APPENDIX 6: BIODIVERSITY AND ECOSYSTEM SERVICES IMPACT ASSESSMENT (MARINE FAUNA)

BASIC ASSESSMENT FOR A SPECULATIVE 3D SEISMIC SURVEY OFF THE EASTERN CAPE COAST, SOUTH AFRICA

Marine Faunal Assessment

Prepared for:

SLR

On behalf of

CGG

December 2021
Revised August 2022

PISCES Environmental Services (Pty) Ltd

With contributions by
Simon Elwen
Sea Search Research & Conservation

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NOTE

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

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ABBREVIATIONS and UNITS

2D	two-dimensional
3D	three-dimensional
ALARP	as low as reasonably practicable
BCC	Benguela Current Commission
CBA	critical biodiversity area
CBD	Convention On Biological Diversity
CCA	CCA Environmental (Pty) Ltd
CITES	Convention on International Trade in Endangered Species
cm	centimetres
cm/sec	centimetres per second
CMS	Convention on Migratory Species
CMS	Centre for Marine Studies
CSIR	Council for Scientific and Industrial Research
CUD	Cumulative Utilization Distribution
dB	decibells
DFO	Department of Fisheries and Oceans (Canada)
E	East
EBSAs	Ecologically or Biologically Significant Areas
EEZ	Exclusive Economoc Zone
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
EMPR	Environmental Management Programme Report
ERM	Environmental Resource Management Southern Africa (Pty) Ltd
ERP	Emergency Response Plan
ESA	Ecological Support Area
ESIA	Environmental and Social Impact Assessment
ESSMMP	Environmental and Social Management and Monitoring Plan
FAO	Food and Agricultural Organisation
gC/m^2	grams Carbon per square metre
h	hour
ha	hectare
Hz	Herz
IBA	Important Bird Area
IMMA	Important Marin emammal Area
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
JNCC	Joint Nature Conservation Committee
KBA	Key Biodiversity Area
kHz	kiloHerz
km	kilometre
km^2	square kilometre
KZN	KwaZulu-Natal
m	metres

mg/m^3	milligrams per cubic metre
m/sec	metres per second
m^3/sec	cubic metres per second
mm	millimetre
MMO	Marine Mammal Observer
MPA	Marine Protected Area
NEMBA	National Environmental Management: Biodiversity Act
NRC	National Research Council
OECMs	Other Effective Area-Based Conservation Measures
PAM	Passive Acoustic Monitoring
ppm	parts per million
ppt	parts per thousand
PTS	permanent threshold shifts
rms	root mean squared
S	south
SANBI	South African National Biodiversity Institute
SAT	saturation
SEL	Sound Exposure Level
SOPEP	Shipboard Oil Pollution Emergency Plan
SPI	Shot Point Interval
SPL	Sound Pressure Level
SWIO	South Western Indian Ocean
TOPS	Threatened or Protected Species
TTS	temporary threshold shifts
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
VME	Vulnerable Marine Ecosystem
WWF	World Wildlife Fund
µg/l	micrograms per litre
µm	micron
µPa	micro Pascal
°C	degrees Centigrade
%	percent
~	approximately
<	less than
>	greater than

PTS — Permanent threshold shift is a raising of the hearing threshold from over-exposure to high-level sound; but, in this case, permanent damage occurs to the inner ear sensory mechanisms and hence the shift is non-reversible.

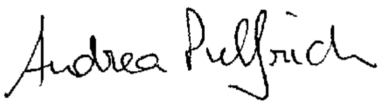
TTS — Temporary threshold shift is the temporary raising of hearing threshold resulting from exposure to high-level sounds. This is the lowest end of the physical effects scale, which is a temporary, reversible form of hearing impairment. In TTS, the lower threshold of hearing in the relevant frequency band is increased (*i.e.* hearing becomes less sensitive) when exposed to a critical combination of sound intensity and duration.

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 / Plans 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 on behalf of SLR Consulting (South Africa) (Pty) Ltd for their use in preparing an Environmental Management Programme for a proposed speculative 3D seismic survey by CGG Services SAS, offshore of the East Coast of South Africa. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and SLR Consulting, and has no vested interests in the proposed project or the study area.



Dr Andrea Pulfrich

1. GENERAL INTRODUCTION

Hydrocarbon deposits occur in reservoirs in sedimentary rock layers. Being lighter than water they accumulate in traps where the sedimentary layers are arched or tilted by folding or faulting of the geological layers. Marine seismic surveys are the primary tool for locating such structures and are thus an indispensable component of offshore oil or gas exploration. Alternative techniques to acquire comparable marine geophysical data are in their infancy (Pramik *et al*. 2015; Feltham *et al*. 2017; Laws *et al*. 2018), and the use of airguns remains the most effective way to identify potential offshore oil and gas resources (Gisiner 2016).

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, fish, and turtles (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 CGG Services SAS Ltd (CGG) is proposing to undertake speculative 3D seismic survey over a number of licence blocks in the Algoa/Outeniqua Basin off the Southeast Coast of South Africa (Figure **1**). SLR Consulting (South Africa) (Pty) Ltd (SLR) has been appointed by CGG to compile the Basic Assessment Report as part of the application for Environmental Authorisation to undertake the survey. SLR in turn has approached Pisces Environmental Services (Pty) Ltd to provide a specialist report on potential impacts of the proposed operations on marine fauna in the area.

1.1. Scope of Work

This specialist report was compiled as a desktop study on behalf of SLR, for their use in preparing a Basic Assessment Report and Environmental and Social Management Programme (ESMP) for proposed speculative 3D seismic acquisition off the Southeast Coast of South Africa.

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

- Provide a general description of the local marine fauna in and around the proposed Reconnaissance Permit area.
- Identify, describe and assess the significance of potential impacts of the proposed speculative 3D seismic survey on the local marine fauna.
- Identify practicable mitigation measures to reduce any negative impacts and indicate how these could be implemented in the implementation and management of the proposed project.

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 on a review and collation of existing information and data from the scientific literature, internal reports and the Generic Environmental Management Programme Report (EMPR) compiled for oil and gas exploration in South Africa (CCA & CMS 2001). The information for the identification of potential impacts and the assessment thereof 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 Basic Assessment Report and ESMP.

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**.
- Some important conclusions regarding the extent of the zones of impact of seismic sound and associated assessments on marine fauna are based on the results of the Underwater Noise Modelling Study (Li & Lewis 2021).
- Potential changes in the marine environment such as sea-level rise and/or increases in the severity and frequency of storms related to climate change are not included in the terms of reference and therefore not dealt with in this report.

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

Information gaps include:

- details of the benthic macrofaunal communities beyond the shelf break;
- details on demersal fish communities beyond the shelf break;
- information specific to the marine communities of submarine canyons (Sundays, Addo and Cannon Rocks Canyons); and
- current information on the distribution, population sizes and trends of most cetacean species occurring in South African waters and the project area in particular.

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

1.4. Assessment Procedure

The assessment convention provided by SLR was used to determine significance ratings in the assessment (see Appendix 1).

2. DESCRIPTION OF THE PROPOSED PROJECT

CGG is applying for an Environmental Authorisation to undertake a speculative three-dimensional (3D) seismic survey to investigate for oil and gas reserves in a number of petroleum licence blocks in the Algoa/Outeniqua Basin off the Southeast Coast of South Africa.

The Reconnaissance Permit Area is approximately 12 750 km^2 in extent. The area is situated roughly between the Robberg Peninsula in the Western Cape and Cape Recife in the Eastern Cape. It extends from approximately 45 km offshore at its nearest point at Cape St Francis to ~4 500 m depth.

The proposed 3D seismic survey would extend across an area of up to 9 000 km^2, excluding the Port Elizabeth Corals Marine Protected Area (MPA) and a buffer of 2 km around the MPA. Although survey commencement would depend on the permit award date and availability of a survey vessel, it is anticipated that the survey would commence in January 2024. The maximum survey duration would be up to 150 days.

The sound source or airgun array would be situated some 80 m to 150 m behind the vessel at a depth of 5 m to 25 m below the surface. Up to eight Seal digital and Sentinel solid of 6 000 m length would be towed behind the seismic vessel at a depth of 12 m and would not be visible, except for the tail-buoys at the far end of the cable.

The survey 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 survey vessel would be restricted in manoeuvrability (a turn radius of 4.5 km is expected), other vessels should remain clear of it. A supply/chase vessel usually assists in the operation of keeping other vessels at a safe distance.

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

Airguns have most of their energy in the 5-300 Hz frequency range, with the optimal frequency required for deep penetration seismic work being 50-80 Hz. Sound levels from individual airguns use today in the seismic industry range from 200 to 232 dB re 1 µPa at 1 m, for small to large individual guns, respectively. For airgun arrays, sound levels range from 235 dB re 1 µPa at 1 m for a small array (500 cubic inches) to 260 dB re 1 µPa at 1 m for large arrays (7 900 cubic inches) (Bröcker 2019). The majority of the produced energy is below 250 Hz, with 90% of the energy between 70 to 140 Hz, although pulses do contain some higher frequencies up to 16 kHz (Bröcker 2019). It must be noted, however, that the sound level specifications for airgun arrays refer to sound levels in the vertical direction directly beneath the airgun array, generally near its centre, with nominal sound levels in the horizontal direction being ~10-20 dB lower (Caldwell & Dragoset 2000; Dragoset 2000).

Figure 1 illustrates the Reconnaissance Permit Area in relation to the bathymetry and bathymetric features off the Southeast coast.

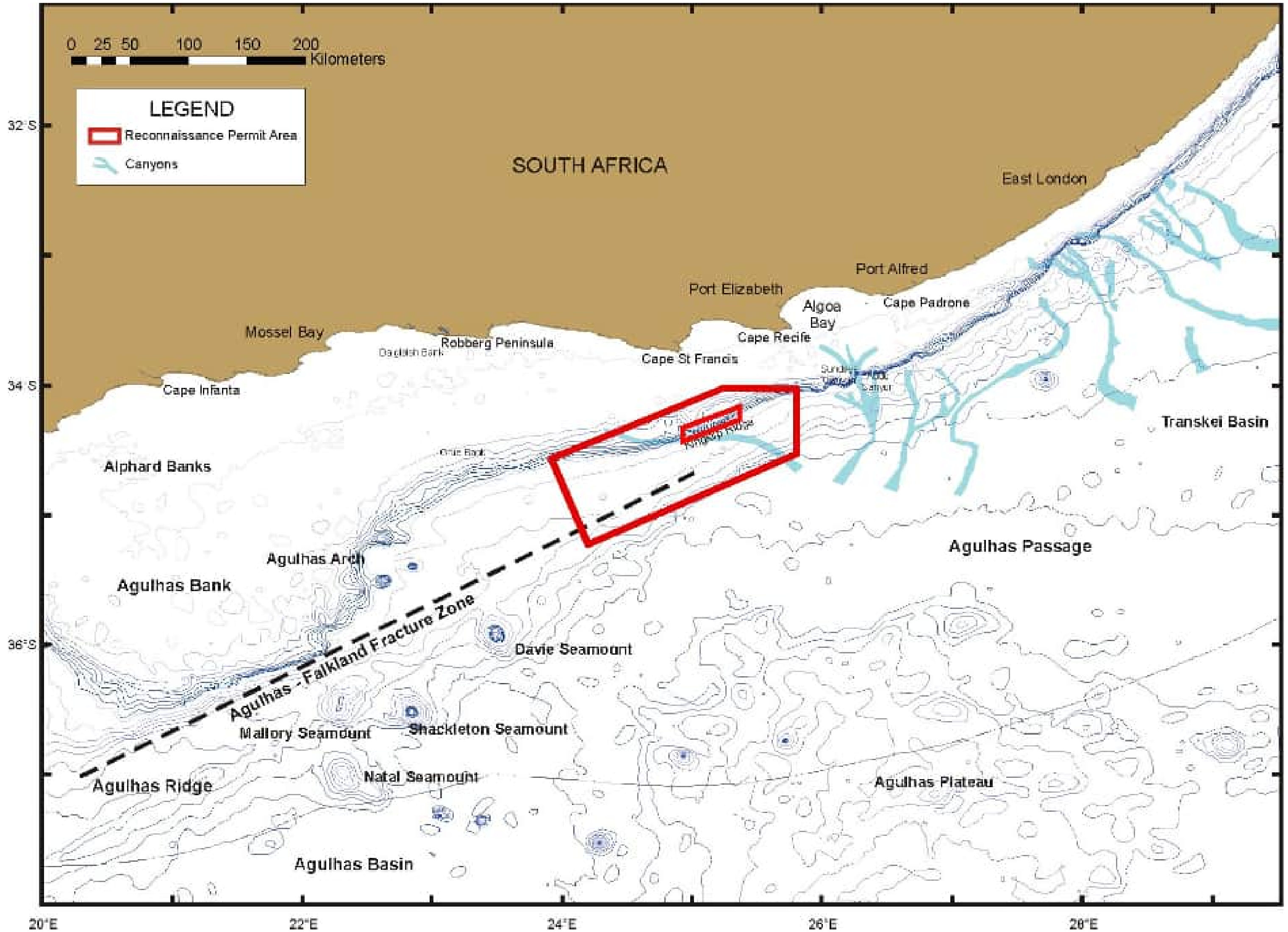


Figure 1: The Reconnaissance Permit Area (red polygon) off the Southeast coast of South Africa. Bathymetry, bathymetric features and submarine canyons and feeder-valleys (blue shading).

3. DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

The proposed reconnaissance survey area is located offshore of the East Coast, stretching between 24°E and 26°E. Descriptions of the physical and biological environments are summarised primarily from information provided in the Generic EMPR for Oil and Gas Prospecting off the Coast of South Africa (CCA & CMS 2001).

3.1. The Physical Environment

3.1.1 Bathymetry and Sediments

Along the East coast, the bathymetry is characterised by a very narrow shelf, with a steep continental slope. The bathymetry drops steeply at the coast to approximately 50 m. In the region of Algoa Bay, the shelf begins to widen, with depth increasing gradually to the shelf break at a depth of 140 m off Gqeberha (Port Elizabeth), 130 m off Cape St Francis, and 300 m south of Cape Agulhas (Birch & Rogers 1973) (Figure 1). Between 22° and 23°E, the shelf break indents towards the coast forming the Agulhas ‘bight’ (Schumann 1998). Major bathymetric features on the Agulhas Bank include various banks (Alphard, 6-Mile, 12-Mile, 45-Mile and 72-Mile Banks, and the “Blues” and “Browns” Banks), situated south of Cape Infanta and off Cape Agulhas, the Agulhas Arch and Alphard Rise (Birch & Rogers 1973; CCA & CSIR 1998). Dalgleish Bank and Grue Bank lie due south of Knysna. Grue Bank extends eastwards as a deep reef complex referred to as Kingklip Koppies and the Agulhas- and Kingklip Ridges. The Kingklip Ridge (situated on the slope between Gqeberha and Cape St. Francis) is a unique 40 km long, 500 m wide feature that rises from a depth of more than 700 m to as shallow as 350 m with very strong currents on the outer ridge (Sink *et al.* 2019). Outside the shelf break, depth increases rapidly to more than 1 000 m (Hutchings 1994) descending into the Transkei Basin. Three submarine canyons are known off Algoa Bay with the Sundays and Addo Canyons breaching the shelf and spanning a depth range of approximately -150 m to -2 000 m. The deeper Cannon Rocks Canyon, off the Boesmans Estuary east of Gqeberha , is confined to the slope (Sink *et al.* 2012, 2019). The Southwest Indian Seamounts are situated to the east of the Agulhas Bank beyond 3 000 m depth (Sink *et al.* 2012) (Figure 1).

Off Gqeberha the seafloor is predominantly rocky, seaward of the inner shelf sediment-wedge (Birch & Rogers 1973; Schumann 1998). Although mud patches occur inshore east of Cape Infanta, the majority of unconsolidated sediment is sand to muddy sand (Birch & Rogers 1973).

The inshore portions of the Reconnaissance Permit Area comprise Agulhas Sandy Shelves and Agulhas Mosaic Shelves. Offshore of the shelf break, benthic habitats are dominated by Southwest Indian Unclassified Slope unconsolidated sediments, with the deeper portions of the project area comprising sediments of the Southwest Indian Unclassified Abyss (Lombard *et al.* 2004; Sink *et al.* 2019)(Figure 2).

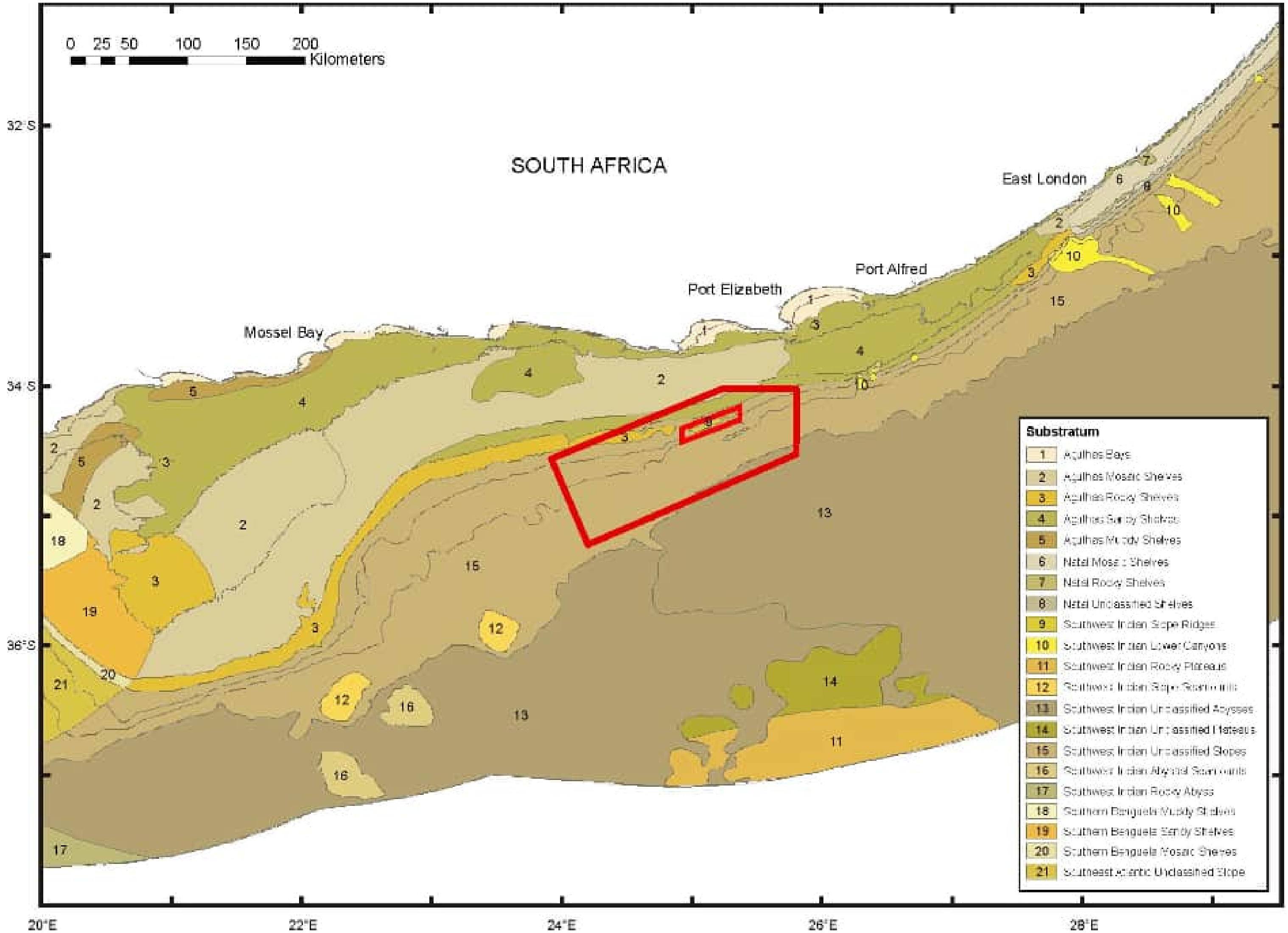


Figure 2: The Reconnaissance Permit Area (red polygon) in relation to coastal and offshore benthic habitat types off the South African Southeast coast (adapted from Sink *et al*. 2019).

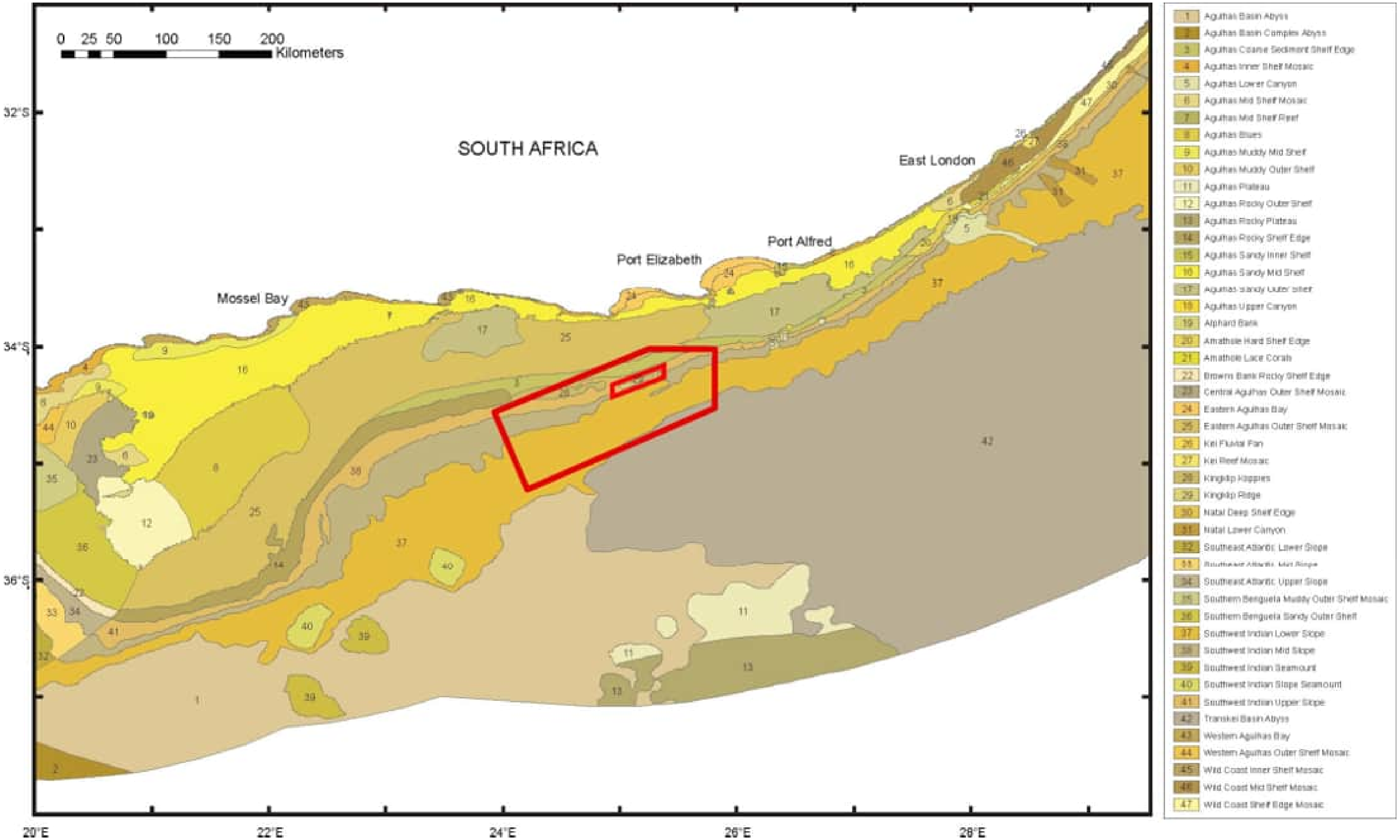


Figure 3: The Reconnaissance Permit Area (red polygon) in relation to to the distribution of ecosystem types along the Southeast coast (adapted from Sink *et al*. 2019).

3.1.2 Water Masses and Circulation

The oceanography of the South Coast is almost totally dominated by the warm Agulhas Current (Figure 4). The current forms between 25° and 30° S, flowing southwards along the shelf edge of the southern African East Coast (Schumann 1998) as part of the anticyclonic Indian Ocean gyre. It is a well-defined and intense jet some 100 km wide and 1 000 m deep (Schumann 1998), flowing in a south-west direction at a rapid rate, with current speeds of 2.5 m/s or more, and water transport rates of over 60 × 10^6 m^3/s have being recorded (Pearce *et al*. 1978; Gründlingh 1980). Following its divergence into deep water off the Tugela Bank, the Agulhas Current re-attaches itself to the coast south of Durban, where the continental shelf again narrows, until off Port Edward where it is so close inshore that the inshore edge (signified by a temperature front) is rarely discernible (Pearce 1977a, 1977b). On the eastern half of the South Coast, the Agulhas Current flows along the shelf break at speeds of up to 3 m/sec, diverging inshore of the shelf break south of Still Bay (34° 28'S, 21° 26'E) before realigning to the shelf break off Cape Agulhas (Heydorn & Tinley 1980). The Agulhas Current may produce large meanders with cross shelf dimensions of approximately 130 km, which move downstream at approximately 20 km per day (Lutjeharms 2006). It may also shed eddies, which travel at around 0.20 m/s and advect onto the Agulhas Bank (Swart & Largier 1987; Penven *et al*. 2001) (Figure 5).

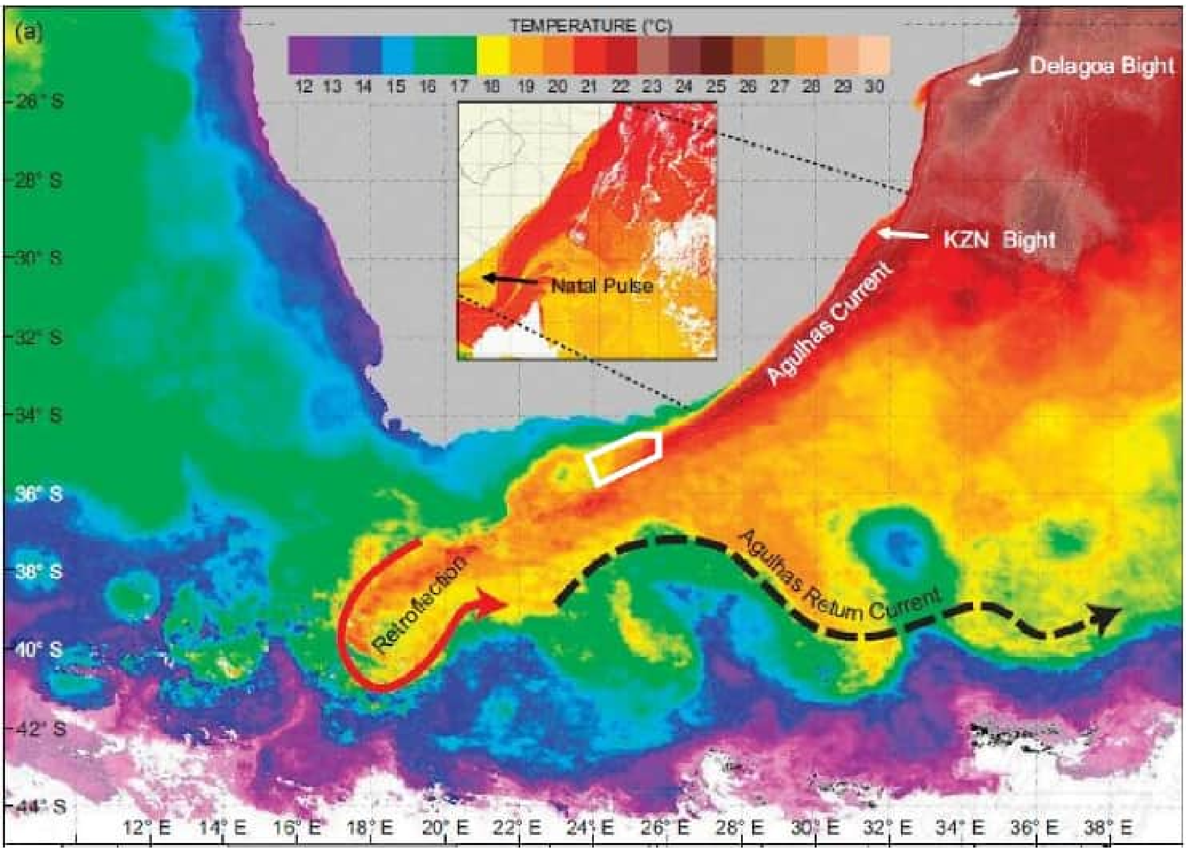


Figure 4: The predominance of the Agulhas current in the oceanography of the Reconnaissance Permit Area (white polygon) (adapted from Roberts *et al*. 2010).

Occasionally huge warm-water rings break off from the main current and slowly spin off into the South Atlantic, carrying heat, salt and some pelagic plants and animals characteristic of the Agulhas Current far into the South Atlantic Ocean (Gründlingh 1988; Luschi *et al*. 2003b; Lutjeharms 2006). This movement of surface waters from the Indian Ocean to the Atlantic is an important component of the global circulation of water, maintaining the input of heat and salt into the Atlantic Ocean. Long-term variations in this input have been linked to global changes in glacial and inter-glacial periods (Peeters *et al*. 2004; Beal *et al*. 2011).

After detaching from the shelf edge at 15° E, the Agulhas Current retroflects and flows eastwards as the Agulhas Return Current (Schumann 1998). The Return Current navigates through shallower features such as the Agulhas Plateau, which result in wide meanders along the eastern edge of the Agulhas Bank in the direction of the equator. These grow downstream and have attendant cyclonic eddies and warm water plumes (Lutjeharms 2006) (Figure 5). These warm water plumes may extend over large parts of the Agulhas Bank and are thought to influence the waters and the biota in bays on the coastline (Goschen & Schumann 1988, 1994).

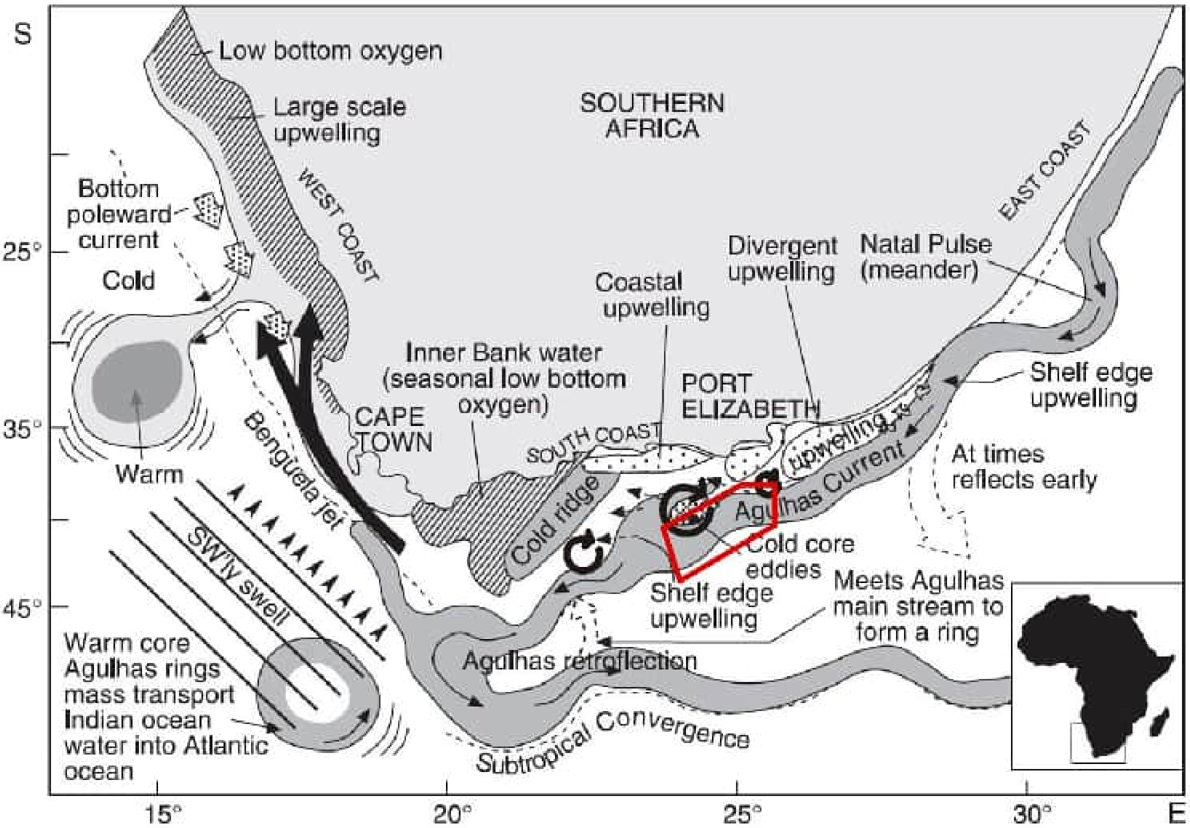


Figure 5: The Reconnaissance Permit Area (red polygon) in relation to important physical processes and features associated with the Southeast coast (adapted from Roberts 2005).

Currents over the inner and mid-shelf (to depths of 160 m) are weak and variable, with velocities along the eastern half of the South Coast ranging from 25 - 75 cm/sec mid-shelf and 10 - 40 cm/sec nearshore. In common with other western boundary currents, a northward (equator-ward) undercurrent — termed the Agulhas Undercurrent — is found on the continental slope of the East

Coast at depths of between 800 m and 3,000 m (Beal & Bryden 1997). Eastward flow may occur close inshore (Boyd *et al.* 1992; Boyd & Shillington 1994), being particularly strong off Gqeberha. Bottom water shows a persistent westward movement, although short-term current reversals may occur (Swart & Largier 1987; Boyd & Shillington 1994; CCA & CSIR 1998). The currents along the Southeast coast are important for the spawning of many pelagic fish species, as eggs and larvae are swept westwards around Cape Agulhas and then northwards up the West Coast to productive nursery areas, returning southwards again as adults to spawn on the Agulhas Bank (Hutchings *et al.* 2002).

The surface waters over most of the project area are a mix of Tropical Surface Water (originating in the South Equatorial Current) and Subtropical Surface Water (originating from the mid-latitude Indian Ocean). The surface waters of the Agulhas Current may be over 25° C in summer and 21° C in winter and have lower salinities than the Equatorial Indian Ocean, South Indian Ocean Central water masses found below. Surface water characteristics, however, vary due to insolation and mixing (Schumann 1998). South Indian Ocean Central Water of 14° C and a salinity of 35.3 ppt occurs below the surface water layers at between 150 - 800 m depth. The deeper waters comprise, from shallowest to deepest, Antarctic Intermediate Water, North Indian Deep Water, North Atlantic Deep Water and Antarctic Bottom Water. Sub-tropical Surface Water of between 15 and 20° C often intrudes into the Agulhas Current at depths of 150 - 200 m from the east (Schumann 1998).

Seasonal variation in temperatures is limited to the upper 50 m of the water column (Gründlingh 1987), increasing offshore towards the core waters of the Agulhas Current. Inshore, waters are warmest during autumn, with warm water tongues found off Cape Recife (near Gqeberha) from January to March, and Knysna from October to January and during August. Warm water also tends to bulge towards Knysna between April and July and during September (Christensen 1980).

3.1.3 Thermal Structure and Variability

The thermal structure of Agulhas Bank waters is mediated by the intrusions of Agulhas Current water at surface and subsurface depths, upwelling and surface heating by insolation. At the inner boundary of the Agulhas current, cold bottom water is advected onto the Agulhas Bank *via* shelf-edge upwelling (Schumann 1998). This process is primarily due to frictional interactions between the Agulhas Current and bottom topography (Hutchings 1994), and is most intense at the eastern boundary of the South Coast, where the cold bottom layer breaks the surface (Figure 6). The core of the upwelling lies at Port Alfred but can extend from the eastern edge of Algoa Bay to Mbashe on the Transkei Coast (Lutjeharms *et al.* 2000b). This upwelling has been associated with large meanders in the Agulhas Current (Jackson *et al.* 2012; Goshen *et al.* 2015; Malan *et al.* 2018). Such shelf-edge upwelling largely defines the strong thermocline and halocline topography that typically develops between the cold bottom water and the sun warmed surface layer during spring (September to November), summer (December to February) and autumn (March to May).

On the central Agulhas Bank, a prominent feature of the midshelf is the ridge of cool water that extends in a north-east (NE) – south-west (SW) direction between the shelf-edge upwelling and inshore waters close to the coast (Swart & Largier 1987; Boyd & Shillington 1994; Schumann 1998; Krug *et al.* 2014). A cool ridge of upwelled water extends in a north-east (NE) – south-west (SW) direction over the mid-shelf regions between the shelf-edge upwelling and inshore waters close to the coast (Swart & Largier 1987; Boyd & Shillington 1994; Schumann 1998). The ridge has its 'base' at the coast between the Robberg Peninsula and Cape St Francis and appears to be most prominent under south-east wind conditions, which cause coastal upwelling in the Knysna region (Walker 1986; Boyd & Shillington 1994; Jury 1994). As easterly winds dominate in the spring-autumn period the cool water ridge is a semi-permanent feature during much of the year. Inshore of the cool water ridge, the thermoclines may be disrupted by coastal upwelling on the lee side of capes under easterly wind conditions (Schumann *et al.* 1982; Walker 1986; Schumann 1998). Such upwelling usually begins at the prominent capes and progresses westwards (Schumann *et al.* 1982; Schumann *et al.* 1988), and can result in temperature changes of up to 8° C within a few hours (Hutchings 1994). However, northeastward moving upwelling along the coast east of Gqeberha has also been reported (Goshen *et al.* 2012).

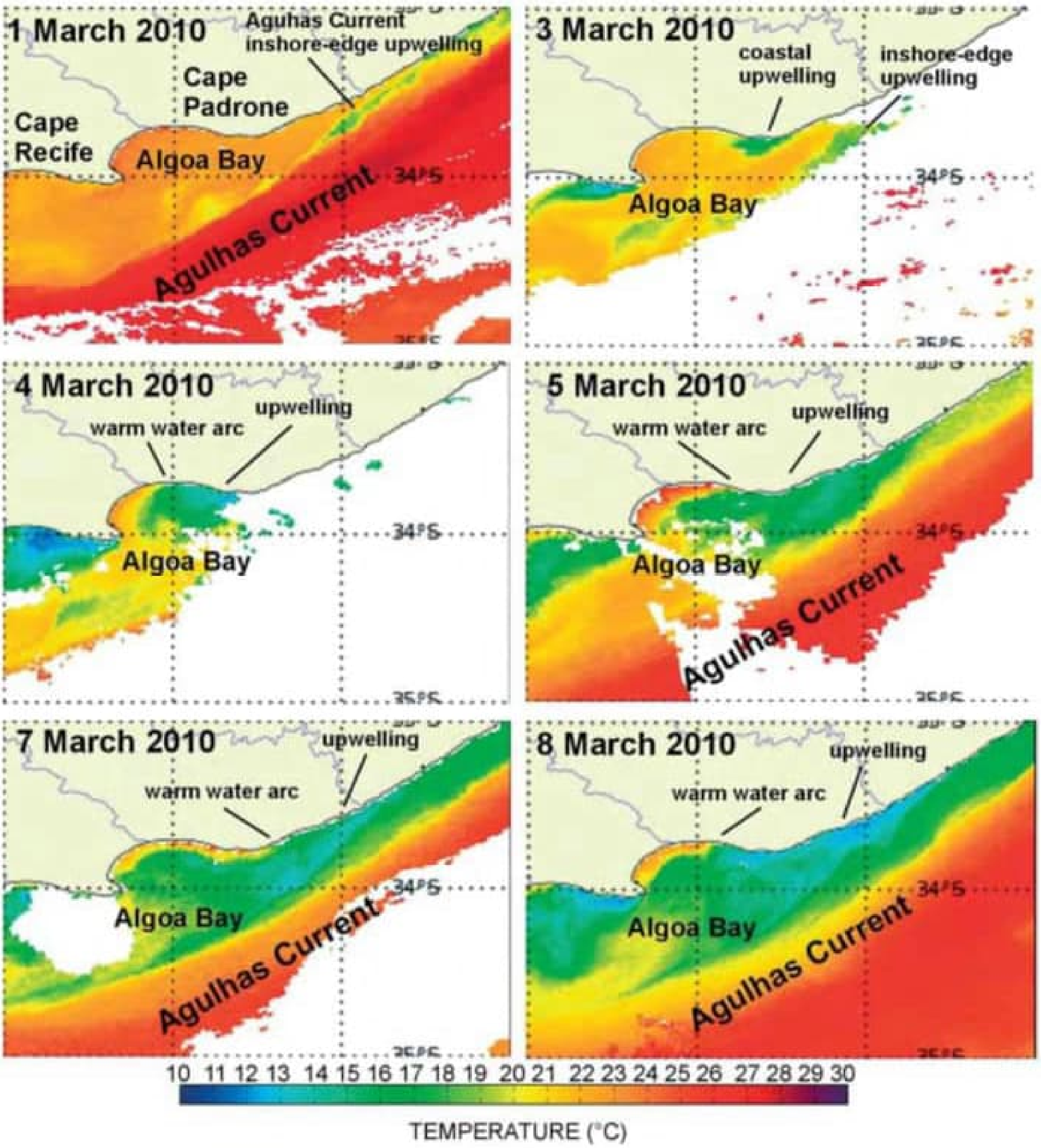


Figure 6: Satellite imagery of sea surface temperature between 1 and 8 March 2010 showing an upwelling event. Cool water first emerges at Woody Cape/ Cape Padrone and expands into Algoa Bay (Source: Hutchings *et al.* 2013).

The thermoclines on the central and eastern Agulhas Bank are resistant to breakdown under strong wind conditions due to their strong gradients and the fact that they are maintained by advection. Temperature gradients are usually around 5-6 °C/10 m close inshore east of Cape Agulhas but reaching extremes of 10 °C/10 m around the Alphard Banks and eastwards inshore towards Cape St. Francis. The thermoclines at the eastern edge of the South Coast are located at 20-40 m depth (Largier & Swart 1987). During strong winds, the isothermal upper mixed layer erodes down into the top of the thermocline, thereby increasing the temperature gradient and thus thermocline stability (Carter *et al.* 1987). In contrast, on the outer Bank, offshore of the cold water ridge, thermocline development is weak. In winter (June – August), when westerly winds dominate, the cold bottom water recedes to the shelf break and the nearer shore water column tends to become isothermal (Schumann & Beekman 1984; Boyd & Shillington 1994).

3.1.4 Winds and Swells

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. Tidal influence in the offshore regions of the Reconnaissance Permit Area will be minimal.

Along the Eastern Cape, westerly winds predominate in winter, frequently reaching gale force strengths. During summer, easterly wind directions increase markedly resulting in roughly similar strength/frequency of east and west winds during that season (Jury 1994) (Figure 7). The strongest winds are observed at capes, including Infanta, Robberg and Cape Recife (Jury & Diab 1989). Calm periods are most common in autumn (CCA & CSIR 1998). At Cape Recife, the winds have a variable west south-westerly component, with the highest frequency of south westerly wind speeds greater than 10.5 m/sec occurring during September and October (Cliff 2013).

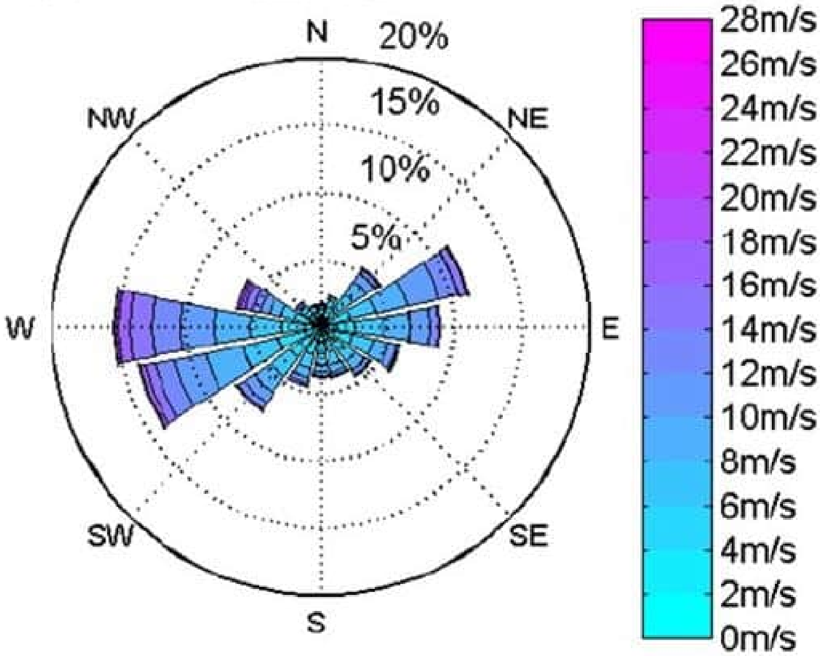


Figure 7: Windrose for a locations at approximately 35°40'S, 23°20'E for the period 1950 – 2019 (ACTIMAR).

On the Southeast coast, the majority of waves arrive from the south-west quadrant (Whitefield *et al.* 1983), dominating wave patterns during winter (June – August) and spring (September – November) (Carter & Brownlie 1990). Waves from this direction frequently exceed 6 m (Swart & Serdyn 1981, 1982) and can reach up to 10 m (Heydorn 1989) (Figure 8). During summer, easterly wind-generated 'seas' occur (Heydorn & Tinley 1980; Heydorn 1989; Carter & Brownlie 1990).

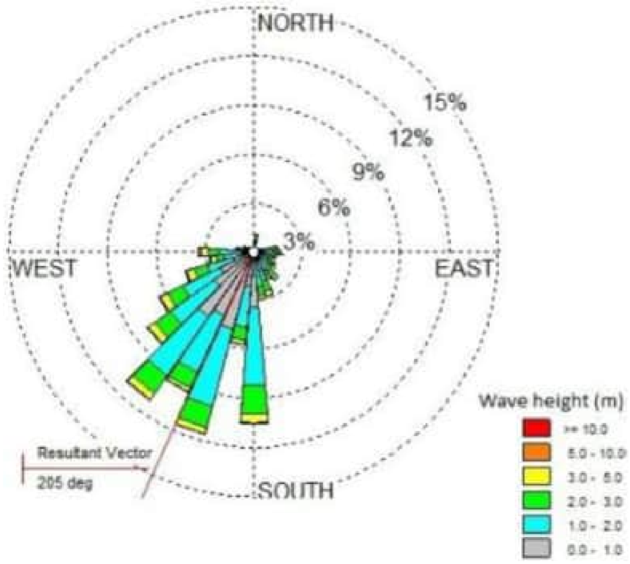


Figure 8: Wave rose showing the direction, proportion and magnitude of waves experienced offshore of the St. Francis- Algoa Bay region (Source: SADCO Voluntary Observing Ships for a 30-year period).

3.1.5 Nutrient Distributions

As the Agulhas Current originates in the equatorial region of the western Indian Ocean its waters are typically blue and clear, with low nutrient levels. In coastal waters, freshwater seepage from dune aquifers on the south coast constitutes an important source of nitrogen for surf-zone phytoplankton (particularly accumulation-forming diatoms) (Campbell & Bate 1991a).

The distribution of nutrients over the Agulhas Bank demonstrates the existence of three distinct nutrient provinces (Lutjeharms *et al.* 1996). The western Agulhas Bank is associated with higher nutrient values driven by coastal upwelling, whereas the shelf edge of the eastern Agulhas Bank is characterised by nutrient-poor surface waters and nutrient-rich bottom water, while the major part of the eastern Agulhas Bank is under the influence of the far-eastern Agulhas Bank upwelling cell, which provides nutrient rich bottom water. Seasonal changes in the nutrient distribution over the whole Agulhas Bank is driven by strong vertical stratification in the austral summer, and vertical mixing of the water column in winter. Nutrient concentrations in surface waters during summer are characteristic of Subtropical Surface Water while those in bottom waters are derived from South Indian and South Atlantic Central Water (Lutjeharms *et al.* 1996).

Nitrate-nitrogen concentrations in Agulhas Current source water range from 7-10 µM/ℓ, while those of sub-thermocline water may be up to 20 µM/ℓ (Carter *et al.* 1987). During winter, when the water column is well mixed, bottom nutrients mix upwards and nutrient concentrations in the surface waters are higher than in summer (CCA & CSIR 1998). On the eastern Agulhas Bank, the shear-edge eddies (cold-core eddies in Figure 8) that result in the shelf-edge upwelling are are responsible for enrichment in productivity (Koné *et al.* 2005), whereas further to the west a regenerative regime dominates (Lebourges-Dhaussy *et al.* 2009).

Primary production is nitrogen-limited in the upper layers of the euphotic zone (to ~30 m depth), but light-limited in the sub-surface chlorophyll maximum layer at depths of between -20 m to -30 m (Probyn & Lucas 1987). It is unlikely that phosphorous would ever become limiting, except perhaps at the primary production maximum. Much of the ammonia and phosphorous needed for phytoplankton growth in the surface layers is supplied by heterotrophic microflagellates (1 - 5 µm) and nanoplankton (1 - 15 µm). However, size-related differences in the relative importance of the microplanktonic groups to the immobilization and recycling of different nutrients occur (Probyn & Lucas 1987). On the Agulhas Bank, the 1 – 5 µm size class were found to be a proportionally greater sink for phosphorous than for ammonium, immobilising on average 36% of the total phosphorous assimilated (Probyn & Lucas 1987). However, microplankton uptake and regeneration of both ammonium and phosphorus were approximately in balance, indicating that variations in assimilation ratios were the result of heterotrophic excretory activity. Here, picoplankton in the 15 – 200 µm size range were more important in the regeneration of phosphorous than of ammonium, the latter primarily being regenerated by the nanoplankton (1 – 15 µm).

In summary, nutrient concentrations in the surface waters of of the Reconnaissance Permit Area are typically low, with primary production being nitrogen-limited. The strong vertical stratification that develops during summer, breaks down during winter when shelf-edge upwelling results in the mixing of the water column bringing the nutrient rich bottom waters to the surface.

3.1.6 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. On the Agulhas Bank, seasonal microphyte production associated with upwelling events, both inshore and along the shelf edge, will play an important role in determining the concentrations of POM. PIM, on the other hand, is primarily of geological origin consisting of fine sands, silts and clays. The PIM loading in nearshore waters is strongly related to natural riverine inputs and resuspension and bedload transport of seabed sediments. As there are no major rivers entering the Southeast coast, PIM loading in the offshore regions of the Reconnaissance Permit Area would be negligible. Offshore of the continental shelf, and within the Reconnaissance Permit Area, the oceanic surface waters are clear and background concentrations are typically <1 mg/ℓ (Emery *et al.* 1973).

A feature of continental shelf waters off the Southeast coast is the benthic nepheloid layer (Zoutendyk & Duvenage 1989; Dorfler 2002). This layer can be up to 10 m thick and may have TSPM values of up to 38 mg/ℓ. It is usually located below the thermocline at a depth of between 20 m and 30 m (Zoutendyk & Duvenage 1989). Initially thought to be associated with the mud belts on the inner Agulhas Bank near Mossel Bay, the nepheloid layer has recently been found associated with the Cape St Francis and Cape Infanta areas (Dorfler 2002) (Figure 9), as well as at about 150 m depth on the continental slope between Knysna and Cape St Francis (Jackson *et al*. 2012). Although thought to originate from detrital fallout from surface waters, Zoutendyk & Duvenage (1989) reported that POM contributed <10% of the TSPM in the turbid layer. The dynamics of the nepheloid layer are complex, and appear to be driven by a combination of wind, waves and currents. Turbidity events, however, not only occur during upwelling but also in isothermal conditions, with down-welling and turbidity being correlated in deeper waters (Dorfler 2002). The benthic nepheloid layer plays a significant role in the benthic community structure of nearshore reefs (Zoutendyk & Duvenage 1989) and is thought to influence the spawning success of squid in Eastern Cape inshore waters (Dorfler 2002). It is primarily located inshore of the Reconnaissance Permit Area.

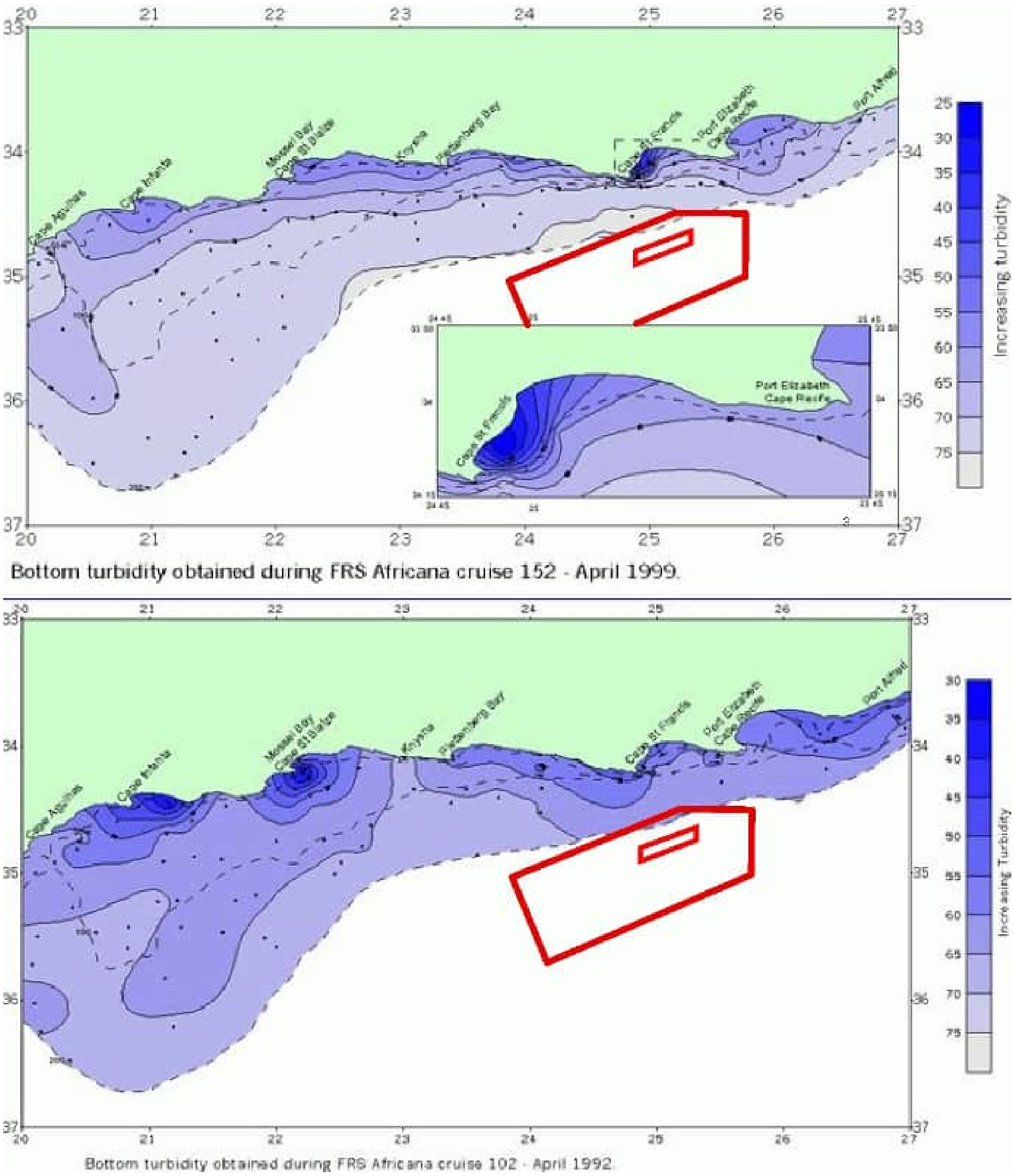


Figure 9: The Reconnaissance Permit Area (red polygon) in relation to benthic turbidity events on the Eastern Agulhas Bank in April 1992 (bottom) and April 1999 (top) (adapted from Dorfler 2002). The turbidity scales are in Nephelometric Turbidity Units (NTU).

3.1.7 Sedimentary Phosphates

Phosphorite, or phosphate-rich rock is defined as sedimentary rock typically containing between 5%-20% phosphate. In the marine environment, it occurs either as a nodular hard ground capping of a few metres thick (Figure 10, left) or as series of unconsolidated sediments (Morant 2013). Several types of sedimentary phosphates occur offshore and onshore in South Africa, the largest of which is the diagenetic replacement resource on the Agulhas Bank. These replacement phosphate resources occur as near-continuous 'pavements' or cappings of limestones at depths between 200 m and 500 m on the continental shelf between Cape Agulhas and Cape Recife, covering an approximate area of 21 500 km^2. Further sporadic phosphate mantles over the continental shelf are known to occur from Lamberts Bay, north to the mouth of the Orange River (Figure 10, right).

The "open shelf" phosphorite deposits, were formed during several episodes over the last 1.7 – 65 million years. They originated from the precipitation of phosphate in the form of calcium phosphate in an environment of intense upwelling and high biological activity along the continental margin of South Africa. The upwelling resulted in a change in temperature and pressure of the phosphate-laden oceanic waters, thus lowering the solubility of the phosphate salts they contained, and consequently precipitating the phosphates (in the form of apatite) over the continental shelf to form phosphatic packstones and colitic pellets at the sediment-water interface. The precipitation is facilitated by the decay of siliceous phytoplankton. The precipitated phosphates subsequently combined with calcium, derived from the disaggregation of calcareous foraminiferal and coccolithophorid debris on the outer continental shelf, to form phosphatised lime-rich muds. These muds subsequently lithified or consolidated through their replacement by secondary calcium phosphate (francolite), to form a near continuous hard capping of phosphate rock over the seafloor sediments (Birch 1990; Morant 2013).

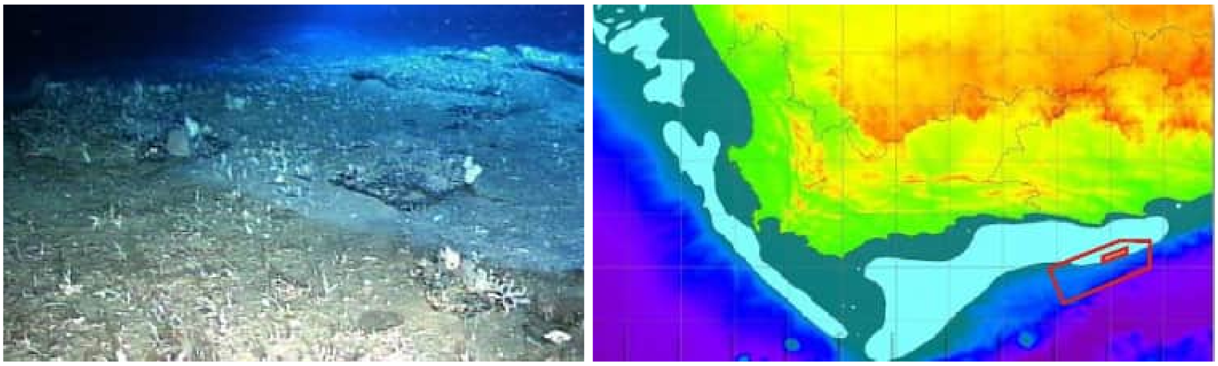


Figure 10: Phosphorite hard ground (left) and its distribution (cyan) on the South African continental shelf (right) in relation to the Reconnaissance Permit Area (red polygon) (adapted from Morant 2013).

During repeated sea level changes, the phosphate-rich rocks were extensively re-worked, eroding the hard capping pavements thereby liberating the heavy phosphate-bearing minerals (mainly glauconite and apatite) and concentrating them in the overlying unconsolidated sediments. Migrating zones of deposition and erosion occurred during repeated transgressive/regressive cycles.

Renewed carbonate deposition and a further period of phosphatization occurred when the deposition zones migrated back across the shelf in response to a rising sea level, thereby incorporating boulders and cobbles of phosphatized limestone and glauconite left behind after the previous regressive cycle into the second-generation phosphatic deposits, forming conglomeratic rock types. Two main periods of phosphatization have been identified, namely the Middle Miocene (ca 15 Ma), and possibly the Upper Eocene (ca 37 Ma) (Birch 1990; Morant 2013).

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

Although not mined at present, an application to prospect for marine phosphate in the Outeniqua West Licence Area, Offshore Mossel Bay, was submitted to the Department of Mineral Resources by Diamond Fields International Ltd in June 2013 (Morant 2013). However, following the moratorium on marine phosphate mining in Namibia and the conclusion that marine mining of phosphate resources in South Africa was unwarranted (Vidima & von Blottnitz 2016; see also Biccard *et al.* 2018), there has been no further development in this regard.

3.2. The Biological Environment

Biogeographically the majority of the study area falls into the Southwest Indian Deep Ocean ecoregion, with only the inshore portions of the Reconnaissance Permit Area falling into the Algoa ecoregion (Figure 11) (Sink *et al.* 2019). The speculative 3D survey area is located beyond the 200 m depth contour and therefore comprises primarily deepwater benthic habitats and the water body. The ecosystem threat status of the benthic habitat types and the offshore pelagic habitat types along most of the Southeast coast, and within most of the Reconnaissance Permit Area have been rated as 'Least Threatened' reflecting the great extent of these habitats within the South African EEZ (Sink *et al.* 2012) (Figure 12). However, the Agulhas Coarse Sediment Shelf Edge, Agulhas Sandy Outer Shelf, Agulhas Upper Canyon and Kingklip Koppies ecosystem types are considered 'Vulnerable' and the Kingklip Ridge ecosystem type is considered 'Endangered' (see Figure 3).

Due to limited opportunities for sampling, information on the pelagic and demersal communities of the continental slope, lower bathyal and abyss are very poorly known. Consequently, much of the information on the baseline environment provided below relates to the continental shelf (<200 m) regions, which fall within the Agulhas Bioregion (Figure 11).

The benthic communities within these deepwater habitats are generally ubiquitous throughout the southern African Southeast Coast region, being particular only to substratum type and/or depth zone. They consist of many hundreds of species, often displaying considerable temporal and spatial variability. The biological communities 'typical' of each of these habitats are described briefly below, focusing both on dominant, commercially important and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the speculative seismic surveys.

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

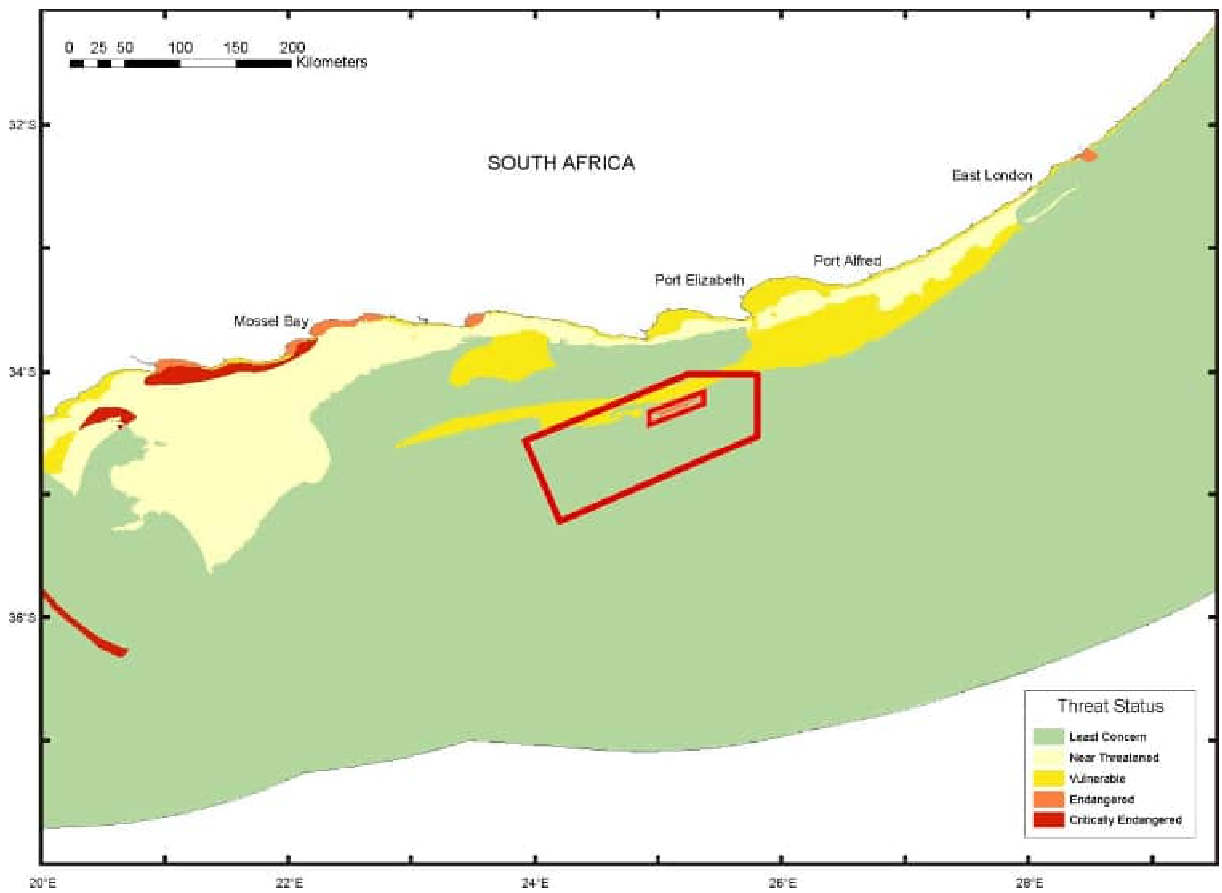


Figure 12: The Reconnaissance Permit Area (red polygon) in relation to the ecosystem threat status for coastal and offshore benthic habitat types (adapted from Sink *et al.* 2019).

3.2.1 Plankton

The nutrient-poor characteristics of the Agulhas Current water are reflected in comparatively low primary productivity on the continental shelf throughout most of the Reconnaissance Permit area. Mean *chlorophyll a* concentrations average between 1-2 mg/m^3 over the whole year in the top 30 m of the water column. *Chlorophyll a* concentrations vary seasonally, being minimal in winter and summer (<1 – 2 mg/m^3), and maximal (2 - 4 mg/m^3) in spring and autumn (Brown 1992). On the South Coast, lower concentrations are partly due to nutrient limitation due to the strong summer thermoclines or light limitations due to deep mixing in winter (Probyn *et al.* 1994), but if the thermocline falls within the 1% light depth, phytoplankton biomass can increase dramatically, with sub-surface chlorophyll concentration maxima often being in excess of 10 mg/m^3 (Carter *et al.* 1987; Hutchings 1994). Chlorophyll concentrations can also be high where upwelling occurs at the coast (Probyn *et al.* 1994). Along the eastern half of the South Coast (Knysna to Cape Padrone), phytoplankton concentrations are usually higher than further west, and the phytoplankton comprises predominantly large cells (Hutchings 1994). The South Coast also boasts several beaches that support surf diatoms *Anaulus*, which are globally rare (Campbell 1996; Campbell & Bate 1991b). These accumulations are visible in the surf as brown patches, forming only on beaches with wide surf zones of medium to high wave energy (e.g. Algoa Bay and St Francis Bay inshore of the Reconnaissance Permit Area), with well-developed rip currents, and that are adjacent to dunes that have nutrient-rich aquifers (Campbell & Bate 1997). Further offshore throughout the project area, the pelagic environment is characterised by very low productivity, with the low variability in water-column temperature resulting in very low frequency of chlorophyll fronts.

Zooplankton and ichthyoplankton abundances in the project area will reflect localised areas of higher primary productivity (Oliff 1973; Probyn *et al.* 1994). Biomass of mesozooplankton increases from west (~0.5-~1.0 gC/m^2) to east (~1.0-~2.0 gC/m^2) across the Agulhas Bank, mirroring the eastward increase in *chlorophyll a* concentrations, peaking on the central and eastern Agulhas Bank during summer in association with the subsurface ridge of cool upwelled water. Standing stocks of mesozooplankton (>200 µm) along the eastern half of the South Coast ranges from 3 – 6 gC/m^2, and is dominated by the calanoid copepod *Calanus aghulensis*, which associates with shallow thermoclines and the mid-shelf cool water ridge (Verheye *et al.* 1994). This species may contribute up to 85% of copepod biomass in the region, and is an important food source for pelagic fishes (Peterson *et al.* 1992). Macrozooplankton (>1,600 µm) standing stocks are estimated to be 0.079 gC/m^2 between Cape Agulhas and Cape Recife (Verheye, unpublished data). Dense swarms of euphausiids dominate this zooplankton component, and form an important food source for pelagic fishes (Cornew *et al.* 1992; Verheye *et al.* 1994). Along the southeast coast, both mesozooplankton and macrozooplankton biomass is greater during summer than winter, with highest densities inshore (<50 m depth), declining offshore towards the continental shelf edge (Verheye *et al.* 2018). Zooplankton communities have comparatively high species diversity, increasing offshore towards the shelf edge, with a high proportion of Indian Ocean and cosmopolitan low-latitude zooplankton species transported poleward by the Agulhas Current (De Decker 1984; Gibbons & Hutchings 1996).

A variety of pelagic fish species including anchovy, round herring and horse mackerel, spawn east of Cape Agulhas between the shelf-edge upwelling and the cold-water ridge (Crawford 1980; Hutchings 1994; Roel & Armstrong 1991; Hutchings *et al.* 2003) (

Figure **13** and Figure 14). Horse mackerel spawn over the east/central Agulhas Bank during winter months, while anchovies spawn on the whole Agulhas Bank, with spawning peaking during mid summer (November–December). Sardines spawn on the whole Agulhas Bank during November, but generally have two spawning peaks, in early spring and autumn, on either side of the peak anchovy spawning period. The eggs and larvae spawned in this area are thought to largely remain on the Agulhas Bank, although some may be carried to the West Coast or be lost to the Agulhas Current retroflection (Hutchings 1994; Duncombe Rae *et al*. 1992; Hutchings *et al*. 2003). Pilchards also spawn on the Agulhas Bank during spring and summer (Crawford 1980), with adults moving eastwards and northwards after spawning.

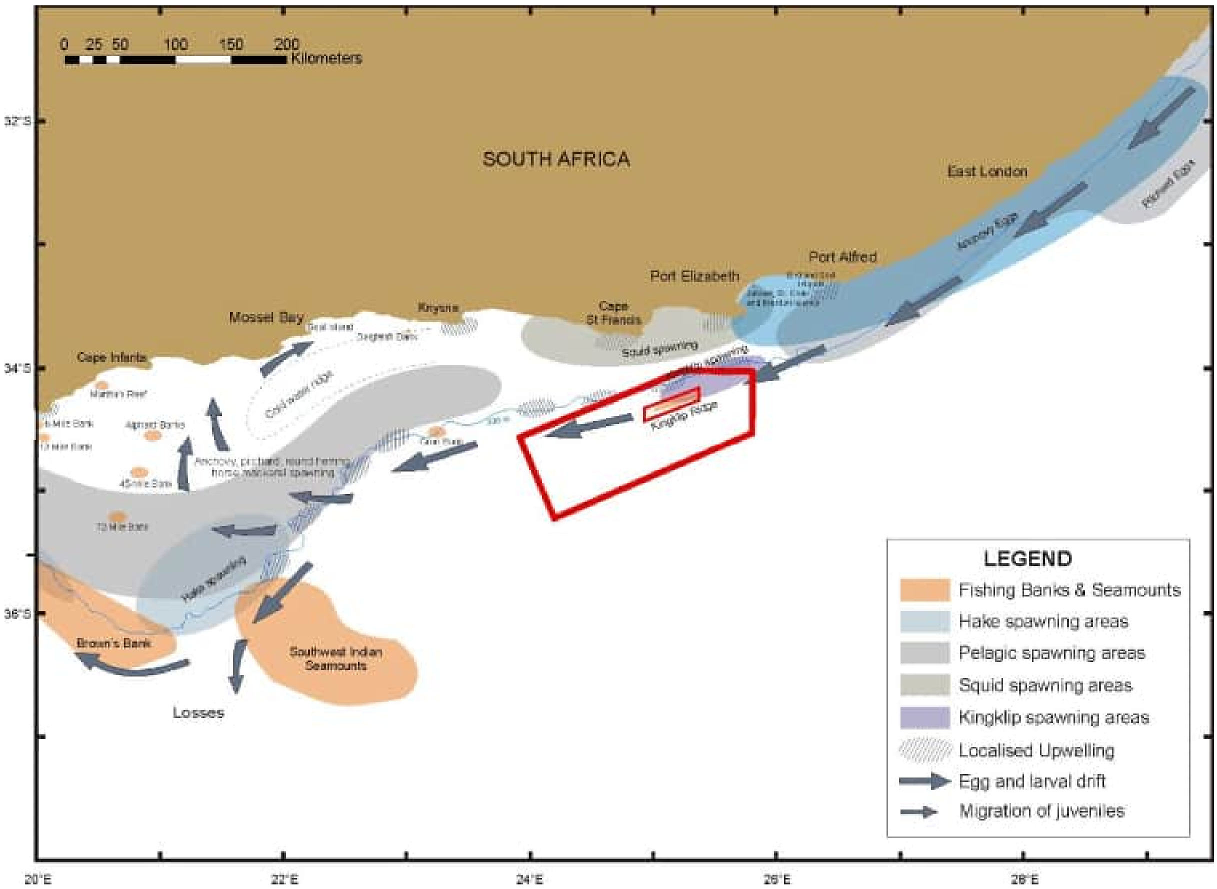


Figure 13: The Reconnaissance Permit Area (red polygon) in relation to important pelagic and demersal fish, and squid spawning areas (after Anders 1975; Crawford *et al*. 1987; Hutchings 1994). The 200 m depth contour is also shown.

After the "sardine run" in June and July (see later), pilchard eggs occur in inshore waters along the Eastern Cape and the southern KwaZulu-Natal coast (Anders 1975; Connell 1996). There is also recent evidence for winter (June-July) spawning of sardines on the central Agulhas Bank in patches of high concentrations of phytoplankton (van der Lingen *et al*. 2006). The sardine and other clupeid eggs persist in inshore waters throughout winter – spring, before disappearing in early summer as the shoals break up and move northwards and further offshore (Connell 2010). Anchovy (*Engraulis japonicus*) eggs have also been reported in the water column during December extending from

Gqeberha eastwards to as far north as St Lucia (Anders 1975). Ichthyoplankton surveys conducted from Algoa Bay to north of Durban in 1990 and 1991 showed that larvae of anchovy and round herring were abundant over the entire shelf throughout much of the year with greatest abundances in summer, while sardine and chub mackerel larvae were abundant over the shelf and along the shelf-edge during winter (Beckley & Hewitson 1994; Beckley & Leis 2000). Larvae of frigate tuna and Eastern little tuna were present over the shelf in February, extending southwards along the shelf-edge (Beckley & Leis 2000). while larvae of the endangered and endemic red steenbras were found during both seasons but more abundantly in winter (Edward in prep.).Demersal species that spawn along the Southeast coast include the cape hakes and kingklip. Spawning of the shallow-water hake occurs primarily over the shelf (<200 m) whereas that by the deep-water hake occurs off the shelf.

Although hake are reported to spawn throughout the year (Strømme *et al*. 2015), they move to the western Agulhas Bank and southern west coast to spawn in late winter and early spring (key period), when offshore Ekman losses are at a minimum. Their eggs and larvae drift northwards and inshore to the west coast nursery grounds, where the greatest concentration of eggs and larvae occurs between September – October (Stenevik *et al*. 2008). Similarly, kingklip aggregate to spawn in an isolated area off the shelf edge to the south of St Francis and Algoa Bays referred to as the 'spawning box' (Shelton 1986; Hutchings 1994) (

Figure **13**). Spawning starts from August through to September and is is habitat associated, occurring mostly in areas dominated by deep-water corals at depths of between 300 m and 500 m. The 'spawning box' is closed to fishing over the spawning period (Leslie 2004). Squid (*Loligo* spp.) spawn principally in the inshore waters (<50 m) between Knysna and Gqeberha reaching a peak between September and December, with larvae and juveniles spreading westwards. Their distribution and abundance is highly erratic and linked to temperature, turbidity, and currents (Augustyn *et al*. 1994).

The inshore area of the Agulhas Bank, especially between the cool water ridge and the shore, serve as an important nursery area for numerous linefish species (e.g. dusky kob *Argyrosomus japonica*, elf *Pomatomus saltatrix*, seventy-four *Polysteganus undulosus*, steenbras *Petrus rupestrus*, black musselcracker *Cymatoceps nasutus*, leervis *Lichia amia*, white musselcracker *Sparodon durbanensis*, silverbream *Rhabdosargus holubi,* strepie *Sarpa salpa,* geelbek *Atractoscion aequidens,* carpenter *Argyrozona argyrozona* and garrick *Lichia amia*) (Wallace *et al*. 1984; Smale *et al*. 1994). Adults undertake spawning migrations along the Southeast coast into KZN waters during the winter months (Van der Elst 1976, 1981; Griffiths 1987; Garret 1988; Beckley & van Ballegooyen 1992). Following spawning during spring and summer (November to April), the eggs and larvae are dispersed southwards inshore of the core Agulhas Current, with juveniles occurring on the inshore Agulhas Bank (Van der Elst 1976, 1981; Garret 1988; Hutchings *et al*. 2002). In the case of the carpenter, a high proportion of the reproductive output comes from the central Agulhas Bank and the Tsitsikamma Marine Protected Area (MPA) Section of the Garden Route National Park, and two separate nursery grounds appear to exist, one near Gqeberha and a second off the deep reefs off Cape Agulhas, with older fish spreading eastwards and westwards (van der Lingen *et al*. 2006). While the dominant flow patterns and trajectory of the Agulhas Current retain these and other neritic larvae within the shelf environment along the East Coast, Agulhas Current meanders (Natal pulses (Krug & Penven 2011)), can potentially entrain and transport these larvae offshore beyond the shelf edge into the deep ocean. Such meanders, which can reach as far south as Gqeberha , can occur on average 1.7 times per year, with typical residence times of 65 days (Krug & Penven 2011; Krug *et al.* 2014), but can occur up to 3 to 4 times per year.

The inshore portions of the project area thus overlap with major fish spawning and migration routes, and ichthyoplankton abundance in inshore waters over the continental shelf (<200 m) is likely to be seasonally high. Larval concentrations vary between 0.005 and 4.576 larvae/m^3 decreasing rapidly with distance offshore (Beckley & Van Ballegooyen 1992). In the offshore portion of the project area, ichthyoplankton abundance is, however, expected to be low.

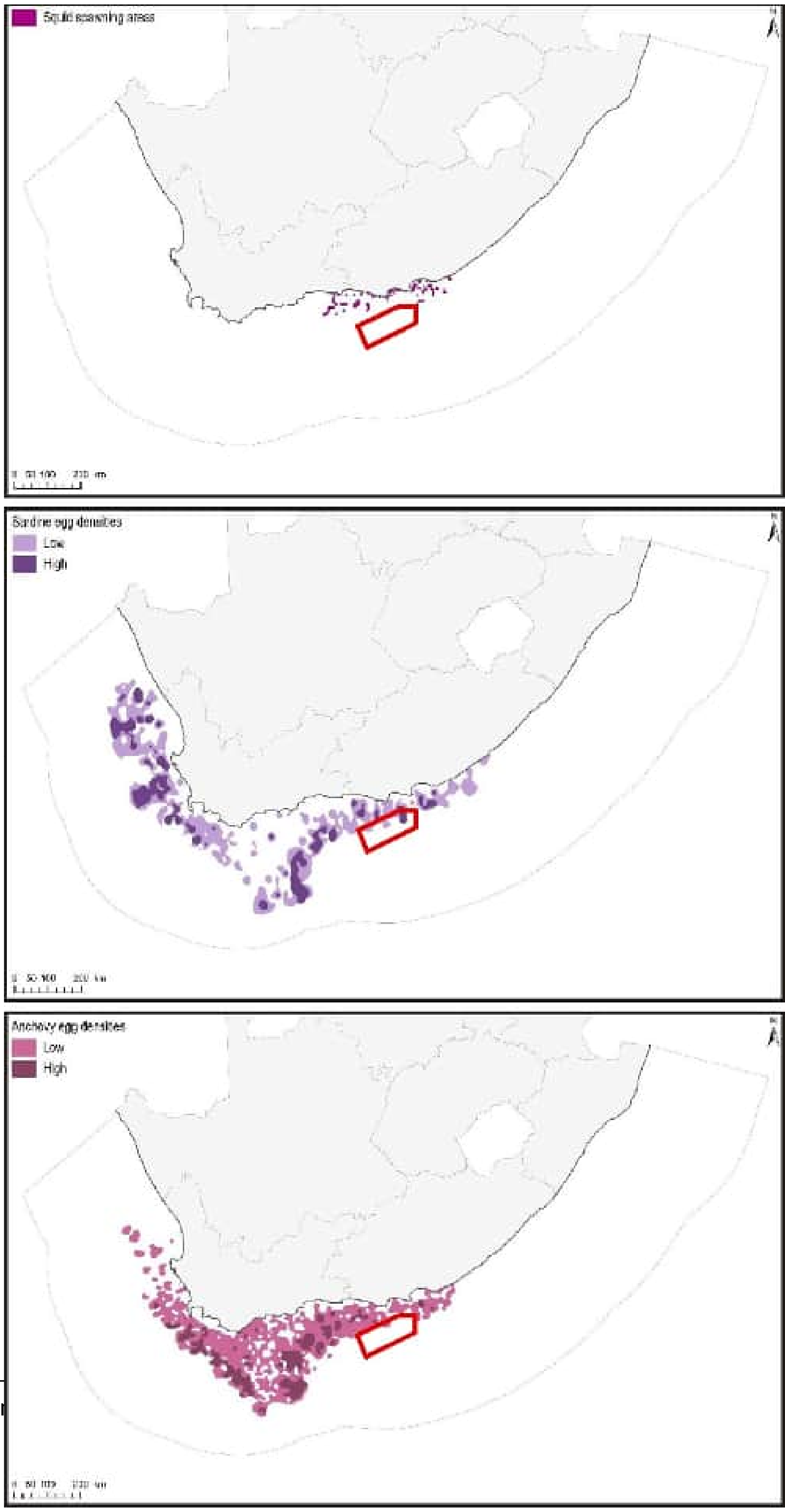


Figure 14: The Reconnaissance Permit Area (red polygon) in relation to squid spawning areas (top), and the distribution of sardine (middle) and anchovy (bottom) spawning areas (adapted from Harris *et al*. 2022).

3.2.2 Harmful Algal Blooms (HABs)

As the upwelling events in Algoa Bay are generally relatively weak and short lived, the proliferation of harmful algal blooms (HABs) was, until recently, not known to occur. Between December 2013 and March 2014, however, a large and persistent harmful algal bloom of *Lingulodinium polyedrum* formed within Algoa Bay and spread along the east coast as far as Wilderness (Bornman 2014). The intensity of the bloom caused waters to turn a dramatic red colour and to display spectacular phosphorescence at night (Figure 15). Fuerthermore, in December 2015 several red tide blooms were sampled in Algoa Bay and St Francis Bay confirming that the HAB-forming dinoflagellate, *Lingulodinium polyedrum*, was again present in Algoa Bay. *Lingulodinium polyedrum* produces yessotoxins that have been proven to be toxic to mice and may accumulate in bivalves, although human toxicity is not known (Bornman 2014). This species irritates the gills of fish, interfering with respiration, and has caused fish kills in several places within Algoa Bay (Bornman 2014). *Lingulodinium polyedrum* has previously been documented as cysts in marine sediments collected from the area, suggesting that it was not a recent introduction and that the bloom was likely triggered by a combination of favourable environmental conditions.

Figure 15: Harmful Algal bloom in Algoa Bay caused by *Lingulodinium polyedrum* during summer 2013-2014 (Source: Laird *et al*. 2016).

3.2.3 Benthic and Pelagic Invertebrate Communities

The seabed communities in the Reconnaissance Permit Area lie within the Agulhas sub-photic and continental slope biozones, which extend from a 30 m depth to the shelf edge, and beyond to the lower slope, respectively. These biozones lie within the 'minimal protected category' (1 - 5%) and portions of the shelf area were defined as 'Vulnerable', 'Endangered' or 'Critically Endangered' as existing Marine Protected Areas (MPAs) were insufficient for conserving marine habitats and their associated biodiversity (Lombard *et al*. 2004; Sink *et al*. 2012a). With the establishment of a network of offshore MPAs in 2019 (see Figure 47), the ocean protection within the South African Exclusive Economic Zone (EEZ) was increased to 5% resulting in a re-assessment of the ecosystem threat status in the 2018 National Biodiversity Assessment (Sink *et al*. 2019). Whereas the majority of the benthic habitats in the Reconnaissance Permit Area now falls within the 'Least Threatened' category, the inshore portions of the Reconnaissance Permit Area along the shelf edge are still considered 'Vulnerable' with the Kingklip Ridge habitat being rated as 'Endangered'. This unique ridge feature on the upper slope in the Southwest Indian Deep Ocean ecoregion, is 40 km long but only 500 m wide and rises from -700 m to -350 m. It supports potentially vulnerable deepwater coral and bryozoan species and is covered by dense clouds of plankton and hake (Sink 2016) (see Figure 16). The area inside of the ridge forms part of the kingklip spawning aggregation area (Sink *et al*. 2019). Similarly, the coastal area in the vicinity of Mossel Bay has been recognised as one of seven areas in the biozone in need of additional protection based on the high endemism known to occur there and consequently much of the inshore regions between Wilderness and Cape Infanta have been rated as 'Endangered' and 'Critically Endangered' (Figure 12). These, however, lie over 200 km inshore and to the northwest of the Reconnaissance Permit Area. Extractive utilisation of marine resources has been identified as the greatest threat to biodiversity in these biozones (Lombard *et al*. 2004; Sink *et al*. 2012a).

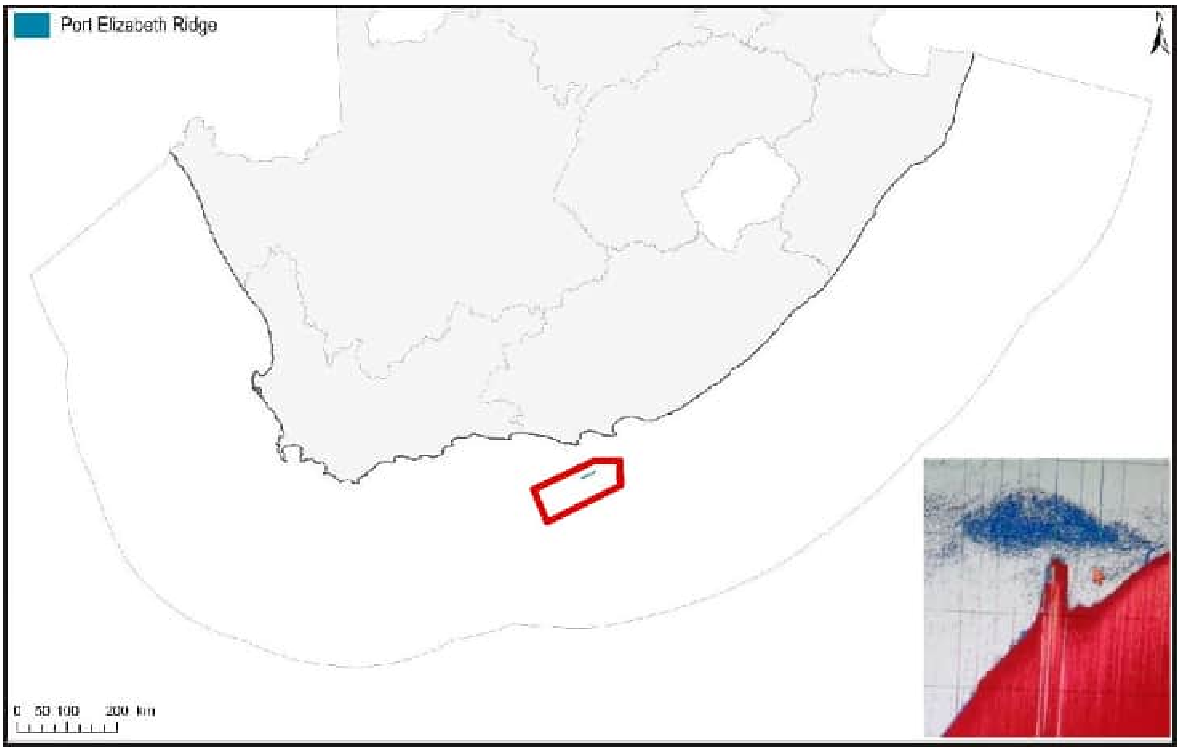


Figure 16: The Reconnaissance Permit Area (red polygon) in relation to the unique Port Elizabeth Ridge. Insert shows the vertical protrusion from the seabed (red), with a cloud of plankton and hake (blue) above the ridge (adapted from Harris *et al*. 2022).

The benthic biota of the offshore substrates constitutes invertebrates that live on (epifauna), or burrow within (infauna), the sediments, and are generally divided into megafauna (animals >10 mm), macrofauna (>1 mm) and meiofauna (<1 mm). The structure and composition of benthic communities is primarily a function of abiotic factors such as water depth and substratum (e.g.

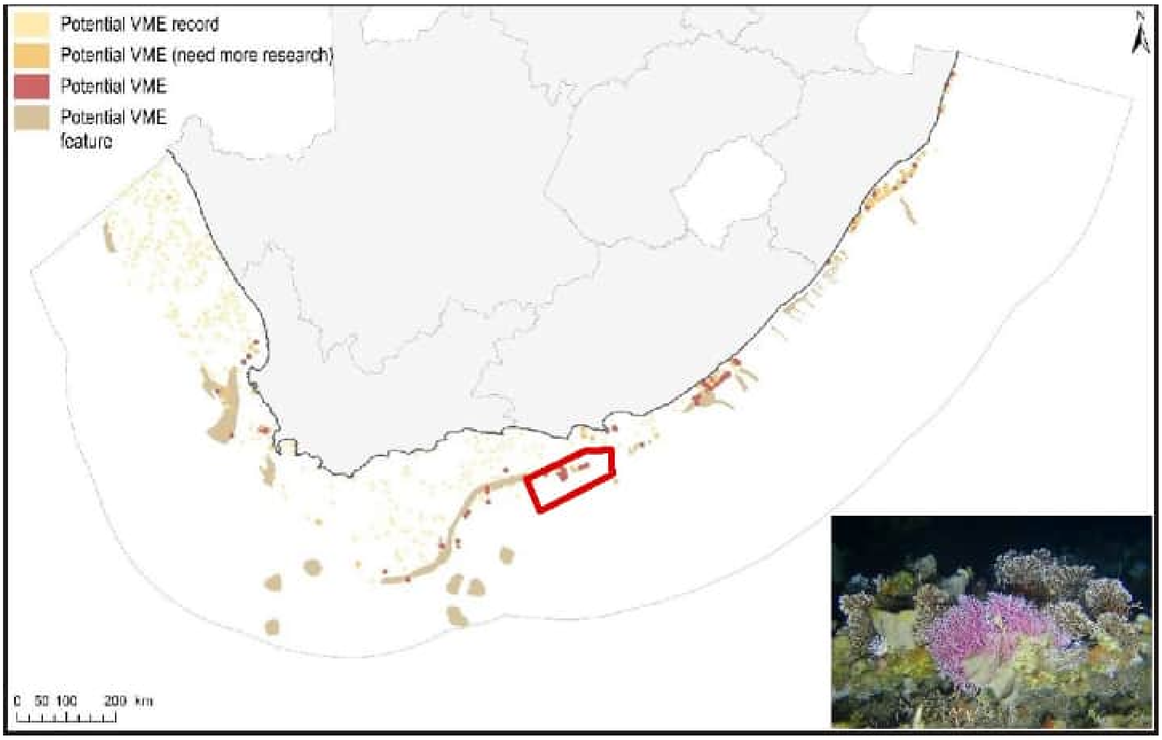
sediment grain size in unconsolidated sediments; reef structure/topography in areas of hard ground), but others such as current velocity and organic content abundance also play a role (Snelgrove & Butman 1994; Flach & Thomsen 1998; Ellingsen 2002). Further shaping of community composition is derived from biotic factors such as predation, food availability, larval recruitment and reproductive success. In unconsolidated sediments, the high spatial and temporal variability of these factors, results in seabed communities being both patchy and variable. In nearshore waters (<50 m) where sediment composition is naturally patchy, and significant sediment movement may be induced by the dynamic wave and current regimes (Fleming & Hay 1988), the benthic macrofauna are typically adapted to frequent disturbance. In contrast, further offshore (>100 m depth) where near-bottom conditions are more stable, the macrofaunal communities will primarily be determined by sediment characteristics and depth.

The seabed communities in the Reconnaissance Permit Area primarily lie on the continental slope within the Southwest Indian Deep Ocean ecoregion, with only minimal overlap over the Agulhas shelf ecoregion. To date there have been no studies examining connectivity between slope, plateau or abyssal ecosystems in South Africa and there is thus limited knowledge on the benthic biodiversity of all three of these broad ecosystem groups in South African waters (Sink *et al.* 2019). There is no quantitative data describing bathyal ecosystems in South Africa and hence limited understanding of ecosystem functioning and sensitivity (Anderson & Hulley 2000).

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). As the component species of VMEs typically exhibit traits of slow growth, late maturity, low fecundity, unpredictable recruitment and high longevity, VMEs are characterised by sensitivity to changes in environmental conditions and slow recovery from damage (FAO 2008).

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

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



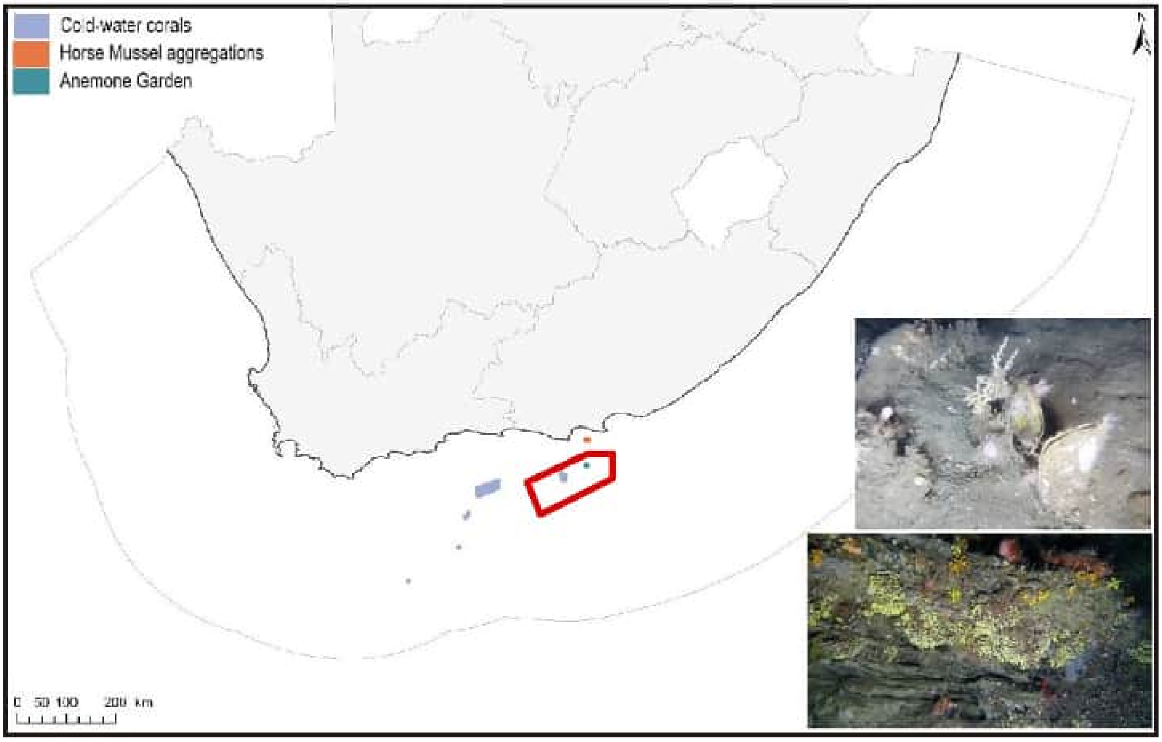


Figure 17: The Reconnaissance Permit Area (red polygon) in relation to the distribution of known and potential Vulnerable Marine Ecosystem habitat (top) based on potential VME features, DFFE and SAEON trawl survey data, and many visual surveys indicating the presence of indicator taxa. Some sites need more research to determine their status. The distribution of cold-water corals, including point localities and Secret Reef, horse Mussel aggregations around St Francis Bay, and the unique anemone garden south of St Francis Bay are also shown (bottom). Adapted from Harris *et al*. (2022).

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).

As information on offshore benthic invertebrate communities occurring along the Southeast coast is sparse, and no formally, peer-reviewed literature is currently available, PetroSA funded a study through a sponsorship agreement with WWF, to assess the offshore benthic biodiversity on the Agulhas Bank (Sink *et al.* 2010). Much of the description below is taken from that report, and from the specialist reports by Quick & Sink (2005) and Shipton & Atkinson (2010) compiled as part of the EIAs for the South Coast Gas project and development of the F-O Gas Field off Mossel Bay, respectively.

These authors categorised the benthic communities expected to occur on the Agulhas Bank, inshore and to the west of the Reconnaissance Permit Area, into four main groups, based on the distribution of the main seabed types identified by Dingle *et al.* (1987).

These were:

- **Terrigenous muds**: although no studies have specifically examined the biota of this habitat type in South Africa, a high biodiversity of benthic macrofauna (polychaetes, nematodes, amphipods, isopods, molluscs, echinoderms etc.) is expected.
- **Relict sands**: sandy habitats of varying grain size typically provide relatively stable environments and are thus able to support highly diverse benthic communities, including seapens, molluscs, echinoderms (brittle stars and heart urchins), cerianthids (tube anemones), sponges and the deep-water rock lobster *Palinurus gilchristi*. A wide diversity of infauna also occurs, including polychaetes, amphipods, isopods, molluscs, etc.
- **Pre-Mesozoic basement rock:** this low profile habitat typically hosts sponges, black corals, gorgonians and ascidians (Sink *et al.* 2006). Although often covered in a thin layer of sediment, the scattered, emergent rock fragments or debris support colonisation by colonial benthic invertebrates.
- **Pre-Mesozoic rock outcrops** – these highly structured reef areas are likely to be characterised by highly diverse benthic and motile biota including sponges, azooxanthellate corals, octocorals, gorgonians, black corals, cerianthids and stylasterine lace corals, bryozoans, ascidians, basket stars and the South Coast rock lobster *Palinurus gilchristi*. Fauna occurring in the deeper reef areas and canyons have community assemblages distinctly different to those from shallower reefs, as also evident in the Greater St Lucia Wetland Park, where deep reefs and canyons support unique and diverse invertebrate fauna (Sink *et al.* 2006).

These stable habitats have been identified as sensitive, as the fauna typically associated with them are frequently slow-growing, slow to mature and long-lived, making them particularly vulnerable to disturbance.

The Agulhas Shelf ecoregion hosts diverse and complex benthic communities, including hard corals, octocorals, bryozoans and sponges, many of which are South African endemics (Griffiths & Robinson

2016; Atkinson & Sink 2018). A diversity of deep-water corals and sponges (Sink & Samaai, 2009; Sink *et al*. 2011) has been reported from the Agulhas Bank (Figure 18 and Figure 19). These communities have established 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. Reef-building cold water corals have also been documented within the Southwest Indian Upper Bathyal, Agulhas Sandy Shelf Edge and in association with deep reefs and submarine canyons on the Agulhas Inner Shelf and Shelf Edge respectively (Sink & Samaai 2009; Sink *et al*. 2011; Sink 2016 in Sink *et al*. 2019). Substantial shelf areas should thus potentially be capable of supporting rich, deep-water benthic, filter-feeding communities. Corals and sponges add structural complexity to otherwise uniform seabed habitats thereby creating areas of high biological diversity (Breeze *et al*. 1997; MacIssac *et al*. 2001). Their frameworks offer refugia for a great variety of invertebrates and fish (including commercially important species) within, or in association with, the living and dead frameworks.

Figure 18: Offshore benthic communities occurring on reefs <50 m depth on the central Agulhas Bank include protected cold water porcelain coral *Styllastera nobilis*, sponges, crinoids and bryozoans (left), whereas a variety of habitat-forming sponges, colonial ascidians and hydroids occur on sandy seabed (right) (Photos: Andrew Penney).

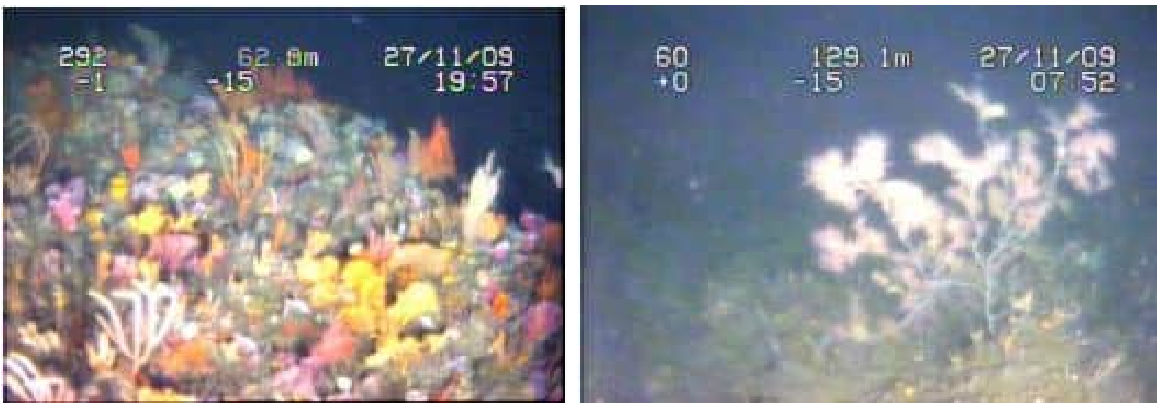


Figure 19: Vulnerable sponge- and soft coral-dominated biota at 60 m depth on the Alphard Bank (left) and black coral at 130 m depth on the 72-Mile Bank (from Sink *et al*. 2010).

The deep water habitats on the Agulhas Bank are thought to be characterised by a number of VME indicator species such as sponges, soft corals and hard corals. The distribution of 22 potential VME indicator taxa for the South African EEZ were recently mapped, with those from the eastern Agulhas Bank listed in Table 1 (Atkinson & Sink 2018; Sink *et al*. 2019).

Table 1: Potential VME species from the eastern Agulhas Bank and shelf edge (Atkinson & Sink 2018).

Phylum	Name	Common Name
Porifera	*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
	Solenosmilia cf. *variabilis*	Thicket coral
	Goniocorella dumosa	Fine bridge coral
	Cladopsammia spp.	Right angled coral
	Eguchipsammia spp.	Right angled coral
	Enallopsammia	Zigzag coral
	Stylaster nobilis	Noble coral
	Stylaster spp.	Fine-branching hydrocoral
	Errina spp.	Red Hydrocoral
	Errinopsis cf. spp.	Fenestrate hydrocoral
	Inferiolabiata cf. spp.	Spiny lace coral
Bryozoa	*Adeonella* spp.	Sabre bryozoan
	Aspidstoma sp.	Pore-plated bryozoan
	Phidoloporidae spp.	Honeycomb false lace coral
Hemichordata	*Cephalodiscus gilchristi*	Agar animal

The Deep Secrets Offshore Research survey undertaken by the NRF and ACEP in 2016 provided further insight into potential VMEs off the South Coast. A key feature mapped during this expedition was the rocky ridge off Gqeberha, which has come to be known as Kingklip Ridge and Kingklip Koppies. The feature spans a broad depth range of -150 to -800 m with a rocky feature rising to form a long narrow ridge 530 m wide and approximately 40 km long. The crest and edges of the northern end of the feature hosted reef-forming Scleractinia corals. However, much of the coral was broken, with evidence of recent and past (6 months) mortality. Some of the coral rubble areas were colonised by deep-water soft corals and brisingid sea stars (Sink *et al*. 2016, cited in Sink *et al*. 2019). In addition, a number of urchins characteristic of sandy habitats on the Agulhas shelf edge and slopes were recorded as well as a diversity of crabs, cerianthid tube anemone and various Foraminifera, as well as various starfish, basket stars, brittlestars and crinoids (Sink *et al*. 2016). The dominant octocoral *Thouarella* was present in rocky areas, with the presence of several associates (brittlestar, scale worm) and fish eggs and larvae within these bottebrush corals.

The Kingklip Ridge and Kingklip Koppies ecosystems were characterised by stony and lace corals (Sink *et al.* 2019) and have been included in the Kingklip Corals Ecologically and Biologically Significant Marine Area (EBSA).

Nonetheless, our understanding of the invertebrate fauna of the sub-photic zone is relatively poor (Gibbons *et al.* 1999) and the conservation status of the majority of invertebrates in this bioregion is not known. Quick & Sink (2005) collated records from the South African Museum of species from the Agulhas Bank area. These included a wide variety of seapens, alcyonacean soft corals, gorgonians and ascidians, many of which are regarded as endemic to the bioregion (see Tables 5.1 and 5.2 in Quick & Sink 2005 for details). This was supplemented by information obtained through analysis of ROV footage taken in reef and unconsolidated habitats and on gas-field infrastructure, SAT diver collections, trap sampling and grab sampling as part of the dedicated PetroSA-WWF study (Sink *et al.* 2010). Although these studies were undertaken on the Agulhas Bank west of the Reconnaissance Permit Area, similar communities would be expected in the shallower portions of Reconnaissance Permit Area. A synthesis of the invertebrate and fish fauna reported from these studies is therefore provided below.

The deep water reefs on the Agulhas Bank (Alphard, 45-Mile and 72-Mile Banks) (see

Figure **13**) support exceptionally diverse and dense assemblages with clear depth zonation patterns. Whereas the shallower regions of the 12-Mile Bank and Alphard Banks (16 to 90 m) supported a kelp community dominated by *Ecklonia radiate* to depths of 35 m, the invertebrate fauna in deeper regions included a high diversity of sponge species (*Antho kellyae*, *Biemna anisotoxa*, *Clathria* spp., *Isodictya elastic, I. frondosa* and *Polymastia* sp.), fragile bryozoans, slow-growing hydrocorals (*Allopora nobilis* and *A. subviolacea*), gorgonians (*Eunicella albicans*, *Eunicella tricorona, Leptogorgia palma* and *Homophyton verrucosum*), gorgonian whip corals (resembling *Ctenocella* sp.) and black corals (*Antipathes* sp.) (Sink *et al.* 2012; Makwela *et al.* 2016).

In the 68 – 75 m depth range of the 45-Mile Bank (60 and 100 m), the invertebrate fauna included large cup- and vase-shaped sponges (*Hemiasterella vasiformis*, *Suberites* sp. and *Axinella* spp.), Geodiid and stove-pipe sponges, black corals, gorgonians, alcyonarian soft corals and slow growing hydrocorals, as well as a diverse fish assemblage. The 110 to 140 m depth range of the 72-Mile Bank revealed a "mass occurrence" of the tubular sponge *Biemna anisotoxa*, as well as *Geodia* sp. *Geodia megastar*, *Pachastrella* sp., *Stelleta trisclera* and *Erylus* sp. Hard corals (*Balanophyllia* and *Caryophyllia*), black corals, hydrocorals and gorgonians (*Eunicella papillosa)* are also present, with high variability in terms of invertebrate diversity and abundance within the reef complex again being evident. Echinoderms included the urchin *Echinus gilchristi* and an unidentified conspicuous orange starfish. Broken bryozoans (*Reteporella* spp.) and solitary hard corals (*Caryophyllia* spp.), occurred at deeper depths.

Benthic epifaunal assemblages on unconsolidated sediments near the 45-Mile Bank were dominated by spiral whelk and various isolated sponges, bryozoans and/or soft corals, suggesting the area may be low profile reef inundated with a layer of sand. Unconsolidated sediments within Block 9 and the frequently-trawled "Blues" area were dominated by the urchins (*Spatangus capensis*, *Brissopsis lyrifera capensis* and *Echinus gilchristi*), starfish (*Marthasterias glacialis, Toraster* sp.), sponges, spiral whelk, horse mussels, crabs (*Mursia cristiata, Gonoplax angulatus*), seapens, soft corals (possibly *Alcyonarium variable*) and burrowing tube anemones (*Cerianthus* sp.).

The benthic environment within the vicinity of the F-O Gas Field, to the west of the Reconnaissance Permit Area, was characterised by sandy unconsolidated sediment with several isolated rocky outcrops (Figure 20). Bioturbation at the sediment surface suggests a rich infaunal community. The rocky outcrops also support a diverse range of gorgonians, bryozoans and sponges. The combination of habitat types (soft sediments and rocky formations) results in a highly diverse benthic fauna.

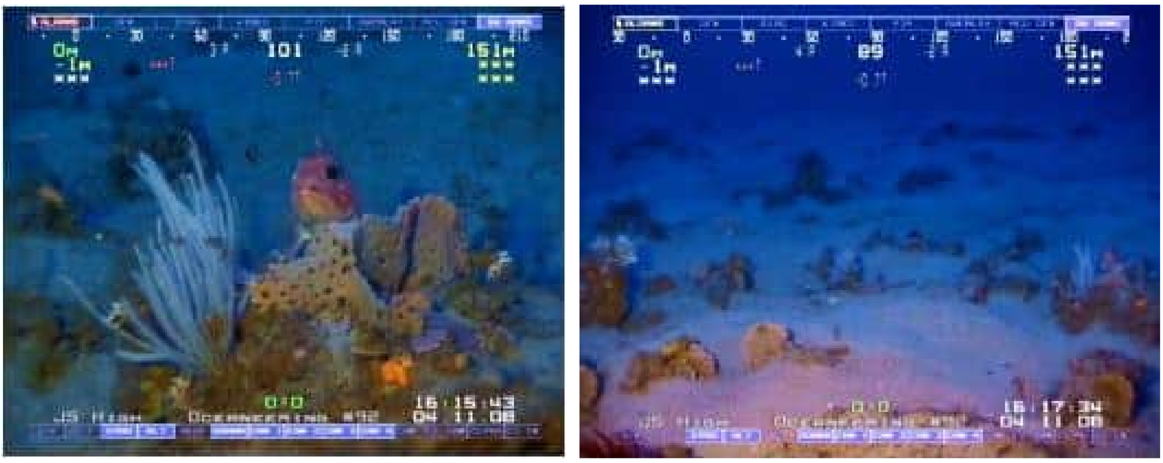


Figure 20: Sandy seabed with rocky outcrops characterising the F-O Field area (from Shipton & Atkinson 2008).

Inshore of the Reconnaissance Permit Area, at depths between 5 m and 30 m lie the Agulhas Inshore Reef and Agulhas Inshore Hard Ground benthic habitats, identified by Sink *et al.* (2012a) as 'Critically endangered - Moderately protected', and 'Vulnerable - Moderately protected', respectively due to their unique invertebrate assemblages. These reefs and hard grounds extend from the Mbashe River (east of East London) to Cape Point (Figure 21). The reefs are considered to be warm temperate reefs, which have a more heterogeneous community structure when compared with those in the Southwestern Cape and Natal inshore regions. In the 2018 National Biodiversity Assessment (Sink *et al.* 2019) these habitats were re-classified as Agulhas Inner Shelf Mosaic and allocated a threat status of 'Vulnerable' (see Figure 12).

Agulhas reefs are dominated by sponges (e.g. golf ball sponge *Tethya aurantium*, the black stink sponge *Ircinia arbuscula*, the orange teat sponge *Polymastia mamillaris* and *Clathria spp.*), ascidians (e.g. *Gynandrocarpa placenta*, *Sycozoa arborescens*, *Didemnum* sp., *Pycnoclavella narcissus*, and the endemic *Clavellina lepadiformis)*, bryozoans (e.g. *Schizoretepora tessellata, Laminopora jellyae* and *Gigantopora polymorpha*) and a variety of octocorals (noble coral *Stylaster nobilis*, the sunburst soft coral *Malacacanthus capensis*, cauliflower soft coral *Drifa thyrsoidea*, purple soft coral *Alcyonium fauri*, Valdivian soft coral *A. valdiviae*, and the Variable soft coral *A. variabile*). Large gorgonians are conspicuous on these reefs with key species including *Leptogorgia palma, Eunicella tricoronata, E. papillosa, E. albicans,* and *Acabaria rubra.* Other important invertebrates include the red-chested sea cucumber *Pseudocnella insolens,* basketstars *Astroclades euryale*, featherstars *Comanthus wahlbergi* and *Tropiometra carinata.* Algal species include *Plocamium* spp., articulated corallines *Corallina* spp. and *Arthrocardia* spp., with the articulated coralline algae *Amphiroa ephedrae* being a dominant species in the shallow subtidal.

Although abalone *Haliotis midae* were dominant space occupiers in shallow waters, poaching and overexploitation have severely depleted the population in their core habitat (Sink *et al*. 2012a).

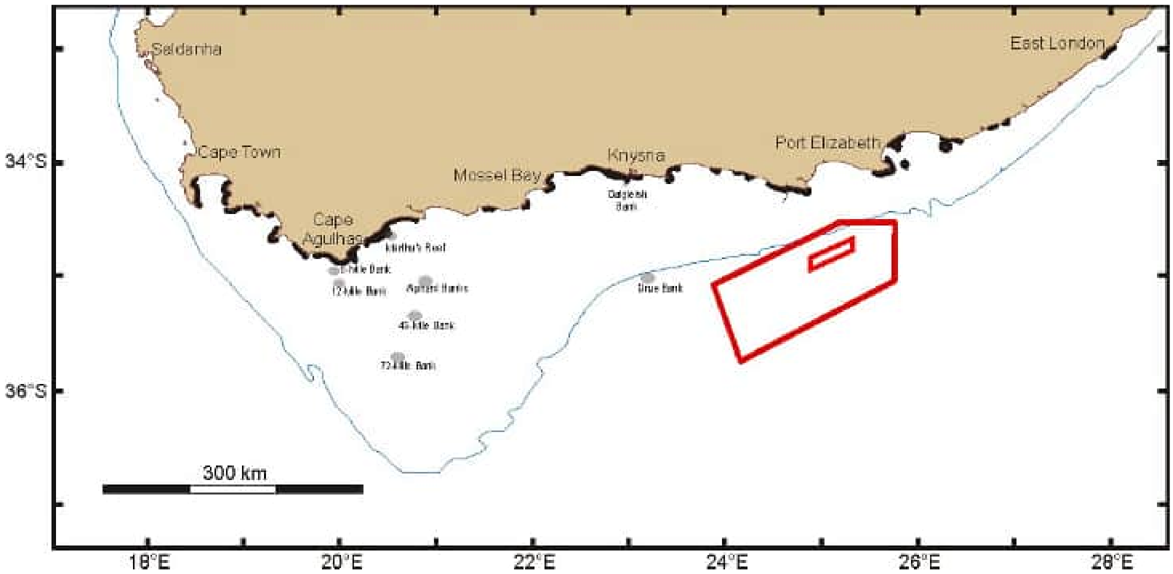


Figure 21: the Reconnaissance Permit Area (red polygon) in relation to the extent of the Agulhas Inshore Reef and Hard Ground habitat types (shown in black) and deep water reefs (adapted from Sink *et al*. 2012a).

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.

The intertidal and shallow subtidal reefs along the South Coast of South Africa support a wide diversity of marine flora and fauna and a relatively high percentage of endemic species (Turpie *et al*. 1999, Awad *et al*. 2002). In the Gqeberha and Mossel Bay areas, inshore reefs to -30 m depth show relatively distinct changes in community structure from those described above, being characterised by uniquely diverse reef assemblages dominated by cauliflower soft coral (Sink *et al*. 2012a) (Figure 22). In particular, the islands in Algoa Bay, form ecologically distinct subtidal habitats, containing many endemic species of invertebrates and seaweeds.

Further south off Goukamma, the reefs are characterised by equally distributed high and low profile areas. The benthic taxa were dominated by bryozoans and sponges (22.9% and 21.1% respectively), followed by gorgonians (16.4%), ascidians (13.7%) and algae (10.1%). Crinoids (8.4%) and hydrozoans (7.5%) constituted <10% of the overall occurrence. Community composition in this area was found to be strongly affected by linefishing, with higher abundance of algae and crinoids at fished sites, and higher sponge cover on reefs within the Goukamma Marine Protected Area (MPA) (Sink *et al*. 2011). The Agulhas Reefs and Hard Grounds in general have been identified as being sensitive to overfishing, anchor damage and to impacts associated with pollution, mariculture, mining and petroleum. Specific reef habitats have thus been identified as 'Endangered' and 'Critically endangered' (see Figure 12).

Figure 22: Diverse and unique reef assemblages, dominated by cauliflower soft coral occur on the inshore reefs to -30 m depth off Gqeberha (Port Elizabeth) (Source: Sink *et al.* 2011).

Information on offshore benthic and pelagic invertebrates occurring in the general project area is sparse. The more motile invertebrate fauna that occurs on the Agulhas Bank includes the squid (*Loligo vulgaris reynaudii*) (Figure 23, left) and the rock lobster (*Palinurus gilchristi*) (Figure 23, right). The deep-water rock lobster is associated with rocky substrate in depths of 90 - 170 m between Cape Agulhas and southern KwaZulu-Natal (Groeneveld & Branch 2002). Larvae drift southwards in the Agulhas Current, settling in the southern portion of the Agulhas Bank before migrating northwards again against the current to the adult grounds (Branch *et al.* 2010). The species is fished commercially along the southern Cape Coast between the Agulhas Bank and East London, with the main fishing grounds being in the 100 – 200 m depth range south of Cape Agulhas on the Agulhas Bank.

Other deep-water crustaceans that may occur inshore of the project area are the shovel-nosed crayfish (*Scyllarides elisabethae*), which occurs primarily on gravelly seabed at depths of around 150 m, although it is sometimes found in shallower water. Its distribution range extends from Cape Point to Maputo. Another rock lobster species occurring on the south coast is the West Coast rock lobster (*Jasus lalandii*), which are typically associated with shallow-water reefs, although the West Coast lobster has been recorded at depths of 120 m (Branch *et al.* 2010).

Forty-five species of cephalopods have been recorded on the Agulhas Bank and the shelf break off the South Coast, the majority of which are cuttlefish (Lipinski 1992; Augustyn *et al.* 1995; Atkinson & Sink 2018). 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). 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.

Figure 23: Squid spawn in nearshore areas off the Southeast coast (left) and South Coast rock lobster occur in deep water (right) (photos: www.mpa.wwf.org.za; Steve Kirkman).

The squid (*Loligo vulgaris reynaudii*) occurs extensively on the Agulhas Bank out to the shelf edge (500 m depth contour) increasing in abundance towards the eastern boundary of the South Coast, especially between Plettenberg Bay and Algoa Bay (Augustyn 1990; Sauer *et al*. 1992; Augustyn *et al*. 1994). Adults are normally distributed in waters >100 m, except along the eastern half of the South Coast where they also occur inshore, forming dense spawning aggregations at depths between 20 - 130 m (Augusty 1990; Roberts *et al*. 2012; Downey 2014). The most important spawning grounds are between Plettenberg Bay and Algoa Bay (Augustyn 1990), these having been linked to specific spawning habitat requirements (Roberts & Sauer 1994; Roberts 2005). Spawning aggregations are a seasonal occurrence, reaching a peak between September and December (Augustyn *et al*. 1992). Spawning is thought to be triggered by upwelling events (Downey *et al*. 2010; Roberts 1998) or possibly a rapid temperature change (Schön *et al*. 2002). Eggs are typically laid on sand and low relief reefs in large and sheltered bays, with environmental conditions playing an important role in the migration of the adults into the spawning areas. Following passive and active planktonic phases, juveniles move offshore, dispersing over the shelf over the full range of their distribution (southern Namibia to East London), eventually returning as adults to their spawning grounds (Augustyn *et al*. 1992). The species is fished commercially along the inshore regions of the southern Cape Coast, with annual catches varying considerably (Roberts & Sauer 1994).

The the giant squid *Architeuthis* sp. is a deep-dwelling species usually found near continental and island slopes all around the world's oceans (Figure 24). This deep-water species could thus potentially occur in the Reconnaissance Permit Area beyond the 1 000 m depth contour, although the likelihood of encounter is extremely low. Growing to in excess of 10 m in length, it is the principal prey of the sperm whale, and is 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. Giant squid lack gas-filled swim bladders and maintain neutral buoyancy through an ammonium chloride solution occurring throughout their bodies.

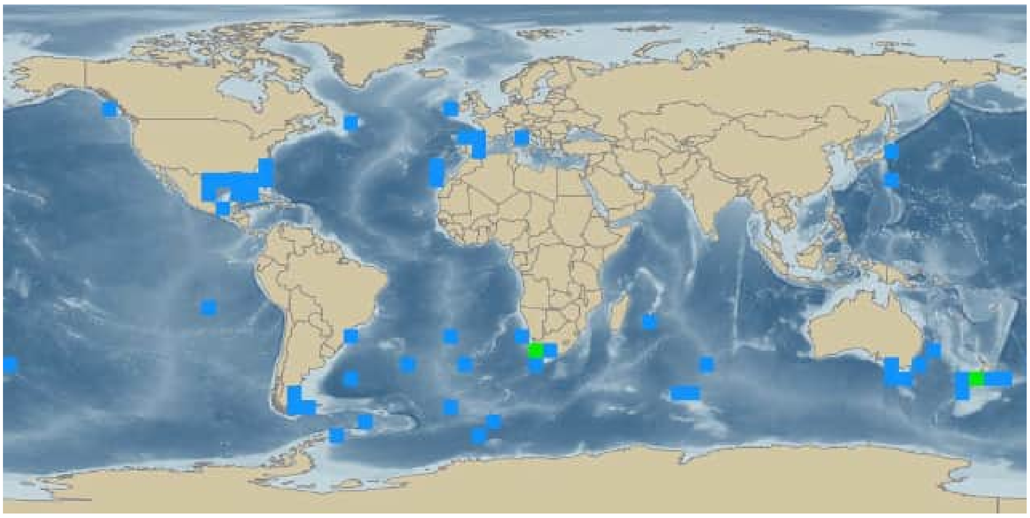


Figure 24: Distribution of the giant squid (http://iobis.org). Blue squares <5 records, green squares 5-10 records.

3.2.4 Pelagic and Demersal Fish

The ichthyofauna of the Southeast coast is diverse, comprising a mixture of temperate and tropical species. As a transition zone between the Agulhas and Benguela current systems, the Southeast coast ichthyofauna includes many species also occurring along the West and/or East Coasts. Pelagic species are those associated with the water column, whereas demersal species are associated with the seabed.

Small pelagic shoaling species occurring along the Eastern Cape include anchovy (*Engraulis encrasicolus*), pilchard (*Sardinops sagax*) (Figure 25, left), round herring (*Etrumeus japonicas*), chub mackerel (*Scomber japonicas*) and horse mackerel (*Trachurus trachurus capensis*) (Figure 25, right). Anchovies are usually located between the cool upwelling ridge and the Agulhas Current (Hutchings 1994). Having spawned intensively in an area around the 200 m depth contour between Mossel Bay and Plettenberg Bay between October and January, most adults move inshore and eastwards ahead of warm Agulhas Current water. Round herring juveniles similarly occur inshore along the South Coast, but move offshore with age (Roel *et al*. 1994; Hutchings 1994).

Pilchards are typically found in water between 14 °C and 20 °C. Spawning occurs on the Agulhas Bank during spring and summer (Crawford 1980), with recruits being found inshore along the South Coast (Hutchings 1994). The shift in the distributions of anchovy and sardine to the south and east during the 1990s and early 2000s was attributed to improved conditions for spawning by these species to the east of Cape Agulhas (van der Lingen *et al*. 2005; 2006; Roy *et al*. 2007; Coetzee *et al*. 2008). Winter (June-July) spawning of sardines on the central Agulhas Bank in patches of high concentrations of phytoplankton (van der Lingen *et al*. 2006) was evidence that the Agulhas Bank served as a refuge for pilchard under low population levels, and therefore vital for the persistence of the species (CCA & CSIR 1998). In late summer and during winter, the penetration of northerly-flowing cooler water along the Eastern Cape coast effectively expands the suitable habitat available for this species, resulting in a 'leakage' of large shoals northwards into southern KwaZulu-Natal in what has traditionally been known as the 'sardin run'. The shoals begin gathering in Algoa Bay as early as late February, moving northwards up the coast between March and May and reach the

KwaZulu-Natal coastline in June. The cool band of inshore water is critical to the 'run' as the sardines will either remain in the south or only move northwards further offshore if the inshore waters are above 20 °C. The shoals can attain lengths of 20-30 km and are typically pursued by Great White Sharks, Copper Sharks, Common Dolphins, Cape Gannets and various other large pelagic predators (www.sardinerun.co.za).

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

Recent studies have indicated that the annual 'sardine run' constitutes a migration to localised upwelling centres inshore of the Agulhas Current (East London and Cape St Lucia) that provide a favourable temperate spawning environment for these small pelagic fish species during and subsequent to their annual migration along the East Coast (Beckley & Hewitson 1994; Coetzee *et al.* 2010).

Other pelagic species that migrate along the coast include elf (*Pomatomus saltatrix*), geelbek (*Atractoscion aequidens*), yellowtail (*Seriola lalandi*), kob (*Argyrosomus* sp) seventy-four (*Cymatoceps nasutus*), strepie (*Sarpa salpa*), Cape stumpnose (*Rhabdosargus holubi*) and mackerel (*Scomber japonicus*)(Van der Elst 1988).

The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of the Reconnaissance Permit Area are the large migratory pelagic species, including various tunas (Figure 26, left), billfish (Figure 26, right) and sharks (Figure 27) (Van der Elst 1988; Smale *et al.* 1994), many of which are considered threatened by the International Union for the Conservation of Nature (IUCN), primarily due to overfishing (

Figure 27: The great white shark *Carcharodon carcharias* (left) and the dusky shark *Charcharhinus obscurus* (right) (photos: www.flmnh.ufl.edu).

Three species likely to be encountered in the Reconnaissance Permit Area are singled out for further discussion, namely the great white shark *Carcharodon carcharias*, the whale shark *Rhincodon typus* and the shortfin mako *Isurus oxyrinchus*. All three species have a cosmopolitan distribution (Figure 33). Although not necessarily threatened with extinction, the great white shark is described as 'Vulnerable' and the whale shark and shortfin mako as 'Endangered' in the IUCN Red listing, and are listed in Appendix II (species in which trade must be controlled in order to avoid utilization incompatible with their survival) of CITES (Convention on International Trade in Endangered Species) and Appendix I and/or II of the Bonn Convention for the Conservation of Migratory Species (CMS). The great white shark and whale shark are both also listed as 'Vulnerable' in the List of Marine Threatened or Protected Species (TOPS) as part of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA). In response to global declines in abundance, white sharks were legislatively protected in South Africa in 1991. Long-term catch-per-unit-effort data from protective gillnets in KwaZulu-Natal, however, suggest a 1.6% annual increase in capture rate of this species following protection, although high interannual variation in these data lessen the robustness of the trend (Dudley & Simpfendorfer 2006). The shortfin mako is not listed in TOPS.

Figure 28: The Reconnaissance Permit Area (red polygon) in relation to the distribution of great white (top), whale shark (middle) and shortfin mako (bottom) (adapted from Harris *et al*. 2022).

Table **2**). Tuna and swordfish are targeted by high seas fishing fleets and illegal overfishing has severely damaged the stocks of many of these species. Similarly, pelagic sharks, are either caught as bycatch in the pelagic tuna longline fisheries, or are specifically targeted for their fins, where the fins are removed and the remainder of the body discarded.

Figure 26: Large migratory pelagic fish such as longfin tuna (left) and sailfish (right) occur in offshore waters (photos: www.arkive.org; www.osfimages.com).

Figure 27: The great white shark *Carcharodon carcharias* (left) and the dusky shark *Charcharhinus obscurus* (right) (photos: www.flmnh.ufl.edu).

Three species likely to be encountered in the Reconnaissance Permit Area are singled out for further discussion, namely the great white shark *Carcharodon carcharias*, the whale shark *Rhincodon typus* and the shortfin mako *Isurus oxyrinchus*. All three species have a cosmopolitan distribution (Figure 33). Although not necessarily threatened with extinction, the great white shark is described as 'Vulnerable' and the whale shark and shortfin mako as 'Endangered' in the IUCN Red listing, and are listed in Appendix II (species in which trade must be controlled in order to avoid utilization incompatible with their survival) of CITES (Convention on International Trade in Endangered Species) and Appendix I and/or II of the Bonn Convention for the Conservation of Migratory Species (CMS). The great white shark and whale shark are both also listed as 'Vulnerable' in the List of Marine Threatened or Protected Species (TOPS) as part of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA). In response to global declines in abundance, white sharks were legislatively protected in South Africa in 1991. Long-term catch-per-unit-effort data from protective gillnets in KwaZulu-Natal, however, suggest a 1.6% annual increase in capture rate of this species following protection, although high interannual variation in these data lessen the robustness of the trend (Dudley & Simpfendorfer 2006). The shortfin mako is not listed in TOPS.

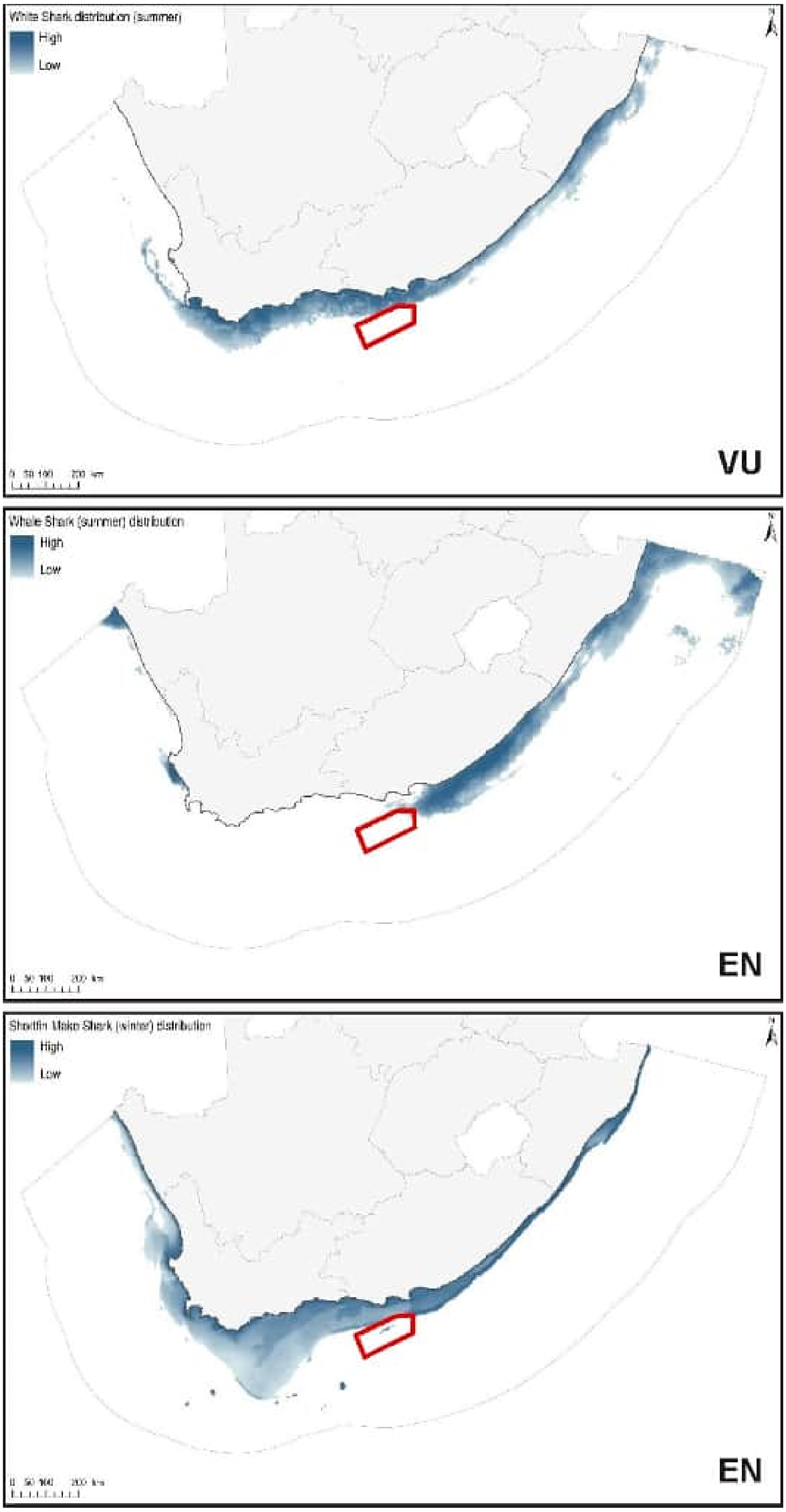


Figure 28: The Reconnaissance Permit Area (red polygon) in relation to the distribution of great white (top), whale shark (middle) and shortfin mako (bottom) (adapted from Harris *et al*. 2022).

Table 2: Some of the more important large migratory pelagic fish likely to occur in the offshore regions of the South Coast (TOPS list under NEMBA, Act 10 of 2004; Sink *et al*. 2019; www.iucnredlist.org;). The National and Global IUCN Conservation Status are also provided.

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

The great white shark *Carcharodon carcharias* is a significant apex predator in the Algoa Bay area, particularly in the vicinity of the seal colony at Black Rocks. Currently there is no consensus on the number of white sharks in South Africa (Cliff *et al*. 1996; Towner *et al*. 2013; Andreotti *et al*. 2016; Irion *et al*. 2017). White sharks migrate along the entire South African coast, typically being present at seal colonies during the winter months, but moving nearshore during summer (Johnson *et al*. 2009). The species is known to seasonally aggregate at specific localities along the South African coast, including False Bay, Gans Bay, Struisbaai, Mossel Bay (Kock & Johnson 2006; Kock *et al*. 2013; Towner *et al*. 2013) and Algoa Bay (Dicken *et al*. 2013). Recent research at Mossel Bay into the residency patterns of white sharks revealed that male sharks display low site fidelity, often rapidly moving in an out of the area. Females in contrast, display high site fidelity and may remain resident in the area for up to two months (Koch & Johnson 2006; see also Jewell *et al*. 2013, 2014;

Ryklief *et al*. 2014). Longer-term emigration of great whites from aggregation sites in response to predation by killer whales has also recently been reported (Towner *et al*. 2022), with their absence inducing some degree of trophic cascade, triggering the emergence of another predator, the bronze whaler shark *Carcharhinus brachyurus*. Great white sharks are, however, capable of transoceanic migrations (Pardini *et al*. 2001; Bonfil *et al*. 2005; Koch & Johnson 2006), with recent electronic tag data suggesting links between widely separated populations in South Africa and Australia and possible natal homing behaviour in the species. Although during transoceanic migrations they appear to spend most of the time just below the sea surface, frequent deep dives to a much as 980 m are made whilst *en route*. Long-distance return migrations along the South African coast are also frequently undertaken (Figure 29), particularly by immature individuals (Bonfil *et al*. 2005). These coastal migrations, which are thought to represent feeding-related events, traverse the project area.

Figure 29: The Reconnaissance Permit Area (red polygon) in relation to the long-distance return migrations of two tracked great white sharks along the South African coast. The black trace shows a migration from 24 May – 2 November 2003; the white trace shows a migration from 31 May – 1 October 2004 (adapted from Bonfil *et al*. 2005).

Whale sharks are regarded as a broad ranging species typically occurring in offshore epipelagic areas with sea surface temperatures of 18–32°C (Eckert & Stewart 2001). Adult whale sharks reach an average size of 9.7 m and 9 tonnes, making them the largest non-cetacean animal in the world. They are slow-moving filter-feeders and therefore particularly vulnerable to ship strikes (Rowat 2007). Although primarily solitary animals, seasonal feeding aggregations occur at several coastal sites all over the world, those closest to the project area being off Sodwana Bay in KZN in the Greater St. Lucia Wetland Park, Tofo Reef near Inhambane in Mozambique, Nosy Be off the northwest coast of Madagascar, and the Tanzanian islands of Mafia, Pemba, and Zanzibar (Cliff *et al*. 2007).

Satellite tagging of whale sharks has revealed that individuals may travel distances of tens of 1 000s of kilometres (Eckert & Stewart 2001; Rowat & Gore 2007; Brunnschweiler *et al*. 2009). Although the fish spend most time in the upper 25 m of the water column while on the continental shelf, once in deep water, the occurrence of dives into mesopelagic and bathypelagic zones increased, with dives to a depth of 1 286 m being recorded. These dives were thought to represent search behaviour for feeding opportunities on deep-water zooplakton (Brunnschweiler *et al*. 2009). Although these slow swimming sharks are vulnerable to ship strikes, the likelihood of an encounter in the speculative 3D survey areas is relatively low.

The shortfin mako shark *Isurus oxyrinchus* inhabits offshore tempertate and tropical seas worldwide. It can be found from the surface to depths of 500 m, and as one of the few endothermic sharks is seldom found in waters <16 °C (Compagno 2001; Loefer *et al*. 2005). This apex predator is targeted by both sport anglers and commercial longline fisheries, and contributes substantially to the bycatch in pelagic driftnet fisheries. They are also taken as an incidental catch in bather protection nets of KwaZulu Natal (Dudley & Cliff 2010; Cliff & Dudley 2011). As the fastest species of shark, shortfin makos have been recorded to reach speeds of 40 km/h with burst of up to 74 km/h, and can jump to a height of 9 m (http://www.elasmo-research.org/education/shark_profiles/i_oxyrinchus.htm). Most makos caught by longliners off South Africa are immature, with reports of juveniles and sub-adults sharks occurring near the edge of the Agulhas Bank and off the South Coast between June and November (Groeneveld *et al*. 2014), whereas larger and reproductively mature sharks were more common in the inshore environment along the East Coast (Foulis 2013).

The varied habitat of rocky reefs and soft-bottom substrates supports a high diversity of Teleosts (bony fish) and Chondrichthyans (cartilaginous fish) associated with the inshore and shelf waters off the South and East Coasts, many of which are endemic to Southern Africa (Smale *et al*. 1994) and form an important component of the demersal trawl and long-line fisheries. The Cape hake (*Merluccius capensis*), is distributed widely on the continental shelf along the Eastern Cape and onto the Agulhas Bank, while the deep-water hake (*Merluccius paradoxus*) is found further offshore in deeper water (Boyd *et al*. 1992; Hutchings 1994). The nursery grounds for both species are located off the west coast and fish move southwards onto the Agulhas Bank as they grow. Juveniles of both species occur throughout the water column in shallower water than the adults. Kingklip (*Genypterus capensis*) is also an important demersal species, with adults distributed in deeper waters along the coast west of Algoa Bay, especially on rocky substrate (Japp *et al*. 1994). Juveniles occur inshore along the entire south coast. They are reported to spawn in an isolated area beyond the 200 m isobaths between Cape St Francis and Gqeberha, within the Reconnaissance Permit Area during spring (see

Figure **13**). Juveniles occur further inshore along the entire South Coast. The Agulhas or East Coast sole (*Austroglossus pectoralis*) inhabits inshore muddy seabed (<125 m) on the shelf between Cape Agulhas and Algoa Bay (Boyd *et al*. 1992). Apart from the above-mentioned target species, numerous other by-catch species are landed by the South Coast demersal trawling fishery including panga (*Pterogymnus laniarius)*, kob (*Argyrosomus hololepidotus*), gurnard (*Chelidonichthyes* spp.), monkfish (*Lophius* sp.), John Dory (*Zeus capensis*) and angel fish (*Brama brama*).

There is a high diversity of endemic sparid and other teleost species along the South Coast (Smale *et al*. 1994) (Figure 30), some of which move into inshore protected bays to spawn (Buxton 1990) or undertake spawning migrations eastwards up the coast into KZN waters. A recent assessment of mesophotic fish and associated habitats across the continental shelf of the Amathole region to the north east of the proposed survey area (Button *et al*. 2021) established that fish assemblages off East London differed from those off Kei Mouth, as well as across the shelf within each sampling area. Although the number of distinct fish assemblages was higher inshore and on the shelf-edge, relative to the mid-shelf, the mid-shelf had the highest species richness. The study revealed a very high biological diversity including evidence of rhodolith beds, deep-water lace corals and critically endangered endemic seabreams. Sixtyfive fish species from 49 genera and 31 families were identified, of which 32 were endemic to southern Africa and 14 to South Africa many of which are of conservation concern.

Those species that undertake migrations along the South and East Coasts include Red Steenbras, White Steenbras (summer), Kob, Geelbek and Elf (winter). Spawning of the majority of species endemic to the area occurs in spring and summer. Many of these species, as well as numerous pelagic species that frequent nearshore waters are targeted by line-fishermen and form an important component of the commercial and recreational linefishery (**Error! Reference source not found.**). These linefish are typically associated with shallow- and deep-water reefs inshore of the Reconnaissance Permit Area.

Figure 30: The Agulhas Inshore and offshore reefs support a wide diversity of teleost species including musselcracker (left) and red stumpnose (right) (photos: http://spearfishingsa.co.za, www.easterncapescubadiving.co.za).

Furthermore, a wide variety of chondrichthyans occur in nearshore waters along the Eastern Cape, (Table 4), some of which, such as St Joseph shark (*Callorhincus capensis*), Soupfin shark (*Galeorhinus galeus*) and Biscuit skate (*Raja straeleni*), are also landed by the trawl and line fishery. The distribution of some of these species is shown in Figure 31.

There is limited information about bathyal fish communities in South Africa. South Africa defines its bathyal zone as extending from 500 m to 3 500 m, recognising an upper slope (500-1 000 m, mid slope (1 000-1 800m) and lower slope (1 800-3 500m). Typical upper slope fishes (200-2 000 m) include rattails (Macrouridae), greeneyes (*Chlorophthalmus* species), notacanthids, halosaurs, chimaeras, skates, bythitids such as *Cataetyx* spp. and morids (deepsea cods) (Smith & Heemstra

2003). Rattails, bythitids, liparidids (snail fishes) and notacanthids (*Polyacanthonotus* species and halosaurs) are characteristic of the lower bathyal (see also Iwamoto & Anderson 1994; Jones 2014).

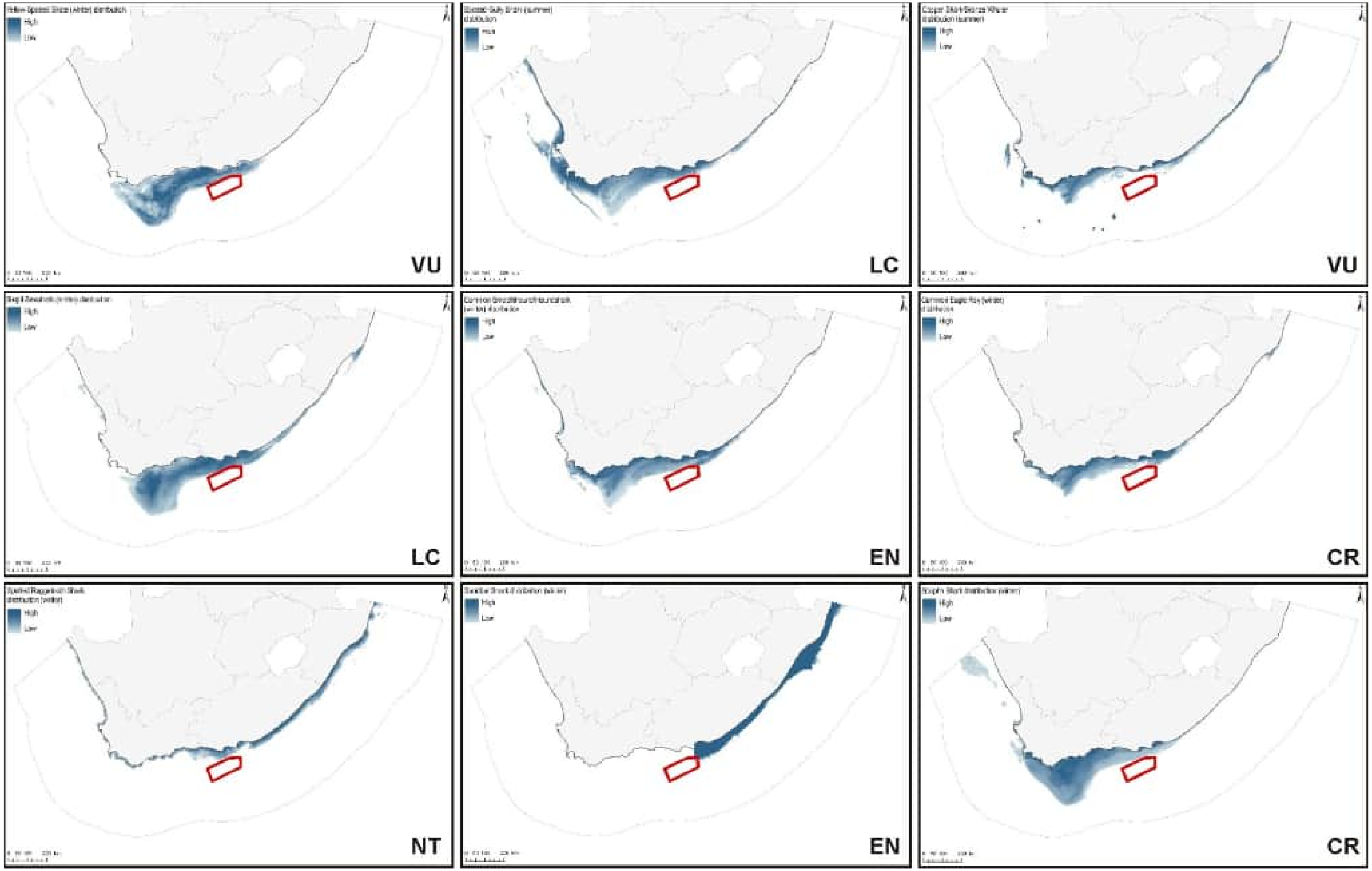


Figure 31: The distribution of various cartilaginous species mentioned in Table 4 in relation to the Reconnaissance Permit Area (red polygon) (adapted from Harris *et al*. 2022). The IUCN conservation status is provided.

Table 3: Some of the more important demersal and pelagic linefish species landed by commercial and recreational boat fishers and shore anglers along the South Coast (adapted from CCA & CMS 2001).

Name	Species Name	National Assessment	Global Assessment
Demersal teleosts			
Bank steenbras	*Chirodactylus grandis*	Least Concern	Not Assessed
Belman	*Umbrina canariensis*	Near Threatened	Near Threatened
Blacktail	*Diplodus sargus*	Not Assessed	Least Concern
Blue hottentot	*Pachymetopon aeneum*	Not Assessed	Least Concern
Bronze bream	*Pachymetopon grande*	Not Assessed	Near Threatened
Cape stumpnose	*Rhabdosargus holubi*	Not Assessed	Least Concern
Carpenter	*Argyrozona argyrozona*	Not Assessed	Near Threatened
Dageraad	*Chrysoblephus christiceps*	Not Assessed	Critically Endangered
Englishman	*Chrysoblephus anglicus*	Not Assessed	Near Threatened
Fransmadam	*Boopsoidea inornata*	Not Assessed	Least Concern
Galjoen	*Dichistius capensis*	Near Threatened	Not Assessed
Silver Kob	*Argyrosomus inodorus*	Vulnerable	Vulnerable
Mini kob	*Johnius dussumieri*	Least Concern	Least Concern
White Musselcracker	*Sparodon durbanensis*	Not Assessed	Near Threatened
Natal stumpnose	*Rhabdosargus sarba*	Not Assessed	Least Concern
Poenskop	*Cymatoceps nasutus*	Not Assessed	Vulnerable
Pompano	*Trachinotus africanus*	Data deficient	Not assessed
Red roman	*Chrysoblephus laticeps*	Not Assessed	Near Threatened
Red steenbras	*Petrus rupestris*	Not Assessed	Endangered
Red stumpnose	*Chrysoblephus gibbiceps*	Not Assessed	Endangered
Picnic sea bream	*Acanthopagrus berda*	Not Assessed	Least Concern
Yellowbelly Rockcod	*Epinephalus marginatus*	Vulnerable	Vulnerable
Catface rockcod	*Epinephalus andersoi*	Near Threatened	Near Threatened
Sand steenbras	*Lithognathus mormyrus*	Not Assessed	Least Concern
Santer	*Cheimerius nufar*	Not Assessed	Data deficient
Scotsman	*Polysteganus*	Not Assessed	Vulnerable
Seventyfour	*Polysteganus undulosus*	Not Assessed	Critically Endangered
Slinger	*Chrysoblephus puniceus*	Not Assessed	Least Concern
Snapper salmon	*Otolithes ruber*	Least Concern	Least Concern
Spotted grunter	*Pomadasys commersonnii*	Vulnerable	Not assessed
Squaretail kob	*Argyrosomus thorpei*	Vulnerable	Endangered
Steentjie	*Spondyliosoma*	Not Assessed	Least Concern
White steenbras	*Lithognathus*	Not Assessed	Endangered
White stumpnose	*Rhabdosargus globiceps*	Not Assessed	Vulnerable
Zebra	*Diplodus cervinus*	Not Assessed	Least Concern

Name	Species Name	National Assessment	Global Assessment
Pelagic teleosts			
Elf/shad	*Pomatomus saltatrix*	Vulnerable	Vulnerable
Garrick/leerfish	*Lichia amia*	Vulnerable	Least Concern
Geelbek	*Atractoscion aequidens*	Vulnerable	Vulnerable
Green jobfish	*Aprion virescens*	Data deficient	Least Concern
King mackerel	*Scomberomorus*	Least Concern	Near Threatened
Kingfish species	*Caranx* spp.	Data deficient	Least Concern
Queenfish	*Scomberoides*	Data deficient	Least Concern
Queen mackerel	*Scomberomorus*	Least Concern	Data deficient
Tenpounder/Springer	*Elops machnata*	Data deficient	Least Concern
Wahoo	*Acanthocybium solandri*	Least Concern	Least Concern
Yellowtail	*Seriola lalandi*	Least Concern	Least Concern

Table 4: Some of the chondrichthyan species occurring along the South Coast (CCA & CMS 2001; Harris *et al*. 2022).

Name	Species Name	National Assessment	Global Assessment
Great white shark	*Carcharodon carcharias*	Least Concern	Vulnerable
Ragged-tooth shark	*Odontaspis taurus*	Data deficient	Near Threatened
Bronze whaler shark	*Carcharhinus brachyurus*	Data deficient	Vulnerable
Dusky shark	*Carcharhinus obscurus*	Data deficient	Endangered
Blacktip shark	*Carcharhinus limbatus*	Least Concern	Vulnerable
Lesser Guitarfish	*Acroteriobatus annulatus*	Least Concern	Vulnerable
Spotted Gully shark	*Triakis megalopterus*	Data deficient	Least Concern
Biscuit skate	*Raja straeleni*	Not Assessed	Near Threatened
Spearnose skate	*Rostroraja alba*	Not Assessed	Endangered
Slime skate	*Dipturus pullopunctatus*	Not Assessed	Least Concern
Blue stingray	*Dasyatis chrysonota*	Data deficient	Near Threatened
St Joseph shark	*Callorhincus capensis*	Least Concern	Least Concern
Soupfin shark	*Galeorhinus galeus*	Endangered	Criticly Endangered
Sevengill cowshark	*Notorynchus cepedianus*	Least Concern	Vulnerable
Sixgill Sawshark	*Pliotrema warreni*	Not Assessed	Least Concern
Spinner shark	*Carcharhinus brevipinna*	Not Assessed	Vulnerable
Sandbar shark	*Carcharhinus plumbeus*	Not Assessed	Endangered
Tiger catshark	*Halaelurus natalensis*	Not Assessed	Vulnerable
Triangular Legskate	*Cruriraja 'triangularis'*	Not Assessed	Least Concern
African Angelshark	*Squatina africana*	Not Assessed	Near Threatened
Twineye skate	*Raja miraletus*	Not Assessed	Least Concern
Spotted spiney dogfish	*Squalus acanthias*	Least Concern	Vulnerable
Puffadder shyshark	*Haploblepharus edwardsii*	Not Assessed	Endangered
Dark shyshark	*Haploblepharus pictus*	Not Assessed	Least Concern
Houndshark	*Mustelus mustelus*	Data deficient	Endangered

Name	Species Name	National Assessment	Global Assessment
Whitespotted smoothhound	*Mustelus palumbes*	Not Assessed	Least Concern
Yellowspotted catshark	*Scyliorhinus capensis*	Not Assessed	Near Threatened
Yellowspotted skate	*Leucoraja wallacei*	Not Assessed	Vulnerable
Leopard catshark	*Poroderma pantherinum*	Least Concern	Least Concern
Pyjama shark	*Poroderma africanum*	Least Concern	Least Concern
Common Eagle ray	*Myliobatis aquila*	Least Concern	Critically Endangered
Electric ray	*Torpedo fuscomaculata*	Not Assessed	Data deficient

3.2.5 Turtles

Five species of sea turtles occur along the East Coast of South Africa; the green turtle (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*) (Figure 32, left), hawksbill (*Eretmochelys imbricata*) and loggerhead (*Caretta caretta*)(Figure 32, right). Green turtles are non-breeding residents often found feeding on inshore reefs. They nest mainly along the coast of Mozambique and on both Europa and Tromelin Islands, well to the north of the Reconnaissance Permit Area (Lauret-Stepler *et al*. 2007). Hawksbills also occur on inshore reefs but nest along the coastlines of Madagascar and the Seychelles (Mortimer 1984). Olive ridleys are infrequent visitors to South African waters and nest throughout the central and northern regions of Mozambique (Pereira *et al*. 2008). Leatherback turtles inhabit the deeper waters of the Atlantic Ocean and are considered a pelagic species. They travel the ocean currents in search of their prey (primarily jellyfish) and may dive to over 600 m and remain submerged for up to 54 minutes (Eckert *et al*. 1989; Hays *et al*. 2004; Lambardi *et al*. 2008; Robinson *et al*. 2018). They come into coastal bays and estuaries to mate, and lay their eggs on the adjacent beaches. Loggerheads tend to keep more inshore, hunting around reefs, bays and rocky estuaries along the African East Coast, where they feed on a variety of benthic fauna including crabs, shrimp, sponges, and fish. In the open sea their diet includes jellyfish, flying fish, and squid (www.oceansafrica.com/turtles.htm; Robinson *et al*. 2018).

Figure 32: Leatherback (left) and loggerhead turtles (right) occur along the East Coast of South Africa (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

Loggerheads and leatherbacks nest along the sandy beaches of the northeast coast of KZN (and thus over 500 km to the north of the Reconnaissance Permit Area), as well as southern Mozambique during summer months. These loggerhead and leatherback nesting populations are the southern-most in the world (Nel *et al.* 2013). Even though these populations are smaller (in nesting numbers) than most other populations, they are genetically unique (Dutton *et al.* 1999; Shamblin *et al.* 2014) and thus globally important populations in terms of conservation of these species.

Loggerhead and leatherback females come ashore to nest from October to March, with peak nesting for both species occurring in December – January (Le Gouvello *et al.* 2020a). The eggs incubate for two months and hatchlings emerge from their nests from mid-January to mid-March. The mean hatching success for loggerheads (73 %) and leatherbacks (76 %) on the South African nesting beaches (de Wet 2013) is higher than reported at other nesting sites globally. Nevertheless, eggs and emerging hatchlings are nutritious prey items for numerous shoreline predators, resulting in the mean emergence success and hatchling success being slightly lower than the hatching success. However, emergence and hatchling success for both species is similarly higher in South Africa than reported at other nesting beaches as mortality is largely limited to natural sources due to strong conservation presence on the nesting beach, which has reduced incidents of egg poaching and female harvesting to a minimum (Nel 2010). The production of both loggerhead and leatherback hatchlings is thus remarkably high in South Africa, making the nesting beaches in northern KZN some of the most productive (relative to nesting numbers) in the world.

Those hatchlings that successfully escape predation *en route* to the sea, enter the surf and are carried ~10 km offshore by coastal rip currents or swim actively offshore for 24-48 hours (frenzy period) to reach the Agulhas Current (Hughes 1974b). Although recent studies have shown that hatchlings actively swim to influence their dispersal trajectories (Scott *et al.* 2014; Putman & Mansfield 2015), they are not powerful swimmers and will primarily drift southwards in the current. While ocean circulation models and numerical dispersal simulations have recently provide insights into the cryptic 'lost years' of neonate turtles (Hamann *et al.* 2011; Putman *et al.* 2012; Putman & Naro-Maciel 2013; Putman *et al.* 2020; DuBois *et al.* 2021), the activities of the post-hatchlings during their first year at sea, largely remaining unknown (Hughes 1974a). After ~10 years, juvenile loggerheads return to coastal areas to feed on crustaceans, fish and molluscs and subsequently remain in these neritic habitats (Hughes 1974b). In contrast, leatherbacks remain in pelagic waters until they become sexually mature and return to coastal regions to breed. Loggerheads reach sexual maturity at about 36 years of age whereas leatherbacks reach maturity at ~15 years (Tucek *et al.* 2014). It has been estimated that only 1 to 5 hatchlings survive to adulthood (Hughes 1974b; de Wet 2013).

Sea turtles are highly migratory and travel extensively throughout their entire life cycle. Adult turtles migrate thousands of kilometres between foraging and breeding grounds, returning to their natal beaches (Hughes 1996; Papi *et al.* 2000; Schroeder *et al.* 2003) by using geomagnetic (Lohmann *et al.* 2007) and olfactory cues (Grassman *et al.* 1984), hearing (Wyneken & Witherington 2001) as well as vision (Witherington 1992) to find their way back to the beach. The duration of the migrations between mating and nesting areas and foraging grounds varies among species. Loggerhead turtles are reported to have a 1 – 2 month long migration period, while that of Leatherback turtles can be up to 11 months (Harris *et al.* 2018). Post-nesting females and hatchlings use natural ambient light to orientate towards the ocean (Bartol & Musick 2002). Artificial light, however, acts as deterrents for nesting females (Witherington 1992; Salmon 2003;

Brazier 2012) and brightly lit beaches thus have reduced female emergences. In contrast, hatchlings are attracted to light even if the source is inland and may consequently suffer higher mortality rates due to desiccation and increased predation (Witherington & Bjorndal 1991; Salmon 2003).

Satellite tracking of female loggerhead and leatherback turtles during inter-nesting periods revealed that loggerheads remained close to the shore (within the boundaries of the iSimangaliso Wetland Park) between nesting events, whereas leatherbacks travelled greater distances (more than 300 km) and beyond the borders of the MPA (Harris *et al.* 2018; Robinson *et al.* 2018). This led to a southward extension of the Marine Protected Area (MPA) in order to include a greater portion of the core range of inter-nesting leatherbacks and provide better protection. The speculative 3D survey areas lie over 500 km to the south of the inter-nesting migration area.

Female turtles do not nest every year due to the high energetic costs of reproduction (Wallace & Jones 2008). During this remigration interval they travel thousands of kilometres (particularly leatherbacks) with ocean currents in search of foraging grounds (Luschi *et al.* 2003a; Luschi *et al.* 2003b). Turtles marked with titanium flipper tags have revealed that South African loggerheads and leatherbacks have a remigration interval of 2 – 3 years, migrating to foraging grounds throughout the South Western Indian Ocean (SWIO) as well as in the eastern Atlantic Ocean. They follow different post-nesting migration routes (Hughes *et al.* 1998; Luschi *et al.* 2006). Loggerheads use one of 3 migration corridors between their nesting and foraging grounds (Figure 33, top) of which the coast-associated Mozambique Corridor is the most commonly used (>80% of the population). Leatherbacks largely follow the same corridors as the loggerheads, with most riding the Agulhas Current southward to forage in high seas regions of the Agulhas Plateau (Hughes *et al.* 1998; Luschi *et al.* 2003b; Luschi *et al.* 2006), at which point they either swim east following the Agulhas Retroflection (Agulhas-Retroflection Corridor) as far north as the Mascarene Plateau or enter the Benguela Current to migrate into the southeastern Atlantic, as far north as central Angola (Agulhas-Benguela Corridor) (Figure 33, bottom) (de Wet 2013; Harris *et al.* 2018). During their journey, leatherbacks dive continuously, mainly at depths shallower than 200 m, but with occasional dives exceeding 1 000 m (Robinson *et al.* 2018).

The Agulhas Current migration corridor will therefore be very active with migrating sea turtles during these months (Harris *et al.* 2018). Both species are thus highly likely to be encountered in the Reconnaissance Permit Area during their foraging migrations.

The South African nesting populations of loggerhead and leatherback sea turtles have been actively protected since 1963 when an annual monitoring and conservation programme was established (Hughes 1996). During the more than 50 years of sea turtle conservation the loggerhead nesting population has increased exponentially from ~ 80 to approximately 700 individuals. The leatherback nesting population showed an initial increase from ~20 to approximately 80 individuals and has remained relatively stable over the last few decades. This conservation programme is considered a global success story and has inspired the inception and persistence of numerous other programmes (Hughes 2012). Nonetheless, the extensive migrations undertaken by these species not only exposes them to threats such as becoming incidental bycatch in commercial and artisanal fisheries but makes protecting them from such potential threats very difficult.

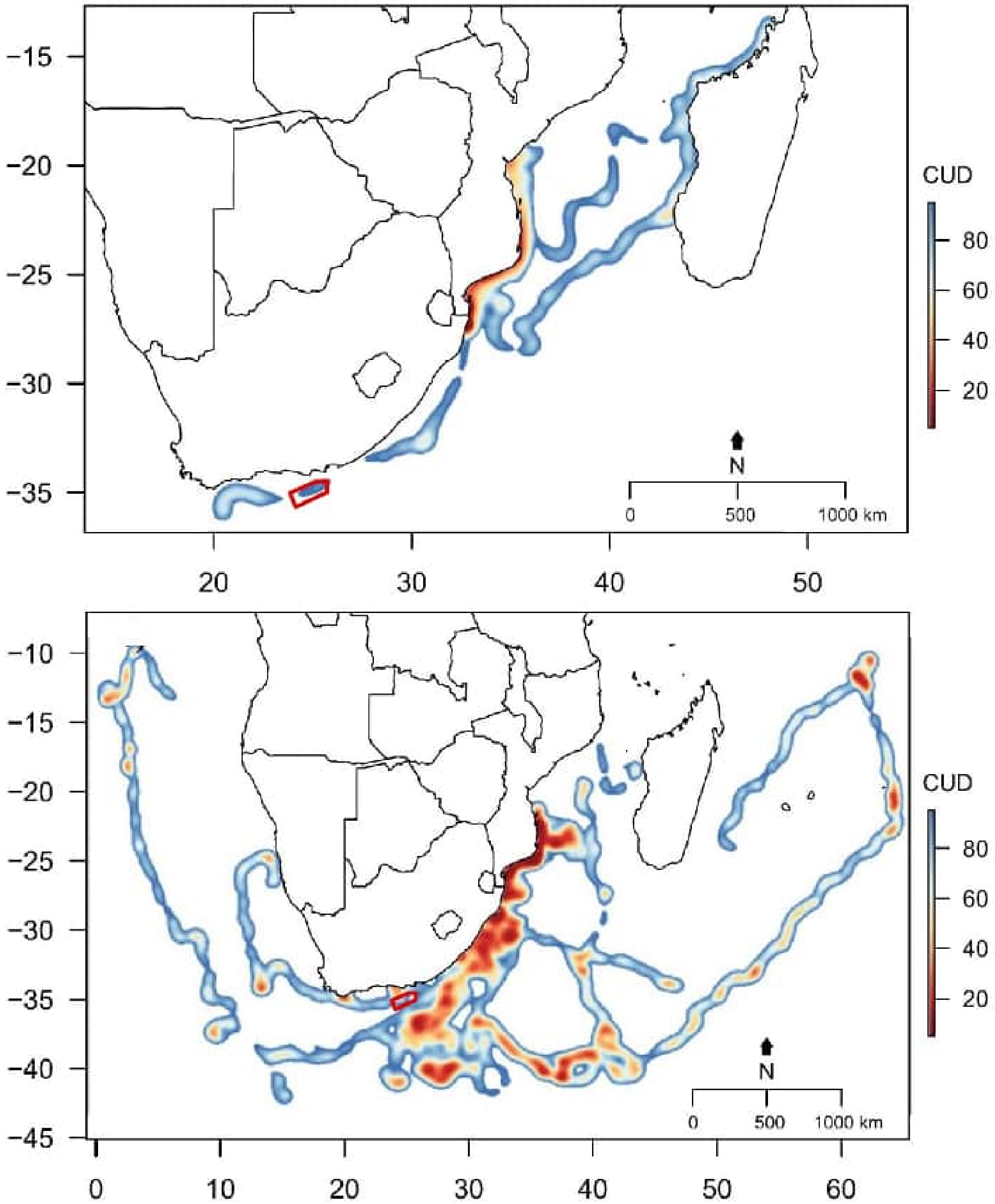


Figure 33: The Reconnaissance Permit Area (red polygon) in relation to the migration corridors of loggerhead (top) and leatherback (bottom) turtles in the south-western Indian Ocean. Intensity of shading for Cumulative Utilization Distribution (CUD): light, low use; dark, high use (adapted from Harris *et al*. 2018).

In the IUCN Red listing, the leatherback is described as 'Critically Endangered', and the loggerhead and green turtles are 'Endangered' on a global scale. Leatherback Turtles are thus in the highest categories in terms of need for conservation in CITES and CMS. As a signatory of CMS, South Africa has endorsed and signed two sister agreements specific to the conservation and management of sea turtles (these are the Africa-Atlantic and Indian Ocean South East Asia Memoranda of Understanding). South Africa, as a nation, is therefore committed to the protection of all species of sea turtles occupying its national waters, whether they are non-resident nesters (loggerhead and leatherback turtles) or resident foragers (hawksbill and green turtles; Oceans and Coast, unpublished data). In addition to sea turtle habitat and physical protection in the St. Lucia and Maputaland Marine Reserves, turtles in South Africa are protected under the Marine Living Resources Act (1998).

The most recent conservation status, which assessed the species on a sub-regional scale, is provided in **Error! Not a valid bookmark self-reference.**.

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

Listing	Leatherback	Loggerhead	Green	Hawksbill	Olive Ridley
IUCN Red List:					
Species (date)	V (2013)	V (2015)	E (2004)	CR (2008)	V (2008)
Population (RMU)	CR (2013)	NT (2017)	*		*
Sub-Regional/National					
NEMBA (2007)	CR	E	E	CR	E
Sink & Lawrence (2008)	CR	E	E	CR	E
Hughes & Nel (2014)	E	V	NT	NT	DD

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

3.2.6 Seabirds

Along the Southeast coast, 60 species are known or thought likely to occur. South Coast seabirds can be categorised into three categories: 'breeding resident species', 'non-breeding migrant species' and 'rare vagrants' (Shaughnessy 1977; Harrison 1978; Liversidge & Le Gras 1981; Ryan & Rose 1989). Fifteen species breed within the Sout-Easth Coast region (

Table **6**), including Cape Gannets (Algoa Bay islands) (Figure 34, left), African Penguins (Algoa Bay islands) (Figure 34, right), Cape Cormorants (a small population at Algoa Bay islands and mainland sites), White-breasted Cormorant, Roseate Tern (Bird and St Croix Islands), Swift Term (Stag Island) and Kelp Gulls. Although none of these breed within the Reconnaissance Permit Area, a number of species breed along the adjacent mainland coast; a breeding colony of Cape Cormorant has recently established on Robberg Peninsula (Marnewick *et al*. 2015), kelp gulls breed in high numbers on the Keurbooms River estuary spit (Witteveen 2015, but see also Whittington *et al*. 2006) and African Black Oystercatcher, Caspian Tern and White-fronted Plover breed on many of the beaches between Plettenberg Bay and the eastern boundary of the Tsitsikamma Section of the Garden Route National Park (http://www.birdlife.org.za/component/k2/item/240-sa098-tsitsikamma-plettenberg-bay). African Black Oystercatchers breed as far east as East London while breeding of Whitefronted Plovers extends into KwaZulu-Natal (Hockey *et al*. 2005). Damara Terns breed inshore between Cape Agulhas and Cape Infanta on the South Coast,, with the bulk of the South African population breeding in Algoa Bay (Taylor *et al*. 2015; Whittington *et al*. 2015).

Table 6: Breeding resident seabirds present along the Southeast coast (adapted from CCA & CMS 2001). IUCN Red List and National Assessment status are provided (Sink *et al*. 2019). * denotes endemicity.

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

Figure 34: Typical diving seabirds on the South Coast are the Cape Gannets (left) (Photo: NACOMA) and the flightless African Penguin (right) (Photo: Klaus Jost).

Recent changes in bird populations along the South Coast include eastward extensions of the breeding range of Hartlaub's gull (*Larus hartlaubii*) and crowned cormorant (*Phalacrocorax coronatus*) (Whittington 2004; van der Lingen *et al*. 2006; Crawford *et al*. 2012), White-breasted Cormorants (Crawford *et al*. 2013), and Cape Gannet (Crawford *et al*. 2015). Bird Island in Algoa Bay now hosts >70% of all Cape Gannets globally (Sherley *et al*. 2019), with the Algoa Bay islands supporting 40% of African Penguins globally. Plettenberg Bay has also recently been identified as a suitable area in which to establish a new African Penguin colony, in attempts to conserve this species.

Most of the breeding resident seabird species feed on fish (with the exception of the gulls, which scavenge, and feed on molluscs and crustaceans), at times intensively target shoals of pelagic fish, particularly during the 'sardine run'. Small pelagic species such as anchovy and pilchard form important prey items for Agulhas Bank seabirds, particularly the Cape Gannet and the various cormorant species. Feeding strategies include surface plunging (gannets and terns), pursuit diving (cormorants and penguins), and scavenging and surface seizing (gulls). All these species feed relatively close inshore, although gannets and kelp gulls may feed further offshore and may be encountered in the speculative 3D survey area (Figure 35). Increases in numbers of breeding pairs at eastern colonies of kelp gull (*L. dominicanus*), crowned cormorant, swift terns (*Sterna bergii*), and Cape gannet (*Morus capensis*) but not African penguins, in response to the eastward shift of sardines have been reported (van der Lingen *et al.* 2006).

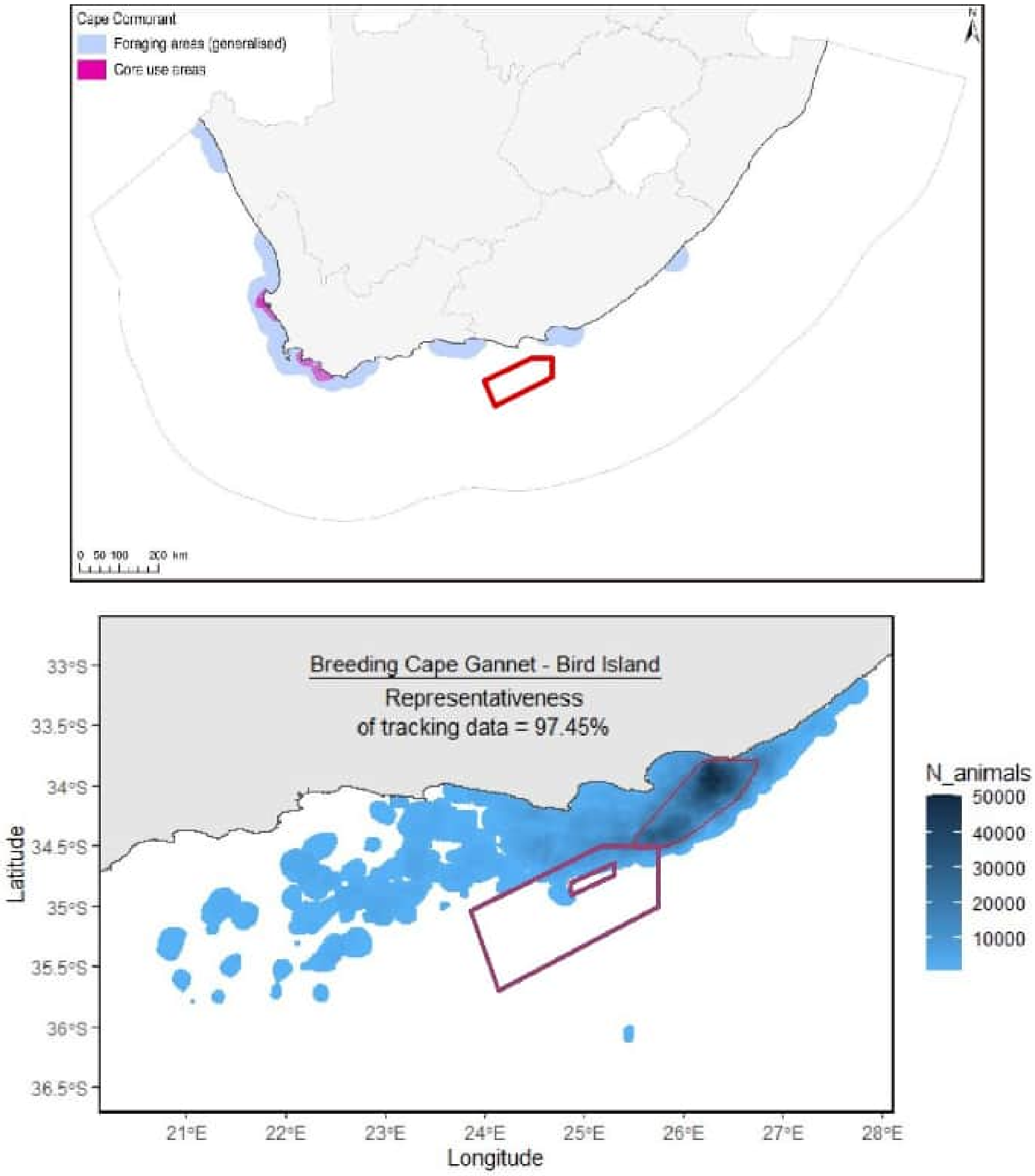


Figure 35: The Reconnaissance Permit Area (red polygon) in relation to the foraging and core usage areas of Cape Cormorant (top) and the core usage areas (red line) and general distribution (blue shading) of breeding Cape Gannets from Bird Island (bottom) (adapted from Harris *et al.* 2022; BirdLife South Africa 2022).

African Penguin colonies in the vicinity of the Reconnaissance Permit Area occur at Cape Recife, and on the Algoa Bay islands (St Croix Island, Jaheel Island, Bird Island, Seal Island, Stag Island and Brenton Rocks). This species forages at sea with most birds being found within 20 km of the coast (Figure 36). The majority of Algoa Bay penguins forage to the south and east of Cape Recife and thus inshore of the area of interest for 3D acquisition. During their pre- and post-moult periods (October to March) penguins forage in inshore areas between Cape Recife and the Robberg Peninsula. African Penguins mainly consume pelagic shoaling fish species such as anchovy, round herring, horse mackerel and pilchard and their distribution is consistent with that of the pelagic shoaling fish, which occur within the 200 m isobath. They are thus unlikely to be encountered in the speculative 3D survey area.

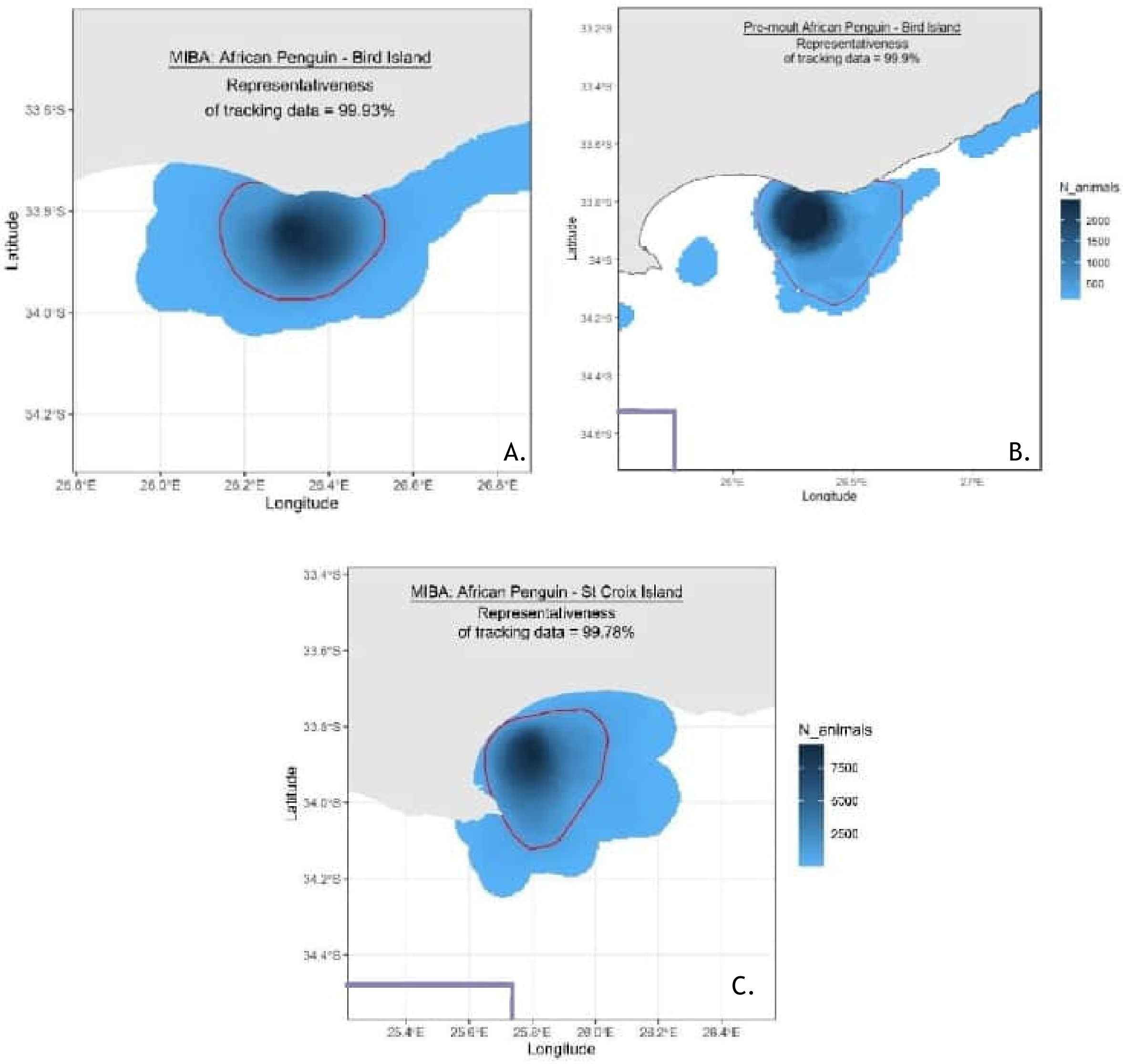


Figure 36: The north-eastern corner of the Reconnaissance Permit Area (purple polygon) in relation to the core usage area (red line) and general distribution (blue shading) of A) breeding and B) pre-moult African penguins from Bird Island and C) St Croix Island (Source: BirdLife South Africa 2022).

Large numbers of pelagic seabirds exploit the pelagic fish stocks of the Southern Benguela and Agulhas Bank. 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 18 species classified as being common in the southern Benguela are listed in **Error! Not a valid bookmark self-reference.**. Pelagic seabirds are therefore likely to be relatively frequently encountered in the offshore waters of the Survey Area (Figure 37). Most of the species in the region reach highest densities offshore of the shelf break (200 – 500 m depth), with highest population levels during their non-breeding season (winter). Pintado petrels and Prion spp. show the most marked variation here.

Table 7: Pelagic seabirds common off Southern Africa (BirdLife South Africa).

Common Name	Species name	Regional Assessment	Global IUCN
Shy Albatross	*Thalassarche cauta*	Near Threatened	Near Threatened
Black-browed Albatross	*Thalassarche melanophrys*	Endangered	Least concern
Atlantic Yellow-nosed Albatross	*Thalassarche chlororhynchos*	Endangered	Endangered
Indian Yellow-nosed Albatross	*Thalassarche carteri*	Endangered	Endangered
Wandering Albatross	*Diomedea exulans*	Vulnerable	Vulnerable
Tristan Albatross	*Diomedea dabbenena*	Critically Endangered	Critically 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
Antarctic Prion	*Pachyptila desolata*	Least concern	Least concern
Salvin's Prion	*Pachyptila salvini*	Near Threatened	Least concern
Fairy Prion	*Pachyptila turtur*	Near Threatened	Least concern
Broad-billed Prion	*Pachyptila vittata*	Least concern	Least concern
White-chinned Petrel	*Procellaria aequinoctialis*	Vulnerable	Vulnerable
Cory's Shearwater	*Calonectris diomedea*	Least concern	Least concern
Great Shearwater	*Puffinus gravis*	Least concern	Least concern
Sooty Shearwater	*Puffinus 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

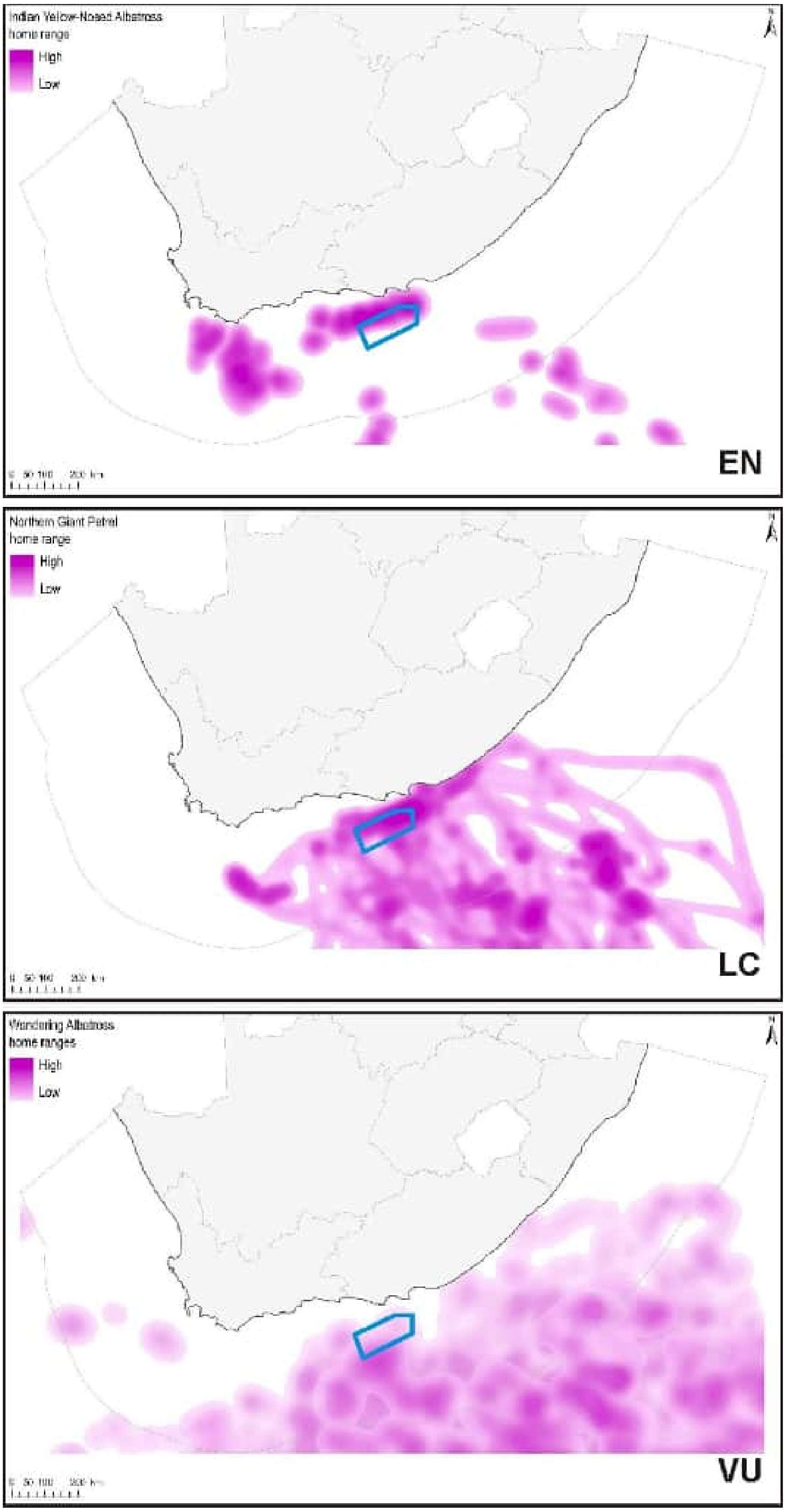


Figure 37: The Reconnaissance Permit Area (blue polygon) in relation to the foraging areas of Indian Yellow-Nosed Albatross (top), Northern Giant Petrels (middle) and Wandering Albatross (bottom) (Adapted from Harris et al. 2022; BirdLife South Africa 2022).

3.2.7 Marine Mammals

The marine mammal fauna of the eastern coast of southern Africa comprises between 28 and 38 species of cetaceans (whales and dolphins) known (historic sightings or strandings) or likely (habitat projections based on known species parameters) to occur here (Table 8) and one seal species, the Cape fur seal (*Arctocephalus pusillus*) (Best 2007). The offshore areas have been particularly poorly studied with almost all available information from deeper waters (>200 m) arising from historic whaling records, although in the past ten years, passive acoustic monitoring and satellite telemetry have begun to shed light on current patterns of seasonality and movement for some large whale species (Mate *et al.* 2011; DEFF 2015; Trudelle *et al.* 2017) but information on smaller cetaceans in deeper waters remains poor outside of reports from seismic surveys themselves. Of the migratory cetaceans listed in Table 8, the blue, sei and humpback whales are listed as 'Endangered' and the Southern Right, South African inshore Bryde's and fin whale as 'Vulnerable' in the IUCN Red Data book. Knowledge of cetacean distribution patterns in the proposed survey area is poor as it falls between the main east and west coast whaling grounds while most recent research in the area has been very coastal in nature (e.g. Caputo *et al.* 2020).

The distribution of whales and dolphins on the Southeast coast can largely be split into species associated with the continental shelf and species which occur in deep, oceanic waters. Species from both environments may, however, be found associated with the shelf break (200 – 1,000 m), so the shelf area is typically 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.

Cetaceans comprise two basic taxonomic groups: the mysticetes (filter-feeding baleen whales) and the odontocetes (toothed predatory whales and dolphins). Due to large differences in their size, sociality, communication abilities, ranging behaviour and acoustic behaviour, these two groups are considered separately.

<u>Mysticetes (baleen whales)</u>

The majority of baleen whales fall into the family Balaenopteridae (rorqual whales). Those potentially occurring in the offshore portions of the proposed exploration area include the blue, fin, sei, minke, and dwarf minke, although the most likely to be seen are the humpback whale, southern right whale and inshore Bryde's which are more strongly associated with the continental shelf. Most of the 'offshore' species occur in pelagic waters, with only occasional visits onto the shelf. These species show some degree of migration either to, or through, the proposed exploration area when *en route* between higher-latitude feeding grounds (Antarctic or Subantarctic) and lower-latitude breeding grounds. Depending on the ultimate location of these feeding and breeding grounds, seasonality off South Africa can be either unimodal (usually in June-August, e.g. minke and blue whales) or bimodal (usually May-July and October-November, e.g. fin whales), reflecting a northward and southward migration through the South Coast area. As whales follow geographic or oceanographic features, the northward and southward migrations may take place at different distances from the coast, thereby influencing the seasonality of occurrence at different locations. Due to the complexities of the migration patterns, each species is discussed in further detail below.

Table 8: Cetaceans occurrence off the Southeast coast of South Africa, their seasonality and likely encounter frequency with proposed seismic survey operations (adapted from S. Elwen, Mammal Research Institute, pers. comm., Best 2007). IUCN Conservation Status is based on the SA Red List Assessment (2014) (Child *et al*. 2016).

Common Name	Species	Hearing Frequency	Shelf (<200 m)	Offshore (>200 m)	Seasonality	RSA Regional Assessment	IUCN Global Assessment
Delphinids							
Common bottlenose dolphin	*Tursiops truncatus*	HF	Yes	Yes	Year round	Least Concern	Least Concern
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*- Ifafa-Kosi Bay subpopulation	HF	Yes		Year round	Vulnerable	Vulnerable
	T. aduncus- Ifafa-False Bay subpopulation	HF	Yes		Year round	Near Threatened	Near threatened
	T. aduncus- Seasonal subpopulation	HF	Yes		Year round	Data Deficient	Data Deficient
Common (short beaked) dolphin	*Delphinus delphis*	HF	Yes	Yes	Year round	Least Concern	Least Concern
Common (long beaked) dolphin	*Delphinus capensis*	HF	Yes		Year round	Least Concern	Least Concern
Fraser's dolphin	*Lagenodelphis hosei*	HF		Yes	Year round	Least Concern	Least Concern
Pantropical Spotted dolphin	*Stenella attenuata*	HF	Yes	Yes	Year round	Least Concern	Least Concern
Striped dolphin	*Stenella coeruleoalba*	HF		Yes	Year round	Least Concern	Least Concern
Spinner dolphin	*Stenella longirostris*	HF	Yes		Year round	Least Concern	Least Concern
Indo-Pacific humpback dolphin	*Sousa plumbea*	HF	Yes		Year round	Endangered	Endangered
Long-finned pilot whale	*Globicephala melas*	HF		Yes	Year round	Least Concern	Least Concern
Short-finned pilot whale	*Globicephala macrorhynchus*	HF		Yes	Year round	Least Concern	Least Concern
Killer whale	*Orcinus orca*	HF	Occasional	Yes	Year round	Least Concern	Least Concern
False killer whale	*Pseudorca crassidens*	HF	Occasional	Yes	Year round	Least Concern	Least Concern
Risso's dolphin	*Grampus griseus*	HF	Yes (edge)	Yes	Year round	Data deficient	Least Concern
Pygmy killer whale	*Feresa attenuata*	HF		Yes	Year round	Least Concern	Least Concern

Common Name	Species	Hearing Frequency	Shelf (<200 m)	Offshore (>200 m)	Seasonality	RSA Regional Assessment	IUCN Global Assessment
Sperm whales							
Pygmy sperm whale	*Kogia breviceps*	VHF		Yes	Year round	Data Deficient	Data Deficient
Dwarf sperm whale	*Kogia sima*	VHF		Yes	Year round	Data Deficient	Data Deficient
Sperm whale	*Physeter macrocephalus*	HF		Yes	Year round	Vulnerable	Vulnerable
Beaked whales							
Cuvier's	*Ziphius cavirostris*	HF		Yes	Year round	Data Deficient	Least Concern
Arnoux's	*Beradius arnouxii*	HF		Yes	Year round	Data Deficient	Data Deficient
Southern bottlenose	*Hyperoodon planifrons*	HF		Yes	Year round	Least Concern	Least Concern
Longman's	*Mesoplodon pacificus*	HF		Yes	Year round	Data Deficient	Data Deficient
True's	*Mesoplodon mirus*	HF		Yes	Year round	Data Deficient	Data Deficient
Gray's	*Mesoplodon grayi*	HF		Yes	Year round	Data Deficient	Data Deficient
Blainville's	*Mesoplodon densirostris*	HF		Yes	Year round	Data Deficient	Data Deficient
Strap-toothed whale	*Mesoplodon layardii*	HF		Yes	Year round	Data Deficient	Data Deficient

Common Name	Species	Hearing Frequency	Shelf (<200 m)	Offshore (>200 m)	Seasonality	RSA Regional Assessment	IUCN Global Assessment
Baleen whales							
Antarctic Minke	*Balaenoptera bonaerensis*	LF	Yes	Yes	>Winter	Least Concern	Least Concern
Dwarf minke	*B. acutorostrata*	LF	Yes		Year round	Least Concern	Least Concern
Southern Hemisphere Fin whale	*B. physalus*	LF		Yes	MJJ & ON	Endangered	Endangered
Pygmy Blue whale	*B. musculus brevicauda*	LF		Yes	MJJ	Data Deficient	Not Assessed
Blue whale (Antarctic)	*B. musculus intermedia*	LF		Yes	Winter	Critically Endangered	Critically Endangered
Sei whale	*B. borealis*	LF		Yes	MJ & ASO	Endangered	Endangered
Bryde's (inshore)	*B. edeni (inshore form)*	LF		Yes	Year round	Vulnerable	Data Deficient
Pygmy right	*Caperea marginata*	LF	Yes		Year round	Least Concern	Least Concern
Humpback	*Megaptera novaeangliae*	LF	Yes	Yes	AMJJASOND	Least Concern	Least Concern
Southern right	*Eubalaena australis*	LF	Yes		JJASON	Least Concern	Least Concern

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

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

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

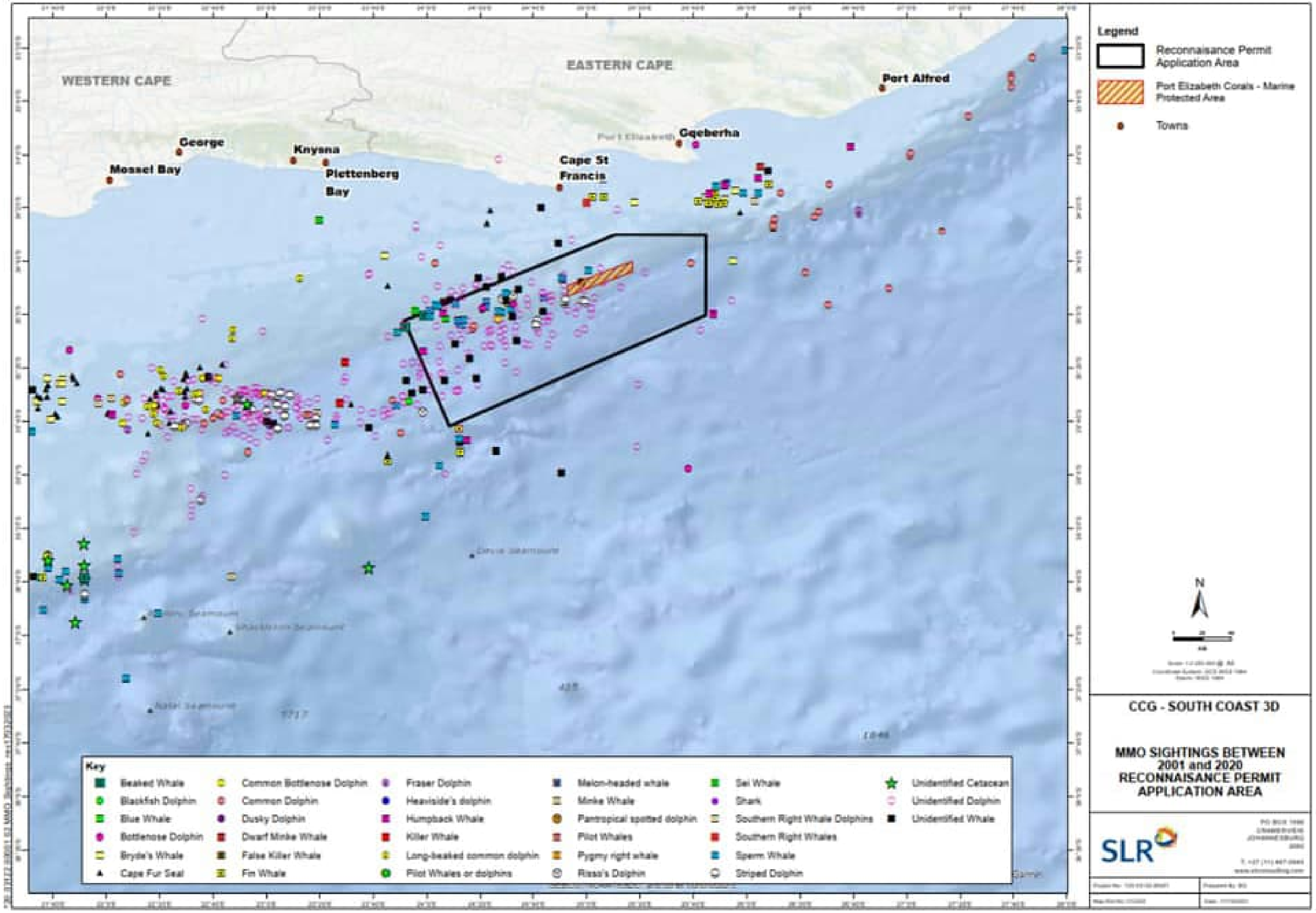


Figure 38a: The Reconnaissance Permit Area (black polygon) in relation to the distribution and movement of cetaceans in the broader project area collated between 2001 and 2020 (SLR MMO database).

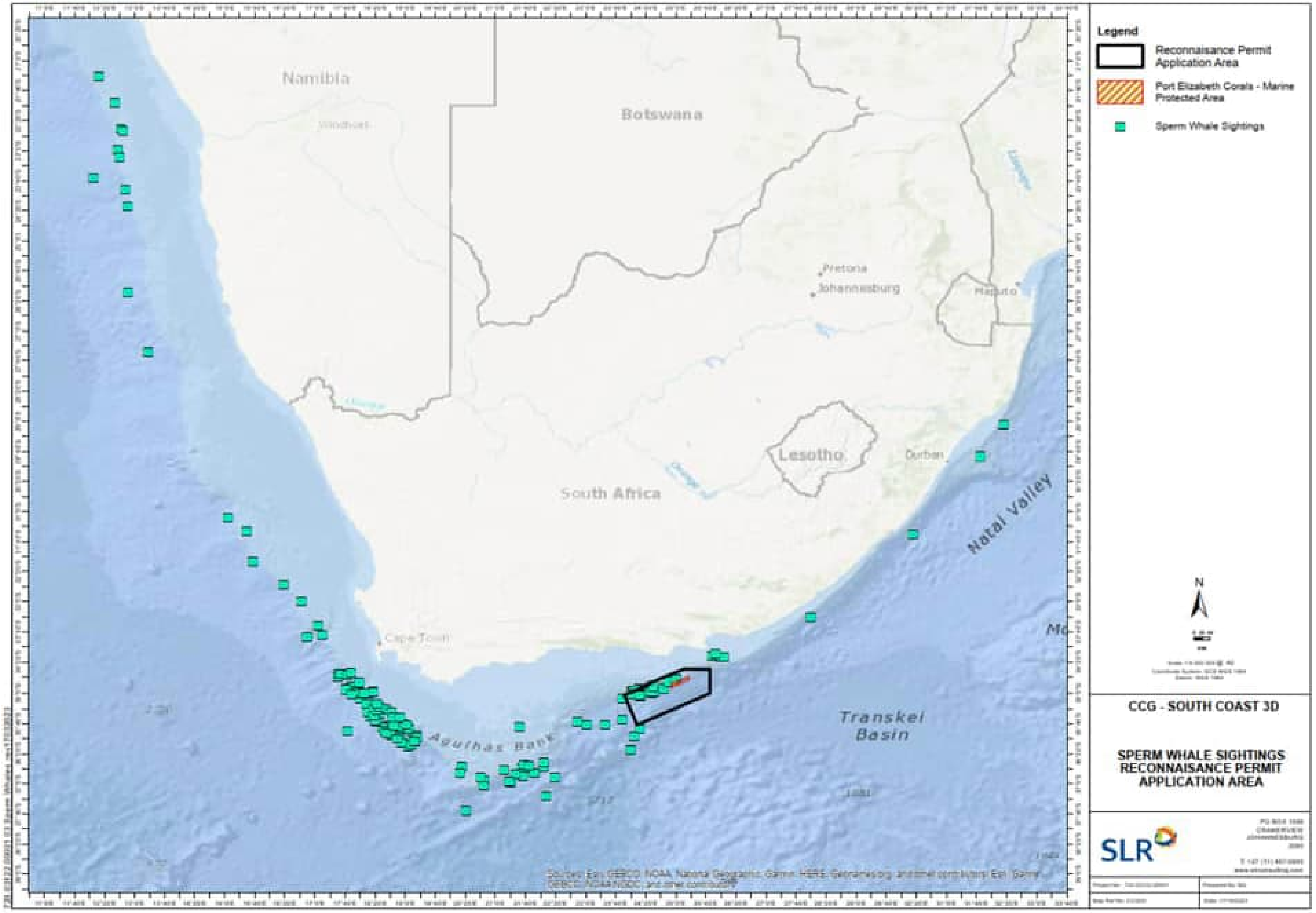


Figure 37b: The Reconnaissance Permit Area (black polygon) in relation to the distribution and movement of Sperm whales along the southern African coast collated between 2001 and 2020 (SLR MMO database).

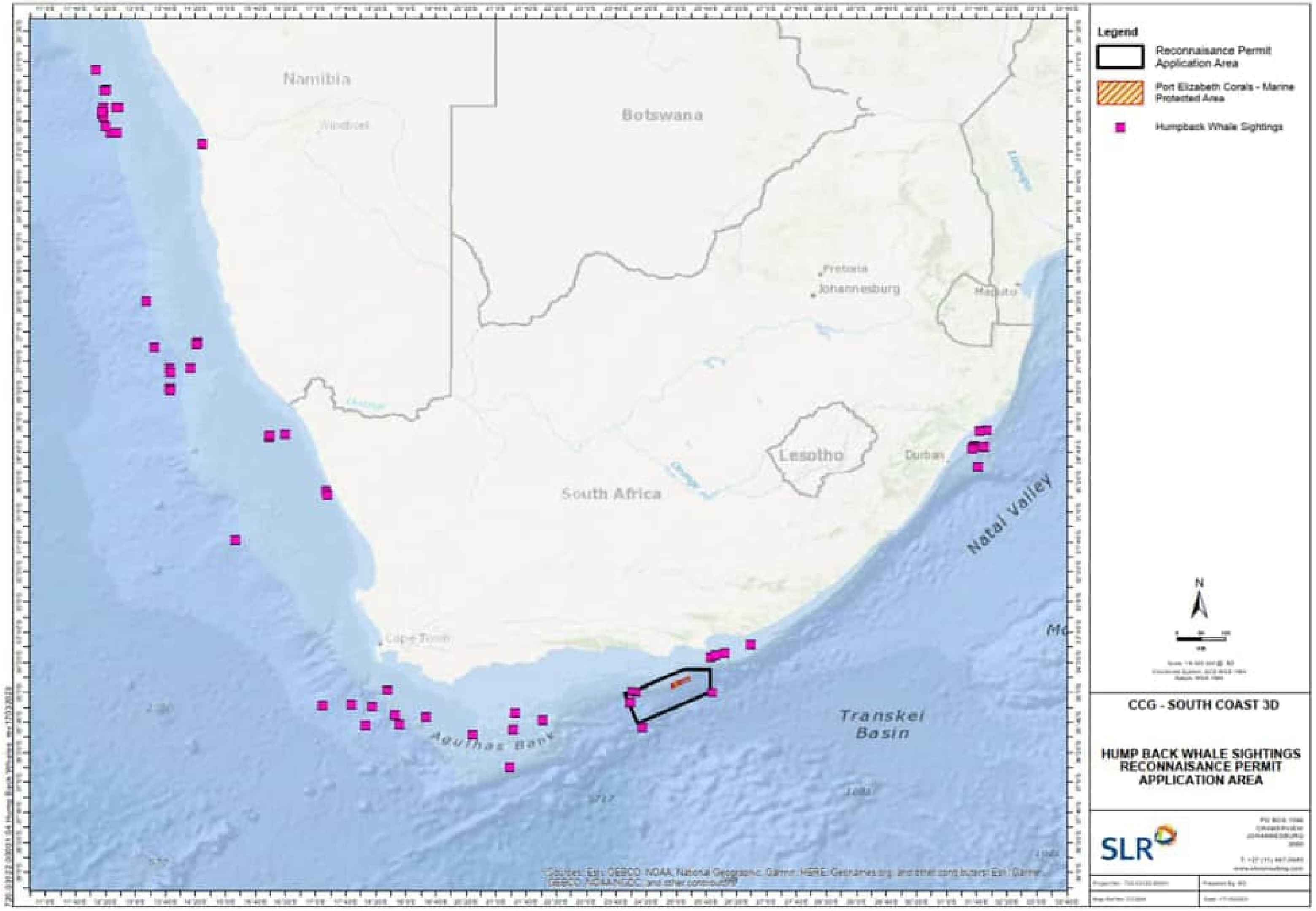


Figure 37c: The Reconnaissance Permit Area (black polygon) in relation to the distribution and movement of Humpback whales along the southern African coast collated between 2001 and 2020 (SLR MMO database).

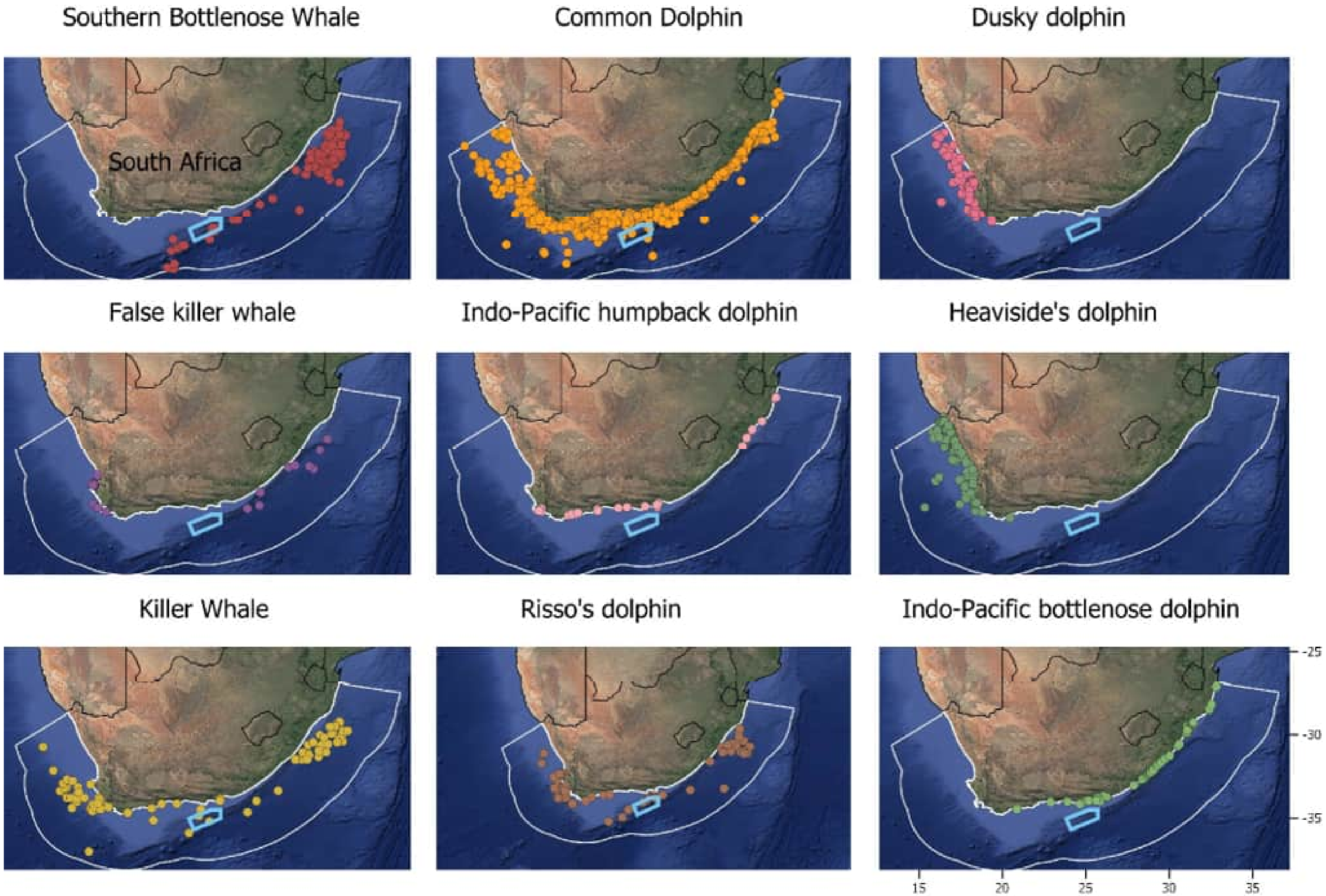


Figure 39: The Reconnaissance Permit Area (cyan polygon) in relation to projections of predicted distributions for nine odontocete species off the coast of South Africa (adapted from: Purdon *et al*. 2020a).

Bryde's whales (*Balaenoptera brydei* spp.)

Two types of Bryde's whales are recorded from South African waters - a smaller neritic 'inshore' form which recent research indicates is a subspecies of the larger pelagic form described as *Balaenoptera brydei* which occurs off the west coast and outside of the survey area (Olsen 1913; Penry 2010) (see Figure 41, top). The inshore population is unique in that it is resident year-round on the Agulhas Bank, only undertaking occasional small seasonal excursions up the east coast in winter during the annual sardine migration. Sightings over the last two decades suggest that the distribution of this population has shifted eastwards, most likely in response to a shift in their prey distribution (Best 2001, 2007; Penry *et al.* 2011). Peak encounter rates in Plettenberg Bay are during late summer and Autumn (Mar – May) (Penry *et al.* 2011), while in Algoa Bay sightings are lowest Aug-Oct but roughly similar in other months of the year suggesting an effective year-round residence. Its current distribution thus implies that this species highly likely to be encountered in the proposed exploration area throughout the year. This is a small population (~600 individuals), which is possibly decreasing in size; an abundance estimate of 150 – 250 individuals was made for Bryde's whales using the Plettenberg Bay/Knysna area in 2005-2008 (Best *et al.* 1984; Penry 2010). As a small, genetically isolated population, recently recognised as its own (yet to be named) sub species (*Balaenoptera brydei edeni*, Penry *et al.* 2018), with a small distributional range largely concentrated on the Agulhas Banks – it is the most vulnerable of the baleen whales to anthropogenic threats. The recent South African National Red Data list assessment has also reclassified this population as 'Vulnerable' (Penry *et al.* 2016).

Southern right whales (*Eubalaena australis*)

Southern right whales migrate to the southern African subregion to breed and calve, inhabiting shallow coastal waters in sheltered bays (90% were found <2 km from shore; Best 1990; Elwen & Best 2004). The southern African population of southern right whales (Figure 40, right) historically extended from southern Mozambique (Maputo Bay) to southern Angola (Baie dos Tigres) and is considered a single population within this range (Roux *et al.* 2015). The main winter breeding concentration is in the bays off the Cape South Coast between Cape Town and Gqeberha, with the highest density between Walker Bay and St Sebastian Bay. Southern right whale sightings east and offshore of Algoa Bay are thus likely to be rare. They typically occur in coastal waters off the south coast between June and November, although animals may be sighted as early as April and as late as January (see Figure 41, bottom).

The most recent abundance estimate for this population (2017), estimated the population at ~6 116 individuals including all age and sex classes (Brandão *et al.* 2018). This is thought to be at least 30 % of the original population size and with the population growing at ~6.5% per year since monitoring began (Brandão *et al.* 2018). While annual surveys have revealed a steady population increase since the protection of the species from commercial whaling, the South African right whale population has undergone substantial changes in breeding cycles and feeding areas (Van Den Berg *et al.* 2020), and numbers of animal using our coast since those studies were done – notably a significant decrease in the numbers of cow-calf-pairs following the all-time record in 2018, a marked decline of unaccompanied adults since 2010 and variable presence of mother-calf pairs since 2015 (Roux *et al.* 2015; Vermeulen *et al.* 2020). The change in demographics are indications of a population undergoing nutritional stress and has been attributed to likely spatial and/or temporal displacement of prey due to climate variability (Vermeulen *et al.* 2020; see also Derville *et al.* 2019; Kershaw *et al.* 2021; van Weelden *et al.* 2021).

Figure 40: The humpback whale (left) and the southern right whale (right) migrate along the Southeast coast during winter (Photos: www.divephotoguide.com; www.aad.gov.au).

Humpback whales (*Megaptera novaeangliae*)

Humpback whales (Figure 40, left) are known to migrate between their Antarctic feeding grounds and their winter breeding grounds in tropical waters e.g. Angola, Mozambique and Madagascar. Until recently it was believed that that these breeding grounds were functionally separate from tone another, with only rare movements between them (Pomilla & Rosenbaum 2005) and movements to other continental breeding grounds being even more rare.

During these migrations they use subtropical coastal areas as important migratory corridors (Best 2007; Meynecke *et al*. 2021). Although they have a cosmopolitan distribution (Best 2007) they exhibit a distinct seasonality in occurrence along the South African East Coast. This species can be observed between May and February, with peak sightings in June and November/December (Banks 2013). These peaks correspond to the northward migration, as animals pass through the Reconnaissance Permit Area *en-route* to their breeding grounds off Mozambique and Madagascar, and the southward migration when they migrate back to their Southern Ocean feeding grounds (see Figure 41, middle). Cow-calf pairs can be seen closer to the coast during the southward migration than non-calf groups, and they appear to use the relatively protected bays along the South Coast to rest during their migration, while Banks (2013) showed the migration stream to extend to at least 16 km offshore with opportunistic sightings suggesting animals are spread across the entire shelf (Figure 38c). Recent satellite tagging of animals between Plettenberg Bay and Port Alfred during the northward migration, showed them to turn around and end up feeding in the Southern Benguela (Seakamela *et al*. 2015) before heading offshore and southwards using the same route as whales tracked off Gabon and the West Coast of South Africa. Unexpected results such as this highlight the complexities of understanding whale movements and distribution patterns and the fact that descriptions of broad season peaks in no way captures the wide array of behaviours exhibited by these animals. Furthermore, three separate matches have been made between individuals off South Africa and Brazil by citizen scientist photo-identification (www.happywhale.com). This included whales from the Cape Town and Algoa Bay-Transkei areas. Analysis of humpback whale breeding song on SubAntarctic feeding grounds also suggests exchange of singing male whales from western and eastern South Atlantic populations (Darling & Sousa-Lima 2005; Schall *et al*. 2021;, but see also Darling *et al*. 2019; Tyarks *et al*. 2021).

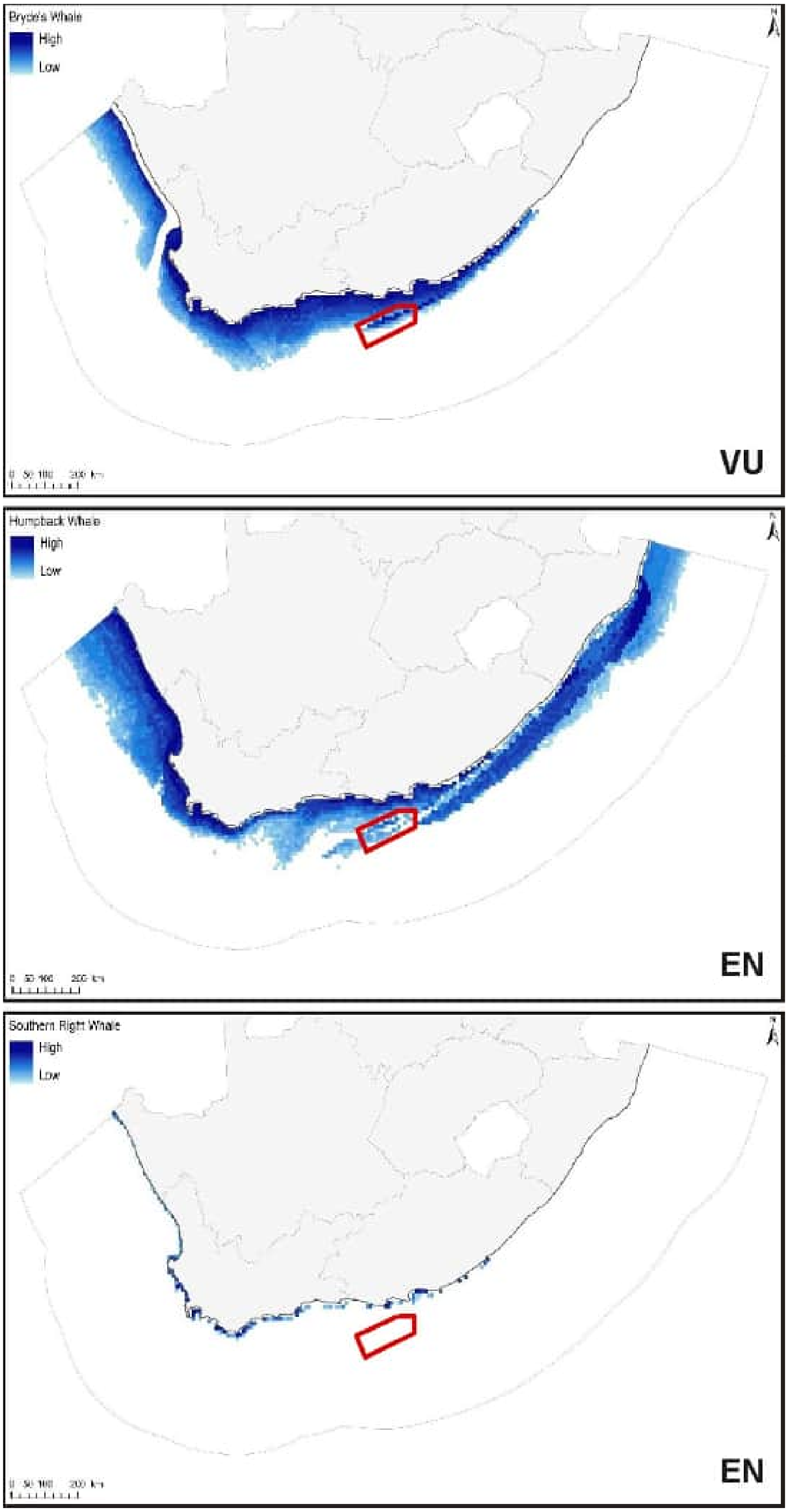


Figure 41: The Reconnaissance Permit Area (red polygon) in relation to projections of predicted distributions for Bryde's whales (top), humpback whales (middle) and Southern right whales (bottom) (adapted from Harris *et al*. 2022).

Sei whales (*Balaenoptera borealis*)

Sei whales migrate through South African waters, where they were historically hunted in relatively high numbers, to unknown breeding grounds further north. Their migration pattern thus shows a bimodal peak with numbers on the east coast highest in June (on the northward migration), and with a second larger peak in September. All whales were caught in waters deeper than 200 m with most deeper than 1 000 m (Best & Lockyer 2002). A recent sighting (January 2020) by a tour operator in Algoa Bay, confirms their current presence along the coast in low numbers. Almost all information is based on whaling records 1958-1963 and there is no current information on abundance or distribution patterns in the region.

Fin whales (*Balaenoptera physalus*)

Fin whales were historically caught off the East Coast of South Africa, with a unimodal winter (June-July) peak in catches off Durban. However, as northward moving whales were still observed as late as August/September, it is thought that the return migration may occur further offshore. 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 Southern Africa.

Blue whales (*Balaenoptera musculus*)

Blue whales were historically caught in high numbers off Durban, showing a single peak in catches in June/July. Sightings of the species in the area between 1968-1975 were rare and concentrated in March to May (Branch *et al*. 2007). Data from the Antarctic and western Africa provide evidence of regular detection of this species there, with likely similar trends in recovery on the east coast. Detections of blue whales in the Antarctic peak between December and January (Tomisch *et al*. 2016) and off western South Africa (Shabangu *et al*. 2019) and in northern Namibia between May and July (Thomisch 2017) supporting observed timing from whaling records. The chance of encountering the species in the proposed exploration area is considered low.

Minke whales

Two forms of minke whale occur in the southern Hemisphere, the Antarctic minke whale (*Balaenoptera bonaerensis*) and the dwarf minke whale (*B. acutorostrata* subsp.); both species occur off the East Coast (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 of the species do migrate from the Southern Ocean (summer) to tropical/temperate waters (winter) where they are thought to breed, some animals, especially juveniles, are known to stay in tropical/temperate waters year-round. Off Durban, Antarctic minke whales were reported to increase in numbers in April and May, remaining at high levels through June to August and peaking in September (Best 2007).

The dwarf minke whale has a more temperate distribution than the Antarctic minke and they do not range further south than 60-65°S. Dwarf minke whales have a similar migration pattern to Antarctic minkes with at least some animals migrating to the Southern Ocean in summer months. Dwarf minke whales occur closer to shore than Antarctic minkes and have been seen <2 km from shore on several occasions around South Africa, particularly on the East Coast during the 'sardine run' (O'Donoghue *et al*. 2010a, 2010b, 2010c). Historic whaling records indicate that off Durban they were taken mainly between April and June. Both species are generally solitary and densities are likely to be low in the Reconnaissance Permit Area.

Minke whales are present year-round, with a large portion of this population consisting of small, sexually immature animals that primarily occur beyond 30 nautical miles from the coast during summer and autumn.

Pygmy right whales

The smallest of the baleen whales, the pygmy right whale, occurs along the southern African East Coast to as far north as 30°S. There are no data on the abundance or conservation status of this species, but it was not subjected to commercial whaling, so the population is expected to be near to original numbers. Sightings of this species at sea are rare (Best 2007) due in part to their small size and inconspicuous blows. Density in the Reconnaissance Permit Area is likely to be low.

In summary, the majority of data available on the seasonality and distribution of large whales on the East Coast of South Africa is largely the result of commercial whaling activities mostly dating from the 1960s, and stranding or by catch records (Meÿer *et al*. 2011) although passive acoustic monitoring (mostly west coast) and satellite tagging is providing some new insights into current patterns. The large whale species for which there are current data available are the humpback, southern right and inshore Bryde's whale, for which additional information on their occurrence in the exploration area has been provided. Even those species, which are relatively well studied around southern Africa, are not fully understood and significant changes in behaviour, movements and timing (e.g. right whale numbers and timing along the coast, humpback whales changing coasts) reveal that much of our assumed knowledge is far from complete and that many changes continue to occur both in response to population recover and local and large scale environmental changes.

<u>Odontocetes (toothed whales)</u>

The Odontoceti are a varied group of animals including the dolphins, porpoises, beaked whales and sperm whales. Species occurring within the broader project area display a diversity of features, for example their ranging patterns vary from extremely coastal and highly site-specific to oceanic and wide ranging. Those in the region can range in size from 1.9 m long (Spinner dolphin) to 17 m (bull sperm whale).

Sperm whales (*Physeter macrocephalus*)

Almost all information about sperm whales in the southern African subregion results from data collected during commercial whaling activities prior to 1985 (Best 2007). Sperm whales (Figure 42, left) are the largest of the toothed whales and have a complex, well-structured social system with adult males behaving differently to younger males and female groups. Sperm whales live in deep ocean waters over 1 000 m deep; however, males occasionally move into depths of 500-200 m on the shelf (Best 2007). They are therefore likely to be encountered in the Reconnaissance Permit Area (see (Figure 38b and Figure 43). Seasonality of catches off the East Coast suggest that medium- and large-sized males are more abundant during winter (June to August), while female groups are more abundant in summer (December - February), although animals occur year-round (Best 2007). Although considered relatively abundant worldwide (Whitehead 2002), no current data are available on density or abundance of sperm whales on the Southeast coast of southern Africa, but passive acoustic monitoring southwest of Cape Town revealed near year-round presence of sperm whale echolocation clicks. Sperm whales feed at great depth, during dives of more than 30 minutes, making them difficult to detect visually. The regular echolocation clicks made by the species when diving, however, make them relatively easy to detect acoustically using Passive Acoustic Monitoring (PAM).

Figure 42: 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).

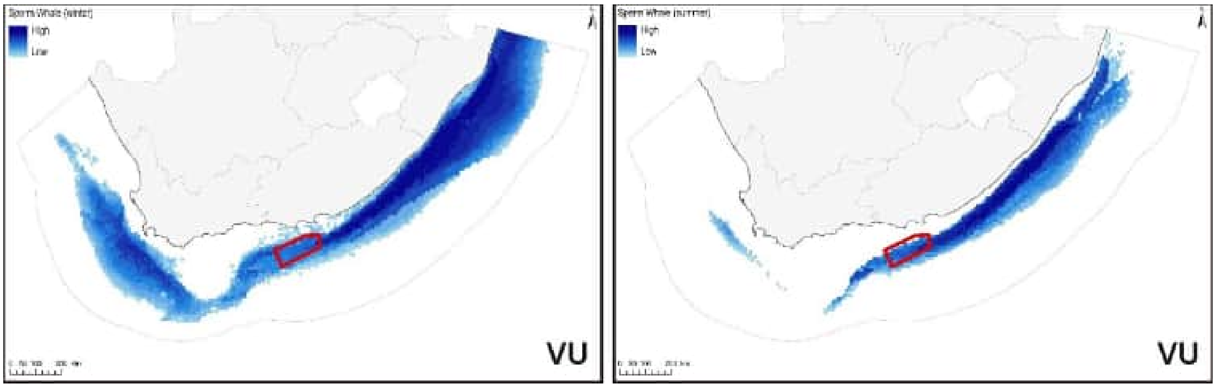


Figure 43: The Reconnaissance Permit Area (red polygon) in relation to projections of predicted winter (left) and summer (right) distributions for sperm whales (adapted from Harris *et al*. 2022).

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 off the shelf of the southeast 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 depth (see various species accounts in Best 2007). Their presence in the area may fluctuate seasonally, but insufficient data exist to define this clearly. Of the smaller odontocetes, the long-beaked common dolphin, Indo-Pacific bottlenose dolphin and Indian Ocean humpback dolphin regularly occur along the southeast coast of South Africa and are frequently encountered in Mossel Bay, Knysna, Plettenberg Bay and Tsitsikamma area (Phillips 2006; Best 2007; Greenwood 2013; James *et al*. 2015). Figure 39 provides the projections of predicted distributions for nine odontocete species off the coast of South Africa (Purdon *et al*. 2020a) in relation to the Reconnaissance Permit Area.

Humpback dolphins (*Sousa plumbea*)

Humpback dolphins (Figure 44, right) occur along the South African South and East coasts in two apparently separate populations. These populations range from False Bay to approximately East London and from Durban to Richards Bay. Humpback dolphins in the western Indian Ocean were only recognised as a separate species in 2014 (Jefferson & Rosenbaum 2014). Globally They are listed as 'Endangered' both globally (Braulik *et al*. 2015) and within South Africa on the IUCN Red List (Plön *et al*. 2015, 2016), and are considered to be South Africa's most endangered marine mammal.

Recent studies in Plettenberg Bay and Algoa Bay indicated a decrease in sightings and group sizes in both locations by approximately 50% in the last decade and a reduction in mean group sizes from 7 to 4 individuals (Greenwood 2013; Koper *et al*. 2016). Several hypotheses have been put forward as likely reasons for the decline; a decrease in prey availability, prolonged disturbance from whale and dolphin watching tourism and other marine recreation, coastal development and sustained pollution that contaminates the prey on which this species depends.

Figure 44: Toothed whales that occur on the South Coast include the Indo-Pacific bottlenose dolphin (left) and the Indian Ocean humpback dolphin (right) (Photos: www.fish-wallpapers.com; www.shutterstock.com).

Humpback dolphins inhabit the extreme inshore coastal environment rarely encountered much beyond 20 m water depth and a few hundred meters of land. There are two well separated populations off the South African coast: along the Cape South Coast (Cape Town to East London) and off northern KwaZulu-Natal (Vermeulen *et al*. 2017). From the national catalogue of photographically identifiable individuals these authors could identify only 248 animals suggesting a total population size in South Africa of fewer than 500 individuals. Although their preferred inshore habitat is well away from the expected areas of seismic acquisition, it is not known how much of the sound from surveys travels into this area. But given their highly endangered nature a precautionary approach is strongly advised.

Indo-Pacific Bottlenose dolphins (*Tursiops aduncus*)

The Indo-Pacific bottlenose dolphin (Figure 44, left) occurs throughout coastal and shallow offshore waters of the temperate and tropical regions of the Indian Ocean and south-west Pacific to as far west as the Cape Peninsula. Off South Africa, they inhabit waters less than 50 m deep between the Mozambique border in the east and False Bay in west (Ross 1984; Ross *et al*. 1987). They occur year-round in the coastal habitat inshore of the exploration area. Indo-Pacific bottlenose dolphins are often seen in large groups of 10s to 100s of animals (Saayman *et al.* 1972; Ross 1984; Melly 2011) with calves seen year-round along the southeast coast (Cockcroft *et al.* 1990; Best 2007). In Algoa Bay peak sightings were recorded in April/May (autumn) and October/November (spring) (Melly *et al.* 2017).

A mark-recapture study conducted in Knysna-Tsitsikamma area estimated a population of approximately 1 873 – 2 479 individuals (Vargas-Fonseca *et al.* 2020), which is a substantial reduction from the ~7 000 bottlenose dolphins in only the Plettenberg Bay area estimated by Phillips (2006). They are thought to be part of a larger population of between 16 000 and 41 000 that ranges along a broader southeast coast area and is now present year-round (Reisinger & Karczmarski 2010; Caputo *et al.* 2020). The large decline is the Plettenberg Bay are is not currently understood and it is not know if it represents a total decline of the population or a more regional shift in habitat use associated with a shift in food resources or increase in human pressures in Plettenberg Bay area (e.g. marine tourism). Regardless, such a large decrease in a population of a significant section of its range (145 km) suggests the population is likely to be stressed at some level making it more vulnerable to external impacts. In contrast, Algoa Bay is recognised as having the largest largest average and maximum group sizes reported both in South Africa and worldwide. Group sizes of this species globally, with average group-size increasing from 18 in 2008 to 75 in 2016 (Bouveroux *et al.* 2018). This suggests a possible eastward shift in at least a portion of the population, the reasons for which are unclear.

Although their distribution is essentially continuous from Cape Agulhas eastwards to southern Mozambique, along the KZN coast the Indo-Pacific bottlenose dolphin seems to have 'preferred areas' (Ross *et al.* 1987; Ross *et al.* 1989; Cockcroft *et al.* 1990, 1991). Areas in which it is more frequently encountered are about 30 km apart, and are thought to correspond to discrete home ranges. Genetic assessments have identified a resident population North of Ifafa (KZN coast, listed as 'Vulnerable'), a resident population south of Ifafa (listed as 'Near Threatened'), as well as a migratory population South of Ifafa ('data deficient'), which appears to undertake seasonal migrations into KZN waters in association with the 'sardine run' (Natoli *et al.* 2008; Cockcroft *et al.* 2016). Little is known about the offshore form of the species, and nothing about their population size or conservation status. They sometimes occur in association with other species, such as pilot whales or false killer whales (Best 2007) and are likely to be present year-round in waters deeper than 200 m.

Common dolphins (*Delphinus spp.*)

Two species of common dolphin are currently recognised, the short-beaked common dolphin (*Delphinus delphis*) and the long-beaked common dolphin (*Delphinus capensis*). The long-beaked common dolphin (*D. capensis*) is resident to the temperate Agulhas Bank (cf. Agulhas Eco-region) with sightings extending as far up the West Coast as St Helena Bay and up the East coast to Richards Bay, in waters less than 500 m deep. Individuals of this species are wide ranging within this area and may move hundreds of kilometers in short periods of time. They are not known to show any degree of residency to coastal areas. Group sizes in this species tend to be large: 100s to even 1 000s of animals. No population estimate is available for the two species, but they are thought to be large (15 000 – 20 000; Cockcroft & Peddemors 1990; Peddemors 1999). The short-beaked common dolphin prefers offshore habitats and is likely to be encountered only in the offshore portions of the Reconnaissance Permit Area. Estimates of the population size and seasonality for the subregion are lacking.

A few studies have suggested that common dolphins inhabit the Eastern Cape coastline during summer, with movements towards the southern KwaZulu-Natal coastline during winter (Ross 1984; Cockcroft & Peddemors 1990; O'Donoghue *et al*. 2010a, 2010b, 2010c), associated with the annual sardine migration up the east coast in winter (Best 2007). Aerial surveys carried out between Gqeberha and East London in the late 1980s detected common dolphins in low densities throughout the year (Cockcroft & Peddemors 1990) and surveys along the Eastern Cape (East London to Port Edward) by the KZN Sharks Board from 1996-2014 (May to August only) showed common dolphins to be the most populous cetacean along this coast with 10s of sightings of large groups per month. Long-beaked common dolphins can thus be assumed to be present in high numbers year round, and are likely to be encountered in the exploration area.

<u>Other species</u>

Killer whales, false killer whales and common bottlenose dolphins are regularly reported by fishermen operating in deeper waters off the Southeast coast of South Africa. These species are therefore likely to occur in the Reconnaissance Permit Area. Rarely encountered dwarf and pygmy sperm whales, pygmy killer whales, Risso's and Frazer's dolphins, striped, spinner and Pan-tropical spotted dolphins, and several beaked whale species have distributions that overlap with the project area (Findlay *et al*. 1992; Best 2007); their occurrence is thought to be rare, but insufficient data is available on the abundance and spatio-temporal distribution of these species to make an accurate assessment of their susceptibility to the proposed seismic exploration.

The genus *Kogia* currently contains two recognised species, the pygmy (*K. breviceps*) and dwarf (*K. sima*) sperm whales. 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 most frequently occur in pelagic and shelf edge waters, are thus likely to occur in the Reconnaissance Permit Area at low levels; seasonality is unknown. Dwarf sperm whales are associated with warmer tropical and warm-temperate waters. However, abundance in the Reconnaissance Permit Area is likely to be very low.

Killer whales (see Figure 42, right) have a cosmopolitan distribution, being found in all oceans from the equator to the ice edge (Best 2007). Killer whales occur year-round in low densities off the South Africa coast (Best *et al*. 2010), although on the East Coast whaling grounds their abundance was reported to be correlated with that of baleen whales, especially sei whales on their southward migration. Killer whales are found in all water depths from the coast to deep open ocean environments and may thus be encountered in the Reconnaissance Permit 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). The species has a tropical to temperate distribution and most sightings off Southern Africa have occurred in waters deeper than 1 000 m but with a few close to shore as well (Findlay *et al*. 1992). False killer whales usually occur in groups ranging in size from 1-100 animals (mean 20.2) (Best 2007), and are thus likely to be fairly easily seen in most weather conditions. However, the strong bonds and matrilineal social structure of this species makes it vulnerable to mass stranding (8 instances of 4 or more animals stranding together have occurred in the western Cape, between St Helena Bay and Cape Agulhas), which may exaggerate the consequences of any injury or harassment by seismic airguns or associated activities. There is no information on population numbers or conservation status and no evidence of seasonality in the region (Best 2007).

Short-finned pilot whales display a preference for warmer tropical waters than their counterparts, the long-finned pilot whales. Although distinguishing between the two pilot whale species at sea is difficult, those occurring in the survey areas are most likely to be the short-finned pilot whales (Best 2007). The species is usually associated with the continental shelf or deep water adjacent to it, and is likely to be among the most commonly encountered odontocete in the vicinity of the seismic survey areas.

Beaked whales were never targeted commercially and their pelagic distribution makes them largely inaccessible to most researchers, making them the most poorly studied group of cetaceans. beaked whales are all considered to be true deep water species, usually being seen in waters in excess of 1 000 – 2 000 m in depth (see various species accounts in Best 2007). With recorded dives of well over an hour to depths in excess of 2 km, beaked whales are amongst the most extreme divers of air breathing animals (Tyack *et al.* 2011). All the beaked whales that may be encountered in the survey areas are pelagic species that tend to occur in small groups of usually less than five individuals, although larger aggregations of some species are known (MacLeod & D'Amico 2006; Best 2007). The long, deep dives of beaked whales make them difficult to detect visually, but PAM will increase the probability of detection as animals are frequently echo-locating when on foraging dives. Beaked whales seem to be particularly susceptible to man-made sounds and several strandings and deaths at sea, often *en masse,* have been recorded in association with naval sonar (Cox *et al.* 2006; MacLeod & D'Amico 2006) and a seismic survey for hydrocarbons also running a multi-beam echo-sounder and sub bottom profiler (Southall *et al.* 2008; Cox *et al.* 2006; DeRuiter *et al.* 2013). The exact reason why is not yet fully understood, but existing evidence shows that animals change their dive behaviour in response to acoustic disturbance (Tyack *et al.* 2011). Necropsy of stranded animals has revealed gas embolisms and haemorrhage in the brain, ears and acoustic fat - injuries consistent with decompression sickness (acoustically mediated bubble formation) may also play a role (Fernadez *et al.* 2005; Jepson *et al.* 2013). Sightings of beaked whales in the project area are expected to be very low.

In summary, the majority of data available on the seasonality and distribution of large whales in the speculative survey areas is largely 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 are limited to the continental shelf. Whaling data indicate that several other large whale species are also abundant on the East Coast for much of the year: fin whales peak in May-July and October-November and sei whale numbers peak in May-June and again in August-October. Data on the abundance, distribution or seasonality of the smaller odontocetes (including the beaked whales and dolphins) known to occur in oceanic waters off the shelf of eastern South Africa is lacking. Beaked whales are all considered to be true pelagic species, usually being seen in small groups in waters in excess of 1 000 – 2 000 m depth. Their presence in the area may fluctuate seasonally, but insufficient data exist to define this clearly.

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 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 45) is the only seal species that has breeding colonies along the Southeast coast, namely on the northern shore of the Robberg Peninsula in Plettenberg Bay and at Black Rocks (Bird Island group) in Algoa Bay (Figure 47). The timing of the annual breeding cycle is very regular occurring between November and January, after which the breeding colonies break up and disperse. Breeding success is highly dependent on the local abundance of food, territorial bulls and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen 1991).

Figure 45: Colony of Cape fur seals (Photo: Dirk Heinrich).

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 movement of seals from the three South Coast colonies are poorly known, however, limited tracking of the Algoa Bay colony has suggested these seals generally feed in the inshore region south of Cape Recife (Figure 46). Benthic feeding to depths of nearly 200 m for periods of up to 2 minutes has, however, also been recorded (Kirkman *et al*. 2015). The diet varies with season and availability and includes pelagic species such as horse mackerel, pilchard, and hake, as well as squid and cuttlefish.

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

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

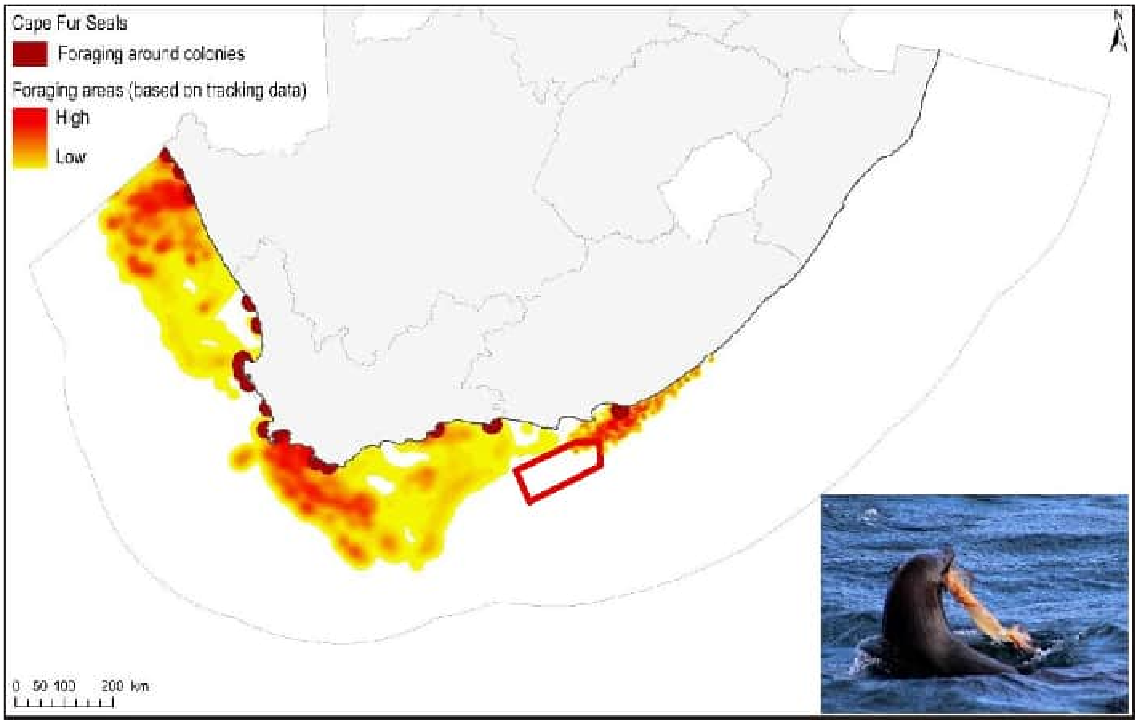


Figure 46: The Reconnaissance Permit Area (red polygon) in relation to seal foraging areas, where brown areas are generalised foraging areas around colonies, and areas in shades of red are foraging areas based on tracking data. Darker shades of red indicate areas of higher use (adapted from Harris *et al.* 2022).

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

Seals are likely to be encountered only in the inshore portions of the Reconnaissance Permit Area (Figure **46**).

3.2.8 Marine Protected Areas and Conservation Areas

Coastal and Offshore MPAs

'No-take' Marine Protected Areas (MPAs) offering protection of the offshore biozones (sub-photic, deep-photic and shallow-photic) were until recently absent around the South African coast. This resulted in substantial portions of the shelf-edge marine biodiversity in the area being assigned a threat status of 'Critically endangered', 'Endangered' or 'Vulnerable' (Lombard *et al*. 2004; Sink *et al*. 2012). Using biodiversity data mapped for the 2004 and 2011 National Biodiversity Assessments a systematic biodiversity plan was developed for the Southwest Coast (Majiedt *et al*. 2013) with the objective of identifying both coastal and offshore priority areas for MPA expansion. Potential 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. The biodiversity data were used to identify numerous focus areas for protection on the South Coast. 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 EEZ to 5%. The approved coastal and offshore MPAs within the broad project area are shown in Figure 47 and described briefly below.

There are two MPAs on the Western Cape coast east of Knysna namely, Robberg and Tsitsikamma. **Robberg MPA** is adjacent to Robberg Nature Reserve, which forms a peninsula with a single access point. The length of the Robberg MPA shoreline is 9 km and includes rocky platforms, sandy beaches, subtidal rocky reefs and subtidal sandy benthos. A Cape Fur Seal colony is also present.

The Tsitsikamma Section of the Garden Route National Park, proclaimed in 1964, includes the **Tsitsikamma MPA**, the oldest and largest 'no-take' MPA in Africa. The MPA extends from Groot River West (33°59´S, 23°34´E) to the Groot River East (34°04´S, 24°12´E) and covers 57 km of coastline with a total surface area of 32,300 hectares. The seaward extent of the MPA is 3 nautical miles. The majority of the MPAs coastline is rugged with high rocky ridges, but boulder bays, subtidal rocky reefs and subtidal sandy benthos also occur. Considered a biodiversity 'hotspot', the MPA provides extensive reef habitats for benthic invertebrates and algae, as well as many endemic slow-growing, and long-lived linefish fish species, many of which are over-exploited. The MPA is thus crucial for the conservation of species such as dageraad, red stumpnose, red steenbras, seventy-four, musselcracker, poenskop, white steenbras and dusky kob.

Eastern Cape MPAs include the Sardinia Bay MPA at Cape Recife, the Addo Elephant MPA in Algoa Bay (which includes the former Bird Island MPA), the Amathole MPA in the vicinity of East London, and the Dwesa-Cwebe, Hluleka and Pondoland MPAs located on the Wild Coast.

The **Sardinia Bay MPA** has a shoreline 7 km in length and extends one nautical mile seawards of the high-water mark, between Schoenmakerskop and Bushy Park. It contains representative habitat including rocky platforms, sandy beaches, subtidal rocky reefs, and subtidal sandy benthos.

The **Port Elizabeth Corals MPA,** which was proclaimed in 2019, lies offshore between Gqeberha and Cape St. Francis and falls within the proposed Algoa 3D survey area. This 270 km^2 MPA features a long narrow rocky ridge and series of underwater hills creating a unique seascape on the continental slope ranging from 200 m to 5,000 m. The area is recognized as an 'Ecologically and Biologically Significant Area' because of its importance in the life history of a wide variety of marine species, including Kingklip. A seasonal fisheries management area that borders on the MPA was established to protect kingklip during their spawning season, when they aggregate in large numbers. To gather in the same place, the fish use specialised drumming muscles to communicate across the ocean. The MPA protects important seabed features that provide important habitat for corals. The three-dimensional structure of these deep coral reefs is an important nursery area for kingklip, as it provides protection to young fish. Although the Reconnaissance Permit Area overlaps with this MPA, the MPA and a 3 km buffer surrounding it have been excluded from the Reconnaissance Permit Area.

The **Addo Elephant MPA**, which incorporates the Algoa Bay Islands was gazetted in May 2019. This 1 200 km^2 MPA expands on the original Bird Island MPA (comprising Bird, Seal, Stag and Black Rock Islands) to protect sandy beaches, rocky shores, reefs, an estuary and islands and aid recovery of valuable fisheries resources such as abalone and kob, as well as great white sharks and whales (brydes, minke, humpback and right). The MPA protects important feeding areas for the 9 000 pairs of Endangered African penguins breeding at St Croix Island and the 60 000 pairs of Endangered Cape gannets breeding at Bird Island. These islands are the only important seabird islands along a 1 800 km stretch of coastline between Dyer Island near Hermanus in the Western Cape and Inhaca Island in Mozambique. Together with St Croix, Jahleel and Brenton Islands (also in Algoa Bay) they are classed as Important Bird Areas (IBAs) because they regularly support significant numbers of globally threatened bird species and hold large concentrations of seabirds. Six of the 14 South African resident seabird species breed either on the islands or at the adjacent coast. The islands play an important national and international role in the conservation of Cape Gannet, African Penguin and Roseate Tern. The islands form ecological distinct subtidal habitats, containing many endemic invertebrates, algae and linefish (e.g. santer and red roman). Black Rocks is an important seal breeding colony and serves as a great white shark feeding area. The MPA is also of particular importance to the threatened abalone as abalone poaching activities are strictly controlled. The northeastern corner of the Reconnaissance Permit Area lies ~70 km south of this MPA at its closest point.

The 400 km^2 **Amathole MPA** was proclaimed in 2019 and extends two of three existing coastal areas protected by the Amathole MPA either side of East London, namely from Christmas Rock to the Gxulu River mouth, from Nahoon Point to Gonubie Point, and from the Nyara River mouth to the Kei River mouth. The offshore portions of the MPA protects the Gxulu canyon, deep reefs and some of the fragile cold-water lace corals, which offer refuge to the South Coast rock lobster. The northern part of the MPA protects the sediment fan of the Kei River mouth that is home to sponge and soft coral gardens. The MPA also protects overexploited and sensitive fish species such as seventy four, dageraad, red steenbras, white steenbras, dusky kob and wreckfish, as well as the spawning, nursery, foraging, aggregation and refuge areas for many of these overexploited species. Because the continental shelf is narrow in this region, the MPA covers a wide variety of shelf and slope ecosytems extending to a depth of 2,200 m thereby protecting an area of life history importance for migratory species including seabirds, turtles, sharks, seabreams, and wreckfish.

The **Dwesa-Cwebe MPA**, which protects 14 km of coastline and covers and area of 193 km^2 was established in 1991. Besides conserving the unique biodiversity of the coastal forests, it provides a critical habitat for the survival of a number of collapsed line fish stocks and abalone, as well as protecting the nursery function of the Mbashe estuary and the recruitment of estuarine dependent fish.

The **Hluleka MPA** was proclaimed in 1991 and stretches along only 3.7 km of coastline but extends 10.8 k m out to sea. This 40.9 km^2 MPA protects a wide diversity of Wild Coast marine habitats

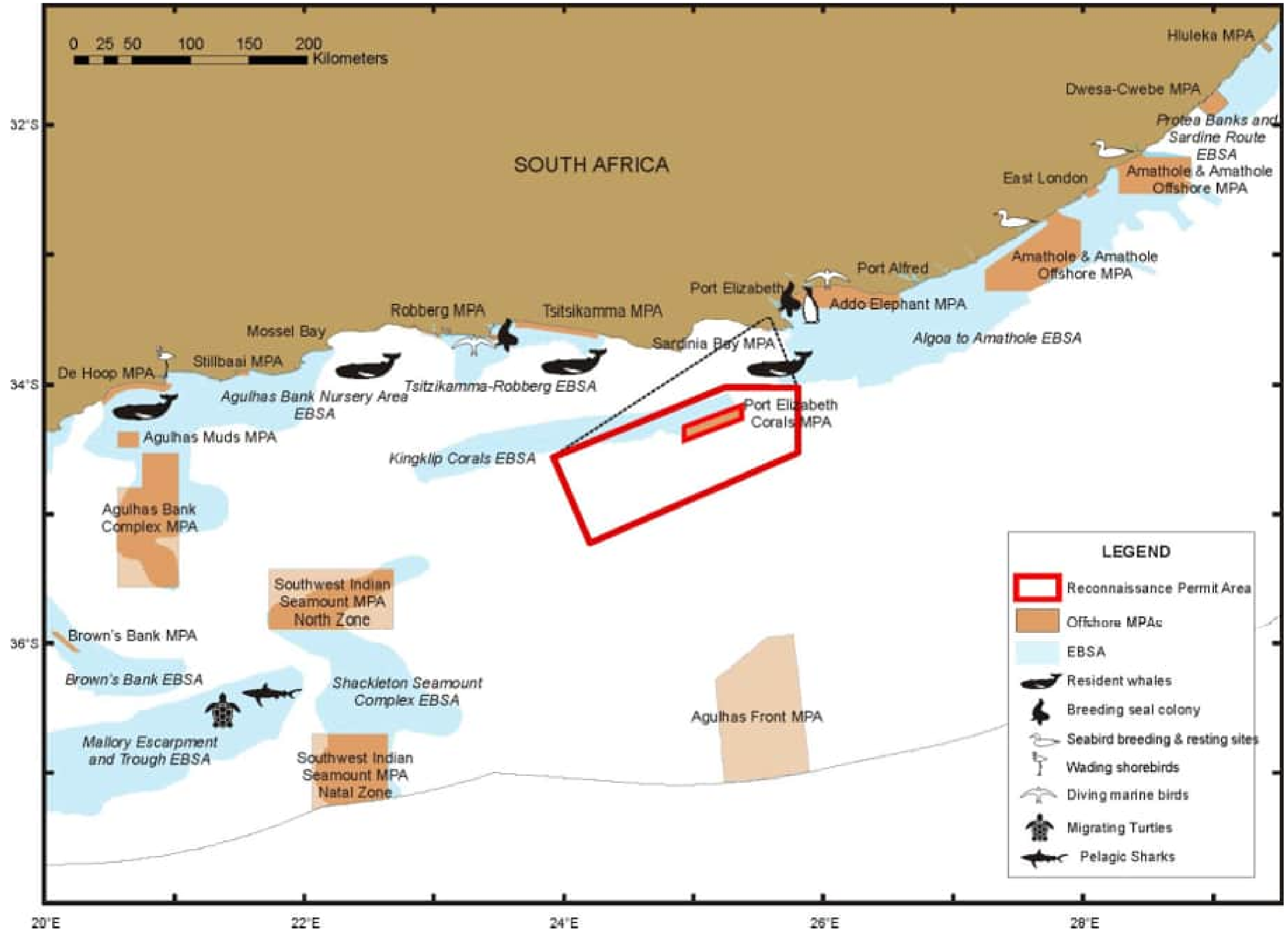


Figure 47: The Reconnaissance Permit Area (red polygon) in relation to Marine Protected Areas (MPAs) and Ecologically and Biologically Significant Areas (EBSAs) on the Southeast coast, illustrating the location of seabird and seal colonies, and seasonal whale populations.

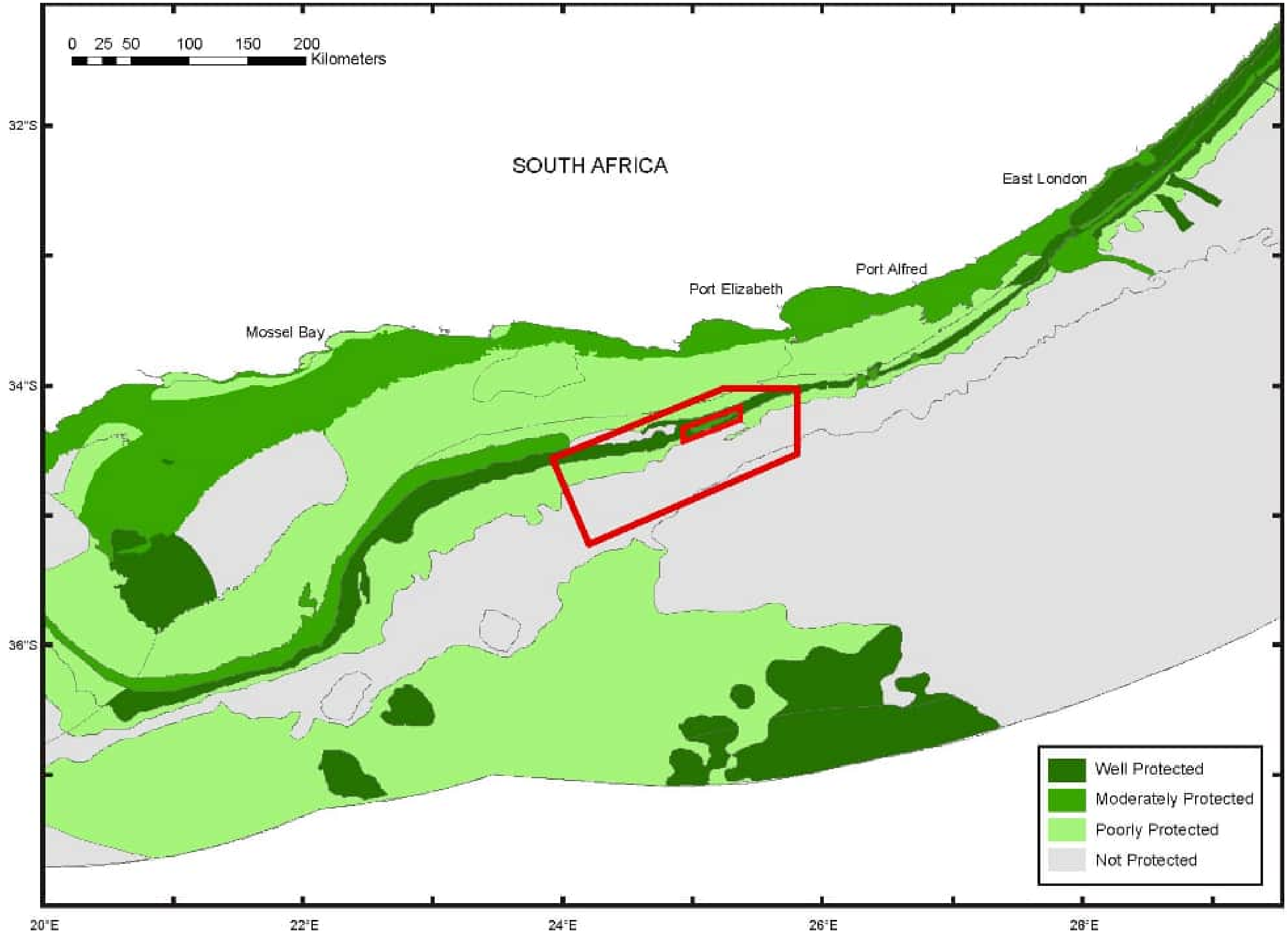


Figure 48: Protection levels of 150 marine ecosystem types as assessed by Sink *et al.* (2019) in relation to the Reconnaissance Permit Area (red polygon).

including rocky shores and sandy beaches, an estuary and adjacent indigenous forests. The intertidal rock pools and shallow subtidal reefs harbour fish such as blacktail, zebra, white musselcracker and bronze bream, and invertebrates such as the East Coast rock lobster.

Sensitive Areas

Despite the development of the offshore MPA network a number of 'Vulnerable' ecosystem types (i.e. Kingklip Koppies, Agulhas Coarse Sediment Shelf Edge, Agulhas Sandy Outer Shelf) are currently 'poorly protected' or 'not protected' and further effort is needed to improve protection of these threatened ecosystem types (Sink *et al.* 2019) (Figure 48). Ideally, all highly threatened ('Critically Endangered' and 'Endangered') ecosystem types should be well protected. Currently, however, most of the Agulhas Coarse Sediment Shelf Edge and Southwest Indian Mid Slope are poorly protected receiving only 0.2-10% protection, whereas the Kingklip Koppies, Southwest Indian Lower Slope and Southwest Indian unclassified Abyss receive no protection at all (Sink *et al.* 2019).

Ecologically or Biologically Significant Areas

As part of a regional Marine Spatial Management and Governance Programme (MARISMA) 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 (see Figure 47) and along the South African West, South and East Coasts, with the intention of implementing improved conservation and protection measures within these sites. South Africa currently has 12 EBSAs solely within its national jurisdiction with a further three having recently been proposed. It also shares eight trans-boundary EBSAs with Namibia (3) Mozambique (2) and the high seas (3). The principal objective of these EBSAs is identification of features of higher ecological value that may require enhanced conservation and management measures. They currently carry no legal status. The impact management and conservation zones within the EBSAs are currently being reviewed and additional zones may be proposed.

The following summaries of the EBSAs in the project area are adapted from http://cmr.mandela.ac.za/EBSA-Portal/South Africa/. Both the Reconnaissance Permit Area and area of interest for 3D acquisition overlap with two EBSAs (namely the Kingklip Corals and Algoa to Amathole EBSAs). The text and figures below are based on the EBSA status as of October 2020.

The **Agulhas Bank Nursery Area EBSA** includes benthic and pelagic features that extend from the dune base to 175 km south of Cape Infanta. Key benthic features include Critically Endangered mud habitats, high-profile volcanic deep reefs, low-profile deep reefs and rare gravels. The Agulhas Bank is important for spawning, larval retention, recruitment, connectivity and provision of nursery and foraging areas for a variety of warm temperate species, including several endemic sparids some of which are threatened or overexploited. Squid also spawn in this area. A spawning area for the threatened, endemic red steenbras is located within this area, and aggregations of this species have recently been observed (Sink *et al.* 2010).

The proposed **Tsitsikamma-Robberg EBSA** is a coastal EBSA that includes the Tsitsikamma MPA, Robberg MPA, Goukamma MPA, and part of the Garden Route Biosphere Reserve. It extends from the shore to the -100 m isobath at the middle shelf, with some extension onto the shallow outer shelf, and includes the extent of five estuaries, including Knysna. The protection afforded to the inshore reefs from these MPAs has contributed to a high diversity and abundance of species, including fragile, vulnerable, sensitive and slow-growing species, that in turn support many top predators. Numerous threatened species occur within this EBSA, including the endangered endemic

Knysna seahorse and several Critically Endangered fish species, with the area also supporting important life-history stages of these threatened and other species. Several Critically Endangered and Endangered ecosystem types are also represented in the EBSA.

The **Kingklip Corals EBSA** was established to offer protection to Secret Reef, Kingklip Koppies and Kingklip Ridge, which lie on and extend east of Grue Bank, on the shelf edge and upper bathyal area, about 100 km offshore of Knysna (Sink 2016, cited in Sink *et al.* 2019). The feature spans a broad depth range of -150 m to -800 m. This newly discovered biogenic coral reef structure is most important for its benthic features as it includes threatened benthic habitats, particularly fragile and sensitive corals (scleractinian corals, stylasterine corals) and byrozoans, as well as vulnerable mollusc and crab species (Sink 2016, cited in Sink *et al.* 2019). Reef-forming scleratinean corals characterise the crest and edges of the northern end of the ridge, and dense clouds of plankton and hake occur above the ridge. The Kingklip Koppies, west of the ridge, are rocky hills that also support fragile benthic species. Secret Reef further west, is a newly discovered biogenic coral reef structure on the shelf edge and upper bathyal area, which includes threatened benthic habitats and fragile, sensitive, vulnerable species, such as scleractinian corals, stylasterine corals, bryozoans, molluscs, and crabs (Sink 2016). The EBSA is thus most important for benthic features, although the overlying water column is also relevant.

The **Algoa to Amathole EBSA** encompasses the likely largest single collection of significant and special marine features in the country that also jointly support key ecological processes, including important land-sea connections. It spans the Eastern Cape shoreline between Sardinia Bay MPA and Amathole MPA/Kei River mouth, extending from the dune base to approximately the continental shelf break/slope at -2000 m. Complex ocean circulation occurs where the Agulhas Current leaves the coast, following the shelf break resulting in the formation of cold-water eddies, intrusions of Agulhas water onto the shelf and large offshore meanders of the Agulhas Current. Consequently, this EBSA includes spawning areas, nursery areas and key transport pathways for demersal and pelagic fish, which in turn support a myriad of top predators, including shark and seabird breeding and foraging areas. The Algoa Bay islands support the easternmost colony of Endangered African penguins and the largest colony of Cape Gannets in southern Africa. Regionally 'Critically Endangered' leatherback and regionally 'Near Threatened' loggerhead turtles migrate through the EBSA between their nesting and foraging grounds, with hatchlings of both species also passing through during their dispersal from the nesting beaches. Green turtles have also been sighted in the area. The EBSA includes 36 ecosystem types, 18 of which are threatened and a further seven that are Near Threatened. Sensitive features and species include submarine canyons, steep shelf edge, deep reefs, outer shelf and shelf edge gravels, and reef-building cold-water corals ranging in depth between 100 and 1,000 m. It also contains several key biodiversity features, including: stromatolites; sites where coelocanths are present; a 'Critically Endangered' localised endemic estuarine pipefish, several priority estuaries, rare ecosystem types of limited spatial extent and a few existing coastal marine protected areas.

Protea Banks and Sardine Route is a coastal EBSA that includes a key component of the migration path for several fish (the sardine run) and an offshore area of high habitat complexity. Benthic features include the unique deep-reef system Protea Banks, steep shelf edge and slope, and several submarine canyons. The sardine run is a temporary feature associated with foraging top predators, including seabirds, mammals, sharks and gamefish. Protea Banks is also an aggregating area, with spawning of sciaenids and sparids some of which are considered threatened. This area has moderate productivity, and the sardine run represents an important ecological process that facilitates the transfer of nutrients from the more productive Agulhas Bank into the more oligotrophic environment further north. This EBSA includes five existing coastal MPAs, two of which were expanded to improve protection of key marine biodiversity assets.

Shackleton Seamount Complex EBSA includes the outer margin along the southern tip of the Agulhas Bank. It lies within the Agulhas-Falkland Fracture zone and is a dynamic offshore area with high productivity and high pelagic and benthic habitat heterogeneity. The Agulhas and Southern Benguela ecoregions meet at this point, and sporadic shelf-edge upwelling enhances productivity along the outer margin. The area is recognized as a spawning area for sardine, anchovy, horse mackerel and hake, and this apex area of the Agulhas Bank serves as a critical area for retention of spawning products. Here, eddies help recirculate water inshore and link important nursery areas with spawning habitat on the shelf edge. This EBSA also contains the Mallory, Shackleton and Natal Seamounts. Leatherback turtles also frequent these seamounts along their migrations. This area was identified as a priority focus areas for offshore protection due to its relatively high habitat diversity and because it can meet multiple benthic and pelagic habitat conservation targets in a small area.

Mallory Escarpment and Trough EBSA includes the outer margin along the southern tip of the Agulhas Bank in South Africa. The area similarly includes important benthic and pelagic features, including the shelf edge, a very steep slope (up to 20° in some places and thought to be globally rare) and a trough as part of the Agulhas-Falkland Fracture zone, shelf-edge driven upwelling, and fragile and sensitive habitat-forming species. Habitat diversity is thus particularly high for a location this far offshore. This dynamic area consequently supports numerous ecological processes, such as spawning and foraging, and comprises a rich diversity of both resident (e.g. benthic gorgonians) and transient (e.g. migrating leatherbacks) species.

The **Browns Bank** EBSA includes unconsolidated sandy habitats, hard ground and deep reef habitats that form part of the western Agulhas Bank spawning ground and is part of a critical area for retention of spawning products. The area ranges from approximately -150 m to -800 m depth and is the meeting point of the Agulhas and Southern Benguela ecoregions. The biodiversity includes benthic macrofaunal communities characterized by high abundances of brittle stars and many species of polychaetes, cold-water corals, brisingid starfish, and 77 morphospecies of macroinvertebrates. The pelagic habitat is characterised by elevated productivity and frequent fronts due to shelf edge upwelling. The area has been proposed as a marine Important Bird Area (IBA) for Cory's Shearwater and Atlantic Yellow-nosed Albatross (BirdLife International 2013), indicating that it holds a significant proportion of the global population of these species during some periods of each year (see below). Wandering, Shy, and Black-browed albatrosses have also been sighted in the area, and Pintado petrels are noted as commonly occurring (Sink 2016).

Biodiversity Priority Areas

The National Coastal and Marine Spatial Biodiversity Plan[3] comprises a map of Critical Biodiversity Areas (CBAs), Ecological Support Area (ESAs) and accompanying sea-use guidelines. The CBA Map presents a spatial plan for the marine environment, designed to inform planning and decision-making in support of sustainable development. The sea-use guidelines enhance the use of the CBA Map in a range of planning and decision-making processes by indicating the compatibility of various activities with the different biodiversity priority areas so that the broad management objective of each can be maintained. The intention is that the CBA Map (CBAs and ESAs) and sea-use guidelines inform the MSP Conservation Zones and management regulations, respectively.

The Reconnaissance Permit Area overlaps with areas mapped as Critical Biodiversity Area 1 (CBA 1): Natural and CBA 1: Restore and Critical Biodiversity Area 2: (CBA 2) Natural and CBA 2: Restore, and Ecological Support Area (ESA) (Figure 49). CBA 1 indicates irreplaceable or near-irreplaceable sites that are required to meet biodiversity targets with limited, if any, option to meet targets elsewhere, whereas CBA 2 are "best design sites" and there often alternative areas where feature targets can be met; however, these will be of higher cost to other sectors and / or will be larger areas. ESAs represent EBSAs outside of MPAs and not already selected as CBAs.

Approximately 13.4 % of the proposed 3D acquisition area is covered by CBA 1 and CBA 2, with 6.5% covered by ESA (including the buffer around the MPA) (see Figure 49).

Regardless of how CBAs are split, CBAs are generally areas of low use and with low levels of human impact on the marine environment, but can also include some moderately to heavily used areas with higher levels of human impact. Given that some CBAs are not in natural or near-natural ecological condition, but still have very high biodiversity importance and are needed to meet biodiversity feature targets, CBA 1 and CBA 2 were split into two types based on their ecological condition. CBA Natural sites have natural / near-natural ecological condition, with the management objective of maintaining the sites in that natural / near natural state; and CBA Restore sites have moderately modified or poorer ecological condition, with the management objective to improve ecological condition and, in the long-term, restore these sites to a natural/near-natural state, or as close to that state as possible. ESAs include all portions of EBSAs that are not already within MPAs or CBAs, and a 5-km buffer area around all MPAs (where these areas are not already CBAs or ESAs), with the exception of the eastern edge of Robben Island MPA in Table Bay where a 1.5-km buffer area was applied (Harris *et al.* 2022). These zones have been incorporated into the most recent iteration of the national Coastal and Marine CBA Map (v1.2 released April 2022) (Harris *et al.* 2022) (Figure 49).

Activities within these management zones are classified into those that are "compatible", those that are "not compatible", and those that have "restricted compatibility". Non-invasive (e.g. seismic surveys) and invasive (e.g. exploration wells) exploration activities are classified as having "restricted compatibility". Activities with restricted compatibility require a detailed assessment to determine whether the recommendation is that they should be permitted (general), permitted subject to additional regulations (consent), or prohibited, depending on a variety of factors. Petroleum production is, however, classified as "not compatible" in CBAs, but may be compatible, subject to certain conditions, in ESAs (Harris *et.al.* 2022). Hydrocarbon production is classified as incompatible in CBAs but may be compatible, subject to certain conditions, in ESAs (Harris *et al.* 2022).

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

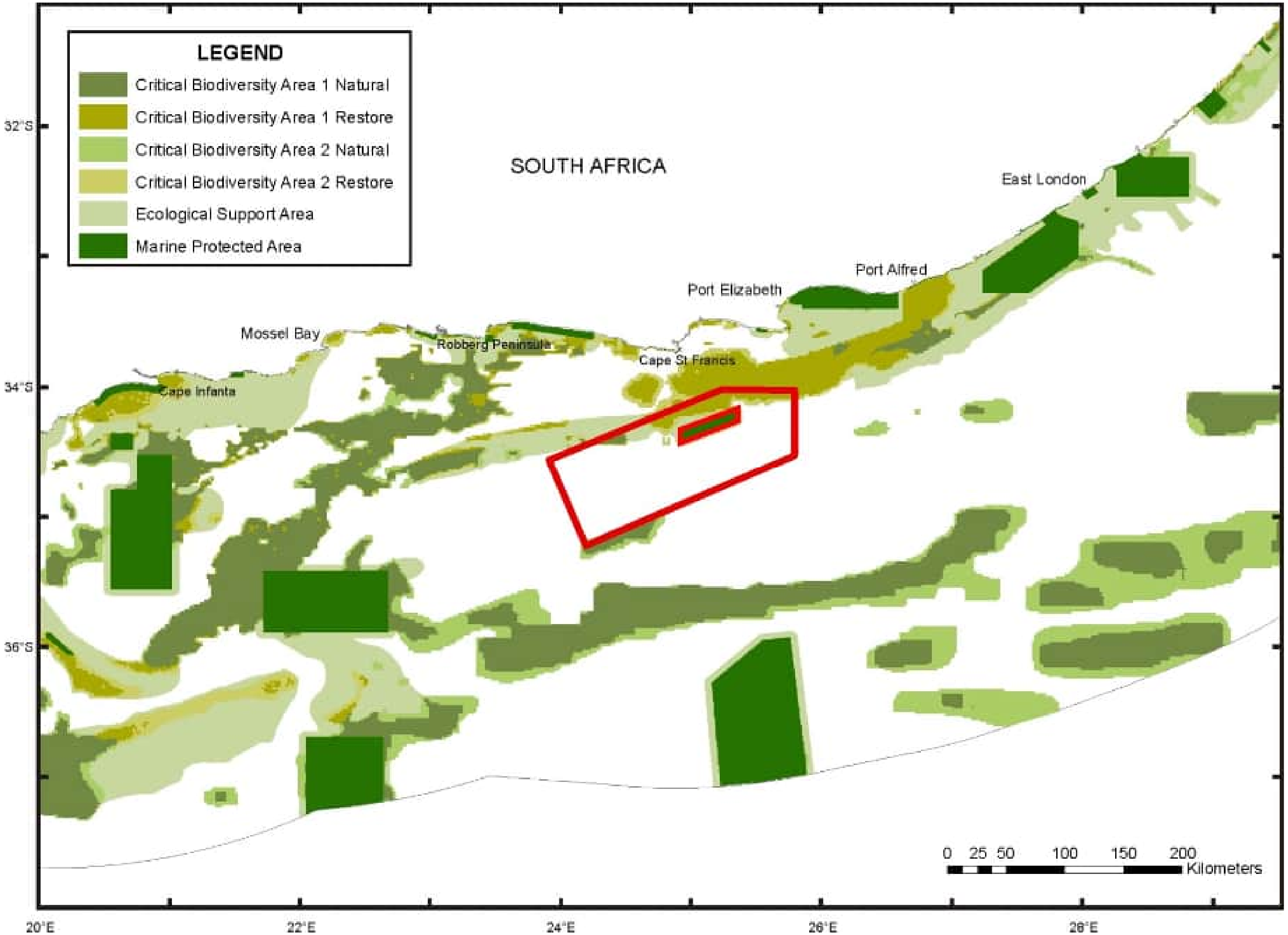


Figure 49: The Reconnaissance Permit Area (red polygon) in relation to Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) (version 1.2) (adapted from Harris *et al*. 2022).

Algoa Bay Systematic Conservation Plan

A fine-scale systematic conservation plan has been compiled for Algoa Bay, as part of the Algoa Bay Project (Dorrington *et al*. 2018). The spatial prioritisation included 137 biodiversity features and fine-scale cost information (Holness *et al*. in review), and sought to encourage selection of marine biodiversity priorities in areas that would also bring social benefits. It identified highest priority areas in natural or near-natural ecological condition that were inside and outside MPAs. There is no overlap of the Reconnaissance Permit Area with this conservation plan (Figure 50).

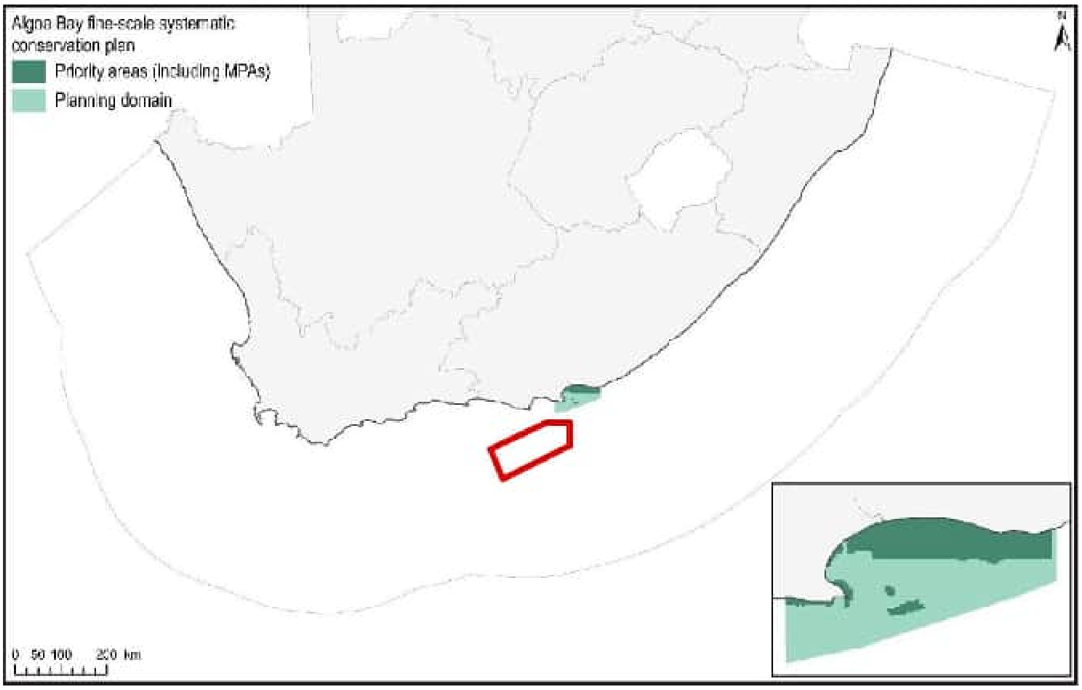


Figure 50: The Reconnaissance Permit Area (red polygon) in relation to fine-scale marine biodiversity priority areas identified for Algoa Bay (adapted from Harris *et al*. 2022).

Hope Spots

Hope Spots are defined by Mission Blue of the Sylvia Earle Alliance as special conservation areas that are critical to the health of the ocean. The first six Hope Spots were launched in South Africa in 2014 and include Aliwal Shoal in KZN, Algoa Bay in the Eastern Cape, and Plettenberg Bay, Knysna, the Cape Whale Coast (Hermanus area) and False Bay in the Western Cape. Of these, the Algoa Bay Hope Spot is are located inshore of the southern portion of the Reconnaissance Permit Area and the proposed Algoa 3D area.

Important Bird Areas (IBAs)

Of the Important Bird Areas (IBAs) designated by BirdLife International in the Southern and Eastern Cape, those located along the coastline of the broader project area are listed in **Error! Not a valid bookmark self-reference.**.

Various marine IBAs have also been proposed in South African territorial waters, with those in the broader project area shown in (Figure 51). Marine IBAs are primarily defined for the regular presence of globally threatened species, and congregations of >1% of biogeographic or global populations. ‘Confirmed’ IBAs are those that have had a full assessment made of qualifying species and populations, as well as a site description and associated boundary, which have been reviewed and approved by both BirdLife Partners and the BirdLife Secretariat. In contrast, 'Proposed' sites are those that have not yet gone through this cycle but are mapped to indicate they are in the process of being identified and reviewed. Although IBA designation does not bring any legal obligation, IBAs may be used to inform the designation of MPAs under national legislation or international agreements. IBA data is submitted to the Convention on Biological Diversity (CBD) workshops to assist in describing EBSAs. The northeastern corner of the Reconnaissance Permit Area overlap with the proposed Alexandria coastal belt/Algoa Bay Islands Nature Reserve Marine IBA, specifically aimed at protecting the African Penguin, Cape Gannet, Kelp Gull, Damara Tern and Roseate Tern (https://maps.birdlife.org/marineIBAs).

Table 10: List of coastal Important Bird Areas (IBAs) and their criteria listings.

Site Name	IBA Criteria
Wilderness-Sedgefield Lakes Complex	A2, A3, A4i, A4iii
Tsitsikamma-Plettenberg Bay	A1, A2, A3
Maitland - Gamtoos Coast	A1, A4i
Swartkops Estuary – Redhouse and Chatty Saltpans	A1, A4i, A4iii
Algoa Bay Islands: Addo Elephant National Park	A1, A4i, A4ii, A4iii
Woody Cape Section: Addo Elephant National Park	A1, A2, A3

A1. Globally threatened species
A2. Restricted-range species
A3. Biome-restricted species
A4. Congregations
- **A4i.** applies to 'waterbird' species
- **A4ii.** This includes those seabird species not covered under i.
- **A4iii.** modeled on criterion 5 of the Ramsar Convention for identifying wetlands of international importance. The use of this criterion is discouraged where quantitative data are good enough to permit the application of A4i and A4ii.

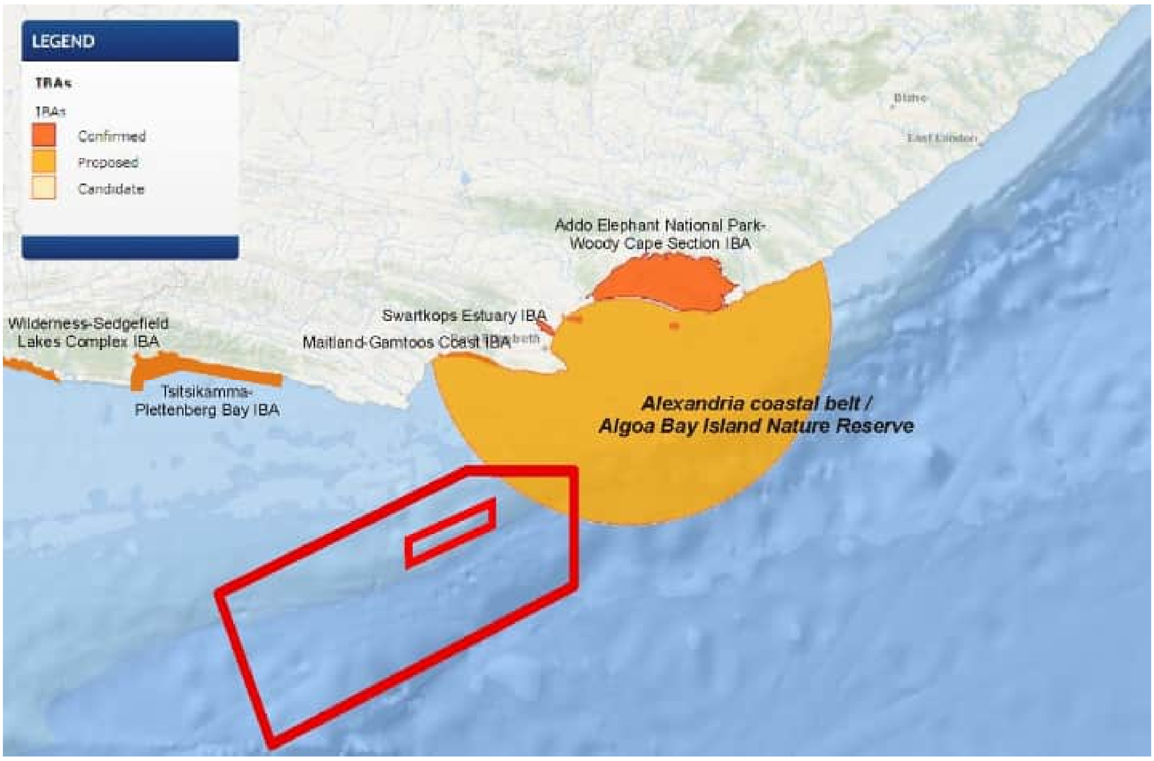


Figure 51: Reconnaissance Permit Area (red polygon) in relation to confirmed and proposed coastal and marine IBAs in the Eastern Cape (Source: https://maps.birdlife.org/marineIBAs).

Important Marine Mammal Areas (IMMAs)

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

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

Criterion A - Species or Population Vulnerability

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

Criterion B – Distribution and Abundance

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

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

Criterion C – Key Life Cycle Activities

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

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

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

Criterion D – Special Attributes

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

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

Although much of the West Coast of South Africa has not yet been assessed with respect to its relevance as an IMMA, the coastline from the Olifants River mouth on the West Coast to the Mozambiquan border overlaps with three declared IMMAs (Figure 52) namely the

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

These are described briefly below based on information provided in IUCN-Marine Mammal Protected Areas Task Force (2021) (www.marinemammalhabitat.org).

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

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

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

The inshore portion of the Reconnaissance Permit Area overlaps with the Southern Coastal and Shelf Waters of South Africa IMMA.

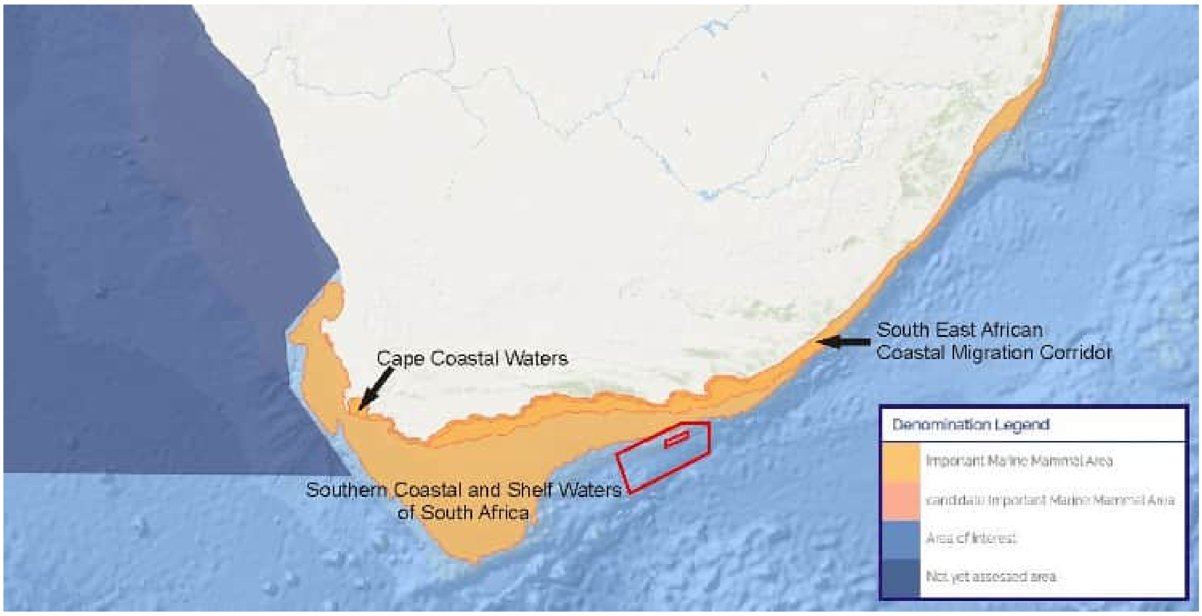


Figure 52: The Reconnaissance Permit Area (red polygon) in relation to coastal and marine IMMAs (Source: www.marinemammalhabitat.org/imma-eatlas/).

4. ASSESSMENT OF IMPACTS

For this project, the identification and assessment of impacts relating specifically to the marine ecology cover the four main activity phases (see Table 11 for an outline of the activities in these phases) of the proposed seismic acquisition project, namely:

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

4.1 Identification of Impacts

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

- Increase in underwater and atmospheric noise levels by the seismic vessel, during seismic acquisition, and by support vessels and helicopters
  - Disturbance / behavioural changes of coastal and marine fauna
  - Avoidance of key feeding/spawning areas (e.g. Port Elizabeth Corals, Kingklip Koppies)
  - Effects on key breeding areas (e.g. squid, 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 southeast Coast ecosystem biodiversity
- Discharge of waste to sea (e.g. deck and machinery space drainage, sewage and galley wastes) from seismic and vessels, and local reduction in water quality
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column
  - Increased food source for marine fauna
  - Fish aggregation and increased predator-prey interactions
- Increase in ambient lighting from seismic vessel and support vessels
  - Disorientation and mortality of marine birds
  - Physiological and behavioural effects on marine fauna
  - Fish aggregation and increased predator-prey interactions
- Localised reduction in water quality due to accidental release of fuel into the sea during bunkering and discharge of hydraulic fluid due to pipe rupture
  - Toxic effects on marine biota and reduced faunal health
- Uncontrolled release of oil/gas from the vessels due to vessel accident/collision
  - Toxic effects on marine biota and reduced faunal health
  - Pollution and smothering of coastal habitats
- Accidental loss of equipment
  - Disturbance and damage to seabed habitats
  - Entanglement of marine fauna

4.2 Application of the Mitigation Hierarchy

A key component of this 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 to negligible significance with very low or zero potential for further mitigation. In such cases the appropriate project Standards will be used and additional best management practices are proposed.

4.3 Acoustic Impacts of Seismic Surveys on Marine Fauna

The ocean is a naturally noisy place and marine animals are continually subjected to both physically produced sounds from sources such as wind, rainfall, breaking waves and natural seismic noise, or biologically produced sounds generated during reproductive displays, territorial defence, feeding, or in echolocation (see references in McCauley 1994; Duarte *et al.* 2021).

Acoustic cues are thought to be important to many marine animals in the perception of their environment as well as for navigation purposes, predator avoidance, and in mediating social and reproductive behaviour. Anthropogenic sound sources in the ocean can thus be expected to interfere directly or indirectly with such activities thereby affecting the physiology and behaviour of marine organisms (NRC 2003; Duarte *et al.* 2021). 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; Duarte *et al.* 2021). 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, with a median level around 100 dB re 1μPa upon calm to strong sea state conditions (Li & Lewis 2020). A comparison of the various noise sources in the ocean is shown in Figure 53.

Table 11: Aspects and impacts register relevant to marine fauna

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

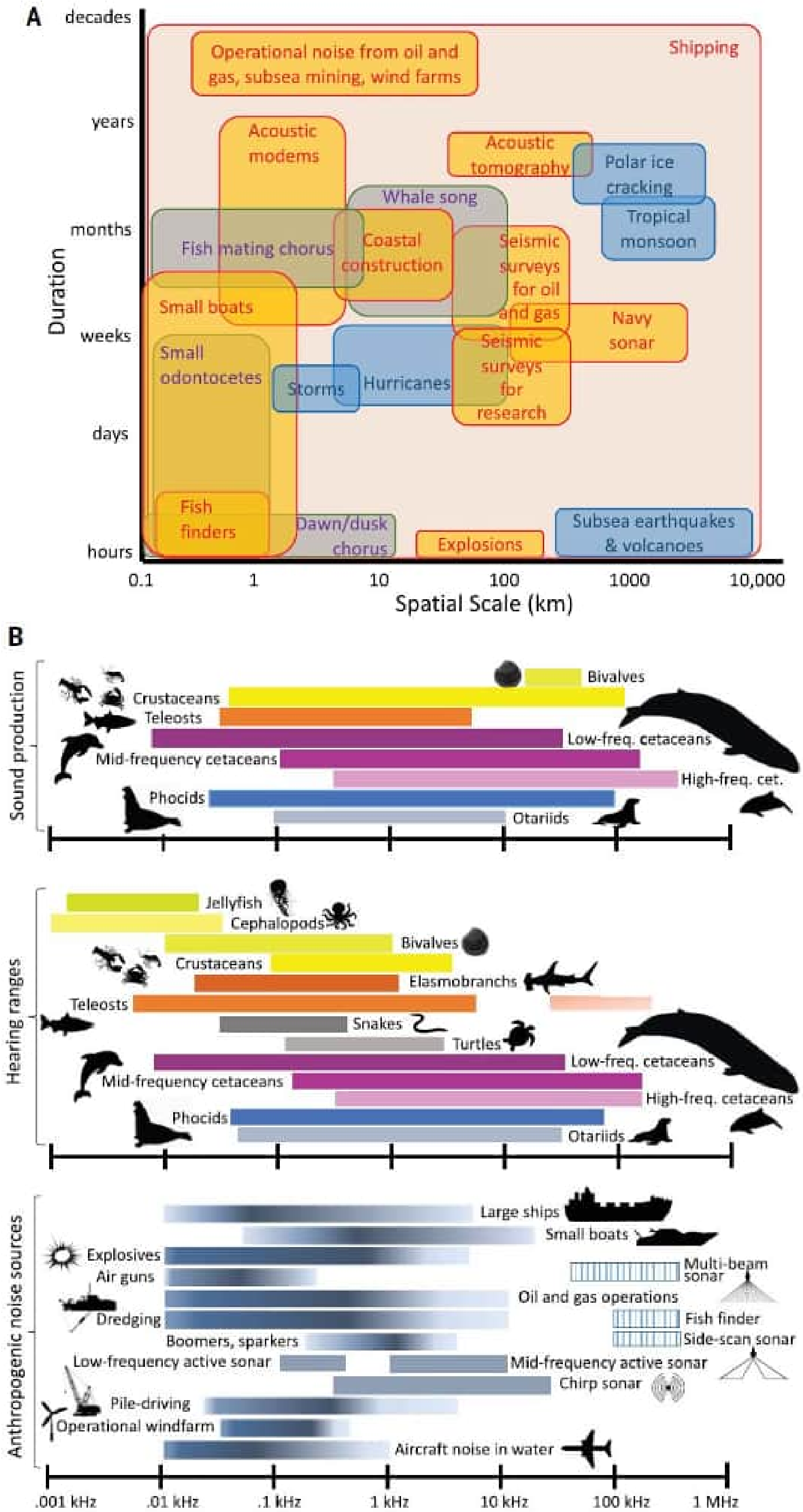


Figure 53: Sources and animal receivers of sound in the ocean. A) Spatial extent and duration of selected sound producing events, and B) Approximate sound production and hearing ranges of marine taxa and frequency ranges of selected anthropogenic sound sources. (Source: Duarte *et al*. 2021).

The airguns used in modern seismic surveys produce some of the most intense non-explosive sound sources used by humans in the marine environment (Gordon *et al.* 2004) and are the second highest contributor of human-caused underwater noise in total energy output per year (Weilgart 2013). Until the demand for petroleum resources is substantially diminished and renewable energy resources can be adopted on a global scale, or alternatives to seismic surveys are found, seismic surveys will remain a major source of noise in the ocean (Przeslawski *et al.* 2018). However, the transmission and attenuation of seismic sound is probably of equal or greater importance in the assessment of environmental impacts than the produced source levels themselves, as transmission losses and attenuation are very site specific, and are affected by propagation conditions, distance or range, water and receiver depth and bathymetrical aspect with respect to the source array. 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[4], respectively (Bowles *et al.* 1991; Richardson *et al.* 1995; see also references in McCauley 1994). On analysing 10 years of recordings from the Mid-Atlantic Ridge, Nieukirk *et al.* (2012), found that airguns could be heard at distances of 4 000 km from the seismic vessels, and were audible for 80-95% of the time for more than 12 consecutive months in some locations.

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

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

Acoustic pressure variation is usually considered the major physical stimulus in 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.

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

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

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

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

4.3.1 Impacts of Seismic Noise on Whales and Dolphins

Source of Impact

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

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

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

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

Project Controls

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

Sensitivity of Receptors

Between 28 and 38 species or sub species/populations of cetaceans (whales and dolphins) are known or likely to occur off the southeast 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 38 species, the blue whale is listed as 'Critically endangered', the fin and sei whales and humpback dolphin are 'Endangered' and the sperm and Bryde's (inshore) whales are considered 'Vulnerable' (South African Red Data list Categories). Due to its location offshore and overlap with the main migration routes, the sensitivity of migratory cetaceans is thus considered to be **HIGH**. However, the numbers of individuals encountered during the survey are likely to be low because of the extensive distributions of the various species concerned.

Impact Assessment

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

The factors that affect the response of marine mammals to sounds in their environment include the sound level and its prevailing acoustic characteristics, the ecological features of the environment in which the animal encounters the sound and the physical and behavioural state of the animal, 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). Furthermore, there is growing recognition that the sub-lethal effects of noise disturbance, which are both difficult to identify and measure, are likely to be relatively widespread and may have a greater impact than direct physical injury (Forney *et al.* 2017). Depending on the duration and spatial scale of noise exposure, sub-lethal effects could be either acute (generally short-term and associated with a specific activity) or chronic (longer-term and associated with many overlapping activities). These authors point out that a lack of observed response does not imply an absence of costs such as physiological stress and reduced reproduction, survival or feeding success. Apparent tolerance of disturbance may in fact have population-level impacts that are more subtle and difficult to record with conventional methodologies.

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

Cetacean vocalisations

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

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

Clicks are high intensity, short sounds associated with orientation and feeding. The frequency composition of echolocation clicks varies with species. 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. For example, Sarnocińska *et al.* (2020) reported a decrease in echolocation signals of harbour porpoise in response to airgun signals 8-12 km away, potentially indicating temporary displacement from the area or changes in foraging behaviour (but see also Pirotta *et al.* 2014; Thompson *et al.* 2013).

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

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

Physiological injury and stress

Exposure to high sound levels can result in physiological injury to cetaceans through a number of avenues, including shifts of hearing thresholds (as either PTS or TTS) (Richardson *et al.* 1995; Au *et al.* 1999; Schlundt *et al.* 2000; Finneran *et al.* 2000, 2001, 2002, 2003), tissue damage (Lien *et al.* 1993; Ketten *et al.* 1993), acoustically induced decompression sickness particularly in beaked whales (Crum & Mao 1996; Cox *et al.* 2006), 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 12). For TTS these values are 226 dB re:1 μPa (peak) and 188 dB re:1 μPa2-s for SPL and SEL, respectively. There is thus a range at which permanent or temporary hearing damage might occur, although some hearing damage may already occur when received levels exceed 1 838 dB re:1 μPa2-s SEL. The behavioural disruptive threshold for impulsive noise for all functional groups is root-mean-square (RMS) SPL of 160 dB re 1μPa (NMFS 2013).

Table 12: 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 $1\mu Pa^2 \cdot S$	Pk SPL, dB re 1μPa	Weighted SEL_{24hr}, dB re $1\mu Pa^2 \cdot S$
Low-frequency cetaceans (mysticetes: southern right, humpback, sei, fin, blue, Bryde's, minke)	219	183	213	168
High-frequency cetaceans (odontocetes: dolphins, toothed, beaked, and bottle nose whales)	230	185	224	170
Very high-frequency cetaceans (Heaviside's dolphins, dwarf and pygmy sperm whales)	202	155	196	140
Sirenians (dugongs, manatees)*	226	203	220	175
Phocid carnivores in water (true seals)*	218	185	212	170
Other marine carnivores in water (sea lions, fur seals)	232	203	226	188

* do not occur in project area

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

Noise induced stress resulting from exposure to sources of marine sound can cause detrimental changes in blood hormones, including cortisol (Romano *et al.* 2004). The timing of the stressor relative to seasonal feeding and breeding cycles (such as those observed in migrating baleen whales) may influence the degree of stress induced by noise exposure (Tyack 2008). However, quantifying stress caused by noise in wild populations is difficult as it is not possible to determine the physiological responses of an animal to a noise stressor based on behavioural observations alone (Wright *et al.* 2007). 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).

Behavioural disturbance

The factors that affect the response of marine mammals to sounds in their environment include the sound level and other properties of the sound, the physical and behavioural state of the animal and its prevailing acoustic characteristics, and the ecological features of the environment in which the animal encounters the sound. The responses of cetaceans to noise sources are often also dependent on the perceived motion of the sound source, as well as the nature of the sound itself. For example, many whales are more likely to tolerate a stationary source than they are one that is approaching them (Watkins 1986; Leung-Ng & Leung 2003), or are more likely to respond to a stimulus with a sudden onset than to one that is continuously present (Malme *et al.* 1985).

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

Typical behavioural response in cetaceans to seismic airgun noise include initial startle responses (Malme *et al.* 1985; Ljungblad *et al.* 1988; McCauley *et al.* 2000), changes in surfacing behaviour (Ljungblad *et al.* 1988; Richardson *et al.* 1985a; McCauley *et al.* 1996, 2000), shorter dives (Ljungblad *et al.* 1988; Robertson *et al.* 2013; Dunlop *et al.* 2015), changes in respiration rate

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

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

Although the consequences of displacement are poorly understood, they likely include increased stress and reduce foraging success, with associated effects on survival and reproduction (Forney *et al.* 2017).

McCauley *et al.* (1996, 2000) found no obvious evidence that humpback whales were displaced by 2D and 3D seismic surveys and no apparent gross changes in the whale's migratory path could be linked to the seismic survey (but see Dunlop *et al.* 2016, 2017). Localised avoidance of the survey vessel during airgun operation was however noted within 4 km of the source at levels over 130 re 1 $\mu Pa^2\ s^{-1}$ (Dunlop *et al.* 2017a, 2018) as was a reduction in social interactions among whales (Dunlop *et al.* 2020). Whales which are not migrating but using the area as a calving or nursery ground may be more seriously affected through disturbance of suckling or resting. Potential avoidance ranges of 7-12 km by nursing animals and >4 km for migrating humpbacks have been suggested, although these might differ in different sound propagation conditions (McCauley *et al.* 2000; Dunlop *et al.* 2017a, 2017b; Ellison *et al.* 2018). Base on the noise exposure criteria of RMS SPL 160 dB re 1µPa provided by Popper *et al.* (2014), the sound transmission loss modelling study undertaken for the current project (Li & Lewis 2021) identified that the maximum horizontal threshold distance from the source to impact threshold levels for marine mammals was 12 km. Disturbance of mating behaviour (which could involve a high degree of acoustic selection) by seismic noise could be of consequence to breeding animals.

Masking of important environmental or biological sounds

Potential interference of seismic emissions with acoustic communication in cetaceans includes direct masking of the communication signal, temporary or permanent reduction in the hearing capability of the animal through exposure to high sound levels or limited communication due to behavioural changes in response to the seismic sound source. Masking can both reduce the range over which the signals can be heard and the quality of the signal's information (Weilgart *et al.* 2007; Cholewiak *et al.* 2018). 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, it has been reported that blue whales call consistently more on days when seismic exploration was taking place, presumably to compensate for the elevated ambient noise levels (Di Iorio & Clarke 2010). More recently, Blackwell *et al.* (2013, 2015) determined that bowhead whales increased calling rates as soon as airgun pulses were detectable, with calling rates leveling off at a received cumulative SEL of ~94 dB re 1 μPa^2, but decreasing once $CSEL_{10\text{-}min}$ exceeded ~127 dB re 1 μPa^2 and ceasing altogether when $CSEL_{10\text{-}min}$ values were above ~160 dB re 1 μPa^2. Similarly, Cerchio *et al.* (2014) reported decreased singing activity in humpbacks off Northern Angola in response to increasing seismic noise, with possible implications on breeding displays by males, which in turn could result in decreased reproductive success.

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

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

Impact Magnitude

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

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

Due to the high level of impulsive signal emissions from the array source, marine mammals are predicted to experience a PTS at close proximity to the source array due to the immediate exposure to individual pulses. The Underwater Noise Modelling Study undertaken for the proposed 3D survey area (Li & Lewis 2021) 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 55 m from the 3D source array at all assessed water depth scenarios, with the the zone of TTS due to a single pulse exposure predicted within approximately 120 m from the 3D source array (

Table 13). 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 from the source array (

Table 13). The maximum threshold distance for TTS onset for very-high frequency cetaceans occurs within 850 m from the source.

Among marine mammals expected to occur in the Reconnaissance Permit Area, low-frequency cetaceans have the highest zones of PTS and TTS impact from multiple pulses (i.e. the maximum horizontal perpendicular distances from assessed survey lines to cumulative impact threshold levels). The zones of PTS impact are predicted to range up to 800 m for the 3D survey, from the adjacent survey lines for the typical 24-hour survey operation scenarios considered, with the maximum zones of TTS impact predicted to be around 12 000 m from the adjacent survey lines (

Table 13) (Li & Lewis 2021). It must be kept in mind that the cumulative zones of impact are conservative, and that being highly mobile, whales and dolphins are thus likely to have moved considerable distances over the cumulative 24-hr period. Cumulative effects would only be expected where the animals do not move away from the area, e.g. from specific coastal areas used as calving sites or from mid-ocean focal sites such as the Southwestern Indian Seamounts.

Although for high-frequency cetaceans it was predicted that the cumulative PTS criteria for the 24-hour survey operation scenario would not to be reached, the zones of TTS impact were predicted to be <10 m from the adjacent survey lines for the cumulative scenario considered (

Table 13). In the case of very high frequency cetaceans, the zones of PTS impact for the cumulative scenario are predicted to range up to 80 m from the adjacent survey lines, for the typical 24-hour survey operation scenario considered, with the zones of TTS impact predicted to be in the order of 4 000 m from the adjacent 3D survey lines (

Table 13).

Table 13: Zones of immediate and cumulative impact from single and multiple pulses for PTS and TTS for the marine mammal groups likely to occur in the Reconnaissance Permit Area.

Marine mammal hearing group	Zones of impact - maximum horizontal distances from source to impact threshold levels (from single 3D pulses)		Zones of impact - maximum horizontal perpendicular distances from assessed 3D survey lines to cumulative impact threshold levels	
	Injury (PTS) onset	TTS onset	Injury (PTS) onset	TTS onset
Low-frequency cetaceans (mysticetes: southern right, humpback, sei, fin, blue, Bryde's, minke)	55 m	120 m	800 m	128 000 m
High-frequency cetaceans (odontocetes: dolphins, toothed whales (e.g. sperm), beaked whales, bottle-nose whales)	20 m	30 m	-	< 10 m
Very High-Frequency cetaceans (Heaviside's dolphins, pygmy	480 m	850 m	80 m	4 000 m

sperm and dwarf sperm whale				
Other marine carnivores in water (sea lions, fur seals)	20 m	25 m	-	< 10 m

Note: a dash indicates the threshold is not applicable.

The majority of baleen whales migrate to the southern African subcontinent to breed during winter months. Humpback whales are reported to reach the coast in the vicinity of Knysna 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 on the South Coast in June, building up to a maximum in September/October and departing again in December. The proposed survey areas thus lie within the migration paths of Humpback and Southern Right whales, but well offshore of areas frequented by Southern Right whales for mating and breeding. As the survey is proposed for the summer months (January to May) encounters with migrating whales should be minimal. 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 inshore population of Bryde's whales implies that it is highly likely to be encountered in the proposed 3D survey area as it is resident on the Aulhas Bank year-round only undertaking occasional small seasonal excursions up the east coast in winter during the annual sardine migration.

Assuming the survey is scheduled so as to avoid the key migration period (early June to late November), there would be a low likelihood of encountering migrating humpback and southern right whales, but a high likelihood of encountering Bryde's whales. The impact of potential physiological injury to mysticete and odontocete cetaceans as a result of seismic sounds is thus deemed to be of HIGH intensity. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL), the potential for physiological injury is therefore considered to be of **MEDIUM** magnitude for resident mysticetes and odontocetes.

Behavioural disturbance

Avoidance of seismic survey activity by cetaceans, particularly mysticete species, begins at distances where levels of approximately 150 to 180 dB are received. More subtle alterations in behaviour may occur at received levels of 120 dB. The Underwater Noise Modelling Study undertaken for the proposed 3D survey area (Li & Lewis 2021) identified that the zones of behavioural disturbance for cetaceans caused by the immediate exposure to individual pulses was within 4.4 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. For example, persistent disturbance of foraging behaviour in response to seismic noise can result in reductions in relative fitness of reproductive female Sperm whales leading to abortions and calf abandonment (Farmer *et al*. 2018), with mid-frequency sonars shown to reduced foraging efficiency in blue whales (Goldbogen *et al*. 2013). Species that feed intensively within a season and depend on dense prey concentrations can therefore experience significant population consequences, which in turn may pose significant risks to the recovery rates of endangered populations. Based on this knowledge, Norway has since 2019, recommended that seismic activity be restricted in areas and periods with intensive feeding of baleen whales (Sivle *et al*. 2021).

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

Of greater concern than general avoidance of migrating whales is avoidance of critical breeding habitat or area where mating, calving or nursing occurs. The humpback whales have their winter breeding concentrations off tropical East Africa, from northern KwaZulu-Natal northwards and therefore over 1 000 km to the north-east of the northern boundary of the Reconnaissance Permit Area. Southern right whales, however, currently have their most significant winter concentrations on the South African South Coast between Gqeberha and Cape Town. The nearshore areas of the De Hoop MPA and St. Sebastian Bay at Cape Infanta ranks as probably the most important nursery area for Southern Right whales in the world, containing 70-80% of the cow-calf pairs on the South African coast. The Reconnaissance Permit Area, which is located beyond the 200 m isobath, therefore does not overlap with such known areas. However 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.

Assuming the survey is scheduled so as to avoid the key northward and southward migration periods (early June and late November, respectively), there is a low likelihood of encountering migrating humpback whales. However, due to the increasing numbers of southern right and humpback whales year round off the southern African South Coast, the potential impact of behavioural avoidance of seismic survey areas by mysticete cetaceans is considered to be of HIGH intensity (resident species), across the Licence Area (REGIONAL) and for the duration of the survey (SHORT TERM – 4-5 months). Considering the distribution ranges of most species of cetaceans, the impact of seismic surveying in the Algoa Basin is considered of **MEDIUM** magnitude for both migrating mysticetes and for resident 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 Reconnaissance Permit Area but several species are considered to be year-round residents. Furthermore, a number of toothed whale species have a more pelagic distribution thus occurring further offshore, with species diversity and encounter rates likely to be highest on the shelf slope. The impact of seismic survey noise on the behaviour of toothed whales is considered to be of HIGH intensity across the Licence Area (REGIONAL) and for the duration of the survey (SHORT TERM – 4-5 months). The overall magnitude 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. Should the survey overlap with the key migration and breeding period when there is a high likelihood of encountering migrating Humpback whales (including possible mother-calf pairs) and no other mitigation measures are in place, the intensity of impacts on baleen whales is likely to be HIGH (mother-calf pairs) over the survey area (REGIONAL) and duration (4-5 months), and of MEDIUM intensity (species specific) in the case of toothed whales over the survey area (LOCAL) and duration (SHORT TERM – 4-5 months). The magnitude for both mysticetes and odontocets would be **MEDIUM**.

Indirect impacts due to effects on prey

As with other vertebrates, the assessment of indirect effects of seismic surveys on resident odontocete cetaceans is limited by the complexity of trophic pathways in the marine environment. Although the fish and cephalopod prey of toothed whales and dolphins may be affected by seismic surveys, impacts will be highly localised and small in relation to the feeding ranges of cetacean species. Cumulative impacts within species ranges must, however, be considered. In the case of odontocetes, the broad ranges of prey species (in relation to the avoidance patterns of seismic surveys of such prey species) suggest that indirect impacts due to effects on prey would similarly be of LOW intensity over the survey area (REGIONAL) and duration (SHORT TERM - 4-5 months) and therefore of **VERY LOW** magnitude.

The majority of baleen whales will undertake little feeding within breeding ground waters and rely on blubber reserves during their migrations so any indirect effects on their food source would thus be of NEGLIGIBLE intensity over the survey area (LOCAL) and duration (SHORT TERM – 4-5 months) and therefore of **NEGLIGIBLE** magnitude. Considering the low sensitivity of the receptor to reductions in food supply the significance of indirect effects on their food source is **NEGLIGIBLE**.

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

Physiological injury and mortality

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

[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.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in mysticetes and odontocetes, high sensitivity and the medium magnitude is deemed to be of **MEDIUM** significance.

Masking of Sounds and Communication

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

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources of mysticetes and odontocetes, considering their high sensitivity, and the very low magnitude, is thus deemed to be of **LOW** significance for odontocetes and **NEGLIGIBLE** significance for mysticetes.

Identification of Mitigation Measures

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.	Avoid
1.2	Plan survey, as far as possible, so that the first commencement of airgun firing in a new area (including gun tests) is undertaken during daylight hours.	Abate on site
1.3	Prohibit airgun use (including airgun tests) outside of the area of operation (which includes line turns undertaken outside the licence area).	Avoid
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	Abate on site

No.	Mitigation measure	Classification
	hydrophone cables) are readily available in the event that PAM breaks down, in order to ensure timeous redeployment	
2.2	**Acoustic Source**	
2.2.1	Define and enforce the use of the lowest practicable airgun volume for production, and design arrays to maximise downward propagation, minimise horizontal propagation and minimise high frequencies in airgun pulses.	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; – 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	Abate on site

No.	Mitigation measure	Classification
	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: – Provide effective regular briefings to crew members, and establish clear lines of communication and procedures for onboard operations; – Ensure that the hydrophone cable is optimally placed, deployed and tested for acoustic detections of marine mammals; – Confirm that there is no marine mammal activity within 500 m of the airgun array prior to commencing with the "soft-start" procedures; – Record species identification, position (latitude/longitude), distance and bearing from the vessel and acoustic source, where possible; – Record general environmental conditions; – Record airgun activities, including sound levels, "soft-start" procedures and pre-firing regimes; and – Request the delay of start-up and temporary termination of the seismic survey, as appropriate.	Abate on site
3.3.	Ensure MMOs and PAM operators are briefed on the area-specific sensitivities and on the seismic survey planning (including roles and responsibilities, and lines of communication).	Abate on site
4. Airgin testing		
4.1	Maintain a pre-shoot watch of 60-minutes before any instances of airgun testing. If only a single lowest power airgun is tested, the pre-shoot watch period can be reduced to 30 minutes	Avoid / Abate on site

No.	Mitigation measure	Classification
4.2	Implement a "soft-start" procedure if testing multiple higher powered airguns. • The "soft-start" should be carried out over a time period proportional to the number of guns being tested and not exceed 20 minutes; airguns should be tested in order of increasing volume. • If testing all airguns at the same time, a 20 minute "soft-start" is required. • If testing a single lowest power airgun a "soft-start" is not required.	Avoid / Abate on site
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. • **during times of poor visibility or darkness** it is confirmed by PAM technology that no vocalising cetaceans are present in the 500 m[6] mitigation zone during the pre-shoot watch (60 minutes).	Avoid / Abate on site
5.3	Delay "soft-starts" if cetaceans are observed within the mitigation zone. • A "soft-start" should not begin until 30 minutes after cetaceans depart the 500 m mitigation zone or 30 minutes after they are last seen or acoustically detected by PAM in the mitigation zone.	Avoid / Abate on site
5.4	As noted above for planning, when arriving at the survey area for the first time, survey activities should, as far as possible, only commence during daylight hours with good visibility. 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] Although for the most sensitive hearing group (very high frequency cetaceans) the maximum zone of impact from a single seismic pulse is 450 m for PTS onset and 800 m for TTS onset, the recommended mitigation zone is 500 m. This is due to the VHF signal attenuating rapidly and the likelihood of picking up VHF on PAM at a distance of beyond 500 m is very low. Thus, although VHF cetaceans may experience TTS at a distance of up to 800 m at full power, this is unlikely when implementing the soft-start procedure, which provides them the opportunity to leave the area.

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

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

Residual Impact Assessment

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

Potential impact of seismic noise to mysticete and odontocete cetaceans

1	*Impacts of seismic noise on mysticetes and odontocetes*	
Project Phase:	Operation	
Type of Impact	Direct	
Nature of Impact	Negative	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	Residual Impact
Magnitude/Consequence	MEDIUM	LOW
Intensity	High	Medium
Extent	Regional	Regional
Duration	Short	Short
Significance	MEDIUM	LOW
Probability	Highly Likely	Possible
Confidence	High	High
Reversibility	Fully Reversible	Fully Reversible
Loss of Resources	Moderate	Low
Mitigation Potential	-	Medium
Cumulative potential	Unlikely	Unlikely

4.3.2 Impacts of Seismic Noise on Seals

Source of Impact

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

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

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

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

Sensitivity of Receptors

Seal colonies in the vicinity of the speculative 3D survey area are located at Black Rocks (Bird Island group) in Algoa Bay and at Robberg Peninsula. Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles (~220 km) offshore, with bulls ranging further out to sea than females. Seals may therefore be encountered in the inshore portions of proposed 3D survey area. Their sensitivity to the proposed seismic operations is considered to be **LOW**.

Impact Magnitude

Physiological injury or mortality

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

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

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

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

The Underwater Noise Modelling Study undertaken for the current project (Li & Lewis 2021) identified that for seals (Other Marine Carnivores in water) PTS and TTS were predicted to occur within only 20 m and 25 m of the source array, respectively (Table 13). Maximum threshold distance for recoverable injury from multiple pulses was not reached, with the maximum threshold distance for TTS estimated at <10 m.

The potential impact of physiological injury to seals as a result of seismic noise is deemed to be of medium intensity and would be limited to the survey area (REGIONAL), although injury could extend beyond the survey duration. As seals are known to forage up to 120 nautical miles (~220 km) offshore, the inshore portions of the proposed 3D survey area therefore falls within the foraging range of seals from the southeast coast colonies. The intensity of the impact is therefore considered to be HIGH. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL), the potential physiological injury is therefore considered to be of **MEDIUM** magnitude.

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 VERY LOW intensity as they are known to show a tolerance to loud noises. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL), the potential for behavioural avoidance of seals is considered to be of **VERY LOW** magnitude.

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 VERY LOW intensity as they are known to show a tolerance to loud noises. As the duration of the impact would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL), the potential for masking of sounds is considered to be of **VERY LOW** magnitude.

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. 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 VERY LOW intensity, would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL). The potential for effects of seismic surveys on prey species is thus considered to be of **VERY LOW** magnitude.

<u>Impact Significance</u>

Physiological injury and mortality

The potential impact of seismic noise on physiological injury or mortality of seals, considering their low sensitivity and MEDIUM magnitude, is deemed to be of **LOW** significance.

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in seals, considering their low sensitivity and the very low magnitude, is deemed to be of **NEGLIGIBLE** significance.

Masking of Sounds and Communication

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

Indirect impacts due to effects on predators or prey

The potential indirect impact of seismic noise on food sources of seals, considering their low sensitivity, and the very low magnitude, is thus deemed to be of **NEGLIGIBLE** significance.

Identification of Mitigation Measures

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

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

Residual Impact Assessment

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

2	*Impacts of seismic noise on seals*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**MEDIUM**	**LOW**
Intensity	**High**	**Medium**
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**LOW**	**VERY LOW**
Probability	**Unlikely**	**Unlikely**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Medium**
Cumulative potential	**Unlikely**	**Unlikely**

4.3.3 Impacts of Seismic Noise on Turtles

Source of Impact

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

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

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition;

Impact Description

The potential effects of seismic surveys on turtles include:

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

Project Controls

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

Sensitivity of Receptors

The leatherback and loggerhead turtles that occur in offshore and coastal waters around southern Africa, and likely to be encountered in the Reconnaissance Permit Area are considered regionally 'Critically Endangered' and 'Endangered', respectively, in the List of Marine Threatened or Protected Species (TOPS) as part of the NEMBA. Following nesting in December-January, loggerhead turtles migrate back to their foraging grounds with studies suggesting that turtles travel from iSimangaliso to Gqeberha (formerly Gqeberha) over a one month period (Harris *et al*. 2018). Hatchlings of both species emerge from their nests from mid-January to mid-March with most dispersing south-westward within the Agulhas Current (Le Gouvelle *et al*. 2020b). The Agulhas Current migration corridor will therefore be very active with migrating sea turtles between January and April (Harris *et al*. 2018). At estimated mean hatchling dispersal rates of 0.54 km/h for loggerheads and 1.08 km/h for leatherbacks (Le Gouvello *et al*. 2020b), loggerheads would take 70-80 days and leatherbacks 30-40 days to reach the Reconnaissance Permit Area (Figure 54). Hatchlings would therefore be expected to be passing by or through the exploration area from mid-March to late-April. Despite their extensive distributions and feeding ranges, the numbers of adult and neonate turtles encountered in the Reconnaissance Permit area are therefore likely to be seasonally high. Consequently, the sensitivity of turtles to seismic noise is considered to be **HIGH**, particularly neonates and juveniles as they are unable to actively avoid seismic sounds and consequently are more susceptible to seismic noise.

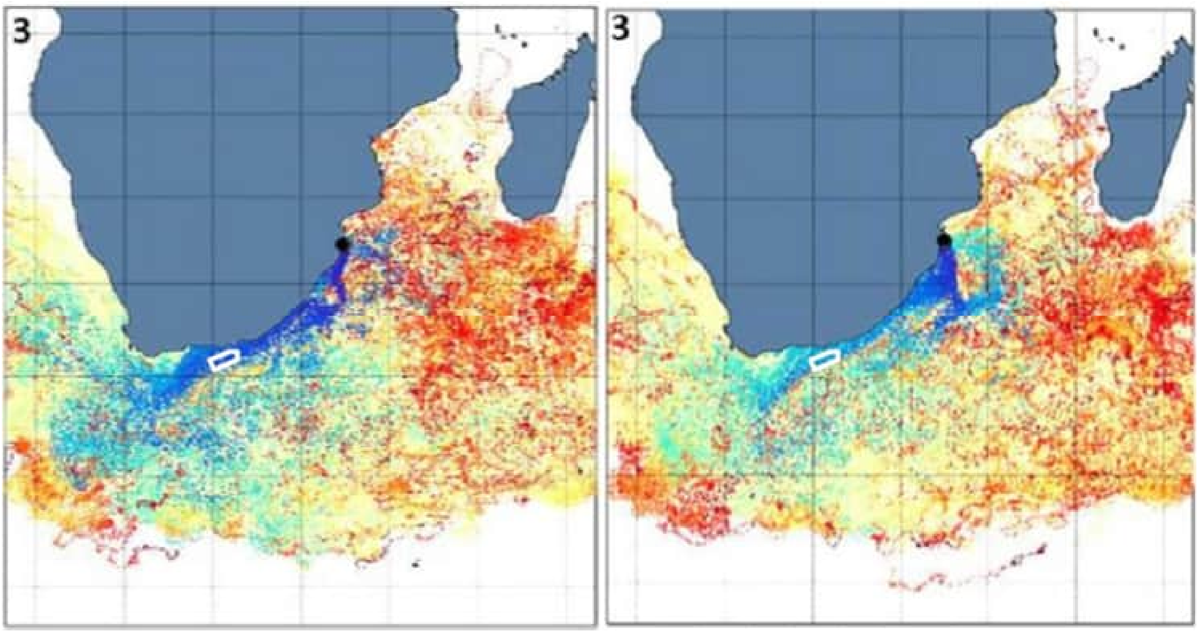


Figure 54: Virtual hatchling trajectories for leatherback (left) and loggerhead (right) turtles after 365 days (48 hr @0.15 m/s then no swim) in relation to Reconnaissance Permit Area (white polygon) (adapted from Le Gouvelle *et al*. 2020b).

Impact Magnitude

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

Physiological injury (including disorientation) or mortality

Due to a lack of research, it is not known what levels of sound exposure (or frequencies) would cause permanent or temporary hearing loss or what effect this may have on the fitness or survival of turtles (DeRuiter & Larbi Doukara 2012), although Eckert *et al.* (1998) assumed physiological effects at levels of 190 dB re 1 µPa ref 1 m, while Popper *et al.* (2014) have predicted that mortality or potential mortal injury will occur at peak sound pressure levels of over 207 dB re 1 µPa. Evidence, however, suggests that turtles only detect airguns at close range (<10 m) or are not sufficiently mobile to move away from approaching airgun arrays (particularly if basking). Initiation of a sound source at full power in the immediate vicinity of a diving, swimming or basking turtle would thus be expected to result in physiological injury. This applies particularly to hatchlings and juveniles as they are unable to avoid seismic sounds whilst being transported in the ocean currents, and consequently are more susceptible to seismic noise. For the first few months following emergence, hatchlings are reported to spend most of their time in the upper 5 m of the water column (Salmon *et al.* 2004; Howell *et al.* 2010; Mansfield *et al.* 2014). Juveniles in contract appear to spend most of their time diving to depths, spending only 43% of their time at the surface during the day and 29% of the time at the surface during the night (Freitas *et al.* 2018, 2019). Both hatchlings and juveniles would therefore be particularly susceptible to airguns at close range. As the numbers of adult and neonate turtles encountered in the Reconnaissance Pemrit Area are likely to be seasonally high, the potential impact is considered to be of medium intensity, but remain within the short-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 14).

Table 14: 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 μPa^2·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).

Using the peak sound pressure level of over 207 dB re 1 μPa as determined by Popper *et al.* (2014), the Underwater Noise Modelling Study undertaken for the current project (Li & Lewis 2021) identified that the maximum horizontal distance from the seismic source to impact threshold levels leading to mortality or potential mortal injury in turtles was 240 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 <10 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 the Reconnaissance Permit Area are highly migratory, and are likely to have moved considerable distances over the cumulative 24-hr period.

Although the speculative 3D survey area lies over 800 km to the southwest of the nesting sites and inter-nesting migration areas for Leatherback and Loggerhead turtles, turtles encountered during the survey are likely to be adults migrating to foraging grounds, and dispersing neonates and juveniles. The number of turtles encountered in the survey area may therefore be seasonally high. The intensity of potential physiological injury would thus be rated as HIGH. However, the duration of the impact on the population would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL). The potential physiological injury or mortality of turtles is considered to be of **MEDIUM** magnitude.

Behavioural avoidance

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

Further trials carried out on caged loggerhead and green turtles indicated that significant avoidance response occurred at received levels ranging between 172 and 176 dB re 1 μPa at 24 m, and repeated 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.

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

The Underwater Noise Modelling Study undertaken for the current project (Li & Lewis 2021) identified that the zones of behavioural disturbance for turtles caused by the immediate exposure to individual pulses was predicted to be within 3 100 m of the 3D 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 survey is expected to be comparatively low, the impact of seismic sounds on turtle behaviour would be of LOW intensity, and would persist only for the duration of the survey (SHORT TERM – 4-5 months), and be restricted to the survey area (REGIONAL). The impact of seismic noise on turtle behaviour is thus deemed to be of **VERY LOW** magnitude.

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 and inter-nesting migration areas for Leatherback and Loggerhead turtles lies over 800 km to the north of the Reconnaissance Permit Area, turtles encountered during the survey are likely to be migrating neonates and adults. Their relatively low abundance in the survey area would suggest that the impact (should it occur) would be of VERY LOW intensity. As the impact would persist only for the duration of the survey (SHORT TERM – 4-5 months), and be restricted to the survey area (REGIONAL), the impact is deemed to be of **VERY LOW** magnitude.

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, whereas loggerhead, green and hawksbill turtles tend to feed on inshore reefs. 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 VERY LOW intensity, persisting only for the duration of the survey (SHORT TERM – 4-5 months), and restricted to the survey area (REGIONAL). The impact would therefore be of **VERY LOW** magnitude.

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

Physiological injury and mortality

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

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in turtles, considering their medium sensitivity and the very low magnitude, is deemed to be of **VERY LOW** significance.

Masking of Sounds and Communication

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

Indirect impacts due to effects on predators or prey

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

Identification of Mitigation Measures

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

No.	Mitigation measure	Classification
1	Schedule surveying so as to be completed by mid-March to avoid interactions with turtle hatchlings off Algoa Bay in late March and April.*	Avoid
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 turtles within 500 m of the seismic source.	Avoid / Abate on site
3	In the case of turtles being observed within the mitigation zone, delay the "soft-start' until animals are outside the 500 m mitigation zone.	Avoid / Abate on site
4	Terminate seismic shooting on: – Observation of turtles within the 500 m mitigation zone. – Observation of any obvious mortality or injuries to turtles when estimated by the MMO to be as a direct result of the survey. For turtles, terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no soft-start required).	Abate on site
5	Avoid surveying within 100 m of the 50 m depth contour in the vicinity of nesting beaches or critical foraging habitats (e.g. seamounts or convergence zones)	Avoid

***** Note: When viewed together with other sensitivities and related time restrictions, this measure is not deemed feasible for implementation and there would thus not be a drop in the residual impact for hatchlings.

Residual Impact Assessment

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

3	*Impacts of seismic noise on turtles*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**MEDIUM**	**LOW**
Intensity	**High**	**Medium**
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**MEDIUM** (adults & hatchlings)	**LOW** (adults) **MEDIUM** (hatchlings)*
Probability	**Likely**	**Possible**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Medium**
Cumulative potential	**Unlikely**	**Unlikely**

* Assumes that it would not be possible to complete the proposed survey by mid-March.

4.3.4 Impacts of Seismic Noise on Seabirds

Source of Impact

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

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

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

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

Project Controls

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

Sensitivity of Receptors

Among the marine avifauna occurring along the southeast 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 southeastern Cape coastline, would be particularly susceptible to impacts from underwater seismic noise. Similarly, Cape Gannets dive for their pelagic prey and would be susceptible to seismic noise. The majority of Cape Cormorants and Algoa Bay penguins forage to the south and east of Cape Recife. During their pre- and post-moult periods (October to March) penguins forage inshore of the Reconnaissance Permit Area. Cape Cormorants and African Penguins are therefore unlikely to be encountered in the area of interest for 3D acquisition due to its location further offshore (see Figure 35 and Figure 36). However, Cape Gannets are known to forage within 200 km offshore (Dundee 2006; Ludynia 2007; Grémillet *et al*. 2008), and are thus likely to be encountered in the inshore portions of the area of interest for 3D acquisition (see Figure 35). All three species are considered 'Endangered' on a national and global scale. Of the pelagic seabirds likely to occur in the offshore regions characterising the Reconnaissance Permit Area, many are considered **regionally** 'Vulnerable' (e.g. Wandering Albatross, White-chinned Petrel) and 'Endangered' (e.g. Atlantic and Indian Yellow-nosed Albatross, Subantarctic skua, African Penguin). However, due to their extensive distributions and feeding ranges, the numbers of individuals encountered during the survey are likely to be comparatively low. Consequently, the sensitivity for both coastal and pelagic seabirds is considered to be **MEDIUM**.

Impact Magnitude

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

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

In African Penguins the best hearing is in the 600 Hz to 4 kHz range with the upper limit of hearing at 15 kHz and the lower limit at 100 Hz (Wever *et al*. 1969). Compared to other birds (Necker 2000), African Penguins were considered to be relatively insensitive to sounds both in terms of frequency and intensity (Wever *et al*. 1969). No critical ratios have, however, been measured.

Principal energy of vocalisation of African penguins was found at <2 kHz, although some energy was measured at up to 6 kHz (Wever *et al.* 1969). Penguins are known to respond to underwater vocalisations of predators (Frost *et al.* 1975). Recently underwater vocalisations have been recorded in King, Gentoo and Macaroni penguins with a frequency of maximum amplitude averaging 998 Hz, 1097 Hz and 680 Hz, respectively (Thiebault *et al.* 2019).

Physiological injury

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

Of the plunge diving species that occur along the southeast 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 Bird Island in Algoa Bay, ~90 km inshore of the northeastern boundary of the area of interest for 3D acquisition. This species forages at sea with most birds being found within 20 km of the coast, although individuals have been recorded as far as 70 km offshore. As the speculative 3D survey area is situated ~45 km from the coast at its nearest point, encounters with Cape Gannets are possible during 3D acquisition, but encounters with African Penguins and Cape Cormorants are unlikely. In the offshore environment, pelagic seabirds that dive for their prey may be encountered.

Should an encounter with diving pelagic seabirds occur, the potential physiological impact on individual pelagic and coastal diving birds would be of HIGH intensity, but as the likelihood of encountering large numbers of diving seabirds is low, due to their extensive distributions and feeding ranges the intensity is considered MEDIUM. Furthermore, the duration of the impact on the population would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL). The potential for physiological injury is therefore considered to be of **LOW** magnitude.

Behavioural avoidance

Diving birds would be expected to hear seismic sounds at considerable distances as they have good hearing at low frequencies (which coincide with seismic shots). Response distances are speculative, however, as no empirical evidence is available. Evidence from studies at Bird and St Croix Islands in Algoa Bay, on the behavioural response of African Penguins to seismic operations within 100 km of their colonies found that they showed a strong avoidance of their preferred foraging areas during seismic activities. Birds 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). For penguins who spend considerable time underwater while hunting, the impact zone for behavioural disturbance may, however, be larger than for plunge diving species that undertake short dives only before returning to the sea surface.

Due to the extensive distribution and feeding ranges of pelagic seabirds, the impact for pelagic seabirds would thus be of LOW intensity within the survey area (REGIONAL) over the duration of the survey period (SHORT TERM – 4-5 months). For African Penguins, Cape Cormorants and Cape Gannets, as there is a likelihood of encountering feeding birds in the inshore portions of the Reconnaissance Permit Area, the intensity is considered MEDIUM. The duration of the impact on the population would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL). The behavioural avoidance of feeding areas by diving seabirds is thus considered to be of **VERY LOW** magnitude and for coastal diving seabirds to be of **LOW** magnitude.

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). Cape Gannets vocalise regularly while at sea to maintain group cohesion and avoid collision, and rely on visual observation of other (diving) gannets as a cue to find food (Thiebault *et al.* 2014, 2016), while African Penguins have been reported to hunt cooperatively larger groups (25 165) to corral shoaling fish to the surface, where they subsequently become more accessible to other avian predators such as Cape Gannets and Cormorants (McInnes *et al.* 2017).

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) (Li & Lewis 2021). This could have implications for plunge-diving seabirds such as African Penguins that forage in restricted areas within a given radius of their breeding sites. Similarly, pelagic seabirds that feed around oceanic fronts may also be affected. The impact on potential food sources for pelagic and coastal diving seabirds would thus be of VERY LOW intensity within the survey area (REGIONAL) over the duration of the survey period (SHORT TERM – 4-5 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** magnitude.

The impact on potential food sources for pelagic seabirds would thus be of VERY LOW intensity within the survey area (LOCAL) over the duration of the survey period (4-5 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** magnitude.

Impact Significance

Physiological injury and mortality

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

Behavioural avoidance

The potential impact of seismic noise on behavioural changes in pelagic seabirds, considering their medium sensitivity and very low to low magnitude, is deemed to be of **VERY LOW** to **LOW** significance.

Indirect impacts due to effects on predators or prey

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

Identification of Mitigation Measures

In addition to the mitigation measures recommended for cetaceans, the following is recommended for penguins and feeding aggregations of diving seabirds:

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

Residual Impact Assessment

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

4	*Impacts of seismic noise on diving seabirds*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**LOW**	**VERY LOW**
Intensity	**Medium**	**Low**
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**LOW**	**VERY LOW**
Probability	**Likely**	**Possible**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Medium**
Cumulative potential	**Unlikely**	**Unlikely**

4.3.5 Impacts of Seismic Noise on Fish

__Source of Impact__

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

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

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

__Impact Description__

Fish hearing has been reviewed by numerous authors including Popper and Fay (1973), Hawkins (1973), Atema *et al.* (1988), Hawkins & Popper (2018) and Slabbekoorn *et al.* (2019)(amongst others). Fish have two different systems to detect sounds namely 1) the ear (and the otolith organ of their inner ear) that is sensitive to sound pressure and 2) the lateral line organ that is sensitive to particle motion. Certain species utilise separate inner ear and lateral line mechanisms for detecting sound; each system having its own hearing threshold (Tavolga & Wodinsky 1963), and it has been suggested that fish can shift from particle velocity sensitivity to pressure sensitivity as frequency increases (Cahn *et al.* 1970, in Turl 1993). More recently, Popper and Hawkins (2018) determined that most fish (and all elasmobranchs) primarily detect particle motion.

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

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

Project Controls

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

Sensitivity of Receptors

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

The greatest risk of physiological injury from seismic sound sources is for species that establish home ranges on shallow- or deep-water reefs or congregate in areas to spawn or feed, and those displaying an instinctive alarm response to hide on the seabed or in the reef rather than flee. Such species would be associated with the seabed (at >200 m) or with the Kingklip Ridge and Kingklip Koppies deepwater reefs. The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of the Reconnaissance Permit Area are the large migratory pelagic species. In many of the large pelagic species, the swim-bladders are either underdeveloped or absent, and the risk of physiological injury through damage of this organ is therefore lower. However, many of the large pelagic fish and shark species likely to occur in the offshore regions along the southeast coast are considered globally 'Vulnerable' (e.g. bigeye tuna, blue marlin, sailfish, smooth hammerhead shark, bigeye thresher and common thresher sharks, great white shark), and 'Endangered' (e.g. Southern bluefin tuna, great hammerhead shark, pelagic thresher, shortfin mako, longfin mako, dusky shark, whale shark). However, the numbers of individuals encountered during the survey are likely to be low, even when these species are *en route* to or from recognised feeding grounds associated with the Agulhas Bank or the Southwest Indian Seamounts where greater concentrations of pelagic fish can be expected. The sensitivity of fish to seismic noise is considered to be HIGH.

<u>Impact Magnitude</u>

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

Physiological injury and mortality

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

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

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

Table 15).

Table 15: 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 µPa^2·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).

Kingklip Ridge and Kingklip Koppies lie within the north eastern portion of the Reconnaissance Permit Area, with Grue Bank and Dalgleish Bank lying approximately 75 km west and 150 km northwest of the western boundary of the Reconnaissance Permit Area. Davies Seamount and the seamounts of the Agulhas Arch lie ~ 150 km and 160 km southwest and west of the western boundary of the Reconnaissance Permit Area. Any demersal species associated with these important fishing banks and mid-oceanic features would receive the seismic noise within the far-field range, and outside of distances at which physiological injury or avoidance would be expected. Impacts on demersal species are thus deemed of VERY LOW intensity across the survey area (REGIONAL) and for the survey duration (SHORT TERM) and are considered to be of **VERY LOW** magnitude.

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

The underwater noise modelling study undertaken for the current survey (Li & Lewis 2021) identified that the maximum horizontal distance from the 3D seismic source to impact threshold levels leading to mortality or potential mortal injury was 120 m for fish lacking swim bladders (e.g. some tunas, sharks and most mesopelagic species) and 240 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) were 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 24-hour survey operation scenario considered, whereas for fish with swim bladders this distance is 20 m from the sound source. 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 50 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 2 000 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 the Reconnaissance Permit Area are the highly migratory pelagic sharks, tunas and billfish, and are likely to have moved considerable distances over the cumulative 24-hr period.

Should an encounter occur, the potential physiological impact on individual migratory pelagic fish, would be of HIGH intensity. Furthermore, the duration of the impact on the population would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL). The impact is therefore considered to be of **MEDIUM** magnitude.

Behavioural avoidance

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

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

Changes in spawning, migration and feeding behaviour of fishes in response to seismic shooting could indirectly affect fisheries through reduced catches resulting from changes in feeding behaviour, abundance and vertical distribution (Skalski *et al.* 1992; Hirst & Rodhouse 2000; Gausland 2003). Such behavioural changes could lead to changes in commercial catch rates if fish move into or out of important fishing grounds (Engås *et al.* 1996; Hirst & Rodhouse 2000; Dalen & Mæsted 2008; Streever *et al.* 2016; Bruce *et al.* 2018). Reports on observed declines in catch rates differ considerably between studies, between target species and gear types used, ranging from no apparent reduction to an 83% reduction in bycatch in a shrimp trawl (Løkkeborg & Soldal 1993) and typically persisting for a relatively short duration only (12 hours to up to 10 days).

The distance from the seismic sound source at which reductions in catch rates were measured also varied substantially between studies ranging from no significant effects in trawl, trammel net and hydraulic dredging fisheries (La Bella *et al.* 1996), through approximately 8 km to as much as 36 km (Hirst & Rodhouse 2000; see also Cochrane & Wilkinson 2015). The potential effects of seismic surveys on fisheries are discussed in more detail in the *Commercial Fisheries Impact Assessment*

(CapMarine 2022). Airgun noise related changes to prey and predator species of commercially important species could also play a role in affecting catch rates (Hirst & Rodhouse 2000). Information on feeding success of fish (or larger predators) in association with seismic survey noise is lacking.

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

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

Reproductive success / spawning

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

Norwegian spawning grounds has now been recommended to be closed for 3D seismic surveys (Sivle *et al*. 2021). To effectively protect spawning areas, however, thorough knowledge of the actual spawning areas and periods of the species involved is crucial.

The major spawning grounds for most small pelagic shoaling species (anchovy, round herring, horse mackerel, chub mackerel) are located east of Cape Point and hake spawning occurring on the western Agulhas Bank. As eggs and larvae are distributed westwards there is no overlap of these spawning areas with the Reconnaissance Permit Area. There is also sardine and anchovy spawning on the east coast and off KwaZulu-Natal, where sardine eggs are found during July–November before they are distributed southwestwards in the Agulhas Current. This egg and larval drift passes through the Reconnaissance Permit Area. Kingklip spawning associated with Kingklip Ridge and Kingklip Koppies occurs within the Reconnaissance Permit Area (see

Figure **13**). 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. As the survey area is not known to be a spawning area for small or large pelagic species, the intensity of the effect for pelagic fish can be considered very low. Considering the wide range over which the potentially affected pelagic species occur, that the main migration routes of endemic sparids lie inshore of the proposed survey area and do not constitute narrow restricted paths, and the relatively short duration of the proposed survey, the impact can be considered of **VERY LOW** magnitude. Although, the survey area overlaps with the 'spawning box' for kingklip and the intensity of the effect of the survey on this demersal species could be medium, the impact would be of **MEDIUM** magnitude.

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 South Coast are unknown. Demersal species in abyssal and continental slope habitats or associated with Kingklip Koppies, Kingklip Ridge and the Southwest Indian Seamounts 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 VERY LOW intensity due to the duty cycle of seismic surveys in relation to the more continuous biological noise. Such impacts would occur across the survey area (REGIONAL) and for the duration of the survey (2 months). The impact is thus considered to be of **VERY LOW** magnitude.

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 in offshore regions, the intensity of the impact would be LOW, restricted to the survey area (REGIONAL) and persisting over the SHORT-TERM only (4-5 months). The impact would thus be of **VERY LOW** magnitude.

Impact Significance

Physiological injury and mortality

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

Behavioural avoidance

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

Reproductive success / spawning

The potential impact of seismic noise on the reproductive success and spawning of nearshore commercial fish species, considering their high sensitivity and the medium magnitude, is deemed to be of **MEDIUM** significance.

Masking of environmental sounds and communication

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

Indirect impacts due to effects on predators or prey

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

Identification of Mitigation Measures

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

No.	Mitigation measure	Classification
1	Undertaking the proposed survey from January to May would avoid the key spring spawning periods.	Avoid
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 shoaling large pelagic fish within 500 m of the seismic source.	Avoid / Abate on site
3	In the case of shoaling large pelagic fish being observed within the mitigation zone, delay the "soft-start' until animals are outside the 500 m mitigation zone.	Avoid / Abate on site

No.	Mitigation measure	Classification
4	Terminate seismic shooting on – Observation of slow swimming large pelagic fish (including whale sharks, basking sharks, manta rays and devil rays) within the 500 m mitigation zone. – Observation of any obvious mass mortalities of fish (specifically large shoals of tuna or surface shoaling small pelagic species such as sardine, anchovy and mackerel) when estimated by the MMO to be as a direct result of the survey. For slow swimming large pelagic fish, terminate shooting until such time as the animals are outside of the 500 m mitigation zone (seismic "pause", no soft-start required).	Abate on site
5	If possible, schedule the 3D survey periods from February to late May, thereby avoiding the sensitive fish spawning period in spring and early summer to some extent.	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. The proposed mitigation measures, which are essentially designed to keep animals out of the immediate area of impact thereby reducing the risk of deliberate injury to fish, reduces the intensity of the impacts relating to physiological injury / mortality to medium, the residual impact will reduce to **low** magnitude and be of **LOW** significance. All other impacts on fish remain of **LOW** significance.

5	*Impacts of seismic noise to large pelagic fish*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**MEDIUM**	**LOW**
Intensity	**High**	**Medium**
	Low for demersal fish; High for large pelagic species	Low for demersal fish; Medium for large pelagic species
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**MEDIUM**	**LOW**
Probability	**Unlikely - Likely (pelagic species)**	**Possible**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Medium**
Cumulative potential	**Unlikely**	**Unlikely**

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

Sensitivity of Receptors

The area of interest for 3D seismic acquisition lies well offshore where the ecosystem threat status is primarily considered of 'Least concern', with the exception of the shelf edge, which considered 'Vulnerable' with Kingklip Ridge being rated as 'Endangered'. Furthermore, most ecosystem types outside the offshore MPAs are either poorly protected or not protected at all (see Figure 48). Pelagic invertebrates that may occur in the Reconnaissance Pemrit Area 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. Further species of potential concern is the commercially fished deep-water rock lobster (*Palinurus gilchristi*), which occurs on rocky substrate in depths of 90 - 170 m (inshore of the proposed survey area), and the squid (*Loligo vulgaris reynaudii*), which occurs extensively on the Agulhas Bank out to the shelf edge (500 m depth contour). Adult squid are normally distributed in waters >100 m, except along the eastern half of the South Coast where they also occur inshore, forming dense seasonal spawning aggregations at depths between 20 - 130 m.

Despite the presence of potential VME species in the project area, some of which may be sensitive to **physical** disturbance, the sensitivity of benthic invertebrates to acoustic impacts is considered to be VERY LOW, whereas for neritic and pelagic invertebrates the sensitivity can be considered LOW. Following the precautionary principle, the LOW sensitivity will be assumed in determining the significance.

Impact Magnitude

Information on hearing by invertebrates, and noise impacts on them is sparse (reviewed in Moriyasu *et al.* 2004; Carroll *et al.* 2017). Although many invertebrates cannot sense the pressure of a sound wave or the lower amplitude component of high frequency sounds, low frequency high amplitude sounds may be detected *via* the mechanoreceptors, particularly in the near-field of such sound sources (McCauley 1994). Sensitivity to near-field low-frequency sounds or hydroacoustic disturbances has been recorded for the lobster *Homarus americanus* (Offut 1970; Day *et al.* 2016; Fitzgibbon *et al.* 2017), cephalopods (Kaifu *et al.* 2008; Hu *et al.* 2009; Mooney *et al.* 2010, 2012; André *et al.* 2011; Fewtrell & McCauley 2012; Samson *et al.* 2014; Mooney *et al.* 2016), scallops (Day *et al.* 2016; Day *et al.* 2017), and various other invertebrate species (Horridge 1965, 1966; Horridge & Boulton 1967; Moore & Cobb 1986; Packard *et al.* 1990; Turnpenney & Nedwell 1994).

Physiological injury

Recent field-based methods on scallop beds (*Pecten fumatus* and *Mimachlamys asperrima*) in the Bass Strait, Australia, showed no evidence of scallop mortality attributable to seismic surveying, although sub-lethal effects could not be excluded (Przeslawski *et al.* 2016, 2018; see also Parry *et al.* 2002; Harrington *et al.* 2010). Another study on exposure of scallops from transplanted populations to an airgun operated in shallow water (<12 m), however, found evidence of seismic impacts (increased mortality, inability to maintain homeostasis, reflex changes, depressed immune response) (Day *et al.* 2016; 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, compromised nutritional condition and immunological capacity, and behavioural changes in crustaceans (DFO 2004; McCauley 1994; McCauley *et al.* 2000; Day *et al.* 2016; Fitzgibbon *et al.* 2017). The effects of seismic survey energy on snow crab (*Chionoecetes opilo*) on the Atlantic coast of Canada, for example ranged from no physiological damage (Lee-Dadswell 2009) but effects on developing fertilized eggs at 2 m range (Christian *et al.* 2003) to possible bruising of the heptopancreas and ovaries, delayed embryo development, smaller larvae, and indications of greater leg loss but no acute or longer term mortality and no changes in embryo survival or post hatch larval mobility (DFO 2004). In contrast, Day *et al.* (2016, 2019, 2021) demonstrated delayed righting time, which was correlated to damage to statocysts in adult rock lobster (*Jasus edwardsii*) persisting up to a year after exposure to airgun sounds, despite larval stages showing no adverse effects (Day *et al.* 2017, 2019). Impairments in righting behaviour were found to extend to at least 500 m form the airgun discharge, with those closest to the source demonstrating both persistent righting impairment and an increased intermoult duration (Day *et al.* 2019, 2021). 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.* (2016), however, reported dose-dependent increased mortality in transplanted scallops reared in suspended lantern nets four months after exposure to an airgun.

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

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

Behavioural avoidance

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

Cephalopods, in contrast, may be receptive to the far-field sounds of seismic airguns, with reported responses to frequencies under 400Hz including alarm response (e.g. jetting of ink), changes in behaviour (aggression and spawning), position in the water column and swimming speeds (Kaifu *et al.* 2008; Hu *et al.* 2009; Mooney *et al.* 2010, 2012; Fewtrell & McCauley 2012; Samson *et al.* 2014; Mooney *et al.* 2016). Squid responded to sounds from 80 to 1 000 Hz pure tone and at sound levels above 140 dB re. 1 µPa rms, with response rates diminishing at the higher and lower ends of this range (Samson *et al.* 2014; 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; Samson *et al.* 2014). Limited avoidance of airgun sounds by mobile neritic and pelagic invertebrates can, however, therefore be expected.

As the area of interest for 3D acquisition is located in waters in excess of 200 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 VERY LOW intensity across the survey area (REGIONAL) and for the four-month survey duration (SHORT TERM) and is therefore considered to be of **VERY LOW** magnitude.

However, as the Reconnaissance Permit Area lies adjacent and offshore of the major squid spawning area, the behavioural impact may be of MEDIUM intensity within the southern portions of the Reconnaissance Permit Area (LOCAL) and for the four-month survey duration (SHORT TERM) and is therefore considered to be of **LOW** magnitude. Considering the medium sensitivity of the receptors, the impact is rated of **LOW** significance for squid.

Impact Significance

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

Identification of Mitigation Measures

The following mitigation measure is however recommended:

No.	Mitigation measure	Classification
1	Terminate seismic shooting on observation of any obvious mass mortalities of squid when estimated by the MMO to be as a direct result of the survey.	Abate on site
2	If possible avoid surveying in the Algoa Bay area during the peak squid spawning periods between early September and late December.	Abate on site

Residual Impact Assessment

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

6	*Impacts of seismic noise to marine invertebrates*	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Low	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	VERY LOW	VERY LOW
Intensity	**Low to Medium (squid)**	**Very Low**
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**VERY LOW**	**NEGLIGIBLE**
Probability	**Unlikely - Possible (squid)**	**Unlikely**
Confidence	**Medium**	**Medium**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Low**
Cumulative potential	**Unlikely**	**Unlikely**

4.3.7 Impacts of Seismic Noise on Plankton (including ichthyoplankton)

Source of Impact

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

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

These activities and their associated aspects are described below:

- Noise generated by airguns during seismic acquisition.

Impact Description

As the movement of phytoplankton 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 acquisition of adjacent lines. Potential impacts of seismic pulses on plankton would include physiological injury or mortality in the immediate vicinity of the airgun sound source.

Project Controls

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

Sensitivity of Receptors

The proposed 3D survey area lies on the shelf edge where localised shelf-edge upwelling can occur seasonally (see

Figure **13**). In the clear offshore waters of the Agulhas Current phytoplankton and zooplankton abundance are low compared to closer inshore, although seasonal peaks may occur associated with the shelf-edge. There is some overlap of the eastern sections of the Reconnaissance Permit Area with kingklip spawning areas and the southward egg and larval drift of pilchards and anchovies (see

Figure **13** and Figure 14). The proposed 3D survey area lies well offshore of the squid spawning areas. Ichthyoplankton abundance in the survey areas is thus likely to be low, although seasonal peaks may occur.

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

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

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

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

Impact Magnitude

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

Due to their importance in commercial fisheries, numerous studies have been undertaken experimentally exposing the eggs and larvae of various zooplankton and ichthyoplankton species to airgun sources (Kostyuchenko 1971; Dalen & Knutsen 1987; Holliday *et al.* 1987; Booman *et al.* 1992; Kosheleva 1992; McCauley 1994; Popper *et al.* 2005; and reviewed in Carroll *et al.* 2017 and Sivle *et al.* 2021). These studies generally identified that for a large seismic array, mortalities and physiological injuries occurred at very close range (<5 m) only. For example, increased mortality rates for fish eggs were proven out to ~5 m distance from the air guns. A mortality rate of 40-50% was recorded for yolk sac larvae (particularly for turbot) at a distance of 2-3 m (Booman *et al.* 1996), although mortality figures for yolk sac larvae of anchovies at the same distances were lower (Holliday *et al.* 1987). Yolk sac larvae of cod experienced significant eye injuries (retinal stratification) at a distance of 1 m from an air gun array (Matishov 1992), and Booman *et al.* (1996) report damage to brain cells and lateral line organs at <2 m distance from an airgun array. Increased mortality rates (10-20%) at later stages (larvae, post-larvae and fry) were proven for several species at distances of 1-2 m. Changes have also been observed in the buoyancy of the organisms, in their ability to avoid predators and effects that affect the general condition of larvae, their growth rate and thus their ability to survive. Temporary disorientation juvenile fry was recorded for some species (McCauley 1994). McCauley (1994) concluded that when compared with total population sizes or natural mortality rates of planktonic organisms, the relative influence of seismic sound sources on these populations can be considered insignificant.

More recently, however, McCauley *et al.* (2017) demonstrated significant declines in zooplankton abundance within a maximum range of 1.2 km of the airguns' passage (see also Tollefson 2017) and suggested that seismic surveys may result in significant and unacknowledged impacts on ocean ecosystem function and productivity. A follow-up publication by Richardson *et al.* (2017), however, queried the robustness of the McCauley *et al.* (2017) study on the grounds of insufficient sample size. Richardson *et al.* (2017) estimated that while zooplankton populations declined 22% within the survey area and 14% within 15 km of the survey area, biomass recovery occurred within 3 days following survey completion and any effects on zooplankton by seismic noise would endure in the very short term only. The time required for recolonisation of the water column by zooplankton (and ichthyoplankton) would depend on a number of variables, including seasonality of zooplankton spawning, water movement, vertical migration of plankton species and proximity of breeding adult populations. The authors stressed that impacts in areas of dynamic ocean circulation (as would be the case in the shelf-edge Agulhas Current and around the nearby Mallory Seamount Cluster) are likely to be even less. A more recent study by Fields *et al.* (2019) reported that there was significantly higher immediate mortality of the copepod *Calanus finmarchicus* at distances of 5 m from the airguns compared to controls, but that increased mortality did not exceed 30% at any distance from airgun blasts. Whether it was the sound pulse itself, the large-scale fluid motion generated by the airgun blasts, or other effects such as the bubble cloud that caused the higher mortality in the copepods, however, remains unknown.

From a fish resource perspective, these effects may potentially contribute to a certain diminished net production in fish populations both directly through mortality of ichthyoplankton, as well as indirectly through reduction in plankton that serves as a food source. However, Sætre & Ona (1996) calculated that under the "worst case" scenario, the number of larvae killed during a typical seismic survey was 0.45% of the total larvae population. When more realistic "expected values" were applied to each parameter of the calculation model, the estimated value for killed larvae during one run was equal to 0.03% of the larvae population. If the same larval population was exposed to multiple seismic runs, the effect would add up for each run. For species such as cod, herring and capelin, the natural mortality is estimated at 5-15% per day of the total population for eggs and larvae. This 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). In Norway, where until 1996 recommendations limiting seismic surveys in areas with drifting eggs and larvae had been in place, these were reviewed to allow surveying in areas of high ichthyoplankton abundance. However, restrictions for spawning areas and areas with spawning migrations, remained in place (Sivle *et al.* 2021).

A peak SPL of >207 dB has been established for mortality and potential mortal injury of fish eggs and larvae (see

Table 15). Based on the noise exposure criteria provided by Popper *et al.* (2014), the Underwater Noise Modelling Study undertaken for the survey (Li & Lewis 2021) 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 240 m. The zones of cumulative impact from multiple pulses (i.e. the maximum horizontal perpendicular distances from assessed survey lines to cumulative impact threshold levels), was estimated as 10 m. Maximum threshold distances for recoverable injury and temporary threshold shifts (TTS) for fish eggs and larvae were not reached. 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 24-hr period. Impacts will thus be of high intensity at close range.

As the survey is scheduled for the summer survey window (start December to end May), there will be some temporal overlap with the peak spawning periods of squid (September to December) and anchovies (November–December), but avoidance of the spawning periods of most other commercially important species (e.g. horse mackerel (winter months), sardines (early spring and autumn), hake (late winter to early spring), kingklip (August to September)). As plankton distribution is naturally temporally and spatially variable and natural mortality rates are high, and most of the survey area lies east of the main Agulhas Bank spawning areas and offshore of the main squid spawning area, any impacts would be of MEDIUM intensity (considering there is some overlap of the area of interest with kingklip spawning areas and assuming surveying occurs during the key spawning period). Also, zooplankton and ichthyoplankton are mainly concentrated on the continental shelf inshore of the Agulhas Current at depths <200 m depth. The inshore boundary of the survey area, adjacent to or overlapping with the shelf edge, will thus be the area of most risk to plankton.

Although the impact is restricted to within a few hundred metres of the airguns, it would extend over the entire survey area (REGIONAL). Should impacts occur, they would persist over the SHORT-TERM (days) only due to the rapid natural turn-over rate of plankton communities. The magnitude of the impact would therefore be **LOW**.

Impact Significance

The potential impact of seismic noise on plankton, considering the medium sensitivity and low magnitude, is thus deemed to be of **LOW** significance both with and without mitigation.

Identification of Mitigation Measures

Although zooplankton and ichthyoplankton appear to have year round presence, undertaking the proposed survey from January to May would avoid the key spring and early summer spawning periods thereby mitigating potential impacts on plankton to some degree. In addition, after further investigation into the data requirements and consultation with the commercial fishing sector, CGG has reduced the proposed area of interest, thereby reducing the overlap with the kingklip spawning area. No other direct mitigation measures for potential impacts on plankton and fish egg and larval stages are feasible or deemed necessary.

7	***Impacts of seismic noise to plankton and ichthyoplankton***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	**Medium**	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**LOW**	**VERY LOW**
Intensity	**Medium**	**Low**
Extent	**Regional**	**Regional**

Duration	Short	Short
Significance	**LOW**	**VERY LOW**
Probability	**Likely**	**Likely**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**None**	**None**
Cumulative potential	**Unlikely**	**Unlikely**

Residual Impact Assessment

This potential impact cannot be eliminated due to the nature of the seismic sound source required during surveying. The residual impact would remain of **NEGLIGIBLE** significance.

4.3.7 Impacts of Seismic Noise at Ecosystem Level

Figure 55 provides a simplified conceptual model for the nearshore and offshore receiving environment on the West and South-West Coasts illustrating key variables, processes, linkages, relationships, dependencies and feed-back-loops.

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

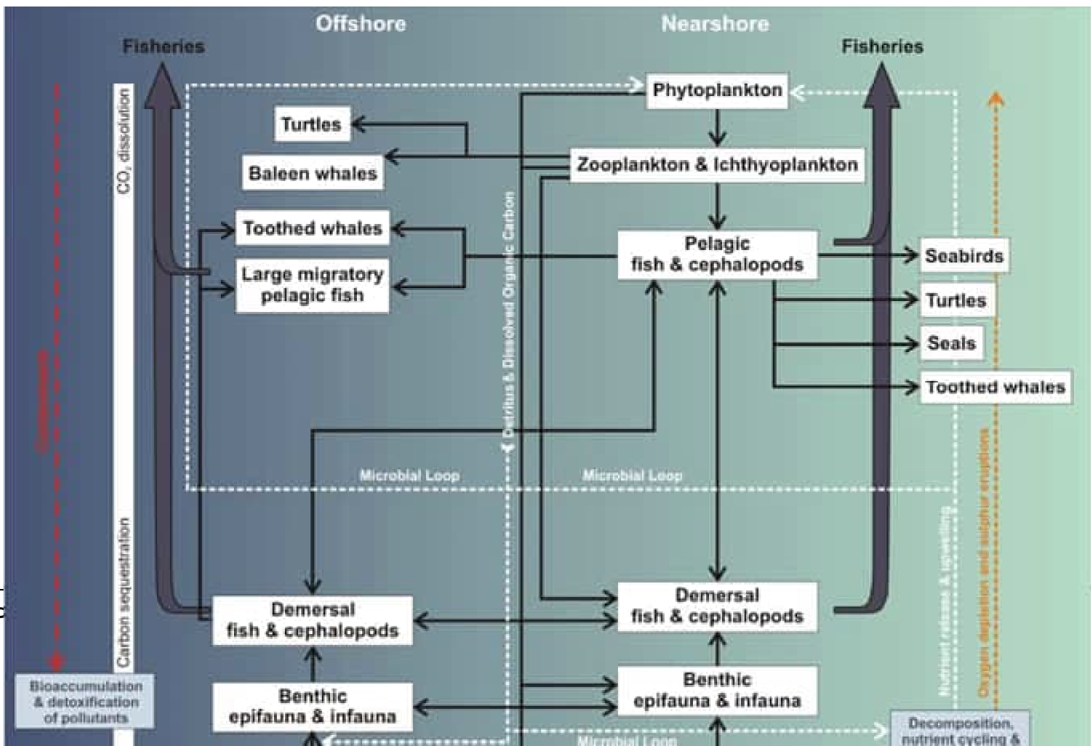


Figure 55: Simplified network diagram indicating the interaction between the key ecosystem components off the West Coast.

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

Ecosystem functions of the offshore deep water environment include the support of highly productive fisheries, the dissolution of CO_2 from the atmosphere and subsequent sequestering of carbon in seabed sediments, as well as waste absorption and detoxification.

The structure and function of these nearshore and offshore marine ecosystems is influenced both by natural environmental variation (e.g. El Niño Southern Oscillation (ENSO)) and multiple human uses, such as hydrocarbon developments and the harvest of marine living resources. The review provided in the impact assessment illustrates that the impacts of anthropogenic noise, at various scales surrounding the stressor, have been recorded in a diverse range of faunal groups. Studies on acoustic impacts, however, largely deal with effects upon individual animals or species, with impacts across large spatial scales, cumulative effects (both of ocean noise and factors other than sound pollution) or multiple species and/or food web levels having rarely been considered.

Below follows a brief discussion of potential population-level and ecosystem-wide effects of disturbance and the application of the integrated ecosystem assessment framework for evaluating the cumulative impacts of multiple pressures on multiple ecosystem components.

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

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

Likewise, long-lived, slow-reproducing species play important stabilizing roles in the marine ecosystem, especially through predation, as they play a vital role in balancing and structuring food webs, thereby maintaining their functioning and productivity. The loss of such predators at population level (either directly on individuals or indirectly through loss of prey) can have repercussions across multiple parts of a food web, resulting in top-down trophic cascades in the marine ecosystem (Ripple *et al*. 2016). This was recently reported by Towner *et al*. (2022) who demonstrated how the emigration of great white sharks from a large aggregation site at Gansbaai in response to predation by killer whales, triggered the emergence of another predator, the bronze whaler. Predator–prey interactions between white sharks, other coastal sharks, and killer whales are increasing in South Africa and may lead to pronounced impacts on the ecosystem.

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

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

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

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

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

4.4 Other Impacts of Seismic Surveys on Marine Fauna

4.4.1 Impact of Vessel and Helicopter Noise on Marine Fauna

<u>Source of Impact</u>

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

Project phase	Activity
Mobilisation	Transit of vessels to survey area

Operation	Operation of survey vessels
	Operation of helicopters
Demobilisation	Survey vessels leave survey area and transit to port or next destination

These activities and their associated aspects are described below:

- The presence and operation of the seismic vessel and support vessels during transit to the survey area, during the proposed survey and during demobilisation will introduce a range of underwater noises into the surrounding water column that may potentially contribute to and/or exceed ambient noise levels in the area.
- Crew transfers by helicopter from Cape Town or a suitable location nearby to the survey vessel, if required (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 seismic contractor will ensure that the proposed seismic survey is undertaken in a manner consistent with good international industry practice and Best Available Techniques.

Sensitivity of Receptors

The vessel and aircraft noise described above would primarily take place in the survey area and along the route taken by the support vessels and helicopters between the survey area and Gqeberha, which has both a commercial port and airport with existing high daily levels of ambient noise. Depending on the location of the seismic vessel at the time of the crew transfer, the flight path between the survey area and Gqeberha would potentially cross over offshore and coastal MPAs (e.g. Sardinia Bay MPA, Port Elizabeth Corals MPA), and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks). In addition, migratory pelagic species transiting through the survey area may also be directly affected.

The taxa most vulnerable to disturbance by underwater noise are 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, Leach's storm petrel, and blue whales), 'Endangered' (e.g. African Penguin, Cape Gannet, Atlantic and Indian Yellow-nosed Albatross, Subantarctic skua, great hammerhead shark, dusky shark, whale shark, shortfin mako shark, longfin mako, Indo-Pacific humpack dolphin, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, sailfish, loggerhead turtles, thresher sharks, great white shark, sperm whale and Bryde's whale) 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 the Southwest Indian Seamounts fall outside of any possible travel / flight path, the sensitivity is considered to be **MEDIUM**.

Impact Magnitude

Vessel Noise

The ocean is a naturally noisy place and marine animals are continually subjected to both physically produced sounds from sources such as wind, rainfall, breaking waves and natural seismic noise, or biologically produced sounds generated during reproductive displays, territorial defence, feeding, or in echolocation (see references in McCauley 1994). Such acoustic cues are thought to be important to many marine animals in the perception of their environment as well as for navigation purposes, predator avoidance, and in mediating social and reproductive behaviour. Anthropogenic sound sources in the ocean can thus be expected to interfere directly or indirectly with such activities thereby affecting the physiology and behaviour of marine organisms (NRC 2003). Natural ambient noise will vary considerably with weather and sea state, ranging from about 80 to 120 dB re 1 μPa for the frequency range 10 – 10k Hz (Croft & Li 2017). Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping (Erbe *et al*. 2018, 2019). 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).

As the proposed survey area overlaps with the main offshore shipping route that pass around southern Africa (Figure 56), the shipping noise component of the ambient noise environment is expected to be the dominant component within and around the survey area (OceanMind Limited 2020). Given the significant local shipping traffic (1 930 – 2 200 vessels monthly) and relatively strong metocean conditions specific to the area, ambient noise levels are expected to be 90 - 130 dB re 1 μPa for the frequency range 10 Hz – 10 kHz (SLR Consulting Australia 2019). The noise generated by the survey vessel, thus falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges before attenuating to below threshold levels. However, unlike the noise generated by the sound source, underwater noise from vessels is not considered to be of sufficient amplitude to cause direct harm to marine life, even at close range (SLR 2019). Due to their extensive distributions, the numbers of pelagic species (large pelagic fish, turtles and cetaceans) encountered during the proposed seismic surveys is expected to be low and consequently the intensity of potential physiological injury or behavioural disturbance as a result of vessel noise would be rated as LOW. Furthermore, the duration of the impact on the populations would be limited to the SHORT-TERM (4-5 months) and extend REGIONALLY between the survey area and the logistics base. The potential physiological injury or behavioural disturbance as a result of vessel noise would thus be of **VERY LOW** magnitude.

Aircraft Noise

The dominant low-frequency components of aircraft engine noise (10-550 Hz) penetrate the water only in a narrow (26° for a smooth water surface) sound cone directly beneath the aircraft, with the angle of the cone increasing in Beaufort wind force >2 (Richardson *et al.* 1995). The peak sound level received underwater is inversely related to the altitude of the aircraft. More recently, Erbe *et al.* (2018) established that commercial passenger airplanes in a coastal underwater soundscape exhibited broadband received levels of 84–132 dB re 1 µPa rms, detectable at between 12 Hz and 10 kHz and exceeding underwater ambient levels by up to 36 dB. Underwater noise from commercial airplanes would thus be audible to a variety of marine fauna, including seals and dolphins.

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

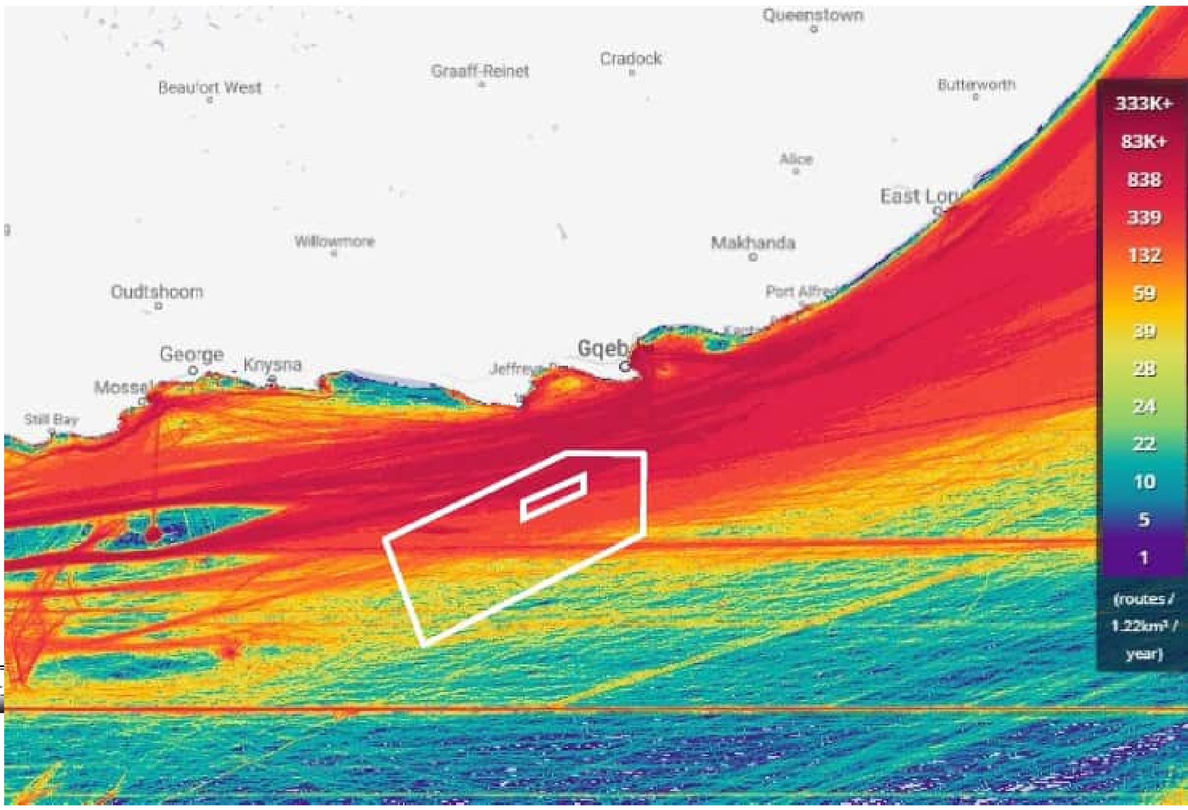


Figure 56: Reconnaissance Permit Area (white polygon) in relation to offshore vessel traffic (adapted from www.marinetraffic.com/en/ais/home).

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

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

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

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

Humpback whales strike the coast in the vicinity of Knysna, during the northern migration resulting in increasing whale density on shelf waters and into deeper pelagic waters as one moves northwards. Humpbacks would therefore potentially transit through the inshore portions of the entire Reconnaissance Permit Area within 40 km of the coast on their northwards migration. 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 numbers peaking in May – August and a smaller peak with the southern breeding migration around September – February. Winter concentrations of Southern Right whales have been recorded all along the South-East Coast, with numbers in Algoa Bay peaking in August. The inshore population of Bryde's whale is resident year-round on the Agulhas Bank, with individuals undertaking occasional seasonal excursions up the East Coast in winter during the annual sardine migration. This species is likely to be encountered in the Reconnaissance Permit Area throughout the year, with peak encounter rates reported from Algoa Bay in March and May (autumn) (Melly *et al.* 2017). Smaller cetaceans in the area include the common dolphin and Indo-Pacific humpback and bottlenose dolphin dolphins, which tend to occur further inshore on the shelf but may be encountered in the shallower portions of the proposed survey area. The level of disturbance of cetaceans by aircraft depends on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions.

Noise generated by helicopters undertaking crew transfers between the logistics base and the survey vessel could affect seabirds and seals in breeding colonies and roosts on the mainland coast. The nearest seabird colonies to Gqeberha airport are on the Algoa Bay Islands. These colonies would fall outside the potential flight path between the Gqeberha airport and the centre of the proposed 3D survey area.

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 LOW intensity for the populations as a whole. As such impacts would be REGIONAL (although temporary in nature -a few minutes in every week while the helicopter passes overhead) to the flight path and SHORT TERM (4-5 months), impacts would be of **VERY LOW** magnitude.

Impact Significance

Vessel Noise

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

Aircraft Noise

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

Aircraft and vessel noise would, however, likely contribute to the growing suite of cumulative acoustic impacts to marine fauna in the area, but assessing the population level consequences of multiple smaller and more localised stressors (see for example Booth *et al*. 2020; Derous *et al*. 2020) is difficult and beyond the scope of this study.

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

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over coastal seal colonies and seabird nesting areas	Avoid / abate on site
2	Avoid extensive low-altitude coastal flights by ensuring that the flight path is perpendicular to the coast, as far as possible	Avoid/ abate on site
3	A flight altitude >1 000 m to be maintained over MPA 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	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Avoid

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

The generation of noise from helicopters cannot be eliminated if helicopters are required for crew changes. Similarly the generation of vessel noise cannot be eliminated. The proposed mitigation, specifically maintaining the regulated altitude over the coastal zone and MPAs and flying perpendicular to the coast would reduce the intensity of the impact to very low, but the residual impact will remain of very low magnitude and of **LOW** significance. Without mitigation measures for vessel noise, the residual impact of vessel noise would remain **VERY LOW**.

8	***Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to vessel noise***	
Project Phase:	**Mobilisation, Operation and Decommissioning**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	**Low**	**Low**
Extent	**REGIONAL**	**Regional**

Duration	Short	Short
Significance	**VERY LOW**	**VERY LOW**
	Pre-Mitigation Impact	**Residual Impact**
Probability	**Possible**	**Possible**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Very Low**
Cumulative potential	**Likely**	**Likely**

9	***Disturbance and behavioural changes in seabirds, seals, turtles and cetaceans due to noise of support aircraft***	
Project Phase:	**Operation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	**Low**	**Very Low**
Extent	**REGIONAL**	**Regional**
Duration	**Short**	**Short**
Significance	**LOW**	**LOW**
Probability	**Possible**	**Unlikely**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Very Low**
Cumulative potential	**Unlikely**	**Unlikely**

4.4.2 Impact of Survey Vessel Lighting on Pelagic Fauna

Source of Impact

The project activities that will result in an increase in lighting 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 40 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 feeding in the area. Operational lights may also result in physiological and behavioural effects of fish and cephalopods as these may be drawn to the lights at night where they may be more easily preyed upon by other fish and seabirds.

Project Controls

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

Sensitivity of Receptors

The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles (particularly hatchlings and neonates), large migratory pelagic fish, and both migratory and resident cetaceans transiting through the survey area may also be attracted by the lights. Some of of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles, Leach's storm petrel, and blue whales), 'Endangered' (e.g. African Penguin, Cape Gannet, Atlantic and Indian Yellow-nosed Albatross, Subantarctic skua, whale shark, shortfin mako shark, Indo-Pacific humpack dolphin, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, loggerhead turtles, thresher sharks, great hammerhead shark, dusky shark, great white shark, longfin mako, sperm whale and Bryde's whale) 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 Algoa Bay. Most of the seabird species breeding along the southeast coast feed relatively close inshore (10-30 km), with African Penguins recorded as far as 60 km offshore and Cape Gannets up to 140 km offshore. Pelagic species occurring further offshore would be unfamiliar with artificial lighting and may be attracted to the survey vessel. Fish and squid may also be attracted to the light sources potentially resulting in increased predation on these species by higher order consumers. It is expected, however, that seabirds and marine mammals in the area would become accustomed to the presence of the survey vessel within a few days. Since the survey area is located within the main traffic routes that pass around southern Africa (see Figure 56), which experience high vessel traffic, animals in the area should be accustomed to vessel traffic.

Operational lights may also result in physiological and behavioural effects of turtles, fish and cephalopods, as these may be drawn to the lights at night where they may be more easily preyed upon by other fish, marine mammals and seabirds. The dispersal of turtle hatchlings is reported to be disrupted by light, causing them to linger, become disoriented in the nearshore and expend energy swimming against ocean currents (Wilson *et al.* 2018). 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 southeast coast colonies. 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 main traffic routes, the increase in ambient lighting in the offshore environment would be of LOW intensity and REGIONAL in extent (although limited to the area in the immediate vicinity of the vessel) over the SHORT-TERM (4-5 months). For support vessels travelling from Cape Town / Gqeberha increase in ambient lighting would likewise be restricted to the immediate vicinity of the vessel over the short-term. The potential for behavioural disturbance as a result of vessel lighting would thus be of **VERY LOW** magnitude.

Impact Significance

The potential for collision with the survey vessel or behavioural disturbance by vessel lighting deemed to be of VERY LOW significance, due to the medium sensitivity of the receptors and the very low magnitude.

Identification of Mitigation Measures

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

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

Residual Impact Assessment

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

10	*Disturbance and behavioural changes in pelagic fauna due to vessel lighting*	
Project Phase:	**Mobilisation, Operation & Demobilisation**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	**Low**	**Very Low**
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**VERY LOW**	**VERY LOW**
Probability	**Possible**	**Possible**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Low**
Cumulative potential	**Unlikely**	**Unlikely**

4.4.3 Impact of Hull Fouling and Ballast Water Discharge

Source of Impact

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

Project phase	Activity
Mobilisation	Transit of vessels to survey area
	Discharge of ballast water by seismic vessel and/or support vessels
Operation	n/a
Demobilisation	n/a

These activities and their associated aspects are described further below:

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

Impact Description

Artificial structures deployed at sea serve as a substrate for a wide variety of larvae, cysts, eggs and adult marine organisms. The transportation of equipment from one part of the ocean to another would therefore also facilitate the transfer of the associated marine organisms. Survey vessels, seismic equipment and support vessels are used and relocated all around the world. Similarly, the ballasting and de-ballasting of these vessels may lead to the introduction of exotic species and harmful aquatic pathogens to the marine ecosystems (Bax *et al.* 2003).

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

Project Controls

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

Sensitivity of Receptors

The discharge of ballast water from the survey and support vessels would take place in the vicinity of the survey area, which is located more than 40 km offshore, far removed from any sensitive coastal receptors (e.g. sessile benthic invertebrates, endemic neritic and demersal fish species). In addition, due to the water depths in the survey area (~100 m up to 5 000 m), colonisation by invasive species on the seabed is considered unlikely. Thus, the sensitivity of benthic receptors in the offshore waters of the Orange Basin is therefore considered **VERY LOW**.

Impact Magnitude

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

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

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

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

The survey vessel, and possibly the support / escort vessels, will more than likely have spent time outside of South Africa's EEZ prior to surveying. This exposure to foreign water bodies and possible loading of ballast water increases the risk of introducing invasive or non-indigenous species into South African waters. The risk of this impact is, however, significantly reduced due by the implementation of ballast water management measures in accordance with the IMO guidelines. The risk is further reduced due to the far offshore location of the survey area. Since the survey area is far removed from the coast, which together with the dominant wind and current direction, will ensure that any invasive species drift mainly in a north-westerly direction away from the coast. In addition, the water depths in the survey area (~100 m up to 4 500 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 offshore 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 MEDIUM intensity (due to it having a minimal effect on receptors) in the SHORT-TERM (due to invasive species not able to establish) and of REGIONAL extent. Thus, the magnitude (or consequence) is, therefore, considered to be **LOW**.

Impact Significance

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

Identification of Mitigation Measures

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

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

Residual Impact Assessment

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

11	***Impacts of marine biodiversity through the introduction of non-native species in ballast water and on ship hulls***	
Project Phase:	**Mobilisation**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Very Low	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	**Medium**	**Very Low**
Extent	**Regional**	**Regional**
Duration	**Short term**	**Short term**
Significance	**VERY LOW**	**NEGLIGIBLE**
Probability	**Unlikely**	**Unlikely**
Confidence	**Medium**	**Medium**
Reversibility	**Irreversible**	**Irreversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Very Low**
Cumulative potential	**Unlikely**	**Unlikely**

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 Mossel Bay
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 nm (± 5.5 km) of the coast.
  - Disposal between 3 nm (± 5.5 km) and 12 nm (± 22 km) needs to be comminuted to particle sizes smaller than 25 mm.
  - Disposal overboard without macerating can occur greater than 12 nm from the coast when the vessel is sailing.
- Discharges of oily water (deck drainage, bilge and mud pit wash residue) to the marine environment are regulated by MARPOL 73/78 Annex I, which stipulates that vessels must have:
  - A Shipboard Oil Pollution Emergency Plan (SOPEP).
  - A valid International Oil Pollution Prevention Certificate, as required by vessel class.
  - Equipment for the control of oil discharge from machinery space bilges and oil fuel tanks, e.g. oil separating/filtering equipment and oil content meter. Oil in water concentration must be less than 15 ppm prior to discharge overboard.
  - Oil residue holding tanks.
  - Oil discharge monitoring and control system.
- Sewage and grey water discharges from vessels are regulated by MARPOL 73/78 Annex IV, which specifies the following:
  - Vessels must have a valid International Sewage Pollution Prevention Certificate.

- Vessels must have an onboard sewage treatment plant providing primary settling, chlorination and dechlorination before discharge of treated effluent.
- The discharge depth is variable, depending upon the draught of the seismic vessel / support vessel at the time, but will be in accordance with MARPOL 73/78 Annex IV.
- Discharge of sewage beyond 12 nm requires no treatment. However, sewage effluent must not produce visible floating solids in, nor cause the discolouration of, the surrounding water.
- Sewage must be comminuted and disinfected for discharges between 3 nm (± 6 km) and 12 nm (± 22 km) from the coast. This will require an onboard sewage treatment plant or a sewage comminuting and disinfecting system.
- Disposal of sewage originating from holding tanks must be discharged at a moderate rate while the ship is proceeding on route at a speed not less than 4 knots.

- Sewage will be treated using a marine sanitation device to produce an effluent with:
  - A biological oxygen demand (BOD) of <25 mg/l (if the treatment plant was installed after 1/1/2010) or <50 mg/l (if installed before this date).
  - Minimal residual chlorine concentration of 0.5 mg/l.
  - No visible floating solids or oil and grease.

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

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

Sensitivity of Receptors

The operational waste discharges from the activities described above would primarily take place in the survey area and along the route taken by the support vessels between the survey area and the logistics base in Gqeberha. The survey area is located in the offshore marine environment, more than 20 km offshore at its nearest point, far removed coastal MPAs and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks); however, discharges could still directly affect migratory pelagic species transiting through the survey area. Vessel discharges *en route* to the onshore supply base could result in discharges closer to shore, thereby potentially having an environmental effect on the sensitive coastal environment.

The taxa most vulnerable to waste discharges are pelagic seabirds, turtles, and large migratory pelagic fish and marine mammals. Some of of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles, Leach's storm petrel, and blue whales), 'Endangered' (e.g. African Penguin, Cape Gannet, Atlantic and Indian Yellow-nosed Albatross, Subantarctic skua, whale shark, shortfin mako shark, Indo-Pacific humpack dolphin, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, loggerhead turtles, thresher sharks, great hammerhead shark, dusky shark, great white shark, longfin mako, sperm whale and Bryde's whale) 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

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

Furthermore the survey area is suitably far removed from sensitive coastal receptors and the dominant wind and current direction will ensure that any discharges are rapidly dispersed north-westwards and away from the coast. There is no potential for accumulation of wastes leading to any detectable long-term impact.

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

Other types of wastes generated during the exploration activities will be segregated, duly identified transported to shore for ultimate valorisation and/or disposal at a licensed waste management facility. The disposal of all waste onshore will be fully traceable.

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

Impact Significance

The impacts associated with normal waste discharges from the survey vessel are deemed to be of **VERY LOW** significance, due to the medium sensitivity of the offshore receptors and the very low magnitude.

Identification of Mitigation Measures

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

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

Residual Impact Assessment

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

12	*Impacts of normal vessel discharges on marine fauna*	
Project Phase:	**Mobilisation, Operation and Decommissioning**	
Type of Impact	**Indirect**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	**Very Low**	**Very Low**
Extent	**Regional**	**Regional**
Duration	**Short**	**Short**
Significance	**VERY LOW**	**VERY LOW**
Probability	**Likely**	**Likely**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Very Low**
Cumulative potential	**Unlikely**	**Unlikely**

4.5 Unplanned Events

4.5.1 Faunal Strikes with Project Vessels and Equipment

Source of Impact

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

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

These activities and their associated aspects are described below:

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

Impact Description

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

Project Controls

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

Sensitivity of Receptors

The leatherback and loggerhead turtles that occur in offshore waters around southern Africa, and likely to be encountered in the proposed survey area are considered regionally 'Critically Endangered' and 'Near Threatened', respectively. However, due to their extensive distributions and feeding ranges, the numbers of individuals encountered during the survey are likely to be low. Consequently, the sensitivity of turtles is considered to be **MEDIUM**.

Between 28 and 38 species or sub species/populations of cetaceans (whales and dolphins) are known or likely to occur off the southeast 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 28-38 species, the blue whale is listed as 'Critically Endangered', the fin and sei whales are 'Endangered' and the sperm and Bryde's (offshore) whales are considered 'Vulnerable' (South African Red Data list Categories). Although the survey area is far removed from the coast, the sensitivity of cetaceans to strikes is considered to be **HIGH**.

Impact Magnitude

Ship strikes are globally the biggest threat to large whales, having direct, long-term and population-level consequences (Schoeman *et al*. 2020). Although most scientific publications to date have focussed on collisions between vessel and whales and manatees, there is growing evidence that at least 75 marine species, including smaller whales, dolphins, porpoises, dugongs, manatees, whale sharks, sharks, seals, sea otters, turtles, penguins, and fish are at risk of collision, especially within coastal areas frequented by smaller vessels (reviewed by Schoeman *et al*. 2020). As the proposed 3D survey area is located in a region of very high vessel traffic (see Figure 56), potential collisions between marine fauna and vessels would not be limited to project-specific vessels. Given the slow speed (about 4 - 6 kts) of the vessel while towing the seismic array ship strikes whilst surveying are unlikely, but may occur during the transit of the vessel to or from the survey area. Ship strikes by the chase vessel may also occur.

The physical presence of the survey vessel and increased vessel traffic 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 (Pirotta *et al*. 2019). Any increase in vessel traffic through areas used as calving grounds or through which these species migrate will increase the risk of collision between a whale and a vessel.

The potential for ship strikes of cetaceans is dependent on the abundance and behaviour of cetaceans in the area and vessel speed. For example, Keen *et al*. (2019) modeled fin whale ship strike risk in the California Current System and found that night-time collision risk was twice as high as the daytime risk. Due to their extensive distributions and feeding ranges, the number of cetaceans encountered by project vessels in the offshore environment is expected to be low.The large amount of equipment towed astern of survey vessels also increases the potential for collision with or entrapped in seismic equipment and towed surface floats. Entanglement of cetaceans in gear is possible in situations where tension is lost on the towed array.

Basking turtles are particularly slow to react to approaching objects and may not be able to move rapidly away from approaching airguns. In the past, almost all reported turtle entrapments were associated with the subsurface structures ('undercarriage') of the tail buoys attached to the end of each seismic cable. Towing points are located on the leading edge of each side of the undercarriage, and these are attached by chains to a swivel leading to the end of the seismic cable (Ketos Ecology 2009). Entrapment occurs either as a result of 'startle diving' in front of towed equipment or following foraging on barnacles and other organisms growing along seismic cables and surfacing to breathe immediately in front of the tail buoy (primarily loggerhead and Olive Ridley turtles). In the first case the turtle becomes stuck within the angled gap between the chains and the underside of the buoy, lying on their sides across the top of the chains and underneath the float with their ventral surface facing the oncoming water thereby causing the turtle to be held firmly in position (Figure 57, 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 57, 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.

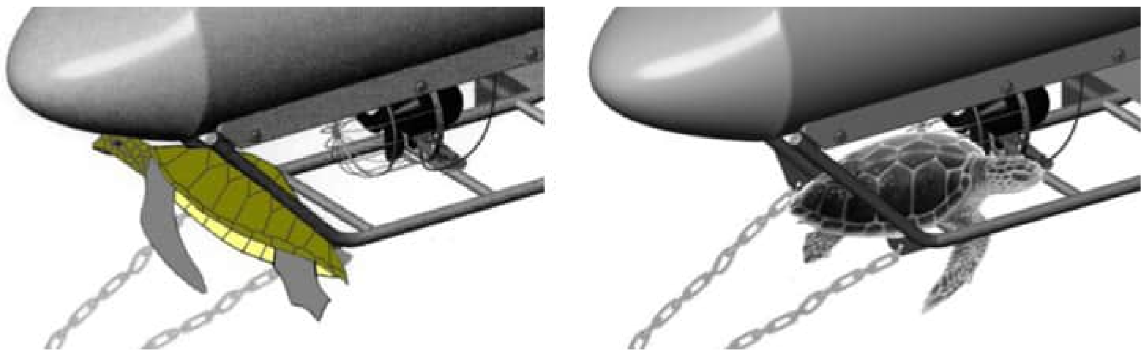


Figure 57: Turtles commonly become trapped in front of the undercarriage of the tail buoy in the area between the buoy and the towing chains (left), and inside the 'twin-fin' undercarriage structure (right) (Ketos Ecology 2009).

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 seismic surveys is expected to be low. Should collisions or entanglements occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL), the potential for collision and entanglement in seismic equipment is therefore considered to be of **VERY LOW** magnitude.

The potential for strikes and entanglement of cetaceans in the towed seismic equipment, is similarly highly dependent on the abundance and behaviour of cetaceans in the survey area at the time of the survey. Due to their extensive distributions and feeding ranges, the number of cetaceans encountered during the proposed seismic surveys is expected to be low. Should entanglements occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole. Furthermore, as the duration of the impact would be limited to the SHORT-TERM (4-5 months) and be restricted to the survey area (REGIONAL), the potential for entanglement in seismic equipment is therefore considered to be of **VERY LOW** magnitude.

Impact Significance

The potential for collision with or entanglement by turtles and cetaceans during the seismic survey or the transit of the vessel to or from the survey area is deemed to be of LOW significance, due to the high sensitivity of the receptors and the low magnitude.

Recommendations for mitigation include:

No.	Mitigation measure	Classification
1	The vessel operators should keep a constant watch for marine mammals and turtles in the path of the vessel.	Avoid
2	Keep watch for marine mammals behind the vessel when tension is lost on the towed equipment and either retrieve or regain tension on towed gear as rapidly as possible.	Avoid
3	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Abate on site
4	Ensure vessel transit speed between the survey area and port is a maximum of 12 knots (22 km/hr), except in the MPA where it is reduced further to 10 knots (18 km/hr) as well as when they are present in the vicinity.	Avoid/reduce at source

Monitoring

Should a collision with a large whale occur, the event must be reported to the IWC database, which has been shown to be a valuable tool for identifying the species most affected, vessels involved in collisions, and correlations between vessel speed and collision risk (Jensen & Silber 2003).

Residual Impact Assessment

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

13	*Impacts on turtles and cetaceans due to ship strikes, collision and entanglement with towed equipment*	
Project Phase:	**Mobilisation, Operation & Decommissioning**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**VERY LOW**	**VERY LOW**
Intensity	Low	Very Low
Extent	Regional	Regional
Duration	Short	Short
Significance	**LOW**	**LOW**
Probability	Unlikely	Unlikely
Confidence	High	High
Reversibility	Fully Reversible	Fully Reversible
Loss of Resources	Low	Low
Mitigation Potential	-	Low
Cumulative potential	Unlikely	Unlikely

4.5.2 Accidental Loss of Equipment

Source of Impact

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

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

These activities and their associated aspects are described further below:

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

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

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

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

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

Impact Description

The potential impacts associated with lost equipment include:

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

Project Controls

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

Sensitivity of Receptors

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

Lost equipment could also pose an entanglement risk to migratory turtles and cetaceans transiting through the survey area. The taxa most vulnerable to entanglement in lost equipment are turtles and marine mammals. Some of of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. southern bluefin tuna, leatherback turtles, Leach's storm petrel, and blue whales), 'Endangered' (e.g. African Penguin, Cape Gannet, Atlantic and Indian Yellow-nosed Albatross, Subantarctic skua, whale shark, dusky shark, great hammerhead shark, shortfin mako shark, longfin mako, Indo-Pacific humpack dolphin, fin and sei whales), 'Vulnerable' (e.g. bigeye tuna, blue marlin, sailfish, loggerhead turtles, thresher sharks, great white shark, sperm whale and Bryde's whale) or 'Near Threatened' (e.g. striped marlin, blue shark, longfin tuna/albacore and yellowfin tuna). In addition, due to their extensive distributions their numbers are expected to be low. Based on the low numbers of listed species, the sensitivity is considered to be MEDIUM.

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

Impact Magnitude

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

Impact Significance

The impacts associated with the accidental loss of equipment are deemed to be of **VERY LOW** significance, due to the medium sensitivity of the offshore receptors and the very low magnitude.

Identification of Mitigation Measures

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

No.	Mitigation measure	Classification
1	Ensuring that loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system.	Avoid
2	Minimise the lifting path between vessels	Avoid
3	Undertake frequent checks to ensure items and equipment are stored and secured safely on board each vessel.	Avoid
4	In the event that equipment is lost during the operational stage, assess safety and metocean conditions before performing any retrieval operations. Establishing a hazards database listing the type of gear left on the seabed and/or in the licence area with the dates of abandonment/loss and locations, and where applicable, the dates of retrieval	Repair/restore

Residual Impact Assessment

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

14	*Impacts on benthic and pelagic fauna due to accidental loss of equipment to the seabed or the water column*	
Project Phase:	Operation	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	Medium	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	VERY LOW	VERY LOW
Intensity	**Low**	**Very Low**
Extent	**Local**	**Local**
Duration	**Short**	**Short**
Significance	**VERY LOW**	**VERY LOW**
Probability	**Unlikely**	**Unlikely**
Confidence	**High**	**High**
Reversibility	**Fully Reversible to Partially Reversible**	**Fully Reversible to Partially Reversible**
Loss of Resources	**Low**	**Low**
Mitigation Potential	**-**	**Low**
Cumulative potential	**Unlikely**	**Unlikely**

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

Source of Impact

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

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

These activities and their associated aspects are described further below:

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

Impact Description

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

Project Controls

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

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

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

Regulation 37 of MARPOL Annex I will be applied, which requires that all ships of 400 gross tonnage and above carry an approved Shipboard Oil Pollution Emergency Plan (SOPEP). The purpose of a SOPEP is to assist personnel in dealing with unexpected discharge of oil, to set in motion the necessary actions to stop or minimise the discharge, and to mitigate its effects on the marine environment.

As standard practice, an Emergency Response Plan (ERP) / Evacuation Plan will be prepared and put in place. A Medical Evacuation Plan (Medevac Plan) will form part of the ERP.

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

Sensitivity of Receptors

Accidental spills and loss of marine diesel during bunkering or in the event of a vessel collision could take place in the survey area and along the route taken by the survey and support vessels between the survey area and the logistics base at Gqeberha. The survey area is located in the offshore marine environment, more than 20 km offshore at its closest point, far removed from coastal MPAs and any sensitive coastal receptors (e.g. key faunal breeding/feeding areas, bird or seal colonies and nursery areas for commercial fish stocks); however, discharges could still directly affect migratory pelagic species transiting through the survey area. Diesel spills or accidents en route to the onshore supply base could result in fuel loss closer to shore, thereby potentially having Oil or diesel spilled in the marine environment will have an immediate detrimental effect on water quality. Being highly toxic, marine diesel released during an operational spill would negatively affect any marine fauna it comes into contact with. The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring in the survey area, are considered regionally or globally 'Critically Endangered' (e.g. Tristan Albatross, Cape Gannet) or

'Endangered' (e.g. Atlantic and Indian Yellow-nosed Albatross, Subantarctic skua, African Penguin, Bank and Cape Cormorant) or 'Vulnerable' (e.g. Hartlaub's Gull, Swift Tern). The sensitivity of marine fauna to diesel spill is thus considered to be HIGH.

Impact Magnitude

Various factors determine the impacts of oil released into the marine environment. The physical properties and chemical composition of the oil, local weather and sea state conditions and currents greatly influence the transport and fate of the released product. The physical properties that affect the behaviour and persistence of an oil spilled at sea are specific gravity, distillation characteristics, viscosity and pour point, all of which are dependent on the oils chemical composition (e.g. the amount of asphaltenes, resins and waxes). Spilled oil undergoes physical and chemical changes (collectively termed 'weathering'), which in combination with its physical transport, determine the spatial extent of oil contamination and the degree to which the environment will be exposed to the toxic constituents of the released product.

As soon as oil is spilled, various weathering processes come into play. Although the individual processes may act simultaneously, their relative importance varies with time. Whereas spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill, the ultimate fate of oil is determined by the longer term processes of oxidation, sedimentation and biodegradation.

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

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

The consequences and effects of small (2 000 – 20 000 litres) diesel fuel spills into the marine environment are summarised below (NOAA 1998). Diesel is a light oil that, when spilled on water, spreads very quickly to a thin film and evaporates or naturally disperses within a few days or less, even in cold water. Diesel oil can be physically mixed into the water column by wave action, where it adheres to fine-grained suspended sediments, which can subsequently settle out on the seafloor. As it is not very sticky or viscous, diesel tends to penetrate porous sediments quickly, but also to be washed off quickly by waves and tidal flushing. In the case of a coastal spill, shoreline cleanup is thus usually not needed. Diesel oil is degraded by naturally occurring microbes within one to two months. Nonetheless, in terms of toxicity to marine organisms, diesel is considered to be one of the most acutely toxic oil types. Many of the compounds in petroleum products are known to smother organisms, lower fertility and cause disease. Intertidal invertebrates and seaweed that come in direct contact with a diesel spill may be killed. Fish kills, however, have never been reported for small spills in open water as the diesel dilutes so rapidly. Due to differential uptake and elimination rates, filter-feeders (particularly mussels) can bio-accumulate hydrocarbon contaminants. Crabs and shellfish can be tainted from small diesel spills in shallow, nearshore areas.

Chronic and acute oil pollution is a significant threat to both pelagic and inshore seabirds. Diving sea birds that spend most of their time on the surface of the water are particularly likely to encounter floating oil and will die as a result of even moderate oiling which damages plumage and eyes. The majority of associated deaths are as a result of the properties of the oil and damage to the water repellent properties of the birds' plumage. This allows water to penetrate the plumage, decreasing buoyancy and leading to sinking and drowning. In addition, thermal insulation capacity is reduced requiring greater use of energy to combat cold.

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

The effects of oil pollution on marine mammals is poorly understood (White *et al.* 2001), with the most likely immediate impact of an oil spill on cetaceans being the risk of inhalation of volatile, toxic benzene fractions when the oil slick is fresh and unweathered (Geraci & St Aubin 1990, cited in Scholz *et al.* 1992). Common effects attributable to the inhalation of such compounds include absorption into the circulatory system and mild irritation to permanent damage to sensitive tissues such as membranes of eyes, mouth and respiratory tract. Direct oiling of cetaceans is not considered a serious risk to the thermoregulatory capabilities, as cetacean skin is thought to contain a resistant dermal shield that acts as a barrier to the toxic substances in oil. Baleen whales may experience fouling of the baleen plates, resulting in temporary obstruction of the flow of water between the plates and, consequently, reduce feeding efficiency. Field observations record few, if any, adverse effects among cetaceans from direct contact with oil, and some species have been recorded swimming, feeding and surfacing amongst heavy concentrations of oil (Scholz *et al.* 1992) with no apparent effects.

In the unlikely event of an operational spill or vessel collision, the magnitude of the impact would depend on whether the spill occurred in offshore waters where encounters with pelagic seabirds, turtles and marine mammals would be low due to their extensive distribution ranges, or whether the spill occurred closer to the shore where encounters with sensitive receptors will be higher. Based on the results of the oil spill modelling undertaken in a portion of Block 11b/12b that falls within the Reconnaissance Permit Area (HES 2019) a diesel slick would be blown as a narrow plume extending in a south-westerly direction. The diesel would most likely remain at the surface for a number of days (5 days) with a negligible probability of reaching sensitive coastal habitats. In offshore environments, impacts associated with a spill or vessel collision would thus be of LOW intensity, REGIONAL (depending on the nature of the spill) over the short-term (<5 days). The impact magnitude for a marine diesel spill is therefore considered **VERY LOW**.

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

<u>Impact Significance</u>

Based on the high sensitivity of receptors and the very low (offshore) and medium magnitude (nearshore), the potential impact on the marine fauna is considered to range from **LOW** significance (offshore) to **MEDIUM** significance (nearshore) without mitigation

Identification of Mitigation Measures

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

No.	Mitigation measure	Classification
1	Use low toxicity dispersants cautiously and only with the permission of DEAT.	Abate on and off site
2	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
3	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
4	Ensure offshore bunkering is not undertake in the following circumstances: – Wind force and sea state conditions of ≥6 on the Beaufort Wind Scale; – During any workboat or mobilisation boat operations; – During helicopter operations; – During the transfer of in-sea equipment; and – At night or times of low visibility.	Avoid / Reduce at source

Residual Impact Assessment

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

15	*Impacts of an operational spill or collision on marine fauna*	
Project Phase:	**(Seismic Exploration)**	
Type of Impact	**Direct**	
Nature of Impact	**Negative**	
Sensitivity of Receptor	High	
	Pre-Mitigation Impact	**Residual Impact**
Magnitude/Consequence	**MEDIUM**	**VERY LOW**
Intensity	**Low to High***	**Low**
Extent	**Regional**	**Local**
Duration	**Short**	**Short**
Significance	**MEDIUM**	**LOW**
Probability	**Unlikely**	**Unlikely**
Confidence	**High**	**High**
Reversibility	**Fully Reversible**	**Fully Reversible**
Loss of Resources	**Low to Medium***	**Low**
Mitigation Potential	**Medium**	**Medium**
Cumulative potential	**Unlikely**	**Unlikely**

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

4.6 Confounding Effects and Cumulative Impacts

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

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

While it is foreseeable that further exploration and future production activities could arise if the current Reconnaissance Permit is granted, there is not currently sufficient information available to make reasonable assertions as to nature of such future activities. This is primarily due to the current lack of relevant geological information, which the proposed exploration process aims to address. While there are many other rights holders in the South African offshore environment, most of these are not undertaking any exploration activities at present or would be concurrently with the proposed CGG survey. Thus, the possible range of the future prospecting, mining, exploration and production activities that could arise will vary significantly in scope, location, extent, and duration depending on whether a resource(s) is discovered, its size, properties and location, etc. As these cannot at this stage be reasonably defined, it is not possible to undertake a reliable assessment of the potential cumulative environmental impacts. It is also possible that the proposed, or future, exploration fails to identify an economic petroleum resource, in which case the potential impacts associated with the production phase would not be realised.

Furthermore, the assessment methodology used in the Basic Assessment by its nature already considers past and current activities and impacts. In particular, when rating the sensitivity of the receptors, the status of the receiving environment (benthic ecosystem threat status, protection level, protected areas, etc.) or threat status of individual species is taken into consideration, which is based to some degree on past and current actions and impacts (e.g. the IUCN conservation rating is determined based on criteria such as population size and rate of decline, area of geographic range / distribution, and degree of population and distribution fragmentation). The environment in and around the Reconnaissance Permit Area is by no means pristine, with most of the Southwest Indian Unidentified Slope habitat being considered moderately modified, and the Agulhas rocky and sandy shelf habitats in the shallower portions of the Reconnaissance Permit Area considered severely to very severely modified due primarily to commercial demersal trawling (Figure 58, top). Furthermore, based the intensity of all cumulative pressures and the sensitivity of the underlying ecosystem types to each of those pressures, Sink *et al*. (2019) identified that the marine biodiversity in the proposed project area has experienced high cumulative impacts (Figure 58, bottom). Thus, past and existing offshore activities (including shipping, prospecting, exploration, production, commercial fishing, etc.) have been taken into account in the assessment of potential cumulative impacts related to the proposed project

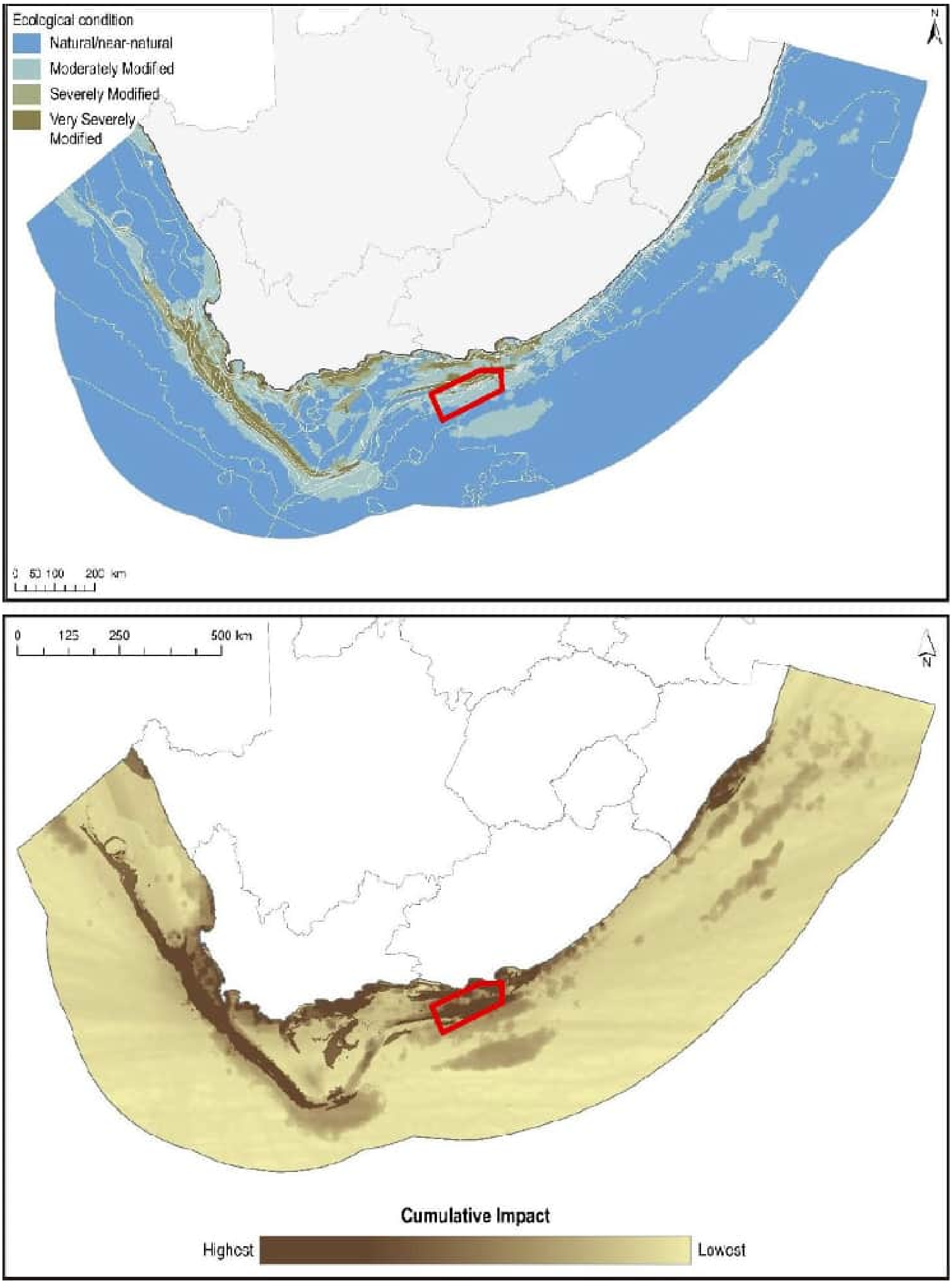


Figure 58: The Reconnaissance Permit Area (red polygon) in relation to ecological condition of the marine realm (top) and cumulative impacts on marine biodiversity (bottom), based on the intensity of all cumulative pressures and the sensitivity of the underlying ecosystem types to each of those pressures (adapted from Sink *et al*. 2019).

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

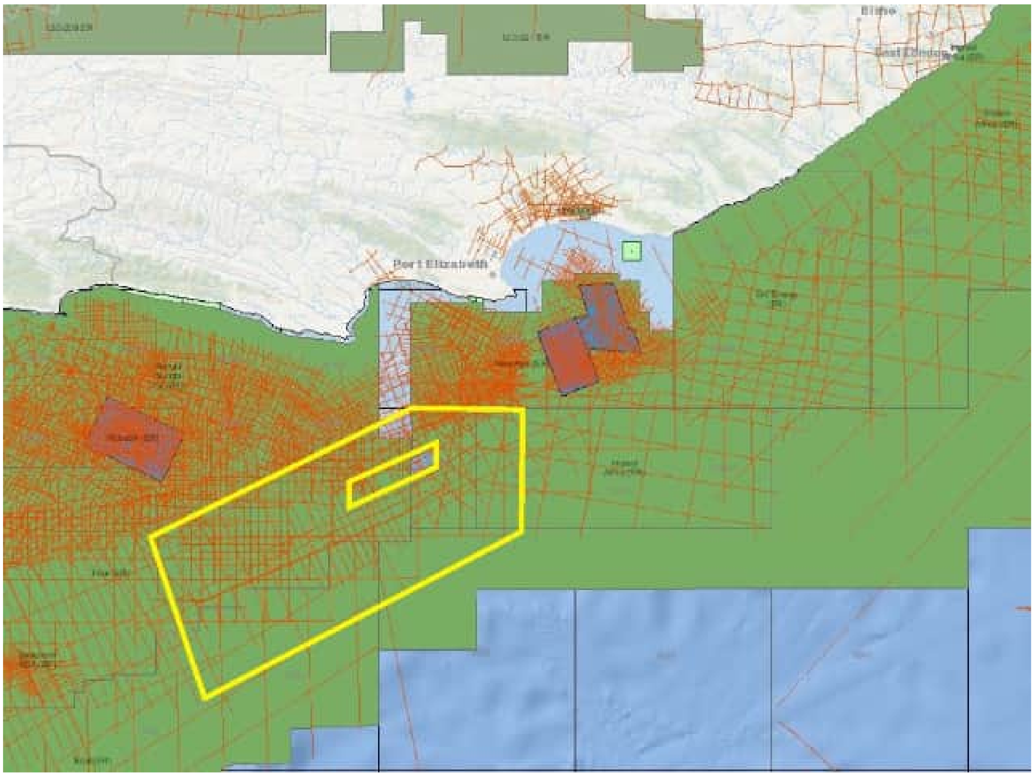


Figure 59: The Reconnaissance Permit Area (yellow polygon) in relation to historical 2D (red lines) and 3D (blue and purple polygons) surveys conducted on the southeast coast between 2001 and 2018 (Source: PASA).

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 southeast coast is illustrated in

Figure **59**, which shows the 2D survey lines shot between 2001 and 2018, and indicates 3D survey areas on the South 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.

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.

Noise, operational lighting and waste discharges associated with the proposed exploration programme would also have cumulative impact on marine fauna. Due to the licence area being located within the main vessel traffic routes that pass around southern Africa, ambient noise levels are naturally elevated. Sensitive receptors and faunal species (cetaceans, turtles and certain fish) are unlikely to be significantly affected as faunal **behaviour** will not be affected beyond 4.4 km during seismic acquisition. Noise levels would return back to ambient after operations are complete.

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

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

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

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; Simmonds *et al*. 2014; Williams *et al*. 2015; Chahouri *et al*. 2021). Furthermore, by applying the avoidance option (from the Mitigation Hierarchy), CGG will actively avoid and reduce potential impact on the MPA and its sensitive deep-water reef habitats and their associated faunal communities.

Although cumulative impacts from other hydrocarbon ventures in the area may increase in future, the cumulative impacts of the proposed seismic survey on the eastern Agulhas Shelf edge can be considered of **LOW** significance.

5. FINDINGS AND RECOMMENDATIONS

5.1 Key Findings

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

A summary of impacts and mitigation measures of seismic noise on marine fauna is provided in Table 16. Other impacts that may occur during seismic surveys are summarised in

Table **17**.

Table 16: Summary of the impacts and mitigation of seismic noise.

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

Table 17: Summary of other impacts and mitigation of seismic surveys.

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

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 southeast 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 & Dolman (2007), Compton *et al.* (2007), US Department of Interior (2007), Reyes Reyes *et al.* (2016), Vilardo & Barbosa (2018), Bröker *et al.* (2015) and Bröker (2019). 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) and by Purdon (2018). Purdon (2018) highlights the importance of developing mitigation guidelines both locally and regionally and points out that if South Africa is to maintain environmental integrity, mitigation guidelines for seismic surveys specific to the country, and based on the most recent scientific data, need to be implemented.

These have been updated as necessary to include salient points from recognised international guidelines, particularly the JNCC (2010, 2017) Guidelines and the 2013 New Zealand Code of Conduct for seismic operations (New Zealand Dept. of Conservation 2013).

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

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

No.	Mitigation measure	Classification
1. Survey Planning		
1.1	Plan seismic surveys to avoid sensitive periods for some marine fauna: • 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). • Spawning of threatened fish species in spring and early summer. • Peak squid spawning periods between early September and late December.	Avoid
1.2	Plan survey, as far as possible, so that the first commencement of airgun firing in a new area (including gun tests) is undertaken during daylight hours.	Abate on site
1.3	Prohibit airgun use (including airgun tests) outside of the licence area.	Avoid
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
1.5	A 1 km buffer zone where no airgun operation is permitted is recommended around all MPAs	Avoid
2. Key Equipment		
2.1	**Passive Acoustic Monitoring (PAM)**	
2.1.1	Ensure the seismic vessel is fitted with Passive Acoustic Monitoring (PAM) technology, which detects some animals through their vocalisations.	Abate on site
2.1.2	As the survey area would largely be in waters deeper than 1 000 m where sperm whales and other deep-diving odontocetes are likely to be encountered, implement the use of PAM 24-hr a day when the airgun is in operation.	Abate on site
2.1.3	Ensure that the PAM hydrophone streamer is towed in such a way that the interference of vessel noise is minimised.	Abate on site
2.1.4	Ensure the PAM streamer is fitted with at least four hydrophones, of which two are HF and two LF, to allow directional detection of cetaceans.	Abate on site
2.1.5	Ensure spare PAM hydrophone streamers (e.g. 4 heavy tow cables and 6 hydrophone cables) are readily available in the event that PAM breaks down, in order to ensure timeous redeployment.	Abate on site
2.2	**Acoustic Source**	
2.2.1	Define and enforce the use of the lowest practicable airgun volume for production, and design arrays to maximise downward propagation, minimise horizontal propagation and minimise high frequencies in airgun pulses.	Abate on site
2.2.2	Ensure a display screen for the acoustic source operations is provided to the marine observers. All information relating to the activation of the acoustic source and the power output levels must be readily available to support the observers in real time via the display screen and to ensure that operational capacity is not exceeded.	Abate on site
2.2.3	Ensure the ramp-up noise volumes do not exceed the production volume.	Abate on site
2.2	**Streamers**	
2.2.1	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Abate on site
2.2.2	Ensure that solid streamers rather than fluid-filled streamers are used to avoid leaks.	Avoid

No.	Mitigation measure	Classification
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; – 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.	Abate on site

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

No.	Mitigation measure	Classification
5.3	Delay "soft-starts" if penguins or feeding aggregations of diving seabirds, shoaling large pelagic fish, turtles, seals or cetaceans are observed within the mitigation zone. • A "soft-start" should not begin until 30 minutes after cetaceans depart the 500 m mitigation zone or 30 minutes after they are last seen or acoustically detected by PAM in the mitigation zone. • In the case of penguins, diving seabirds, shoaling large pelagic fish and turtles, delay the "soft-start" until animals are outside the 500 m mitigation zone. • In the case of fur seals, which may occur commonly around the vessel, delay "soft-starts" for at least 10 minutes until it has been confirmed that the mitigation zone is clear of all seal activity. However, if after a period of 10 mins seals are still observed within 500 m of the airgun, the normal "soft-start" procedure should be allowed to commence for at least a 20-minute duration. Seal activity should be carefully monitored during "soft-starts" to determine if they display any obvious negative responses to the airgun and gear or if there are any signs of injury or mortality as a direct result of the seismic activities.	Avoid / Abate on site
5.4	As noted above for planning, when arriving at the survey area for the first time, survey activities should, as far as possible, only commence during daylight hours with good visibility. 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; and • The power is increased and the SPI is decreased in uniform stages during the final 10 minutes of the line change (or geophone repositioning), prior to data collection re-commencing (i.e. a form of mini soft start). • Normal MMO and PAM observations continue during this period when reduced power airgun is firing.	Abate on site

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

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

Vessel and Aircraft Operations

No.	Mitigation measure	Classification
1	Pre-plan flight paths to ensure that no flying occurs over the Algoa Bay Islands seal colonies	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	Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals	Avoid
5	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
6	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
7	Avoid the unnecessary discharge of ballast water.	Reduce at source
8	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
9	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
10	Ensure all equipment (e.g. arrays, streamers, tail buoys etc) that has been used in other regions is thoroughly cleaned prior to deployment	Avoid/Reduce at Source
11	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

No.	Mitigation measure	Classification
12	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid/Reduce at Source
13	Use a low-toxicity biodegradable detergent for the cleaning of all deck spillages.	Reduce at Source
14	The vessel operators should keep a constant watch for marine mammals and turtles in the path of the vessel.	Avoid
15	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
16	Ensure that 'turtle-friendly' tail buoys are used by the survey contractor or that existing tail buoys are fitted with either exclusion or deflector 'turtle guards'.	Avoid
17	Ensure vessel transit speed between the survey area and port is a maximum of 12 knots (22 km/hr), except in MPAs where it is reduced further to 10 knots (18 km/hr) as well as when they are present in the vicinity.	Avoid/reduce at source
18	Ensuring that loads are lifted using the correct lifting procedure and within the maximum lifting capacity of crane system.	Avoid
19	Minimise the lifting path between vessels	Avoid
20	Undertake frequent checks to ensure items and equipment are stored and secured safely on board each vessel.	Avoid
21	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
22	Use low toxicity dispersants cautiously and only with the permission of MET/MFMR.	Abate on and off site
23	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
24	Ensure adequate resources are provided to collect and transport oiled birds to a cleaning station.	Restore
25	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

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APPENDIX 1: METHOD FOR ASSESSING IMPACT SIGNIFICANCE

Term	Definition
Nature of Impact	The direction of impact and whether it leads to an adverse effect (negative), beneficial effect (positive) or no effect (neutral)
Positive	An impact that is considered to represent an improvement to the baseline conditions or introduces a positive change to a receptor.
Negative	An impact that is considered to represent an adverse change from the baseline conditions or receptor, or introduces a new adverse effect.
Neutral	An impact that has no or negligible effect on the receptor.
Type	Cause and effect relationship between the project activity and the nature of effect on receptor
Direct	Impacts that result from a direct interaction between a proposed project activity and the receiving environment (e.g. effluent discharge and receiving water quality). Sometimes referred to as primary impacts.
Indirect	Impacts that are not a direct result of a proposed project, often produced away from or as a result of a complex impact pathway. Sometimes referred to as secondary impacts.
Induced	A type of indirect impact resulting from factors or activities caused by the presence of the Project but which are not always planned or expected (e.g. human in-migration along new access or for jobs creating increased demand on resources).
Residual	The impacts that remain after implementation of the project and all associated mitigation and other environmental management measures.

Definitions of Impact Assessment Criteria and Categories Applied

Definitions of the criteria used in assessing impact significance and the assigned categories, and the additional criteria used to describe the impacts, are summarised in the table below.

Criterion	Definition	Categories
Sensitivity	Sensitivity is a rating given to the importance and/ or vulnerability of a receptor (e.g. conservation value of a biodiversity feature or cultural heritage resource or social receptor.	Very Low Low Medium High Very High
Magnitude (or consequence)	A term describing the actual change predicted to occur to a resource or receptor caused by an action or activity or linked effect. It is derived from a combination of Intensity, Extent and Duration and takes into account scale, frequency and degree of reversibility	Very Low Low Medium High Very High
Intensity	A descriptor for the degree of change an impact is likely to have on the receptor which takes into account scale and frequency of occurrence.	Very Low Low Medium High

Criterion	Definition	Categories
Extent	The spatial scale over which the impact will occur.	Site Local National Regional International /Transboundary
Duration	Time scale over which the consequence of the effect on the receptor/s will last. [Note that this does not apply to the duration of the project activity]. The terms 'Intermittent' and 'Temporary' may be used to describe the duration of an impact.	Short-term Medium-term Long-term Permanent
Probability	A descriptor for the likelihood of the impact occurring. Most assessed impacts are likely to occur but Probability is typically used to qualify and contextualise the significance of unplanned events or major accidents.	Unlikely Possible Likely Highly Likely Definite
Confidence	A descriptor for the degree of confidence in the evaluation of impact significance.	Low Medium High Certain
Mitigation potential	A descriptor for the degree to which the impact can be mitigated to an acceptable level.	None Very Low Low Medium High
Loss of Irreplaceable resources	A descriptor for the degree to which irreplaceable resources will be lost, fragmented or damaged.	Low Medium High
Reversibility	A descriptor for the degree to which an impact can be reversed.	Irreversible Partially Reversible Fully Reversible
Cumulative	A descriptor of the potential for an impact to have cumulative impacts to arise.	Unlikely Possible Likely

Determination of Sensitivity

Sensitivity is a term that covers the 'importance' (e.g. value of an ecological receptor or heritage resource) or 'Vulnerability' (e.g. ability of a social receptor to cope with change) of a receptor to a project-induced change. It takes into account 'Irreplaceability' - measure of the value of, and level of dependence on, impacted resources to society and/ or local communities, as well as of consistency with policy (e.g. conservation) targets or thresholds.

Broad definitions of sensitivity ratings for social, ecological and physical/abiotic receptors are defined below. These are not exhaustive and may be modified on a case by case basis, as appropriate. Additional ratings can be developed for other receptors such as cultural heritage.

Sensitivity Rating	Definition
Ecological Receptor	Species, habitats or ecosystems including processes necessary to maintain ecosystem functions
Very Low	Species or habitats with negligible importance for biodiversity including habitats that are largely transformed or highly modified.
Low	Species or habitats listed as Least Concern (LC) on the International Union for Conservation of Nature (IUCN) Red List or on regional or national Red Lists and/or habitats or species which are common and widespread, of low conservation interest, or habitats which are degraded and qualify as 'modified habitat' under international definitions (e.g. IFC or World Bank standards).
Medium	Species, habitats or ecosystems listed as globally Vulnerable (VU) or Near Threatened (NT) on IUCN Red List; or listed as VU or NT on national or regional Red Lists, or which meet the IUCN criteria based on expert-driven biodiversity planning processes. It includes habitats that meet definitions of 'natural habitat'; or ecosystems with important functional value in maintaining the biotic integrity of these habitats or VU or NT species.

Sensitivity Rating	Definition
High	Species, habitats or ecosystems listed as globally Endangered (EN) or Critically Endangered (CR) by IUCN, or listed as EN/CR on national or regional Red Lists; or which meet IUCN criteria for range-restricted species[3] or which meet the definition of migratory and congregatory species[4], but which do not qualify as Critical Habitat based on IUCN Key Biodiversity Area thresholds[5]. It includes habitats or ecosystems which are important for meeting national conservation targets based on expert-driven national or regional systematic conservation planning processes, but which do not meet global IUCN thresholds. It can also include protected areas such as national parks, marine protected areas or ecological support areas designated for biodiversity protection containing species that are nationally or globally listed as EN or CR, or other designated areas important for the persistence of EN/CR species or habitats.
Very High	Species, habitats or ecosystems listed as globally Endangered (EN) or Critically Endangered (CR) by IUCN, or listed as EN/CR on expert-verified national or regional Red Lists; or which meet IUCN criteria for range-restricted or migratory /congregatory species and which meet IUCN thresholds for Key Biodiversity Areas. It includes habitats or ecosystems which are of high importance for maintaining the persistence of species or habitats that meet critical habitat thresholds. Habitats of high sensitivity may typically include legally protected areas that meet IUCN categories 1, 1a and 1b[6], or KBAs or Important Bird Areas (IBAs) with biodiversity features that meet the IUCN KBA criteria and thresholds.
Physical Abiotic Receptors	**Water quality, sediment quality, air quality, noise levels**

[3] Restricted range species are those with limited Extent Of Occurrence (EOO) (GN74):

- For terrestrial vertebrates and plants, a restricted-range species is defined as those species that have an EOO < 50 000 square kilometres (km^2).
- For marine systems, restricted-range species are provisionally being considered those with an EOO of <100 000 km^2.
- For coastal, riverine, and other aquatic species in habitats that do not exceed 200 km width at any point (for example, rivers), restricted range is defined as having a global range of less than or equal to 500 km linear geographic span (i.e., the distance between occupied locations furthest apart)

[4] Migratory species are defined as any species of which a significant proportion of its members cyclically and predictably move from one geographical area to another (including within the same ecosystem) (GN76). Congregatory species are defined as species whose individuals gather in large groups on a cyclical or otherwise regular and/or predictable basis.

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

[6] IUCN, "Protected Areas Category", https://www.iucn.org/theme/protected-areas/about/protected-area-categories

Sensitivity Rating	Definition
Very Low	Receptors are highly resilient to project-induced change and changes remain undetectable and within any applicable thresholds.
Low	Receptors are resilient to project-induced change and changes, while detectable, are within the range of natural variation and remain within any applicable thresholds.
Medium	Receptors are moderately resilient to project-induced changes, but these changes are easily detectable, exceed the limit of the normal range of variation on an intermittent basis and / or periodically exceed applicable thresholds.
High	Receptors are vulnerable to project-induced change and changes are readily detectable, well outside the range of natural variation or occurrence, and regularly exceed any applicable thresholds.
Very High	Receptors are highly vulnerable to project-induced change and changes are easily detectable, fall well outside the range of natural variation or occurrence, and will continually exceed any applicable thresholds.

Determination of Magnitude (or Consequence)

The term 'magnitude' (or 'consequence') describes and encompasses all the dimensions of the predicted impact including:

- the nature of the change (what is affected and how);
- its size, scale or intensity;
- degree of reversibility; and
- its geographical extent and distribution.

Taking the above into account, Magnitude (or consequence) is derived from a combination of 'Intensity', 'Duration' and 'Extent'.

The criteria for deriving Intensity, Extent and Duration are summarised below.

Criteria	Rating	Description
Criteria for ranking of the INTENSITY of environmental impacts taking into account reversibility and scale	**VERY LOW**	Negligible change, disturbance or nuisance which is barely noticeable or may have minimal effect on receptors or affect a tiny proportion of the receptors.
	LOW	Minor (Slight) change, disturbance or nuisance which is easily tolerated and/or reversible in the short term without intervention, or which may affect a small proportion of receptors.
	MEDIUM	Moderate change, disturbance or discomfort caused to receptors or which is reversible over the medium term, and/or which may affect a moderate proportion of receptors.
	HIGH	Prominent change, or large degree of modification, disturbance or degradation caused to receptors or which may affect a large proportion of receptors, possibly entire species or community and which is not easily reversed.
Criteria for ranking the EXTENT / SPATIAL SCALE of impacts	**SITE**	Impact is limited to the immediate footprint of the activity and immediate surrounds within a confined area.
	LOCAL	Impact is confined to within the project concession / licence area and its nearby surroundings.
	REGIONAL	Impact is confined to the region, e.g. coast, basin, catchment, municipal region, district, etc.
	NATIONAL	Impact may extend beyond district or regional boundaries with national implications.
	INTERNATIONAL	Impact extends beyond the national scale or may be transboundary.
Criteria for ranking the DURATION of impacts	**SHORT TERM**	The duration of the impact will be < 1 year or may be intermittent.
	MEDIUM TERM	The duration of the impact will be 1-5 years.
	LONG TERM	The duration of the impact will be 5-25 years, but where the impact will eventually cease either because of natural processes or by human intervention.
	PERMANENT	The impact will endure for the reasonably foreseeable future (>25 years) and where recovery is not possible either by natural processes or by human intervention.

Determining Magnitude (or consequence)Ratings

Once the intensity, extent and duration are defined based on the definitions set out above, the magnitude (or consequence) of negative and positive impacts is derived based on the table below. It should be noted that there may be times when these definitions may need to be adjusted to suit the specific impact where justification should be provided. For instance, the permanent loss of the only known occurrence of a species in a localised area of impact can only achieve a "High" magnitude rating but could, in this instance, warrant a Very High rating. The justification for amending the rating should be indicated in the impact table.

Magnitude/Consequence Rating	Description
VERY HIGH	Impacts could be EITHER: of ***high intensity*** at a ***regional level*** and endure in the ***long term***; OR of ***high intensity*** at a ***national level*** in the ***medium or long term***; OR of ***medium intensity*** at a ***national level*** in the ***long term***.
HIGH	Impacts could be EITHER: of ***high intensity*** at a ***regional level*** and endure in the ***medium term***; OR of ***high intensity*** at a ***national level*** in the ***short term***; OR of ***medium intensity*** at a ***national level*** in the ***medium term***; OR of ***low intensity*** at a ***national level*** in the ***long term***; OR of ***high intensity*** at a ***local level*** in the ***long term***; OR of ***medium intensity*** at a ***regional level*** in the ***long term***.
MEDIUM	Impacts could be EITHER: of ***high intensity*** at a ***local level*** and endure in the ***medium term***; OR of ***medium intensity*** at a ***regional level*** in the ***medium term***; OR of ***high intensity*** at a ***regional level*** in the ***short term***; OR of ***medium intensity*** at a ***national level*** in the ***short term***; OR of ***medium intensity*** at a ***local level*** in the ***long term***; OR of ***low intensity*** at a ***national level*** in the ***medium term***; OR of ***low intensity*** at a ***regional level*** in the ***long term***.
LOW	Impacts could be EITHER of ***low intensity*** at a ***regional level*** and endure in the ***medium term***; OR of ***low intensity*** at a ***national level*** in the ***short term***; OR of ***high intensity*** at a ***local level*** and endure in the ***short term***; OR of ***medium intensity*** at a ***regional level*** in the ***short term***; OR of ***low intensity*** at a ***local level*** in the ***long term***; OR of ***medium intensity*** at a ***local level*** and endure in the ***medium term***.
VERY LOW	Impacts could be EITHER of ***low intensity*** at a ***local level*** and endure in the ***medium term***; OR of ***low intensity*** at a ***regional level*** and endure in the ***short term***; OR of ***low or medium intensity*** at a ***local level*** and endure in the ***short term***. OR **Zero to very low *intensity*** with any combination of extent and duration.

Determination of Impact Significance

The significance of an impact is based on expert judgement of the sensitivity (importance or vulnerability) of a receptor and the magnitude (or consequence) of the effect that will be caused by a project-induced change.

In summary, the impact assessment method is based on the following approach:

Significance = Magnitude x Sensitivity

Where Magnitude = Intensity +Extent + Duration

Once ratings are applied to each of these parameters the following matrix is used to derive Significance:

		SENSITIVITY				
		VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
MAGNITUDE (or CONSEQUENCE)	VERY LOW	NEGLIGIBLE	NEGLIGIBLE	VERY LOW	LOW	LOW
	LOW	VERY LOW	VERY LOW	LOW	LOW	MEDIUM
	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	HIGH
	HIGH	MEDIUM	MEDIUM	HIGH	HIGH	VERY HIGH
	VERY HIGH	HIGH	HIGH	HIGH	VERY HIGH	VERY HIGH

Broad definitions of impact significance ratings are provided in the table below. Impacts of 'High' and 'Very High' significance require careful evaluation during decision-making and need to be weighed up against potential long-term socioeconomic benefits of the project to inform project authorisation. Where there are residual biodiversity impacts of 'High' and 'Very High' significance this will require careful examination of offset feasibility and confirmation that an offset is possible prior to decision-making.

Significance Rating	Interpretation
Very High	**Impacts** where an accepted limit or standard is far exceeded, changes are well outside the range of normal variation, or where long-term to permanent impacts of large magnitude (or consequence) occur to highly sensitive resources or receptors. For **adverse residual impacts** of very high significance, there is no possible further feasible mitigation that could reduce the impact to an acceptable level or offset the impact, and natural recovery or restoration is unlikely. The impact may represent a possible fatal flaw and decision-making will need to evaluate the trade-offs with potential social or economic benefits. **Positive** social impacts of very high significance would be those where substantial economic or social benefits are obtained from the project for significant duration (many years).
High	**Impacts** where an accepted limit or standard is exceeded; impacts are outside the range of normal variation or adverse changes to a receptor are long-term. Natural recovery is unlikely or may only occur in the long-term and assisted and ongoing rehabilitation is likely to is required to reduce the impact to an acceptable level. High significance **residual impacts** warrant close scrutiny in decision-making and strict conditions and monitoring to ensure compliance with mitigation or other compensation requirements. **Positive** social impacts of high significance would be those where considerable economic or social benefits are obtained from the project for an extended duration in the order of several years.

Significance Rating	Interpretation
Medium	Moderate **adverse changes** to a receptor where changes may exceed the range of natural variation or where accepted limits or standards are exceeded at times. Potential for natural recovery in the medium-term is good, although a low level of residual impact may remain. Medium impacts will require mitigation to be undertaken and demonstration that the impact has been reduced to as low as reasonably practicable (even if the **residual impact** is not reduced to Low significance). **Positive** social impacts of medium significance would be those where a moderate level of benefit is obtained by several people or a community, or the local, regional or national economy for a sustained period, generally more than a year.
Low	**Minor effects** will be experienced, but the impact magnitude (or consequence) is sufficiently small (with and without mitigation) and well within the range of normal variation or accepted standards, or where effects are short-lived. Natural recovery is expected in the short-term, although a low level of localised residual impact may remain. In general, impacts of low significance can be controlled by normal good practice but may require monitoring to ensure operational controls or mitigation is effective. **Positive** social impacts of low significance would be those where a few people or a small proportion of a community in a localised area may benefit for a few months.
Very Low	Very minor effects on resources or receptors are possible but the predicted effect represents a minimal change to the distribution, presence, function or health of the affected receptor, and **no mitigation is required**.
Negligible	Predicted impacts on resources or receptors of very low or low sensitivity are imperceptible or indistinguishable from natural background variations, and **no mitigation is required**.

Additional Assessment Criteria

Additional criteria that are taken into consideration in the impact assessment process and specified separately to further describe the impact and support the interpretation of significance, include the following:

- **Probability (Likelihood) of the impact occurring** (which is taken into account mainly for unplanned events);
- **Degree of Confidence in the impact prediction;**
- **Degree to which the impact can be mitigated;**
- **Degree of Resource Loss** (i.e. the extent to which the affected resource/s will be lost, taking into account irreplaceability); and
- **Reversibility** – the degree to which the impact can be reversed.
- **Cumulative Potential -** potential for cumulative impacts with other planned projects or activities.

Definitions for these supporting criteria are indicated below.

Criteria	Rating	Description
Criteria for determining the PROBABILITY of impacts	**UNLIKELY**	Where the possibility of the impact to materialise is very low either because of design or historic experience, i.e. ≤ 5% chance of occurring.
	POSSIBLE	Where the impact could occur but is not reasonably expected to occur i.e. 5-35% chance of occurring.
	LIKELY	Where there is a reasonable probability that the impact would occur, i.e. > >35 to ≤75% chance of occurring.
	HIGHLY LIKELY	Where there is high probability that the impact would occur i.e. >75 to <99% chance of occurring.
	DEFINITE	Where the impact would occur regardless of any prevention measures, i.e. 100% chance of occurring.
Criteria for determining the **DEGREE OF CONFIDENCE** of the assessment	**LOW**	Low confidence in impact prediction (≤ 35%)
	MEDIUM	Moderate confidence in impact prediction (between 35% and ≤ 70%)
	HIGH	High confidence in impact prediction (> 70%).
	CERTAIN	Absolute certainty in the impact prediction (100%)
Criteria for the DEGREE TO WHICH IMPACT CAN BE MITIGATED	**NONE**	No mitigation is possible or mitigation even if applied would not change the residual impact.
	VERY LOW	Some mitigation is possible but will have marginal effect in reducing the residual impact or its significance rating.
	LOW	Some mitigation is possible and may reduce the residual impact, possibly reducing the impact significance.
	MEDIUM	Mitigation is feasible and will reduce the residual impact and may reduce the impact significance rating.
	HIGH	Mitigation can be easily applied or is considered standard operating practice for the activity and will reduce the residual impact and impact significance rating.
Criteria for DEGREE OF IRREPLACEABLE RESOURCE LOSS	**LOW**	Where the activity results in a marginal effect on an irreplaceable resource.
	MEDIUM	Where an impact results in a moderate loss, fragmentation or damage to an irreplaceable receptor or resource.
	HIGH	Where the activity results in an extensive or high proportion of loss, fragmentation or damage to an irreplaceable receptor or resource.
Criteria for REVERSIBILITY - the degree to which an impact can be reversed	**IRREVERSIBLE**	Where the impact cannot be reversed and is **permanent**.
	PARTIALLY REVERSIBLE	Where the impact can be partially reversed and is temporary
	FULLY REVERSIBLE	Where the impact can be completely reversed.

Criteria	Rating	Description
Criteria for POTENTIAL FOR CUMULATIVE IMPACTS – the extent to which cumulative impacts may arise from interaction or combination from other planned activities or projects	**UNLIKELY**	Low likelihood of cumulative impacts arising.
	POSSIBLE	Cumulative impacts with other activities or projects may arise.
	LIKELY	Cumulative impacts with other activities or projects either through interaction or in combination can be expected.

APPENDIX 2

C*urriculum Vitae* Dr Andrea Pulfrich

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Academic Qualifications

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

Membership in Professional Societies

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

Employment History and Professional Experience

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

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

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

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

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

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

South African National Research Institute of Oceanography and Gqeberha 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.