SCOPING AND ENVIRONMENTAL IMPACT ASSESSMENT FOR PROPOSED OIL AND GAS EXPLORATION ACTIVITIES IN BLOCKS 3617 AND 3717 OFF THE SOUTH-WEST COAST OF SOUTH AFRICA

Marine Faunal Assessment

Prepared for:

CCA ENVIRONMENTAL

On behalf of

Rhino Oil and Gas Exploration South Africa (Pty) Ltd

November 2015

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MARINE FAUNAL ASSESSMENT

Prepared for

CCA Environmental (Pty) Ltd

Prepared by

Andrea Pulfrich
Pisces Environmental Services (Pty) Ltd

With contributions by Simon Elwen & Tess Gridley
Sea Search Africa

November 2015

PISCES Environmental Services (Pty) Ltd

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ABBREVIATIONS and UNITS

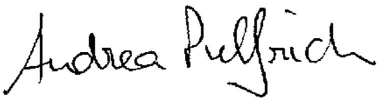
CCA	CCA Environmental (Pty) Ltd
cm	centimetres
cm/s	centimetres per second
CMS	Centre for Marine Studies
CSIR	Council for Scientific and Industrial Research
dB	decibells
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EMP	Environmental Management Programme
EMPR	Environmental Management Programme Report
GAENP	Greater Addo Elephant National Park
h	hour
Hz	Herz
IUCN	International Union for the Conservation of Nature
kHz	kiloHerz
km	kilometre
km/h	kilometres per hour
km^2	square kilometre
kts	knots
KZN	KwaZulu-Natal
M&CM	Marine & Coastal Management: Department of Environment Affairs
MMO	Marine Mammal Observer
MPA	Marine Protected Area
MPRDA	Mineral and Petroleum Resources Development Act
m	metres
m/sec	metres per second
NEMA	National Environmental Management Act
PAM	Passive Acoustic Monitoring
ppt	parts per thousand
PTS	permanent threshold shifts
rms	root mean squared
S	south
SEIA	Scoping and Environmental Impact Assessment
TTS	temporary threshold shifts
2D	two-dimensional
3D	three-dimensional
µg/l	micrograms per litre
µPa	micro Pascal
°C	degrees Centigrade
%	percent
~	approximately
<	less than
>	greater than

EXPERTISE AND DECLARATION OF INDEPENDENCE

This report was prepared by Dr Andrea Pulfrich of Pisces Environmental Services (Pty) Ltd. Andrea has a PhD in Fisheries Biology from the Institute for Marine Science at the Christian-Albrechts University, Kiel, Germany.

As Director of Pisces since 1998, Andrea has considerable experience in undertaking specialist environmental impact assessments, baseline and monitoring studies, and Environmental Management Programmes / 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 CCA Environmental (Pty) Ltd for their use in preparing an Environmental Impact Report for proposed oil and gas exploration activities by Rhino Oil and Gas Exploration South Africa (Pty) Ltd (Rhino), in Block 3617 & 3717. offshore of the South African South-West Coast. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and CCA Environmental.



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.

For this investigation Rhino Oil and Gas Exploration South Africa (Pty) Ltd (Rhino) is proposing to undertake both multi-beam bathymetry and 2D / 3D seismic surveys over Blocks 3617 and 3717 offshore of the South-West Coast of South African (Figure 1) to determine the presence of hydrocarbons within the Exploration Area. The exploration programme would commence with multi-beam and 2D seismic acquisition. Depending on the results of these data, further exploration activities may be undertaken including 3D seismic survey acquisition.

In terms of Section 79 of the Mineral and Petroleum Resources Development Act (No. 28 of 2002) (MPRDA), as amended, a requirement for obtaining an Exploration Right is that the applicant must comply with Chapter 5 of the National Environmental Management Act (No. 107 of 1998) (NEMA), as amended, with regards to consultation and reporting. In terms of NEMA, the proposed application requires Environmental Authorisation as it triggers Activity 18 in Listing Notice 2 (GN No. R984). As such a Scoping and Environmental Impact Assessment (SEIA) process must be undertaken in terms of the Environmental Impact Assessment (EIA) Regulations 2014.

CCA Environmental (Pty) Ltd (CCA) has been appointed by Rhino to conduct the SEIA process and compile the Environmental Impact Report (including Environmental Management Programme - EMP) to meet the requirements of the MPRDA, NEMA and Regulations thereto. CCA 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 CCA, for their use in preparing an SEIA for the proposed oil and gas exploration activities in Block 3617 & 3717 offshore of the South-West Coast of South Africa.

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

- Provide a general description of the local marine fauna (including cetaceans, seals, turtles, seabirds, fish, invertebrates and plankton species) within the proposed exploration licence area and greater South-West Coast. The description to be based on, *inter alia*, a review of existing information and data from the international scientific literature, the Generic EMP prepared for seismic surveys in South Africa, information sourced from the internet, as well as Marine Mammal Observer (MMO) close-out reports prepared for previous surveys undertaken off the coast of South Africa;
- Identify, describe and assess the significance of potential impacts of the proposed exploration activities on the local marine fauna, including but not limited to:
    - > physiological injury;
    - > behavioural avoidance of the survey area;

> masking of environmental sounds and communication; and
> indirect impacts due to effects on prey.

- Identify practicable mitigation measures to avoid/reduce any negative impacts and indicate how these could be implemented in the start-up and management of the proposed project.

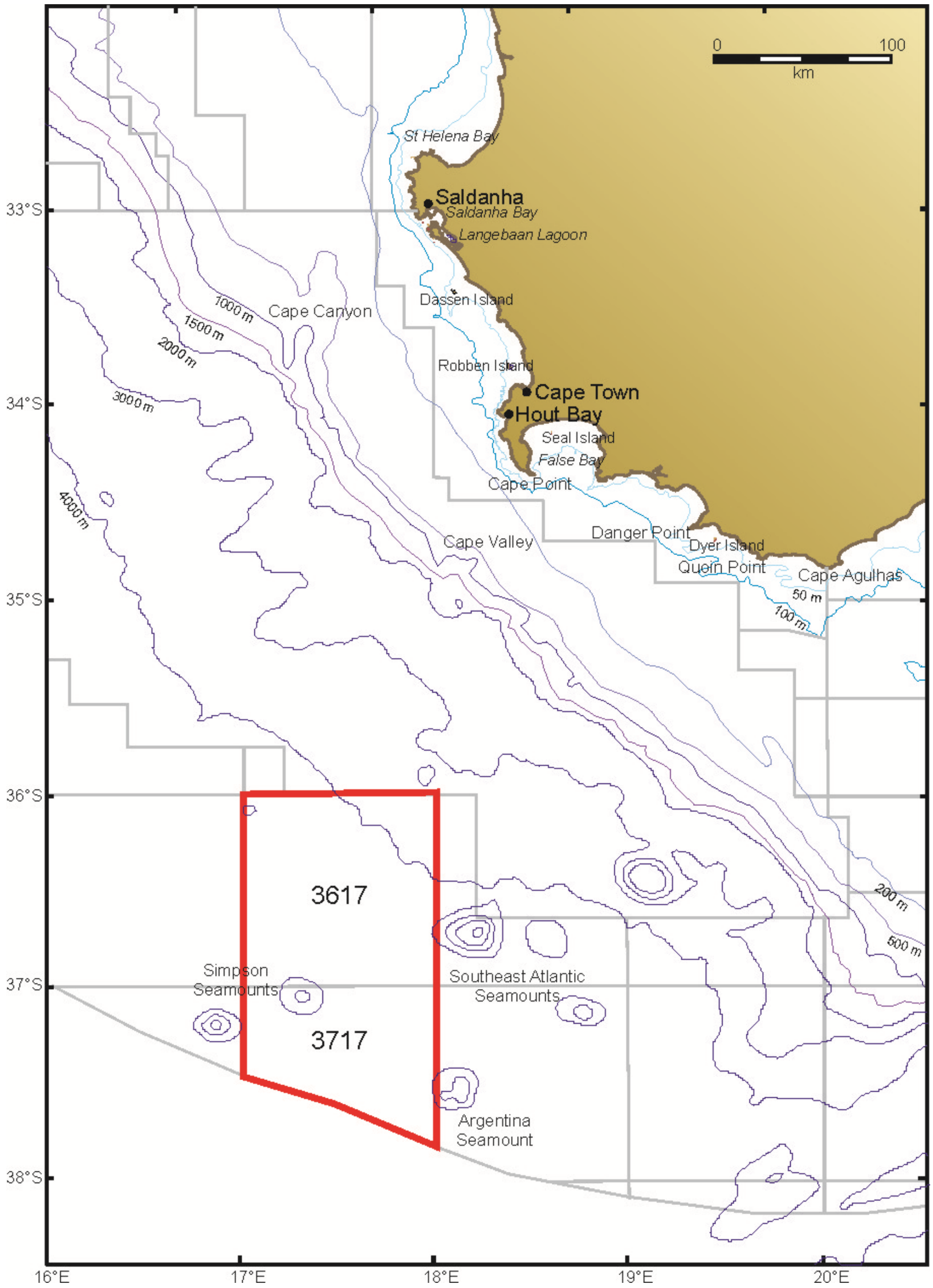


Figure 1: Bathymetry of the South African South-West Coast showing the Exploration Area (red polygon) in relation to the hydrocarbon exploration blocks (grey) and features and places mentioned in the text.

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 MMO close-out Reports. The sources consulted are listed in the Reference chapter.

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

2. DESCRIPTION OF THE PROPOSED PROJECT

Rhino is proposing to explore for oil and gas in Blocks 3617 and 3717, located approximately 190 km off the coast in water depths greater than 3 500 m. The area is approximately 13,279 km^2 in extent. The proposed three-year exploration programme would commence with acquisition and collation of existing data. Thereafter multi-beam bathymetry and 2D/3D seismic surveys would be conducted to identify potential target areas for future exploration.

2.1. Seismic Survey

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 in specific target areas identified during 2D applications, and provide a cube image of the seafloor geology along each survey track–line. 3D seismic acquisition is applied to promising petroleum prospects to assist in fault interpretation, distribution of sand bodies, estimates of oil and gas in place and the location of exploration wells.

During seismic surveys high-level, low frequency sound impulses are generated by an array of acoustic instrumentation towed behind a survey vessel, just below the sea surface. The sounds are directed towards the seabed and the seismic signal is reflected by the geological interfaces below the seafloor. The reflected signals are received by receivers or sets of hydrophones towed behind the vessel in a single streamer (2D) or in multiple streamers (3D) and are fed back to the recording instruments on board. The spacing between the hydrophone groups is commonly 25 m or shorter, depending on the purpose of the seismic survey. Each group contains many hydrophones, spaced less than 1 m apart. The hydrophone streamers must be towed at constant depth (6 - 10 m), with flotation usually achieved by filling the cables with kerosene, so that they are neutrally buoyant. To compensate for minor adjustments, Automatic Cable Levellers, or "birds" are used. The ends of the hydrophone streamers are marked with tail buoys, to warn shipping about the presence of the cable in the water. The tail buoys also act as a platform for surface positioning systems so that the cable locations can be accurately monitored (Figure **2**).

While acquiring the seismic data, the survey vessel would travel along transects of a prescribed grid within the survey area that have been chosen to cross any known or suspected geological structure in the area. The vessel typically travels at a speed of between four and six knots (*i.e.* 2 to 3 metres per second) while surveying.

The seismic survey would involve a seismic sound source (airgun array) and a hydrophone streamer. The configuration of the airgun and hydrophone array would be dependent on whether a 2D or 3D seismic survey is undertaken. Typically the streamer(s) can be up to 12,000 m long and towed at variable depths between 6 – 30 m depth below the surface. The streamer(s) would therefore not be visible, except for the tail-buoy(s) at the terminal end(s) of the cable(s). The airgun array would be towed 80 - 150 m behind the vessel at a depth of between 5 - 25 m below the surface. 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.

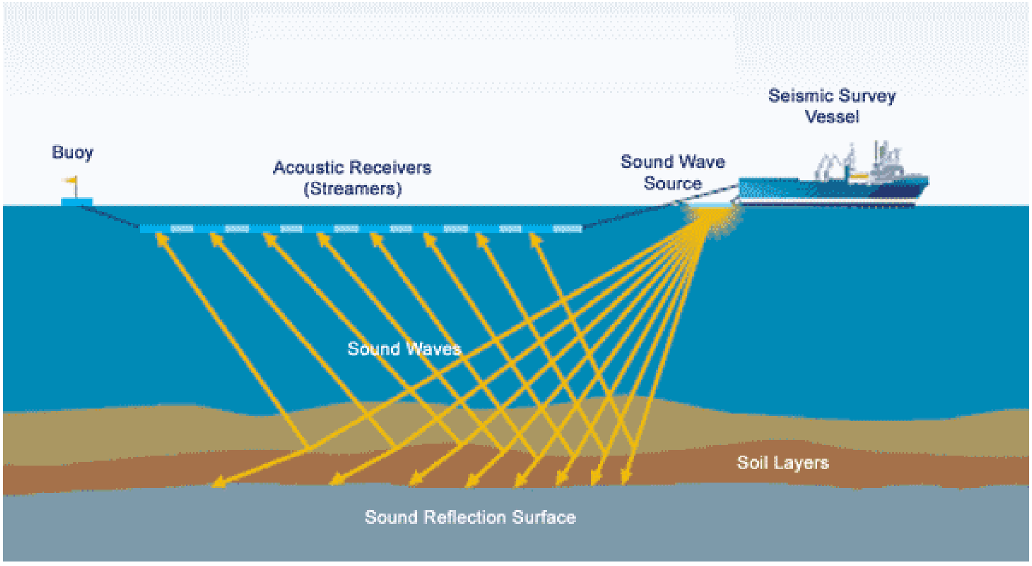


Figure 2: The principles of offshore seismic data acquisition (Source: www.fishsafe.eu).

Each triggering of a sound pulse is termed a seismic shot, and these are fired at intervals of 10 - 20 seconds and at an operating pressure of between 2,000 to 2,500 psi and a volume of 3,000 to 5,000 cubic inches. 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. The maximum sound pressure levels at the source of airgun arrays in use today in the seismic industry are typically around 220 dB re 1µPa at 1 m, with the majority of their produced energy being low frequency of 10-100 Hz (McCauley 1994; NRC 2003). The location where this level of sound is attained is directly beneath the airgun array, generally near its centre, but the exact location and depth beneath the array are dependent on the detailed makeup of the array, the water depth, and the physical properties of the seafloor (Dragoset 2000). However, based on analogue sound sources, sound levels for the seismic survey can notionally be expected to attenuate below 160 dB less than 1,325 m from the source array.

For this investigation Rhino is proposing to undertake the acquisition of 2D seismic data. However, if it is determined by subsequent analysis of existing data, that acquisition of a seismic dataset utilising 3D seismic techniques might be a more advantageous approach for data collection, then a 3D seismic survey might be undertaken in addition to the 2D seismic survey.

The proposed seismic survey would be in the order of 200 km in total length. Two alternative survey programmes are currently being considered (Figure **3**); the first comprises widely-spaced lines over the Exploration Area, while the second would involve an area where the lines will be closer together. The commencement of the surveys will depend on an Exploration Right award date and availability of seismic contractors. It is anticipated that the 2D survey would be undertaken during the summer of 2016/2017 and would take approximately 15-20 productive days to complete.

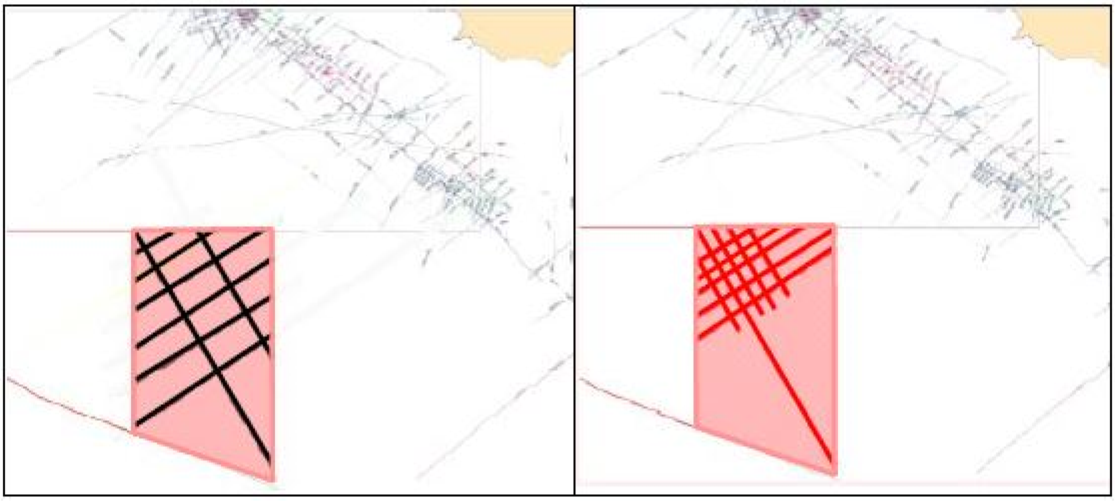


Figure 3: Indicative alternatives for the seismic survey lines in the offshore exploration licence area.

2.2. Multi-beam Bathymetry and Sub-bottom Profiling Survey

The multi-beam bathymetry survey would be undertaken over the majority of the Exploration Area, in order to produce a digital terrain model of the seafloor (Figure **4**). The survey vessel would be equipped with a multi-beam echo sounder to obtain swath bathymetry, and a sub-bottom profiler to image the seabed and the near-surface geology. Multi-beam technology is a complex sonar array that allows surveying of the seafloor at a resolution and accuracy sufficient to image the typical scale of active seafloor seeps. The multi-beam system provides depth-sounding information on either side of the vessel's track across a swath width of approximately two times the water depth, thereby allowing for highly accurate imaging and mapping of seafloor topography in the form of digital terrain models. The multi-beam echo sounder emits a fan of acoustic beams from a transducer at frequencies ranging from 10 kHz to 200 kHz and typically produces sound levels in the order of 207 db re 1 µPa at 1 m. The sub-bottom profiler emits an acoustic pulse from a transducer at frequencies ranging from 3 kHz to 40 kHz and typically produces sound levels in the order of 206 db re 1 µPa at 1 m. The operating frequencies of the acoustic equipment used in sonar surveys typically fall into the high frequency kHz range, and are thus beyond the hearing abilities of most marine fauna.

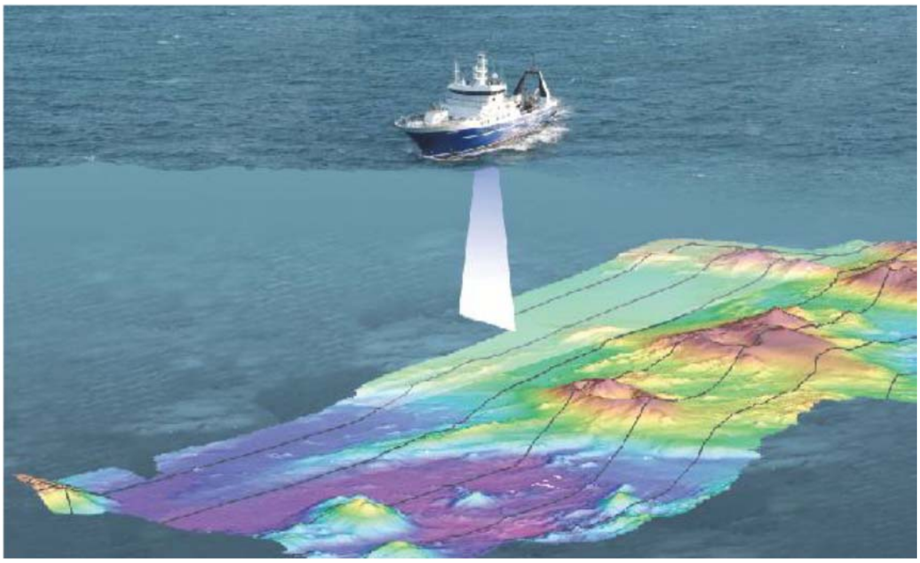


Figure 4: Schematic of a vessel using multi-beam depth/echo sounders (http://www.gns.cri.nz/).

These bathymetric data alone are not sufficient to identify all possible hydrocarbon seeps, as many seeps have no bathymetric expression. Backscatter data is typically collected concurrently by multi-beam echosounders as it can measure several properties of the seafloor associated with hydrocarbon seeps including; hardness; roughness; and volumetric heterogeneity. One or more of these three properties can result in an increase in backscatter intensity recorded by the multi-beam system and aid in the identification of potential natural hydrocarbon seeps on the seafloor in the survey area.

It is anticipated that data acquisition would take in the order of 15 - 20 productive days to complete at a vessel speed of 5 knots.

3. DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

The proposed survey area is located offshore of the South-West Coast, stretching between 17°E and 18°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

The continental shelf along the South-West Coast maintains a general NNW trend. It is narrowest between Cape Columbine and Cape Point (40 km), widening to the north of Cape Columbine reaching its widest off the Orange River (180 km), widening south of Cape Point and reaching its apex 250 km offshore on the Agulhas Bank. The immediate nearshore area consists mainly of a narrow (about 8 km wide) rugged rocky zone and slopes steeply seawards to a depth of around 80 m. The middle and outer shelf normally lacks relief and slopes gently seawards reaching the shelf break at a depth of ~300 m (Birch & Rogers 1973). Major bathymetric features in the region are the Protea Seamount (36.8°S, 18.1°E), Simpson Seamounts (37.2°S, 16.9°E), Argentina Seamount (37.6°S, 18.1°E)and the Cape Canyon (~33.5°S, 17.5°E) (Birch & Rogers 1973; CCA & CSIR 1998). Outside the shelf break, depth increases rapidly to more than 1,000 m (Hutchings 1994).

The inner shelf is underlain by Precambrian bedrock (also referred to as Pre-Mesozoic basement), whilst the middle and outer shelf areas are composed of Cretaceous and Tertiary sediments (Dingle 1973; Birch *et al.* 1976; Rogers 1977; Rogers & Bremner 1991). As a result of erosion, the middle shelf has a minimum cover of sandy sediment, thinning out markedly over the underlying rocky features of the outer shelf. The cover of unconsolidated sediment on the shelf is thus generally thin (often less than 1 m). Sediments are finer seawards, changing from sand on the inner and outer shelves to muddy sand and sandy mud in deeper water. The continental slope, seaward of the shelf break, has a smooth seafloor, underlain by calcareous ooze. Isolated areas of seabed associated with the Cape Valley and Cape Canyon are characterised by hard outer shelf and shelf edge sediments (Sink *et al*. 2012).

3.1.2 Winds and Swells

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

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

These seasonal changes result in substantial differences between the typical summer and winter wind patterns in the region, as the southern hemisphere anti-cyclonic high-pressures system, and the associated series of cold fronts, moves northwards in winter, and southwards in summer. The strongest winds occur in summer, during which winds blow 99% of the time, with a total of 226 gales (winds exceeding 18 m/s or 35 kts) being recorded over the period. Virtually all winds in summer come from the southeast to south-west, strongly dominated by southerlies which occur over 40% of the time, averaging 20 - 30 kts and reaching speeds in excess of 100 km/h (60 kts). South-easterlies are almost as common, blowing about one-third of the time, and also averaging 20 - 30 kts. The combination of these southerly/south-easterly winds drives the massive offshore movements of surface water, and the resultant strong upwelling of nutrient-rich bottom waters, which characterise this region in summer.

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

The wave regime along the southern African West Coast shows only moderate seasonal variation in direction, with virtually all swells throughout the year coming from the SW - S direction. Winter swells, however, are strongly dominated by those from the SW - SSW, which occur almost 80% of the time, and typically exceed 2 m in height, averaging about 3 m, and often attaining over 5 m. With wind speeds capable of reaching 100 km/h during heavy winter south-westerly storms, winter swell heights can exceed 10 m, and have been reported to reach in excess of 20 m height at the internationally renowned “Dungeons’” surf spot on the Cape Peninsula West Coast.

In comparison, summer swells tend to be smaller on average, typically around 2 m, not reaching the maximum swell heights of winter. There is also a more pronounced southerly swell component in summer. These southerly swells tend to be wind-induced, with shorter wave periods (~8 seconds), and are generally steeper than swell waves (CSIR 1996).

3.1.3 Circulation, Upwelling and Water Masses

The southern African West and Southwest Coasts are strongly influenced by the Benguela Current. Current velocities in continental shelf areas generally range between 10–30 cm/s (Boyd & Oberholster 1994). On its western side, flow is more transient and characterised by large eddies shed from the retroflection of the Agulhas Current (Figure **5**).. In the south the Benguela current has a width of 200 km, widening rapidly northwards to 750 km. The flows are predominantly wind-forced, barotropic and fluctuate between poleward and equatorward flow (Shillington *et al.* 1990; Nelson & Hutchings 1983). Fluctuation periods of these flows are 3 - 10 days, although the long-term mean current residual is in an approximate northwest (alongshore) direction. Near bottom shelf flow is mainly poleward (Nelson 1989) with low velocities of typically 5 cm/s. The poleward flow becomes more consistent in the southern Benguela.

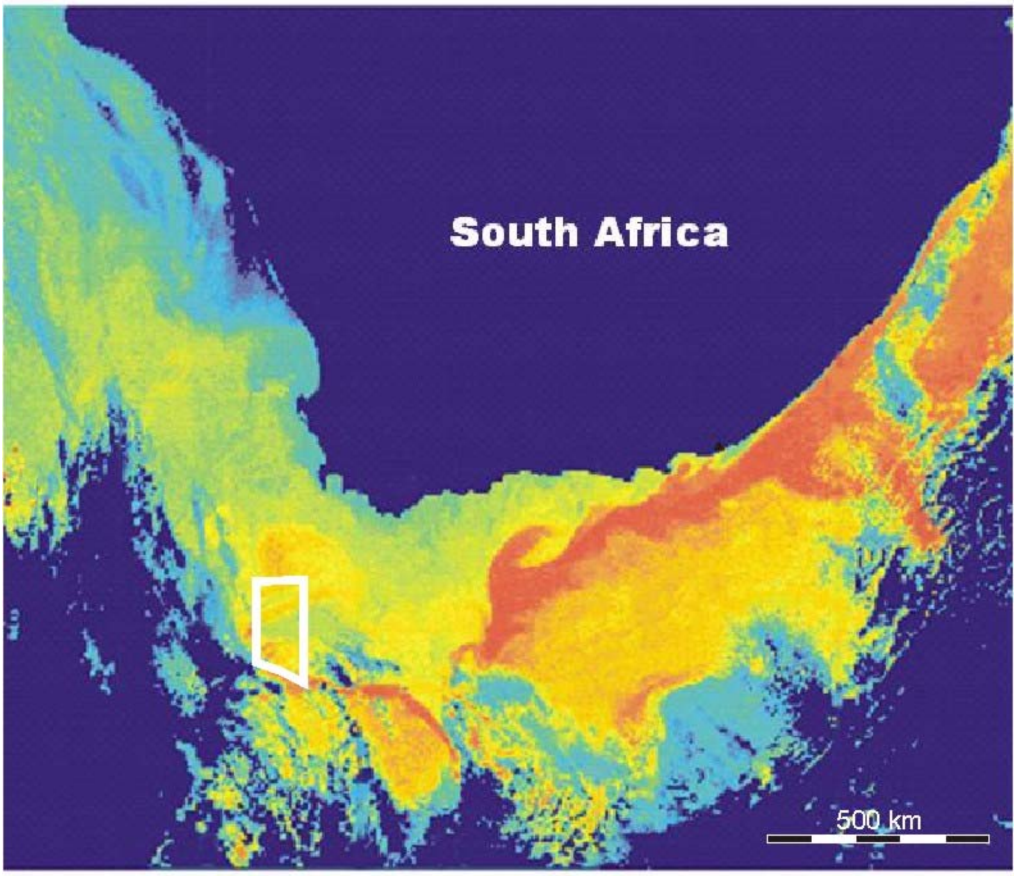


Figure 5: The location of the Exploration Right Area (white outline) to the west of the Agulhas retroflection area.

The major feature of the Benguela Current is coastal upwelling and the consequent high nutrient supply to surface waters leads to high biological production and large fish stocks. The prevailing longshore, equatorward winds move nearshore surface water northwards and offshore. To balance the displaced water, cold, deeper water wells up inshore. Although the rate and intensity of upwelling fluctuates with seasonal variations in wind patterns, the most intense upwelling tends to occur where the shelf is narrowest and the wind strongest. There are three upwelling centres in the southern Benguela, namely the Namaqua (30°S), Cape Columbine (33°S) and Cape Point (34°S) upwelling cells (Taunton-Clark 1985). Upwelling in these cells is seasonal, with maximum upwelling occurring between September and March. These cells are all located well inshore of the exploration area.

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

South Atlantic Central Water (SACW) comprises the bulk of the seawater in the study area, either in its pure form in the deeper regions, or mixed with previously upwelled water of the same origin on the continental shelf (Nelson & Hutchings 1983). Salinities range between 34.5‰ and 35.5‰ (Shannon 1985).

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

Seawater temperatures on the continental shelf of the southern Benguela typically vary between 6°C and 16°C. Well-developed thermal fronts exist, demarcating the seaward boundary of the upwelled water. Upwelling filaments are characteristic of these offshore thermal fronts, occurring as surface streamers of cold water, typically 50 km wide and extending beyond the normal offshore extent of the upwelling cell. Such fronts typically have a lifespan of a few days to a few weeks, with the filamentous mixing area extending up to 625 km offshore. South and east of Cape Agulhas, the Agulhas retroflection area is a global "hot spot" in terms of temperature variability and water movements.

3.2. The Biological Environment

The proposed survey area is located well beyond the 3,000 m depth contour, the closest point to shore being ~190 km offshore of Cape Point. Communities within the offshore marine habitat are comparatively homogenous, largely as a result of the greater consistency in water temperature at depths around the South African coastline, than in the shallower coastal waters. The proposed survey area, falls within the Atlantic Offshore bioregion (Lombard *et al*. 2004) (Figure **6**). The biological communities occurring in the survey area consist of many hundreds of species, often displaying considerable temporal and spatial variability (even at small scales). The deep-water marine ecosystems comprise a limited range of habitats, namely unconsolidated seabed sediments, seamounts and the water column. The biological communities 'typical' of these habitats are described briefly below, focussing both on dominant, commercially important and conspicuous species, as well as potentially threatened species.

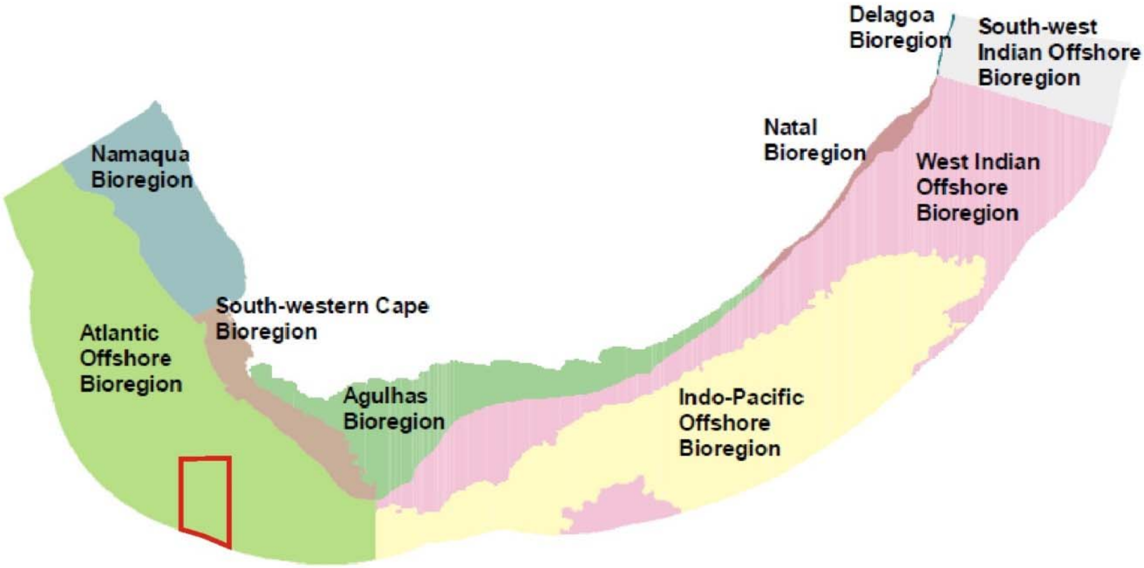


Figure 6: The inshore and offshore bioregions occurring in the Exploration Right Area (red outline) (adapted from Lombard *et al*. 2004).

3.2.1 Demersal Communities

3.2.1.1 Benthic Invertebrate Macrofauna

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

Due to the lack of information on benthic macrofaunal communities beyond the shelf break, no description can be provided for the proposed offshore Exploration Area. Generally, however, polychaetes, crustaceans and molluscs make up the largest proportion of individuals, biomass and species of macro-infauna communities on the west coast. Typically species richness increases from the inner-shelf across the mid-shelf and is influenced by sediment type. The distribution of species are typically inherently patchy reflecting the high natural spatial and temporal variability associated with macro-infauna of unconsolidated sediments (e.g. Kenny *et al*. 1998; Kendall & Widdicombe 1999; van Dalfsen *et al.* 2000; Zajac *et al.* 2000; Parry *et al.*

2003), with evidence of mass mortalities and substantial recruitments recorded on the South African West Coast (Steffani & Pulfrich 2004).

Despite the current lack of knowledge of the community structure and endemicity of South African macro-infauna off the edge of the continental shelf, the marine component of the 2011 National Biodiversity Assessment (Sink *et al.* 2012), rated the South Atlantic bathyal and abyssal unconsolidated habitat types that characterise depths beyond 500 m, as 'least threatened' (Figure 7, left). This primarily reflects the great extent of these habitats in the South African Exclusive Economic Zone (EEZ).

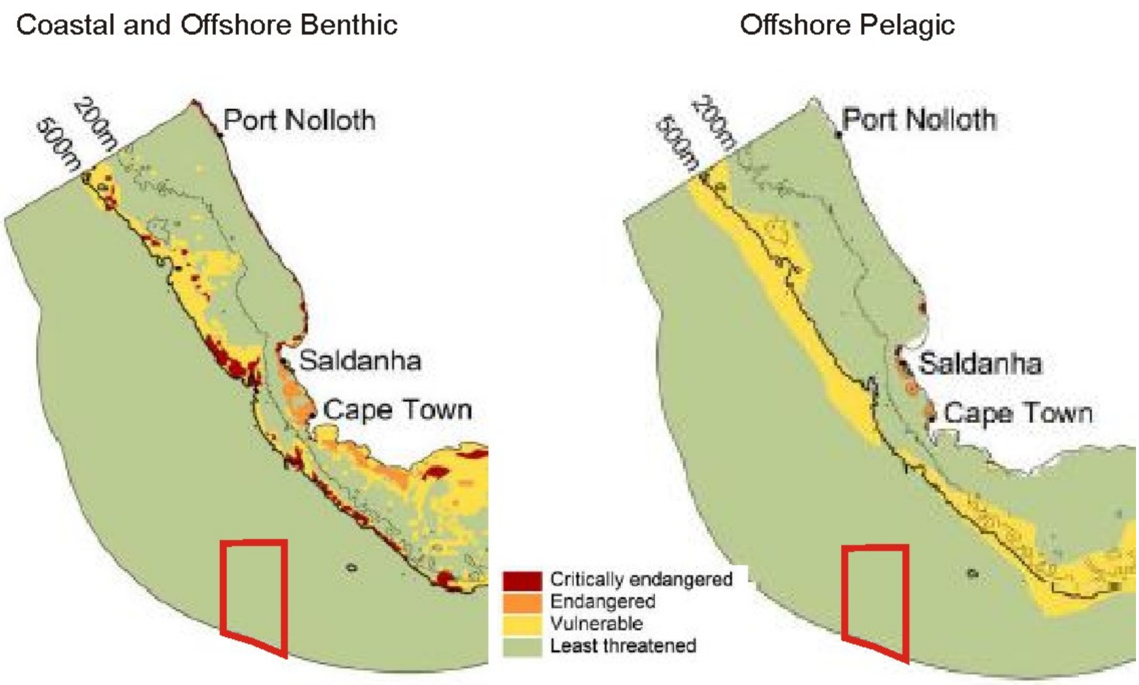


Figure 7: Ecosystem threat status for coastal and offshore benthic habitat types (left), and offshore pelagic habitat types on the South African West Coast in relation to the South West Orange Basin Deep Water area (red outline) (adapted from Sink *et al.* 2012).

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

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

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

3.2.1.2 Demersal Fish Species

Demersal fish are those species that live and feed on or near the seabed. Information on fish communities beyond the shelf break are limited, but on the continental shelf of the West Coast (east of the Exploration Area), as many as 110 species of bony and cartilaginous fish have been identified at depths of <500 m (Roel 1987). Changes in fish communities occur with increasing depth (Roel 1987; Smale *et al.* 1993; Macpherson & Gordoa 1992; Bianchi *et al.* 2001; Atkinson 2009), with the most substantial change in species composition occurring in the shelf break region between 300 m and 400 m depth (Roel 1987; Atkinson 2009). The shelf community (<380 m) is dominated by the Cape hake *M. capensis*, and includes jacopever *Helicolenus dactylopterus*, Izak catshark *Holohalaelurus regain*, soupfin shark *Galeorhinus galeus* and whitespotted houndshark *Mustelus palumbes*. The more diverse deeper water community (380 – 500 m) is dominated by the deepwater hake *Merluccius paradoxus*, monkfish *Lophius vomerinus*, kingklip *Genypterus capensis*, bronze whiptail *Lucigadus ori* and hairy conger *Bassanago albescens* and various squalid shark species. There is some degree of species overlap between the depth zones.

Roel (1987) showed seasonal variations in the distribution ranges shelf communities, with species such as the pelagic goby *Sufflogobius bibarbatus*, and West Coast sole *Austroglossus microlepis* occurring in shallow water north of Cape Point during summer only. The deep-sea community (380 – 500 m) was found to be homogenous both spatially and temporally. In a more recent study, however, Atkinson (2009) identified two long-term community shifts in demersal fish communities; the first (early to mid-1990s) being associated with an overall increase in density of many species, whilst many species decreased in density during the second shift (mid-2000s). These community shifts correspond temporally with regime shifts detected in environmental forcing variables (Sea Surface Temperatures and upwelling anomalies) (Howard *et al.* 2007) and with the eastward shifts observed in small pelagic fish species and rock lobster populations (Coetzee *et al.* 2008, Cockcroft *et al.* 2008).

The diversity and distribution of demersal cartilagenous fishes on the West Coast over a depth range of 33 – 1,016 m is discussed by Compagno *et al.* (1991). However, as with demersal fish communities discussed above, information on cartilagenous fish beyond the shelf break and from depths corresponding to those in the Exploration Area is lacking.

3.2.1.3 Seamount Communities

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

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

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

Enhanced currents, steep slopes and volcanic rocky substrata, in combination with locally generated detritus, favour the development of suspension feeders in the benthic communities characterising seamounts (Rogers 1994). Deep- and cold-water corals (including stony corals, black corals and soft corals) (Figure **8**, left) are a prominent component of the suspension-feeding fauna of many seamounts, accompanied by barnacles, bryozoans, polychaetes, molluscs, sponges, sea squirts, basket stars, brittle stars and crinoids (reviewed in Rogers 2004). There is also associated mobile benthic fauna that includes echinoderms (sea urchins and sea cucumbers) and crustaceans (crabs and lobsters) (reviewed by Rogers 1994).

(Figure **8**, right). Compared to the surrounding deep-sea environment, seamounts typically form biological hotspots with a distinct, abundant and diverse fauna, many species of which remain unidentified. Consequently, the fauna of seamounts is usually highly unique and may have a limited distribution restricted to a single geographic region, a seamount chain or even a single seamount location (Rogers *et al.* 2008). Levels of endemism on seamounts are also relatively high compared to the deep sea. As a result of conservative life histories (*i.e.* very slow growing, slow to mature, high longevity, low levels of recruitment) and sensitivity to changes in environmental conditions, such biological communities have been identified as Vulnerable Marine Ecosystems (VMEs). They are recognised as being particularly sensitive to anthropogenic disturbance (primarily deep-water trawl fisheries and mining), and once damaged are very slow to recover, or may never recover (FAO 2008).

Figure 8: Seamounts are characterised by a diversity of deep-water corals that add structural complexity to seabed habitats and offer refugia for a variety of invertebrates and fish (Photos: www.dfo-mpo.gc.ca/science/Publications/article/2007/21-05-2007-eng.htm, Ifremer & AWI 2003).

It is not always the case that seamount habitats are VMEs, as some seamounts may not host communities of fragile animals or be associated with high levels of endemism. South Africa's seamounts and their associated benthic communities have not been sampled by either geologists or biologists (Sink & Samaai 2009). Important deep-water reefs occur in the vicinity of the Exploration Area are Brown's Bank (~150 km east), Protea and Argentina Seamounts (on the eastern boundary), and Simpson Seamounts (within Block 3717 and on the western boundary) (see Figure **9**).

3.2.2 Pelagic Communities

In contrast to demersal and benthic biota that are associated with the seabed, pelagic species live and feed in the open water column. The pelagic communities are typically divided into plankton, cephalopods and fish, and their main predators, marine mammals (seals, dolphins and whales), seabirds and turtles. These are discussed separately below. Noteworthy is that the marine component of the 2011 National Biodiversity Assessment (Sink *et al.* 2012), rated the majority of the offshore pelagic habitat types that characterise depths beyond ~500 m, as 'least threatened' (see Figure 7, right), with only a narrow band along the shelf break of the West Coast being rated as 'vulnerable', primarily due to its importance as a migration pathway for various resource species (e.g. whales, tuna, billfish, turtles). At its closest point (north-eastern corner), the Exploration Area lies ~100 km offshore of the shelf break.

3.2.2.1 Plankton

Plankton is particularly abundant in the shelf waters off the South-West Coast, being associated with the upwelling characteristic of the area. Plankton range from single-celled bacteria to jellyfish of 2-m diameter, and include bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton. No upwelling events are expected within the Exploration Area and consequently phytoplankton and zooplankton abundance will be extremely low in the warm, clear, nutrient-poor oceanic waters of the survey area.

Although ichthyoplankton (fish eggs and larvae) comprise a minor component of the overall plankton, it remains significant due to the commercial importance of the overall fishery in the region. The western portion of the Agulhas Bank in particular is an important spawning area for a variety of pelagic and demersal fish species, including anchovy, pilchard, horse mackerel, round herring, chub mackerel, lanternfish and hakes (Crawford *et al.* 1987) (Figure **9**). 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). Pilchards also spawn on the Agulhas Bank (Crawford 1980), with adults moving eastwards and northwards after spawning. Round herring are also reported to spawn along the South-West Coast (Roel & Armstrong 1991). Demersal species that spawn along the South-West Coast include the cape hake (Shelton 1986; Hutchings 1994). Eggs and larvae of important linefish species (e.g. elf, leervis and geelbek) are also present inshore along the South-West Coast, with a significant proportion of the eggs and larvae originating from spawning grounds located along the East Coast (Beckley & van Ballegooyen 1992). The inshore waters of the Agulhas Bank acts as a nursery area for numerous fish species (Wallace *et al.* 1984; Smale *et al.* 1994). The Exploration Area is, however, located well offshore and to the west of the major spawning areas (Figure 9) and ichthyoplankton abundance in these offshore oceanic waters is expected to be extremely low.

3.2.2.2 Cephalopods

Fourteen species of cephalopods have been recorded in the southern Benguela, the majority of which are cuttlefish (Lipinski 1992; Augustyn *et al.* 1995). Most of the cephalopod resource is distributed on the mid-shelf with *Sepia australis* being most abundant at depths between 60-190 m, whereas *S. hieronis* densities were higher at depths between 110-250 m. *Rossia enigmatica* occurs more commonly on the edge of the shelf to depths of 500 m. Biomass of these species was generally higher in the summer than in winter. Cuttlefish are largely epi-benthic and occur on mud and fine sediments in association with their major prey item; mantis shrimps (Augustyn *et al.* 1995). They form an important food item for demersal fish.

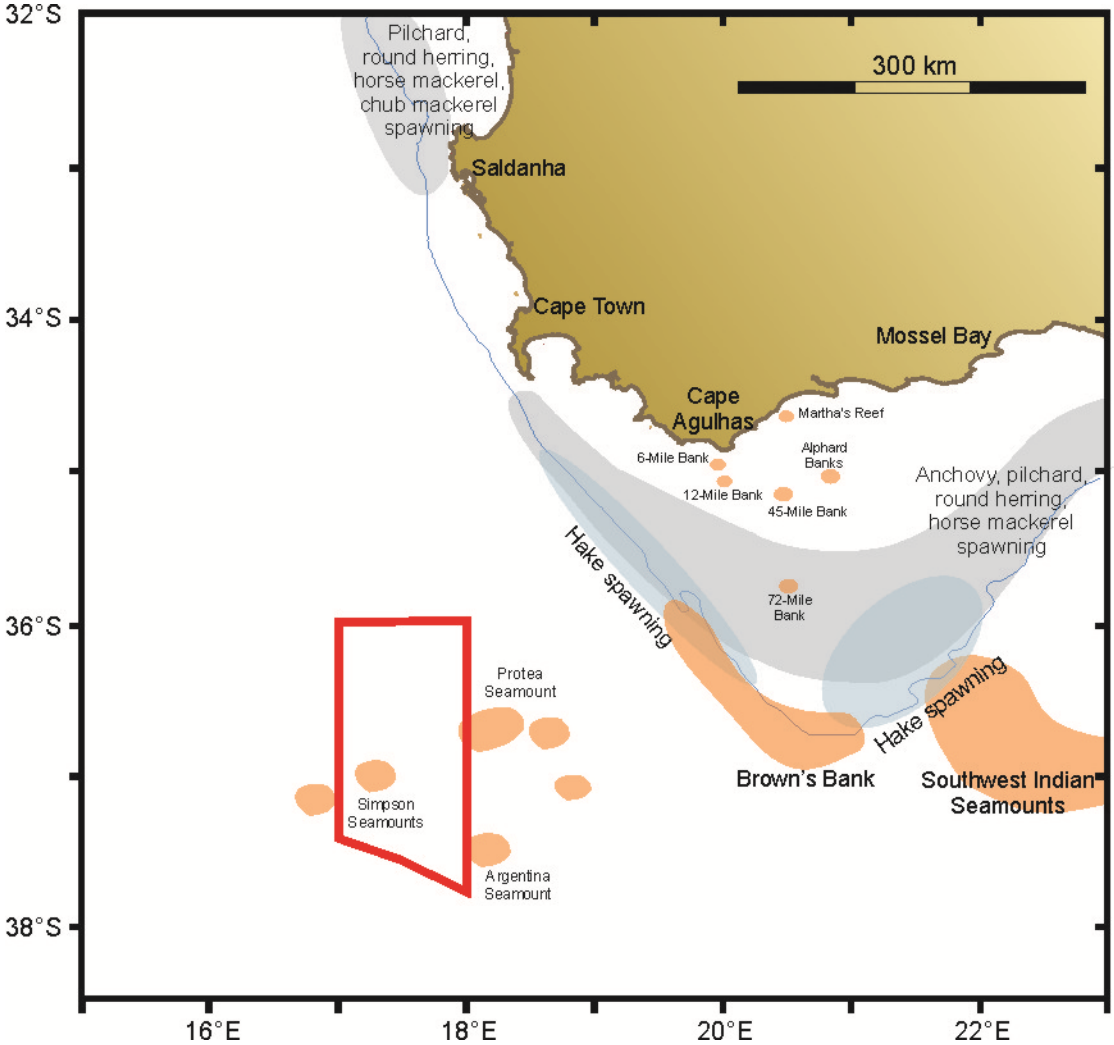


Figure 9: Important fishing banks, seamounts, and pelagic and demersal fish spawning areas in relation to the Exploration Area (red polygon) (after Anders 1975, Crawford *et al.* 1987, Hutchings 1994). The 200 m depth contour is also shown.

Pelagic invertebrates that may be encountered in the Exploration Area are the colossal squid *Mesonychoteuthis hamiltoni* and the giant squid *Architeuthis* sp. Both are deep dwelling species, with the colossal squid's distribution confined to the entire circum-Antarctic Southern Ocean (Figure 10, left) while the giant squid is usually found near continental and island slopes all around the world's oceans (Figure 10, right). Both species could thus potentially occur in the Exploration Area, although the likelihood of encounter is extremely low. Growing to in excess of 10 m in length, they are the principal prey of the sperm whale, and are also taken by beaked whaled, pilot whales, elephant seals and sleeper sharks. Nothing is known of their vertical distribution, but data from trawled specimens and sperm whale diving behaviour suggest they may span a depth range of 300 – 1,000 m. They lack gas-filled swim bladders and maintain neutral buoyancy through an ammonium chloride solution occurring throughout their bodies.

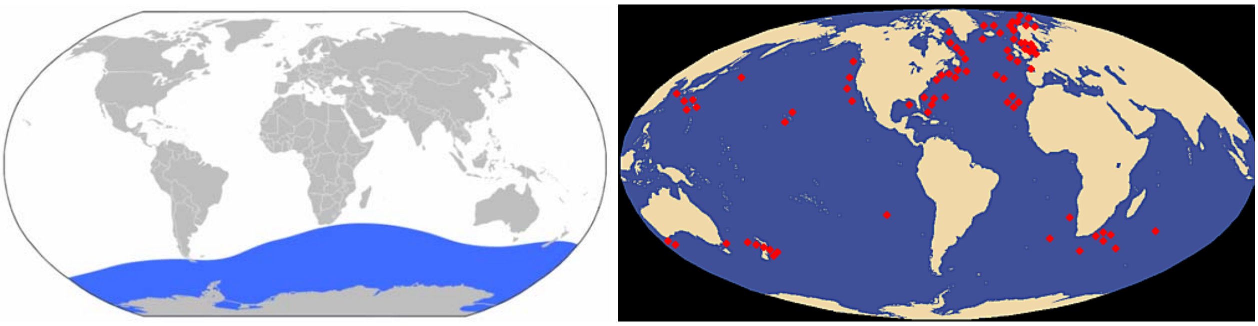


Figure 10: Distribution of the colossal squid (left) and the giant squid (right) (www.wikipedia.org).

3.2.2.3 Pelagic Fish

Small pelagic species include the sardine/pilchard (*Sadinops ocellatus*), anchovy (*Engraulis capensis*), chub mackerel (*Scomber japonicus*), horse mackerel (*Trachurus capensis*) and round herring (*Etrumeus whiteheadi*). These species typically occur in mixed shoals of various sizes (Crawford *et al.* 1987), and generally occur within the 200 m contour and thus unlikely to be encountered in the Exploration Area (this is confirmed by the CapFish 2015 - Fisheries Specialist Study). Most of the pelagic species exhibit similar life history patterns involving seasonal migrations between the west and south coasts. The spawning areas of the major pelagic species are distributed on the continental shelf and along the shelf edge extending from south of St Helena Bay to Mossel Bay on the South Coast (Shannon & Pillar 1986) (see Figure **9**). They spawn inshore of the shelf edge and downstream of major upwelling centres (particularly on the Agulhas Bank), in spring and summer and their eggs and larvae are subsequently carried around Cape Point and up the coast in northward flowing surface waters. The spawning areas and northward egg and larval drift thus occurs well inshore of the Exploration Area.

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

Two species that migrate along the West Coast following the shoals of anchovy and pilchards are snoek *Thyrsites atun* and chub mackerel *Scomber japonicas*. Their appearance along the West and South-West coasts are highly seasonal. Snoek migrating along the southern African West Coast reach the area between St Helena Bay and the Cape Peninsula between May and August. They spawn in these waters between July and October before moving offshore and commencing their return northward migration (Payne & Crawford 1989). They are voracious predators occurring throughout the water column, feeding on both demersal and pelagic invertebrates and fish. Chub mackerel similarly migrate along the southern African West Coast reaching South-Western Cape waters between April and August. They move inshore in June and July to spawn before starting the return northwards offshore migration later in the year. Their abundance and seasonal migrations are thought to be related to the availability of their shoaling prey species (Payne & Crawford 1989).

The fish most likely to be encountered in the Exploration Area are the large pelagic species such as tunas, billfish and pelagic sharks, which migrate throughout the southern oceans, between surface and deep waters (>300 m). Species occurring off western southern Africa include the albacore/longfin tuna *Thunnus alalunga* (Figure 11, right), yellowfin *T. albacares*, bigeye *T. obesus*, and skipjack *Katsuwonus pelamis tunas*, as well as the Atlantic blue marlin *Makaira nigricans* (Figure 11, left), the white marlin *Tetrapturus albidus* and the broadbill swordfish *Xiphias gladius* (Payne & Crawford 1989). The distributions of these species is dependent on food availability in the mixed boundary layer between the Benguela and warm central Atlantic waters. These species have a highly seasonal abundance in the Benguela and show seasonal associations with underwater feature such as canyons and seamounts as well as meteorologically induced oceanic fronts (Penney *et al.* 1992). The closest underwater features to the Exploration Area are the Protea Seamount and Brown's Banks, which lie adjacent to the eastern boundary of the Exploration Area and ~250 km east of the Exploration Area, respectively (see **Error! Reference source not found.**). Protea Seamount lies. Seasonal association with Child's Bank (off Namaqualand) and Tripp Seamount (off southern Namibia) well to the north of the Exploration Area occurs between October and June, with commercial catches often peaking in March and April (www.fao.org/fi/fcp/en/ NAM/body.htm; see CapFish 2015 – Fisheries Specialist Study).

Figure 11: Large migratory pelagic fish such as blue marlin (left) and longfin tuna (right) occur in offshore waters (photos: www.samathatours.com; www.osfimages.com).

A number of species of pelagic sharks are also known to occur on the West and South-West Coast, including blue *Prionace glauca*, short-fin mako *Isurus oxyrinchus* and oceanic whitetip sharks *Carcharhinus longimanus*. Occurring throughout the world in warm temperate waters, these species are usually found further offshore on the West Coast. Great whites *Carcharodon* *carcharias* and whale sharks *Rhincodon typus* may also be encountered in coastal and offshore areas, although the latter occurs more frequently along the South and East coasts. Of these the blue shark is listed as “Near threatened”, and the short-fin mako, whitetip, great white and whale sharks as “Vulnerable” on the International Union for Conservation of Nature (IUCN).

3.2.2.4 Turtles

Three species of turtle occur along the southern African South-West Coast, namely the leatherback (*Dermochelys coriacea*) (Figure 12, left), and occasionally the loggerhead (*Caretta caretta*) (Figure 12 right) and the Green (*Chelonia mydas*) turtle. Loggerhead and green turtles are expected to occur only as occasional visitors along the West Coast.

Figure 12: Leatherback (left) and loggerhead turtles (right) occur along the West Coast of Southern Africa (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

The leatherback is the only turtle likely to be encountered in the offshore waters of west South Africa. The Benguela ecosystem is increasingly being recognized as a potentially important feeding area for leatherback turtles from several globally significant nesting populations in the south Atlantic (Gabon, Brazil) and south east Indian Ocean (South Africa) (Lambardi *et al.* 2008, Elwen & Leeney 2011). Leatherback turtles from the east South Africa population have been satellite tracked swimming around the West Coast of South Africa and remaining in the warmer waters west of the Benguela ecosystem (Lambardi *et al.* 2008) (Figure 13).

Leatherback turtles inhabit deeper waters and are considered a pelagic species, travelling the ocean currents in search of their prey (primarily jellyfish). While hunting they may dive to over 600 m and remain submerged for up to 54 minutes (Hays *et al.* 2004). Their abundance in the Exploration Area is unknown but expected to be low. Leatherback turtles are listed as “Vulnerable” worldwide by the IUCN (Red List 2013), with the regional population considered “Endangered” (Hughes & Nel 2014a) and are in need for conservation in CITES (Convention on International Trade in Endangered Species), and CMS (Convention on Migratory Species). Loggerhead and green turtles are listed globally as “Endangered”. Regionally, however, they have been classified as ‘Vulnerable’ and ‘Near Threatened’, respectively (Hughes & Nel 2014b). As a signatory of CMS, South Africa has endorsed and signed a CMS International Memorandum of Understanding specific to the conservation of marine turtles. South Africa is thus committed to conserve these species at an international level.

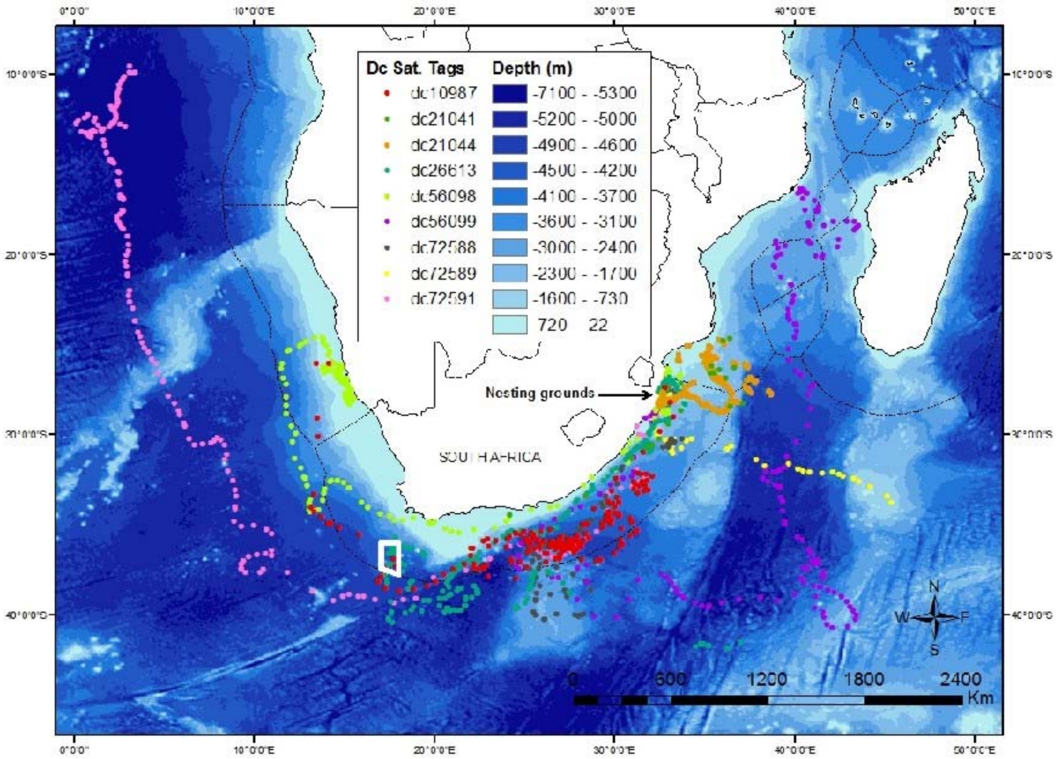


Figure 13: The post-nesting distribution of nine satellite tagged leatherback females (1996 – 2006; Oceans and Coast, unpublished data).

3.2.2.5 Seabirds

Large numbers of pelagic seabirds exploit the pelagic fish stocks of the Benguela system. Of the 49 species of seabirds that occur in the Benguela region, 14 are defined as resident, 10 are visitors from the northern hemisphere and 25 are migrants from the southern Ocean. The 18 species classified as being common in the southern Benguela are listed in

Table **1**. The area between Cape Point and the Orange River supports 38% and 33% of the overall population of pelagic seabirds in the southern Benguela in winter and summer, respectively. Most of the species in the region reach highest densities offshore of the shelf break (200 – 500 m depth), well inshore of the Exploration Area, with highest population levels during their non-breeding season (winter). Pintado petrels and Prion spp. show the most marked variation here.

14 species of seabirds breed in southern Africa: Cape gannet (Figure 14, left), African penguin (Figure 14, right), four species of cormorant, white pelican, three gull and four tern species (
Table **2**). The breeding areas are distributed around the coast with islands being especially important. The closest nesting grounds are at the Saldanha Bay islands, over 300 km north, and Dyer Island over 200 km north-east, of the Exploration Area. The number of successfully breeding birds at the particular breeding sites varies with food abundance. Most of the breeding seabird species forage at sea with most birds being found relatively close inshore (10-

30 km). Cape Gannets are known to forage up to 140 km offshore (Dundee 2006; Ludynia 2007), and African Penguins have been recorded as far as 60 km offshore. However, due to the extreme offshore location of the Exploration Area, penguins and gannets are unlikely to be encountered during exploration activities.

Table 1: Pelagic seabirds common in the southern Benguela region (Crawford *et al.* 1991).

Common Name	Species name	Global IUCN
Shy albatross	*Thalassarche cauta*	Near Threatened
Black browed albatross	*Thalassarche melanophrys*	Endangered[1]
Yellow nosed albatross	*Thalassarche chlororhynchos*	Endangered
Giant petrel sp.	*Macronectes halli/giganteus*	Near Threatened
Pintado petrel	*Daption capense*	Least concern
Greatwinged petrel	*Pterodroma macroptera*	Least concern
Soft plumaged petrel	*Pterodroma mollis*	Least concern
Prion spp	*Pachyptila* spp.	Least concern
White chinned petrel	*Procellaria aequinoctialis*	Vulnerable
Cory's shearwater	*Calonectris diomedea*	Least concern
Great shearwater	*Puffinus gravis*	Least concern
Sooty shearwater	*Puffinus griseus*	Near Threatened
European Storm petrel	*Hydrobates pelagicus*	Least concern
Leach's storm petrel	*Oceanodroma leucorhoa*	Least concern
Wilson's storm petrel	*Oceanites oceanicus*	Least concern
Blackbellied storm petrel	*Fregetta tropica*	Least concern
Skua spp.	*Catharacta/Stercorarius* spp.	Least concern
Sabine's gull	*Larus sabini*	Least concern

[1]. May move to Critically Endangered if mortality from long-lining does not decrease.

Figure 14: Cape Gannets *Morus capensis* (left) (Photo: NACOMA) and African Penguins *Spheniscus demersus* (right) (Photo: Klaus Jost) breed primarily on the offshore Islands.

Table 2: Breeding resident seabirds present along the West Coast (CCA & CMS 2001).

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

3.3.3.6 Marine Mammals

The marine mammal fauna occurring in the offshore environment (>200 m depth) of South Africa includes several species of whales and dolphins, some of which are present year round and others are seasonal migrants through the area. Thirty species of whales and dolphins are known (based on historic sightings or strandings records) or likely (based on habitat projections of known species parameters) to occur in these waters. The offshore environment has been poorly studied with the majority of information arising from historic whaling records prior to 1970, with some more recent inputs from a range of opportunistic records including MMO on seismic surveys since 2000. Current information on the distribution, population sizes and trends of most cetacean species occurring in the offshore environment of southern Africa is poor. Information on smaller cetaceans in deeper waters is particularly poor and the precautionary principal must be used when considering possible encounters with cetaceans in this area.

Cetaceans are comprised of two taxonomic groups, the mysticetes (filter feeders with baleen) and the odontocetes (predatory whales and dolphins with teeth). The term 'whale' is used to describe species in both these groups and is taxonomically meaningless (e.g. the killer whale and pilot whale are members of the Odontoceti, family Delphinidae and are thus dolphins). Due to differences in sociality, communication abilities, ranging behaviour and acoustic behavior, these two groups are considered separately for this assessment. A review of the distribution and seasonality of the key cetacean species likely to be found within the impact zone[1] is provided below.

Mysticete (Baleen) whales

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

BRYDE'S WHALE (*BALAENOPTER BRYDEI*) - Two genetically and morphologically distinct populations of Bryde's whales live off the coast of southern Africa (Best 2001; Penry 2010) (Figure 15, left). The "offshore population" lives beyond the shelf (>200 m depth) off west Africa and migrates between wintering grounds off equatorial west Africa (Gabon) and summering grounds off western South Africa. Its seasonality on the West Coast is thus opposite to the majority of the balaenopterids with abundance likely to be highest in the broader study area in January - March. The "inshore population" of Bryde's whales is unique amongst baleen whales in the region by being non-migratory. It lives on the continental shelf and Agulhas Bank of South Africa ranging from ~Durban in the east to at least St Helena Bay off the West Coast. The Exploration Area lies to the south and offshore of the known distributions of both these populations, so encounters are likely to be low.

SEI WHALE (*BALAENOPTERA BOREALIS*) - Almost all information on this species from the southern African sub-region originates from whaling data from shore based whaling stations in the Saldanha Bay area, which operated from 1958-1963. Sei whales spend time at high latitudes (40-50°S) during summer months and migrate north through South African waters where they were historically hunted in high numbers, to unknown breeding grounds further north along the

[1] The term 'impact zone' is used to define the survey area and region surrounding this that is likely to be affected by the increased shipping and noise levels associated with seismic and sonar activities. Exact definitions of the impact zone are not possible as sound propagation modelling in the survey area has not been undertaken place and distribution of many species is poorly understood. The term is thus used in a broad sense to encompass the species and region likely to be most affected by seismic activities.

Table 3: Species of whale and dolphin likely to be encountered within the impact zone, along with their general habitat preference for shelf of offshore waters, IUCN red list status and likely encounter frequency. Note: encounter frequency is a very broad estimate based on seasonality and distribution patterns to give a relative index of presence and is not a literal estimate of the likely number of times these species will be detected by observers.

Common Nam	Scientific Name	Occurrence on Shelf	Occurrence offshore	IUCN Conservation Status (2008)	Seasonality in impact zone	Likely encounter frequency
Delphinids						
Dusky dolphin	*Lagenorhynchus obscurus*	Yes 0-800m	No	Data Deficient	Year round	Unlikely
Common bottlenose dolphin (Offshore)	*Tursiops truncatus*	Yes	Yes	Least Concern	Year round	Weekly
Indo-Pacific bottlenose dolphin (Inshore)	*Tursiops aduncus*	Yes 0-50m	No	Data Deficient		Unlikely
Common dolphin - Short-beaked	*Delphinus delphis*	Occasional	Yes	Least Concern	Year round	Weekly
Common dolphin - Long-beaked	*Delphinis capensis*	Yes	No	Data Deficient		Weekly
Southern right whale dolphin	*Lissodelphis peronii*	Yes	Yes	Data Deficient	Year round	Rare
Long-finned pilot whale	*Globicephala melas*	Edge	Yes	Data Deficient	Year round	Weekly
Short-finned pilot whale	*Globicephala macrorhynchus*	?	?	Data Deficient	Year round	Unlikely
Killer whale	*Orcinus orca*	Occasional	Yes	Data Deficient	Year round	Weekly
False killer whale	*Pseudorca crassidens*	Occasional	Yes	Data Deficient	Year round	Weekly
Pygmy killer whale	*Feresa attenuata*	?	Yes	Data Deficient	Year round	Unlikely
Risso's dolphin	*Grampus griseus*	Edge	Yes	Least Concern	Year round	Monthly
Sperm whales						
Pygmy sperm whale	*Kogia breviceps*	Edge	Yes	Data Deficient	Year round	Weekly
Dwarf sperm whale	*Kogia sima*	Edge	?	Data Deficient	Year round	Weekly
Sperm whale	*Physeter macrocephalus*	Edge	Yes	Vulnerable A1d	Year round	Weekly

Common Nam	Scientific Name	Occurrence on Shelf	Occurrence offshore	IUCN Conservation Status (2008)	Seasonality in impact zone	Likely encounter frequency
Beaked whales						
Cuvier's	*Ziphius cavirostris*	No	Yes	Least Concern	Year round	Rare
Arnoux's	*Beradius arnuxii*	No	Yes	Data Deficient	Year round	Rare
Southern bottlenose	*Hyperoodon planifrons*	No	Yes	Least Concern	Year round	Rare
Layard's	*Mesoplodon layardii*	No	Yes	Data Deficient	Year round	Rare
True's	*M. mirus*	No	Yes	Data Deficient	Year round	Rare
Gray's	*M. grayi*	No	Yes	Data Deficient	Year round	Rare
Blainville's	*M. densirostris*	No	Yes	Data Deficient	Year round	Rare
Baleen whales						
Antarctic minke	*Balaenoptera bonaerensis*	Yes	Yes	Data Deficient	Higher in winter	Weekly
Dwarf minke	*B. acutorostrata*	Yes	Yes	Not assessed	Year round	Weekly
Fin whale	*B. physalus*	Yes	Yes	Endangered	May-Jul, Oct-Nov	Occasional
Blue	*B. musculus*	No	Yes	Endangered	May-Aug	Unlikely
"Pygmy" Blue	*B. musculus brevicauda*	No	Yes	Endangered	May-Aug	Unlikely
Sei	*B. borealis*	Edge	Yes	Endangered	May-Jun, Aug-Oct	Weekly
Bryde's (both forms)	*B. brydei*	Yes	Yes	Data Deficient	Higher in summer	Monthly
Humpback	*Megaptera novaeangliae*	Yes	Yes	Least Concern	Year round, higher in Jun-Nov	Weekly
Pygmy right	*Caperea marginata*	Yes	?	Data Deficient	Year round	Unlikely
Southern right	*Eubalaena australis*	Yes	No	Least Concern	Year round, higher in Jul-Nov	Monthly

west African coast (Best 2007). Due to their migration pattern, densities in the broader study area are likely to show a bimodal peak with numbers predicted to be highest in May - June and again in August – October, although with likely occurrence year round. During commercial whale hunts, all whales were caught in waters deeper than 200 m with most caught deeper than 1,000 m (Best & Lockyer 2002). Importantly, there may be considerable variation in the number of sei whales within an area between years, which may be influenced by food availability in feeding areas. Sei whales are likely to be one of the more commonly seen baleen whales in the Exploration Area.

Figure 15: The Bryde's whale *Balaenoptera brydei* (left) and the Minke whale *Balaenoptera bonaerensis* (right) (Photos: www.dailymail.co.uk; www.marinebio.org).

FIN WHALE (*BALAENOPTERA PHYSALUS*) - Fin whales were historically caught off the West Coast of South Africa and Namibia. A bimodal peak in the catch data from whaling stations at Saldanha Bay suggests that animals were migrating further north to breed (during May-June) before returning to Antarctic feeding grounds (during August-October). However, the location of the breeding ground (if any) and how far north it is remains unknown (Best 2007). Some juvenile animals may feed year round in deeper waters off the shelf (Best 2007). Sightings of a live animal in St Helena Bay, South Africa in November 2011 (MRI unpubl. data) and off Lüderitz in southern Namibia in March-May (Sea Search unpubl. Data) confirm their contemporary occurrence in the region during summer months.

BLUE WHALE (*BALAENOPTERA MUSCULUS*) - Antarctic blue whales were historically caught in high numbers during commercial whaling activities, with a single peak in catch rates during July in Walvis Bay, Namibia and at Namibe, Angola suggesting that in the eastern South Atlantic these latitudes are close to the northern migration limit for the species (Best 2007). Very few confirmed sightings of blue whales have occurred off the west coast of South Africa and Namibia since 1973 (Branch *et al.* 2007), although reports are increasing as data from pelagic waters becomes available, confirming their current presence in the area, although at very low densities. Note: "Pygmy" blue whales *B. m. brevicauda* may also occur in the Exploration Area, but it is unlikely that the species can be distinguished visually at sea.

MINKE WHALE (*BALAENOPTERA BONAERENSIS / ACUTOROSTRATA*) - Two forms of minke whale occur in the southern Hemisphere, the Antarctic minke whale (*Balaenoptera bonaerensis*) (Figure 15, right) and the dwarf minke whale (*B. acutorostrata* subsp.); both species are likely to occur in the Exploration Area (Best 2007, NDP unpublished data). Antarctic minke whales range from the pack ice of Antarctica to tropical waters and are usually seen more than ~50 km offshore. Although adults of the species do migrate from the Southern Ocean (summer) to tropical/temperate waters (winter) where they are thought to breed, some animals, especially juveniles, are known to stay in tropical/temperate waters year round. The dwarf minke whale has a more temperate distribution than the Antarctic minke and they do not range further south than 60-65°S. Dwarf minke whales have a similar migration pattern to Antarctic minkes with at least some animals migrating to the Southern Ocean in summer months. Around southern Africa, dwarf minke whales occur closer to shore than Antarctic minkes and have been seen <2 km from shore, but also well off the shelf (Best 2007). Both species may be encountered in the Exploration Area.

The most abundant baleen whale species around southern Africa are southern right whales (Figure 16, left) and humpback whales (Figure 16, right). In the last decade, both species have been increasingly observed to remain on the West Coast of South Africa well after the 'traditional' South African whale season (June – November) into spring and early summer (October – February) where they have been observed feeding in upwelling zones, especially off Saldanha and St Helena Bays (Barendse *et al.* 2011; Mate *et al.* 2011).

Figure 16: The humpback whale (left) and the southern right whale (right) migrate along the South Coast during winter (Photos: www.divephotoguide.com; www.aad.gov.au).

HUMPBACK WHALE (*MEGAPTERA NOVAEANGLIAE*) - The majority of humpback whales passing along the West Coast of South Africa are migrating to breeding grounds off tropical west Africa, between Angola and the Gulf of Guinea (Rosenbaum *et al.* 2009; Barendse *et al.* 2010), while those migrating up the East Coast of heading to breeding grounds of Mozambique and Madagascar (Findlay *et al.* 2011). The location of the offshore survey area puts it outside the known migration corridors of either population, but its location to the west of Cape Agulhas makes it likely that 'West Coast' whales are more likely to be encountered. Importantly, a large number of humpback whales can be found feeding within the Benguela ecosystem (especially between Saldanha Bay and St Helena Bay) in the spring and summer months (Barendse *et al.* 2011). Importantly, animals using this West Coast feeding ground may migrate through the Exploration Area *en route* to or from the Antarctic. The exact relationship between whales using this feeding ground and those breeding further north is not fully understood at the moment, but there is some overlap of individuals (Carvalho *et al.* 2009; Barendse *et al.* 2011). Recent abundance estimates put the number of animals in the west African breeding population to be in excess of 9,000 individuals in 2005 (IWC 2012) and it is likely to have increased since this time at about 5% per annum (IWC 2012). Humpback whales are thus likely to be one of the most frequently encountered baleen whales in in the survey area.

SOUTHERN RIGHT WHALE (*EUBALAENA AUSTRALIS*) – Southern right whales migrate from Southern Ocean feeding grounds at approximately 60°S to the coastline of southern Africa where they were historically found from southern Mozambique (Maputo Bay) to southern Angola (Baie dos Tigres). The most recent abundance estimate for this population is available for 2008 which estimated the population at ~4,600 individuals including all age and sex classes, which is thought to be at least 23% of the original population size (Brandão *et al.* 2011). Since the population is still continuing to grow at ~7% per year (Brandão *et al.* 2011), the population size in 2015 is likely to number more than 7,000 individuals. Southern right whales also feed during spring and summer months on the West Coast of South Africa between St Helena and Saldanha Bays, and possibly further north and now have an almost year round presence along the South African coast (Mate *et al.* 2011; Peters *et al.* 2011; Barendse & Best 2014). Right whales tend to remain within a few kilometres of shore except when migrating to and from sub-Antarctic feeding grounds when it is possible they will pass through the Exploration Area.

Odontocetes (toothed) whales

The Odontoceti are a varied group of animals including the dolphins, porpoises, beaked whales and sperm whales. Species occurring within the broader study area display a diversity of behaviours and sizes ranging from solitary to groups of thousands and from about 2-m long for the smaller dolphins to a 17-m long bull sperm whale.

SPERM WHALE (*PHYSETER MACROCEPHALUS*) – Almost all information about sperm whales in the southern African sub-region results from data collected during commercial whaling activities prior to 1985 (Best 2007) (Figure 17, left). Sperm whales are the largest of the toothed whales and have a complex, structured social system with adult males behaving differently to younger males and female groups. They live in deep ocean waters, usually greater than 1,000 meters depth, although they occasionally come onto the shelf in water 500-200 m deep (Best 2007). They are considered to be relatively abundant globally (Whitehead 2002), although no estimates are available for southern Africa. Seasonality of catches off west South Africa suggests that medium and large sized males are more abundant in winter months while female groups are more abundant in autumn (March - April), although animals occur year round (Best 2007). Sperm whales feed at great depths during dives in excess of 30 minutes making them difficult to detect visually, however the regular echolocation clicks made by the species when diving make them relatively easy to detect acoustically using Passive Acoustic Monitoring (PAM).

There are almost no data available on the abundance, distribution or seasonality of the smaller odontocetes (including the beaked whales and dolphins) known to occur in oceanic waters (greater than 200 m) off the shelf of southern Africa (see Table 3). Beaked whales are all considered to be true deep-water species usually being seen in waters in excess of 1,000-2,000 m deep (see various species accounts in Best 2007). Presence in the survey area may fluctuate seasonally, but insufficient data exist to define this clearly.

PYGMY AND DWARF SPERM WHALES (KOGIA SPP) - 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 (Ross 1979; Findlay *et al.* 1992; Elwen *et al.* 2013). *Kogia* species are most frequently occur in pelagic and shelf edge waters, are thus likely to occur in the Exploration Area at low levels, seasonality is unknown. Dwarf sperm whales are associated with the warmer waters south and east of St Helena Bay. Pygmy sperm whales are recorded from both the Benguela and Agulhas ecosystem (Best 2007) and are likely to occur in the Exploration Area in waters deeper than ~1,000 m.

Figure 17: 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).

KILLER WHALE (*ORCINUS ORCA*) - Killer whales have a circum-global distribution being found in all oceans from the equator to the ice edge (Best 2007). Killer whales occur year round in low densities off western South Africa (Best *et al.* 2010), Namibia (Elwen & Leeney 2011) and in the Eastern Tropical Atlantic (Weir *et al.* 2010). Killer whales are found in all depths from the coast to deep open ocean environments and may thus be encountered in the Exploration Area at low levels (Figure 17, right).

FALSE KILLER WHALE (*PSEUDORCA CRASSIDENS*) – Although 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 water 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, all between St Helena Bay and Cape Agulhas), which may aggrandize the consequences of any injury or harassment by seismic airguns, multi-beam sonar or associated activities. Use of multi-beam sonar was identified as the probable underlying cause of a mass-stranding of melon-headed whales in Madagascar in 2008 (Southall *et al.* 2013).

There is no information on population numbers or conservation status and no evidence of seasonality in the region (Best 2007), but they are likely to be encountered regularly in the Exploration Area.

PYGMY KILLER WHALE (*FERESA ATTENUATA*) – the species is found worldwide in tropical and subtropical waters. Within the sub region it has been recorded from Gabon, Namibia, South Africa, Comoro Islands and the Seychelles, typically occurring offshore in oceanic waters. Information on population numbers, conservation status and seasonality in the region is lacking (Best 2007).

LONG-FINNED PILOT WHALES (*GLOBICEPHALA MELAS*) – Long-finned pilot whales display a preference for temperate waters and are usually associated with the continental shelf or deep water adjacent to it (Mate *et al.* 2005; Findlay *et al.* 1992; Weir 2011) (Figure 18, right). They are regularly seen associated with the shelf edge by MMOs and fisheries observers and researchers operating in South African and Namibian waters (Sea Search Africa unpubl. data). The distinction between long-finned and short-finned (*G. macrorhynchus*) pilot whales is difficult to make at sea. As the latter are regarded as more tropical species (Best 2007), it is likely that the vast majority of pilot whales encountered in the Exploration Area will be long-finned. Pilot whales are likely to be among the most commonly encountered odontocetes in vicinity of the Exploration Area.

COMMON BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) – Two species of bottlenose dolphins occur around southern Africa. The smaller Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), which occurs exclusively to the east of Cape Point in water usually less than 30 m deep (and thus outside the impact area) and the larger common bottlenose dolphin (*T. truncatus*) (Figure 18, left), which is found on and beyond the shelf. Little is known about this offshore form of bottlenose dolphins around southern Africa, and nothing about their population size or conservation status. They sometimes occur association with other species such as pilot whales (NDP unpublished data) or false killer whales (Best 2007) and are likely to be present year round in waters deeper than 200 m.

COMMON DOLPHIN (*DELPHINUS* SPP.) – Two species of common dolphin are known to occur in warm temperate waters around Southern Africa, although distinguishing them at sea is challenging so they have been combined here. The short-beaked (*D. delphis*) has a worldwide distribution in offshore waters and confirmed sightings within southern Africa occur primarily off the continental shelf. The long-beaked common dolphin (*D. capensis*) is primarily associated with the waters of the continental shelf to the east of the Cape Peninsula although sightings regularly occur as far north as St Helena Bay (Findlay *et al.* 1992). Both species generally form large groups of hundreds to thousands of animals and are easily spotted at sea. Encounter rate in oceanic waters is not known but animals of either species might be encountered occasionally.

DUSKY DOLPHINS (*LAGENORHYNCHUS OBSCURUS*) - Dusky dolphins are resident year round in the Benguela ecosystem where they occupy waters from the coast to approximately 500 m deep. Although no information is available on the size of the population, they are regularly encountered in near shore waters suggesting a relatively large population of at least several thousand. Dusky dolphins are unlikely to be encountered in the survey area.

RISSO'S DOLPHIN *(GRAMPUS GRISEUS)* – A medium sized dolphin with a distinctively high level of scarring and a proportionally large dorsal fin and blunt head. Risso's dolphins are distributed world wide in tropical and temperate seas and show a general preference for shelf edge waters <1,500 m deep (Best 2007). Although sightings have occurred beyond this, encounters are likely to be rare in the Exploration Area.

SOUTHERN RIGHT WHALE DOLPHINS (*LISSODELPHIS PERONII*) – The cold waters of the Benguela provide a northwards extension of the normally subantarctic habitat of this species (Best 2007). Most records in the region originate in a relatively restricted region between 26˚S and 28˚S off Lüderitz (Rose & Payne 1991) in water 100-2,000 m deep (Best 2007), where they are seen several times per year (Findlay *et al*. 1992; JP Roux pers comm.). Encounters in the Exploration Area are likely to be low.

Figure 18: Toothed whales that occur offshore of the Southwest Coast include the Bottlenose dolphin (left) and the long-finned pilot whale (right) (Photos: www.fish-wallpapers.com; www.seapics.com).

BEAKED WHALES (VARIOUS SPECIES) – Beaked whales were never targeted commercially and their pelagic distribution makes them largely inaccessible to most researchers making them the most poorly studied group of cetaceans. With recorded dives of well over an hour and in excess of 2 km deep, beaked whales are amongst the most extreme divers of any air breathing animals (Tyack et al. 2011). They also appear to be particularly vulnerable to certain types of man-made noise, although the exact reason for this is not yet fully understood. All possible precautions should thus be taken to avoid causing any harm. All the beaked whales that may be encountered in the Exploration Area are pelagic species that tend to occur in small groups usually less than 5, although larger aggregations of some species are known (MacLeod & D'Amico 2006; Best 2007). The long, deep dives of beaked whales make them both difficult to detect visually, but PAM will increase the probability of detection as animals are frequently echo-locating when on foraging dives.

In summary, there are no current data on the presence, density or conservation status of any cetaceans within the planned survey area. All information provided above is based on at least some level of projection of information from studies elsewhere in the region, at some time in the past (often decades ago) or extrapolated from knowledge of habitat choice of the species.

Of the migratory cetaceans, the Blue, Sei and Fin whales are listed as "Endangered" and the Southern Right and Humpback whale as "Least Concern" in the IUCN Red Data book. 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[2], killed or fished. No vessel or aircraft may approach closer than or remain within 300 m of any whale without a permit 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.

Pinnepeds

The Cape fur seal (*Arctocephalus pusillus pusillus*) (Figure 19) is the only species of seal resident along the west coast of Africa, occurring at numerous breeding and non-breeding sites on the mainland and on nearshore islands and reefs (see Figure 21). Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leoninas),* subantarctic fur seal (*Arctocephalus tropicalis),* crabeater *(Lobodon carcinophagus)* and leopard seals (*Hydrurga leptonyx)* (David 1989).

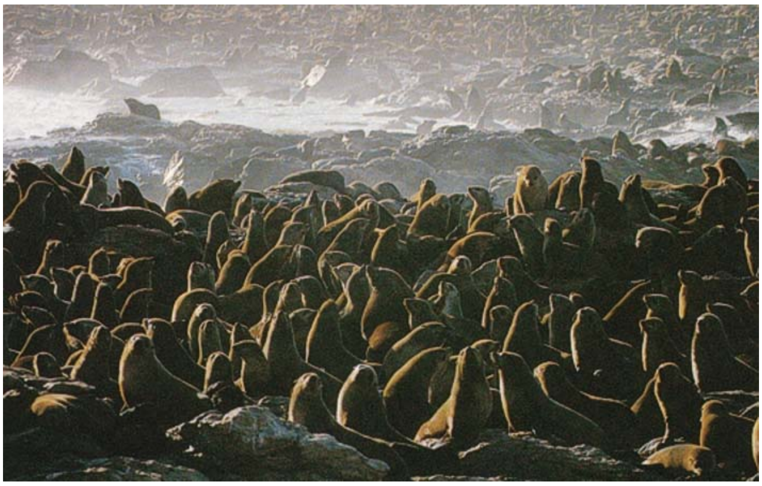


Figure 19: Colony of Cape fur seals *Arctocephalus pusillus pusillus* (Photo: Dirk Heinrich).

There are a number of Cape fur seal colonies within the broader study area: Paternoster Rocks and Jacobs Reef at Cape Columbine, Robbesteen near Koeberg and Seal Island in False Bay. Non-breeding colonies occur at Paternoster Point at Cape Columbine and Duikerklip in Hout Bay. These colonies all fall well outside of the Exploration Area. The nearest breeding colonies are at Seal Island in False Bay, ~200 km to the northeast of the Exploration Area. All have important conservation value since they are largely undisturbed at present. The timing of the annual breeding cycle is very regular, occurring between November and January. Breeding success is highly dependent on the local abundance of food, territorial bulls and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen 1991). Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles offshore (Shaughnessy 1979), with bulls ranging further out to sea than females. They are therefore unlikely to be encountered during exploration activities in Blocks 3617 and 3717.

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

3.3. Conservation Areas and Marine Protected Areas

Numerous conservation areas and marine protected areas (MPAs) exist along the coastline of the Western Cape, although none fall within the Exploration Area (

Figure **20**).

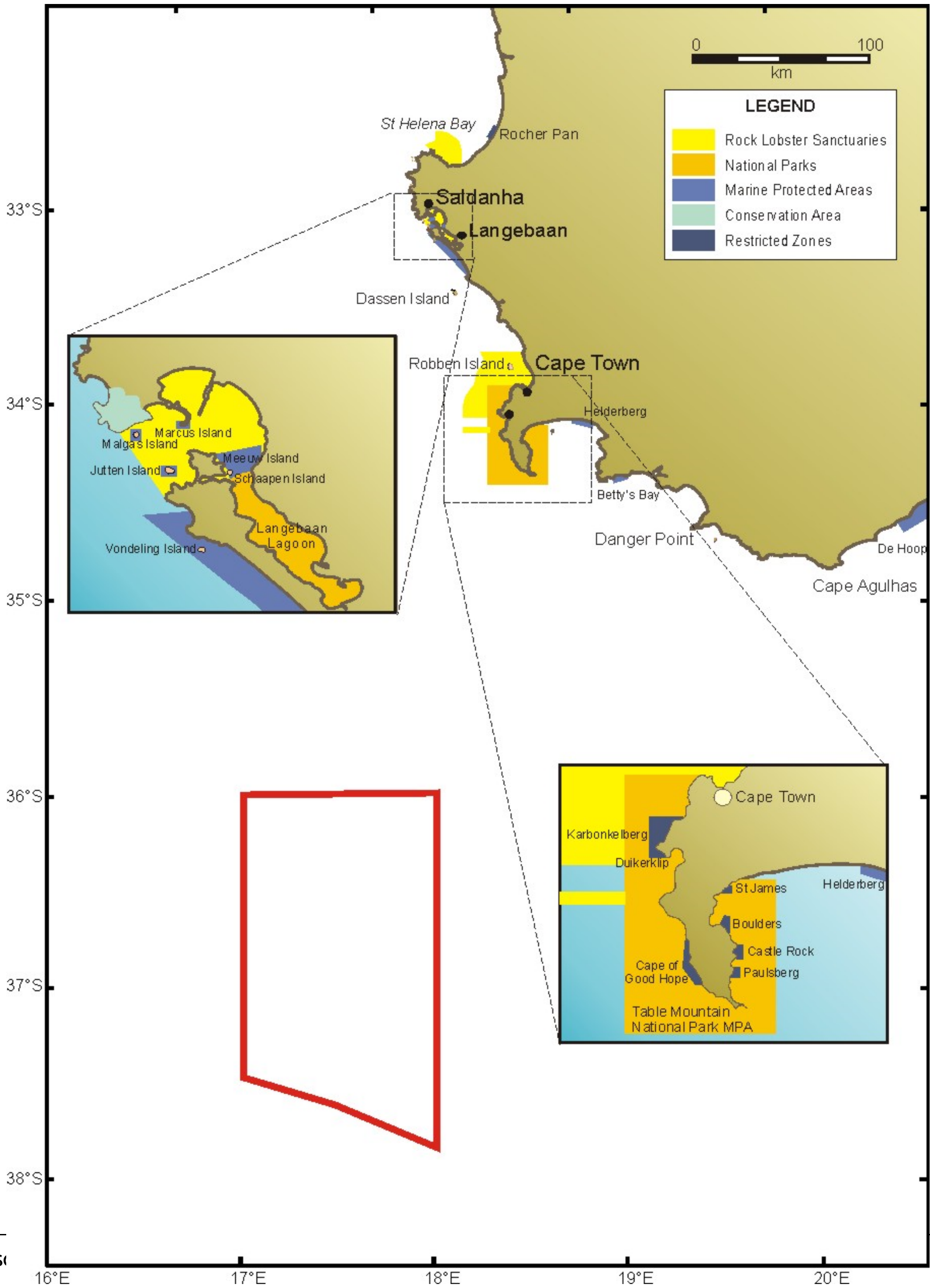


Figure 20: Reserves and Marine Protected Areas on the South-West Coast in relation to the Exploration Area (red polygon).

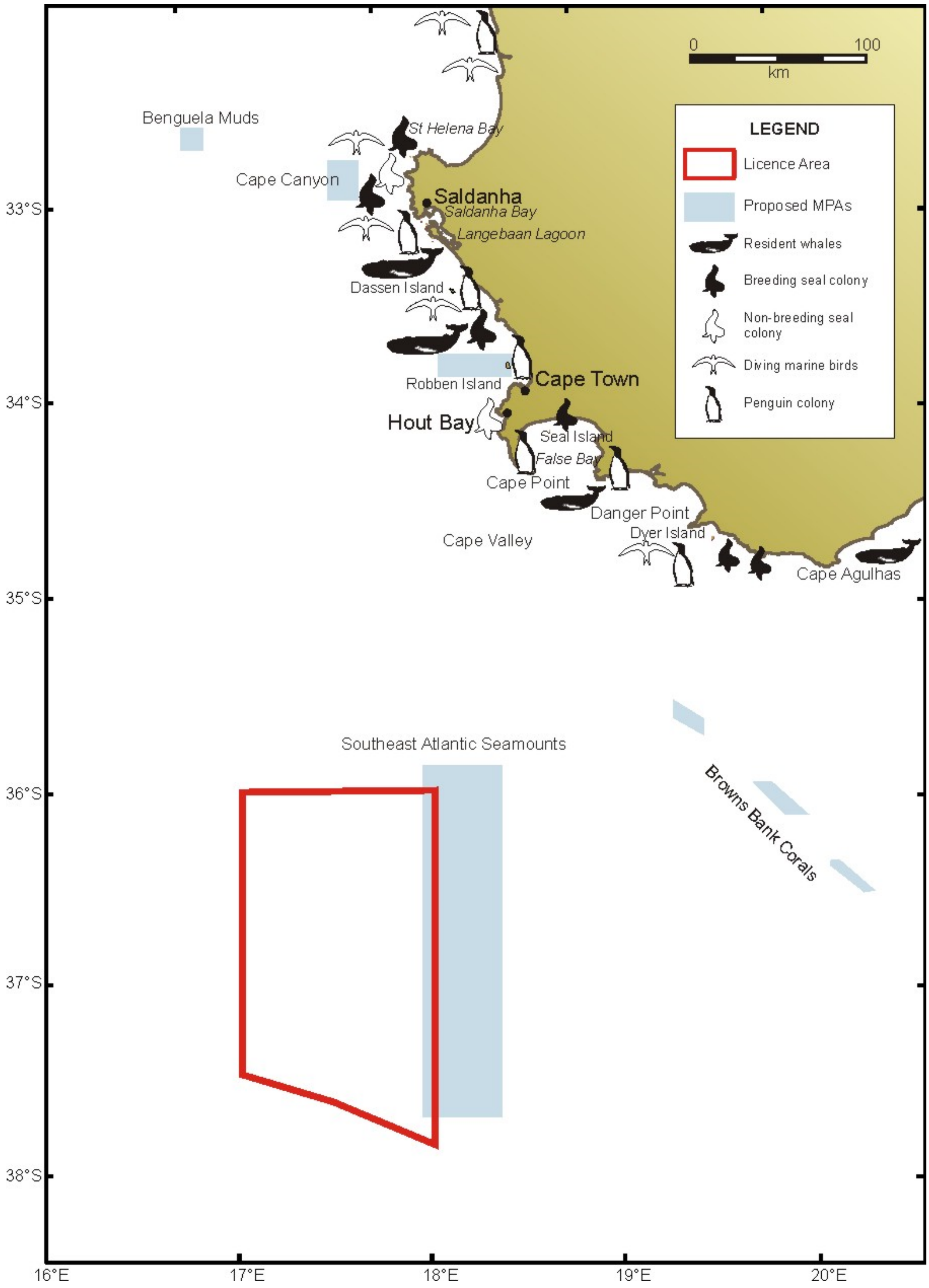


Figure 21: Project - environment interaction points on the South-West Coast, illustrating the location of seabird and seal colonies and resident whale populations in relation to the Block 3617 and 3717 Exploration Area. Areas identified by Operation Phakisa as potential offshore Marine Protected Areas are shaded blue.

'No-take' MPAs offering protection of the Namaqua biozones (sub-photic, deep-photic, shallow-photic, intertidal and supratidal zones) are absent northwards from Cape Columbine (Emanuel *et al.* 1992, Lombard *et al.* 2004). This has resulted in substantial portions of the coastal and shelf-edge marine biodiversity in the area being assigned a threat status of 'critically endangered', 'endangered' or 'vulnerable' (Lombard *et al.* 2004; Sink *et al.* 2012) (see Figure 7). Using biodiversity data mapped for the 2004 and 2011 National Biodiversity Assessments a systematic biodiversity plan has been developed for the West Coast (Majiedt *et al.* 2013) with the objective of identifying both coastal and offshore priority areas for MPA expansion. To this end, nine focus areas were identified for protection on the West Coast between Cape Agulhas and the South African – Namibian border, and these carried forward through Operation Phakisa for the proposed development of offshore MPAs. Those within the broad project area are shown in Figure 21. The eastern border of the Exploration Area falls within the proposed Southeast Atlantic Seamounts MPA, although the seamount itself is located ~7 km east of the Exploration Area. Before formal declaration of these proposed MPAs, a full public participation process with other stakeholders in the affected areas will need to be undertaken.

3.4. Summary of Features Specific to the Exploration Area

Features specific to the Block 3617 and 3717 Exploration Area are summarised below:

- The Exploration Area is approximately 13,280 km^2 in extent;
- Water depths extend beyond 3,500 m;
- The Exploration Area lies beyond the edge of the continental shelf with the nearest point being ~190 km offshore of Cape Point;
- Seabed sediments comprise primarily muds and sandy muds;
- Information on seabed communities specific to the Exploration Area is lacking, but the sediments are likely to host a range of benthic macrofaunal species;
- The Exploration Area lies well offshore of the influence of coastal upwelling, and waters are likely to be comparatively warm and clear with low abundances of phytoplankton, zooplankton and ichthyoplankton;
- Fish species likely to be encountered comprise primarily the large pelagic species (e.g. tunas, billfish and pelagic sharks), which migrate throughout the southern oceans, between surface and deep waters (>300 m);
- Migrating leatherback turtles are also likely to occur, as are a variety of pelagic seabirds;
- Marine mammals likely to be encountered include sperm whales, migrating humpback whales and various baleen and toothed whales known to frequent offshore waters; and
- The Exploration Area lies well offshore of existing MPAs, but overlaps with the proposed Southeast Atlantic Seamounts offshore MPA.

4. 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). 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). Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping. Depending on size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 μPa at 1 m (NRC 2003). Especially at low frequencies between 5 to 100 Hz, vessel traffic is a major contributor to noise in the world's oceans, and under the right conditions, these sounds can propagate 100s of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al.* 2003). Other forms of anthropogenic noise include 1) aircraft flyovers, 2) multi-beam sonar systems, 3) seismic acquisition, 4) hydrocarbon and mineral exploration and recovery, and 5) noise associated with underwater blasting, pile driving, and construction. Below follows a detailed review of the effects of seismics on marine fauna and a brief summary of the effects of multi-beam sonars.

4.1. Seismics

The airguns used in modern seismic surveys produce some of the most intense non-explosive sound sources used by humans in the marine environment (Gordon *et al.* 2004). However, the transmission and attenuation of seismic sound is probably of equal or greater importance in the assessment of environmental impacts than the produced source levels themselves, as transmission losses and attenuation are very site specific, and are affected by propagation conditions, distance or range, water and receiver depth and bathymetrical aspect with respect to the source array. In water depths of 25 - 50 m airgun arrays are often audible 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, respectively (Bowles *et al.* 1991; Richardson *et al.* 1995; see also references in McCauley 1994). The signal character of seismic shots also changes considerably with propagation effects. Reflective boundaries include the sea surface, the seafloor 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.

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

Below follows a brief review of the impacts of seismic surveys on marine faunal communities. This information is largely drawn from McCauley (1994), McCauley *et al.* (2000), the Generic EMPR for Oil and Gas Prospecting off the Coast of South Africa (CCA & CMS 2001) and the very comprehensive review by Cetus Projects (2007), compiled as part of the Environmental Impact Assessment for the Ibhubesi Gas Field. While the effects on pelagic and benthic invertebrates, fish, turtles and seabirds is covered briefly, the discussion and assessments focus primarily on marine mammals.

Impacts on Plankton

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. Phytoplankton are not known to be affected by seismic surveys and are unlikely to show any significant effects of exposure to airgun impulses outside of a 1 m distance (Kosheleva 1992; McCauley 1994).

Zooplankton comprises meroplankton (organisms which spend a portion of their life cycle as plankton, such as fish and invertebrate larvae and eggs) and holoplankton (organisms that remain planktonic for their entire life cycle, such as siphonophores, nudibranchs and barnacles). The abundance and spatial distribution of zooplankton is highly variable and dependent on factors such as fecundity, seasonality in production, tolerances to temperature, length of time spent in the water column, hydrodynamic processes and natural mortality. Zooplankton densities are generally low and patchily distributed. The amount of exposure to the influence of seismic airgun arrays is thus dependent on a wide range of variables. 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. However, for a large seismic array, a physiological effect out to 10 m from the array is considered a generous value with known effects demonstrated to 5 m only (Kostyuchenko 1971).

McCauley (1994) concludes that when compared with total population sizes or natural mortality rates of planktonic organisms, the relative influence of seismic sound sources on these populations can be considered insignificant. The wash from ships propellers and bow waves can be expected to have a similar, if not greater, volumetric effect on plankton than the sounds generated by airgun arrays.

Due to their importance in commercial fisheries, numerous studies have been undertaken experimentally exposing the eggs and larvae of various ichthyoplankton species to airgun sources (reviewed in McCauley 1994). These are discussed further in the Section on Impacts on Fish, below.

Impacts on Marine Invertebrates

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. However, information on hearing by invertebrates, and noise impacts on them is sparse. Although many invertebrates cannot sense the pressure of a sound wave or the lower amplitude component of high frequency sounds, low frequency high amplitude sounds may be detected *via* the mechanoreceptors, particularly in the near-field of such sound sources (McCauley 1994). Sensitivity to near-field low-frequency sounds or hydroacoustic disturbances has been recorded for the lobster *Homarus americanus* (Offut 1970), and various other invertebrate species (Horridge 1965, 1966; Horridge & Boulton 1967; Moore & Cobb 1986; Packard *et al.* 1990; Turnpenney & Nedwell 1994).

Despite no quantitative records of invertebrate mortality from seismic sound exposure under field operating conditions, lethal and sub-lethal effects have been observed under experimental conditions where invertebrates were exposed to airguns up to five metres away. These include reduced growth and reproduction rates and behavioural changes in crustaceans (DFO 2004; McCauley 1994; McCauley *et al.* 2000). The effects of seismic survey energy on snow crab (*Chionoecetes opilo*) on the Atlantic coast of Canada, for example ranged from no physiological damage but effects on developing fertilized eggs at 2 m range (Christian *et al.* 2003) to possible bruising of the heptopancreas and ovaries, delayed embryo development, smaller larvae, and indications of greater leg loss but no acute or longer term mortality and no changes in embryo survival or post hatch larval mobility (DFO 2004). The ecological significance of sub-lethal or physiological effects could thus range from trivial to important depending on their nature.

Behavioural responses of invertebrates to particle motion of low frequency stimulation has been measured by numerous researchers (reviewed in McCauley 1994). Again a wide range of responses are reported ranging from no avoidance by free ranging invertebrates (crustaceans, echinoderms and molluscs) of reef areas subjected to pneumatic airgun fire (Wardle *et al.*

2001), and no reduction in catch rates of brown shrimp (Webb & Kempf 1998), prawns (Steffe & Murphy 1992, in McCauley, 1994) or rock lobsters (Parry & Gasson 2006) in the near-field during or after seismic surveys.

Cephalopods, in contrast, may be receptive to the far-field sounds of seismic airguns. Recent electrophysiological studies have confirmed that cephalopods show sensitivity to frequencies under 400 Hz (*Octopus vulgaris*, Kaifu *et al.* 2008; *Sepioteuthis lessoniana, Octopus vulgaris*, Hu *et al.* 2009; *Loligo pealei*, Mooney *et al.* 2010). Behavioural response range from attraction at 600 Hz pure tone (Maniwa 1976), through 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). Based on the results of caged experiments, McCauley *et al.* (2000) suggested that squid would significantly alter their behaviour at an estimated 2 - 5 km from an approaching large seismic source. More recently, Andre *et al.* (2011) demonstrated that received sound levels of 175 dB re 1 μPa resulted in severe acoustic trauma (morphological damage to the statoscysts and afferent dendrites) in four cephalopod species tested under controlled-exposure experiments. Giant squid strandings coincident with seismic surveys have been reported (Guerra *et al.* 2004). Although animals showed no external damage, all had severe internal injuries (including disintegrated muscles and unrecognisable organs) indicative of having ascended from depth too quickly. The causative link to seismic surveys has, however, not been established with certainty.

Impacts on Fish

Fish hearing has been reviewed by numerous authors including Popper and Fay (1973), Hawkins (1973), Tavolga *et al.* (1981), Lewis (1983), Atema *et al.* (1988), and Fay (1988). Fish have two different systems to detect sounds namely 1) the ear (and the otolith organ of their inner ear) that is sensitive to sound pressure and 2) the lateral line organ that is sensitive to particle motion. Certain species utilise separate inner ear and lateral line mechanisms for detecting sound; each system having its own hearing threshold (Tavolga & Wodinsky 1963), and it has been suggested that fish can shift from particle velocity sensitivity to pressure sensitivity as frequency increases (Cahn *et al.* 1970, in Turl 1993).

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

Most species of fish and elasmobranchs are able to detect sounds from well below 50 Hz (some as low as 10 or 15 Hz) to upward of 500 - 1,000 Hz (Popper & Fay 1999; Popper 2003; Popper *et al.* 2003), and consequently can detect sounds within the frequency range of most widely occurring anthropogenic noises. Within the frequency range of 100 - 1,000 Hz at which most fish hear best, hearing thresholds vary considerably (50 and 110 dB re 1 μPa). They are able to discriminate between sounds, determine the direction of a sound, and detect biologically relevant sounds in the presence of noise. In addition, some clupeid fish can detect ultrasonic sounds to over 200 kHz (Popper & Fay 1999; Mann *et al.* 2001; Popper *et al.* 2004). Fish that possess a coupling between the ear and swim-bladder have probably the best hearing of fish species (McCauley 1994). Consequently, there is a wide range of susceptibility among fish to seismic sounds, with those with a swim-bladder will be more susceptible to anthropogenic sounds than those without this organ.

Studies have shown that fish can be exposed directly to the sound of seismic survey without lethal effects, outside of a very localised range of physiological effects. Physiological effects of impulsive airgun sounds on fish species include swim-bladder damage (Falk & Lawrence 1973), transient stunning (Hastings 1990, in Turnpenney & Nedwell 1994), short-term biochemical variations in different tissues typical of primary and secondary stress response (Santulli *et al.* 1999; Smith *et al.* 2004), and temporary hearing loss due to destruction of the hair cells in the hearing maculae (Enger 1981; Lombarte *et al.* 1993; Hastings *et al.* 1996; McCauley *et al.* 2000; Scholik & Yan 2001, 2002; McCauley *et al.* 2003; Popper *et al.* 2005; Smith *et al.* 2006). 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.

Behavioural responses to impulsive sounds are varied and include leaving the area of the noise source (Suzuki *et al.* 1980; Dalen & Rakness 1985; Dalen & Knutsen 1987; Løkkeborg 1991; Skalski *et al.* 1992; Løkkeborg & Soldal 1993; Engås *et al.* 1996; Wardle *et al.* 2001; Engås & Løkkeborg 2002; Hassel *et al.* 2004), changes in depth distribution (Chapman & Hawkins 1969; Dalen 1973; Pearson *et al.* 1992; Slotte *et al.* 2004), spatial changes in schooling behaviour (Slotte *et al.* 2004), and startle response to short range start up or high level sounds (Pearson *et al.* 1992; Wardle *et al.* 2001). 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). 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. In some cases behaviour patterns returned to normal within minutes of commencement of surveying indicating habituation to the noise. Disturbance of fish is believed to cease at noise levels below 160 dB re 1μPa. The ecological significance of such effects is therefore expected to be low, except in cases where they influence reproductive activity.

There are currently concerns that seismic survey activities in southern Namibia are linked to reductions in tuna catches (David Russel, *pers. comm.*). The respective Ministries have however, agreed that additional research is needed on the subject before policy decisions on seismics and fisheries can be made (G. Schneider, Geological Survey of Namibia, *pers. comm.*). According to other sources, it is probable that fluctuating tuna catches are caused by a number of variables (e.g. fluctuation of fishing effort, general decline in longfin tuna abundance and changes in fishing strategy) (Attwood 2014). This is supported by the briefing paper prepared by Dr Gabi Schneider of the GSN (Schneider & Muyongo 2013), which states that a simple correlation between seismic survey acquisition in Namibian waters and reduced tuna catches cannot be inferred and more in-depth research is required.

Although the effects of airgun noise on spawning behaviour of fish have not been quantified to date, it is predicted that if fish are exposed to powerful external forces on their migration paths or spawning grounds, they may be disturbed or even cease spawning altogether. The deflection from migration paths may be sufficient to disperse spawning aggregations and displace spawning geographically and temporally, thereby affecting recruitment to fish stocks.

Indirect effects of seismic shooting on fish include reduced catches resulting from changes in feeding behaviour or vertical distribution (Skalski *et al.* 1992), but information on feeding success of fish (or larger predators) in association with seismic survey noise is lacking.

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. Numerous studies have been undertaken experimentally exposing the eggs and larvae of various fish species to airgun sources (Kostyuchenko 1971; Dalen & Knutsen 1987; Holliday *et al.* 1987; Booman *et al.* 1992; Kosheleva 1992; Popper *et al.* 2005, amongst others). These studies generally identified mortalities and physiological injuries at very close range (<5 m) only. For example, increased mortality rates for fish eggs were proven out to ~5 m distance from the airguns. 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). Fish larvae with swim-bladders 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 others.

From a fish resource perspective, these effects may potentially contribute to a certain diminished net production in fish populations. However, Sætre & Ona (1996) calculated that under the "worst case" scenario, the number of larvae killed during a typical seismic survey was 0.45% of the total larvae population. When more realistic "expected values" were applied to each parameter of the calculation model, the estimated value for killed larvae during one run was equal to 0.03% of the larvae population. If the same larval population was exposed to multiple seismic runs, the effect would add up for each run. For species such as cod, herring and capelin, the natural mortality is estimated at 5-15% per day of the total population for eggs and larvae. This declines to 1-3% per day once the species reach the 0 group stage *i.e.* at approximately 6 months (Sætre & Ona 1996). Consequently, Dalen *et al.* (1996) concluded that seismic-created mortality is so low that it can be considered to have an inconsequential impact on recruitment to the populations.

Impacts on Seabirds

Among the marine avifauna of South African waters, 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 (*Spheniscus demersus*), which is flightless and occurs along the South Coast, would be particularly susceptible to impacts from underwater seismic noise. 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). 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).

The continuous nature of the intermittent seismic survey pulses suggest that African penguins and other 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. Consequently, the potential for injury to seabirds from seismic surveys in the open ocean is deemed to be low (see also Stemp 1985, in Turnpenny & Nedwell 1994), particularly given the extensive feeding range of the potentially affected seabird species.

Impacts on Turtles

The potential effects of seismic surveys on turtles include:

- Physiological injury (including disorientation), mortality from seismic noise or collision with or entanglement in towed seismic apparatus;
- Behavioural avoidance of seismic survey areas;
- Masking of environmental sounds and communication; and
- Indirect effects due to effects on prey.

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). The overlap of this hearing sensitivity with the higher frequencies produced by airguns, suggest that turtles may be considerably affected by seismic noise.

No information on physiological injury to turtle hearing could be sourced in the literature. 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.

Behavioural changes in response to anthropogenic sounds have been reported for some sea turtles and include startle response (Lenhardt *et al.* 1983), an increase in swim speed and erratic behaviour indicative of avoidance (O'Hara & Wilcox 1990; McCauley *et al.* 2000). 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; McCauley *et al.* 2000).

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 was double that of full-array seismic activity, although these results should be treated with caution 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.

Although collisions between turtles and vessels are not limited to seismic vessels, the large amount of equipment towed astern of survey vessels does increase the potential for collision, or entrapped within seismic equipment and towed surface floats. Basking turtles are particularly slow to react to approaching objects 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 22, 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 22, 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.

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.

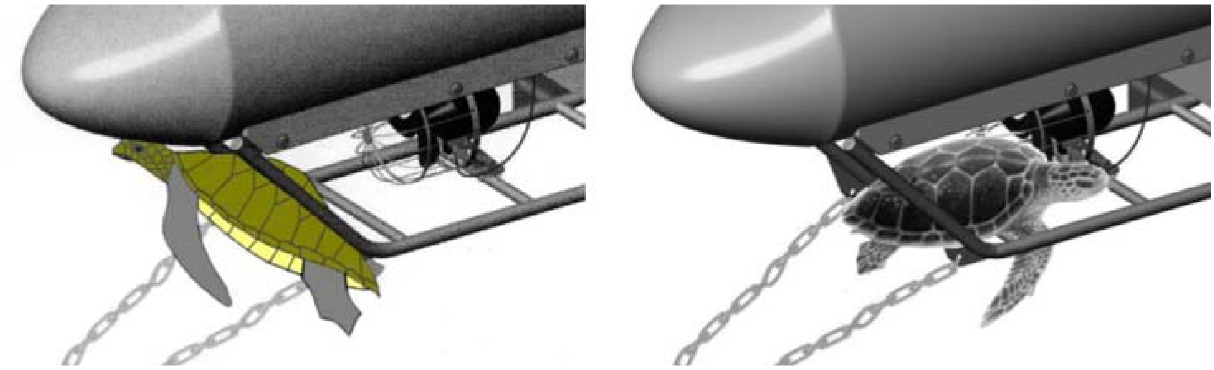


Figure 22: Turtles commonly become trapped in front of the undercarriage of the tail buoy in the area between the buoy and the towing chains (left), and inside the 'twin-fin' undercarriage structure (right) (Ketos Ecology 2009).

Impacts on Seals

The Cape fur seal forages over the continental shelf to depths of over 200 m (up to approximately 120 nautical miles offshore) and would therefore not be expected to occur within the survey area.

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 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 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), temporary threshold shifts (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.

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). 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.

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.

Impacts on Whales and Dolphins

The cetaceans comprise baleen whales (mysticetes) and toothed whales and dolphins (odontocetes). The potential impact of seismic survey noise on cetaceans includes

a) physiological injury to individuals, b) behavioural disturbance (and subsequent displacement from key habitat), c) masking of important environmental or biological sounds, or d) effects due to indirect effects on prey. Reactions of cetaceans to anthropogenic sounds have been reviewed by McCauley (1994), Richardson *et al.* (1995), Gordon & Moscrop (1996) and Perry (1998). More recently reviews have focused specifically on the effects of sounds from seismic surveys on marine mammals (DFO 2004; NRC 2005; Nowacek *et al.* 2007; Southall *et al.* 2007; Abgrall *et al.* 2008, amongst others).

Cetacean vocalisations

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

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

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

Cetacean hearing

Cetacean hearing has received considerable attention in the international literature, and available information has been reviewed by several authors including Popper (1980), Fobes &

Smock (1981), Schusterman (1981), Ridgway (1983), Watkins & Wartzok (1985), Johnson (1986), Moore & Schusterman (1987) and Au (1993).

Marine mammals as a group have wide variations in ear anatomy, frequency range and amplitude sensitivity. The hearing threshold is the amplitude necessary for detection of a sound and varies with frequency across the hearing range (Nowacek *et al.* 2007). Considerable differences also exist between the hearing sensitivities of baleen and toothed whales and dolphins and between individuals, resulting in different levels of sensitivity to sounds at varying frequencies.

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; Table 4). The high hearing thresholds at low frequency for those species tested implies that the low frequency component of seismic shots (10 - 300 Hz) will not be audible to the small to medium odontocetes at any great distance. However, the higher frequency of an airgun array shot, which can extend to 15 kHz and above (Madsen *et al.* 2006) may be audible from tens of kilometres away, due to the very low sensitivity thresholds of many toothed whales at frequencies exceeding 1 kHz.

No psycho-acoustical or electrophysical work on the sensitivity of baleen whales to sound has been conducted (Richardson *et al.* 1995) and hypotheses regarding the effects of sound in baleen whales are extrapolations from what is known to affect odontocetes or other marine mammals and from observations of behavioural responses. A partial response "audiogram" exists for the gray whale based on the avoidance of migrating whales to a pure tone source (Dahlheim & Ljungblad 1990). Frankel *et al.* (1995, in Perry 1998) found humpback whales in the wild to detect sounds ranging from 10 Hz to 10 kHz at levels of 102 to 106 dB re 1 µPa. Blue whales reduce calling in the presence of mid-frequency sonar (1-8 kHz) providing evidence that they are receptive to sound in this range (Melcón *et al.* 2012). Based on the low frequency calls produced by larger toothed whales, and anatomical and paleaontological evidence for baleen whales, it is predicted that these whales hear best in the low frequencies (Fleischer 1976, 1978; McCauley 1994), with hearing likely to be most acute below 1 kHz (Fleischer 1976, 1978; Norris & Leatherwood 1981; Table 4). The available information demonstrates that the larger toothed whales and baleen whales will be very receptive to the sound produced by seismic airgun arrays and consequently this group may be more affected by this type of disturbance than toothed whales (Nowacek *et al.* 2007).

Physiological injury

Exposure to high sound levels can result in physiological injury to cetaceans through a number of avenues, including shifts of hearing thresholds (as either permanent (PTS) or temporary threshold shifts (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; Fernandez *et* *al.* 2005; 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; MacLeod & D'Amico 2006), and the results are thus not directly applicable to non-explosive seismic sources such as those from airgun arrays. Cox *et al.* (2006), however, linked a stranding two Cuvier's beaked whales in the Gulf of California to a seismic survey (also running a multi-beam echo-sounder and sub bottom profiler).

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 levels for PTS are 230 dB re:1 µPa (peak) and 198 re:1 µPa^2-s for SPL and SEL respectively for low, medium and high frequency cetaceans (**Error! Reference source not found.**). For TTS these values are 224 dB re:1 µPa (peak) and 183 dB re:1 µPa^2-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 183 dB re:1 µPa^2-s SEL.

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).

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).

Noise induced stress resulting from exposure to sources of marine sound can cause detrimental changes in blood hormones, including cortisol (Romano *et al.* 2004). The timing of the stressor relative to seasonal feeding and breeding cycles (such as those observed in migrating baleen whales) may influence the degree of stress induced by noise exposure (Tyack 2008). However, quantifying stress caused by noise in wild populations is difficult as it is not possible to determine the physiological responses of an animal to a noise stressor based on behavioural observations alone (Wright *et al.* 2007). One recent study was able to identify a reduction in stress-related faecal hormone metabolites (glucocorticoids) in North Atlantic right whales concurrent with a 6 dB reduction in shipping noise. This study provided the first evidence that exposure to low-frequency ship noise may be associated with chronic stress in whales (Rolland *et al.* 2013).

Table 4: Functional hearing groups, auditory bandwidth (estimated lower to upper frequency hearing cut-off) and proposed injury criterion of marine mammals (exposed through either single or multiple noise events within a 24-h period) found in Namibia (adapted from Southall *et al.* 2007).

<table>
<tr><th>Functional hearing group</th><th>Estimated auditory bandwidth</th><th>Marine mammal group</th><th>Proposed injury criteria for pulsed sounds -
a) Sound pressure level
b) Sound exposure level.</th></tr>
<tr><td>Low frequency cetaceans</td><td>7 Hz to 22 kHz</td><td>All baleen whales</td><td rowspan="3">PTS
a) 230 dB re:1μPa (peak)
b) 198 dB re: 1μPa^2 - s

TTS
a) 224 dB re:1μPa (peak)
b) 183 dB re: 1 μPa^2-s</td></tr>
<tr><td>Mid frequency cetaceans</td><td>150 Hz to 160 kHz</td><td>Steno, Sotalia, Tursiops, Stenella, Delphinus, Lagenorhynchus, Lissodelphis, Grampus, Feresa, Pseudorca, Orcinus, Globicephala, Physeter, Ziphius, Berardius, Hyperoodon, Mesoplodon</td></tr>
<tr><td>High frequency cetaceans</td><td>200 Hz to 180 kHz</td><td>Cephalorhynchus, Kogia,</td></tr>
<tr><td>Pinnepeds
(in water)</td><td>75 Hz to 75 kHz</td><td>Arctocephalus</td><td>PTS
a) 218 dB re:1μPa (peak)
b) 186 dB re: 1μPa^2 - s
TTS
a) 212 dB re:1μPa (peak)
b) 171 dB re: 1 μPa^2-s</td></tr>
</table>

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 sound exposure level (SEL) (Madsen *et al.* 2006).

Typical behavioural response in cetaceans to seismic airgun noise include initial startle responses (Malme *et al.* 1985; Ljungblad *et al.* 1988; McCauley *et al.* 2000), changes in surfacing behaviour (Ljungblad *et al.* 1988; Richardson *et al.* 1985a; McCauley *et al.* 1996, 2000), shorter dives (Ljungblad *et al.* 1988), changes in respiration rate (Ljungblad *et al.* 1988; Richardson *et al.* 1985a, 1985b, 1986; Malme *et al.* 1983, 1985,1986), slowing of travel (Malme *et al.* 1983, 1984), and changes in vocalisations (McDonald *et al.* 1993, 1995) and call rate (Di lorio & Clarke 2010). These subtle changes in behavioural measures are often the only observable reaction of whales to reception of anthropogenic stimuli, and there is no evidence that these changes are biologically significant for the animals (see for example McCauley 1994). Possible exceptions are impacts at individual (through reproductive success) and population level through disruption of feeding within preferred areas (as reported by Weller *et al.* (2002) for Western gray whales). For continuous noise, whales begin to avoid sounds at exposure levels of 110 dB, and more than 80% of species observed show avoidance to sounds of 130 dB. For seismic noise, most whales show avoidance behaviour above 160 dB (Malme *et al.* 1983, 1984; Ljungblad *et al.* 1988; Pidcock *et al.* 2003). Behavioural responses are often evident beyond 5 km from the sound source (Ljungblad *et al.* 1988; Richardson *et al.* 1986, 1995), 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 (but see also Tyack *et al.* 2011).

In an analysis of marine mammals sightings recorded from seismic survey vessels in United Kingdom waters, Stone (2003) reported that responses to large gun seismic activity varied between species, with small odontocetes showing the strongest avoidance response. Responses of medium and large odontocetes (killer whales, pilot whales and sperm whales) were less marked, with sperm whales showing no observable avoidance effects (see also Rankin & Evans 1998; Davis *et al.* 2000; Madsen *et al.* 2006). Baleen whales showed fewer responses to seismic survey activity than small odontocetes, and although there were no effects observed for individual baleen whale species, fin and sei whales were less likely to remain submerged during firing activity. All baleen whales showed changes in behavioural responses further from the survey vessel (see also Ljungblad *et al.* 1988; McCauley 2000; Abgrall *et al.* 2008), and both orientated away from the vessel and altered course more often during shooting activity. The author suggests that different species adopt different strategies in response to seismic survey disturbance, with faster smaller odontocetes fleeing the survey area (e.g. Weir 2008), while larger slower moving baleen whales orientate away from and move slowly from the firing guns, possibly remaining on the surface as they do so (see also Richardson *et al.* 1985a, 1985b, 1986, 1995). Responses to small airguns were less, and although no difference in distance to firing and non-firing small airguns were recorded, there were fewer sightings of small odontocetes in association with firing airguns. Other reports suggest that there is little effect of seismic surveys on small odontocetes such as dolphins, as these have been reported swimming near operating seismic vessels (Duncan 1985; Evans & Nice 1996; Abgrall *et al.* 2008; but see also Schlundt *et al.* 2000).

McCauley *et al.* (1996, 2000) found no obvious evidence that humpback whales were displaced by 2D and 3D seismic surveys and no apparent gross changes in the whale's migratory path could be linked to the seismic survey. Localised avoidance of the survey vessel during airgun operation was however noted. Whales which are not migrating but using the area as a calving or nursery ground may be more seriously affected through disturbance of suckling or resting. Potential avoidance ranges of 7-12 km by nursing animals have been suggested, although these might differ in different sound propagation conditions (McCauley *et al.* 2000). 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. Baleen whales generally appear to vocalise almost exclusively within the frequency range of the maximum energy of seismic sounds, while toothed whales vocalise at much higher frequencies, 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 be also considered (Madsen *et al.* 2006).

Indirect effects on prey species

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

4.2. Multi-beam Sonars

There are significant differences in the effects of seismic and multi-beam/side-scan surveys. Despite having similar sound levels to seismic surveys, the higher frequency emissions utilised in normal multi-beam and sub-bottom profiling operations tend to be dissipated to safe levels over a relatively short distance. The anticipated radius of influence of multi-beam sonar would thus be significantly less than that for an airgun array. Hence the most likely scenario for injury to an animal by acoustic equipment would be if the equipment were turned on full power while the animal was close to it (Anon 2007). Active sonar systems operate at frequency ranges >10 kHz, producing levels of sound pressure ranging from about 200 dB re 1µPa to 240 dB re 1µPa. Although these higher frequency sounds attenuate more rapidly in seawater than do lower frequency sounds, they do have the potential to impact marine fauna. Available information on cetacean hearing suggests that baleen whales are 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). Both baleen whales and toothed whales would thus be expected to hear sonar signals from most types of oceanographic sonars at frequencies within their functional hearing range if the whales are within the sonar beam. Similarly, pinnipeds are also expected to hear sonar signals at frequencies within their functional hearing range if the animals are within the sonar beam, and phocids (true seals) and otariids (fur seals) would hear sonars operating at frequencies up to about 75 kHz and 35 kHz, respectively (Richardson *et al.*1995). Marine turtles, however, appear to have their highest auditory sensitivity at frequencies of 250 – 700 Hz, and thus well below the frequency ranges typically used by oceanographic sonars.

In 2003, the German Federal Environmental Agency (UBA) decreed restrictions on the use of multi-beam systems in Antarctic waters, with the arguement that marine mammals could theoretically be ensonified by the fan-shaped sonar beam, potentially resulting in a TTS or PTS, and leading to disorientation. However, the statistical probability of crossing a cetacean with a narrow multi-beam fan several times, or even once, is very small. In contrast, the US National Marine Fisheries Service (NMFS), believed that marine mammals were unlikely to be harassed or injured from the multi-beam sonar or the sub-bottom profiler as the multi-beam sonar had an anticipated radius of influence significantly less than that for an airgun array.

It is thus generally understood that in open coastal waters the effects of multi-beam sonars on marine fauna are negligible.

5. ASSESSMENT OF ACOUSTIC IMPACTS ON MARINE FAUNA

5.1. Assessment Procedure

The following convention was used to determine significance ratings in the assessment:

Rating	Definition of Rating
Extent – defines the physical extent or spatial scale of the impact	
Local	Extending only as far as the activity, limited to the site and its immediate surroundings
Regional	Limited to the South-West Coast
National	Limited to the coastline of South Africa
International	Extending beyond the borders of South Africa
Duration – the time frame over which the impact will be experienced	
Short-term	0 – 5 years
Medium-term	6 – 15 years
Long-term	Where the impact would cease after the operational life of the activity, either because of natural processes or by human intervention
Permanent	Where mitigation either by natural processes or by human intervention would not occur in such a way or in such time span that the impact can be considered transient
Intensity – establishes whether the magnitude of the impact is destructive or benign in relation to the sensitivity of the receiving environment	
Zero – Very Low	Where natural environmental functions and processes are not affected
Low	Where the affected environment is altered, but natural functions and processes continue, albeit in a slightly modified way
Medium	Where the affected environment is altered, but natural functions and processes continue, albeit in a modified way
High	Where environmental functions and processes are altered to the extent that they temporarily or permanently cease

Using the core criteria above, the significance of the impact is determined:

Significance – attempts to evaluate the importance of a particular impact, and in doing so incorporates extent, duration and intensity	
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 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 enduring 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.

Significance – attempts to evaluate the importance of a particular impact, and in doing so incorporates extent, duration and intensity	
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, enduring 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, enduring 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 to medium intensity at a local level, enduring in the short term.
INSIGNIFICANT	Impacts with: Zero to Very Low intensity with any combination of extent and duration.
UNKNOWN	Where it is not possible to determine the significance of an impact.

Status of the Impact – describes whether the impact would have a negative, positive or zero effect on the affected environment	
Positive	The impact benefits the environment
Negative	The impact results in a cost to the environment
Neutral	The impact has no effect
Probability – the likelihood of the impact occurring	
Improbable	Possibility very low either because of design or historic experience
Probable	Distinct possibility
Highly Probable	Most likely
Definite	Impact will occur regardless of preventive measures
Degree of confidence in predictions – in terms of basing the assessment on available information and specialist knowledge	
Low	Less than 35% sure of impact prediction.
Medium	Between 35% and 70% sure of impact prediction.
High	Greater than 70% sure of impact prediction

Degree to which impact can be mitigated – indicates the degree to which an impact can be reduced / enhanced	
None	No change in impact after mitigation.
Very Low	Where the significance rating stays the same, but where mitigation will reduce the intensity of the impact.
Low	Where the significance rating drops by one level, after mitigation.
Medium	Where the significance rating drops by two to three levels, after mitigation.
High	Where the significance rating drops by more than three levels, after mitigation.
Reversibility of an impact – refers to the degree to which an impact can be reversed	
Irreversible	Where the impact is permanent.
Partially Reversible	Where the impact can be partially reversed.
Fully Reversible	Where the impact can be completely reversed.
Loss of Resources – refers to the degree to which a resource is permanently affected by the activity, i.e. the degree to which a resource is irreplaceable	
Low	Where the activity results in a loss of a particular resource but where the natural, cultural and social functions and processes are not affected.
Medium	Where the loss of a resource occurs, but natural, cultural and social functions and processes continue, albeit in a modified way.
High	Where the activity results in an irreplaceable loss of a resource.

Additional criteria to be considered, which could “increase” the significance rating are:

- Permanent / irreversible impacts (as distinct from long-term, reversible impacts);
- Potentially substantial cumulative effects; and
- High level of risk or uncertainty, with potentially substantial negative consequences.

Additional criteria to be considered, which could “decrease” the significance rating are:

- Improbable impact, where confidence level in prediction is high.

The relationship between the significance ratings after mitigation and decision-making can be broadly defined as follows:

Significance after Mitigation - considering changes in intensity, extent and duration after mitigation and assuming effective implementation of mitigation measures	
Very Low; Low	Will not have an influence on the decision to proceed with the proposed project, provided that recommended measures to mitigate negative impacts are implemented.
Medium	Should influence the decision to proceed with the proposed project, provided that recommended measures to mitigate negative impacts are implemented.
High; Very High	Would strongly influence the decision to proceed with the proposed project.

5.2. Impacts of Seismic Surveys

5.2.1 Impacts to Plankton (including ichthyoplankton)

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. Impacts will thus be of high intensity at very close range (<5 m from the airguns) only, and no more significant than the effect of the wash from ships propellers and bow waves. As plankton distribution is naturally temporally and spatially variable and natural mortality rates are high, any impacts would thus be of low to negligible intensity across the Exploration Area and for the duration of the survey (short-term).

The proposed Exploration Area lies well offshore of the Cape Peninsula and Cape Columbine upwelling cells. Offshore areas are characterised by diminished phytoplankton biomass due to the predominance of nutrient-poor oceanic waters. A deficiency of phytoplankton results in poor feeding conditions for micro-, meso- and macrozooplankton, and for ichthyoplankton. Phytoplankton, zooplankton and ichthyoplankton abundances in the Exploration Area are thus expected to be low.

The proposed Exploration Area also does not overlap with the spring to early summer spawning areas for a number of commercially important species (see Figure **9**), or the northward egg and larval drift for anchovy. Ichthyoplankton abundance is thus expected to be negligible.

The overall potential impact of seismic noise on plankton and ichthyoplankton is thus deemed to be **INSIGNIFICANT**.

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

Impacts of seismic noise to plankton and ichthyoplankton		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Very Low	Very Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.2.2 Impacts to Marine Invertebrates

Although some marine invertebrates have mechanoreceptors or statocyst organs that are sensitive to hydroacoustic disturbances, most do not possess hearing organs that perceive sound pressure. Potential impacts of seismic pulses on invertebrates include physiological injury and behavioural avoidance of seismic survey areas. Masking of environmental sounds and indirect impacts due to effects on predators or prey have not been documented and are highly unlikely.

Physiological injury and mortality

There is little published information on the effects of seismic surveys on invertebrate fauna. It has been postulated, however, that shellfish, crustaceans and most other invertebrates can only hear seismic survey sounds at very close range, such as less than 15 m away. This implies that only surveys conducted in very shallow water will have any detrimental effects. As the survey would mostly be conducted in excess of 3,000 m depth the received noise at the seabed would be within the far-field range, and outside of distances at which physiological injury of benthic invertebrates would be expected. The potential impact of seismic noise on physiological injury or mortality of benthic invertebrates is consequently deemed of low to negligible intensity across the Exploration Area and for the survey duration and is considered to be **INSIGNIFICANT**.

Pelagic invertebrates that may be encountered in the Exploration Area in low numbers are the colossal squid and the giant squid. Although a causative link to seismic surveys has not been established with certainty, giant squid strandings coincident with seismic surveys have been reported (Guerra *et al.* 2004), the animals all having severe internal injuries indicative of having ascended from depth too quickly. The potential impact of seismic noise on physiological injury or mortality of pelagic cephalopods could thus potentially be of high intensity across the Exploration Area and for the survey duration. However, as the probability of an encounter is considered low, the impact is deemed to be of **VERY LOW** significance both without and with mitigation.

Behavioural avoidance

Similarly, there is little published information on the effects of seismic surveys on the response of invertebrate fauna to seismic impulses. Limited avoidance of airgun sounds may occur in mobile neritic and pelagic invertebrates and is deemed to be of low intensity. Of the marine invertebrates only cephalopods are receptive to the far-field sounds of seismic airgun arrays. Although consistent avoidance has not been reported, behavioural changes have been observed at 2 – 5 km from an approaching large seismic source (McCauley *et al.* 2000). The received noise at the seabed would be within the far-field range, and thus outside of distances at which avoidance of benthic invertebrates would be expected, but potentially within the response range of cephalopods. The potential impact of seismic noise on invertebrate behaviour is consequently deemed of low to negligible intensity across the Exploration Area and for the survey duration and is considered to be of **VERY LOW** significance both with and without mitigation, and no mitigation measures are deemed necessary.

Mitigation

No direct mitigation measures for potential impacts on benthic and pelagic invertebrates and their larvae are feasible or deemed necessary.

Impacts of seismic noise to benthic marine invertebrates resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area.	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Zero – Very Low	Zero – Very Low
Significance	Insignificant	Insignificant
Status	Insignificant	Insignificant
Probability	Improbable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic noise to pelagic invertebrates resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area.	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic noise to marine invertebrates resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area.	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.2.3 Impacts to Fish

A review of the available literature suggests that potential impacts of seismic pulses to fish species (including sharks) could include physiological injury and mortality, behavioural avoidance of seismic survey areas, masking of environmental sounds and communication, and indirect impacts due to effects on predators or prey.

Physiological injury and mortality

The greatest risk of pathological injury from seismic sound sources is for species that establish home ranges on shallow-water reefs or congregate in inshore waters to spawn or feed, and those displaying an instinctive alarm response to hide on the seabed or in the reef rather than flee. Large demersal or reef-fish species with swim-bladders are also more susceptible than those without this organ. Such species may suffer pathological injury or severe hearing damage and adverse effects may intensify and last for a considerable time after the termination of the sound source. However, as the Exploration Area is mostly located in water depths of >3,000 m, the received noise by demersal species at the seabed would be within the far-field range, and outside of distances at which physiological injury or avoidance would be expected. The impact on demersal species is therefore considered to be **INSIGNIFICANT**.

The most likely fish species to be encountered in the Exploration Area are the large pelagic species such as the highly migratory tuna and billfish, which show seasonal association with Child's Bank (off Namaqualand) and Tripp Seamount (off southern Namibia) to the north of the Exploration Area between October and June, with commercial catches often peaking in March and April (see CapFish 2015 – Fisheries Specialist Study). As the survey is scheduled during the summer of 2016/17 there is thus a high likelihood that the survey vessel would encounter tuna and billfish *en route* to their seasonal aggregation around the seamounts. However, given the high mobility of most large pelagic species, it is assumed that the majority of these would avoid seismic noise at levels below those where physiological injury or mortality would result. Furthermore, 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. 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. The potential physiological impact on pelagic species, would be of high intensity. The duration of the impact on the population would be limited to the short-term. The impact is therefore considered to be of **LOW** significance without the implementation of mitigation measures, and of **VERY LOW** significance with mitigation measures.

Behavioural avoidance

Behavioural responses such as avoidance of seismic survey areas and changes in feeding behaviours of some fish to seismic sounds have been documented at received levels of about 160 dB re 1 μPa. Recent concerns that seismic survey activities in southern Namibia and the Australian Bight are responsible for substantially reduced catches of albacore and southern bluefin tuna, respectively, however still need to be substantiated. According to other sources, it is probable that fluctuating tuna catches are caused by a number of variables (e.g. fluctuation of fishing effort, general decline in longfin tuna abundance and changes in fishing strategy) (Attwood 2014). This is supported by the briefing paper prepared by Dr Gabi Schneider of the GSN (Schneider & Muyongo, 2013) which states that a simple correlation between seismic survey acquisition in Namibian waters and reduced tuna catches cannot be inferred and more in-depth research is required.

The potential impact on fish behaviour could therefore be of high intensity (particularly in the near-field of the airgun array), over the short-term 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. Any observed effects will be limited to the survey area, and are unlikely to persist for more than a few days after termination of the seismic source. Consequently it is considered to be of **MEDIUM** significance without mitigation and **LOW** significance with mitigation.

Reproductive success / spawning

Fish populations can be further impacted if behavioural responses result in deflection from migration paths or disturbance of spawning. If fish on their migration paths or spawning grounds are exposed to powerful external forces, they may be disturbed or even cease spawning altogether 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. Studies undertaken experimentally exposing the eggs and larvae of various fish species to airgun sources, however, identified mortalities and physiological injuries at very close range (<5 m) only.

Considering the wide range over which the potentially affected species occur, the relatively short duration of the proposed exploration activities, the offshore location of the Exploration Area, and that the migration routes are located further inshore (see **Error! Reference source not found.**) do not constitute narrow restricted paths, the impact is considered to be **INSIGNIFICANT** both without and with the implementation of mitigation measures. Indirect effects of mortality to ichthyoplankton on recruitment to adult fish populations is also considered to be **INSIGNIFICANT** both with and without mitigation (see Section 5.2.1).

Masking of environmental sounds and communication

Communication and the use of environmental sounds by fish in the offshore environment off the southern African west coast are unknown. Impacts arising from masking of sounds are expected to be of 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 and for the duration of the survey and are consequently considered of **VERY LOW** significance both with and without mitigation.

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 and tunas to pelagic fish 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 species in association with seismic survey noise. Although large pelagic species are known to aggregate around seamounts to feed, considering the extensive range over which large pelagic fish species can potentially feed in relation to the survey area, and the low abundance of pelagic shoaling species that constitute their main prey, the impact is likely to be of **VERY LOW** significance both with and without mitigation.

Mitigation

Recommendations for mitigation include:

- Implement a “soft-start” procedure of a minimum of 20 minutes’ duration when initiating seismic surveying, to allow pelagic fish to move out of the survey area and thus avoid potential physiological injury as a result of seismic noise.
- All breaks in airgun firing of longer than 20 minutes must be followed by a “soft-start” procedure of at least 20 minutes prior to the survey operation continuing. Breaks of shorter than 20 minutes should be followed by a “soft-start” of similar duration.
- Airgun firing should be terminated if mass mortalities of fish as a direct result of shooting are observed.

Impacts of seismic noise on demersal fish resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Very Low	Very Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic noise on pelagic fish resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low to Medium
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low to Medium
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic noise on pelagic fish resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Medium
Significance	Medium	Low
Status	Negative	Negative
Probability	Probable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low to Medium
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic noise on reproductive success and spawning		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Very Low	Very Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic noise on fish resulting in masking of sounds		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Low	Low
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic noise on fish resulting in indirect impacts on food sources		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Low	Low
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.2.4 Impacts to Seabirds

Among the marine avifauna occurring along the South African West coast, it is only the species that feed by plunge-diving or that rest on the sea surface, which may be affected by the underwater noise of seismic surveys. 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 overrides a flight response to seismic survey sounds. The potential for physiological injury or behavioural avoidance in non-diving seabird species is considered **INSIGNIFICANT** and will not be discussed further here.

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. The potential for physiological impact of seismic noise on diving birds could be of high intensity but would be limited to the survey area and survey duration (short term). Of the plunge diving species that occur along the Southwest Coast, only the Cape Gannet regularly feeds as far offshore as 100 km, the rest foraging in nearshore areas up to 40 km from the coast. The nearest nesting grounds are at the Saldanha Bay islands, over 300 km to the north and Dyer Island over 200 km north-east, of the northern portion of the Exploration Area. There is therefore a low likelihood of encountering gannets in the Exploration Area. African Penguins are known to forage as far as 60 km offshore and juveniles have been reported to travel up the coast regularly. The nearest African Penguin nesting sites are Boulder, Betty's Bay and Dyer Island, all over 200 km to the north of the Exploration Area. The exploration activities are thus unlikely to encounter penguins. Pelagic seabirds that dive for their prey may, however, be encountered. The potential physiological impact on diving species could thus be of **LOW** significance without mitigation, and **VERY LOW** significance with mitigation.

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. Behavioural avoidance by diving seabirds would be limited to within the long range of the operating airgun over the duration of the survey period. The impact is likely to be of medium to high intensity. Due to the low likelihood of encountering diving seabirds in the Exploration Area, the potential impact on the behaviour of diving seabirds is considered to be of **LOW** significance without mitigation, and of **VERY LOW** significance with mitigation.

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. No information is available on the feeding success of seabirds in association with seismic survey noise. With few exceptions, most plunge-diving birds forage on small shoaling species relatively close to the shore and are unlikely to feed extensively in offshore waters that would primarily be targeted during the seismic survey. 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 **VERY LOW** with and without mitigation.

Other Potential Impacts

Other potential adverse interactions between seabirds and seismic surveys are (1) stranding of birds on the survey vessel due to being attracted to the vessel lights at night, and (2) oiling through accidental loss of buoyancy liquid or hydraulic fluid from the towed gear. However, while there is some potential for effects on individual seabirds through strandings or oiling, no significant effects on seabird populations are predicted, as the number of animals potentially affected will be small. The impacts are thus assessed as being **INSIGNIFICANT.**

Mitigation

Recommendations for mitigation include:

- All initiation of airgun firing be carried out as “soft-starts” of for least 20 minutes (JNCC 2010).
- An area of radius of 500 m be scanned by an independent observer for the presence of diving seabirds prior to the commencement of “soft-starts” and that these be delayed until such time as this area is clear of significant diving seabird activity.
- Seabird incidence and behaviour should be recorded by an onboard Independent Observer/ MMO. Any obvious mortality or injuries to seabirds as a direct result of the survey should result in temporary termination of operations.
- Any attraction of predatory seabirds (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should be recorded by an onboard Independent Observer / MMO.
- If obvious mortality or injuries to diving seabirds is observed, the survey should be terminated temporarily until such time the Independent Observer / MMO confirms that the risk to diving seabirds has been significantly reduced.

Impacts of seismic noise on diving seabirds resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic noise on diving seabirds resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Medium to High	Low
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impact: Impacts of seismic noise on seabirds resulting in indirect impacts on food sources		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Low	Low
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic surveys to seabirds through stranding or oiling		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Very Low	Very Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.2.5 Impacts to Turtles

Although three species of turtles occur along the South-West Coast, it is only the Leatherback turtle which is likely to be encountered in deeper waters. However, abundances are likely to be low, comprising occasional migrants. The most likely impacts to turtles from seismic survey operations include physiological injury (including disorientation) or mortality from seismic noise or collision with or entanglement in towed seismic apparatus, behavioural avoidance of seismic survey areas, and indirect effects due to the effects of seismic sounds on prey species.

Physiological injury (including disorientation) or mortality

Although no information could be sourced on physiological injury to turtle hearing as a result of seismic sounds, the overlap of their hearing sensitivity with the higher frequencies produced by airguns, suggest that turtles may be considerably affected by seismic noise. Recent evidence, however, suggests that turtles only detect airguns at close range (<10 m) or are not sufficiently mobile to move away from approaching airgun arrays (particularly if basking). Initiation of a sound source at full power in the immediate vicinity of a swimming or basking turtle would be expected to result in physiological injury. The potential impact could therefore be of high intensity, but remain within the short-term. However, as the abundance of adult turtles in the survey area is low, the likelihood of encountering turtles during the proposed exploration activities is thus expected to be very low. The potential physiological impact on turtles is thus considered to be of **LOW** significance without mitigation, and **VERY LOW** significance with mitigation.

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 Exploration Area at the time of the survey. As the breeding areas for Leatherback turtles occur over 3,000 km to north-west of the survey area (in Republic of Congo and Gabon), and over 1,500 km northeast of the survey area in northern KwaZulu-Natal, turtles encountered during the survey are likely to be migrating vagrants and impacts through collision or entanglement would be of low intensity and short-term. The impacts on turtles through collision or entanglement of seismic equipment is thus considered to be of **VERY LOW** significance both without and with mitigation.

Behavioural avoidance

Behavioural changes by turtles in response to seismic sounds range from apparent lack of movement away from active airgun arrays through to startle response and avoidance by fleeing an operating sound source. The impact of seismic sounds on turtle behaviour is of high intensity, but would persist only for the duration of the survey, and be restricted to the survey area. Given the general extent of turtle migrations relative to the seismic survey target grid, the impact of seismic noise on turtle migrations is deemed to be of **LOW** significance without mitigation and **VERY LOW** with mitigation.

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

Leatherback turtles feed on jellyfish, which are pelagic and therefore have a naturally temporally and spatially variable distribution. Adverse modification of such pelagic food sources would thus be insignificant, and the effects of seismic surveys on the feeding behaviour of turtles is thus expected to be **VERY LOW** both with and without mitigation.

Masking of environmental sounds and communication

Breeding adults of sea turtles undertake large migrations between distant foraging areas and their nesting sites (which on the African West coast are >3,000 km north-west of survey area in Republic of Congo and Gabon, and over 1,500 km north-east of the survey area in northern KwaZulu-Natal on the East Coast). Although it is speculated that turtles may use acoustic cues for navigation during migrations, information on turtle communication is lacking. There is no information available in the literature on the effect of seismic noise in masking environmental cues and communication in turtles, but their low abundance in the survey area would suggest that the potential significance of this impact (should it occur) would be **INSIGNIFICANT**.

Mitigation

A number of mitigation measures are recommended for potential impacts of seismic surveys on turtles:

- All initiation of airgun firing be carried out as “soft-starts” of at least 20 minutes duration (JNCC 2010).
- An area of radius of 500 m be scanned by an Independent Observer / MMO for the presence of turtles prior to the commencement of “soft-starts” and that these be delayed until such time as this area is clear of turtles.
- Daylight observations of the survey region should be carried out by onboard Independent Observers / MMO and incidence of turtles and their responses to seismic shooting should be recorded.
- Seismic shooting should be terminated when obvious negative changes to turtle behaviour is observed from the survey vessel, or animals are observed diving within the immediate vicinity (within 500 m) of operating airguns.
- Any obvious mortality or injuries to turtles as a direct result of the survey should result in temporary termination of operations.
- 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’.

Impacts of seismic noise on turtles resulting in physiological injury, or collision and entanglement with towed equipment		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Medium
Degree to which impact can be mitigated		Low

Impacts of seismic noise on turtles resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	High	High
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic noise on turtles resulting in indirect impacts on food sources		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Low	Low
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic noise on turtles resulting in masking of sounds		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Very Low	Very Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Low	Low
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.2.6 Impacts to Seals

Physiological injury or mortality

The physiological effects of loud low frequency sounds on seals have not been well documented. The potential for physiological injury to seals from seismic noise is expected to be low as being highly mobile, fur seals would avoid severe sound sources at levels well below those at which discomfort occurs. Past studies suggest that noise of moderate intensity and duration is sufficient to induce temporary threshold shifts in seals, as individuals did not appear to avoid the survey area. Their tendency to swim at or near the surface will also expose them to reduced sound levels when in close proximity to an operating airgun array. The nearest breeding colonies are at Seal Island in False Bay, ~200 km to the north-east of the Exploration Area. The Exploration Area therefore lies on the outer limit of the foraging range of seals from the nearby colonies. The potential impact of physiological injury to seals as a result of seismic noise is therefore deemed to be of medium intensity and would be limited to the survey area, although injury could extend beyond the survey duration. However, as the survey area is located offshore of the foraging range of seals, encounters are highly unlikely and the significance of the impact is thus rated as **VERY LOW**, both with and without mitigation.

Behavioural avoidance

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 behaviour in response to seismic surveys is thus considered to be of low to medium intensity and limited to the survey area and duration. The significance of behavioural avoidance impacts are consequently deemed **VERY LOW**, both with and without mitigation.

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 (one firing every 10 to 15 seconds). As encounters with seals in the offshore areas are highly unlikely, the significance of the impact is rated as **INSIGNIFICANT**.

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. 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 in the proposed Exploration Area would be **INSIGNIFICANT**.

Mitigation

Mitigation measures recommended for potential impacts of seismic surveys on seals are:

- Daylight observations of the survey region should be carried out by onboard Marine Mammal Observers (MMOs) and the presence of seals (including number and position / distance from the vessel) and their behaviour should be recorded prior to “soft-start” procedures. All initiation of airgun firing be carried out as “soft-starts” of at least 20 minutes duration (JNCC 2010).
- “Soft-start” procedures should, if possible, only commence once it has been confirmed that there is no seal activity within 500 m of the airguns. If after a period of 30 minutes seals are still within 500 m of the airguns, the normal “soft-start” procedure should be allowed to commence for at least a 20-minutes duration.
- The MMO should monitor seal behaviour during “soft-starts” to determine if the seals display any obvious negative responses to the airguns and gear or if there are any signs of injury or mortality to seals as a direct result of seismic shooting operations.

- Seismic shooting should be terminated when obvious negative changes to seal behaviour are observed or there is any obvious mortality or injuries to seals as a direct result of the survey.
- The MMO's daily report should record general seal activity, numbers and any noticeable change in behaviour.

Impacts of seismic noise on seals resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Medium	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Very Low

Impacts of seismic noise on seals resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low to Medium	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	High	High
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Very Low

Impacts of seismic surveys on seals resulting in masking of sounds and communication		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic surveys on seals resulting from indirect effects on their prey		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	High	High
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.2.7 Impacts to Whales and Dolphins

A wide diversity of cetaceans (whales and dolphins) occur off the South African South-West Coast. The majority of migratory cetaceans in southern African waters are baleen whales (mysticetes), while toothed whales (odontocetes) may be resident or migratory. Potential impacts of seismic pulses on whales and dolphins could include physiological injury, behavioural avoidance of seismic survey areas, masking of environmental sounds and communication, and indirect impacts due to effects on prey.

When assessing the potential effects of seismic surveys on marine mammals we should bear in mind the lack of data (uncertainty) concerning the auditory capabilities and thresholds of impacts on the different species encountered and the individual variability in hearing thresholds and behavioural responses which are likely to influence the degree of impact (Luke *et al.* 2009; Gedamke *et al.* 2011). This uncertainty and variability can have a significant bearing on how risk to marine mammals is assessed. Deficiencies in the current data prohibit a full understanding of the encounter frequencies with cetaceans or corresponding impacts of seismic surveys on marine mammals, and high resolution baseline data from the proposed survey area and impact zone are necessary to fully understand the effect that seismic exploration may have on South Africa's cetacean community.

Physiological injury

Typical sound source levels for this seismic survey are 243-249 dB re 1 µPa @1 m, which exceed the sources levels required for hearing damage (PTS and TTS) (see Table 4). Marked differences occur in the hearing capabilities 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. These species may react to seismic shots at long ranges, but hearing damage from seismic shots is only likely to occur at close range.

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. However, avoidance may be complicated by the multipath nature of sound in the ocean. Mitigation measures involving a "soft-start" procedure would help to alert cetaceans to the increasing sound level and promote movement away from the sound source. Deep-diving cetacean species 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.

The impact of physiological injury to both mysticete and odontocete cetaceans as a result of high-amplitude seismic sounds is deemed to be of high intensity, but would be limited to the immediate vicinity of operating airguns within the impact zone. The proposed survey is scheduled to be undertaken during the summer 2016/2017 and continue for approximately 20 days. It is thus planned outside of peak humpback and southern right whale migration periods, but resident whales may be still be encountered, particularly the offshore population of Bryde's whales whose seasonality on the West Coast is opposite to the majority of the balaenopterids with abundance likely to be highest in the broader study area in January - March. Without mitigation the impact is therefore considered to be of **MEDIUM** significance for mysticetes and **LOW** significance for odontocetes. With mitigation this would reduce to **LOW** and **VERY LOW** significance, respectively.

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 110 dB. 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 survey location overlaps with the migration route of humpback whales and other baleen whale species. However, as the survey is planned to outside of the main winter migration periods (June - November), interactions with migrating whales should be low.

Of greater concern than general avoidance of migrating whales is avoidance of critical feeding or breeding habitat. Displacement from a 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. Southern right whales mostly remain in the coastal area south of Lambert's Bay, but are seen regularly along the northern Namaqualand coast and in southern Namibia, and are increasingly expanding their range as the population grows (see Section 3.3.3.6 on cetacean distributions). The Exploration Area is located well offshore, and therefore does not overlap with nearshore West and South coast regions typically utilised by southern right whales as a mating, calving, or nursery grounds. There is, however, potential overlap with migration routes of both humpback and southern right whales. The Exploration Area is located offshore of the West Coast feeding ground around Cape Columbine, where local abundances of temporary resident humpbacks and southern rights whales occur during summer months. Interaction between the proposed exploration activities and the summer feeding aggregations is thus unlikely. Although encounter rates peak in migration periods, humpback and right whales are found in West Coast waters year round. Other baleen whale species are also found year round or have seasonal occurrences which are not well known, but existing data shows year-round presence of mysticetes.

The potential impact of behavioural avoidance of seismic survey areas by mysticete cetaceans is considered to be of high intensity, across the survey area and for the duration of the survey. As the proposed survey is scheduled to be undertaken during Summer 2016 / 2017 and continue for approximately 20 days, it falls outside humpback and southern right whale migration periods. The impact of seismic surveying is thus considered of **MEDIUM** significance before mitigation. Keeping surveys to this set timeline will in itself be a good mitigating action, minimising, but not eliminating, encounter rates with large whales in the proposed survey area and reduce the intensity of potential impacts to **LOW** significance with mitigation.

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 Exploration Area but several species are considered to be year round residents (see Section 3.3.3.6). 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. A precautionary approach to avoiding impacts is thus recommended, and consequently the impact of seismic survey noise on the behaviour of toothed whales is considered to be of medium intensity over the survey area and duration. The overall significance will therefore vary between species, and consequently ranges between **LOW** and **VERY LOW** before mitigation and **VERY LOW** with mitigation.

Masking of environmental sounds and communication

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-frequency range can travel far (at least 8 km) and extend up to 22kHz (Goold & Fish 1998), masking of communication sounds produced by whistling dolphins and blackfish[3] is likely. In the migratory baleen whale species, vocalisation increases once they reach the breeding grounds and on the return journey in December – January when accompanied by calves, so is likely to be low in the impact area. Additionally, the effect of masking may be reduced by the intermittent nature of seismic pulses (Gordon *et al.* 2003). Consequently, the intensity of impact on baleen whales is likely to be medium over the survey area, but high in the case of toothed whales, or mother-calf pairs of baleen whales on their return migration. Whereas for mysticetes the significance is rated as **LOW** without mitigation and **VERY LOW** with mitigation, for odontocetes (particularly the offshore deep-diving blackfish species and sperm whales) it is rated as **MEDIUM** without mitigation and **LOW** with mitigation.

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. However, it is likely that both fish and cephalopod prey of toothed whales and dolphins may be affected over limited areas, although the impacts are difficult to determine. The broad ranges of prey species (in relation to the avoidance patterns of seismic surveys of such prey species) suggest that indirect impacts due to effects on prey would be of **VERY LOW** significance with and without mitigation. Baleen whales seldom feed while on breeding migrations and rely on blubber reserves and the proposed Exploration Area is located well to the south (approximately 350 km) of the summer feeding grounds around Cape Columbine, so the indirect effects on their food source would be **INSIGNIFICANT**.

Other potential impacts

Given the slow speed (about 4 - 6 kts) of the vessel while towing the seismic array, ship strikes are also unlikely. Entanglement in gear is, however, possible.

Mitigation

Mitigation measures to reduce the impact of seismic survey impulses on cetaceans include:

- To minimise encounters with large whales in the survey area (shelf edge and deeper), seismic surveys should be scheduled for late summer and early winter (January - June), although some whale species are present all year round.
- All survey vessels must be fitted with Passive Acoustic Monitoring (PAM) technology, which detects animals through their vocalisations. As the survey is taking place in waters deeper than 1,000 m depth where sperm whales are likely to be encountered, the use of PAM 24-h a day is highly recommended. As a minimum, PAM technology must be used during the pre-watch period and when surveying at night or during adverse weather conditions and thick fog. The hydrophone streamer should ideally be towed

[3] The term blackfish refers to the delphinids: Melon-headed whale, Killer whale, Pygmy Killer Whale, False Killer Whale, Long-finned Pilot Whale and Short-finned Pilot Whale.

behind the airgun array to minimise the interference of vessel noise, and be fitted with two hydrophones to allow directional detection of cetaceans.

- As no seasonal patterns of abundance are known for odontocetes occupying the proposed study area, a precautionary approach to avoiding impacts throughout the year is recommended.
- Independent onboard MMOs and PAM operators must be appointed for the duration of the seismic survey. The MMOs and PAM operators must have experience in seabird, turtle and marine mammal identification and observation techniques.
- The implementation of "soft-start" procedures of a minimum of 20-minutes' duration on initiation of seismic surveying would mitigate any extent of physiological injury in most mobile vertebrate species as a result of seismic noise and is consequently considered a mandatory management measure for the implementation of the proposed seismic survey. This requires that the sound source be ramped from low to full power, thus allowing a flight response to outside the zone of injury or avoidance. This build up of power should occur in uniform stages to provide a constant increase in output. The rationale for the 20 minute "soft-start" period is based on the flight speeds of cetacean species. Where possible, "soft-starts" should be planned so that they commence within daylight hours.
- Prior to the commencement of "soft-starts" an area of 500-m radius around the survey vessel (exclusion zone) should be scanned (visually and using PAM technology) for the presence of diving seabirds, turtles, seals and cetaceans. There should be a dedicated pre-shoot watch of at least 60 minutes (to account for deep-diving species). "Soft-starts" should be delayed until such time as this area is clear of cetaceans, and should not begin until after the animals depart the 500 m exclusion zone or 30 minutes after they are last seen.
- All breaks in airgun firing of longer than 20 minutes must be followed by the 60-minute pre-shoot watch and a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing. Breaks shorter than 20 minutes should be followed by a visual assessment for marine mammals within the 500 m mitigation zone (not a 60 minute pre-shoot watch) and a "soft-start" of similar duration.
- Seismic shooting should be terminated when obvious negative changes to cetacean behaviour is observed from the survey vessel, or animals are observed within the immediate vicinity (within 500 m) of operating airguns and appear to be approaching the firing airgun.
- During night-time line changes low level warning airgun discharges should be fired at regular intervals in order to keep animals away from the survey operation while the vessel is repositioned for the next survey line.
- The use of the lowest practicable airgun volume should be defined and enforced, and airgun use should be prohibited outside of the licence area.
- All data recorded by MMOs should as a minimum form part of a survey close–out report. Furthermore, daily or weekly reports should be forwarded to the necessary authorities to ensure compliance with the mitigation measures.
- Marine mammal incidence data and seismic source output data arising from surveys should be made available on request to the Marine Mammal Institute, Department of

Agriculture, Fisheries and Forestry, and the Petroleum Agency of South Africa for analyses of survey impacts in local waters.

Potential impact of seismic noise to mysticete cetaceans.

Impacts of seismic noise on baleen whales resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low to Medium
Significance	Medium	Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic noise on baleen whales resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low
Significance	Medium	Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	High	High
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic surveys on baleen whales resulting in masking of sounds and communication		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Medium	Low
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Impacts of seismic surveys on baleen whales resulting from indirect effects on their prey		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Very Low	Very Low
Significance	Insignificant	Insignificant
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	High	High
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

Potential impact of seismic noise to odontocete cetaceans.

Impacts of seismic noise on toothed whales and dolphins resulting in physiological injury		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low to Medium
Significance	Low	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Partially reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic noise on toothed whales and dolphins resulting in behavioural avoidance		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Medium	Low to Medium
Significance	Very Low – Low (species specific)	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	High	High
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic surveys on toothed whales and dolphins resulting in masking of sounds and communication		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	High	Low
Significance	Medium	Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		Low

Impacts of seismic surveys on toothed whales and dolphins resulting from indirect effects on their prey		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term: for duration of survey	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Probable	Probable
Confidence	Medium	Medium
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

5.3. Impacts of Multi-beam Surveys

Although baleen whales, toothed whales and pinnepeds would be expected to hear sonar signals from most types of oceanographic sonars at frequencies within their functional hearing range, the animals would only be affected if they were within the sonar beam. As the anticipated radius of influence of a multi-beam sonar or the sub-bottom profiler is significantly less than that for an airgun array, and the statistical probability of crossing a cetacean or pinniped with the narrow multi-beam fan several times, or even once, is very small, the effects of high frequency sonars on these fauna can be considered to be of **VERY LOW** significance without mitigation. However, despite the low significance of impacts, the Joint Nature Conservation Committee (JNCC) provides a list of guidelines to be followed by anyone planning marine sonar operations that could cause acoustic or physical disturbance to marine mammals. These have been revised to be more applicable to the southern African situation.

- Onboard MMOs should conduct visual scans for the presence of diving birds, marine mammals and/or turtles around the survey vessel prior to the initiation of any acoustic impulses.
- The duties of the MMO would be to:
  - Monitor the survey pre-watch period;
  - Record sound levels, pre-watch sightings and "soft-start" procedures (where required);
  - Observe and record responses of diving birds, marine mammals and/or turtles to the multi-beam bathymetry survey. Data captured should include species identification, position (latitude/longitude), distance 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 survey activities; and
  - Request the temporary termination of survey, as appropriate. A log of all termination decisions must be kept for inclusion in both daily and "close-out" reports.
- PAM technology, which detects animals through their vocalisations, must be used when surveying at night or during adverse weather conditions and thick fog. If there is a technical problem with PAM during nighttime surveying, night-vision/infra-red binoculars must be used.
- The duties of the PAM operator would be similar to those of the MMO.

For a survey using a source level <190 dB re 1 μPa at 1 m the following is recommended:

- Surveying must only commence (subject to the need for a "soft-start") once it has been confirmed for a 30-minute period (visually during the day) that there is no diving bird, marine mammal and/or turtle activity within 500 m of the vessel. However, if after a period of 30 minutes cetaceans smaller than 3 m, seals and/or diving seabirds are still within 500 m of the vessel, the survey may commence;
- Surveying is terminated if diving birds, marine mammals and/or turtles show obvious negative behavioural changes within 500 m of the survey vessel or equipment. The survey should be terminated until such time it is confirmed that the identified animal(s) has moved to a point that is more than 500 m from the source or despite continuous observation or 30 minutes has elapsed since the last sighting of the identified animal(s) within 500 m of the source.

For a survey using a source level >190 dB re 1 μPa at 1 m the following is recommended, in addition to the above:

- A "soft-start" procedure shall be implemented for a period of 20 minutes. This requires that the sound source be ramped from low to full power rather than initiated at full power, thus allowing a flight response by diving birds, marine mammals and/or turtles to outside the zone of injury or avoidance. Where the equipment does not provide for a "soft-start", the equipment should be turned on and off over a 20 minute period to act as a warning signal and allow the above-mentioned animals to move away from the sound source;

- “Soft-starts” should, as far as possible, be planned to commence within daylight hours;
- “Soft-start” procedures must only commence once it has been confirmed by the MMO (visually during the day and in favourable weather conditions) or the PAM operator (at night or in unfavourable weather conditions), where applicable, that there is no diving bird, marine mammal and/or turtle activity within 500 m of the vessel for a 30-minute period. However, if after a period of 30 minutes diving birds, marine mammals smaller than 3 m and/or turtles are still within 500 m of the vessel, the normal “soft-start” procedure should be allowed to commence; and
- “Soft-start” procedures must also be implemented after breaks in surveying (for whatever reason) of longer than 20 minutes. Breaks of shorter than 20 minutes should be followed by a “soft-start” of similar duration.

Impacts of multi-beam and sub-bottom profiling sonar on cetaceans		
	Without Mitigation	**Assuming Mitigation**
Extent	Local: limited to survey area	Local
Duration	Short-term	Short-term
Intensity	Low	Low
Significance	Very Low	Very Low
Status	Negative	Negative
Probability	Improbable	Improbable
Confidence	High	High
Nature of Cumulative impact		Very Low
Degree to which impact can be reversed		Fully reversible
Degree to which impact may cause irreplaceable loss of resources		Low
Degree to which impact can be mitigated		None

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

If all environmental guidelines, and appropriate mitigation measures advanced in this report, and the EMP for the proposed project as a whole, are implemented, there is no reason why the proposed seismic survey should not proceed. The proposal to undertake the survey outside the cetacean migration period has mitigated the potential impact on migratory cetaceans to a large extent. 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.

The assessments of impacts of seismic sounds provided in the scientific literature usually consider short-term responses at the level of individual animals only, as our understanding of how such short-term effects relate to adverse residual effects at the population level are limited. Data on behavioural reactions acquired over the short-term could, however, easily be misinterpreted as being less significant than the cumulative effects over the long-term, *i.e.* what is initially interpreted as an impact not having a detrimental effect and thus being of low significance, may turn out to result in a long-term decline in the population. 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. However, the southern right whale population is reported to be increasing by 7% per annum (Best 2000) over a time when seismic surveying frequency has increased, suggesting that, for the southern right 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 significance of the impacts both before and after mitigation are summarised overleaf.

Seismic Surveys

Impact	Significance (before mitigation)	Significance (after mitigation)
Plankton and ichthyoplankton		
Mortality and/or physiological injury	Insignificant	Insignificant
Marine invertebrates		
Mortality and/or physiological injury of benthic invertebrates	Insignificant	Insignificant
Mortality and/or physiological injury of pelagic invertebrates	Very Low	Very Low
Behavioural avoidance	Very Low	Very Low
Fish		
Mortality and/or physiological injury of demersal fish	Insignificant	Insignificant
Mortality and/or physiological injury of pelagic fish	Low	Very Low
Avoidance behaviour of pelagic fish	Medium	Low
Reproductive success / spawning	Insignificant	Insignificant
Masking of sounds	Very Low	Very Low
Indirect impacts on food sources	Very Low	Very Low
Seabirds		
Physiological injury	Low	Very Low
Avoidance behaviour	Low	Very Low
Indirect impacts on food sources	Very Low	Very Low
Stranding or oiling	Insignificant	Insignificant
Turtles		
Physiological injury, collision and entanglement	Low	Very Low
Avoidance behaviour	Low	Very Low
Indirect impacts on food sources	Very Low	Very Low
Masking of sounds	Insignificant	Insignificant
Seals		
Physiological injury	Very Low	Very Low
Avoidance behaviour	Very Low	Very Low
Masking of sounds	Insignificant	Insignificant
Indirect impacts on food sources	Insignificant	Insignificant
Whales and dolphins		
Baleen whales		
Physiological injury	Medium	Low
Avoidance behaviour	Medium	Low
Masking of sounds and indirect impacts on food sources	Low	Very Low
Indirect impacts on food sources	Insignificant	Insignificant
Toothed whales and dolphins		
Physiological injury	Low	Very Low
Avoidance behaviour	Very Low - Low	Very Low
Masking of sounds and indirect impacts on food sources	Medium	Low
Indirect impacts on food sources	Very Low	Very Low

Multi-beam Surveys

Impact	Significance (before mitigation)	Significance (after mitigation)
Marine Fauna		
Auditory and behavioural disturbance of turtles	Insignificant	Insignificant
Auditory and behavioural disturbance of cetaceans	Very Low	Very low

6.2. Recommended Mitigation Measures

Detailed mitigation measures for seismic surveys in other parts of the world are provided by Weir *et al.* (2006), Compton *et al.* (2007) and US Department of Interior (2007). Many of the international guidelines presented in these documents are extremely conservative as they are designed for areas experiencing repeated, high intensity surveys and harbouring particularly sensitive species, or species with high conservation status. The guidelines currently applied for seismic surveying in South African waters are those proposed in the Generic EMPR (CCA & CMS 2001), and to date these have not resulted in any known or recorded mortalities of marine mammals, turtles or seabirds. The mitigation measures proposed below are based largely on the guidelines currently accepted for seismic surveys in South Africa, but have been revised to include salient points from international guidelines discussed in the documents cited above.

- To minimise encounters with large whales in the survey area (shelf edge and deeper), seismic surveys should be scheduled for late summer and early winter (January - June), although some whale species are present all year round.
- All survey vessels must be fitted with PAM technology, which detects animals through their vocalisations. As the survey is taking place in waters deeper than 1,000 m depth where sperm whales are likely to be encountered, the use of PAM 24-h a day is highly recommended. As a minimum, PAM technology must be used during the 30-minute pre-watch period and when surveying at night or during adverse weather conditions and thick fog. The hydrophone streamer should ideally be towed behind the airgun array to minimise the interference of vessel noise, and be fitted with two hydrophones to allow directional detection of cetaceans.
- As no seasonal patterns of abundance are known for odontocetes occupying the proposed study area, a precautionary approach to avoiding impacts throughout the year is recommended.
- Independent onboard MMOs and PAM operators must be appointed for the duration of the seismic survey. The MMOs and PAM operators must have experience in seabird, turtle and marine mammal identification and observation techniques. The duties of the MMO would be to:
  - Record airgun activities, including sound levels, "soft-start" procedures and pre-firing regimes;
  - Observe and record responses of marine fauna to seismic shooting, including seabird, turtle, seal and cetacean incidence and behaviour and any mortality or injuries of marine fauna as a result of the seismic survey. Data captured should include species identification, position (latitude/longitude), distance from the

vessel, swimming speed and direction (if applicable) and any obvious changes in behaviour (e.g. startle responses or changes in surfacing/diving frequencies, breathing patterns) as a result of the seismic activities. Both the identification and the behaviour of the animals must be recorded accurately along with current seismic sound levels. Any attraction of predatory seabirds, large pelagic fish or cetaceans (by mass disorientation or stunning of fish as a result of seismic survey activities) and incidents of feeding behaviour among the hydrophone streamers should also be recorded;

- Sightings of any injured or dead protected species (marine mammals, seabirds and sea turtles) should be recorded, regardless of whether the injury or death was caused by the seismic vessel itself. If the injury or death was caused by a collision with the seismic vessel, the date and location (latitude/longitude) of the strike, and the species identification or a description of the animal should be recorded.
- Record meteorological conditions;
- Request the temporarily termination of the seismic survey or adjusting of seismic shooting, as appropriate. It is important that MMOs have a full understanding of the financial implications of terminating firing, and that such decisions are made confidently and expediently. A log of all termination decisions must be kept (for inclusion in both daily and "close-out" reports);
- Prepare daily reports of all observations, to be forwarded to the necessary authorities on a daily or weekly basis to ensure compliance with the mitigation measures.

The duties of the PAM operator would be to:

- Ensure that hydrophone streamers are optimally placed within the towed array;
- Confirm that there is no marine mammal activity within 500 m of the vessel prior to commencing with the "soft-start" procedures;
- Record species identification, position (latitude/longitude) and distance from the vessel, where possible;
- Record airgun activities, including sound levels, "soft-start" procedures and pre-firing regimes; and
- Request the temporary termination of the seismic survey, as appropriate.

- The implementation of "soft-start" procedures of a minimum of 20-minutes' duration on initiation of seismic surveying would mitigate any extent of physiological injury in most mobile vertebrate species as a result of seismic noise and is consequently considered a mandatory management measure for the implementation of the proposed seismic survey. This requires that the sound source be ramped from low to full power, thus allowing a flight response to outside the zone of injury or avoidance. This build up of power should occur in uniform stages to provide a constant increase in output. The rationale for the 20 minute "soft-start" period is based on the flight speeds of cetacean species. Where possible, "soft-starts" should be planned so that they commence within daylight hours.
- Prior to the commencement of "soft-starts" an area of 500-m radius around the survey vessel (exclusion zone) should be scanned (visually and using PAM technology) for the

presence of diving seabirds, turtles, seals and cetaceans. There should be a dedicated pre-shoot watch of at least 60 minutes (to account for deep-diving species). As the Exploration Area is located far offshore and sperm whales are likely to be encountered, a 60 minute pre-shoot watch for deep-diving species (JNCC 2010) is recommended. "Soft-starts" should be delayed until such time as this area is clear of individuals of diving seabirds, seals, turtles and cetaceans, and should not begin until after the animals depart the 500 m exclusion zone or 30 minutes after they are last seen.

- All breaks in airgun firing of longer than 20 minutes must be followed by the 60-minute pre-shoot watch and a "soft-start" procedure of at least 20 minutes prior to the survey operation continuing. Breaks shorter than 20 minutes should be followed by a visual assessment for marine mammals within the 500 m mitigation zone (not a 60 minute pre-shoot watch) and a "soft-start" of similar duration.
- Seismic shooting should be terminated on observation of any obvious mortality or injuries to cetaceans, turtles, seabirds, seals or large mortalities of invertebrate and fish species as a direct result of the survey. Such mortalities would be of particular concern where a) commercially important species are involved, or b) mortality events attract higher order predator and scavenger species into the seismic area during the survey, thus subjecting them to acoustic impulses. Seismic shooting should also be terminated when obvious negative changes to turtle, seabird, seal or cetacean behaviours are observed from the survey vessel, or turtles and cetaceans (not seals) are observed within the immediate vicinity (within 500 m) of operating airguns and appear to be approaching firing airgun[4]. The rationale for this is that animals at close distances (i.e. where physiological injury may occur) may be suffering from reduced hearing as a result of seismic sounds, that frequencies of seismic sound energy lies below best hearing frequencies (certain toothed cetaceans and seals), or that animals have become trapped within the ensonified area through diving behaviour.
- The survey should be terminated until such time the MMO confirms that:
    - Cetaceans and turtles have moved to a point that is more than 500 m from the source;
    - Despite continuous observation, 30 minutes has elapsed since the last sighting of the turtles or cetaceans within 500 m of the source; and
    - Risks to seabirds, turtles or cetaceans have been significantly reduced.
- 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'.
- During night-time line changes low level warning airgun discharges should be fired at regular intervals in order to keep animals away from the survey operation while the vessel is repositioned for the next survey line.
- The use of the lowest practicable airgun volume should be defined and enforced, and airgun use should be prohibited outside of the licence area.

4. Recommended safety zones in some of the international guidelines include implementation of an observation zone of 3 km radius, low-power zone of 1.5 - 2 km radius (to cater for cow-calf pairs), and safety shut-down zone of 500 m radius around the survey vessel. Alternatively, a safety zone of 160 dB root mean squared (rms) can be calculated based on site-specific sound speed profiles and airgun parameters. The application of propagation loss models to calculate safety radii based on sound pressure levels represents a more scientific approach than the arbitrary designation of a 500 m radius (see Compton *et al.* (2007) for details).

- All data recorded by MMOs should as a minimum form part of a survey close–out report. Furthermore, daily or weekly reports should be forwarded to the necessary authorities to ensure compliance with the mitigation measures.
- Seabird, turtle and marine mammal incidence data and seismic source output data arising from surveys should be made available on request to the Marine Mammal Institute, Department of Agriculture, Fisheries and Forestry, and the Petroleum Agency of South Africa for analyses of survey impacts in local waters.

6.2.2 Multi-beam Surveys

The mitigation measures recommended for multi-beam and sub-bottom profiling surveys are:

- Onboard MMOs should conduct visual scans for the presence of diving birds, marine mammals and/or turtles around the survey vessel prior to the initiation of any acoustic impulses.
- The duties of the MMO would be to:
  - Monitor the survey pre-watch period;
  - Record sound levels, pre-watch sightings and “soft-start” procedures (where required);
  - Observe and record responses of diving birds, marine mammals and/or turtles to the multi-beam bathymetry survey. Data captured should include species identification, position (latitude/longitude), distance 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 survey activities; and
  - Request the temporary termination of survey, as appropriate. A log of all termination decisions must be kept for inclusion in both daily and “close-out” reports.
- PAM technology, which detects animals through their vocalisations, must be used when surveying at night or during adverse weather conditions and thick fog. If there is a technical problem with PAM during nighttime surveying, night-vision/infra-red binoculars must be used.
- The duties of the PAM operator would be similar to those of the MMO.

For a survey using a source level <190 dB re 1 μPa at 1 m the following is recommended:

- Surveying must only commence (subject to the need for a “soft-start”) once it has been confirmed for a 30-minute period (visually during the day) that there is no diving bird, marine mammal and/or turtle activity within 500 m of the vessel. However, if after a period of 30 minutes cetaceans smaller than 3 m, seals and/or diving seabirds are still within 500 m of the vessel, the survey may commence;
- Surveying is terminated if diving birds, marine mammals and/or turtles show obvious negative behavioural changes within 500 m of the survey vessel or equipment. The survey should be terminated until such time it is confirmed that the identified animal(s) has moved to a point that is more than 500 m from the source or despite continuous observation or 30 minutes has elapsed since the last sighting of the identified animal(s) within 500 m of the source.

For a survey using a source level >190 dB re 1 μPa at 1 m the following is recommended, in addition to the above:

- A "soft-start" procedure shall be implemented for a period of 20 minutes. This requires that the sound source be ramped from low to full power rather than initiated at full power, thus allowing a flight response by diving birds, marine mammals and/or turtles to outside the zone of injury or avoidance. Where the equipment does not provide for a "soft-start", the equipment should be turned on and off over a 20 minute period to act as a warning signal and allow the above-mentioned animals to move away from the sound source;
- "Soft-starts" should, as far as possible, be planned to commence within daylight hours;
- "Soft-start" procedures must only commence once it has been confirmed by the MMO (visually during the day and in favourable weather conditions) or the PAM operator (at night or in unfavourable weather conditions), where applicable, that there is no diving bird, marine mammal and/or turtle activity within 500 m of the vessel for a 30-minute period. However, if after a period of 30 minutes diving birds, marine mammals smaller than 3 m and/or turtles are still within 500 m of the vessel, the normal "soft-start" procedure should be allowed to commence; and
- "Soft-start" procedures must also be implemented after breaks in surveying (for whatever reason) of longer than 20 minutes. Breaks of shorter than 20 minutes should be followed by a "soft-start" of similar duration.

The proposed exploration activities to be undertaken by Rhino are expected to result in impacts on marine invertebrate fauna in the Exploration Area ranging from INSIGNIFICANT to VERY LOW significance. Only in the case of the seismic survey components are impacts of LOW to MEDIUM significance expected for higher order consumers and marine mammals. Whereas there may thus still be interaction with migration pathways of large pelagic fish, turtles and marine mammals, effects on demersal species would be in the far-field.

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