Annex C

Marine Fauna Study
ENVIRONMENTAL IMPACT ASSESSMENT FOR NAMIBIA
3D SEISMIC SURVEY FOR BLOCKS 2913A & 2914B (PEL 39)

MARINE FAUNA STUDY

Prepared for: ERM (South Africa) (Pty) Ltd

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ABBREVIATIONS and UNITS

CCA  CCA Environmental (Pty) Ltd
cm  centimetres
CITES  Convention on International Trade in Endangered Species
CMS  Convention on Migratory Species
CMS  Centre for Marine Studies
CSIR  Council for Scientific and Industrial Research
dB  decibells
DEA  Department of Environmental Affairs
EEZ  Exclusive Economic Zone
ESMP  Environmental and Social Management Plan
ERM  Environmental Resources Management
g m⁻²  grams per square metre
g C m⁻² day⁻¹  grams Carbon per square metre per day
h  hour
HAB  Harmful Algal Bloom
Hz  Herz
IA  Impact Assessment
IUCN  International Union for the Conservation of Nature
kHz  kiloHerz
km  kilometre
km²  square kilometre
kts  knots
MPA  Marine Protected Area
MMO  Marine Mammal Observer
m  metres
m²  square metres
m³  cubic metre
mm  millimetres
m s⁻¹  metres per second
mg l⁻¹  milligrams per litre
N  north
NW  north-west
PAM  Passive Acoustic Monitoring
PIM  Particulate Inorganic Matter
POM  Particulate Organic Matter
PRDW  Prestedge Retief Dresner Wijnberg Coastal Engineers
PTS  permanent threshold shifts
S  south
SACW  South Atlantic Central Water
SANBI  South African National Biodiversity Institute
SW  south-west
TSPM  Total Suspended Particulate Matter
TTS  temporary threshold shifts
UPC  Universal Power Corp
VOS  Voluntary Observing Ships
2D  two-dimensional
3D  three-dimensional
µg l⁻¹  micrograms per litre
µPa  micro Pascal
°C  degrees Centigrade
%  percent
‰  parts per thousand
~  approximately
<  less than
>  greater than
EXPERTISE AND DECLARATION OF INDEPENDENCE

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

As Director of Pisces since 1998, Andrea has considerable experience in undertaking specialist environmental impact assessments, baseline and monitoring studies, and Environmental Management Programmes relating to marine diamond mining and dredging, hydrocarbon exploration and thermal/hypersaline effluents. She is a registered Environmental Assessment Practitioner and member of the South African Council for Natural Scientific Professions, South African Institute of Ecologists and Environmental Scientists, and International Association of Impact Assessment (South Africa).

This specialist report was compiled for Environmental Resources Management South Africa (Pty) Ltd (ERM) on behalf of Shell South Africa Upstream BV for their use in preparing an Environmental Impact Assessment Update Report and Environmental and Social Management Plan for the proposed 3D seismic survey in Blocks 2913A and 2914B off the southern Namibian coast. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicants and ERM.

Dr Andrea Pulfrich
EXPERTISE AND DECLARATION OF INDEPENDENCE

The section of this report relating to marine mammal presence and seasonality in the proposed study area was prepared by Dr Simon Elwen in consultation with Dr Andrea Pulfrich. The section of this report relating to the acoustic impacts of seismic surveys on marine mammals was prepared by Dr Andrea Pulfrich in consultation with Dr Tess Gridley. Dr Simon Elwen and Dr Tess Gridley of the Namibian Dolphin Project and the University of Pretoria (Mammal Research Institute).

Simon Elwen has MSc and PhD degrees from the University of Pretoria with both degree theses focusing on cetacean biology in South Africa. Tess Gridley has a Masters degree (MRes) in Marine and Fisheries Science from the University of Aberdeen (Scotland) and a PhD focusing on acoustic communication in bottlenose dolphins from the University of St Andrews (Scotland, UK).

Simon Elwen has more than 10 years experience studying cetacean ecology off the west coast of Africa. Tess Gridley has 8 years experience working in marine science and with marine mammals in the UK and Africa.

This specialist report was compiled as a desktop study on behalf of Pisces Environmental Services (Pty) Ltd and ERM (Pty) Ltd. The compilation followed a review process of published (peer reviewed) and unpublished literature and the assessment of potential impacts based on proposed activities and identification of impacts (and their mitigation) within the available literature.

We do hereby declare that we are financially and otherwise independent of the Applicant, Pisces Environmental Services and ERM.

Simon Elwen, PhD  Teresa Gridley, PhD
INTRODUCTION

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

Seismic survey programmes comprise data acquisition in either two-dimensional (2D) and/or three dimensional (3D) scales, depending on information requirements. 2D surveys are typically applied to obtain regional data from widely spaced survey grids and provide a vertical picture 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 tighter survey grid, producing a higher resolution representation. Such surveys are typically applied to promising petroleum prospects to assist in fault line interpretation.

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

For this investigation Shell South Africa Upstream BV is proposing to undertake a 3D seismic survey in Blocks 2913A and 2914B in the Orange Basin, offshore of southern Namibia (Figure 1). Environmental Resources Management (Pty) Ltd (ERM) has been appointed by Shell to prepare an Environmental Impact Assessment (IA) Update Report and Environmental and Social Management Plan (ESMP). ERM in turn has approached Pisces Environmental Services (Pty) Ltd to provide a specialist assessment 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 ERM, for their use in compiling an EIA Update Report and ESMP for the proposed seismic survey off the southern Namibian coast.

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

• Undertake a marine faunal study and impact assessment for the proposed 3D seismic acquisition programme in Block 2913A and 2914B off shore from the Namibian coast;
As part of this study the contractor is expected to:

- Provide a general description of the local marine fauna within the study area;

- Describe the coastal and offshore habitats that are likely to be affected by project activities;

- Identify sensitive habitats and species that may be potentially affected by the proposed exploration activities;

- Describe seasonal and migratory occurrences of key marine fauna;

- Identify, describe and assess the significance of potential impacts of the proposed exploration activities on the local marine fauna;

- Identify practicable mitigation measures to reduce any negative impacts.
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 and CMS 2001). The information for the identification of potential impacts was drawn from various scientific publications, the Generic, information sourced from the Internet as well as Marine Mammal Observer Close-out Reports. The sources consulted are listed in the Reference chapter.

All identified marine impacts are summarised, categorised and ranked in appropriate impact assessment tables, to be incorporated in the overall EIR.
DESCRIPTION OF THE PROPOSED PROJECT

A detailed project description is provided in Chapter 2 of the Environmental Impact Assessment Report Update.
DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

The descriptions of the physical and biological environments along the southern Namibian coast focus primarily on the study area between the Orange River mouth and Lüderitz. However, the description has been extended into South Africa, where appropriate, to cater for potential transboundary impacts. The purpose of this environmental description is to provide the marine baseline environmental context within which the proposed seismic surveys would take place. The summaries presented below are based on information gleaned from Lane and Carter (1999), Morant (2006), and Penney et al. (2007). The description of benthic macrofaunal communities was provided by Natasha Karenyi of the South African National Biodiversity Institute (SANBI), and the section on marine mammals was provided by Dr Simon Elwen of the Namibian Dolphin Project and Mammal Research Institute (University of Pretoria).

3.1 GEOPHYSICAL CHARACTERISTICS

3.1.1 Bathymetry

The continental shelf off southern Namibia is variable in width. Off the Orange River the shelf is wide (230km) and characterised by well-defined shelf breaks, a shallow outer shelf and the aerofoil-shaped submarine Recent River Delta on the inner shelf. It narrows to the north reaching its narrowest point (90km) off Chameis Bay, before widening again to 130km off Lüderitz (Rogers 1977) (See figure 2).

The salient topographic features of the shelf include the relatively steep descent to about 100m, the gentle decline to about 180m, and the undulating depths to about 200m. The Orange Banks comprise three low mounds rising to about 160m on the outer shelf. North of Chameis Bay, the shelf becomes a stepped feature, with a low step having an elevation between roughly 400-450m below mean sea level, making it one of the deepest in the world. The variable topography of the shelf is of significance for nearshore circulation and for fisheries (Shannon and O'Toole 1998).

Banks on the continental shelf include the Orange Bank (Shelf or Cone), a shallow (160-190m) zone that reaches maximal widths (180km) offshore of the Orange River, and the submarine knoll known as Child's Bank, which is situated ~150km offshore at about 31°S. Tripp Seamount is a geological feature located within the survey area, which rises from the seabed at ~1000m to a depth of 150m.

3.1.2 Coastal and Inner-shelf Geology and Seabed Geomorphology

Figure 2 illustrates the distribution of seabed surface sediment types off the southern Namibian coast. 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 and Bremner 1991). As a result of erosion on the continental shelf, the unconsolidated sediment cover is generally thin, often less than 1m. Sediments are finer seawards, changing from sand on the inner and outer shelves to muddy sand and sandy mud in deeper water. However, this general pattern has been modified considerably by biological deposition (large areas of shelf sediments contain high levels of calcium carbonate) and localised river input. A ~500km long mud belt (up to 40km wide, and of 15m average thickness) is situated over the outer edge of the middle shelf between the Orange River and St Helena Bay (Birch et al. 1976). Further offshore, sediment is dominated by muddy sands, sandy muds, mud and some sand. The continental slope, seaward of the shelf break, has a smooth seafloor, underlain by calcareous ooze.

Present day sedimentation is limited to input from the Orange River. This sediment is generally transported northward. Most of the sediment in the area is therefore considered to be relict deposits by now ephemeral rivers active during wetter climates in the past. The Orange River, when in flood, still contributes largely to the mud belt as suspended sediment is carried southward by poleward flow. In this context, the absence of large sediment bodies on the inner shelf reflects on the paucity of terrigenous sediment being introduced by the few rivers that presently drain the South African West Coast coastal plain.

**Figure 2:** The Exploration Area and indicative 3D survey area in relation to sediment distribution on the continental shelf of the southern African West Coast (Adapted from Rogers 1977).
3.2 **BIOPHYSICAL CHARACTERISTICS**

3.2.1 **Climate**

The climate of the southern Namibian coastline is classified as hyper-arid with typically low, unpredictable winter rains and strong predominantly southerly or south-westerly winds. Further out to sea, a south-easterly component is more prominent. Winds reach a peak in the late afternoon and subside between midnight and sunrise.

The Namibian coastline is characterised by the frequent occurrence of fog, which occurs on average between 50-75 days per year, being most frequent during the months of February through May. The fog lies close to the coast extending about 20 nautical miles (~35km) seawards (Olivier, 1992, 1995). This fog is usually quite dense, appears as a thick bank hugging the shore and visibility may be reduced to <300m. Fog should in no way affect seismic operations in the offshore areas.

Average precipitation per annum ranges from 16.4 mm at Lüderitz to 51.5mm at Oranjemund. Due to the combination of wind and cool ocean water, temperatures are mild throughout the year. Coastal temperatures average around 16°C, gradually increasing inland (Barnard 1998). In winter, maximum diurnal shifts in temperature can occur caused by the hot easterly ‘Berg’ winds which blow off the desert. During such occasions temperatures up to 30°C are not uncommon.

3.2.2 **Wind Patterns**

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

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

These seasonal changes result in substantial differences between the typical summer and winter wind patterns in the region, as the southern hemisphere anti-cyclonic high-pressure system, and the associated series of cold fronts,
move northwards in winter, and southwards in summer. The strongest winds occur in summer, when winds blow 99% of the time, with a total of 226 gales (winds >18 m s⁻¹ or 35 kts) being recorded over the period (CSIR 2006). Virtually all winds in summer come from the south to south-southeast (Figure 3). 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 (Figure 3). 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.

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

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3.2.3 Large-Scale Circulation and Coastal Currents

The southern African West Coast is strongly influenced by the Benguela Current. Current velocities in continental shelf areas generally range between 10-30 cm s⁻¹ (Boyd and Oberholster 1994), although localised flows in excess of 50 cm/s occur associated with eddies (PRDW 2013). On its western side, flow is more transient and characterised by large eddies shed from the retroflexion of the Agulhas Current. In the south the Benguela current has a width of 200km, widening rapidly northwards to 750km. The flows are predominantly
wind-forced, barotropic and fluctuate between poleward and equatorward flow (Shillington et al. 1990; Nelson and Hutchings 1983) (Figure 4). Fluctuation periods of these flows are 3-10 days, although the long-term mean current residual is in an approximate northwest (alongshore) direction. Current speeds decrease with depth, while directions rotate from predominantly north-westerly at the surface to south-easterly near the seabed. Near bottom shelf flow is mainly poleward (Nelson 1989) with low velocities of typically 5 cm s\(^{-1}\).

**Figure 4:** Major features of the predominant circulation patterns and volume flows in the Benguela System, along the southern Namibian and South African west coasts (re-drawn from Shannon and Nelson 1996).
The major feature of the Benguela Current Coastal is 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. Consequently, it is a semi-permanent feature at Lüderitz and areas to the north due to perennial southerly winds (Shannon 1985). The Lüderitz upwelling cell is the most intense upwelling cell in the system (}
Figure 5), with the seaward extent reaching nearly 300km, and the upwelling water is derived from 300-400m depth (Longhurst 2006). A detailed analysis of water mass characteristics revealed a discontinuity in the central and intermediate water layers along the shelf north and south of Lüderitz (Duncombe Rae 2005). The Lüderitz / Orange River Cone (LUCORC) area between approximately 29°S - 31°S, thus forms a major environmental barrier between the northern and southern Benguela sub-systems (Ekau and Verheye 2005). The Exploration Licence is situated between the Namaqua and Lüderitz upwelling cells, and offshore of the LUCORC area. Off northern and central Namibia, several secondary upwelling cells occur. Upwelling in these cells is perennial, with a late winter maximum (Shannon 1985).

### Waves

Typical seasonal swell-height rose-plots, compiled from Voluntary Observing Ship (VOS) data off Oranjemund (and therefore inshore of the project area), are shown in Figure 6 (supplied by CSIR). Swell data for the offshore regions of the project area is limited. Along the southern African west coast, the wave regime 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 2m in height, averaging about 3m, and often attaining over 5m. With wind speeds capable of reaching 100km h\(^{-1}\) during heavy winter south-westerly storms, winter swell heights can exceed 10m.

In comparison, summer swells inshore of the project area tend to be smaller on average, typically around 2m, 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). These wind-induced southerly waves are relatively local and, although less powerful, tend to work together with the strong southerly winds of summer to cause the northward-flowing nearshore surface currents, and result in substantial nearshore sediment mobilisation, and northwards transport, by the combined action of currents, wind and waves.
Figure 5: The Exploration Area and proposed 3D survey area in relation to upwelling centres on the west coast of Namibia (Adapted from Shannon 1985).
Figure 6: VOS Wave Height vs Wave Direction data for the offshore area (28°-29°S; 15°-16°E recorded during the period 1 February 1906 and 12 June 2006) (Source: Voluntary Observing Ship (VOS) data from the Southern African Data Centre for Oceanography (SADCO)).
3.2.5 Water

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

Seawater temperatures on the continental shelf of the southern Benguela typically vary between 6°C and 16°C. Well-developed thermal fronts exist, demarcating the seaward boundary of the upwelled water. Upwelling filaments are characteristic of these offshore thermal fronts, occurring as surface streamers of cold water, typically 50km 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 625km offshore. South and east of Cape Agulhas, the Agulhas retroflexion area is a global ‘hot spot’ in terms of temperature variability and water movements.

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

Nutrient concentrations of upwelled water of the Benguela system attain 20µm nitrate-nitrogen, 1.5µm phosphate and 15-20µm silicate, indicating nutrient enrichment (Chapman and Shannon 1985). This is mediated by nutrient regeneration from biogenic material in the sediments (Bailey et al. 1985). Modification of these peak concentrations depends upon phytoplankton uptake which varies according to phytoplankton biomass and production rate. The range of nutrient concentrations can thus be large but, in general, concentrations are high.

3.2.6 Upwelling and Plankton Production

The cold, upwelled water is rich in inorganic nutrients, the major contributors being various forms of nitrates, phosphates and silicates (Chapman and Shannon 1985). During upwelling the comparatively nutrient-poor surface waters are displaced by enriched deep water, supporting substantial seasonal primary phytoplankton production. This, in turn, serves as the basis for a rich food chain up through zooplankton, pelagic baitfish (anchovy, pilchard, round-herring and others), to predatory fish (hake and snoek), mammals (primarily seals and dolphins) and seabirds (jackass penguins, cormorants, pelicans, terns and others). High phytoplankton productivity in the upper layers again depletes the nutrients in these surface waters. This results in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays.
3.2.7 Organic Inputs, Hypoxia and Sulphur Eruptions

Balanced multispecies ecosystem models have estimated that 36% of the phytoplankton and 5% of the zooplankton are lost to the seabed annually (Shannon et al. 2003). This natural annual input of millions of tons of organic material onto the seabed has a substantial effect on the ecosystems of the Benguela region. It provides most of the food requirements of the particulate and filter-feeding benthic communities, and results in the high organic content of the muds in the region. As most of the organic detritus is not directly consumed, it enters the seabed decomposition cycle, resulting in subsequent depletion of oxygen in deeper waters. As the mud on the shelf is distributed in discrete patches (see Figure 2), there are corresponding preferential areas for the formation of oxygen-poor water, one of these being located inshore of the project area in the Orange River Bight (Chapman and Shannon 1985; Bailey 1991; Shannon and O'Toole 1998; Bailey 1999).

The spatial distribution of oxygen-poor water is subject to short- and medium-term variability. Subsequent upwelling processes can move this hypoxic water onto the inner shelf and into nearshore waters, often with devastating effects on marine communities.

Closely associated with seafloor hypoxia, is the generation of toxic hydrogen sulphide and methane within the organically-rich, anoxic muds. Under conditions of severe oxygen depletion, hydrogen sulphide (H$_2$S) gas is formed by anaerobic bacteria in anoxic seabed muds (Brüchert et al. 2003). This is periodically released from the muds as ‘sulphur eruptions’, causing upwelling of anoxic water and formation of surface slicks of sulphur discoloured water (Emeis et al. 2004). Although these processes are common off central Namibia, they are not expected in the project area.

3.3 The Biological Environment

Biogeographically, the study area falls into the cold temperate Namaqua Bioregion, which extend from Sylvia Hill, north of Lüderitz in Namibia to Cape Columbine (Emanuel et al. 1992; Lombard et al. 2004). The portion of the proposed survey area that extends beyond the shelf break onto the continental slope and into abyssal depths fall into the Atlantic Offshore Bioregion (Lombard et al. 2004). The coastal, wind-induced upwelling characterising the western Cape coastline, is the principle physical process which shapes the marine ecology of the southern Benguela region. The Benguela system is characterised by the presence of cold surface water, high biological productivity, and highly variable physical, chemical and biological conditions.

Communities within marine habitats are largely ubiquitous throughout the southern African West Coast region, being particular only to substrate type or depth zone. These biological communities consist of many hundreds of species, often displaying considerable temporal and spatial variability (even at small scales). The majority of the proposed survey area is located beyond the 300m depth contour, the closest points to shore for the 3D survey being ~180km offshore of Oranjemund. The offshore marine ecosystems comprise a
limited range of habitats, namely unconsolidated seabed sediments and the water column. The biological communities 'typical' of these habitats are described briefly below, focussing both on dominant, commercially important and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the proposed seismic survey.

3.3.1 Demersal Communities

Benthic Invertebrate Macrofauna

The benthic biota of unconsolidated marine sediments constitute invertebrates that live on (epifauna) or burrow within (infauna) the sediments, and are generally divided into macrofauna (animals >1mm) and meiofauna (<1mm). Although numerous studies have been conducted on southern African West Coast continental shelf benthos (Parkins and Field 1997; 1998; Pulfrich and Penney 1999; Goosen et al. 2000; Savage et al. 2001; Steffani and Pulfrich 2004a, 2004b; 2007; Steffani 2007a; 2007b; Steffani 2009, 2010; Atkinson et al. 2011; Steffani 2012), the benthic fauna of the outer shelf and continental slope (beyond ~450m depth) are very poorly known. To date very few areas on the continental slope off the southern African West Coast have been biologically surveyed. This is primarily due to limited opportunities for sampling as well as the lack of access to Remote Operated Vehicles (ROVs) for visual sampling of hard substrata.

Due to the lack of information on benthic macrofaunal communities beyond the shelf break, no description can be provided for the Exploration Licence Area. In general, however, benthic communities are structured by the complex interplay of a large array of environmental factors, with water depth and sediment grain size being considered the two major factors that determine benthic community structure and distribution on the South African west coast (Christie 1974, 1976; Steffani and 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). Other 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. The periodic intrusion of low oxygen water masses in the deepwater shelf areas of the West Coast is likely to also contribute to benthic community variability (Monteiro and van der Plas 2006; Pulfrich 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. Atkinson (2009) reported numerous species of urchins and burrowing anemones beyond 300m depth off the South African West Coast.
Deep-water Coral Communities

There has been increasing interest in deep-water corals in recent years because of their likely sensitivity to disturbance and their long generation times. These benthic filter-feeders generally occur at depths exceeding 150m. Some species form reefs while others are smaller and remain solitary. Corals add structural complexity to otherwise uniform seabed habitats thereby creating areas of high biological diversity (Breeze et al. 1997; MacIsaac et al. 2001). Deep water corals establish themselves below the thermocline where there is a continuous and regular supply of concentrated particulate organic matter, caused by the flow of a relatively strong current over special topographical formations which cause eddies to form. Nutrient seepage from the substratum might also promote a location for settlement (Hovland et al. 2002). No corals have been discovered to date but this is most likely the result of the lack of surveys. Substantial shelf areas in the productive Benguela region could potentially be capable of supporting rich, cold water, benthic, filter-feeding communities.

Demersal Fish Species

Demersal fish are those species that live and feed on or near the seabed. As many as 110 species of bony and cartilaginous fish have been identified in the demersal communities on the continental shelf of the West Coast (Roel 1987). Changes in fish communities occur with increasing depth (Roel 1987; Smale et al. 1993; Macpherson and Gordoa 1992; Bianchi et al. 2001; Atkinson 2009), with the most substantial change in species composition occurring in the shelf break region between 300m and 400m depth (Roel 1987; Atkinson 2009). Common commercial demersal species found mostly on the continental shelf but also extending beyond 500m water depth include both the shallow-water hake (Merluccius capensis) and the deep-water hake (Merluccius paradoxus), monkfish (Lophius vomerinus), and kingklip (Genypterus capensis). There are also many other demersal ‘bycatch’ species that include jacopever (Helicolenus dactylopterus), angelfish/pomfret (Brama brama), kingklip (Genypterus capensis) and gurnard (Chelidonichthyes sp), as well as many elasmobranch (sharks and rays) species. The survey area includes four demersal fish communities (Shine 2006) based broadly on depth bands and related to a shift in abundance of the shallow-water and deep-water hake species, Merluccius capensis and Merluccius paradoxus respectively. Merluccius capensis dominates the shallowest community (30-130m depths). The shallow and deep-water hake species have similar abundances in the community found mainly between 130m and 200m depths. The two deeper communities are dominated by M. paradoxus but differ in species composition. The distribution of the shelf community varies seasonally (Lane and Carter 1999; Hampton et al. 1999).

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

The diversity and distribution of demersal cartilaginous fishes on the West Coast is discussed by Compagno et al. (1991). The species likely to occur in the Exploration Licence Area, and their approximate depth range, are listed in Table 3.1.

**Table 3.1:** Demersal cartilaginous species found on the continental shelf along the West Coast, with approximate depth range at which the species occurs (Compagno et al. 1991).

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific name</th>
<th>Depth Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frilled shark</td>
<td>Chlamydoselachus anguineus</td>
<td>200-1 000</td>
</tr>
<tr>
<td>Six gill cowshark</td>
<td>Hexanchus griseus</td>
<td>150-600</td>
</tr>
<tr>
<td>Gulper shark</td>
<td>Centrophorus granulosus</td>
<td>480</td>
</tr>
<tr>
<td>Leafscale gulper shark</td>
<td>Centrophorus squamosus</td>
<td>370-800</td>
</tr>
<tr>
<td>Bramble shark</td>
<td>Echinorhinus brucus</td>
<td>55-285</td>
</tr>
<tr>
<td>Black dogfish</td>
<td>Centroscyllium fabrici</td>
<td>&gt;700</td>
</tr>
<tr>
<td>Portuguese shark</td>
<td>Centroscymnus coelolepis</td>
<td>&gt;700</td>
</tr>
<tr>
<td>Longnose velvet dogfish</td>
<td>Centroscymnus crepidater</td>
<td>400-700</td>
</tr>
<tr>
<td>Birdbeak dogfish</td>
<td>Deania calcea</td>
<td>400-800</td>
</tr>
<tr>
<td>Arrowhead dogfish</td>
<td>Deania profundorum</td>
<td>200-500</td>
</tr>
<tr>
<td>Longsnout dogfish</td>
<td>Deania quadrispinosum</td>
<td>200-650</td>
</tr>
<tr>
<td>Sculpted lanternshark</td>
<td>Etmopterus brachyrus</td>
<td>450-900</td>
</tr>
<tr>
<td>Brown lanternshark</td>
<td>Etmopterus compagnoi</td>
<td>450-925</td>
</tr>
<tr>
<td>Giant lanternshark</td>
<td>Etmopterus granulosus</td>
<td>&gt;700</td>
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<tr>
<td>Smooth lanternshark</td>
<td>Etmopterus pusillus</td>
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<tr>
<td>Spotted spiny dogfish</td>
<td>Squalus acanthias</td>
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</tr>
<tr>
<td>Shortnose spiny dogfish</td>
<td>Squalus megalops</td>
<td>75-460</td>
</tr>
<tr>
<td>Shortspine spiny dogfish</td>
<td>Squalus mitsukurii</td>
<td>150-600</td>
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<tr>
<td>Sixgill sawshark</td>
<td>Pliotrema warreni</td>
<td>60-500</td>
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<tr>
<td>Goblin shark</td>
<td>Mitsukurina owstoni</td>
<td>270-960</td>
</tr>
<tr>
<td>Smalleye catshark</td>
<td>Apristurus microps</td>
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<td>Saldanha catshark</td>
<td>Apristurus saldanha</td>
<td>450-765</td>
</tr>
<tr>
<td>‘grey/black wonder’ catsharks</td>
<td>Apristurus spp</td>
<td>670-1 005</td>
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<td>Tigar catshark</td>
<td>Haelaeurus natalensis</td>
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<td>Izak catshark</td>
<td>Holohaelaeurus regani</td>
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<tr>
<td>Yellowspotted catshark</td>
<td>Scyliorhinus capensis</td>
<td>150-500</td>
</tr>
<tr>
<td>Soupfin shark/Vaalhaai</td>
<td>Galeorhinus galeus</td>
<td>&lt;10-300</td>
</tr>
<tr>
<td>Houndshark</td>
<td>Mustelus mustelus</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Whitespotted houndshark</td>
<td>Mustelus palumbes</td>
<td>&gt;350</td>
</tr>
<tr>
<td>Little guitarfish</td>
<td>Rhinobatos annulatus</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Atlantic electric ray</td>
<td>Torpedo nobiliana</td>
<td>120-450</td>
</tr>
<tr>
<td>African softnose skate</td>
<td>Bathyraja smithii</td>
<td>400-1 020</td>
</tr>
<tr>
<td>Smoothnose legskate</td>
<td>Cruriraja durbanensis</td>
<td>&gt;1 000</td>
</tr>
<tr>
<td>Roughnose legskate</td>
<td>Crurirajaparcomaculata</td>
<td>150-620</td>
</tr>
<tr>
<td>African dwarf skate</td>
<td>Neoraja stehmanni</td>
<td>290-1 025</td>
</tr>
</tbody>
</table>
### 3.3.2 Seamount Communities

Tripp Seamount is a geological feature within the Block 2914B licence area, which rises from the seabed at ~1 000m to a depth of 150m. A further geological feature of note to the south of the proposed survey area is Child’s Bank, situated ~150km offshore at about 31°S (see Figure 1). These features are located ~50km and ~270km southeast of the southern boundary of the proposed 3D survey area, respectively. Both these features have not been well studied, and little is known about the benthic and neritic communities associated with them.

Features such as banks, knolls and seamounts (referred to collectively here as ‘seamounts’), which protrude into the water column, are subject to, and interact with, the water currents surrounding them. The effects of such seafloor features on the surrounding water masses can include the upwelling 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 seafloor features.

Studies conducted on other seamounts have identified that enhanced fluxes of detritus and plankton that develop in response to the complex current regimes lead to the development of detritivore-based food-webs, which in turn lead to the presence of seamount scavengers and predators. Seamounts can provide an important habitat for commercial deepwater fish stocks, which aggregate around these features for either spawning or feeding (Koslow 1996).

Species likely to be encountered around Tripp Seamount include orange roughy (Hoplostethus atlanticus), oreos (Allocyttus spp and Psuedocyttus spp), alfonsino (Beryx splendens) and Patagonian toothfish (Dissostichus eleginoides).
The deep-sea red crab *Chaceon erytheiae* and southern boarfish *Pseudopentaceros richardsoni* are also likely to occur. Most of these species are long-lived and slow-growing. Their eggs, larvae and juveniles are pelagic, recruiting onto and aggregating around the summits of seamounts and migrating into deeper waters with age. Orange roughy in particular form spawning aggregations during winter, making them vulnerable to deepwater trawling operations.

The complex benthic ecosystems that can develop around seamounts 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 7, 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). Some of the smaller cnidarians species remain solitary while others form reefs thereby adding structural complexity to otherwise uniform seabed habitats. The coral frameworks offer refugia for a great variety of invertebrates and fish (including commercially important species) within, or in association with, the living and dead coral framework (*Figure 7, right*) thereby creating spatially fragmented areas of high biological diversity. 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 dermal/benthic fauna of seamounts is often 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). Large pelagic species in contrast are migratory and can travel vast distances across the oceans.

Levels of endemism on seamounts are also relatively high compared to the deep sea. As a result of conservative life histories (ie 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 deepwater trawl fisheries and mining), and once damaged are very slow to recover, or may never recover (FAO 2008).
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. Southern Africa’s seamounts and their associated benthic communities have not been sampled by either geologists or biologists (Sink and Samaai 2009). There is reference to decapods crustaceans from Tripp Seamount (Kensley 1980, 1981) and exploratory deepwater trawl fishing (Hampton 2003), but otherwise knowledge of benthic communities characterising southern African seamounts is lacking. Evidence from video footage taken on hard-substrate habitats in 100 - 120m depth off southern Namibia and to the south-east of the Child's Bank off the Namaqualand coast (De Beers Marine, unpublished data) (Figure 8), however, suggest that sensitive communities including gorgonians, octocorals and reef-building sponges occur on the continental shelf, and similar communities may thus be expected on Tripp Seamount. These should, however, not be affected by the proposed 3D survey activities, which are located ~50km to the northwest of Tripp Seamount.
3.3.3 Pelagic Communities

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

**Plankton**

Plankton is particularly abundant in the shelf waters off Namibia, being associated with the upwelling characteristic of the area. Plankton range from single-celled bacteria to jellyfish of 2-m diameter, and include bacterio-plankton, phytoplankton, zooplankton, and ichthyoplankton (Figure 9).

Off the Namibian coastline, phytoplankton are the principle primary producers with mean annual productivity being comparatively high at 2g C m\(^{-2}\) day\(^{-1}\) (Barnard 1998). The phytoplankton is dominated by diatoms, which are adapted to the turbulent sea conditions. Diatom blooms occur after upwelling events, whereas dinoflagellates are more common in blooms that occur during quiescent periods.

Namibian zooplankton reaches maximum abundance in a belt parallel to the coastline and offshore of the maximum phytoplankton abundance. The mesozooplankton (<2mm body width) community includes egg, larval, juvenile and adult stages of copepods, cladocerans, euphausiids, decapods, chaetognaths, hydromedusae and salps, as well as protozoans and meroplankton larvae (Maartens 2003; Hansen et al. 2005). Copepods are the most dominant group making up 70-85% of the zooplankton.
Figure 9: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells.

Ichthyoplankton constitutes the eggs and larvae of fish. The Orange River Cone (LUCORC) area, between approximately 29°S - 31°S, is considered to be an environmental barrier to the transport of ichthyoplankton from the southern to the northern Benguela upwelling ecosystems. Areas of powerful upwelling are considered unfavourable spawning habitats, with pelagic fish species reported as spawning on either side of the LUCORC area, but not within it (Figure 14). The area is characterised by diminished phytoplankton biomass due to high turbulence and deep mixing in the water column. A deficiency of phytoplankton in turn results in poor feeding conditions for micro-, meso- and macrozooplankton and for ichthyoplankton (Lett et al. 2007). Phytoplankton, zooplankton and ichthyoplankton abundances in the Exploration Licence Area are thus expected to be low.

Cephalopods

The major cephalopod resource in the southern Benguela are cuttlefish with up to 14 species being recorded (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 60-190m, whereas S. hieronis densities were higher at depths between 110-250m. Rossia enigmatica occurs more commonly on the edge of the shelf to depths of 500m. 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.
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 11, top*) while the giant squid is usually found near continental and island slopes all around the
world’s oceans (Figure 11, bottom). Both species could thus potentially occur in the Exploration Area, although the likelihood of encounter is extremely low. Growing to in excess of 10m in length, they are the principal prey of the sperm whale, and are also taken by beaked whales, 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 000m. They lack gas-filled swim bladders and maintain neutral buoyancy through an ammonium chloride solution occurring throughout their bodies.

Figure 11: Distribution of the colossal squid (top-blue area; http://iobis.org) and the giant squid (bottom- red dots; www.wikipedia.org).

Fish

Small pelagic species include the sardine/pilchard (Sardinops 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 200m contour and thus unlikely to be encountered in the Exploration Licence Area. These species spawn downstream of major upwelling centres in spring and summer, and their eggs
and larvae are carried around Cape Point and up the coast in northward flowing surface waters (Shannon and Pillar 1986).

Two species that migrate along the southern African West Coast following the shoals of anchovy and pilchards are snoek *Thysites atun* and chub mackerel *Scomber japonicus*. Their appearance along the southern African West Coast are highly seasonal. Snoek spawn in the area between St Helena Bay and the Cape Peninsula between July and October before moving offshore and commencing their return northward migration (Payne and Crawford 1989). They are voracious predators occurring throughout the water column, feeding on both demersal and pelagic invertebrates and fish. Chub mackerel move inshore to spawn in June and July before starting the return northwards offshore migration later in the year (Payne and 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 (>300m). Species occurring off western southern Africa include the albacore/longfin tuna *Thunnus alalunga* (Figure 12, right), yellowfin *T. albacares*, bigeye *T. obesus*, and skipjack *Katsuwonus pelamis* tunas, as well as the Atlantic blue marlin *Makaira nigricans* (Figure 12, left), the white marlin *Tetrapturus albidus* and the broadbill swordfish *Xiphias gladius* (Payne and Crawford 1989). The distribution of these species is dependent on food availability in the mixed boundary layer between the Benguela and warm central Atlantic waters. 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). Seasonal association with Tripp Seamount and Child’s Bank 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 2014 – Fisheries Specialist Study).

**Figure 12:** *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 southern African 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).

**Turtles**

Five of the eight species of turtle worldwide occur off Namibia (Bianchi *et al.* 1999). Of these, only three species are likely to be encountered in the Exploration Area, namely the Leatherback (*Dermochelys coriacea*) (Figure 13, left), and occasionally the Loggerhead (*Caretta caretta*) (Figure 13, right) and the Green (*Chelonia mydas*) turtle, the latter two being infrequent visitors to the area.

**Figure 13:** 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 southern Namibia. The Benguela ecosystem, especially the northern Benguela where jelly fish numbers are high, is increasingly being recognized as a potentially important feeding area for leatherback turtles from several globally significant nesting populations in the south Atlantic (Gabon, Brazil) and south east Indian Ocean (South Africa) (Lambardi *et al.* 2008; Elwen and Leeney 2011; SASTN 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 14).
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 600m and remain submerged for up to 54 minutes (Hays et al. 2004). Their abundance in the study area is unknown but expected to be low. Although they tend to avoid nearshore areas, they may be encountered further offshore where seawater temperatures are higher.

Leatherback turtles have recently washed up in significant numbers on the central Namibian shore, with some being recorded as far south as Mining Area 1 (28°27'S)(pers. obs.) inshore of the Exploration Licence Area. During the past five years 200 to 300 dead turtles were found (www.nacoma.org.na). Leatherback Turtles are listed as ‘Critically Endangered’ worldwide by the IUCN and are in the highest categories in terms of need for conservation in CITES (Convention on International Trade in Endangered Species), and CMS (Convention on Migratory Species). Loggerhead and green turtles are listed as ‘Endangered’. Although not a signatory of CMS, Namibia has endorsed and signed a CMS International Memorandum of Understanding specific to the conservation of marine turtles. Namibia is thus committed to conserve these species at an international level.

Figure 14: The Exploration Licence Area (white polygon) in relation to the post-nesting distribution of nine satellite tagged leatherback females (1996 – 2006; Oceans and Coast, unpublished data). is indicated
Seabirds

The Namibian coastline sustains large populations of breeding and foraging seabird and shorebird species, which require suitable foraging and breeding habitats for their survival. In total, 11 species of seabirds are known to breed along the southern Namibian coast (
Most seabirds breeding in Namibia are restricted to areas where they are safe from land predators, although some species are able to breed on the mainland coast in inaccessible places. In general most breed on islands, or on the man-made guano platforms in Walvis Bay, Swakopmund and Cape Cross. The islands along the Namibian coast therefore provide a vital breeding habitat to most species of seabirds that breed in Namibia (Figure 15). However, the number of successfully breeding birds at the particular breeding sites varies with food abundance (J. Kemper, MFMR Lüderitz, pers comm). With the exception of Kelp Gull all the breeding species are listed Red Data species in Namibia.

Most of the seabird species breeding in Namibia feed relatively close inshore (10-30km). Cape Gannets, however, are known to forage up to 140km offshore (Dundee 2003; Ludynia 2007), and African Penguins have also been recorded as far as 60km offshore. As the northern portion of the Exploration Area is located over 200km offshore, encounters with these species during the proposed survey is highly unlikely.

Figure 15: *Cape Gannets* *Morus capensis* (left) (Photo: NACOMA) and *African Penguins* *Spheniscus demersus* (right) (Photo: Klaus Jost) breed primarily on the offshore Islands.

Other Red-listed species found foraging, or roosting along the coastline of southern Namibia are listed in

Table 3.2. Most seabirds breeding in Namibia are restricted to areas where they are safe from land predators, although some species are able to breed on the mainland coast in inaccessible places. In general most breed on islands, or on the man-made guano platforms in Walvis Bay, Swakopmund and Cape Cross. The islands along the Namibian coast therefore provide a vital breeding habitat to most species of seabirds that breed in Namibia (Figure 15). However, the number of successfully breeding birds at the particular breeding sites varies with food abundance (J. Kemper, MFMR Lüderitz, pers comm). With the exception of Kelp Gull all the breeding species are listed Red Data species in Namibia.

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Other Red-listed species found foraging, or roosting along the coastline of southern Namibia are listed in
Table 3.2. Among the species present there are five species of albatrosses, petrels or giant-petrels recorded in the waters off Namibia's southern coast (Boyer and Boyer, in press). However, population numbers are poorly known and they do not breed in Namibian waters.
Table 3.2: Southern Namibian breeding seabird species with their Namibian and global IUCN Red-listing classification (from Kemper et al. 2007; Simmons and Brown in press).

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>Namibian</th>
<th>Global IUCN</th>
</tr>
</thead>
<tbody>
<tr>
<td>African Penguin <em>Spheniscus demersus</em></td>
<td>Endangered</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>Bank Cormorant <em>Phalacrocorax neglectus</em></td>
<td>Endangered</td>
<td>Endangered</td>
</tr>
<tr>
<td>Cape Cormorant <em>Phalacrocorax capensis</em></td>
<td>Near Threatened</td>
<td>Near Threatened</td>
</tr>
<tr>
<td>Cape Gannet <em>Morus capensis</em></td>
<td>Endangered</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>Crowned Cormorant <em>Phalacrocorax coronatus</em></td>
<td>Near Threatened</td>
<td>Least Concern</td>
</tr>
<tr>
<td>African Black Oystercatcher <em>Haematopus moquini</em></td>
<td>Near Threatened</td>
<td>Near Threatened</td>
</tr>
<tr>
<td>White-breasted cormorant <em>Phalacrocorax carbo</em></td>
<td>Least Concern</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Kelp Gull <em>Larus dominicanus</em></td>
<td>Least Concern</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Hartlaub's Gull <em>Larus hartlaubii</em></td>
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</tr>
<tr>
<td>Swift Tern <em>Sterna bergii bergii</em></td>
<td>Vulnerable</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Damara Tern <em>Sterna balaenarum</em></td>
<td>Near Threatened</td>
<td>Near Threatened</td>
</tr>
</tbody>
</table>

*In the IUCN scheme Endangered is a more extinction-prone class than Vulnerable, and differences between Namibia and global classifications are the result of local population size, and the extent and duration of declines locally.

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

The Orange River Mouth wetland provides an important habitat for large numbers of a great diversity of wetland birds. Six species of wetland birds, which occur regularly in the Orange River Mouth have been identified as being of special concern to Namibian Conservation authorities, these being Black-necked Grebe, Lesser Flamingo, Greater Flamingo, Chestnut-banded Plover, Red Knot and Bartailed Godwit. Furthermore, the wetland supports significant proportions of the world's populations of Cape Cormorant and Hartlaub's Gull, both of which are endemic to south-western Africa.

Forty-nine species of pelagic seabirds have been recorded in the region, of which 14 are resident. Highest pelagic seabird densities occur offshore of the shelf-break in winter. Pelagic seabirds likely to be encountered in the Exploration Licence Area are provided in
Table 3.3
Table 3.3: Pelagic seabirds common in the southern Benguela region (Crawford et al. 1991).

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

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

Marine Mammals

The marine mammal fauna occurring off the central Benguela ecosystem coast includes several species of whales and dolphins and one resident seal species. Thirty four species of whales and dolphins are known (based on sightings or strandings records) or likely (based on habitat projections of known species parameters) to occur in the central Benguela region and in the offshore waters of the proposed survey area (see Table 3-4). Apart from the resident species such as the endemic Heaviside’s dolphin and dusky dolphin, the Benguela also hosts species that migrate between Antarctic feeding grounds and warmer breeding ground waters, as well as species with a global distribution. The area has been poorly studied with almost all available information in deeper waters (>200m) arising from historic whaling records. Current information on the distribution, population sizes and trends of most cetacean species occurring on the west coast of southern Africa is lacking. Information on smaller cetaceans in deeper waters and deep diving species (e.g. beaked whales) is particularly poor and the precautionary principal must be used when considering possible encounters with cetaceans in this area. Available data from the Namibian Dolphin Project (unpublished) suggests that the survey area is one of the most species rich areas in Namibia for cetaceans,
possibly due to the proximity to Tripp Seamount, and the Lüderitz Upwelling Cell and its associated nutrient rich waters.

Records from stranded specimens show that the area between St Helena Bay (~32°S) and Cape Agulhas (~34°S, 20°E) is an area of transition between Atlantic and Indian Ocean species, as well as those more commonly associated with colder waters of the west coast (e.g. dusky dolphins and long finned pilot whales) and those of the warmer east coast (e.g. striped and Risso's dolphins) (Findlay et al. 1992). The location of the survey lies north of this transition zone and can be considered to be truly on the 'west coast'. However, the warmer waters that occur offshore of the Benguela ecosystem (more than ~100km offshore and including the survey area) provide an entirely different habitat, that despite the relatively high latitude may host some species associated with the more tropical and temperate parts of the Atlantic such as rough toothed dolphins, Pan-tropical spotted dolphins and short finned pilot whales. Owing to the uncertainty of species occurrence offshore, species that may occur there have been included here for the sake of completeness.

The distribution of cetaceans can largely be split into those associated with the continental shelf and those that occur in deep, oceanic water. Importantly, species from both environments may be found on the continental slope (200-2 000m) making this the most species rich (1) area for cetaceans. Cetacean density (i.e. number of animals encountered) on the continental shelf is usually higher than in pelagic waters as species associated with the pelagic environment tend to be wide ranging across 1 000s of km.

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

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(1) Species richness refers to the number of different species likely to be encountered.
Table 3-4: Summary of cetacean species known or likely to occur and their likely encounter frequency within the proposed seismic survey area based on the best available knowledge of density and seasonality. Note that for beaked whales knowledge of numbers, density and encounter rates is particularly poor and (together with the Kogiids and pygmy right whale) they are difficult to detect visually and are thus likely to be underestimated in any visual survey, due to generally small group sizes and cryptic behaviour.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Species</th>
<th>Likely encounter frequency</th>
<th>IUCN Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Delphinids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dusky dolphin</td>
<td><em>Lagenorhynchus obscurus</em></td>
<td>Daily</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Heaviside’s dolphin</td>
<td><em>Cephalorhynchus heavisidii</em></td>
<td>Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Common bottlenose dolphin</td>
<td><em>Tursiops truncatus</em></td>
<td>Weekly</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Common (short beaked) dolphin</td>
<td><em>Delphinus delphis</em></td>
<td>Monthly</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Southern right whale dolphin</td>
<td><em>Lissodelphis peronii</em></td>
<td>Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Striped dolphin</td>
<td><em>Stenella coeruleoalba</em></td>
<td>Very rare</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Pantropical spotted dolphin</td>
<td><em>Stenella attenuata</em></td>
<td>Very rare</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Long-finned pilot whale</td>
<td><em>Globicephala melas</em></td>
<td>Daily</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Short-finned pilot whale</td>
<td><em>Globicephala macrorhynchus</em></td>
<td>Vagrant</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Rough-toothed dolphin</td>
<td><em>Steno bredanensis</em></td>
<td>Very rare</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Killer whale</td>
<td><em>Orcinus Orca</em></td>
<td>Occasional</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>False killer whale</td>
<td><em>Pseudorca crassids</em></td>
<td>Occasional</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Pygmy killer whale</td>
<td><em>Feresa attenuata</em></td>
<td>Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Risso’s dolphin</td>
<td><em>Grampus griseus</em></td>
<td>Occasional</td>
<td>Least Concern</td>
</tr>
<tr>
<td><strong>Sperm whales</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pygmy sperm whale</td>
<td><em>Kogia breviceps</em></td>
<td>Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Dwarf sperm whale</td>
<td><em>Kogia sima</em></td>
<td>Very rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Sperm whale</td>
<td><em>Physeter macrocephalus</em></td>
<td>Weekly</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>Beaked whales</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Cuvier’s</td>
<td><em>Ziphius cavirostris</em></td>
<td>Occasional</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Arnoux’s</td>
<td><em>Beradius arnouxii</em></td>
<td>Occasional</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Southern bottlenose</td>
<td><em>Hyperoodon planifrons</em></td>
<td>Occasional</td>
<td>Not assessed</td>
</tr>
<tr>
<td>Layard’s</td>
<td><em>Mesoplodon layardii</em></td>
<td>Occasional</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>True’s</td>
<td><em>M. mirus</em></td>
<td></td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Gray’s</td>
<td><em>M. grayi</em></td>
<td>Occasional</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Blainville’s</td>
<td><em>M. densirostris</em></td>
<td></td>
<td>Data Deficient</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Baleen whales</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minke</td>
<td><em>Balaenoptera bonaerensis</em></td>
<td>Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Dwarf minke</td>
<td><em>B. acutorostrata</em></td>
<td>Rare</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Fin whale</td>
<td><em>B. physalus</em></td>
<td>Occasional</td>
<td>Endangered</td>
</tr>
<tr>
<td>Blue whale</td>
<td><em>B. musculus</em></td>
<td>Very Rare</td>
<td>Endangered</td>
</tr>
<tr>
<td>Sei whale</td>
<td><em>B. borealis</em></td>
<td>Occasional</td>
<td>Endangered</td>
</tr>
<tr>
<td>Bryde’s (offshore)</td>
<td><em>B. brydei</em></td>
<td>Occasional</td>
<td>Not assessed</td>
</tr>
<tr>
<td>Bryde’s (inshore)</td>
<td><em>B. brydei (subssp)</em></td>
<td>Very Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Pygmy right</td>
<td><em>Caperea marginata</em></td>
<td>Very Rare</td>
<td>Data Deficient</td>
</tr>
<tr>
<td>Humpback</td>
<td><em>Megaptera novaeangliae</em></td>
<td>Daily</td>
<td>Least Concern</td>
</tr>
<tr>
<td>Southern right</td>
<td><em>Eubalaena australis</em></td>
<td>Rare</td>
<td>Least Concern</td>
</tr>
</tbody>
</table>
Table 3.5: Seasonality of baleen whales in the impact zone based on data from multiple sources, predominantly commercial catches (Best 2007 and other sources) and data from stranding events (NDP unpubl data). Values of high (H), Medium (M) and Low (L) are relative within each row (species) and not comparable between species. For abundance / likely encounter rate within the impact zone, see Table 3-4.

<table>
<thead>
<tr>
<th>Species</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bryde's Inshore</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Bryde's Offshore</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Sei</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>Fin</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Blue</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Minke</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Humpback</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Southern Right</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Pygmy right</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
</tbody>
</table>
Table 3-4 lists the cetaceans likely to be found within impact zone, based on data sourced from: Findlay et al. (1992), Best (2007), Weir (2011), Dr J-P Roux, (MFMR pers comm) and unpublished records held by the Namibian Dolphin Project. Of the 33 species listed, three are endangered and one is considered vulnerable (IUCN Red Data list Categories). Altogether 18 species are listed as ‘data deficient’ underlining how little is known about their distributions and population trends. The majority of data available on the seasonality and distribution of large whales in the survey area is the result of commercial whaling activities mostly dating from the 1960s. Changes in the timing and distribution of migration may have occurred since these data were collected due to extirpation of populations or behaviours (eg migration routes may be learnt behaviours). The large whale species for which there are current data available are the humpback and southern right whale, although almost all data is limited to that collected on the continental shelf close to shore.

A review of the distribution and seasonality of the key cetacean species likely to be found within the impact zone is provided below, based on information provided by the Namibian Dolphin Project (NDP), which has been conducting research in Namibian waters since 2008. The NDP holds the most up-to-date data of cetacean occurrence and distribution since whaling times, with the records including a database of nearly 500 opportunistic records and sightings made by marine mammal observers on seismic vessels and observers operating on scientific, tourism and fishing vessels; over 150 records of cetaceans stranded along the Namibian coast; over 250 cetacean sightings from scientific surveys of the Namibian Islands Marine Protected Area and over 1 300 sightings from near shore surveys in the region of Walvis Bay and Lüderitz.

**Mysticete (Baleen) whales**

The majority of mysticetes whales fall into the family Balaenopteridae. Those occurring in the area include the blue, fin, sei, Antarctic minke, dwarf minke, humpback and Bryde’s whales. The southern right whale (Family Balaenidae) and pygmy right whale (Family Neobalaenidae) are from taxonomically separate groups. The majority of mysticete species occur in pelagic waters with only occasional visits to shelf waters (<200m deep). All of these species show some degree of migration either to or 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. Depending on the ultimate location of these feeding and

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1 The term ‘impact zone’ is used to define the survey area and surrounding regions likely to be affected by increased shipping and noise levels associated with airgun activities. Exact definitions of the impact zone are, however, not possible as sound propagation modelling was not undertaken. Furthermore, as the distribution of many species is poorly understood, the term is used in a broad sense to encompass the species and region likely to be most affected by seismic activities.
breeding grounds, seasonality may be either unimodal, usually in winter months, or bimodal (e.g. May to July and October to November), reflecting a northward and southward migration through the area. Northward and southward migrations may take place at different distances from the coast due to whales following geographic or oceanographic features, thereby influencing the seasonality of occurrence at different locations. Because of the complexities of the migration patterns, each species is discussed separately below, and a best estimate of expected seasonality within the impact zone is provided in Table 3.5.

The most abundant baleen whales in the Benguela are southern right whales and humpback whales (Figure 16). 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). Increasing numbers of summer records of both species, suggest that animals may also be feeding in upwelling areas of Namibia, especially the southern half of the country near the Lüderitz upwelling cell (NDP unpubl. data) and will therefore occur in or pass through the impact zone.

HUMPBACK WHALES (MEGAPTERA NOVAEANGLIAE) - The majority of humpback whales passing through the Benguela are migrating to breeding grounds off tropical west Africa, between Angola and the Gulf of Guinea (Rosenbaum et al. 2009; Barendse et al. 2010). A recent synthesis of available humpback whale data from Namibia (Elwen et al. 2013) shows that in coastal waters, the northward migration stream is larger than the southward peak supporting earlier observations from whale catches (Best and Allison 2010). This supports previous suggestions that animals migrating north strike the coast at varying places mostly north of St Helena Bay (South Africa) resulting in increasing whale density on shelf waters as one moves north towards Angola, but no clear migration ‘corridor’. On the southward migration, there is evidence from satellite tagged animals and the smaller secondary peak in numbers in Walvis Bay, that many humpback whales follow the Walvis Ridge offshore then head directly to high latitude feeding grounds, while others follow a more coastal route (including the majority of mother-calf pairs), possibly lingering in the feeding grounds off west South Africa in summer (Elwen et al. 2013, Rosenbaum et al. 2014). Although migrating through the Benguela, there is no existing evidence of a clear 'corridor' and humpback whales appear to be spread out widely across the shelf and into deeper pelagic waters, especially during the southward migration (Barendse et al. 2010; Best and Allison 2010; Elwen et al. 2013). Regular sightings of humpback whales in spring and summer months in Namibia, especially in the Lüderitz area, suggest that summer feeding is occurring in Namibian waters as well (or at least that animals foraging off West South Africa range up into southern Namibia). 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
Humpback whales are thus likely to be the most frequently encountered baleen whale in the impact site, ranging from the coast out beyond the shelf, with year round presence but numbers peaking in June – July (northern migration) and a smaller peak with the southern breeding migration around September – October but with regular encounters until February associated with subsequent feeding in the Benguela ecosystem.

**Figure 16:** The Humpback whale *Megaptera novaeangliae* (left) and the Southern Right whale *Eubalaena australis* (right) are the most abundant large cetaceans occurring along the southern African West Coast (Photos: www.divephotoguide.com; www.aad.gov.au).

**SOUTHERN RIGHT WHALE (EUBALAENA AUSTRALIS)** - The southern African population of southern right whales historically extended from southern Mozambique (Maputo Bay) to southern Angola (Baie dos Tigres) and is considered to be a single population within this range (Roux *et al.* 2011). The most recent abundance estimate for this population is available for 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 (Brandaõ *et al.* 2011). Since the population is still continuing to grow at ~7% per year (Brandaõ *et al.* 2011), the population size in 2013 would number more than 6 000 individuals. When the population numbers crashed, the range contracted down to just the south coast of South Africa, but as the population recovers, it is repopulating its historic grounds including Namibia (Roux *et al.* 2001, 2011) and Mozambique (Banks *et al.* 2011). Southern right whales are seen regularly in Namibian coastal waters (<3km from shore), especially in the southern half of the Namibian coastline (Roux *et al.* 2001, 2011) Right whales have been recorded in Namibian waters in all months of the year (J-P Roux pers comm) but with numbers peaking in winter (June - August). A secondary peak in summer (November - January) also occurs, probably associated with animals feeding off the west coast of South Africa performing exploratory trips into southern Namibia (NDP unpubl. data).
BRYDE'S WHALE (BALAENOPTER EDENI) - Two genetically and morphologically distinct populations of Bryde’s whales live off the coast of southern Africa (Best 2001; Penry 2010) (Figure 17, left). The ‘offshore population’ lives beyond the shelf (>200m 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 potential impact zone in January - March. A recent stranding of an adult offshore Bryde’s whales in January 2012 in Walvis Bay, Namibia (population assigned genetically - G Penry pers. comm.) confirms the population's current occurrence in Namibian waters. 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 approximately Durban in the east to at least St Helena Bay off the west coast. It may move further north into the Benguela current areas of the west of coast of South Africa and Namibia, especially in the winter months (Best 2007). A recent live stranding of a calf of this population (population assigned genetically - G Penry pers. comm.) in Walvis Bay, Namibia confirms the current occurrence of this population in Namibian waters. An additional live sighting in the Namibian Islands MPA and a third stranding of a Bryde’s whale adult in April 2013 have not been assigned to population but supports regular, year round occurrence of the species in the northern Benguela ecosystem (NDP unpubl. data).

Figure 17: The Bryde’s whale Balaenoptera brydei (left) and the minke whale Balaenoptera bonaerensis (right) (Photos: www.dailymail.co.uk; www.marinebio.org).

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 (Best 2007) (Figure 17, right). Since whaling catches were confirmed off Congo and Angola, it is likely that they migrate through the impact zone. Due to their migration pattern, densities in the broader potential impact zone are

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likely to show a bimodal peak with numbers predicted to be highest in May - June and again in August - October. During hunting, all whales were caught in waters deeper than 200m with most caught deeper than 1 000m (Best and 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. However, a recent sighting of a sei whale mother-calf pair in March 2012 (NDP unpubl data) and a live stranding in July 2013 in Walvis Bay supports their contemporary and probably year round occurrence in the Benguela waters.

**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 South African shore based stations suggests 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 a mystery (Best 2007). Some juvenile animals may feed year round in deeper waters off the shelf (Best 2007). Four strandings have occurred between Walvis Bay and the Kunene River, Namibia in the last decade during January, April (2) and October (NDP unpubl. data) and a live animal was seen at Dassen Island, South Africa in November 2011 (MRI unpubl. data). Recent data (April-May, 2014) provides evidence of their contemporary occurrence in Namibian Waters. At least 6 fin whales were observed feeding coastally (within 5km of shore) 30km either side of Lüderitz for over 6 weeks during April and May 2014 (NDP unpubl. data). Combined, the strandings data and increasing number of sightings in recent years suggests the population abundance of fin whales may be recovering post whaling, and that the species is likely to be seen with greater regularity in coming years. To date, most sightings or strandings have occurred in late summer (April-May), supporting evidence from whaling data that this is a peak time of occurrence in southern Namibia.

**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 June to 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). Only three confirmed sightings of blue whales have occurred off the entire west coast of Africa since 1973 (Branch et al. 2007), although search effort (and thus information), especially in pelagic waters is very low. A recent sighting (May 2014) by an MMO working near the current proposed survey area was reported to the NDP and confirmed from photographs to be a blue whale - this is the first confirmed sighting of the species in Namibia since the end of commercial whaling. This suggests that the population using the area may have been extirpated by whaling and there is a low chance of encountering the species in the survey or impact area.

**MINKE WHALE (Balaenoptera bonaerensis / Acutorostrata)** - Two forms of minke whale occur in the southern Hemisphere, the Antarctic minke whale (*Balaenoptera bonaerensis*) and the dwarf minke whale (*B. acutorostrata subsp*);
Both species occur in the Benguela (Best 2007, NDP unpubl data). Antarctic minke whales range from the pack ice of Antarctica to tropical waters and are usually seen more than ~50km 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. Regular sightings of semi-resident Antarctic minke whales in Lüderitz Bay, especially in summer months (December - March) and a live stranded of a juvenile animal in Walvis Bay in February 2014, confirm the contemporary occurrence of the species in Namibia (NDP unpubl. data).

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 <2km from shore on several occasions. Both species are generally solitary and densities are likely to be low in the impact area.

**Pygmy Right Whale (Caperea marginata)** - The smallest of the baleen whales, the pygmy right whale occurs in the Benguela, and has a history of stranding within or near Walvis Bay, Namibia (Leeney et al. 2013), although a recent (January 2014) live stranding of an individual in Lüderitz Bay confirms the species occurrence close to the impact zone. Records in Namibia are the northern most for the species, which is more commonly associated with cool temperate waters between 30°S and 55°S. Strandings in Namibia are concentrated in the summer months (November - March) and are predominantly juvenile animals, suggesting that the central Namibian coast may act as a nursery area (Leeney et al. 2013). There are no data on the abundance or conservation status of this species. As it was not subjected to commercial whaling, the population is expected to be near to original numbers. Sightings of this species at sea are rare (Best 2007) due in part to their small size and inconspicuous blows. Density in the impact area is likely to be low.

*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 impact zone display a diversity of features, for example their ranging patterns vary from extremely coastal and highly site specific to oceanic and wide ranging. Those in the region can range in size from 1.6-m long (Heaviside's dolphin) to 17m (bull sperm whale).

**Sperm Whale (Physeter macrocephalus)** - All information about sperm whales in the southern African sub-region results from data collected during commercial whaling activities prior to 1985 (Best 2007). Sperm whales are the largest of the toothed whales (*Figure 18, left*) 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 000m depth, although they occasionally come onto the shelf in water 500-200m deep (Best 2007). They are considered to be relatively abundant globally (Whitehead 2002), although no estimates are available for Namibian waters. Seasonality of historic 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 were one of the most frequently seen cetacean species during a series of observations made from offshore seismic survey vessels operating in tropical west Africa between Angola and the Gulf of Guinea, with a sighting rate of 0.3 groups per 8 hours (Weir 2011). Sightings in northern Angola were all made in water deeper than 780m and showed a seasonal pattern with most animals seen during April - June (Weir 2011). Thus sperm whales in the impact zone are likely to be encountered in relatively high numbers in deeper waters (>500m), predominantly in the winter months (April - October). Data from the Namibian coast is limited as sightings of sperm whales are scarce and there are few records from MMOs operating on seismic surveys, however, a large male stranded near Henties Bay in November 2013 (NDP unpubl. data). The MMO data available from seismic surveys of southern Namibian waters may poorly reflect the number of animals using the region as sperm whales are deep divers and have long dive durations in excess of 30 mins, making them difficult to detect visually. However, due to their powerful echolocation clicks they can be detected easily using Passive Acoustic Monitoring (PAM). Sperm whales in the impact zone are likely to be encountered in deeper waters (>500m), predominantly in the winter months (April - October).

Figure 18: Sperm whales Physeter macrocephalus (left) and killer whales Orcinus orca (right) are toothed whales likely to be encountered in offshore waters (Photos: www.onpoint.wbur.org; www.wikipedia.org).

There are almost no data available on the abundance, distribution or seasonality of the smaller odontocetes (including the beaked whales and dolphins) known to occur in oceanic waters (>200m) off the shelf of Namibia. Beaked whales are all considered to be true deep water species usually being seen in waters in excess of 1 000-2 000m deep (see various species accounts in
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 (e.g. Ross 1979; Findlay et al. 1992; Plön 2004; Elwen et al. 2013). *Kogia* species are most frequently occur in pelagic and shelf edge waters, are thus likely to occur in the impact area at low levels, seasonality is unknown.

Dwarf sperm whales are associated with the warmer waters south and east of St Helena Bay although a single stranded specimen in Walvis Bay, Namibia in 2010, demonstrates that this species also occurs in Namibian waters. However abundance in the impact site is likely to be very low and only in the warmer waters west of the Benguela current. Pygmy sperm whales are recorded from both the Benguela and Agulhas ecosystem (Best 2007) and are likely to occur in the impact site in waters deeper than ~1 000m.

**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) (*Figure 18, right*). Killer whales occur year round in low densities off western South Africa (Best et al. 2010), Namibia (Elwen and 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 impact area at low levels.

**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 000m 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 or associated activities (as has recently been shown for the closely related melon headed whale by Southall et al. 2013). There is no information on population numbers and no evidence of seasonality in the region (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). They are regularly seen associated with the shelf edge by marine mammal observers (MMOs) and fisheries observers and researchers operating in Namibian waters (NDP unpubl. data). The distinction between long-fin 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 impact site will be long-fin. Pilot whales are likely to be among the most commonly encountered odontocetes in vicinity of the seismic survey and impact area.

COMMON BOTTLENOSE DOLPHINS (TURSIOPS TRUNCATUS) - Two species of bottlenose dolphins occur around southern Africa the smaller Indo-Pacific bottlenose dolphins, which occurs exclusively to the east of Cape Point in water usually <30m deep (and thus outside the impact area) and the larger common bottlenose forms of bottlenose dolphin. The latter species occurs in two forms. The inshore form occurs as a small and apparently isolated population that occupies the very coastal (usually <15m deep) waters of the central Namibian coast and is considered a conservation concern. Members of this population have been seen as far south as Lüderitz, but this is considered to be near the limit of the population range (NDP unpubl data) and is unlikely to be encountered in the impact area (except in the area of Lüderitz harbour). Little is known about the offshore form of the species, and nothing about their population size or conservation status. They sometimes occur in association with other species such as pilot whales (NDP unpubl data) or false killer whales (Best 2007) and are likely to be present year round in waters deeper than 200m.

COMMON DOLPHIN (DELPHINUS SPP) - The common dolphin is known to occur offshore in Namibian waters (Findlay et al. 1992), with a recent stranding in Lüderitz (May 2012, NDP unpubl. data) and MMO reports confirming their occurrence in the region. The extent to which they occur in the impact zone is unknown, but likely to be low. Group sizes of common dolphins can be large, averaging 267 (± SD 287) for the South Africa region (Findlay et al. 1992) and 92 (± SD 115) for Angola (Weir 2011) and 37 (± SD 31) in Namibia (NDP unpubl data). They are more frequently seen in the warmer waters offshore and to the north of the country, seasonality is not known.

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 and Payne 1991) in water 100-2 000m deep (Best, 2007), where they are seen several times per year (Findlay et al. 1992; JP Roux pers comm.), including a recent live stranding of two individuals in Lüderitz Bay in December 2013. They are often seen in mixed species groups with other dolphins such as dusky dolphins. This small area where they are regularly seen overlaps almost
entirely with the proposed impact zone. It is possible that the Namibian sightings represent a regionally unique and resident population (Findlay et al. 1992) and as such caution is needed to minimize negative effects of seismic exploration. Encounters in the impacts zone are likely at low levels.

**DUSKY DOLPHINS (LAGENORHYNCHUS OBSCURUS) (Figure 19, right)** - In water <500m deep, dusky dolphins are likely to be the most frequently encountered small cetacean. The species is very boat friendly and will often approach boats to bowride. This species is resident year round throughout the Benguela ecosystem in waters from the coast to at least 500m deep, but may occur as far as 2000m depth (Findlay et al. 1992). Although no information is available on the size of the population, they are regularly encountered in near shore waters between Cape Town and Lamberts Bay and around Lüderitz, but further north they are usually found further from shore in slightly deeper waters (Elwen et al. 2010a; NDP unpubl data). Abundances estimates are being calculated but currently suggest a relatively large population of several thousand at least. In a recent survey of the Namibian Islands Marine Protected Area (between latitudes of 24°29’S and 27°57’S and depths of 30-200m) dusky dolphin were the most commonly detected cetacean species encountered with group sizes ranging from 1 to 500 individuals (NDP unpubl data), although group sizes up to 800 have been reported in southern African waters (Findlay et al. 1992). A hiatus in sightings (or low density area) is reported between ~27°S and 30°S, associated with the Lüderitz upwelling cell (Findlay et al. 1992). This area aligns fairly closely with the proposed seismic survey area, which suggests that sightings during the survey may be uncommon. Dusky dolphins are resident year round in the Benguela.

**Figure 19:** The endemic Heaviside’s Dolphin Cephalorhynchus heavisidii (left) (Photo: De Beers Marine Namibia), and Dusky dolphin Lagenorhynchus obscurus (right) (Photo: scottelowitzphotography.com).

**HEAVISIDE’S DOLPHINS (CEPHALORHYNCHUS HEAVISIDII) (Figure 19, left)** - This species is relatively abundant in the Benguela ecosystem with in the region of 10 000 animals estimated to live in the 400km of coast between Cape Town and Lamberts Bay, and about 1 000 around Lüderitz (Elwen et al. 2009; NDP unpubl data). Individuals show high site fidelity to small home ranges,
50-80km along shore (Elwen et al. 2006) and may thus be more vulnerable to threats within their home range. This species occupies waters from the coast to at least 200m depth, (Elwen et al. 2006; Best 2007) suggesting they would largely be inshore of the impact zone. They may show a diurnal onshore-offshore movement pattern (Elwen et al. 2010b), but this varies throughout the species range. Their small group sizes and inconspicuous behaviour when offshore make monitoring their presence very difficult. However, their echolocation clicks can be detected using PAM technology at ranges up to ~500m and the characteristic high frequency, narrow band nature of the clicks (Morisaka et al. 2011) makes them easily distinguished from other species in the area. Heaviside’s dolphins are resident year round.

OTHER DELPHINIDS - Several other species of dolphins that might occur in the deeper waters of impact area at low levels include the pygmy killer whale, Risso’s dolphin, rough toothed dolphin, pan tropical spotted dolphin and striped dolphin (Findlay et al. 1992; Best 2007). Nothing is known about the population size or density of these species in the impact zone but it is likely that encounters would be rare.

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 2km deep, beaked whales are amongst the most extreme divers of any air breathing animals (Tyack et al. 2011), but they also appear to be particularly vulnerable to certain types of anthropogenic noise. Several species of beaked whale (mainly Cuvier’s but also Blainville’s and Gervais’ beaked whales) have been recorded to strand or die at sea, often en masse, in response to man made sounds, particularly mid frequency naval sonar and potentially multi-beam echo-sounders (Cox et al. 2006, MacLeod and D’Amico, 2006). Although the exact reason for this vulnerability is not yet fully understood, the existing evidence clearly shows that these animals are susceptible to man made noise and precautions should be taken to avoid causing any harm. All the beaked whales that may be encountered in the impact zone are pelagic species that tend to occur in small groups usually less than five, although larger aggregations of some species are known (MacLeod and 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.

Summary of Cetaceans

There are very little current data on the presence, density or conservation status of any cetaceans within the planned survey area as the majority of data available is largely the result of commercial whaling activities mostly dating from the 1960s. Changes in the timing and distribution of migration may have occurred since these data were collected due to extirpation of populations or behaviours (e.g. migration routes may be learnt behaviours). The large whale species for which there are current data available are the humpback and southern right whale, although with almost all data being limited to the
continental shelf. Both these species are known to use a feeding ground around Cape Columbine with numbers here highest between September and February, and not during winter as is common on the South Coast breeding grounds. Whaling data indicates that several other large whale species are also most abundant on the West Coast during this period: fin whales peak in May-July and October-November; sei whale numbers peak in May-June and again in August-October and offshore Bryde's whale numbers are likely to be highest in January-February. Whale numbers on the shelf and in offshore waters are thus likely to be highest between October and February.

Of the migratory cetaceans, the Blue, Sei and Fin whales are listed as ‘Endangered’ in the IUCN Red Data book. All whales and dolphins are given protection under the Namibian Law. The regulations under the Namibian Marine Resources Act, 2000 (No. 27 of 2000) states that no whales or dolphins may be harassed, killed or fished.

Seals

The Cape fur seal (Arctocephalus pusillus pusillus) (
Figure 20) 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 20). Vagrant records from four other species of seal more usually associated with the subantarctic environment have also been recorded: southern elephant seal (*Mirounga leonina*), subantarctic fur seal (*Arctocephalus tropicalis*), crabeater (*Lobodon carcinophagus*) and leopard seals (*Hydrurga leptonyx*) (David 1989).

Currently, half the Namibian seal population occurs in southern Namibia, south of Lüderitz. It consists of about 300 000 seals, producing roughly 100 000 pups per year. Atlas Bay, Wolf Bay and Long Islands (near Lüderitz) together represent the largest breeding concentration (about 68 000 pups) of seals in Namibia. Further colonies are located at van Reenen Bay and Bakers Bay, approximately 215km and 230km northeast of the northern boundary of the Exploration Licence Area. Population estimates fluctuate widely between years in terms of pup production, particularly since the mid-1990s (MFMR unpubl. Data; Kirkman et al. 2007).
There is a controlled annual quota, determined by government policy, for the harvesting of Cape fur seals on the Namibian coastline. The Total Allowable Catch (TAC) currently stands at 60,000 pups and 5,000 bulls, distributed among four licence holders. The seals are exploited mainly for their pelts (pups), blubber and genitalia (bulls).

There are a further two Cape fur seal colonies south of the proposed survey area: at Kleinzee (incorporating Robeiland), and at Buchu Twins near Alexander Bay in South Africa. The colony at Kleinzee has the highest seal population and produces the highest seal pup numbers on the South African Coast (Wickens 1994). The colony at Buchu Twins, formerly a non-breeding colony, has also attained breeding status (M. Meyer, SFRI, pers comm). Non-breeding colonies on the South African West Coast occur south of Hondeklip Bay at Strandfontein Point, with the McDougalls Bay islands and Wedge Point being haul-out sites only and not permanently occupied by seals.

The Cape fur seal population in the Benguela is regularly monitored by the South African and Namibian governments (e.g. Kirkman et al. 2012). Surveys of the full species range done every three years providing data on seal pup production (which can be translated to adult population size), thereby allowing for the generation of high quality data on the population dynamics of this species. The population is considered to be healthy and stable in size although there has been a northward shift in the distribution of the breeding population (Kirkman et al. 2012).

Seals are highly mobile animals with a general foraging area covering the continental shelf up to 120 nautical miles (~220km) offshore (Shaughnessy
1979), with bulls ranging further out to sea than females. The timing of the annual breeding cycle is very regular occurring between November and January. Breeding success is highly dependent on the local abundance of food, territorial bulls and lactating females being most vulnerable to local fluctuations as they feed in the vicinity of the colonies prior to and after the pupping season (Oosthuizen 1991).

3.4 OTHER USES OF THE PROPOSED SURVEY AREAS

3.4.1 Other Users

The proposed survey area is located well offshore beyond the 1 000m depth contour. Other users of the area inshore of the Exploration Licence blocks include the commercial fishing industry (see Specialist Report on Fisheries), oil and gas licence holders and Namibia marine diamond mining concession holders (see Figure 21). Recreational use of the survey area will be negligible due to its location offshore. The coastal area onshore of the Exploration Licence block falls within the diamond mining area (Sperrgebiet) and as public access is restricted, no recreational activities occur along the coastline between Lüderitz and Oranjemund.

The main shipping lanes off the west coast of southern Africa lie seawards of the proposed survey area, however, both coastal shipping and fishing craft may be encountered in the survey area.

The proposed survey area lies well offshore of Exclusive Prospecting Licences (EPLs) and Mining Licences. Current activities in the EPLs is minimal to non-existent, the only active operations being diamond mining in ML-47 (Atlantic 1) held by De Beers Marine Namibia. Deep-water diamond mining operations in the Atlantic 1 Mining Licence Area are typically conducted to depths of 150m from fully self-contained mining vessels with on board processing facilities, using either large-diameter drill or seabed crawler technology. These vessels operate as semi-mobile mining platforms, anchored by a dynamic positioning system, commonly on a three to four anchor spread (Figure 22). Computer-controlled positioning winches enable the vessels to locate themselves precisely over a mining block of up to 400m x 400m. These mining vessels thus have limited manoeuvrability and other vessels should remain at a safe distance. No deep-water diamond mining is currently underway in the South African concession areas, with marine diamond mining activity restricted to nearshore, diver-mining from small, converted fishing vessels.

Other industrial uses of the marine environment include the intake of feed-water for fish processing, mariculture, or diamond-gravel treatment. As these activities are all located on the coast and well inshore of the proposed survey area, none should in any way be affected by seismic survey activities.
Figure 21: Project - environment interaction points on the West Coast, illustrating the location of existing hydrocarbon wells, marine diamond mining concessions and ports for commercial and fishing vessels.

Figure 22: Typical crawler-vessel (left) and drillship (right) operating in the Atlantic 1 Mining Licence Area (Photos: De Beers Marine).
3.4.2 Conservation Areas and Marine Protected Areas

Numerous conservation areas and a marine protected area (MPA) exist along the coastline of southern Namibia, although none fall within the proposed seismic survey area (Figure 23). However, for the sake of completeness, they are briefly summarised below.

Conservation areas in southern Namibia include the Sperrgebiet, which was proclaimed in 1908 and covers an area of approximately 26,000km² between latitude 26° in the north and the Orange River in the south, extending inland from the coast for 100km. The Sperrgebiet was proclaimed to prevent public access to the rich surface diamond deposits occurring in the area, and has largely remained closed off to general public access since then. However, as diamond mining has actually remained confined to the narrow coastal strip and along the banks of the Orange River, most of the area has effectively been preserved as a pristine wilderness. Although large parts of the Sperrgebiet have since been de-proclaimed from exclusive prospecting and mining licences previously owned by Namdeb, and have now reverted to unproclaimed State land, most of the area is not yet formally managed as a conservation area.

The first Namibian MPA was launched on 2 July 2009 under the Namibian Marine Resources Act (No. 29 of 1992 and No. 27 of 2000), with the purpose of protecting sensitive ecosystems and breeding and foraging areas for seabirds and marine mammals, as well as protecting important spawning and nursery grounds for fish and other marine resources (such as rock lobster). The MPA comprises a coastal strip extending from Hollamsbird Island (24º38'S) in the north, to Chamais Bay (27º57'S) in the south, spanning approximately three degrees of latitude and an average width of 30km, including 16 specified offshore islands, islets and rocks (Currie et al. 2008). The Namibian Islands' Marine Protected Area (NIMPA) spans an area of 9,555km², and includes a rock-lobster sanctuary constituting 478km² between Chamais Bay and Prince of Wales Bay. The offshore islands, whose combined surface area amounts to only 2.35km² have been given priority conservation and highest protection status (Currie et al. 2009). The proposed area has been further zoned into four degrees of incremental protection. These are detailed in Currie et al. (2008).

The Orange River Mouth wetland provides an important habitat for large numbers of a great diversity of wetland birds. The area was designated a Ramsar site in June 1991, and processes are underway to declare a jointly-managed transboundary Ramsar reserve.

On the South African coast immediately east of the Exploration Area, the only conservation area in which restrictions apply is the McDougall's Bay rock lobster sanctuary near Port Nolloth, which is closed to commercial exploitation of rock lobsters.

‘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). 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 have been identified for protection on the West Coast between Cape Agulhas and the South African – Namibian border. Those within the broad project area are shown in
3.5 FEATURES SPECIFIC TO THE LICENCE AREA

The PEL39 licence area, situated approximately 170 to 350km off the coast of Namibia. The license area covers 12 299km² with water depths ranging from 300m to 3 000m. The area of interest defined for the 3D survey is approximately 2 500km² in extent with water depths ranging between 1 000m and 2 500m. It is situated in the north-eastern portion of the PEL39 licence area. The highest sensitivities (Figure 23) in the general project area are:

- Tripp Seamount, which rises from the seabed at ~1 000m to a depth of 150m. Seamounts serve as mid-ocean focal points for a variety of pelagic species (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. Tripp is located within PEL39, but some 50km southeast of the proposed 3D survey area.
- The 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 (>300m). They exhibit a seasonal association with Tripp Seamount and Child’s Bank between October and June, during which time they are targeted by the pelagic longline fishing sector.
- Migrating leatherback turtles are also likely to occur, as are a variety of pelagic seabirds. Leatherback Turtles are listed as ‘Critically Endangered’ worldwide, and some of the pelagic seabirds likely to be encountered are listed as ‘Near Threatened’ or ‘Endangered’.
- Marine mammals likely to be encountered include sperm whales, migrating humpback whales and various baleen and toothed whales known to frequent offshore waters. Of the migrating whales the Blue, Sei and Fin whales are listed as ‘Endangered’ in the IUCN Red Data book. Sperm whales are listed as ‘Vulnerable’ and Humpback and Southern Right whales are listed as “least Concern”.
- Various marine protected areas and proposed priority areas for the protection of benthic and pelagic habitats occur within the region, but none fall within PEL39 or the proposed 3D survey area.
Figure 23: The Exploration Licence Area and proposed survey area in relation to biodiversity sensitivities along the southern Namibian and Namaqualand coasts.
ASSESSMENT OF IMPACTS ON MARINE FAUNA

4.1 ASSESSMENT PROCEDURE

The assessment of impacts is an iterative process with four key elements:

1. Prediction of impacts and risks and characterisation in terms of magnitude;

2. Evaluation of the significance of impacts taking into account the sensitivity of the environmental resources and human receptors;

3. Development of mitigation measures to avoid, reduce or manage the impacts; and

4. Assessment and disclosure of the residual impacts.

In the event that a significant residual impacts remains, further options for mitigation may be considered and impacts re-assessed.

Potential impacts are characterised in the following way:

4.1.1 Nature of Impact

The nature of an impact is defined as the type of change from baseline conditions or the introduction of a new desirable or undesirable factor. The nature of an impact is described as being either positive or negative.

4.1.2 Type of Impact

Impact type indicates the relationship of the impact to the project activity in terms of cause and effect, as either:

- Direct impact resulting from the direct interaction between a project activity and the receiving environment; or

- Indirect impact between the proposed activity and the environment as a result of subsequent interactions within the environment, or

- Induced impact resulting from other non-project activities that happen as a consequence of the project activities.

4.1.3 Extent of Impact

Impact extent relates to the geographic reach of the impact and is described as:

- Local impact would affect local resources or receptors and would be restricted to a single community (i.e., impacts in the footprint of project activities and the immediate adjacent area);
• Regional impact would affect regional resources or receptors and would be experienced at a regional scale such as the Namibian EEZ;

• National impact would affect nationally important environmental resources or receptors such as nationally protected areas/species;

• International impact would affect internationally important resources or receptors such as areas protected by international conventions and endangered species, and

• Trans-boundary impact would be those that are experienced in one country as a result of activities in another.

4.1.4 Duration of Impact

Impact duration refers to the time period over which a resource or receptor will be affected, and includes:

• Temporary - of short duration, reversible and intermittent or occasional in nature. The resource or receptor would return to the previous state when the effect ceases or after a short period of recovery;

• Short-term impact would last for the life of the proposed short term activity and a limited short period thereafter (e.g., three months after the survey completion). The impact would cease when the effect ceases following a short period of recovery;

• Long-term impact would continue for an extended period of time after the project activity (e.g., 10 years), and

• Permanent impact would be one where the resource or receptor is altered indefinitely, well beyond the end of project activities.

4.1.5 Scale of Impact

Impact scale relates to the size of the impact. Where possible this is expressed quantitatively.

4.1.6 Frequency

Impact frequency relates to the constancy or periodicity of the impact. Where possible this is expressed quantitatively.

4.1.7 Likelihood

Likelihood is an additional characteristic that pertains only to unplanned events (e.g., accidental release of oil). Designations used to describe this characteristic include:
• Unlikely events are unlikely but may occur at some time during normal operating conditions;

• Likely events are likely to occur at some time during normal operating conditions, and

• Definite events will occur during normal operating conditions (i.e., it is essentially inevitable).

4.1.8 Impact Magnitude

Impact magnitude describes the degree of change that the impact is likely to impart upon the resource/receptor. Once the impact characteristics are understood, the characteristics are used to determine the magnitude of the impact in a manner specific to the particular resource or receptors. Magnitude is a function of the following characteristics:

• Extent;
• Duration;
• Scale;
• Frequency, and
• Likelihood (for unplanned events only).

The universal magnitude designations are:

• Positive;
• Negligible;
• Small;
• Medium, and
• Large.

4.1.9 Resources and Receptors Sensitivity

The significance of an impact of a given magnitude will depend on the sensitivity of the particular resource and receptor.

For ecological impacts, sensitivity is assigned as low, medium or high based on the conservation importance of habitats and species. For habitats, these are based on naturalness, extent, rarity, fragility, diversity and importance as a community resource. Table 4.1 presents the criteria for deciding on the value or sensitivity of individual species.
### Table 4.1: Species Value / Sensitivity Criteria

<table>
<thead>
<tr>
<th>Value / Sensitivity Criteria</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not protected or listed</td>
<td>Not protected or listed</td>
<td>Specifically protected under Namibia legislation and/or international conventions eg CITIES</td>
<td>Listed as rare, threatened or endangered eg IUCN</td>
</tr>
<tr>
<td>and common / abundant; or</td>
<td>or not critical to other ecosystem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>not critical to other</td>
<td>functions (eg key prey species to other</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ecosystem functions</td>
<td>species).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4.1.10 Significance

Impact significance is a function of magnitude and sensitivity (Table 4.2) as follows:

- Magnitude of the change to the physical or biological environment expressed preferably in quantitative terms. The magnitude of an impact is viewed from the perspective of resource and receptor;

- Sensitivity of the resource and receptor. Where the receptor is physical, the assessment considers the quality, sensitivity to change and importance of the receptor. Sensitivity is also based on stakeholder view, and

- Compliance with relevant Namibian legislation, policies and plans and any relevant international policies, accepted industry standards and Shell’s internal policies, standards and guidelines.

For this assessment, significance will be designated as follows:

- Positive impact is one that provides resources or receptors with positive benefits. Positive impact is not evaluated in terms of level of significance;

- Negligible impact is one where a resource or receptor will not be affected in any way by a particular activity or the predicted effect is deemed to be negligible or imperceptible or is virtually indistinguishable from natural variation;

- Minor significance impact is one where an effect will be experienced, but where the magnitude is sufficiently small and well within accepted standards, and/or the resource or receptor is of low sensitivity or value;

- Moderate significance impact is one where the magnitude and/or sensitivity of the resource or receptor is of a moderate to high value. Effects of a moderate significance impact would still be within accepted limits and standards. The emphasis for moderate significance impacts is on demonstrating that the effect has been reduced to ALARP. This does not
necessarily mean that moderate impacts would be reduced to minor impacts, but that the effects are minimised and managed effectively, and

- Major significance impact is one where the magnitude and the sensitivity of the resource or receptor is of a high value. Effects of a major significance impact could exceed accepted limits or standards. Major significance impact would be prioritised for action and the emphasis would be on determining ways to reduce the effect of the impact including possibly alternatives that would avoid the effects.

### Table 4.2 Significance Criteria

<table>
<thead>
<tr>
<th>Magnitude Impact</th>
<th>Negligible</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low value / low sensitivity receptor or resource, within standards</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Minor</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate value / sensitivity receptor or resource, within standards</td>
<td>Negligible</td>
<td>Minor</td>
<td>Moderate</td>
<td>Major</td>
</tr>
<tr>
<td>High value / sensitivity receptor or resource, exceeding standards</td>
<td>Negligible</td>
<td>Moderate</td>
<td>Major</td>
<td>Major</td>
</tr>
</tbody>
</table>

### 4.2 Assessment of Impacts

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 potentially affecting the physiology and behaviour of marine organisms (NRC 2003). The magnitude of the effects will, however, depend on the hearing thresholds of the receptor, these varying substantially among faunal groups and between species (Table 4.3). 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 1µPa at 1m (NRC 2003). Especially at low frequencies between 5 to 100Hz, 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 potentially affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock et al. 2003).

Table 4.3  Known hearing frequency ranges of various marine taxa (adapted from Koper & Plön 2012)

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Hearing Frequency (kHz)</th>
<th>Sound Production (kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crustaceans</td>
<td>0.1 - 3</td>
<td>0.1 - &gt;200</td>
</tr>
<tr>
<td>Teleosts</td>
<td></td>
<td>0.4 - 4</td>
</tr>
<tr>
<td>Hearing specialists</td>
<td>0.03 - &gt;3</td>
<td></td>
</tr>
<tr>
<td>Hearing generalists</td>
<td>0.03 - 1</td>
<td></td>
</tr>
<tr>
<td>Elasmobranchs</td>
<td>0.1 - 1.5</td>
<td>Unknown</td>
</tr>
<tr>
<td>Turtles</td>
<td>0.1 - 1</td>
<td>Unknown</td>
</tr>
<tr>
<td>Seals</td>
<td>0.075 - 10</td>
<td>1 - 4</td>
</tr>
<tr>
<td>Manatees and Dugongs</td>
<td>0.4 - 46</td>
<td>4 - 25</td>
</tr>
<tr>
<td>Toothed whales</td>
<td>0.1 - 180</td>
<td>0.05 - 200</td>
</tr>
<tr>
<td>Baleen whales</td>
<td>0.005 - 30</td>
<td>0.01 - 28</td>
</tr>
</tbody>
</table>

Seismic surveys are another source of anthropogenic noise. The air-guns used in modern seismic surveys produce some of the most intense non-explosive sound sources used by humans in the marine environment (Gordon et al. 2004) and consequently are of particular environmental concern. However, the transmission and attenuation of seismic sound is probably of equal importance in the assessment of environmental impacts than the produced source levels themselves, as transmission losses and attenuation will affect the spatial distribution of sound and the zone of potential effect. Transmission losses and attenuation are very site specific, and affected by propagation condition which include water properties and receiver depth and bathymetrical aspect with respect to the sound source. In water depths of 25-50m airgun arrays are often audible to ranges of 50-75km, and with efficient propagation conditions such as experienced on the continental shelf or in deep oceanic water, the distance over which sound can be detected can exceed 100km and 1000km, respectively (Bowles et al. 1991; Richardson et al. 1995; see also references in McCauley 1994). The signal character of seismic shots also changes considerably with propagation effects. Reflective boundaries include the sea surface, the sea floor and boundaries between water masses of different temperatures or salinities, with each of these preferentially scattering or absorbing different frequencies of the source signal. This results in the received signal having a different spectral makeup from the initial source signal. In shallow water (<50m) at ranges exceeding 4km from the source, signals tend to increase in length from <30milliseconds, 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 200-500Hz 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). Quantitative measurements by these authors identified that the received levels fell to a minimum between 5-9km from the source and then started increasing again at
ranges between 9-13km, so that absolute received levels (131-167 dB re. 1 µPa) were as high at 12km as they were at 2km, 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 <200millisecond 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).

Acoustic effects on marine faunal communities are reviewed below, and the impacts of seismic surveys on different faunal groups is assessed. The information on acoustic effects 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 and CMS 2001) and the very comprehensive reviews by Cetus Projects (2007, 2008), compiled as part of the Environmental Impact Assessment for the Ibhubesi Gas Field and the CGGVeritas surveys on the Namibian shelf, respectively.

### 4.2.1 Impacts on Plankton

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.

The movement of phytoplankton and zooplankton is largely limited by currents. As they are not able to actively avoid the seismic vessel, they are thus 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 air-gun impulses outside of a 1 m distance (Kosheleva 1992; McCauley 1994). 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 pathological effect out to 10m 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 in more detail in Section 4.2.3.

### Table 4.4 Impact Characteristics: Impacts on Plankton

<table>
<thead>
<tr>
<th>Operational Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Aspect/ activity</td>
</tr>
<tr>
<td>Impact Type</td>
</tr>
<tr>
<td>Receptors Affected</td>
</tr>
</tbody>
</table>

**Impact Description**

Impacts of seismic pulses on plankton would include mortality or physiological injury in the immediate vicinity of the airgun sound source.

**Impact Assessment**

The impact of seismic noise on plankton could include mortality at very close range (<5m from the airguns) only, and is considered 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 impact caused by seismic survey would thus be of low to negligible magnitude, the extent is local limited to across the survey area and for the duration of the survey (short-term).

The proposed survey area lies to the north and offshore of the Namaqua upwelling cell, in the Orange River Cone (LUCORC) area, between approximately 29°S-31°S. Important pelagic fish species, including anchovy, redeye round herring, horse mackerel and shallow-water hake, are reported as spawning on either side of the LUCORC area, but not within it. The area is characterised by diminished phytoplankton biomass due to high turbulence and deep mixing in the water column, and consequently is considered to be an environmental barrier to the transport of ichthyoplankton from the southern to the northern Benguela upwelling ecosystems. A deficiency of phytoplankton results in poor feeding conditions for micro-, meso- and macrozooplankton, and for ichthyoplankton. Phytoplankton, zooplankton
and ichthyoplankton abundances in the survey area are thus expected to be comparatively low.

This, in combination with its offshore location, results in no direct overlap of the Exploration Licence and proposed survey area with either the spring to early summer spawning areas for commercially important species (eg anchovy, pilchard, round herring and chub mackerel) or with the northward egg and larval drift for anchovy (see Figure 10). Ichthyoplankton abundances are thus expected to be negligible.

**Box 4.1 Impact on Plankton and Ichthyoplankton**

**Nature:** Seismic survey activities would result in a negative direct impact on plankton abundance in the survey area.

Sensitivity/Vulnerability/Importance of Resource/Receptor: Low

**Impact Magnitude:** Negligible

- **Extent:** The extent of the impact is local and limited to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact will result in negligible changes to the receptor.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): NEGLIGIBLE**

**Mitigation**

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

**Residual Impacts**

Limited disturbance to plankton is, however, inevitable although the residual impacts are negligible.

**Table 4.5 Pre- and Post- Mitigation Significance: Impacts on Plankton**

<table>
<thead>
<tr>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEGLIGIBLE</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

**4.2.2 Impacts on Marine Invertebrates**

Although most marine invertebrates do not possess hearing organs that perceive sound pressure, many 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 and 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), cephalopods (Hanlon and Budelman 1987; Packard et al. 1990; McCauley et al. 2000) and various other invertebrate species (Horridge 1965, 1966; Horridge and Boulton 1967; Moore and Cobb 1986; Turnpenney and Nedwell 1994).

No quantitative records of invertebrate mortality from seismic sound exposure under field operating conditions exist, but lethal and sub-lethal effects have been observed under experimental conditions where invertebrates were exposed to airguns up to 5m 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 opilio*) on the Atlantic coast of Canada, for example ranged from no physiological damage but effects on developing fertilized eggs at 2m 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.

Impacts of seismic pulses on invertebrates thus 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.

**Table 4.6 Impact Characteristics: Impacts on Invertebrates**

<table>
<thead>
<tr>
<th>Operational Phase</th>
<th>Sound emissions</th>
<th>Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Aspect/ activity</td>
<td>Benthic (eg lobsters) and pelagic (eg squid) invertebrates</td>
<td></td>
</tr>
</tbody>
</table>

**Impact Description**

**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 15m away. This implies that only surveys conducted in very shallow water will have any direct detrimental effects on
benthic invertebrates. As the survey would mostly be conducted in excess of 1000m depth the received noise at the seabed would be within the far-field range, and outside of distances at which physiological injury to benthic invertebrates would be expected, but potentially within the response range of neritic and pelagic cephalopods.

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). Although animals showed no external damage, all had severe internal injuries that the authors suggested were indicative of having ascended from depth too quickly. Furthermore, controlled-exposure experiments during which cephalopods were subjected to low-frequency sounds resulted in permanent and substantial alterations of the sensory hair cells of the statocysts of four squid species (André et al. 2011).

**Behavioural avoidance**

Behavioural responses of invertebrates to particle motion of low frequency stimulation has been measured by numerous researchers (reviewed in McCauley 1994). Again a wide range of responses are reported ranging from no avoidance of airgun sounds 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 and Kempf 1998), prawns (Steffe and Murphy 1992, in McCauley, 1994) or rock lobsters (Parry and Gasson 2006) in the near-field during or after seismic surveys.

In contrast, mobile neritic and pelagic invertebrates such as cephalopods, may be receptive to the far-field sounds of seismic airguns. Recent electrophysiological studies have confirmed that cephalopods show sensitivity to frequencies under 400Hz (*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 600Hz pure tone (Maniwa 1976), through startle responses at received levels of 174dB re 1µPa, to increase levels of alarm responses once levels had reached 156-161dB re 1µPa (McCauley et al. 2000). Based on the results of caged experiments, although consistent avoidance has not been reported, McCauley et al. (2000) suggested that squid would significantly alter their behaviour at an estimated 2-5km from an approaching large seismic source. More recently, Andre et al. (2011) demonstrated that received sound levels of 175dB re 1µPa resulted in severe acoustic trauma (morphological damage to the statocysts and afferent dendrites) in four cephalopod species tested under controlled-exposure experiments.

**Impact Assessment**

**Physiological Injury and Mortality**

The impact of seismic noise on physiological injury or mortality of benthic invertebrates is deemed of low magnitude across the survey area because of the water depths in the proposed survey area and the distance of the seabed
from the sound source. The impact is thus considered to be NEGLIGIBLE both with and without mitigation.

There is potential for physiological injury or mortality of pelagic cephalopods across the survey area and for the survey duration. However, as the probability of an encounter with cephalopods in the pelagic environment and in the survey area is limited and of short duration, the magnitude of the impact is considered low and the impact is deemed to be of NEGLIGIBLE significance both without and with mitigation.

Box 4.2 Impact on Invertebrates: Physiological Injury and Mortality

**Nature:** Seismic survey activities would result in a negative direct impact on benthic and pelagic invertebrates in the survey area through injury and mortality.

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Low

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact will result in notable changes to pelagic invertebrates (squid), but negligible changes to benthic invertebrates.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): NEGLIGIBLE**

Behavioural avoidance
The impact of seismic noise on invertebrate behaviour is deemed of low to negligible magnitude across the survey area and for the survey duration and is considered to be of NEGLIGIBLE significance both with and without mitigation, and no mitigation measures are deemed necessary.

Box 4.3 Impact on Invertebrates: Behavioural Avoidance

**Nature:** Seismic survey activities would result in a negative direct impact on benthic and pelagic invertebrates in the survey area through behavioural avoidance.

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Low

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact will result in notable changes to pelagic invertebrates (squid), but negligible changes to benthic invertebrates.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): NEGLIGIBLE**
Mitigation

No mitigation measures for impacts on marine invertebrates and their larvae are feasible or deemed necessary.

Residual Impacts

Limited disturbance to pelagic and neritic invertebrates is, however, inevitable although the residual impacts are negligible.

Table 4.7 Pre- and Post- Mitigation Significance: Impact on Invertebrates

<table>
<thead>
<tr>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEGLIGIBLE</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

4.2.3 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 and 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 of the seismic source could 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 are considered more likely to be potentially damaging to swim-bladders of larger fish (McCauley 1994). The lateral line is sensitive to low frequency (between 20 and 500Hz) stimuli through the particle velocity component of sound.

Most species of fish and elasmobranchs are able to detect sounds from well below 50Hz (some as low as 10 or 15Hz) to upward of 500-1000Hz (Popper and Fay 1999; Popper 2003; Popper et al. 2003), and consequently can detect sounds within the frequency range of most widely occurring anthropogenic noises (Vasconcelos et al. 2007; Codarin et al. 2009). Within the frequency range of 100-1000Hz at which most fish hear best, hearing thresholds vary
considerably (50 and 110dB re 1µPa). 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 200kHz (Popper and 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 potential susceptibility among fish to seismic sounds, with those with a swim-bladder are expected to be more susceptible to anthropogenic sounds than those without this organ.

A review of the available literature revealed that while some fish appear not to be affected by seismic noise to a great extent, seismic pulses could potentially impact fish species (including sharks) directly through physiological injury and mortality, behavioural avoidance of seismic survey areas, masking of environmental sounds and communication, and indirectly through effects on predators or prey.

Table 4.8 Impact Characteristics: Impacts on Fish

<table>
<thead>
<tr>
<th>Operational Phase</th>
<th>Impact Type</th>
<th>Receptors Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Aspect/ activity</td>
<td>Sound emissions</td>
<td>Direct and indirect</td>
</tr>
<tr>
<td>Impact Type</td>
<td></td>
<td>Demersal (associated with the seabed) and pelagic (associated with the water column) fish</td>
</tr>
</tbody>
</table>

Impact Description

Physiological Injury and Mortality

Studies have shown that fish can be exposed directly to the sound of seismic survey without lethal effects, but showing a variety of physiological effects. Physiological effects of impulsive airgun sounds on fish species include swim-bladder damage (Falk and Lawrence 1973), transient stunning (Hastings 1990, in Turnpenney and Nedwell 1994), short-term biochemical variations in different tissues typical of primary and secondary stress response (Santulli et al. 1999; Smith et al. 2004; Buscaino et al. 2010), 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 and 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 close enough to the sound source to be directly killed or damaged by sounds from seismic airgun arrays. Popper (2008), however, notes that responses by fish to seismic sounds are species specific and that it is difficult to extrapolate between species with the regard to the effects of intense noise.

When surveying in shallow coastal regions, 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 or in the upper water column 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. If subjected to seismic sounds at close range, such species could suffer pathological injury or severe hearing damage and adverse effects may last for a considerable time after the termination of the sound source. Mortality would occur at very close range only. For the current project, however, the proposed survey area is located in water depths beyond 1000m, and 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 could be expected.

The most likely fish species to be encountered in the survey area are the large pelagic species such as the highly migratory tuna and billfish, which occur offshore of the 100m isobath. These species show seasonal association with Child’s Bank and Tripp Seamount between October and June, with commercial catches often peaking in March and April (www.fao.org/fi/fcp/en/NAM/body.htm; Wilkinson and Japp 2009). As the survey is scheduled to commence in November 2014 and take in the order of 50 days to complete there is thus a high likelihood that the survey vessel would encounter tuna and billfish en route to their seasonal aggregation around the seamount. However, given the high mobility of most large pelagic species, it is assumed that the majority of these could avoid seismic noise at levels below those where physiological injury or mortality could 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 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 and 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 (<5m) only.

For example, increased mortality rates for fish eggs were proven out to ~5m distance from the airguns. A mortality rate of 40-50% was recorded for yolk sac larvae (particularly for turbot) at a distance of 2-3m (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 1m from an airgun array (Matishov 1992), and Booman et al. (1996) report damage to brain.
cells and lateral line organs at \(<2m\) 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 1-2m. 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 contribute to a certain diminished net production in fish populations. However, Sætre and 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 ie at approximately 6 months (Sætre and 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.

**Behavioural avoidance**

Behavioural responses to impulsive sounds are varied and include leaving the area of the noise source (Suzuki et al. 1980; Dalen and Rakness 1985; Dalen and Knutsen 1987; Løkkeborg 1991; Skalski et al. 1992; Løkkeborg and Soldal 1993; Engås et al. 1996; Wardle et al. 2001; Engås and Løkkeborg 2002; Hassel et al. 2004), changes in depth distribution and feeding behaviour (Chapman and 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 5km 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 received noise levels below 160dB re 1\(\mu\)Pa. The ecological significance of such effects is therefore expected to be low, except in cases where they influence reproductive activity (see later).
Reproductive success / spawning

Although the effects of airgun noise on spawning behaviour of fish have not been quantified to date, it is postulated 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. For this reason, Dalen et al. (1996) recommended that in areas with concentrated spawning or narrow spawning migration routes, seismic shooting be avoided at a distance of ~50km from these areas. The magnitude of effect in cases where spawning aggregations are displaced or spawning temporarily ceases will depend on the biology of the species and the extent of the dispersion or deflection.

Although spawning aggregations in the offshore pelagic location of the proposed survey area are unlikely, Tripp Seamount within the Exploration Licence Area may serve as a spawning and nursery ground for various deepwater demersal and neritic species. However, as the proposed seismic operations will located ~50km northwest of the seamount, they are unlikely to affect spawning aggregations around Tripp Seamount, should they occur.

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. Some nearshore tropical reef species are likely to produce isolated sounds or to call in choruses. For the large migratory pelagic species most likely to be encountered in the proposed survey area, impacts arising from masking of sounds are expected to be of negligible magnitude due to the duty cycle of seismic surveys in relation to the more continuous biological noise. Such impacts could occur across the survey area and for the duration of the survey and are consequently considered of MINOR significance both with and without mitigation.

Indirect impacts due to effects on predators or prey

An assessment of potential indirect effects of seismic surveys on fish is limited by the complexity of trophic pathways in the marine environment. 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 predatory fish in association with seismic survey noise is lacking. The impacts would depend on the diet make-up of the predatory species concerned, the effect of seismic surveys on the prey species and any impacts on the behaviour of the predator. Little information is available on the feeding success of large migratory species in association with seismic survey noise.
Impact Assessment

Physiological Injury and Mortality
The potential physiological impact on pelagic fish species, would be of low magnitude. The potential physiological impact on demersal fish species would, however, be insignificant as they would only be affected in the far-field range, if at all. Given the high mobility of most large pelagic and neritic species, these would be capable of avoiding seismic noise at levels below those where physiological injury or mortality would result. The duration of the impact on the population would be limited to the short-term. The impact is therefore considered to be of MINOR significance without the implementation of mitigation measures.

Box 4.4 Impact on Fish: Physiological Injury or Mortality

Nature: Seismic survey activities would result in a negative direct impact on demersal and large migratory pelagic fish in the survey area through injury and mortality

Sensitivity/Vulnerability/Importance of Resource/Receptor: Low

Impact Magnitude: Small

- Extent: The extent of the impact is local and confined to the survey area.
- Duration: The expected impact will be short-term and for the duration of the survey only.
- Scale: The impact would result in negligible changes to demersal and seamount-associated species.
- Frequency: The frequency of the impact will be once-off.

IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR

Behavioural Avoidance
The potential impact of seismic sounds on the behaviour of demersal fish would, be NOT SIGNIFICANT as they would only be affected in the far-field range, if at all, because of the water depths in the proposed survey area and the distance of the seabed from the sound source. In the case of large migratory pelagic fish, however, impacts may be of Low magnitude (particularly in the near-field of the airgun array), over the short to medium term with duration of the effect being equal to the duration of exposure, although these vary between species and individuals, and are dependent on the properties of the received sound. Observed effects may extend beyond the survey area, but are unlikely to persist for more than a few days after termination of airgun use. Consequently it is considered to be of MINOR significance without mitigation.
**Box 4.5 Impact on Fish: Behavioural Avoidance**

**Nature:** Seismic survey activities would result in a negative direct impact on demersal and large migratory pelagic fish in the survey area through behavioural avoidance.

Sensitivity/Vulnerability/Importance of Resource/Receptor: Low (demersal) to Medium (large pelagies)

Impact Magnitude: Negligible (demersal) to Small (large pelagic)

- **Extent:** The extent of the impact could be local to regional, potentially extending beyond the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact may potentially result in negligible changes to pelagic fish behaviour, but negligible changes to demersal and seamount-associated species.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): NEGLIGIBLE (DEMERSAL SPECIES) to MINOR (LARGE PELAGIC SPECIES)**

Reproductive success and spawning

The potential impact of seismic sounds on reproductive success and spawning behaviour in fish could potentially be of high magnitude. However, as the survey will primarily be conducted at depths in excess of 1000m and thus well offshore of the major spawning areas, and ~50km northwest of Tripp Seamount potential impacts on reproductive success and spawning is considered to be of MINOR significance without mitigation. Any indirect effects of mortality to ichthyoplankton (assessed in Section 4.2.1) on recruitment to adult fish populations is also considered to be of NEGLIGIBLE significance without mitigation.

**Box 4.6 Impact on Fish: Reproductive Success**

**Nature:** Seismic survey activities could result in a negative direct impact on the reproductive success and spawning behaviour of fish.

Sensitivity/Vulnerability/Importance of Resource/Receptor: Low

Impact Magnitude: Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes to the reproductive success of fish.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

Masking of Sounds

Impacts arising from masking of sounds are expected to be of low magnitude 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 MINOR significance without mitigation.

Box 4.7 Impact on Fish: Masking of Sounds

**Nature:** Seismic survey activities could result in a negative direct impact on acoustic communication in fish

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes in communication in fish.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

Indirect impacts due to effects on predators or prey

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, the low abundance of pelagic shoaling species that constitute their main prey, and the distance (~50km) of the proposed survey area from Tripp Seamount, the impact is likely to be of MINOR significance both with and without mitigation.

Box 4.8 Impact on Fish: Effects on Predators and Prey

**Nature:** Seismic survey activities could result in a negative indirect impact due to effects on predators and prey.

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes in predators or prey.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

Mitigation

**Mitigation Objectives**

The mitigation measures provided below are intended to reduce the disturbance to fish as a result of the seismic sounds.
Mitigation Measures

- All initiation of airgun firing be carried out as ‘soft-starts’ of at least 20 minutes duration, allowing fish to move out of the survey area and thus avoid potential physiological injury as a result of seismic noise (JNCC 2010; IAGC 2011);

- 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;

Residual Impacts

Even with the implementation of the above mentioned mitigation measures, limited disturbance to fish (particularly large pelagic species) is inevitable although the residual impacts are minor.

<table>
<thead>
<tr>
<th>Table 4.9 Pre- and Post- Mitigation Significance: Impact on Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Physiological injury or mortality</td>
</tr>
<tr>
<td>Behavioural avoidance</td>
</tr>
<tr>
<td>Reproductive success and spawning</td>
</tr>
<tr>
<td>Masking of Sounds</td>
</tr>
<tr>
<td>Effects on predators and prey</td>
</tr>
</tbody>
</table>

4.2.4 Impacts to Seabirds

Among the marine avifauna occurring along the southern Namibian coast, 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.

Potential direct impacts of seismic pulses to diving birds (including penguins) could include physiological injury and behavioural avoidance of seismic survey areas. Indirect impacts may occur due to effects on prey. The potential for physiological injury or behavioural avoidance in non-diving seabird species is considered NOT SIGNIFICANT and will not be discussed further here.

<table>
<thead>
<tr>
<th>Table 4.10 Impact Characteristics: Impacts on Diving Seabirds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Phase</td>
</tr>
<tr>
<td>Project Aspect/ activity</td>
</tr>
<tr>
<td>Impact Type</td>
</tr>
<tr>
<td>Receptors Affected</td>
</tr>
</tbody>
</table>
Impact Description

Physiological Injury and Mortality
The African penguin (Spheniscus demersus), which occurs along the West Coast, is flightless and relies on diving both to feed and travel underwater. The species may thus be susceptible to impacts from underwater seismic noise. In African penguins the best hearing is in the 600Hz to 4kHz range with the upper limit of hearing at 15kHz and the lower limit at 100Hz (Wever et al. 1969). No critical ratios have, however, been measured. Principal energy of vocalisation of African penguins was found at <2kHz, although some energy was measured at up to 6kHz (Wever et al. 1969). The threshold of perception by penguins for the relatively high frequency sounds of seismic shots used in high resolution surveys (100-1 000Hz) will thus be high. While they are only likely to be adversely affected at close ranges, the high intensity of the seismic pulses could be detected underwater at long ranges (McCauley 1994).

The continuous nature of the intermittent seismic survey pulses suggest that diving birds would hear the sound sources underwater at distances where levels would not induce mortality or injury. Plunge-diving seabirds would thus be expected to avoid an approaching sound source at distances well beyond those that could cause physiological injury. Consequently, the potential for injury to diving seabirds from seismic surveys in the open ocean is deemed to be low (see also Stemp 1985, in Turnpenny and Nedwell 1994; Lacroix et al. 2003), particularly given the extensive feeding range of the most plunge-diving seabird species. Should an impact occur, it would be limited to the survey area and survey duration (short term). In the unlikely event of a bird diving in the wake of the seismic array (eg if feeding behaviour overrides a flight response to the perceived underwater sound) and thus receiving the sound source at full power, injury or mortality could be expected.

Of the plunge diving species that occur along the Namibian coastline, only the Cape Gannet regularly feeds as far offshore as 100km, the rest foraging in nearshore areas up to 40km from the coast. The nearest nesting grounds for gannets in Namibia are at Possession Island, ~250km to the north of the survey area, and at Bird Island in Lambert’s Bay, South Africa, over 300km to the southeast of the survey area. African Penguins are known to forage as far as 60km offshore and juveniles have been reported to travel up the coast regularly. The nearest African Penguin nesting sites in Namibia are at Possession Island and ~400km south at the Saldanha Bay Islands in South Africa. As the survey area is located over 250km from the coast, encounters with gannets and penguins are highly unlikely. Pelagic seabirds that dive for their prey may, however, be encountered in the area and also around Tripp seamount, 50km from the survey area, as such features act as mid-ocean focal points for a variety of pelagic species that may migrate large distances in search of food. The potential physiological impact on diving species could thus be of MINOR significance without mitigation.
**Box 4.9 Impact on Seabirds: Physiological Injury and Mortality**

*Nature:* Seismic survey activities would result in a negative direct impact on diving seabirds through injury and mortality.

*Sensitivity/Vulnerability/Importance of Resource/Receptor:* Moderate to High

**Impact Magnitude: Small**

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in notable changes to seabirds only if initiation of a sound source at full power occurred in the immediate vicinity of diving seabirds.
- **Frequency:** The frequency of the impact will be once-off.

*IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR*

**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, if it occurs, would be limited to the zone of noise above the behavioural response threshold of the species. This may extend beyond the survey area but would be limited to the duration of the survey period. The impact is likely to be of medium magnitude. The potential impact on the behaviour of diving seabirds is considered to be of MINOR significance without mitigation.

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**Box 4.10 Impact on Seabirds: Behavioural Avoidance**

*Nature:* Seismic survey activities would result in a negative direct impact on diving seabirds through behavioural avoidance.

*Sensitivity/Vulnerability/Importance of Resource/Receptor:* Moderate to High

**Impact Magnitude: Small**

- **Extent:** The extent of the impact would be local to regional, potentially extending beyond the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes to behavioural responses in diving seabirds.
- **Frequency:** The frequency of the impact will be once-off.

*IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR*

**Indirect impacts due to effects on food source**

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 or around offshore features such as Tripp Seamount and are unlikely to feed extensively in open offshore waters where the seismic survey is undertaken. The broad ranges of potential fish prey species (in relation to potential avoidance patterns of seismic surveys of such prey species) and extensive ranges over which most seabirds feed suggest that indirect impacts would be of MINOR significance without mitigation.

**Box 4.11 Impact on Seabirds: Effects on Food Source**

**Nature:** Seismic survey activities could result in a negative indirect impact due to effects on their food source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Moderate to High

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

**Mitigation**

**Mitigation Objectives**
The mitigation measures provided below are intended to reduce the potential disturbance to diving seabirds as a result of the seismic sounds.

**Mitigation Measures**

- All initiation of airgun firing be carried out as ‘soft-starts’ of for least 20 minutes (JNCC 2010; IAGC 2011);

- An area of radius of 500m be scanned by an independent Marine Mammal Observer (MMO) 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 diving seabirds.

- Seabird incidence and behaviour should be recorded by an onboard MMO;

- Any attraction of predatory seabirds and incidents of feeding behaviour among the hydrophone streamers should be recorded by an onboard MMO.
Residual Impacts

Even with the implementation of the above mentioned mitigation measures, limited disturbance to diving seabirds, should they be encountered, is likely. The residual impacts will, however, be negligible.

### Table 4.11 Pre- and Post- Mitigation Significance: Impact on diving Seabirds

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological injury or mortality</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Behavioural avoidance</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Effects on food source</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Ship strikes and oiling</td>
<td>NOT SIGNIFICANT</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

#### 4.2.5 Impacts to Turtles

The potential effects of seismic surveys on turtles include:

- Physiological injury (including disorientation) or mortality from seismic noise;
- 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 250-700Hz, and some sensitivity to frequencies at least as low as 60Hz (Ridgway *et al.* 1969; Wever *et al.* 1978, in McCauley 1994; O’Hara and 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.

Of the three turtle species potentially occurring off southern Namibia, only the Leatherback is likely to be encountered in the offshore waters of the project area. Encounter rates are, however, expected to be low.

### Table 4.12 Impact Characteristics: Impacts on Turtles

<table>
<thead>
<tr>
<th>Operational Phase</th>
<th>Project Aspect/ activity</th>
<th>Impact Type</th>
<th>Receptors Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sound emissions</td>
<td>Direct and indirect</td>
<td>Turtles</td>
</tr>
</tbody>
</table>
Impact Description

Physiological Injury and 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 (<10m) and may not be sufficiently mobile to move away from approaching towed equipment (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, temporary or permanent hearing impairment, 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. Hatchlings, post-hatchlings and juveniles are not powerful swimmers and largely drift in the currents. They may thus be unable to avoid seismic sounds in the open ocean, and consequently may be more susceptible to seismic noise.

Although collisions between turtles and vessels are not limited to seismic ships, the large amount of equipment towed astern of survey vessels does increase the potential for collision, or entrapment within seismic equipment and towed surface floats. However, most of the seismic array is located at 5-10m below the sea surface, with surface equipment limited to floats designed to keep the airgun array at the desired depth, and floats and tail buoys, which keep the hydrophone streamers at the desired depths. Basking turtles are particularly slow to react to approaching objects and may not be able to move rapidly away from approaching seismic equipment even if motivated to do so. In the past, almost all reported turtle entrapments have been associated with the tail buoy; the large float attached to the end of each hydrophone streamer, which is used to monitor the location of the streamer and maintain its desired depth. The tail buoys have a subsurface structure (‘undercarriage’) consisting of a ‘twin-fin’ design, which is primarily used for counter-balancing the upper structure to ensure stability in the water. 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). It is thought that entrapment occurs either as a result of ‘startle diving’ in front of towed equipment or following foraging on barnacles and other organisms growing on the streamers 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 24, left). Depending on the size of the turtle, they can also become stuck within the gap below a tail buoy, which extends to 0.8m below water level and is ~0.6m 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 24, right*). Once stuck inside or in front of a tail buoy, the water pressure generated by the 4-5kts 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 tail buoys thereby largely eliminating the risk of entrapment (*Figure 25*).

*Figure 24: Before the introduction of turtle guards, turtles frequently became 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).*

*Figure 25: Examples of turtle guards used on tail buoys (Ketos Ecology 2009).*

The potential impact could therefore be of high magnitude, 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 survey is
thus expected to be very low. The potential physiological impact on turtles is thus considered to be of MINOR significance without 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 survey area at the time of the survey. The breeding areas for Leatherback turtles occur over 2 000km to north-west of the survey area (in Republic of Congo and Gabon). Adult Leatherbacks inhabit oceanic waters and outside their breeding areas abundance are low. The likely low encounter rate in the proposed survey area in combination with the standard use of turtle guards on the tail buoys implies that impacts through collision or entanglement would be of low magnitude and short-term. The impacts on turtles through collision or entanglement of seismic equipment is thus considered to be of MINOR significance without mitigation.

Box 4.12 Impact on Turtles: Physiological Injury and Mortality

| Nature: | Seismic survey activities would result in a negative direct impact on turtles through injury and mortality due to the sound source, or through collision and entanglement with towed equipment |
| Sensitivity/Vulnerability/Importance of Resource/Receptor: | High |
| Impact Magnitude: | Small |
| Extent: | The extent of the impact is local and limited to the survey area. |
| Duration: | The expected impact will be short-term and for the duration of the survey only. |
| Scale: | The impact would result in notable changes to turtles only if initiation of a sound source at full power occurred in the immediate vicinity of turtles, or they became trapped in the tailbuoys. |
| Frequency: | The frequency of the impact will be once-off. |

IMPACT SIGNIFICANCE (PRE-MITIGATION): MODERATE

Behavioural avoidance

Behavioural changes in response to anthropogenic sounds have been reported for some sea turtles. Controlled exposure experiments on captive turtles found an increase in swim speed and erratic behaviour indicative of avoidance, at received airgun sound levels of 166-176dB re 1µPa (O’Hara and Wilcox 1990; McCauley et al. 2000). Sounds of frequency of 250 and 500Hz resulted in a startle response from a loggerhead turtle (Lenhardt et al. 1983, in McCauley 1994), and avoidance by 30m of operating airguns where the received level would have been in the order of 175-176dB re 1µPa (O’Hara 1990). McCauley (1994), however, pointed out that these results may have been influenced by echo associated with the shallow environment in which the test was undertaken.

Further trials carried out on caged loggerhead and green turtles include those of Moein et al. (1994) and McCauley et al. (2000), who investigated responses to airgun impulses by measuring avoidance behaviour, physiological response
and electroencephalogram measurements of hearing capability. Results indicated that significant avoidance response occurred at received levels ranging between 172 and 176dB re 1µPa at a distance of 24m from the sound source, 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). McCauley et al. (2000) reported that above levels of 166dB re 1µPa turtles increased their swimming activity compared to periods when airguns were inactive. Above 175dB re 1µPa turtle behaviour became more erratic possibly reflecting an agitated behavioural state at which unrestrained turtles would show avoidance response by fleeing an operating sound source. These noise levels would correspond to distances of 2km (166dB) and 1km (176dB) from a seismic vessel operating in 100-120m of water, respectively.

Observations of marine turtles during a ten-month seismic survey in deep water (1 000-3 000m) off Angola found that turtle sighting rate during guns-off (0.43turtles h⁻¹) was double that of full-array seismic activity (0.20turtles h⁻¹) (Weir 2007). In contrast, Parente et al. (2006), working off Brazil found no significant differences in turtle sightings with airgun state. Weir (2007) notes that while her results are suggestive of avoidance of airguns by turtles, they 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. While there was indication that turtles occurred closer to the source during guns-off than full-array, there was no significant difference in the median distance of turtle sightings from the airguns during full-array or guns-off, suggesting a lack of movement away from active airguns. It is thus 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). Weir (2007), however, points out that a confident assessment of turtle behaviour in relation to seismic status was hindered 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 <10m) to approaching objects, they appeared to be based principally on visual detection.

The impact of seismic sounds on turtle behaviour in the open ocean is of low magnitude, and 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 area, and the extended distance of the nearest breeding grounds from the proposed survey area, the impact of seismic noise on the behavioural avoidance of turtles is deemed to be of MINOR significance without mitigation.
Box 4.13 Impact on Turtles: Behavioural Avoidance

**Nature:** Seismic survey activities would result in a negative direct impact on turtles through behavioural avoidance

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** High

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is **local** and limited to the survey area.
- **Duration:** The expected impact will be **short-term** and for the duration of the survey only.
- **Scale:** The impact would result in **negligible** changes in behavioural responses.
- **Frequency:** The frequency of the impact will be **once-off**.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

Indirect impacts due to effects on food source

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 **MINOR** without mitigation.

Box 4.14 Impact on Turtles: Effects on Food Source

**Nature:** Seismic survey activities could result in a negative indirect impact due to effects on their food source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** High

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is **local** and limited to the survey area.
- **Duration:** The expected impact will be **short-term** and for the duration of the survey only.
- **Scale:** The impact would result in **negligible** changes to turtles due to indirect effects on their prey.
- **Frequency:** The frequency of the impact will be **once-off**.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

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 >3000km north-west of survey area in Republic of Congo and Gabon). 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 (150-500Hz), which overlaps the frequencies of optimal hearing in turtles (McCauley 1994), is unknown and speculative. There is thus a lack of 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 **NOT SIGNIFICANT**.

**Mitigation**

**Mitigation Objectives**
The mitigation measures provided below are intended to reduce the potential for physiological injury, mortality and disturbance to turtles as a result of the seismic sounds and towed gear.

**Mitigation Measures**
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; IAGC 2011);

- Daylight observations of the survey region should be carried out by onboard MMOs and incidence of turtles and their responses to seismic shooting should be recorded;

- The MMO shall monitor the mitigation zone and the area around the survey vessel equipment for the presence of sea turtles during survey operations. The MMO may request that the survey operations be temporarily stopped if it is determined that sea turtles have been harmed or have the risk of being harmed. The MMO shall record and report actions related to sea turtles.

- 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’.

**Residual Impacts**
Even with the implementation of the above mentioned mitigation measures, limited disturbance to turtles is inevitable although the residual impacts are negligible.

<table>
<thead>
<tr>
<th>Table 4.13 Pre- and Post- Mitigation Significance: Impact on Turtles</th>
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<tbody>
<tr>
<td>Aspect</td>
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<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Physiological injury or mortality</td>
</tr>
<tr>
<td>Behavioural avoidance</td>
</tr>
<tr>
<td>Effects on predators and prey</td>
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<tr>
<td>Masking of Sounds</td>
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</tbody>
</table>
4.2.6 Impacts to Seals

The Cape fur seal forages over the continental shelf to depths of over 200m and up to 120 nautical miles (~220km) offshore. As the proposed 3D survey area is located ~200km offshore at its closest point, seal may be expected to encountered, although likely to a limited extent only.

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 100Hz would result in hearing thresholds above which discomfort may occur of approximately 140-150dB re 1µPa for the California sea lion and well above 150dB re 1µPa for the Northern fur seal. The range of greatest sensitivity in fur seals lies between the frequencies of 2-32kHz (McCauley 1994). The audiograms available for otariid pinnipeds suggest they are less sensitive to low frequency sounds (<1kHz) than to higher frequency sounds (>1kHz). The range of low frequency sounds (30-100Hz) 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.

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.

Table 4.14 Impact Characteristics: Impacts on Seals

<table>
<thead>
<tr>
<th>Project Aspect/ activity</th>
<th>Operational Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact Type</td>
<td>Sound emissions</td>
</tr>
<tr>
<td>Receptors Affected</td>
<td>Direct and indirect</td>
</tr>
<tr>
<td>Seals</td>
<td></td>
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</table>

Physiological injury or mortality
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, in McCauley 1994), temporary threshold shifts (TTS) following exposure to octave-band noise (frequencies ranged from 100Hz to 2000Hz, octave-band exposure levels were approximately 60-75dB, while noise-exposure periods lasted a total of 20-22min) (Kastak et al. 1999), with recovery to baseline threshold levels within 24h of noise exposure. Proposed injury criteria for seals exposed to noise events within a 24-h period are provided in Table 4.15.
Table 4.15: 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).

| Functional hearing group | Estimated auditory bandwidth | Marine mammal group | Proposed injury criteria for pulsed sounds -
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<tr>
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</thead>
<tbody>
<tr>
<td><strong>Low frequency cetaceans</strong></td>
<td>7Hz to 22kHz</td>
<td>All baleen whales</td>
<td>a) Sound pressure level b) Sound exposure level.</td>
</tr>
<tr>
<td>Mid frequency cetaceans</td>
<td>150Hz to 160kHz</td>
<td><em>Steno</em>, <em>Sotalia</em>, <em>Tursiops</em>, <em>Stenella</em>, <em>Delphinus</em>, <em>Lagenorhynchus</em>, <em>Lissodelphis</em>, <em>Grampus</em>, <em>Feresa</em>, <em>Pseudorca</em>, <em>Orcinus</em>, <em>Globicephala</em>, <em>Physeter</em>, <em>Ziphius</em>, <em>Berardius</em>, <em>Hyperoodon</em>, <em>Mesoplodon</em></td>
<td>PTS a) 230dB re:1µPa (peak) b) 198dB re: 1µPa² - s</td>
</tr>
<tr>
<td>High frequency cetaceans</td>
<td>200Hz to 180kHz</td>
<td><em>Cephalorhynchus</em>, <em>Kogia</em>, <em>Pinnepeds</em> (in water)</td>
<td>PTS a) 218dB re:1µPa (peak) b) 186dB re: 1µPa² - s</td>
</tr>
<tr>
<td></td>
<td>75Hz to 75kHz</td>
<td><em>Arctocephalus</em></td>
<td>TTS a) 224dB re:1µPa (peak) b) 183dB re: 1µPa² - s</td>
</tr>
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<td></td>
<td></td>
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</table>

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 185-200dB re 1µPa. As seismic sound is above this threshold, the impact of physiological injury to seals from seismic noise is deemed to be low. As seals have a tendency to swim at or near the surface, this will expose them to reduced sound levels when in close proximity to an operating airgun array. This suggests that they are not adversely affected by the seismic noise, as being highly mobile creatures, it is assumed that they would avoid severe sound sources at levels below those at which discomfort occurs. However, Kastak et al. (1999) reported that noise of moderate intensity and duration may be sufficient to induce TTS in pinniped species. 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.

There are two breeding colonies located to the south of the survey area in South Africa, namely at Buchu Twins near Alexander Bay, Robeiland at
Kleinzee. The nearest Namibian breeding sites are at van Reenen Bay and Baker's Bay ~200km and 210km northeast of the northern corner of the proposed survey area. As seals can forage up to 220km offshore, the survey area therefore falls within the foraging range of seals from the nearby colonies. The potential impact of physiological injury to seals as a result of seismic noise is deemed to be of low magnitude and would be limited to the survey area, although the sounds would be audible beyond the survey area. The significance of the impact without mitigation is MINOR.

Box 4.15 Impact on Seals: Physiological Injury and Mortality

**Nature:** Seismic survey activities would result in a negative direct impact on seals through injury and impaired hearing due to the sound source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Low

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible physiological effects on seals.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

**Behavioural avoidance**
Information on the behavioural response of fur seals to seismic exploration noise is lacking (Richardson et al. 1995; Gordon et al. 2004). Reports of studies conducted with Harbour and Grey seals include initial startle reaction to airgun arrays, and range from partial avoidance of the area close to the vessel (within 150m) (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 (ie 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 produce loud noise pulses which are probably more invasive than the slower rise-time seismic sound pulses. Despite an initial startle reaction, individuals quickly reverted back to normal behaviour. 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 1kHz 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.
The potential impact of seal behaviour in response to seismic surveys is thus considered to be of low to medium magnitude and limited to the survey area and duration. The significance of behavioural avoidance impacts are consequently deemed MINOR without mitigation.

**Box 4.16 Impact on Seals: Behavioural Avoidance**

| Nature: Seismic survey activities would result in a negative direct impact on seals through behavioural avoidance |
| Sensitivity/Vulnerability/Importance of Resource/Receptor: Low |
| Impact Magnitude: Small |
| Extent: The extent of the impact is local and confined to the survey area. |
| Duration: The expected impact will be short-term and for the duration of the survey only. |
| Scale: The impact would result in negligible changes to seal behaviour. |
| Frequency: The frequency of the impact will be once-off. |
| IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR |

Masking of environmental sounds and communication
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 150Hz. Aerial calls of seals range up to 6Hz, with the dominant energy in the 2-4kHz band. However, these calls have strong tonal components below 1kHz, suggesting some low frequency hearing capability and therefore some susceptibility to disturbance from the higher frequency components of seismic airgun sources (Goold and Fish 1998; Madsen *et al.* 2006).

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). The impacts of masking are considered MINOR without mitigation.
**Box 4.17 Impact on Seals: Masking of Sounds**

**Nature:** Seismic survey activities could result in a negative direct impact on acoustic communication in seals

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Low

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes to underwater communication in seals.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

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 would be **MINOR** without mitigation.

**Box 4.18 Impact on Seal: Effects on Food Source**

**Nature:** Seismic survey activities could result in a negative indirect impact due to effects on their food source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Low

**Impact Magnitude:** Small

- **Extent:** The extent of the impact is local and confined to the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible changes to seals through indirect effects on their prey.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

**Mitigation**

**Mitigation Objectives**
The mitigation measures provided below are intended to reduce the potential disturbance to seals as a result of the seismic sounds.
Mitigation Measures

- 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; IAGC 2011);

- ‘Soft start’ procedures should, if possible, only commence once it has been confirmed that there is no seal activity within 500m of the airguns. If after a period of 30 minutes seals are still within 500m 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 temporarily halted 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; and

- The MMO's daily report should record general seal activity, numbers and any noticeable change in behaviour.

Residual Impacts

Even with the implementation of the above mentioned mitigation measures, limited disturbance to seals is inevitable although the residual impacts are negligible.

Table 4.16  Pre- and Post- Mitigation Significance: Impact on Seals

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological injury or mortality</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Behavioural avoidance</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Masking of Sounds</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Effects on predators and prey</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

4.2.7  Impacts to Whales and Dolphins

The cetaceans comprise baleen whales (mysticetes) and toothed whales and dolphins (odontocetes), a wide diversity of which occur off the southern Namibian coast. The majority of migratory cetaceans in southern African waters are baleen whales, while toothed whales may be resident or migratory. Reactions of cetaceans to anthropogenic sounds have been reviewed by

Cetacean vocalisations

Cetacean are highly reliant on acoustic channels for orientation in their environment, feeding and social communication (Tyack and Clark 2000). Baleen whales produce a wide repertoire of sounds ranging in frequencies from 12Hz to 8kHz (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 and 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 1-30kHz frequency range but may extend up to 75kHz (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 (150-240Hz) and low frequency modulated tonal calls (990Hz) (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 >100kHz (Richardson et al. 1995). Sperm whales produce broadband echolocation clicks reaching up to 40kHz in frequency (Backus and Schevill, 1966; Madsen et al., 2002). Neonatal sperm whales produce lower frequency sounds at 300-1 700Hz (Madsen et al., 2003). Porpoise, Kogiids and dolphins in the genus Cephalorhynchus (including the Heaviside's dolphin) produce characteristic narrow band, high frequency echolocation clicks with a central frequency around 125kHz (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 10kHz 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 and Smock (1981), Schusterman (1981),

Marine mammals as a group have wide variations in ear anatomy, frequency range and amplitude sensitivity. The hearing threshold is the amplitude necessary for detection of a sound and varies with frequency across the hearing range (Nowacek et al. 2007). Hearing thresholds differ between odontocetes and mysticetes, and between individuals, resulting in different levels of sensitivity to sounds at varying frequencies. For most species, hearing sensitivity corresponds closely to the frequencies at which they vocalise, however it is likely that hearing range is broader than vocalisation range (Bradley and Stern 2008).

Behavioural and electrophysical audiograms are available for several species of small- to medium-sized toothed whales (killer whale: Hall and 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 and Hall 1972; Risso’s dolphin: Nachtigall et al. 1995, 1996, Harbour porpoise: Lucke et al. 2009). In these species, hearing is centred at frequencies between 10 and 100kHz (Richardson et al. 1995; Table 4.15). The high hearing thresholds at low frequency for those species tested implies that the low frequency component of seismic shots (10-300Hz) will not be audible to the small to medium odontocetes at any great distance. Due to the very low hearing thresholds of many toothed whales at frequencies exceeding, the higher frequency of an airgun array shot, which can extend to 15kHz and above (Madsen et al. 2006), may be audible from tens of kilometres away.

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 and Ljungblad 1990). Frankel et al. (1995, in Perry 1998) found humpback whales in the wild to detect sounds ranging from 10Hz to 10kHz at levels of 102-106dB re 1µPa. Blue whales reduce calling in the presence of mid-frequency sonar (1-8kHz) 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 paleontological 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 and Leatherwood 1981; Table 4). The available information demonstrates that the 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).
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.

As odontocetes and mysticetes have different levels of sensitivity to sounds at varying frequencies, and display different vocalisation abilities, the two groups will be assessed separately below.

Table 4.17 Impact Characteristics: Impacts on Cetaceans

<table>
<thead>
<tr>
<th>Operational Phase</th>
<th>Project Aspect/activity</th>
<th>Impact Type</th>
<th>Receptors Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sound emissions</td>
<td>Direct and indirect</td>
<td>Whales and Dolphins</td>
</tr>
</tbody>
</table>

Physiological injury and stress
Exposure to high sound levels can result in physiological injury to cetaceans through a number of avenues, including shifts of hearing thresholds (as either 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 and Mao 1996; Cox et al. 2006), and non-auditory physiological effects including elevated blood pressures, increased heart and respiration rates, and temporary increases in blood catecholamines and glucocorticoids (Bowles and 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 and Lopez-Jurado 1991; Crum and Mao 1996; Frantzis 1998; Balcomb and Claridge 2001; Evans and England 2001; Jepson et al. 2003; Cox et al. 2006; MacLeod and D’Amico 2006), and the results are thus not directly applicable to non-explosive seismic sources such as those from airgun arrays. Nonetheless, mid-frequency naval sonar has been linked to strandings in the Bahamas, Greece, Madeira and the Canary Islands, while a seismic survey for hydrocarbons (also running a multi-beam echo-sounder and sub bottom profiler) was linked to a stranding of two Cuvier’s beaked whales in the Gulf of California (Cox et al. 2006). Necropsy of several of these stranded animals has revealed gas embolisms and haemorrhage in the brain, ears and acoustic fat - injuries consistent with decompression sickness (although acoustically mediated bubble formation may also play a role) (Fernandez et al. 2005). These findings suggest that changes in diving behaviour in response to sound plays a major role.

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 230dB re 1µPa (peak) and 198 re 1µPa2-s for SPL and SEL respectively for low, medium and high frequency cetaceans (Table 4.15). For TTS these values are 224dB re 1µPa (peak) and 183dB re 1µPa2-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 183dB re:1µPa2-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 kilometres. 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 (over distances of kilometres), but that hearing damage from seismic shots is only likely to occur at close range (over distances of metres). A controlled study of the response of beaked whales to a variety of sounds including mid-frequency sonar, killer whale calls and pseudo-random noise confirmed animals to respond to sounds by a) changing their dive behaviour by ending dives early and surfacing more slowly than normal and b) avoiding the affected area and moving at least 16km away from the sound (Tyack et al. 2011).

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 both the level of stress experienced by the animal due to noise exposure as well as the impact resulting from the stress (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).

Typical sound source levels for this seismic survey are 220 dB re 1 µPa 2m, which exceed the sources levels required for hearing damage (PTS and TTS) (see Table 4.15). The vocalisation and estimated hearing range of baleen whales (centred at below 1kHz) 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) than odontocetes, in which the hearing is centred at frequencies of between 10kHz and 100kHz.

Available information suggests that baleen whales 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.

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 magnitude, but would be limited to the immediate vicinity of operating airguns within the impact zone. The proposed survey is scheduled to commence in November 2014 and continue for 50 days. It is thus planned outside of peak humpback and southern right whale migration periods, but resident whales and those making exploratory trips northwards from summer feeding grounds may be still be encountered. The impact is therefore considered to be of MODERATE significance without mitigation for resident odontocetes and mysticetes.

Box 4.19 Impact on Mysticetes: Physiological Injury and Mortality

| Nature: Seismic survey activities could result in a negative direct impact on mysticetes through injury and impaired hearing due to the sound source |
| Sensitivity/Vulnerability/Importance of Resource/Receptor: Moderate to High (species specific) |
| Impact Magnitude: Medium |
| • Extent: The extent of the impact is regional, extending beyond the survey area. |
| • Duration: The expected impact will be short-term and for the duration of the survey only. |
| • Scale: The impact could result in notable physiological changes. |
| • Frequency: The frequency of the impact will be once-off. |

IMPACT SIGNIFICANCE (PRE-MITIGATION): MODERATE
Impact on Odontocetes: Physiological Injury and Mortality

**Nature:** Seismic survey activities would result in a negative direct impact on odontocetes through injury and impaired hearing due to the sound source.

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Moderate to High (species specific)

**Impact Magnitude:** Medium

- **Extent:** The extent of the impact is *regional*, extending beyond the survey area.
- **Duration:** The expected impact will be *short-term* and for the duration of the survey only.
- **Scale:** The impact would result in *notable* physiological changes.
- **Frequency:** The frequency of the impact will be *once-off*.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MODERATE**

**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 and 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 1-13km from the seismic source does not necessarily lessen (attenuate) with increasing range. In some cases this can lead to received levels at 12km being as high as those at 2km (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. 1985, 1986;
Malme et al. 1983, 1985, 1986), slowing of travel (Malme et al. 1983, 1984), and changes in vocalisations (McDonald et al. 1993, 1995) and call rate (Di Lorio and 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 110dB, and more than 80% of species observed show avoidance to sounds of 130dB re 1µPa. For seismic noise, most whales begin showing avoidance behaviour at distances where levels of approximately 150-180dB re 1µPa are received (Malme et al. 1983, 1984; Ljungblad et al. 1988; Pidcock et al. 2003). Behavioural responses are often evident beyond 5km 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 24km distance.

In an analysis of marine mammals sightings recorded from seismic survey vessels in United Kingdom waters, Stone (2003) reported that responses to large gun seismic activity varied between species, with small odontocetes showing the strongest avoidance response. Responses of medium and large odontocetes (killer whales, pilot whales and sperm whales) were less marked, with sperm whales showing no observable avoidance effects (see also Rankin and 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 or riding the bow-waves of operating seismic vessels (Duncan 1985; Evans and 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 7-12km 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.

The survey location overlaps with the migration route of humpback whales and other baleen whale species, and behavioural avoidance of seismic noise in the proposed survey area by baleen whales is highly likely. Such avoidance is, however, generally considered of minimal impact in relation to the distances of migrations of the majority of baleen whale species. If the survey is scheduled to be undertaken outside of the main winter migration periods (June - November), interactions with migrating whales should be low.

Of greater concern than general avoidance of migrating whales is avoidance of critical breeding habitat or area where mating, calving or nursing occurs. Southern right whales mostly remain in the coastal area south of Lambert's Bay in South Africa, but are seen regularly along the northern Namqualand coast and in southern Namibia, and are increasingly expanding their range as the population grows. The proposed survey area is located well offshore of the nearshore West Coast regions typically utilised by southern right whales as a mating, calving, or nursery grounds, and interactions are thus unlikely. Similarly, the proposed survey area is located well to the north of the West Coast feeding ground around Cape Columbine, where local abundances of temporary resident humpbacks and southern rights whales occur during summer months, and interaction with summer feeding aggregations is thus unlikely. There is, however, potential overlap with the southward migration of both humpback and southern right whales. Humpbacks either follow the Walvis Ridge offshore before heading directly to high latitude feeding grounds, or follow a more coastal route. Southern Right whales occur in Namibian waters throughout the year, but with numbers peaking in winter (June - August) and again in summer (November - January), the latter representing animals performing exploratory trips into southern Namibia from summer feeding grounds off Cape Columbine. Although encounter rates would peak during migration periods, it must be kept in mind that humpbacks, southern rights and other baleen whales are found year round in southern African West Coast waters.

The potential impact of behavioural avoidance of seismic survey areas by mysticete cetaceans is considered to be of medium magnitude, across the survey area and for the duration of the survey. As the proposed survey is scheduled to commence in November 2014, it overlaps with the end of the southern migration period for humpback and southern right whales. Resident whales and those making exploratory trips northwards from summer feeding grounds may also be encountered. The impact of seismic surveying is thus considered of MODERATE to HIGH 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.

Information available on behavioural responses of toothed whales and dolphins to seismic surveys is more limited than that for baleen whales. No seasonal patterns of abundance are known for odontocetes occupying the proposed study area but several species are considered to be year round residents. A number of toothed whale species have a more pelagic offshore distribution, with species diversity and encounter rates likely to be highest on the shelf slope and in the vicinity of Tripp Seamount. A precautionary approach to avoiding impacts is thus recommended, and consequently the impact of seismic survey noise on the behaviour of toothed whales will depend on the species involved and is considered to be of small to medium magnitude over the survey area and duration. The overall significance will therefore vary between species, and consequently ranges between MINOR and NEGLIGIBLE before mitigation.

Box 4.21 Impact on Mysticetes: Behavioural Disturbance

**Nature:** Seismic survey activities would result in a negative direct impact on mysticetes through behavioural disturbance in response to the sound source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Moderate to High (species specific)

**Impact Magnitude:** Medium

- **Extent:** The extent of the impact is regional, extending beyond the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact could result in notable behavioural changes.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MODERATE**

Box 4.22 Impact on Odontocetes: Behavioural Disturbance

**Nature:** Seismic survey activities would result in a negative direct impact on odontocetes through behavioural disturbance in response to the sound source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Moderate to High (species specific)

**Impact Magnitude:** Small to Medium (species specific)

- **Extent:** The extent of the impact is regional, extending beyond the survey area.
- **Duration:** The expected impact will be short-term and for the duration of the survey only.
- **Scale:** The impact would result in negligible or notable changes depending on the species.
- **Frequency:** The frequency of the impact will be once-off.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**
Masking of important environmental or biological sounds

Potential interference of seismic emissions with acoustic communication in cetaceans includes direct masking of the communication signal, temporary or permanent reduction in the hearing capability of the animal through exposure to high sound levels or limited communication due to behavioural changes in response to the seismic sound source. Masking can both reduce the range over which the signals can be heard and the quality of the signal's information (Weilgart et al. 2007). Baleen whales generally appear to vocalise almost exclusively within the frequency range of the maximum energy of seismic sounds, i.e. under 1kHz. Whales may respond to masking by calling more frequently, calling louder, calling less frequently (Weilgart et al. 2007) or showing no change in calling behaviour (Madsen et al. 2002). For example, a recent study shows that blue whales called consistently more on days when seismic exploration was taking place, presumably to compensate for the elevated ambient noise levels (Di Lorio et al. 2010). The masking effect of seismic pulses might be reduced by their intermittent production. However, the length of seismic pulses increases with distance from the source, thereby increasing the potential to cause masking at range (Gordon et al. 2004).

Toothed whales vocalise at much higher frequencies, and it is likely that clicks are not masked by seismic survey noise (Goold and 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 22kHz) and travelling up to at least 8km (Goold and Fish 1998). Masking of communication sounds produced by whistling dolphins and blackfish is thus likely (Madsen et al. 2006).

In the migratory baleen whale species, vocalisation increases once they reach the breeding grounds and on the return journey in November-December when accompanied by calves. The offshore location of the survey area, however, suggests that vocalisation is likely to relatively low. Additionally, the effect of masking may be reduced by the intermittent nature of seismic pulses (Gordon et al. 2003). Consequently, the magnitude of impacts on baleen whales is likely to be low over the survey area and duration, but high in the case of toothed whales. Whereas for mysticetes the significance is rated as MINOR without mitigation, for odontocetes it is rated as MODERATE without mitigation.
Box 4.23  Impact on Mysticetes: Masking of Sounds and Communication

**Nature:** Seismic survey activities would result in a negative direct impact on mysticetes through masking of sounds due to the sound source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Moderate to High (species specific)

**Impact Magnitude:** Small (due to offshore location of survey area)

- **Extent:** The extent of the impact is **regional**, extending beyond the survey area.
- **Duration:** The expected impact will be **short-term** and for the duration of the survey only.
- **Scale:** The impact could result in **negligible** changes in communication.
- **Frequency:** The frequency of the impact will be **once-off**.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

Box 4.24  Impact on Odontocetes: Masking of Sounds and Communication

**Nature:** Seismic survey activities would result in a negative direct impact on odontocetes through masking of sounds due to the sound source

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Moderate to High (species specific)

**Impact Magnitude:** Small to Medium (species specific)

- **Extent:** The extent of the impact is **regional**, extending beyond the survey area.
- **Duration:** The expected impact will be **short-term** and for the duration of the survey only.
- **Scale:** The impact would result in **notable** changes in communication.
- **Frequency:** The frequency of the impact will be **once-off**.

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MODERATE**

**Indirect effects on prey species**

Exposure to seismic airguns can cause hearing damage to fish (reviewed in Popper and 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, so the significance of indirect effects on their food source is **NOT SIGNIFICANT**.

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 by seismic surveys, but impacts will be highly localised and small in relation to the feeding ranges of cetacean species. Cumulative impacts within species ranges must, however, be considered. 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 **MINOR** significance without mitigation.
Mitigation

Mitigation Objectives
The mitigation measures provided below are intended to reduce the potential disturbance to cetaceans as a result of the seismic sounds.

Mitigation Measures
• Seismic surveys should take account of the key migration periods or winter breeding concentrations (particularly baleen whales, beginning of June to end of November) and ensure that migration paths are not blocked. When surveying in December, be on the lookout for humpback whales, which may still be moving through the area on their return migrations, and Southern Right whales, which may be undertaking exploratory trips from summer feeding grounds off Cape Columbine;

• During line changes and at night, low level warning airgun discharges should be fired at regular intervals in order to keep cetaceans and other marine animals away from the survey operation while the vessel is repositioned for the next survey line. If interactions are not likely, it may
be better to halt firing for the turning period and thus reduce the overall noise. This will be done at the discretion of the MMO;

- “Soft starts” should only commence once it has been confirmed (visually and using PAM technology) that there are no cetaceans within 500m of the airguns. There should be a dedicated pre-shoot watch of 60 minutes to account for deep-diving species. “Soft starts” should be delayed until such time as this area is clear of individuals of diving seabirds, turtles and cetaceans, and should not begin until 30 minutes after the animals depart the exclusion zone or 30 minutes after they are last seen. If, during the soft-start, cetacean activity is sighted within 500m of the vessel, air-gun firing should be stopped or postponed. In the case of small odontocetes, which may occur commonly around the vessel, their presence (including number and position / distance from the vessel) and behaviour should be recorded prior to “soft start” procedures. If after a period of 30 minutes they are still within 500m of the airguns, the normal “soft start” procedure should be allowed to commence for at least a 20-minute duration (JNCC 2010), during which time their activity must be carefully monitored to determine if they display any obvious negative responses to the airguns and gear or if there are any signs of injury or mortality as a direct result of the seismic activities;

- 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;

- An independent onboard MMO and PAM operator must be appointed for the duration of the seismic survey. The MMO should have experience in seabird, turtle and marine mammal identification and observation techniques. The duties of the MMOs would be to:
  - Record initiation of seismic firing activity and associated “soft starts”, airgun activities and seismic noise levels;
  - 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 notable 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 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 temporary termination of the seismic survey or adjusting of seismic shooting, as appropriate. 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.

• 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;

• Seismic shooting should be temporarily terminated on observation of any obvious mortality or injuries to cetaceans, turtles, diving seabirds or large mortalities of invertebrate and fish species as a direct result of the survey. Such mortalities would be of particular concern where a) commercially important species are involved, or b) mortality events attract higher order predator and scavenger species into the seismic area during the survey, thus subjecting them to acoustic impulses. Seismic shooting should also be terminated when obvious changes to turtle or cetacean behaviours are observed from the survey vessel, or turtles and cetaceans are observed within 500m of operating airguns and appear to be approaching firing airgun3. 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), or that animals have become trapped within the ensonified area through diving behaviour;

• All survey vessels must be fitted with PAM technology, which detects animals through their vocalisations. 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; and

• Marine mammal incidence data and seismic source output data arising from surveys should be made available on request to the Namibian Ministry of Fisheries and Marine Resources, Namibian Ministry of Mines and Energy, NAMCOR and the Namibian Dolphin Project (University of Pretoria, to feed into studies of cetacean distribution and timing in Namibia.

Residual Impacts

Even with the implementation of the above mentioned mitigation measures, disturbance to mysticetes and odontocetes is inevitable, the magnitude
depending on the species encountered. There is growing concern that the increase in frequency of seismic surveys being undertaken along the southern African coast over the past few years may result in some residual impacts in cetaceans, but these are difficult to quantify and likely to be low, if at all.

**Table 4.18**  
*Pre- and Post- Mitigation Significance: Impact on Mysticetes*

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
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<tbody>
<tr>
<td>Physiological injury or mortality</td>
<td>MODERATE</td>
<td>MINOR</td>
</tr>
<tr>
<td>Behavioural disturbance</td>
<td>MODERATE</td>
<td>MINOR</td>
</tr>
<tr>
<td>Masking of Sounds</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Effects on prey</td>
<td>NEGLIGIBLE</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

**Table 4.19**  
*Pre- and Post- Mitigation Significance: Impact on Odontocetes*

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological injury or mortality</td>
<td>MODERATE</td>
<td>MINOR</td>
</tr>
<tr>
<td>Behavioural disturbance</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
<tr>
<td>Masking of Sounds</td>
<td>MODERATE</td>
<td>MINOR</td>
</tr>
<tr>
<td>Effects on prey</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>

**4.2.7 Impacts from Unplanned Events**

*Impact Description*

Other potential adverse interactions between marine fauna and seismic surveys include:
- Stranding of pelagic seabirds on the survey vessel due to being attracted to the vessel lights at night;
- Oiling of marine fauna through accidental loss of buoyancy liquid from the towed gear;
- Operational diesel spills from the survey vessel or chase boats;
- Ship strikes and entanglement of turtles and/or cetaceans in the towed equipment.

**Table 4.20**  
*Impact Characteristics: Impacts on Biodiversity through Unplanned Events*

<table>
<thead>
<tr>
<th>Operational Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Aspect/ activity</td>
</tr>
<tr>
<td>Impact Type</td>
</tr>
<tr>
<td>Receptors Affected</td>
</tr>
<tr>
<td>Operational spills and entanglement</td>
</tr>
<tr>
<td>Seabirds, turtles, whales and dolphins</td>
</tr>
</tbody>
</table>
Impact Assessment

Stranding and oiling of seabirds
While there is some potential for effects on individual seabirds through strandings these occur rarely and typically do not result in mortality. The use of solid, foam- or gel-filled streamers will negate any potential oiling effects from buoyancy/hydraulic liquids. No significant effects on seabird populations through stranding are thus predicted, as the number of animals potentially affected will be small. The impacts are thus assessed as being NOT SIGNIFICANT.

Operational Spills
Operational spills may arise from bunkering of fuel oil (offshore or in port), or the storage and handling of oil drums onboard the vessels. Any release of liquid hydrocarbons has the potential for direct, indirect and cumulative effects on the marine environment. These effects include physical oiling and toxicity impacts to marine fauna and flora, localised mortality of plankton (particularly copepods), pelagic eggs and fish larvae, and or contamination (CSIR 1998; Perry 2005). Oils with a volatile nature, low specific gravity and low viscosity (e.g. diesel) are less persistent and tend to disappear rapidly from the sea surface through evaporation of lighter fuel oil fractions. Despite the likely low volumes spilled and evaporation potential, the environmental consequences of a nearshore spill are potentially significant, although the severity will depend on where the spill takes place. If a spill occurs in port while bunkering/loading the impact would most likely be easily managed and the risk / impact would be low. If the spill occurs offshore, it may be more difficult to contain and would more readily disperse, but would be unlikely to reach the shore due to the offshore location of the survey area.

In the unlikely event of an operational spill from either the survey vessel or chase vessels, the potential impact on the marine environment would be of low magnitude but would likely only persist over the short-term. Results of the oil spill modelling study conducted for proposed drilling operations in Shell’s South African Orange Basin Deepwater Block (PRDW 2013) indicated that an offshore spill would spread in a north-westerly direction and will not reach the shore. Areas experiencing a >30% probability of oiling would extend ~20 km from the source of the spill within 8 hrs. Unless contained and managed within a port, a nearshore spill is likely to reach the shore though wave action and tidal currents. The significance of the impact of an operational spill in the survey area or near the coast is dependent on the biota likely to be affected. In most cases the impacts can be considered of MINOR significance both before and after mitigation, with the exception of seabirds, where the impact is considered to be of MODERATE significance before mitigation, and of MINOR significance with mitigation.
Box 4.27  Impact on Biodiversity: Operational Diesel Spills

**Nature:** Operational spills from the survey vessel or chase vessels could result in negative direct impacts on pelagic seabirds, turtles, seals and cetaceans through oiling.

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Low to Medium

**Impact Magnitude:** Low to Moderate

- **Extent:** The extent of the impact would be *regional* as spills could be transported beyond the survey area boundaries.
- **Duration:** The expected impact will be *short-term* as diesel evaporates rapidly.
- **Scale:** The impact could result in *notable* changes to seabirds, but negligible changes to turtles, seals and cetaceans.
- **Frequency:** The frequency of the impact would be *once-off*.
- **Likelihood:** Unlikely

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR to MODERATE**

**Mitigation**

**Mitigation Objectives**
The mitigation measures provided below are intended to reduce the potential impacts to biodiversity as a result of operational spills.

**Mitigation Measures**
The following mitigation measures are recommended for operational spills:

- Ensure that adequate oil spill contingency plans are in place at all times to ensure that spills can be effectively handled.
- For small operational spills near the shore, as far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill.
- For small operational spills offshore, no mitigatory action would be necessary, unless large numbers of pelagic seabirds are present, in which case consideration should be given to spraying the spill with dispersants, if sea conditions permit and permission has been obtained from DEA.

**Table 4.21  Pre- and Post- Mitigation Significance: Operational Spills**

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effects of operational spills on marine fauna</td>
<td>MODERATE</td>
<td>MINOR</td>
</tr>
</tbody>
</table>

**Ship Strikes and Entanglement**

Given the slow speed (about 4-6kts) of the survey vessel while towing the seismic array, ship strikes are unlikely. Ship strikes by the chase vessels could however occur. In situations where tension is lost on the towed array, entanglement of cetaceans in gear is possible.
Ship strikes and entanglement of cetaceans in towed equipment could lead to injury, or in the worse-case scenario to death of the affected animal. In the unlikely event of a strike or entanglement the potential impact on the affected animal would be of high magnitude, but the effect on the population as a whole would be negligible. The risk would persist only over the short-term and for the duration of the survey. The impacts are thus assessed as being MINOR.

**Box 4.28 Impact on Cetaceans: Ship Strikes and Entanglement in Towed Equipment**

**Nature:** The survey vessel or chase vessels could accidentally collide with a cetacean, or a cetacean may become entangled when tension is lost in the towed equipment.

**Sensitivity/Vulnerability/Importance of Resource/Receptor:** Medium to High

**Impact Magnitude:** High (individual), Low (population as a whole)

- **Extent:** The extent of the impact would be local and limited to the survey area.
- **Duration:** The risk of the impact occurring will be short-term.
- **Scale:** The impact could result in notable changes to cetaceans through injury or death.
- **Frequency:** The frequency of the impact would be once-off.
- **Likelihood:** Unlikely

**IMPACT SIGNIFICANCE (PRE-MITIGATION): MINOR**

**Mitigation**

**Mitigation Objectives**
The mitigation measures provided below are intended to reduce the risks to cetaceans of ship strikes or entanglement.

**Mitigation Measures**
- The vessel operators should keep a constant watch for marine mammals in the path of the vessel.
- Keep watch for marine mammals behind the vessel when tension is lost on the towed equipment and either retrieve or regain tension on towed gear as rapidly as possible.

**Table 4.22 Pre- and Post-Mitigation Significance: Ship Strikes and Entanglement in Towed Equipment**

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Significance (Pre-mitigation)</th>
<th>Residual Impact Significance (Post-mitigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury or mortality of cetaceans</td>
<td>MINOR</td>
<td>NEGLIGIBLE</td>
</tr>
</tbody>
</table>
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 and 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.

- Seismic surveys should where practicable take account of cetacean migration periods or winter breeding concentrations (June to end November), and ensure that migration paths are not blocked;

- All survey vessels must be fitted with PAM technology to be used 24-h a day, which detects animals through their vocalisations. This will not only improve detection of deep-diving species such as sperm whales, likely to be encountered at the proposed survey depths, but will ensure early detection of mysticetes on their southward return migrations. As a minimum, PAM technology must be used during the 60-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.

- Independent onboard MMOs and PAM operators must be appointed for the duration of the seismic survey to ensure 24-h coverage. 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 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 and weekly monitoring reports and submit to authorities as required;

- 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 500m 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. PAM Operators need to specify in writing to Shell and the main geophysical contractor, prior to survey mobilisation, under what conditions they would make such a request and what specific criteria they would apply.

- 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 30 minutes for cetaceans. ‘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 30 minutes after the animals depart the 500m exclusion zone or 60 minutes after they are last seen. In the case of fur seals, which may occur commonly around the vessel, the presence of seals (including number and position / distance from the vessel) and their behaviour should be recorded prior to ‘soft start’ procedures. However, if after a period of 30 minutes seals are still within 500m of the airguns, the normal ‘soft start’ procedure should be allowed to commence for at least a 20-minute duration (JNCC 2010). Their activity should be carefully monitored during ‘soft starts’ to determine if they display any obvious negative responses to the airguns and gear or if there are any signs of injury or mortality as a direct result of the seismic activities;

- All breaks in airgun firing of longer than 20 minutes must be followed by the 30-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 500m mitigation zone (not a 30 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 temporarily terminated when obvious 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 500m) of operating airguns and appear to be approaching firing airgun. The rationale for this is that animals at close distances (ie 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 temporarily terminated until such time the MMO confirms that:
  
  - Turtles or cetaceans have moved to a point that is more than 500m from the source;
  
  - Despite continuous observation, 60 minutes has elapsed since the last sighting of the turtles or cetaceans within 500m 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;

- 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 Namibian Ministry of Fisheries and Marine Resources, Namibian Ministry of Mines and Energy, NAMCOR and the Namibian Dolphin Project (University of Pretoria, to feed into studies of cetacean distribution and timing in Namibia;
ASSUMPTIONS AND LIMITATIONS

This marine faunal assessment was conducted as a desk-top study based on existing measurements and data, and no new data were collected or measurements made. In undertaking the assessment, it was assumed that all data and information provided by project proponents were valid and true.

Due to limited opportunities for sampling, information on the pelagic communities of the continental slope and Tripp Seamount are poorly known. All information provided is based on at least some level of projection of information from studies elsewhere in the region, at some time in the past (often decade ago) or extrapolated from knowledge of habitat choice of the species.

When discussing the potential effects of seismic surveys on marine fauna we should thus bear in mind the uncertainty surrounding the auditory capabilities and thresholds of impacts on the different species encountered and the individual variability in hearing thresholds and behavioural responses which are likely to influence the degree of impact (Luke et al. 2009; Gedamke et al. 2011). This uncertainty and variability can have a large impact on how risk to marine mammals is assessed. Furthermore, as sound propagation modelling has not taken place in the survey area, exact definitions of the impact zone are not possible, and seismic sounds generated in the Exploration Area may thus be audible, and have effects far beyond the boundary of the project area.

Assessing the impact of seismic activity on populations in the PEL39 area is further hampered by a poor understanding of the abundance and distribution of species found there. The offshore areas have been very poorly studied and there are no current data on the presence and density of large pelagic fish, turtles and cetaceans within the planned survey area. Information on the distribution and migration routes of large pelagic fish and turtles is based on limited data from tagging studies, and almost all available information on the seasonality and distribution of large whales beyond the shelf comes from historic whaling records mostly dating from the 1960s. Changes in the timing and distribution of migration may have occurred since these data were collected due to extirpation of populations or behaviours. The large whale species for which there are current data available are the humpback and southern right whale, although almost all data is limited to that collected on the continental shelf close to shore. Information on smaller cetaceans in deeper waters is particularly poor.
CONCLUSIONS

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. Consequently, suitable mitigation measures must be implemented during seismic data acquisition to ensure the least possible disturbance of marine fauna in an environment where the cumulative impact of increased background anthropogenic noise levels has been recognised as an ongoing and widespread issue of concern (Koper & Plön 2012).

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.
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