed to be of medium intensity and would be limited to the survey area (LOCAL). As seals are known to forage up to 120 nautical miles (~220 km) offshore, the proposed 3D survey area falls within the foraging range of seals from the Buchu Twins, Cliff Point and Kleinzee colonies. The intensity of the impact is considered to be MINOR. Furthermore, as the duration of the impact would be limited to the IMMEDIATE-term (4 months) (although injury could extend beyond the survey duration) and be restricted to the survey area (SITE), the potential physiological injury is therefore considered to be of **(VERY) LOW** 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 seals 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 IMMEDIATE-term (4 months) and be restricted to the survey area (SITE), the potential for behavioural avoidance of seals is considered to be of **(VERY) 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 (18.75 m interval between consecutive shot-points). 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 IMMEDIATE-term (4 months) and be restricted to the survey area (SITE), the potential for masking of sounds is considered to be of **(VERY) 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 IMMEDIATE-term (4 months) and be restricted to the survey area (SITE). The potential for effects of seismic surveys on prey species is thus considered to be of **(VERY) LOW** environmental risk.

<u>Identification of Mitigation Measures</u>

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	All initiation of airgun firing be carried out as "soft-starts" of at least 20 minutes duration, allowing seals to move out of the survey area and thus avoid potential physiological injury or behavioural avoidance as a result of seismic noise.	Avoid / Abate on site
2	An area of radius of 500 m from the centre of the airgun array be scanned (visually during the day) by an independent observer for the presence of seals prior to the commencement of "soft starts" and that these be delayed until such time as this area is clear of seals for a period of 10 minutes. If after a period of 10 minutes seals are still within 500 m of the airguns, the normal "soft start" procedure should be allowed to commence for at least a 20-minutes duration. Their 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

No.	Mitigation measure	Classification
3	Seal incidence and behaviour should be recorded by an onboard Independent Observer. – Seismic shooting should be terminated when obvious negative changes to seal behaviour is observed from the survey vessel. – Any obvious mortality or injuries to seals as a direct result of the survey should result in temporary termination of operations.	Avoid / Abate on site
4	All breaks in airgun firing of longer than 5 minutes but less than 20 minutes should be followed by a "soft-start" of similar duration. All breaks in firing of 20 minutes or longer must be followed by a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing.	Avoid

Residual Impact Assessment

With the implementation of the typical 'soft-start' procedures, the residual impacts would all remain of very low environmental risk and **(VERY) LOW** significance.

16	***Impacts of seismic noise on seals resulting in physiological injury***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Minor**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Medium**	

17	*Impacts of seismic noise on seals resulting in behavioural avoidance*	
Project Phase:	Operation	
Type of Impact	Direct	
Nature of Impact	Negative	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	Residual Impact
Intensity	Minor	Minor
Extent	Site	Site
Duration	Immediate	Immediate
Probability	Very Low	Very Low
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	Fully Reversible	Fully Reversible
Confidence	High	
Cumulative potential	Low	
Loss of Resources	Low	
Priority Factor	1	
Significance	(VERY) LOW	
Mitigation Potential	Medium	

18	*Impacts of seismic noise on seals resulting in masking of sounds*	
Project Phase:	Operation	
Type of Impact	Direct	
Nature of Impact	Negative	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	Residual Impact
Intensity	Minor	Minor
Extent	Site	Site
Duration	Immediate	Immediate
Probability	Very Low	Very Low
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	Fully Reversible	Fully Reversible
Confidence	Medium	
Cumulative potential	Low	
Loss of Resources	Low	
Priority Factor	1	
Significance	(VERY) LOW	
Mitigation Potential	Low	

19	*Impacts of seismic noise on seals resulting in indirect impacts on food sources*	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Minor**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Low**	

4.3.7 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 (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

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 the location of the survey area in <200 m depth on the continental shelf, the number of individuals encountered during the survey may be comparatively high, and the sensitivity of migratory cetaceans is thus considered to be **MEDIUM**.

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, 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, and the ecological features of the environment in which the animal encounters the sound. 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). This uncertainty and variability can have a large impact 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). 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). 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), 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. 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.* 2002). 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.

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). Frankel *et al.* (1995, in Perry 1998) found Humpback whales in the wild to detect sounds ranging from 10 Hz to 10 kHz at levels of 102 to 106 dB re 1 µPa. Blue whales 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). 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 toothed whales (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), 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 19).

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).

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).

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). 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*. 2013).

Table 19: The Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) levels for marine mammals 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 $1µPa^2·S$	Pk SPL, dB re 1µPa	Weighted SEL_{24hr}, dB re $1µPa^2·S$
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 Block 1

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).

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), changes in respiration rate (Ljungblad *et al.* 1988; Richardson *et al.* 1985, 1986; Malme *et al.* 1983, 1985,1986), slowing of travel (Malme *et al.* 1983, 1984), and changes in vocalisations (McDonald *et al.* 1993, 1995) and call rate (Di Lorio & Clarke 2010). 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 (as reported by Weller *et al.* (2002) for Western gray whales). 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). Behavioural responses are often evident beyond 5 km from the sound source (Ljungblad *et al.* 1988; Richardson *et al.* 1986, 1995; NMFS 2013), 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.

In an analysis of marine mammals 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. 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). 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), 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, 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).

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. Localised avoidance of the survey vessel during airgun operation was however noted. 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 have been suggested, although these might differ in different sound propagation conditions (McCauley *et al.* 2000). Base on the noise exposure criteria of RMS SPL 160 dB re 1µPa provided by Popper *et al.* (2014), The sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) identified that the maximum horizontal threshold distance from the source to impact threshold levels for marine mammals was 4 km. Disturbance of mating behaviour (which could involve a high degree of acoustic selection) by seismic noise could therefore be of consequence to breeding animals in the general survey area.

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.* 2007) or showing no change in calling behaviour (Madsen *et al.* 2002). For example, a recent study shows that blue whales called consistently more on days when seismic exploration was taking place, presumably to compensate for the elevated ambient noise levels (Di Lorio and Clarke 2010). 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 (Englas *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 sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) identified that the low frequency cetaceans expected to occur in the licence area (e.g. southern right, humpback, fin, sei, blue, Bryde’s, minke) were predicted to experience PTS effects within approximately 65 m from the source array at all assessed water depth scenarios, with the the zone of a TTS due to a single pulse exposure predicted within approximately 150 m from the source array. 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 20 m and 500 m from the source array, respectively. For these hearing groups, the maximum threshold distance for TTS onset occurs within 40 m and 1,000 m, respectively.

Among marine mammals expected to occur in the licence 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 300 m from the adjacent survey lines for the typical (24-hour) cumulative survey operation scenario, with the zones of TTS impact predicted to be as much as 8,000 m from the adjacent survey lines. 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 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.

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 are predicted to range around 10 m from the adjacent survey lines for the cumulative scenario. In the case of very high frequency cetaceans, the zones of PTS impact for the cumulative scenario are predicted to range up to 20 m from the adjacent survey lines for the typical cumulative survey operation scenario, with the zones of TTS impact predicted to be around 1,000 m from the adjacent survey lines.

The majority of baleen whales migrate to the southern African subcontinent to breed during winter months. Humpback whales migrating north strike the coast north of St Helena Bay resulting in increasing whale density on shelf waters and into deeper pelagic waters as one moves northwards on their northern migrations around April, continuing through to September/October when the southern migration begins and continues through to December. Southern right whales arrive in coastal waters in June, building up to a maximum in September/October and departing again in December. Block 1 thus lies within the migration paths of both humpback and southern right whales, and overlaps with inshore coastal areas frequented by southern right whales for mating and breeding. As the survey would most likely be undertaken during the summer survey window (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 surveys are likely to frequently encounter resident odontocetes such as common dolphins and pilot whales, which are present year-round, and may encounter sperm whales in offshore areas.

The current distribution of the offshore population of Bryde's whales implies that it is likely to be encountered in the deeper portions of Block 1 during the proposed 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. As the species typically frequents depths of >200 m, encounters in the proposed 3D survey area are likely to be infrequent.

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 moderate likelihood of encountering Bryde's whales. The impact of potential physiological injury to mysticete cetaceans as a result of seismic sounds is thus deemed to be of HIGH intensity, while the intensity of the impact on odontocetes is considered to be of MODERATE intensity. Furthermore, as the duration of the impact would be limited to the IMMEDIATE-term (4 months) and be restricted to the survey area (SITE) for mysticetes and LOCALLY for odontocetes due to their better hearing abilities at the frequencies concerned, the potential for physiological injury is therefore considered to be of **MEDIUM** environmental risk for resident odontocetes, and **MEDIUM** environmental risk for mysticetes.

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 sound transmission loss modelling undertaken for a licence block on the Agulhas Bank, where the shallowest point modelled was at similar depth to that of the proposed 3D survey area in Block 1 (Li & Lewis 2020a) identified that the zones of behavioural disturbance for cetaceans caused by the immediate exposure to individual pulses was within 5 km from the 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. The survey area overlap with the migration routes of humpback whale 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 migration periods (June - 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 Block 1. 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. As the proposed 3D survey area is located within 25 km of the coast, there should be no overlap with potential coastal nursery areas for this species.

Assuming the survey is scheduled so as to avoid the key migration period (early June to late November), 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 and slightly beyond the Licence Area (LOCAL) and for the duration of the survey (4 months). Considering the distribution ranges of most species of cetaceans, the impact of seismic surveying in Block 1 is considered of **MEDIUM** environmental risk for both migrating mysticetes and for resident Bryde's whales.

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 Licence 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 MODERATE intensity, audible to odontocetes well beyond the Licence Area (REGIONAL) and for the duration of the survey (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[5] 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 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. Assuming the survey is scheduled to avoid the key migration and breeding period, there would be a low likelihood of encountering migrating humpback whales (including possible mother-calf pairs), the intensity of impacts on baleen whales is likely to be HIGH (mother-calf pairs) over the survey area (LOCAL) and duration (4 months), and of MODERATE intensity (species specific) in the case of toothed whales beyond the survey area (REGIONAL) and duration (4 months). The environmental risk for mysticetes will therefore be **MEDIUM** and for odontocets be **LOW**.

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.

[5] 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

Although the upwelling zone off Cape Columbine has become an important summer feeding area, baleen whales have not been reported to feed while in the location of Block 1. Any indirect effects on their food source would thus be of MINOR intensity over the survey area (SITE) and duration (4 months) and therefore of **(VERY) 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 be of LOW intensity over the survey area (SITE) and duration (4 months) and therefore of **LOW** environmental risk.

<u>Identification of Mitigation Measures</u>

Please refer to Section 5.3 for detailed mitigation measures for cetaceans.

<u>Residual Impact Assessment</u>

With the implementation of the mitigation measures outlined in Section 6.3, the magnitude of the impacts in most cases will be reduced resulting in the residual impacts all being of LOW or VERY LOW environmental risk and of **LOW** or **VERY LOW** significance.

Physiological injury and mortality

The potential impact of 3D seismic noise on physiological injury of mysticetes and odontocetes, considering their medium sensitivity and very low environmental risk for mysticetes but low environmental risk for odontocetes, is deemed to be of **LOW** significance.

Behavioural avoidance

The potential impact of 3D seismic noise on behavioural changes in mysticetes and odontocetes, considering their medium sensitivity and the low environmental risk, is deemed to be of **LOW** significance for both mysticetes and odontocetes.

Masking of Sounds and Communication

The potential impact of 3D seismic noise on the masking of environmental sounds and communications in mysticetes and odontocetes, considering their medium sensitivity and the low environmental risk, is deemed to be of **LOW** significance for both mysticetes and odontocetes.

Indirect impacts due to effects on predators or prey

The potential indirect impact of 3D seismic noise on food sources of mysticetes and odontocetes, considering their medium sensitivity, and the very low environmental risk, is thus deemed to be of **(VERY) LOW** significance for both mysticetes and odontocetes.

Potential impact of seismic noise to mysticete cetaceans

20	***Impacts of seismic noise on mysticetes resulting in physiological injury***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**High**	**Low**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**High**	**Low**
Environmental Risk	**MEDIUM**	**(VERY) LOW**
Reversibility	**Reversible with time**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Medium**	
Loss of Resources	**Medium**	
Priority Factor	**1.25**	
Significance	**LOW**	
Mitigation Potential	**High**	

21	***Impacts of seismic noise on mysticetes resulting in behavioural avoidance***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**High**	**Low**
Extent	**Local**	**Local**
Duration	**Immediate**	**Immediate**
Probability	**High**	**Medium**
Environmental Risk	**MEDIUM**	**LOW**
Reversibility	**Reversible with time**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Medium**	
Loss of Resources	**Low**	
Priority Factor	**1.13**	
Significance	**LOW**	
Mitigation Potential	**High**	

22	*Impacts of seismic noise on mysticetes resulting in masking of sounds*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**High**	**Moderate**
Extent	**Local**	**Local**
Duration	**Immediate**	**Immediate**
Probability	**High**	**Medium**
Environmental Risk	**MEDIUM**	**LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Medium**	
Loss of Resources	**Low**	
Priority Factor	**1.13**	
Significance	**LOW**	
Mitigation Potential	**Medium**	

23	*Impacts of seismic noise on mysticetes resulting in indirect impacts on food sources*	
Project Phase:	Operation	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Minor**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**None**	

Potential impact of seismic noise to odontocete cetaceans

24	*Impacts of seismic noise on odontocetes resulting in physiological injury*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Moderate**	**Low**
Extent	**Local**	**Local**
Duration	**Immediate**	**Immediate**
Probability	**High**	**Medium**
Environmental Risk	**MEDIUM**	**LOW**
Reversibility	**Reversible with time**	**Partially Reversible**
Confidence	**High**	
Cumulative potential	**Medium**	
Loss of Resources	**Medium**	
Priority Factor	**1.25**	
Significance	**LOW**	
Mitigation Potential	**High**	

25	*Impacts of seismic noise on odontocetes resulting in behavioural avoidance*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Moderate**	**Low**
Extent	**Regional**	**Regional**
Duration	**Immediate**	**Immediate**
Probability	**High**	**Medium**
Environmental Risk	**MEDIUM**	**LOW**
Reversibility	**Reversible with time**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Medium**	
Loss of Resources	**Low**	
Priority Factor	**1.13**	
Significance	**LOW**	
Mitigation Potential	**Medium**	

26	*Impacts of seismic noise on odontocetes resulting in masking of sounds*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Moderate**	**Low**
Extent	**Local**	**Local**
Duration	**Immediate**	**Immediate**
Probability	**High**	**Medium**
Environmental Risk	LOW	LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Medium**	
Loss of Resources	**Low**	
Priority Factor	**1.13**	
Significance	**LOW**	
Mitigation Potential	**Medium**	

27	*Impacts of seismic noise on odontocetes resulting in indirect impacts on food sources*	
Project Phase:	**Operation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Low**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Low**	

4.4 Other Impacts of Seismic Surveys on Marine Fauna

4.4.1 Impact of Non-seismic 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 Saldanha Bay/Port Nolloth or a suitable location nearby to the survey vessel, if required (prefer alterative 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 operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

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[6], killed or fished. No vessel or aircraft may approach closer than 300 m to any whale and a vessel should move

[6] In the Regulations for the management of boat-based whale watching and protection of turtles as part of the Marine Living Resources Act of 1998 the definition of "harassment" is given as "behaviour or conduct that threatens, disturbs or torments cetaceans".

to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft.

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

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 Saldanha Bay. Although the eastern boundary of the proposed 3D survey area is located ~20 km offshore, the flight path between the survey area and Port Nolloth would potentially cross over the Namaqua Fossil Forest MPA. If the logistics base is located at Saldanha Bay, the flight path to the survey area would potentially cross over the Namaqua MPA, and numerous sensitive coastal receptors (e.g. key faunal breeding/feeding areas and bird or seal colonies). In addition, migratory pelagic species transiting through the survey area may also be directly affected.

The taxa most vulnerable to disturbance by underwater noise are turtles, 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 and since Child's Bank falls outside of any possible travel / flight path, the sensitivity is considered to be **MEDIUM**.

Environmental Risk

The ocean is a naturally noisy place and marine animals are continually subjected to both physically produced sounds from sources such as wind, rainfall, breaking waves and natural seismic noise, or biologically produced sounds generated during reproductive displays, territorial defence, feeding, or in echolocation (see references in McCauley 1994). Such acoustic cues are thought to be important to many marine animals in the perception of their environment as well as for navigation purposes, predator avoidance, and in mediating social and reproductive behaviour. Anthropogenic sound sources in the ocean can thus be expected to interfere directly or indirectly with such activities thereby affecting the physiology and behaviour of marine organisms (NRC 2003). Natural ambient noise will vary considerably with weather and sea state, ranging from about 80 to 120 dB re 1 μPa for the frequency range 10 – 10k Hz (Croft & Li 2017). Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping. 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).

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.

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

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

The reactions of pinnipeds to aircraft noise 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 varies with species, populations, and demographics (age, sex). Any reactions to over flights would thus be short-term and isolated occurrences would unlikely be of any long-term biological significance.

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.

Although the proposed 3D survey area in Block 1 is located inshore of the main offshore shipping routes that pass around southern Africa, local fishing and mining vessels would contribute to the shipping noise component of the ambient noise environment within and around the licence block. 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 airguns, underwater noise from vessels is not considered to be of sufficient amplitude to cause direct harm to marine life, even at close range (SLR Consulting Australia 2019). 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 and consequently the intensity of potential physiological injury or behavioural disturbance as a result of vessel noise would be rated as MINOR. Furthermore, the duration of the impact on the populations would be limited to the IMMEDIATE-term (4 months) and extend along the vessel route at any one time (although extending PROVINCIALLY between the survey area and the logistics base in Saldanha Bay). The potential physiological injury or behavioural disturbance as a result of vessel noise would thus be of **(VERY) LOW** environmental risk.

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 potentiall transit through the entire Block 1 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 west South Africa 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 Block 1. 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 Saldanha Bay 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.

Indiscriminate low altitude flights over whales, seals, seabird colonies and turtles by helicopters used to support the seismic vessl could thus have an impact on behaviour and breeding success. The intensity of disturbance would depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions and could range from low to high intensity for individuals but of MINOR intensity for the populations as a whole. As such impacts would be limited to the area along the flight path and IMMEDIATE term (4 months), impacts would be of **(VERY) LOW** environmental risk.

Identification of Mitigation Measures

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over seal colonies and bird breeding area	Avoid / abate on site
2	Avoid extensive low-altitude coastal flights (<2,500 ft and within 1 nautical mile of the shore)	Avoid/ abate on site
3	The flight path between the onshore logistics base and seismic vessel should be perpendicular to the coast	Avoid/ abate on site
4	A flight altitude >1,000 m to be maintained at all times, except when taking off and landing or in a medical emergency.	Avoid/ abate on site
5	Maintain an altitude of at least 2,500 ft above the highest point of a Special Nature Reserve, National Park or World Heritage Site	Avoid/ abate on site
6	Contractors should comply fully with aviation and authority guidelines and rules	Avoid
7	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Avoid

Residual Impact Assessment

The generation of noise from helicopters cannot be eliminated if helicopters are required for crew changes. Similarly the generation of vessel noise cannot be eliminated. With the implementation of the mitigation measures above, the residual impact would be of (very) low environmental risk and **(VERY) LOW** significance considering their medium sensitivity of the pelagic and coastal species potentially impacted.

28	***Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to vessel noise and the noise of support aircraft***	
Project Phase:	**Mobilisation (vessel only), Operation (vessel and helicopter), and Demobilisation (vessel only)**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Minor**	**Minor**
Extent	**Activity**	**Activity**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Very Low (helicopter) to Low (vessel)**
Environmental Risk	**(VERY) LOW**	**(VERY) LOW**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**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 25 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 licence area. The strong operational lighting used to illuminate the survey vessel at night may disturb and disorientate pelagic seabirds, seals and small odontocetes 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, seabirds and dolphins.

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 (BAT), and in compliance with the applicable requirements in the MPRDA regulations.

Sensitivity of Receptors

The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans transiting through the 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**.

Impact Magnitude

Although little can be done on the survey vessel to prevent seabird collisions, reports of collisions or death of seabirds on vessels are rare. Should they occur, the light impacts would primarily take place in the 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 inshore of the main traffic routes that pass around southern Africa, but within local traffic routes for fishing and mining vessels, animals in the area should be accustomed to vessel traffic.

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, marine mammals and seabirds. As seals are known to forage up to 120 nautical miles (~220 km) offshore, the inshore portions of the proposed survey area therefore fall within the foraging range of seals from the West Coast colonies at Buchu Twins, Cliff Point and Kleinzee. The closest coly is at Kleinzee, which lies approximately 20 km inshore of the eastern boundary of the proposed 3D survey area. Odontocetes are also highly mobile, supporting the notion that various species are likely to occur in the licence area and thus potentially be attracted to the area.

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 local traffic routes, the increase in ambient lighting in the offshore environment would be of LOW intensity and limited to the area in the immediate vicinity of the vessel (ACTIVITY) within the survey area (SITE) over the IMMEDIATE-term (4 months). For support vessels travelling from Port Nolloth increase in ambient lighting would likewise be restricted to the immediate vicinity of the vessel over the IMMEDIATE-term. The potential for behavioural disturbance as a result of vessel lighting would thus be of **VERY LOW** magnitude.

<u>Identification of Mitigation Measures</u>

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

<u>Residual Impact Assessment</u>

With the implementation of the mitigation measures above, the potential for behavioural disturbance by vessel lighting is deemed to be of (**VERY) LOW** significance, due to the medium sensitivity of the receptors and the very low.environmental risk.

29	*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**
Intensity	**Minor**	**Minor**
Extent	**Activity**	**Activity**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**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.

Although the the Operator will follow IMO requirements, de-ballasting is limited to biologically compatible receiving environments. The project would therefore follow the requirements of the IFC Project Standard 6, through the implementation of the 2004 Ballast Water Management Convention, and its guidelines, as regards ballast water management.

The International Convention for the Control and Management of Ships' Ballast Water and Sediments (IMO 2004), that entered into force in September 2017, offers the first international tool for managing this global vector. The efficacy there of will, however, depend on its implementation, a process which is facing a variety of technical and administrative challenges (Sink *et al*. 2019).

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 25 km offshore, and potentially within reach of sensitive coastal receptors (e.g. sessile benthic invertebrates, endemic neritic and demersal fish species). However,, due to the water depths in the survey area (~100 – 200 m), colonisation by invasive species on the seabed is considered unlikely. Thus, the sensitivity of benthic receptors in the offshore waters of the proposed 3D survey area is considered **VERY LOW**, but the sensitivity of coastal receptors **HIGH**.

Environmental Risk

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

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

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

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

The 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 Namibian waters. The risk of this impact is, however, significantly reduced due by the implementation of ballast water management measures in accordance with the IMO guidelines. The risk is further reduced due to the far offshore location of the 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 south-westerly away from the coast. In addition, the water depths in the survey area (~100 m up to 5 000 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 on the southern boundary of the main traffic routes (further inshore) 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, inshore of the survey area, on a daily basis.

Considering the remote 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 potentially enduring PERMANENTly if the species becomes established and potentially of REGIONAL extent. Thus, the environmental risk is considered to be **MEDIUM**.

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

30	***Impacts of marine biodiversity through the introduction of non-native species in ballast water and on ship hulls***	
Project Phase:	**Mobilisation, Operation & Demobilisation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low (offshore)	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Moderate**	**Minor**
Extent	**Regional**	**Activity**
Duration	**Permanent**	**Immediate**
Probability	**Medium**	**Very Low**
Environmental Risk	**MEDIUM**	**(VERY) LOW**
Reversibility	**Irreversible**	**Fully Reversible**
Confidence	**Medium**	
Cumulative potential	**Medium**	
Loss of Resources	**Low**	
Priority Factor	**1.38**	
Significance	**(VERY) LOW**	
Mitigation Potential	**High**	

4.4.4 Impacts of Waste Discharges to Sea

Source of Impact

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

Project phase	Activity
Mobilisation	Transit of vessels to survey area
Operation	Operation of survey vessels and transit of support vessels between the survey area and Port Nolloth
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 16 000 litres per day for the duration of the seismic study based on 200 litres per 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 nautical miles (± 5.5 km) of the coast.
  - Disposal between 3 nautical miles (± 5.5 km) and 12 nautical miles (± 22 km) needs to be comminuted to particle sizes smaller than 25 mm.
  - Disposal overboard without macerating can occur greater than 12 nautical miles 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 nautical miles (± 6 km) and 12 nautical miles (± 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 1.0 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 (BAT).
- 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 Saldanha Bay. The survey area is located in the offshore marine environment, more than 25 km offshore at its nearest 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. Vessel discharges *en route* to the onshore supply base in Port Nolloth 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 south-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, 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 LOW intensity, IMMEDIATE duration and mainly limited to the immediate area around the survey vessel (ACTIVITY). The environmental risk is therefore considered **(VERY) LOW** before mitigation and **NEGLIGIBLE** with mitigation.

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 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
2	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
3	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, and considering the medium sensitivity of the offshore receptors and the very low environmental risk the residual impact will be of **NEGLIGIBLE** significance.

Impact Significance

The impacts associated with normal waste discharges from the survey vessel is deemed to be of **VERY LOW** significance, due to the.

31	*Impacts of normal vessel discharges on marine fauna*	
Project Phase:	**Mobilisation, Operation & Demobilisation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Minor**
Extent	**Activity**	**Activity**
Duration	**Immediate**	**Immediate**
Probability	**Low**	**Very Low**
Environmental Risk	**(VERY) LOW**	**LOW (NEGLIGIBLE)**
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**LOW (NEGLIGIBLE)**	
Mitigation Potential	**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 (BAT).

Sensitivity of Receptors

The leatherback and loggerhead turtles that occur in offshore waters around southern Africa, and likely to be encountered in Block 1 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). However, due to its location offshore, and the extensive distributions of the various species concerned, the numbers of individuals encountered during the surveys are likely to be low. The sensitivity of migratory cetaceans is thus considered to be **MEDIUM**.

Environmental Risk

Collisions between turtles or cetaceans and vessels are not limited to seismic ships, and 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 south 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. 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 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 39, 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 39, 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.

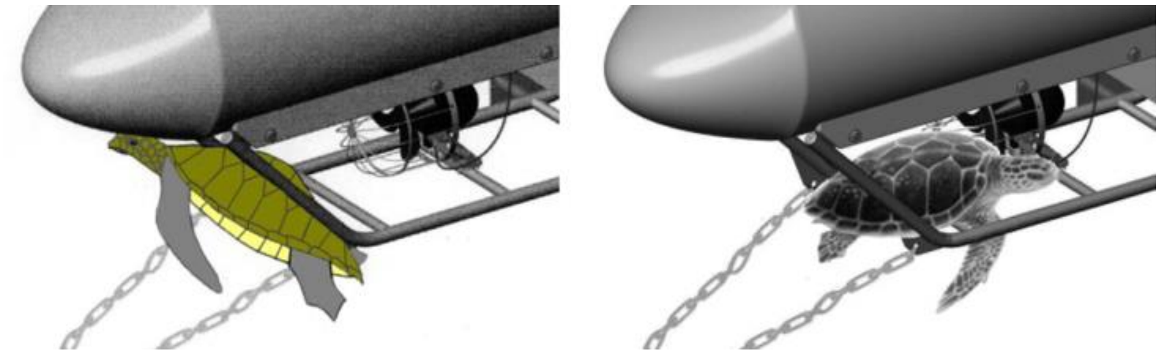

Figure 39: Turtles commonly become trapped in front of the undercarriage of the tail buoy in the area between the buoy and the towing chains (left), and inside the 'twin-fin' undercarriage structure (right) (Ketos Ecology 2009).

The potential for 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 3D survey 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 IMMEDIATE-term (4 months) and be restricted to the survey area (SITE), the potential for collision and entanglement in seismic equipment is therefore considered to be of **(VERY) LOW** environmental risk.

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 3D survey 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 (SITE), the potential for entanglement in seismic equipment is therefore considered to be of **VERY LOW** environmental risk.

Identification of Mitigation Measures

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	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)	
3	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

No.	Mitigation measure	Classification
4	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

Residual Impact Assessment

With the implementation of the mitigation measures above, the residual impact would be of (VERY) LOW significance due to the medium sensitivity of the receptors and the very low environmental risk.

32	***Impacts on turtles and cetaceans due to ship strikes, collision and entanglement with towed equipment***	
Project Phase:	**Mobilisation, Operation & Demobilisation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Partially Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**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 seismic acquisition
- 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 operator will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques (BAT). Due to the cost of the equipment, redundancy has been factored in to ensure that gear will still be recoverable at or near the surface.

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, ~25 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); however, lost equipment could still pose an entanglement risk to migratory turtles and cetaceans transiting through the survey area. Losses to the seabed would affect the continental shelf benthos in unconsolidated sediments.

The taxa most vulnerable to lost equipment are turtles and marine mammals. Some of 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, 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 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 continental shelf are, however, 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 ACTIVITY 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 **(VERY) 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 ACTIVITY (although would potentially float around the SITE) over the IMMEDIATE-term. The impact magnitude for equipment lost to the water column is therefore considered **(VERY) LOW**.

Identification of Mitigation Measures

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

No.	Mitigation measure	Classification
1	In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the licence area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval	Repair/restore
2	Notify Department of Transport (Directorate of Maritime Affairs) and the SAN Hydrographer of any hazards left on the seabed or floating in the water column, and request that they send out a Notice to Mariners with this information.	Avoid

Residual Impact Assessment

With the implementation of the project controls and mitigation measures, the residual impact associated with the accidental loss of equipment is will be of **(VERY) LOW** significance due to the medium sensitivity of the offshore receptors and the very low environmental risk.

33	*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**
Intensity	**Low**	**Minor**
Extent	**Site**	**Site**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Fully to Partially Reversible**	**Fully to Partially Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low**	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**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 (BAT). 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 surveying operations 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 Saldanha Bay and/or Port Nolloth. The survey area is located in the offshore marine environment, ~25 km offshore at its closest point, 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 in Port Nolloth could result in fuel loss closer to shore, thereby potentially having an environmental effect on the sensitive coastal environment.

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 'Endangered' (e.g. African Penguin, Cape Gannet, Cape Cormorant, Bank Cormorant, Roseate Tern) or 'vulnerable' (e.g. White Pelican, Caspian Tern, Damara Tern). Although species listed as 'Endangered' or 'vulnerable' 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

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 is thought to primarily affect hatchling survival (CSIR & CIME 2011). Turtles encountered in the project area would mainly be migrating adults and vagrants. Similarly, little work has been done on the effect of an oil spill on fur seals.

The effects of oil pollution on marine mammals 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 to include absorption into the circulatory system and mild irritation to permanent damage to sensitive tissues such as membranes of eyes, mouth and respiratory tract. Direct oiling of cetaceans is not considered a serious risk to the thermoregulatory capabilities, as cetacean skin is thought to contain a resistant dermal shield that acts as a barrier to the toxic substances in oil. Baleen whales may experience fouling of the baleen plates, resulting in temporary obstruction of the flow of water between the plates and, consequently, reduce feeding efficiency. Field observations record few, if any, adverse effects among cetaceans from direct contact with oil, and some species have been recorded swimming, feeding and surfacing amongst heavy concentrations of oil (Scholz *et al.* 1992) with no apparent effects.

In the unlikely event of an operational spill or 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 Block 1 (PRDW 2014) a diesel slick released 32 km offshore would be blown as a narrow plume extending in a northerly direction. The diesel would most likely remain at the surface for <36 hours with no probability of reaching sensitive coastal habitats, but potentially crossing the Namaqua Fossil Forest MPA. In offshore environments, impacts associated with a spill or vessel collision would thus be of LOW intensity, LOCALISED over the IMMEDIATE-term (5 days). The environmental risk for a marine diesel spill is therefore considered **(VERY) LOW**.

However, in the case of a spill or collision *en route* to the survey area, the spill may extend into coastal MPAs or EBSAs and reach the shore affecting intertidal and shallow subtidal benthos and sensitive coastal bird species, in which case the intensity would be considered MEDIUM, but still remaining LOCAL over the IMMEDIATE-term. The environmental risk would however remain **(VERY) 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 to reduce wastes at the source:

No.	Mitigation measure	Classification
1	Prepare and implement a Shipboard Oil Pollution Emergency Plan and an Oil Spill Contingency Plan. In doing so take cognisance of the South African Marine Pollution Contingency Plan, which sets out national policies, principles and arrangements for the management of emergencies including oil pollution in the marine environment.	Avoid
2	Use low toxicity dispersants cautiously and only with the permission of DEA.	Abate on and off site
3	As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill	Abate on site
4	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
5	Ensure offshore bunkering is not undertake in the following circumstances: • Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; • During any workboat or mobilisation boat operations; • During helicopter operations; • During the transfer of in-sea equipment; and • At night or times of low visibility.	Avoid / Reduce at source

Residual Impact Assessment

With the implementation of the project controls and mitigation measures, the significance of the residual impact will be **(VERY) LOW** significance due to the medium sensitivity of the receptors and the very low environmental risk. It must be pointed out that the probability of a spill or collision is unlikely.

34	*Impacts of an operational spill or vessel accidenton marine fauna*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Intensity	**Low to Medium***	**Minor**
Extent	**Local**	**Local**
Duration	**Immediate**	**Immediate**
Probability	**Very Low**	**Very Low**
Environmental Risk	(VERY) LOW	(VERY) LOW
Reversibility	**Fully Reversible**	**Fully Reversible**
Confidence	**High**	
Cumulative potential	**Low**	
Loss of Resources	**Low to Medium***	
Priority Factor	**1**	
Significance	**(VERY) LOW**	
Mitigation Potential	**Medium**	

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

4.7 Confounding Effects and Cumulative Impacts

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, 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 stressors (e.g. temperature, competition for food, shipping noise) (Przeslawski *et al*. 2015). 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 either 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 40, 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*. 2018), 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.

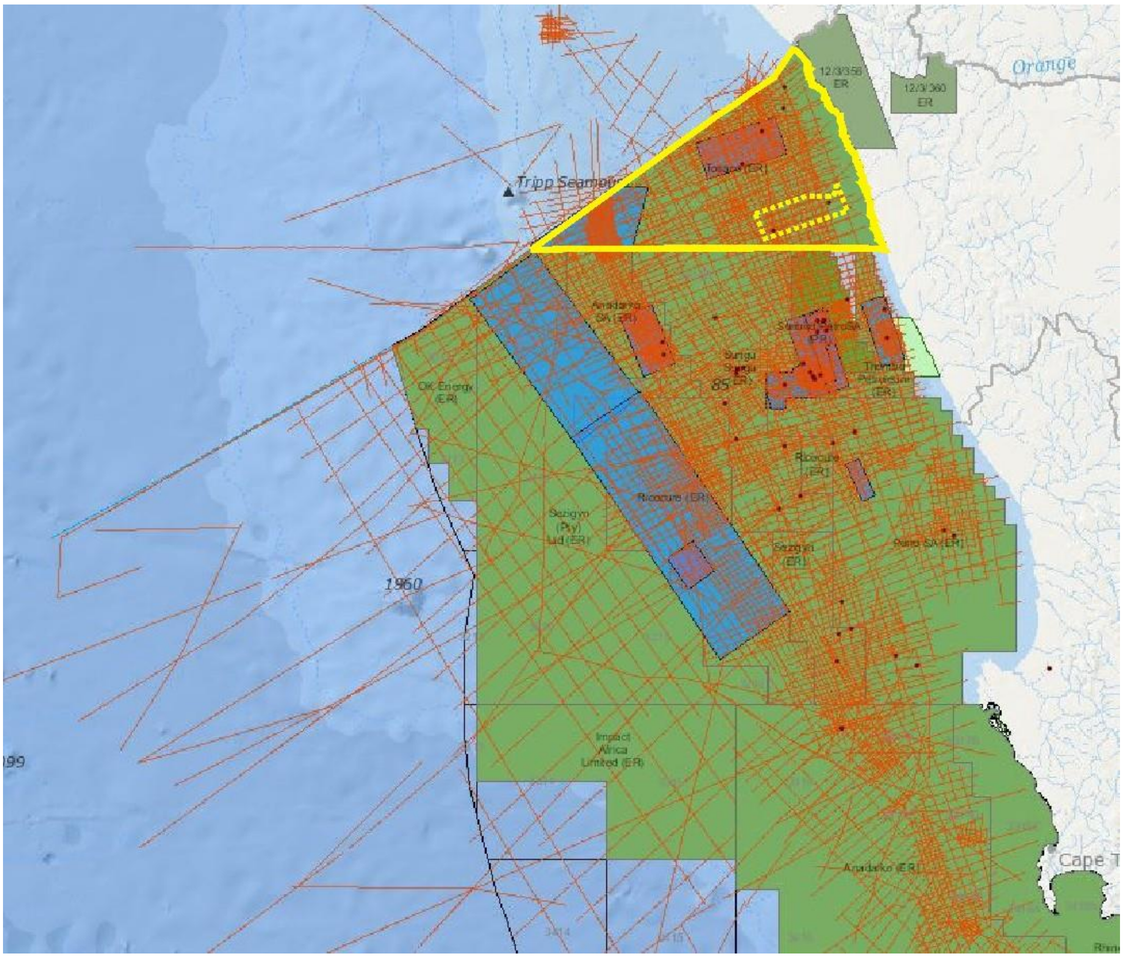

Figure 40: Block 1 (yellow polygon) and the proposed 3D survey area (dotted line) in relation to historical 2D (red lines) and 3D (blue and purple polygons) surveys conducted on the West Coast between 2001 and 2018 (Source: PASA).

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.

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 (Koper & Plön 2012). If the survey is undertaken by two vessels working concurrently as proposed, cumulative impacts can be expected.

5. FINDINGS AND RECOMMENDATIONS

5.1 Key Findings

The proposed exploration activities to be undertaken by Tosaco are expected to result in impacts on marine invertebrate fauna in Block 1, ranging from negligible to very low significance. Only in the case of potential impacts to 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 20. Other impacts that may occur during seismic surveys are summarised in Table 21.

Table 20: Summary of residual impact significance for seismic noise.

Impact	Significance of Residual Impact
Plankton and ichthyoplankton	
Mortality and/or pathological injury	Very Low
Marine invertebrates	
Mortality and/or pathological injury in benthic and pelagic/neritic invertebrates	Very Low
Behavioural avoidance	Very Low
Fish	
Mortality and/or pathological injury in demersal species	Very Low
Mortality and/or pathological injury in pelagic species	Very Low
Avoidance behaviour	Very Low
Reproductive success / spawning	Very Low
Masking of sounds	Very Low
Indirect impacts on food sources	Very Low
Seabirds	
Pathological injury	Very Low
Avoidance behaviour	Very Low
Indirect impacts on food sources	Very Low
Turtles	
Pathological injury, collision and entanglement	Very Low
Avoidance behaviour	Very Low
Masking of sounds	Very Low
Indirect impacts on food sources	Very Low

Impact	Significance of Residual Impact
Seals	
Pathological injury	Very Low
Avoidance behaviour	Very Low
Masking of sounds	Very Low
Indirect impacts on food sources	Very Low
Whales and dolphins	
Baleen whales	
Pathological injury	Low
Avoidance behaviour	Low
Masking of sounds and indirect impacts on food sources	Low
Indirect impacts on food sources	Very Low
Toothed whales and dolphins	
Pathological injury	Low
Avoidance behaviour	Low
Masking of sounds and indirect impacts on food sources	Low
Indirect impacts on food sources	Very Low

Table 21: Other residual impacts on marine habitats and communities associated with the proposed project are summarised below:

Impact	Significance (before mitigation)	Significance (after mitigation)
Non-seismic noise	Very Low	Very Low
Vessel lighting	Very Low	Very Low
Hull fouling and ballast water discharge	Negligible	Negligible
Waste Discharges to sea	Very Low	Very Low
Geophysical Surveys (Sonar)	Negligible	Negligible
Ship strikes and entanglement in gear	Very Low	Very Low
Accidental loss of equipment	Very Low	Very Low
Operational spills and vessel collision	Very Low	Very 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 Recommendations

Detailed mitigation measures for seismic surveys in other parts of the world are provided by Weir *et al.* (2006), Compton *et al.* (2007) and US Department of Interior (2007). 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 more recently 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). These have been updated as necessary to include salient points from recognised international guidelines, particularly the JNCC (2010, 2017) Guidelines and the 2013 New Zealand Code of Conduct for seismic operations.

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

Mobilisation Phase

<u>1) Pre-survey Planning</u>

- Plan seismic surveys to avoid the periods of movement of migratory cetaceans (particularly baleen whales) from their southern feeding grounds into low latitude waters (June to November inclusive), and ensure that migration paths are not blocked by seismic operations. In addition, avoid surveying during December when humpback whales may still be moving through the area on their return migrations. This would also avoid the period when juvenile penguins feed in inshore waters along the West Coast.
- 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.
- Although a seismic vessel and its gear may pass through a declared Marine Protected Area, acoustic sources (airguns) must not be operational during this transit.
- A buffer of at least 5 km is recommended around MPAs.

<u>2) Key Equipment</u>

- All seismic vessels must be fitted with Passive Acoustic Monitoring (PAM) technology, which detects animals through their vocalisations.
- The use of PAM 24-h a day must be implemented to detect deep diving species.
- 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.
- Ensure the PAM hydrophone streamer is towed in such a way that the interference of vessel noise is minimised.
- 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
- Define and enforce the use of the lowest practicable airgun volume for production.
- Ensure the ramp-up noise volumes do not exceed the production volume.
- Prohibit airgun use (including airgun tests) outside of the area of operation (which includes line turns undertaken outside the licence area).

- The operator must provide a display screen for the acoustic source operations. 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.
- 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'.
- Ensure that solid streamers rather than fluid-filled streamers are used to avoid leaks.

2) MMO and PAM Duties

- Two qualified, independent MMOs are required on board at all times; as a minimum one must be on watch during daylight hours while the acoustic source is in the water in the operational area.
- The duties of the MMO would be to:
  - Give effective 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, 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;
  - Sightings of any injured or dead protected species (marine mammals, seabirds and sea turtles) should be recorded, 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;
  - 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 the JNCC (2017) recording spreadsheet in order to record all the above observations and decisions; and
  - Prepare daily reports of all observations, to be forwarded to the necessary authorities on a daily or weekly basis to ensure compliance with the mitigation measures.

- At least two qualified, independent PAM operators are required on board at all times[7], as a minimum one must be on watch while the acoustic source is in the water in the operational area.
- The duties of the PAM operator would be to:
  - Give effective 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 1 000 m (very high frequency cetaceans) or 500 m (low and high frequency cetaceans) 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.
- 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).
- Seabird, turtle and marine mammal incidence data and seismic source output data arising from surveys should be made available on request to the Marine Mammal Institute, DFFE, and the Petroleum Agency South Africa for analyses of survey impacts in local waters.

Operational Phase

1) Airgun Testing

- For airgun testing the following should apply:
  - If testing a single lowest power airgun a "soft-start" is not required;
  - If testing multiple higher powered airguns a "soft-start" is required. 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;
  - A pre-shoot watch must be maintained before any instances of airgun testing;
  - No airgun testing may be undertaken outside the licence block.

2) Pre-Start Observations

- Soft starts should be scheduled so as to minimise, as far as possible, the interval between reaching full power operation and commencing a survey line.
- The implementation of "soft-start" procedures of a minimum of 20 minutes' duration on initiation of seismic surveying is required.
- The "soft-start" cannot commence during daylight hours unless:

[7] If PAM is to be operational 24/7 then 3 PAM operators are required.

  - An area of 500 m radius from the centre of the airgun array (exclusion zone) has been scanned for the presence of diving seabirds (including penguins) and in particular feeding aggregations of diving seabirds, turtles, seals and cetaceans. As the survey will primarily be conducted in water depths of more than 200 m, there should be a dedicated pre-shoot watch of at least 60 minutes for deep-diving species. "Soft-starts" should be delayed until such time as this area is clear of individuals or aggregations of diving seabirds, turtles and cetaceans. A "soft-start" should not begin until 60 minutes after the animals depart the exclusion zone or 60 minutes after they are last seen or acoustically detected by PAM in the exclusion zone. In the case of fur seals, which may occur commonly around the vessel, the presence of seals (including number and position / distance from the vessel) and their behaviour should be recorded prior to "soft-start" procedures. "Soft-starts" should only commence once it has been confirmed that no seal activity has been observed within 500 m of the airguns for at least 10 minutes. However, if after a period of 10 minutes they are still within 500 m of the airguns, the normal "soft-start" procedure should be allowed to commence for at least a 20-minute duration. Their 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.
  - Passive Acoustic Monitoring for the presence of marine mammals has been carried out for at least 60 minutes before activation of "soft-starts" and no vocalising cetaceans have been detected in the mitigation zone.
  - If PAM has malfunctioned then revert to requirements under Section 5.
- "Soft-start" procedures cannot commence during times of poor visibility or darkness unless:
  - Passive Acoustic Monitoring for the presence of marine mammals has been carried out by a PAM operator for at least 60 minutes before activation and no vocalising cetaceans have been detected in the mitigation zone.
- When arriving at a new location in the survey programme for the first time, the initial acoustic source activation must not be undertaken at night or during poor sighting conditions unless either:
  - MMOs have undertaken observations within 20 nautical miles of the planned start up position for at least the previous two hours of good sighting conditions preceding proposed operations, and no marine mammals have been detected; or
  - Where there have been less than two hours of good sighting conditions preceding proposed operations (within 20 nautical miles of the planned start up position), the source may be activated if:
    - PAM monitoring has been conducted for 2 hours immediately preceding proposed operations and no marine mammals have been acoustically detected, AND
    - MMOs have conducted visual monitoring for 2 hours immediately preceding proposed operations and no marine mammals have been visually detected, AND
    - No fur seals have been sighted in the mitigation zone during visual monitoring in the 10 minutes immediately preceding proposed operations.

3) Line Turns and Breaks in Firing

- When surveying in deeper waters (>200 m) and for surveys which have relatively fast line turn times, the searches for marine mammals can commence before the end of the survey line if line changes take less time than a pre-shoot search and soft-start combined (i.e. 80 minutes). If marine mammals are detected when the airguns have ceased firing, the commencement of the "soft-start" for any subsequent survey lines should be preceded by the usual 60 minute pre-watch period.
- If line changes are expected to take longer than 40 minutes, firing must be terminated at the end of the survey line and the usual pre-shoot search undertaken during the line change, followed by a "soft-start";
- If during unplanned breaks 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 detected** in the mitigation zone during the break-down period.
- All breaks in airgun firing of longer than 5 minutes but less than 20 minutes should be followed by a "soft-start" of similar duration. All breaks in firing of 20 minutes or longer must be followed by a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing.
- For planned breaks longer than 40 minutes normal start-up procedures apply. For planned breaks less than 10 minutes, monitoring must commence 20 minutes prior to the break and continue for the duration of the break. In this regard, good communication between the seismic contractor and MMOs and PAM operators is key in order to ensure that all parties are aware of planned breaks and early commencement of pre-watch periods.

4) Shut-downs

- Seismic shooting should be terminated on observation of diving seabirds (including penguins) and in particular feeding aggregations of diving seabirds, turtles, seals and cetaceans within the 500 m mitigation zone. If PAM detects the presence of very high frequency cetaceans (Heaviside's dolphins, pygmy sperm whale and dwarf sperm whale) within 1 000 m of the sound source, seismic shooting should be terminated.
- Seismic shooting should be terminated on observation of any obvious mortality or injuries to cetaceans, turtles, seals or large mortalities of invertebrate and fish species as a direct result of the survey. Such mortalities would be of particular concern where a) commercially important species are involved, or b) mortality events attract higher order predator and scavenger species into the seismic area during the survey, thus subjecting them to acoustic impulses.
- Seismic shooting should also be terminated when obvious changes to turtle, seal or cetacean behaviours are observed from the survey vessel, or turtles and cetaceans (not seals) are observed within 500 m of operating airguns or appear to be approaching firing airguns (particularly if the MMO has lost sight of the approaching animal prior to it entering the mitigation zone). The rationale for this is that animals at close distances (i.e. where physiological injury may occur) may be suffering from reduced hearing as a result of seismic sounds, that frequencies of seismic sound energy lies below best hearing frequencies (certain toothed cetaceans and seals), or that animals have become trapped within the area filled with sound through diving behaviour.

- Although a seismic vessel and its gear may pass through a declared Marine Protected Area, acoustic sources (airguns) must not be operational during this transit.

5) PAM Malfunctions

- If the PAM system malfunctions or becomes damaged during night-time operations or periods of low visibility, surveying must be discontinued until such time as the functional PAM system can be redeployed.
- If the PAM system breaks down during daylight hours operations may continue 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 solely 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 without an active PAM system is recorded.
- Sufficient time should be provided to the PAM operator to redeploy fixed or replacement PAM equipment prior to survey activities (with appropriate pre-watch and "soft-start" operations) recommencing.

Vessel and Aircraft Operations

- Pre-plan flight paths to ensure that no flying occurs over the Mossel Bay and Robber Peninsula seal colonies;
- Avoid extensive low-altitude coastal flights (<2,500 ft and within 1 nautical mile of the shore);
- The flight path between the onshore logistics base and seismic vessel should be perpendicular to the coast;
- A flight altitude >1 000 ft be maintained at all times, except for when the aircraft lands on or takes off from the seismic vessel and logistics base;
- Maintain an altitude of at least 2 500 ft over of a Special Nature Reserve, National Park or World Heritage Site;
- Contractors should comply fully with aviation and authority guidelines and rules;
- Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals.
- The lighting on the seismic vessel 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.
- 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.
- Develop a ballast water management plan that considers all IMO requirements .
- Ensure all infrastructure (e.g. arrays, streamers, tail buoys etc.) that has been used in other regions is thoroughly cleaned prior to deployment.

- 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).
- Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.
- Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.
- In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations.
- Establishing a hazards database listing the type of gear left on the seabed and/or in the licence area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval.
- Prepare and implement a Shipboard Oil Pollution Emergency Plan and an Oil Spill Contingency Plan. In doing so take cognisance of the South African Marine Pollution Contingency Plan, which sets out national policies, principles and arrangements for the management of emergencies including oil pollution in the marine environment.
- As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill.
- Ensure 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.

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APPENDIX A

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)
- Registered Environmental Assessment Practitioner (Certification Board for Environmental Assessment Practitioners of South Africa).

Employment History and Professional Experience

1998-present: Director: Pisces Environmental Services (Pty) Ltd. Specifically responsible for environmental impact assessments, baseline and monitoring studies, marine specialist studies, and environmental management plan reports.

1999: Senior researcher on contract to Namdeb Diamond Corporation and De Beers Marine South Africa, at the University of Cape Town; investigating and monitoring the impact of diamond mining on the marine environment and fisheries resources; experimental design and implementation of dive surveys; collaboration with fishermen and diamond divers; deep water benthic sampling, sample analysis and macrobenthos identification.

1996-1999: Senior researcher at the University of Cape Town, on contract to the Chief Director: Marine and Coastal Management (South African Department of Environment Affairs and Tourism); investigating and monitoring the experimental fishery for periwinkles on the Cape south coast; experimental design and implementation of dive surveys for stock assessments; collaboration with fishermen; supervision of Honours and Masters students.

1989-1994: Institute for Marine Science at the Christian-Albrechts University of Kiel, Germany; research assistant in a 5 year project to investigate the population dynamics of mussels and cockles in the Schleswig-Holstein Wadden Sea National Park (employment for Doctoral degree); extensive and intensive dredge sampling for stock assessments, collaboration with and mediation between, commercial fishermen and National Park authorities, co-operative interaction with colleagues working in the Dutch and Danish Wadden Sea, supervision of Honours and Masters projects and student assistants, diving and underwater scientific photography. Scope of doctoral study: experimental design and implementation of a regular sampling program including: (i) plankton sampling and identification of lamellibranch larvae, (ii) reproductive biology and condition indices of mussel populations, (iii) collection of mussel spat on artificial collectors and natural substrates, (iv) sampling of recruits to the established populations, (v) determination of small-scale recruitment patterns, and (vi) data analysis and modelling. Courses and practicals attended as partial fulfilment of the degree: Aquaculture, Stock Assessment and Fisheries Biology, Marine Chemistry, and Physical and Regional Oceanography.

1988-1989: Australian Institute of Marine Science; volunteer research assistant and diver; implementation and maintenance of field experiments, underwater scientific photography, digitizing and analysis of stereo-photoquadrats, larval culture, analysis of gut contents of fishes and invertebrates, carbon analysis.

1985-1987: Sea Fisheries Research Institute of the South African Department of Environment Affairs and Tourism: scientific diver on deep diving surveys off Cape Agulhas; censusing fish populations, collection of benthic species for reef characterization.

South African National Research Institute of Oceanography and Port Elizabeth Museum: technical assistant and research diver; quantitative sampling of benthos in Mossel Bay, and census of fish populations in the Tsitsikamma National Park.

University of Cape Town, Department of Zoology and Percy Fitzpatrick Institute of African Ornithology; research assistant; supervisor of diving survey and collection of marine invertebrates, Prince Edward Islands.

1984-1986: University of Cape Town, Department of Zoology; research assistant (employment for MSc Degree) and demonstrator of first year Biological Science courses. Scope of MSc study: the biology, ecology and fishery of the western Cape linefish species *Pachymetopon blochii*, including (i) socio-economic survey of the fishery and relevant fishing communities, (ii) collection and analysis of data on stomach contents, reproductive biology, age and growth, (iii) analysis of size-frequency and catch statistics, (iv) underwater census, (v) determination of hook size selectivity, (vi) review of historical literature and (vii) recommendations to the Sea Fisheries Research Institute of the South African Department of Environment Affairs and Tourism for the modification of existing management policies for the hottentot fishery.