Annex D

Specialist Studies

Annex D1

Marine Ecology

1.1. Marine Ecology Study

A marine ecology study to determine the potential impacts of the drilling on the marine ecology of the area was conducted by Pisces Environmental Services (Pty) Ltd.

1.2. Contact details of Pisces Environmental Services.

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR A PROPOSED EXPLORATION DRILLING CAMPAIGN WITHIN BLOCK ER236 OFF THE EAST COAST OF SOUTH AFRICA

MARINE AND COASTAL ECOLOGY ASSESSMENT

Prepared by

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Prepared for the Environmental Assessment Practitioner:

ERM

On behalf of the Applicant:

Eni South Africa BV

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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 ERM Southern Africa (Pty) Ltd on behalf of Eni South Africa B.V. for their use in preparing an Environmental Impact Assessment (EIA) process for the proposed exploration drilling programme in Block ER236 off the east coast of South Africa. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and ERM.

Andrea Pulfrich

Dr Andrea Pulfrich

ACRONYMS, ABBREVIATIONS AND UNITS

ALARP	as low as reasonably practicable
BOP	Blow out preventer
CAPP	Canadian Association of Petroleum Producers
CBD	Convention of Biological Diversity
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
DAH	dissolved aromatic hydrocarbons
dB	decibel
DEAT	Department of Environment Affairs and Tourism
DSP	Dynamic Positioning System
DWAF	Department of Water Affairs and Forestry
E	east
EBSA	Ecologically or Biologically Significant Area
EEZ	Exclusive Economic Zone
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EMBF	Enhanced Mineral-oil Based Fluid
EMP	Environmental Management Programme
EMPr	Environmental Management Programme report
EPA	Environmental Protection Agency
ER	Exploration Right
ft	feet
GSLWP	Greater St Lucia Wetland Park
h	hour
H_2S	hydrogen sulphide
Hz	Herz
IBA	Important Bird Area
IFC	International Finance Corporation
IMO	International Maritime Organisation
IOGP	International Association of Oil and Gas Producers
IOPP	International Oil Pollution Prevention
ITOPF	International Tanker Owners Pollution Federation Limited
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kiloHerz
km	kilometre
km^2	square kilometre
KZN	KwaZulu-Natal
LC_{50}	median lethal concentration
LTMBF	Low Toxicity Mineral Oil Based Fluids
MPA	Marine Protected Area

m	metres
m^2	square metres
m^3	cubic metre
mm	millimetres
m/s	metres per second
mg/l	milligrams per litre
mg/kg	milligrams per kilogram
MMO	Marine Mammal Observer
N	north
NADF	Non-aqueous drilling fluid
NW	north-west
NRC	National Research Council (Canada)
OBMs	Oil-based muds
OSPAR	The Oslo and Paris Convention for the Protection of the marine Environment of the North-East Atlantic
PAH	polycyclic aromatic hydrocarbon
PAM	Passive Acoustic Monitoring
ppb	parts per billion
ppm	parts per million
PSV	Platform Supply Vessel
ROV(s)	Remotely Operated Vehicle(s)
S	south
SA	South Africa
SANBI	South African National Biodiversity Institute
SBMs	Synthetic-based muds
SCUBA	Self-Contained Underwater Breathing Apparatus
SW	south-west
SWIO	Southwest Indian Ocean
TSS	Total Suspended Solids
UNEP-WCMC	United Nations Environment Programme – World Conservation Monitoring Centre
USDOI/FWS	United States Department of Interior/Fish and Wildlife Service
U.S.	United States (of America)
VMEs	Vulnerable Marine Ecosystems
VOS	Voluntary Observing Ships
VSP	Vertical Seismic Profiling
WBMs	Water-based muds
µg	micrograms
µg/l	micrograms per litre
µPa	micro Pascal
°	degrees
°C	degrees Centigrade
%	percent
~	approximately
<	less than
>	greater than

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1. GENERAL INTRODUCTION

Eni South Africa BV (Eni), and Sasol Limited hold an Exploration Right 12/3/236 (ER236) offshore of the KwaZulu-Natal coast, between St Lucia and Port Shepstone. Eni and Sasol intend to conduct an exploration drilling programme in Block ER236 to further assess the commercial viability of the resource to ascertain whether oil extraction will be feasible. Eni is considering to drill up to six deep-water wells within Block ER236. Four of the wells would be located within a 1,717.5 km^2 area of interest in the north of the Block, in water depths ranging between 1,500 m and 2,100 m inside Block ER236. A further two wells are considered within the 2,905 km^2 southern area of interest, in water depth ranging between 2,600 m and 3,000 m. (see Figure 1).

The specific number of wells and their locations would be based on a number of factors, including further analysis of the seismic data, the geological target, the presence of any seafloor obstacles and the success of first well/s.

The drilling of the first exploration well is planned to take place in late 2019 to early 2020. The expected drilling depth would be approximately 3,800 m and 4,100 m from the sea surface, through the seabed, to target depth in the northern area, while at around 5,100 m in the southern one. The drilling of one well is expected to take in the order of two months to complete. The drilling of the northern and the southern areas of interest will be undertaken as two separate campaigns, commencing either in northern or southern area of interest.

Depending on the success of the first well within the northern area of interest, up to three additional wells comprising an additional exploration well at a second location and the possibility of one appraisal well close to each exploration well location, may be drilled to establish the quantity and potential flow rate of any hydrocarbon present. The time sequence of these possible additional wells will be dependent on the results of the first exploration well, and will not occur immediately after the drilling of the initial well. Within the southern area of interest one potential exploration well will be drilled and a possible appraisal well depending on the results of the first well. Well testing may be conducted on the appraisal wells if they present potential commercial quantities of hydrocarbon.

The drilling of the wells will be undertaken by a deep-water drillship held in position by dynamic positioning thrusters. While the drillship is drilling, a temporary 500 m operational safety zone would be imposed around the unit. The drillship would be supported / serviced by at least three vessels, which would facilitate equipment, material and waste transfer between the drillship and onshore logistics base. The supply vessels would call into port regularly during the drilling campaign.

An onshore logistics base would be located in either Richards Bay or Durban. Eni's preferred alternative is Richards Bay due to its proximity to the drilling area. This shore base would provide for the storage of materials (including wellbore materials, diesel, water and drilling fluids) and equipment that would be transported from/to the drillship by sea. The shore base would also be used for bunkering vessels.

1.1. Scope of Work

This specialist report was compiled as a desktop study on behalf of ERM, for their use in compiling an Environmental Impact Assessment (EIA) and EMPr for the proposed exploration drilling off the South African East Coast.

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

1 Provide a general description of the marine ecological environment in Block ER236 by updating the Tugela South and the Durban Basin marine ecology baseline studies undertaken previously in the Project Area. The baseline study will be based on secondary data and will include a description of the marine environment and habitats as well as marine fauna, especially sensitive species. A general description of the physical environment will also be prepared. The study will focus on sensitive aspects of the marine environment. This will include marine reserves and other sensitive locations. It will also include sensitive species such as marine mammals, sea turtles, and sea birds. The baseline description and impact assessment will be included into the EIA Report.

2 Use the results of the oil spill and cuttings discharge modelling to assess the impacts (direct, indirect and cumulative) of the proposed offshore drilling on the marine biota off KZN through decreased water quality, smothering of benthic habitats through cuttings disposal, as well as the primary risks to the marine and coastal environment in the unlikely event of an accidental leak or spill during well drilling, testing and production.

3 Identify, describe and assess the significance of potential impacts of the proposed exploration drilling programme on the local marine fauna, focussing particularly on the benthic environment, but including generic effects on cetaceans, turtles, seals, fish and pelagic invertebrates.

4 Identify practicable mitigation measures to reduce the significance of any negative impacts and indicate how these can be implemented in the construction phase and management of the proposed project.

1.2. Approach to the Study

As determined by the terms of reference, this study has adopted a 'desktop' approach. Consequently, the description of the natural baseline environment in the study area is based on a review and collation of existing information and data from the scientific literature, internal reports and the Generic EMPr compiled for oil and gas exploration in South Africa (CCA & CMS 2001). The information for the identification of potential impacts of well-drilling activities on the benthic marine environment was drawn from various scientific publications, the Generic EMPr (CCA & CMS 2001), previous specialist reports on well-drilling (Atkinson 2010; Atkinson & Shipton 2010) and information sourced from the Internet. 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 EIA.

2. DESCRIPTION OF THE PROPOSED PROJECT

2.1. Project Location

Eni proposes to drill exploration wells inside Block ER236, within two areas of interest:

- a northern 1,717.5 km2 area of interest, which is located, at its closest point, approximately 62 km from shore, in water depths ranging between 1,500 m and 2,100 m (Figure 1).
- a southern approximately 2,905 km^2 area of interest, which is located, at its closet point, approximately 65 km from shore, in water depths ranging between 2,600 m and 3,000 m (Figure 1).

The expected drilling depth would be between approximately 3,800 m and 4,100 m from sea level in the northern area, while around 5,450 m for the southern area.

2.2. Project Schedule

The drilling of the first exploration well is planned to take place in late 2019 to early 2020. The drilling of one well is estimated to take approximately 71 days to complete. The time sequence of any additional wells will be dependent on the results of the first exploration well.

The drillship will be mobilised from either West or East Africa and will enter South African waters either at the Namibian or Mozambican border, as such at the worst case mobilisation will take in the order of 5 days.

2.3. Main Project Components

The main project components include:

- Deep Water Drillship;
- Exclusion Zone;
- Shore base;
- Supply and stand-by vessels;
- Personnel;
- Crew transfer; and
- Infrastructure and services.

Only those components relevant to the marine environment will be detailed below. For a full project description the reader is referred to the overall EIA compiled for the project.

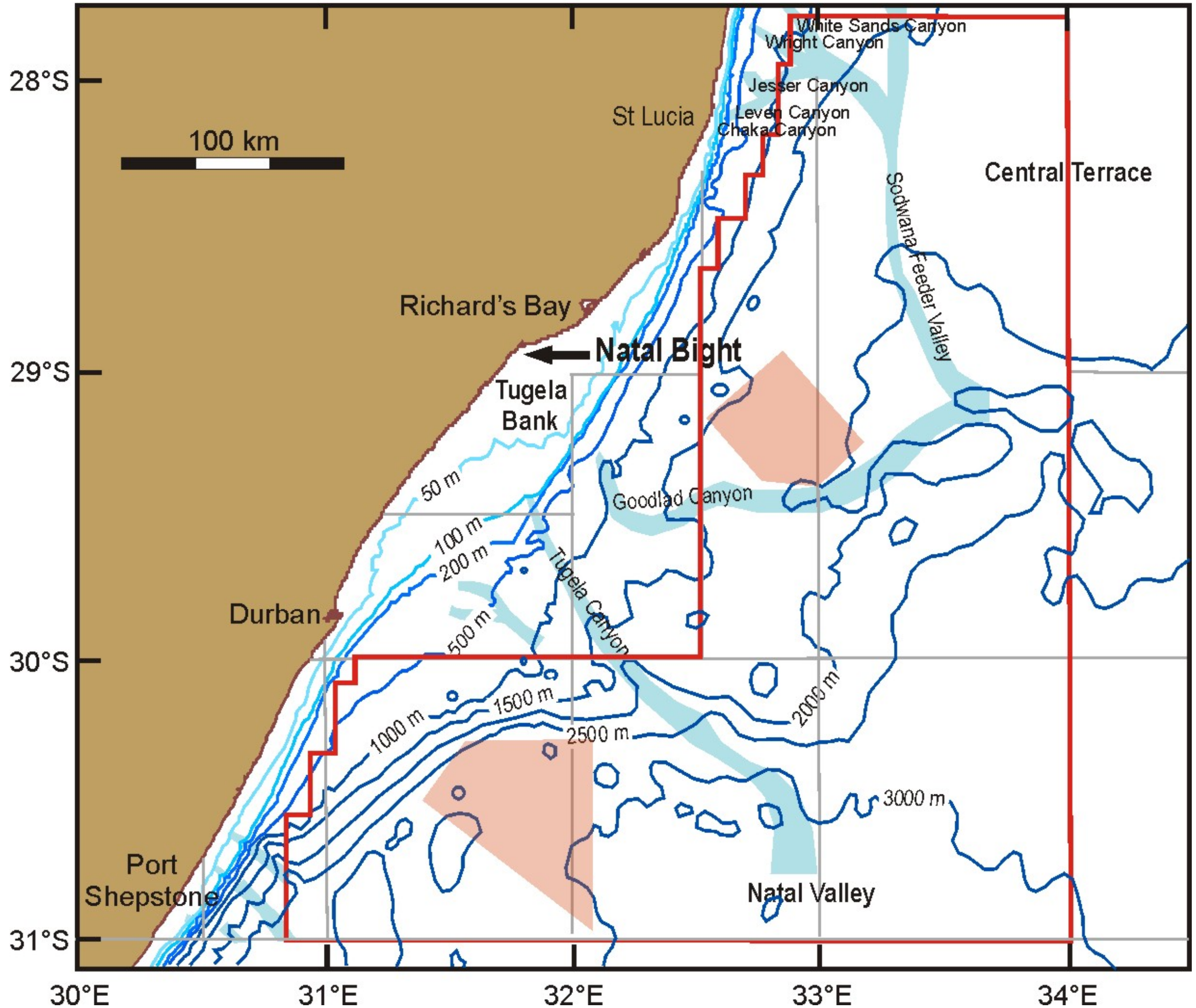


Figure 1:Bathymetry of the South African East Coast showing Block ER236 (red polygon), the direct areas of interest for well-drilling (orange shading) and features and places mentioned in the text. The positions of submarine canyons and feeder valleys (blue shading) as identified in Lombard *et al.* (2004) are also indicated.

2.3.1 Deep Water Drillship

Various types of drilling technology can be used to drill an exploration well depending on, *inter alia*, the water depth and marine operating conditions experienced at the well site, e.g. barges, platform rigs, jack-up rigs, semi-submersible drilling units (rigs), drillships and tension leg platform rigs. Due to water depth in the area of interest, exploratory drilling would be conducted using a deep water drillship. The deep water drillship (Figure 2) would maintain its position using a dynamic positioning system (DPS), which allows for minimal subsea disturbance due to its ability to operate without moorings. A significant benefit to using a drillship is the ease of mobility as it is a self-propelled vessel with the flexibility to move from location to location without the need of transport vessels.

Figure 2: Example of a typical drillship (Source: Shutterstock 2017).

2.3.2 Exclusion Zone

During the drilling operations, there will be a temporary 500 m safety zone around the drillship, which will be enforced by a standby vessel. The safety zone would be described in a Notice to Mariners as a navigational warning.

2.3.3 Shore Base

An onshore logistics base would be located within the Port or the Industrial Development Zone of either Richards Bay or Durban. This base would provide storage for drilling materials and other minor equipment, and would be used by the supply vessels providing fuel, food supplies, water etc. to the drillship. Areas for temporary storage of municipal solid waste, and for temporary drilling waste management transfer facilities would also be provided.

The location of the heliport for crew change and MEDEVAC services, as well as the commercial airport to be utilised will be determined once the logistic base location is confirmed.

2.3.4 Supply and Standby Vessels

For the duration of the drilling operation, the drillship will be supported by platform supply vessels (PSVs), which are general purpose vessels designed to carry a variety of equipment and cargo. These vessels will supply the drillship three to four times a week with drilling muds, cement and equipment such as casing, drill pipe and tubing. They will also remove waste that must be appropriately disposed of on land. There will likely be two or three PSVs although the exact requirements have not yet been defined.

A standby vessel (or a PSV in dual mode – supply and standby) would also be available to support the drilling operations during an emergency, including oil containment/recovery and rescue and to supply any specialised equipment necessary in case of an emergency. The standby vessel would also be used to patrol the area to ensure that other vessels adhere to the 500 m exclusion zone around the drillship.

2.3.5 Crew Transfers

Transportation of personnel to and from the drillship would most likely be provided by helicopter operations from Richards Bay or Durban. Crew changes would be staggered, and in combination with *ad hoc* personnel requirements. Thus helicopter operations to and from the drillship would occur on an almost daily basis.

2.4. Project Activities

Project activities associated with drilling include the following phases:

- Mobilisation of the supply vessels to Richards Bay or Durban, operation of the shore-based facilities for handling support services needed by the drillship;
- Drilling of a well;
- Well execution (side track, logging, completion) options;
- Optional well testing;
- Well abandonment; and
- Demobilisation of the drillship, vessel and local logistics base.

All activities will be conducted in conformity with recognised industry international best practice.

2.4.1 Mobilisation Phase

During mobilisation, the drillship will arrive directly on location from previous country of intervention (probably from West Africa or North/East Africa). Support vessels could sail directly in convoy with the drillship to site or from the Richards Bay or Durban mooring area.

Once in position, the drillship will carry out its pre-drilling activities comprising a seabed survey; remote operated vehicle (ROV) dive; positioning; beacon placement and dynamic positioning trials. These activities would be followed up with safety checks, drills, communication tests and drilling of the pilot hole.

2.4.2 Drilling Procedure

Drilling method

The strategy for the first planned exploration well has not yet been defined but would involve either the drilling of a main hole in between 1,500 m and 2,100 m water depth in the northern area of interest approximately 62 km south east of Richards Bay, or in water depths around 3,000 m in the southern drilling area approximately 145 km east north-east of Port Shepstone. The drilling of a vertical well to a total depth of approximately 3,800 m and 4,100 m below the seafloor is proposed for the wells located in the northern area, while in the southern area a vertical well to a total depth of 5,100 m is proposed to evaluate and confirm the commercial viability of the oil reservoir.

Two drilling methods can be employed on a drilling unit, namely rotary or downhole motor drilling. The primary drilling method would be rotary drilling, where the whole drill string is rotated to penetrate the formations. However, a downhole motor may be included in the bottom hole assembly to provide additional power to the bit. The downhole motor is driven by the drilling fluid, which is pumped down the drill string.

Drilling sequence or stages

The well would be created by jetting and drilling a hole into the seafloor with a drilling unit that rotates a drill string with a bit attached. After the hole is drilled, sections of steel pipe (or casings), slightly smaller in diameter than the borehole, are placed in the hole and permanently cemented in place. The hole diameter decreases with increasing depth as progressively smaller diameter casings are inserted into the hole at various stages and cemented into place.

The casing provides structural integrity to the newly drilled wellbore, in addition to isolating potentially dangerous high pressure zones from each other and from the surface. With these zones safely isolated and the formation protected by the casing, the well would be drilled deeper with a smaller bit, and also cased with a smaller size casing (Figure 3). This continues until the final hole, which is the smallest, reaches the reservoir level. For the current project it is proposed to have four to five sets of subsequently smaller hole sizes drilled inside one another, each cemented with a casing.

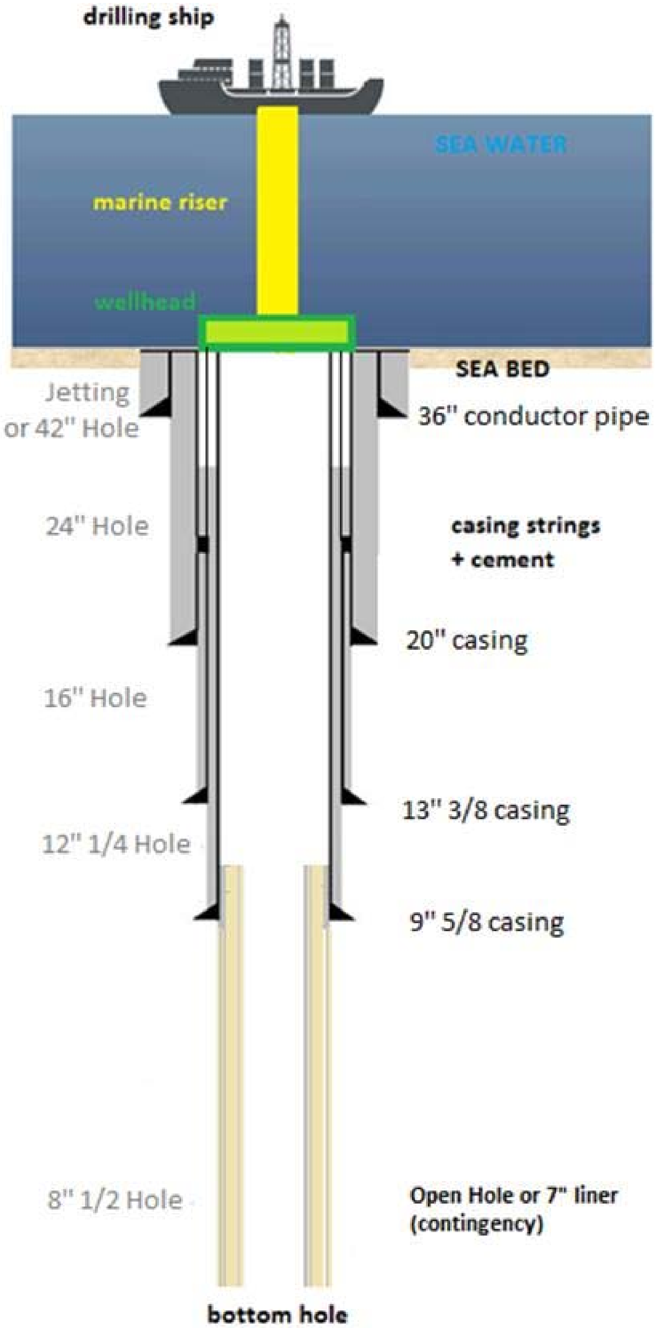


Figure 3: Subsea Well Schematic at the End of Drilling Phase.

Drilling is essentially undertaken in two stages, namely the riserless and risered drilling stages.

Initial (riserless) drilling stage

Sediments just below the seafloor are often very soft and loose, and to keep the well from caving in and to carry the weight of the wellhead a 36 inch (91 cm) diameter structural conductor pipe is jetted and / or drilled and cemented into place depending on the shallow seabed properties.

The conductor pipe is assembled at the drilling unit floor and a drill bit, connected to a drill pipe, is run through the inside to the bottom of the casing. The entire assembly is lowered to the seafloor by the rig hoist. At the seafloor the driller spuds the assembly into the seafloor sediments and then turns on a pump, which uses water or drilling fluid to jet the pipe into place.

When the conductor pipe and wellhead are at the correct depth the drill bit and drill string are released in order to commence with drilling operations. The rotating drill string causes the drill bit to crush rock into small particles, called “cuttings”. While the wellbore is being drilled, drilling fluid is pumped from the surface down through the inside of the drill pipe, the drilling fluid passes through holes in the drill bit and travels back to the seafloor through the space between the drill string and the walls of the hole, thereby removing the cuttings from the hole. At the planned depth the drilling is stopped and the bit and drill string is pulled out of the hole. The conductor pipe would be approximately 30 m deep.

Below the conductor pipe, typically a 24 inch (61 cm) diameter hole would be drilled for a 20 inch (51 cm) surface casing, which would extend to approximately 600 m below the seabed. The surface casing would be permanently cemented into place. In the event of technical issues in the riserless section, intermediate liners could be required in order for the surface casing to be installed at a sufficient depth to accommodate the drilling riser and BOP.

These initial hole sections would be drilled using seawater with high viscous pills and sweeps. All cuttings and sweeps from this initial drilling stage would be discharged directly onto the seafloor adjacent to the wellbore.

<u>Risered drilling stage</u>

Following the initial drilling stage described above, a BOP and marine riser is run and installed on the wellhead. The riser connects the drilling unit to the well and allows the drilling fluid and rock cuttings to be circulated back to the drilling unit, thereby isolating the drilling fluid and cuttings from the marine environment.

Drilling is continued by lowering the drill string, with a smaller bit, through the riser to the 16 inch (41 cm) diameter casing shoe and rotating the drill string. WBMs will be used during the risered drilling stage. However, should WBMs not provide the necessary characteristics, a low toxicity synthetic-based mud (SBM), which is a type of non-aqueous drilling fluid, would be used to (a) obtain critical reservoir parameters, b) provide a greater level of lubrication, and (c) provide more tolerance to high temperatures.

While drilling is in progress, drilling fluid is continuously recirculated to the drilling unit. The returned drilling fluid is treated to remove solids and drill cuttings from the re-circulating mud stream. The cuttings are also treated before being discharged overboard.

The hole diameter decreases in steps with depth as progressively smaller diameter casings are inserted into the hole at various stages and cemented into place. As indicated previously, the expected final depth of the wells is between 3,800 m and 5,450 m below the seafloor.

Cementing operation

The casings are permanently secured into place by pumping cement slurry, followed by drilling fluid, through the drill pipe and/or cement stinger at the bottom of the hole and back up into the space between the casing and the borehole wall (annulus). To separate the cement from the drilling fluid in order to minimise cement contamination a cementing plug and/or spacer fluids are used. The plug is pushed by the drilling fluid to ensure the cement is placed outside the casing filling the annular space between the casing and the hole wall.

To ensure effective cementing, an excess of cement is often used. Until the marine riser is set, this excess emerges out of the top of the well onto the seafloor. This cement does not set and is slowly dissolved into the seawater. For cementing jobs subsequent to riser installation, excess cement could be returned to the drilling vessel *via* the riser and treated using the solids control system. Unused cement slurry that has already been mixed is discharged overboard to avoid plugging the lines and tanks.

Offshore drilling operations typically use Portland cements, defined as pulverised clinkers consisting of hydrated calcium silicates and usually containing one or more forms of calcium sulphate. The raw materials used are lime, silica, alumina and ferric oxide. The cement slurry used is specially designed for the exact well conditions encountered.

Additives can be used to adjust various properties in order to achieve the desired results. There are over 150 cementing additives available. The amount (concentrations) of these additives generally make up only a small portion (<10%) of the overall amount of cement used for a typical well. Usually, there are three main additives used: retarders, fluid loss control agents and friction reducers. These additives are polymers generally made of organic material and are considered non-toxic.

Once the cement has set, a short section of new hole is drilled. A pressure test is performed to ensure that the cement and formation are able to withstand the higher pressures of fluids from deeper formations.

Drilling fluid circulation system and solids control equipment

While drilling is in progress, drilling fluid is continuously pumped down the inside of the hollow drill string. The fluid emerges through ports (“nozzles”) in the drill bit and then rises (carrying the rock cuttings with it) up the annular space between the sides of the hole (the casing and riser pipe) and the drill string, to the drilling unit. The returned drill mud is treated to remove the cuttings from the re-circulating mud stream.

The solids control system sequentially applies different technologies to remove the cuttings from the drilling fluid and to recover drilling fluid so that it can be reused. A typical solids control system consists of the following main components:

- Shale shakers (removes large-sized cuttings);
- Degasser (removes entrained gas);
- Desanders (removes sand-sized cuttings);

- Desilters (removes silt-sized cuttings);
- Centrifuge (recovers fine solids and weighting materials such as barite); and
- Cuttings dryer (removes residual liquids for reuse).

The components of the solids control system depends on the type of drilling fluid used, the formations being drilled, the available equipment on the drilling unit and the specific requirements of the disposal option. Solids control may involve both primary and secondary treatment steps. Solids removal efficiency for each hole section will be monitored to ensure solids control and fluids recovery equipment is operating as designed. Drill cuttings would only be discharged overboard following treatment in accordance with International recommendations, local regulation and Eni's Waste Management Guidelines. Residual non-aqueous base fluid retained on cuttings will not exceed 5% (C16-C18 internal olefins) or 9.4% (C12-C14 ester or C8 esters) on wet cuttings.

Anticipated well design

Described below is a standard well design and program for subsea well-drilling. The well design ultimately depends upon factors such as planned depths, expected pore pressures and anticipated hydrocarbon-bearing formations. The well design and program will be updated after the completion of seismic interpretation and stratigraphy evaluation by the geologists and petroleum engineers, and the well path defined accordingly. The various components of the anticipated well design are shown in Table 1.

Table 1: Estimated well design and cutting volumes.

Drill Section	Hole diameter (in)	Pipe diameter (in)	Depth of section (m)	Drilling duration (days)*	Type of drilling fluid used	Volume/Mass of drilling fluid discharged	Volume of cuttings (m^3)	Drilling fluid and cuttings discharge location
Riserless drilling stage								
1	42	36	30	2	Seawater, viscous sweeps	200 m^3	100	Seabed
2	24	20	600	8		700 m^3	300	Seabed
Risered drilling stage								
3	16	13 3/8	600	10	WBMs/NADF	15.9 MT	120	WBM **/ NADF recovered
4	12.25	9 5/8	700	12		9.28 MT	70	WBM **/ NADF recovered
5	8.5	Open hole or 7	700	13		3.97 MT	30	WBM **/ NADF recovered

*45 days is the estimated time for the effective drilling phase. 71 days is the estimated overall time for a single well campaign without well-testing but including mob/demob, drilling phase, casing runs, cement jobs, logs, BOP run and retrieve.

** during drilling WBMs would be recycled and re-used, before being taken back to shore for disposal at the end of the drilling campaign. Discharge of muds overboard would occur only if onland disposal was not feasible, and then only if in compliance with MARPOL standards.

2.4.3 Drilling Fluids or Muds

An important component in the drilling operation is the drilling fluid or drilling mud, which is used for:

- Maintaining a stable wellbore and preventing the open hole from collapsing;
- Providing sufficient hydrostatic pressure to control subsurface pressures as well as chemical stability to the rock to prevent kicks or blow-outs;
- Transport of the cuttings from the bottom of the well and from the well bore to the surface;
- Cooling and lubrication of the drill bit and drill string (reduce friction);
- Corrosion control of the metal components of the drilling tools;
- Powering mud motors / downhole tools during the drilling process;
- Regulation of the chemical and physical characteristics of returned mud slurry on the drilling unit; and
- Displacing cements during the cementing process.

Drilling fluid is a complex mixture of fluids, solids and chemicals that are carefully tailored to provide the correct physical and chemical characteristics required to safely drill the well. The physical and chemical properties of the drilling fluid are constantly monitored and adjusted to suit varying down-hole conditions. These conditions are, in part, due to the variation in formation pressure within the well bore at different depths. In particular, fluid density (or mud weight) is adjusted via weighting materials such as barite.

A combination of seawater, sweeps and WBMs/NADFs will be used for drilling activities in the drilling area of interest. The mud program will be defined based on final well design and expected rheology.

Sweeps

The sweeps and high viscous pills to be used for hole cleaning during drilling the initial sections of the well are a solution prepared with fresh or seawater and bentonite viscosifer, a non-toxic, insoluble and inert natural phyllosilicate clay with limited presence of caustic soda as pH and alkalinity control. The sweeps and high viscous pills do not contain spotting fluids or lubricating hydrocarbons.

Water-based muds

Due to the variability in conditions that can be encountered drilling fluid mixtures vary to some extent. Typically, the major ingredient making up 85 to 90 % of the total volume of a WBM is fresh and / or seawater, with the remaining 10 to 15 % of the volume being barite, potato or corn starch, cellulose-based polymers, xanthan gum, bentonite clay, soda ash, caustic soda and salts (these are usually either potassium chloride [KCl] or sodium chloride [NaCl]).

Barite (barium sulphate) is an inert compound used as a weighting agent. Potato or corn starch and other cellulose-based polymers are used to control the rate of filtration of water in the mud into the formation being drilled by forming a thin filter cake on the borehole wall. Xanthan gum and minor amounts of bentonite clay are used to provide viscosity and impart rheological properties to the mud for cuttings transport, as well as to provide gel strength for cuttings

suspension. Caustic soda (sodium hydroxide) is used to maintain the required pH in the drilling fluid. KCl or NaCl are used to reduce the swelling tendencies of clays being drilled and help to maintain a stable wellbore. Other minor additives may be used in special circumstances. A listing of the WBM chemicals used on a typical well, their functions and comments on their ecotoxicity are provided in
Table 2.

Table 2: Main components of water-based fluids.

Material	Use	Ecotoxicity
Aluminium stearate	Defoamer	Non-toxic, insoluble
Barite	Weighting agent	Non-toxic, insoluble, non-biodegradable
Bentonite	Viscosifer	Non-toxic, insoluble, non-biodegradable
Calcium carbonate	Bridging, loss of circulation	Non-toxic, insoluble
Caustic soda	pH and alkalinity control	Soluble, corrosive
Cellulose based polymers	Fluid loss control	Insoluble, non-toxic
Citric acid	pH control	Soluble, low toxicity, irritant
Diesel oil pill (< 0.1 % mud volume)	Stuck pipe spotting fluid	Slightly soluble, 96 hr LC_{50} >0.1-1000 ppm
Gilsonite (asphalt based)	Lubricant, fluid loss reducer	Low toxicity, slightly soluble
Gluteraldehyde (0.01% mud vol)	Bactericide (biocide)	Noted for its toxic properties, irritant
Lime	Carbonate and CO_2 control	Slightly soluble, non-toxic, irritant
Organic synthetic polymer blends	Filtrate reducing agent	Non-toxic, 96 hr LC_{50} >500 ppm
Palm oil ester	Lubricant, stuck pipe pills	Slightly soluble, biodegradable
Potassium chloride	Shale / clay inhibitor	Soluble, non-toxic
Soda ash	Alkalinity, calcium reducer	Soluble, non-toxic
Sodium bicarbonate	Alkalinity, calcium reducer	Soluble, non-toxic
Xanthan gum	Viscosity, rheology	Soluble, non-toxic

Should WBMs be used for drilling the lower sections of the well, these would be recycled and re-used, before being taken back to shore for disposal/recycling. Only if onshore disposal of spent muds is not feasible would the muds be discharge overboard, and that only if in compliance with Eni's Waste Management Guidelines, local regulations and international best practice (e.g. MARPOL standards). Under the worst-case scenario, the maximum amount of muds discharge would amount to 29.15 MT.

Non-Aqueous Drilling Fluids

Non-aqueous drilling fluids (NADF) are used to:

- Provide optimum wellbore stability and enable a near gauge hole to be drilled;

- Prevent the formation of hydrates;
- Minimise damage to reservoirs that contain clays that react adversely to WBM; and
- Obtain irreducible water saturation log data for gas reservoirs.

The main chemicals used in a NADF are presented in
Table 3.

Table 3: Main chemicals used in a non-aqueous drilling fluid (adapted from Swan *et al.* 1994).

Material	Description
Base oil	Non-aqueous drilling fluids use base fluids with significantly reduced aromatics and extremely low polynuclear aromatic compounds. Low toxicity mineral oil based fluids, highly refined mineral oils and synthetic fluids (esters, paraffins and olefins) are generally used.
Brine phase	$CaCl_2$, NaCl, KCl.
Gelling products	Modified clays reacted with organic amines.
Alkaline chemicals	Lime e.g. $Ca(OH)_2$.
Fluid loss control	Chemicals derived from lignites reacted with long chain or quaternary amines.
Emulsifiers	Fatty acids and derivatives, rosin acids and derivatives, dicarboxylic acids, polyamines.

The disadvantage of using a NADF is that base fluid and other chemicals would result in an increase in toxicity. Drill cuttings that derive from the reservoir section contain residual base fluids, which cannot be removed easily.

There are three types of NADF that are used for offshore drilling and can be defined as follows:

- **Group I NADF (high aromatic content)**

  These base fluids were used during initial days of oil and gas exploration and include diesel and conventional mineral oil based fluids. They are refined from crude oil and are a non-specific collection of hydrocarbon compounds including paraffins, olefins and aromatic and polycyclic aromatic hydrocarbons (PAHs). Group 1 NADFs are defined by having PAH levels greater than 0.35%.

- **Group II NADF (medium aromatic content)**

  These fluids are sometimes referred to as Low Toxicity Mineral Oil Based Fluids (LTMBF) and were developed to address the rising concern over the potential toxicity of diesel-based fluids. They are also developed from refining crude oil but the distillation process is controlled such that the total aromatic hydrocarbon concentration is less than Group I NADFs (0.5 – 5%) and the PAH content is less than 0.35% but greater than 0.001%.

- **Group III NADF (low to negligible aromatic content)**

  These fluids are characterised by PAH contents less than 0.001% and total aromatic contents less than 0.5%. They include SBMs, which are produced by chemical reactions of relatively pure compounds and can include synthetic hydrocarbons (olefins, paraffins and esters). Using special refining and/or separation processes, base fluids of Group III can also be derived from highly processed mineral oils (paraffins, enhanced mineral oil based fluid (EMBF)). PAH content is less than 0.001%.

The trend in the industry has been to move towards low toxicity NADF (Group III NADF) that are biodegradable and will not persist in the long-term. Group III NADF will be used during the risered drilling stage for this project.

2.4.4 Well Execution Options

Well Logging

Continuous testing is carried out on the drill cuttings transferred to the surface. These tests are used to determine and obtain information on the presence of hydrocarbons, formation types being drilled and formation pressures. Further information is obtained on the physical properties of the rock formations by means of open and cased hole logging using sensors introduced down-hole on a wireline cable, or by means of sensors located in the drill collar (measurement while drilling). A logging plan will be developed and implemented in accordance with standard industry best practices.

In the case of exploration wells, once a full log of the reservoir section has been undertaken, the well will be permanently plugged and abandoned.

Well Completion

Well completion and well testing operations would not be conducted during the drilling of exploration wells, but may be performed after drilling of the appraisal wells if hydrocarbons are discovered.

The completion phase of an oil or gas well takes place after the reservoir formation has been drilled and the production casing cemented. Preliminary completion operations are usually required to clean and condition a wellbore from mud to prepare the well for:

- displacement of the wellbore with a completion brine, necessary to balance the downhole pressure and complete the removal of mud and solids from the well thereby minimising any potential damage to the formation;
- running of a completion string in hole for use during well testing or in preparation for further production. This string allows subsea safety, guaranteeing full control of hydrocarbon flow during the testing or production phase;
- displacement out of the well-bore of the weighted completion fluid that maintains sufficient pressure and prevents formation fluids from migrating into the hole

Well Testing

Well testing may be conducted on the appraisal wells if they present potential commercial quantities of hydrocarbon. A well test is a temporary completion of a well to acquire dynamic rate through time, pressure, and fluid property data. The well test often indicates how the well will perform when subjected to various flow conditions. An analysis is usually performed on the data to determine reservoir parameters and characteristics including pressure, volume, and temperature.

Current testing practices are carried out using modern testing equipment and high resolution pressure data acquisition systems. The behaviour of the formation fluid properties, well completion, and flow assurance situations can only be determined if testing is carried out.

The well test objectives are to:

1. Determine key technical factors of the reservoir (e.g. size, permeability and fluid characteristics) and values for use in future drilling.
2. Obtain representative data including reservoir pressure, production rates and sample(s).

While testing, hydrocarbons are sent to a flare boom with a burner to ensure complete combustion of fluids. Flaring may be initiated using LNG or similar fuel to ignite the mixture. To ensure that burning can be done downwind of the drillship, more than one flare boom may be used, or the ships positioning may be adjusted. Water misters may be used to mitigate heat exposure on the rig.

The flow periods and rates will be limited to the minimum necessary to obtain the required reservoir information during the well test. It is anticipated that the maximum well test duration for this project would be in the order of 20 days.

Downhole sampling, if required, normally consists of recovering reservoir fluids *via* wireline or through specific tools added directly to the temporary test string. Wireline testing involves running instruments into the borehole on a cable to measure formation pressures and obtain fluid samples. Formation fluids are brought to the surface where the composition can then be analysed.

The following key well testing preventative measures would be implemented during the well testing program:

- Monitor flare performance to maximise efficiency of flaring operation;
- Ensure sufficient compressed air is provided to the oil burner for efficient flaring;
- Flare equipment is appropriately inspected, certified and function-tested prior to operations;
- Flare equipment is appropriately maintained and monitored throughout well testing operations;
- The equipment is designed and built to appropriate codes and standards and certified;
- The appropriate emergency stop mechanisms are in place to halt testing in case of emergency.

Well Control and Blowout Prevention

Health, safety and environmental protection are prioritised throughout the drilling process . In particular, there is specific focus and attention during preparation and operations to avoid any potential accidental events relating to hydrocarbon release or uncontrolled flow from down-hole to either the seabed or to the surface (rig floor).

Well control is a routine function during well operations, with each well being specifically designed and executed to minimise the risk of a well control incident developing. Down-hole conditions, such as shallow gas and high-pressure zones, can result in sudden variations in well pressure thereby resulting in well-control problems. If there is an influx of formation fluids with sufficient pressure to displace the well fluid, a well kick can result. The primary control against a well kick is the maintenance of a sufficient hydrostatic head of weighted drilling mud/completion brine in the well bore to balance the pressures exerted by formation fluids during drilling.

Secondary well control is provided by the installation of mechanical devices, such as the float collar in the drilling string and the blowout preventer (BOP) at the seabed. The BOP is installed on the wellhead after the running and setting of the surface casing. Should there be a sudden uncontrolled influx of formation fluids into the well bore, the BOP effectively closes and seals the annulus with a series of hydraulically/electrically actuated rams. The BOP allows the formation fluids to be safely vented or pumped to the surface with the well closed, thereby enabling other methods to be applied to restore sufficient hydrostatic pressure in the well bore (e.g. by pumping higher density mud - 'kill mud' – into the well. The capacity and pressure rating of drilling equipment, safety devices and the BOP exceed the predicted reservoir pressures. The BOP would undergo a thorough inspection prior to installation and subsequently pressure and function tested on a regular basis. The well control philosophy and procedure, constantly updated by the Eni drilling department, includes the identification and assessment of all well blowout risks.

In addition to the above, advanced well intervention and capping equipment is available in Saldanha Bay for deployment in the event of a subsea well control incident. The subsea well intervention system includes four capping stacks to shut-in an uncontrolled subsea well and two hardware kits to clear debris and apply subsea dispersant at a wellhead. This unique piece of equipment is only stored in four international locations, namely Norway, Brazil, Singapore and South Africa, and is maintained ready for immediate mobilisation in the event of an incident.

Well Abandonment

Once drilling is completed, the well will be plugged and abandoned. This will involve setting cement plugs inside the wellbore and testing them for integrity. The BOP will be then retrieved from the surface and the wellhead left in place on the seabed.

2.4.5 Demobilisation

On completion of drilling, the drillship and support vessels will leave the well location. A final ROV survey of the seabed at the drill site will be performed.

2.5. Planned Emissions and Discharges, Waste Management

Eni's principle for waste management is to follow Eni's Waste Management Heirarchy of: reduce, reuse, recycle, recover, treat, dispose. All vessels would have equipment, systems and protocols in place for prevention of pollution by oil, sewage and garbage in accordance with MARPOL 73/78.

A project specific Waste Management Plan (covering all wastes generated offshore and onshore) would be developed in accordance with MARPOL requirements, South African regulations and Eni's waste management guidelines. On-land waste disposal sites and waste management facilities would be identified, verified and approved prior to commencement of drilling.

2.5.1 Discharges to Sea

Drill Cuttings and Mud Disposal

Drill cuttings are produced during the drilling of the well as the rock is broken into small rock particles by the advancing drill bit. The volumes of drill cuttings that will be discharged to the marine environment during the drilling of the planned wells are provided in Table 1.

During the riserless drilling stage cuttings are discharged directly on the seabed in immediate proximity of the well, where they would form a cone-shaped cuttings pile affecting an area of ~0.03 km^2 around the wellhead. At its apex the cone would be in the order of 1 m high. Maximum depositional thicknesses of >5 mm would be restricted to an area <0.008 km^2 around the wellhead. An estimated 400 m^3 of cuttings and 900 m^3 of drilling fluid (sweeps) would be discharged at the seabed.

During drilling of the deeper sections of the well with NADFs, the drilling muds are separated from the cuttings and recycled. The cuttings are passed through a cuttings dryer to reduce the volume of base fluid retained before they are discharged to sea. The 220 m^3 of cleaned cuttings are discharged overboard through a cuttings chute located several metres below the sea surface, where they will disperse as a plume and settle back onto the seabed over a maximum area of ~7 km^2. Discharged cuttings must comply with the following limits:

- Organic Phase Drilling Fluid concentration: maximum NADF 5% (C16-C18 internal olefins) or 9.4% (C12-C14 ester or C8 esters) on wet cuttings;
- Hg: max 1 mg/kg dry weight in stock barite; and
- Cd: max 3 mg/kg dry weight in stock barite.

At the end of operation, the residual NADF in the loop and in tanks will be delivered to shore for recycling or disposal in dedicated waste management facilities.

Should WBMs be used during the drilling of the deeper sections, the 29.15 MT of WBMs would be discharged directly overboard with the 220 m3 of cuttings. Discharge would occur through a cuttings chute or caisson located several metres below the sea surface, where they will disperse as a plume and settle back onto the seabed. Residual mud at the end of drilling operations would be delivered to shore for recycling or disposal in dedicated waste management facilities. If this is not feasible, they would be discharged overboard, but only if in line with internation best practice. Under the worst-case scenario, the maximum volume of muds discharge would amount to 29.15 MT.

Cement

During cementing of the tophole section, excess cement (maximum of 100 m^3) would emerge out of the top of the well and onto the seabed, where it would dissolve into the surrounding water. Excess cement is necessary to guarantee that the conductor pipe and surface casing are cemented all the way to the seafloor.

During subsequent cementing jobs excess cement would be returned to the drilling vessel via the riser and treated using the solids control system. Unused cement slurry that has already been mixed is discharged overboard.

Deck drainage, vessel machinery spaces, mud pit wash residue and ballast water

All deck drainage from work spaces (bilge water) will be collected and piped into a sump tank on board the project vessels to ensure MARPOL 1973/78 Annex I compliance. The fluid will be monitored and any oily water would be processed through a suitable separation and treatment system prior to discharge overboard at a maximum of 15 ppm oil in water. Oily waste substances must be shipped to land for treatment and disposal.

Sewage

Sewage discharge from the project vessels would meet the requirements of MARPOL 73/78 Annex IV. MARPOL 73/78 Annex IV requires that sewage discharged from vessels be disinfected, comminuted and that the effluent must not produce visible floating solids in, nor cause discoloration of the surrounding water. The treatment system must provide primary settling, chlorination and dechlorination. The treated effluent is then discharged into the sea.

Galley Wastes

The disposal into the sea of galley waste is permitted, in terms of MARPOL 73/78 Annex V, when the vessel is located more than 3 nautical miles (approximately 5.5 km) from land and the food waste has been ground or comminuted to particle sizes smaller than 25 mm. Discharge of food wastes not comminuted is permitted beyond 12 nautical miles. The ground wastes must be capable of passing through a screen with openings <25 mm.

Detergents

Detergents used for washing exposed marine deck spaces would be managed as bilge water. The toxicity of detergents varies greatly depending on their composition. Water-based or biodegradable detergents are preferred for use due to their low toxicity. In certain cases where cleaning of specific non-contaminated areas is undertaken using no toxic detergent, direct overboard discharge may be considered.

Cooling Water

Electrical generation on drilling units is typically provided by large diesel-fired engines and generators, which are cooled by pumping water through a set of heat exchangers. The cooling water is then discharged overboard. Other equipment is cooled through a closed loop system, which may use chlorine as a disinfectant. Such water would be tested prior to discharge and would comply with relevant Water Quality Guidelines.

Opening and closing of BOP

A further operational discharge is associated with routine well opening and closing operations. As part of these operations, the subsea BOP stack elements will vent between 500 to 1,000 litres per month of oil-based hydraulic fluid into the ocean at the seafloor.

2.5.2 Noise Emissions

The main sources of noise from the proposed drilling programme include noise produced by the drillship and supply vessels, as well as noise produced by the helicopters undertaking crew transfers. The noise characteristics and level of various vessels used in the drilling programme will vary between 130 and 182 dB re 1µPa at 1 m (Simmonds *et al.* 2003; Richardson *et al.* 1995). The particular activity being conducted by the vessels changes the noise characteristics, for example, if it is at idle, holding position using bow thrusters, or accelerating.

The dominant low-frequency components of aircraft engine noise (10-550 Hz) penetrate the water only in a narrow (26° for a smooth water surface) sound cone directly beneath the aircraft, with the angle of the cone increasing in Beaufort wind force >2 (Richardson *et al.* 1995). The peak sound level received underwater is inversely related to the altitude of the aircraft.

2.6. Unplanned Emissions and Discharges

2.6.1 Hydrocarbons and Chemical Spills

The main types of accidental events that may arise during well drilling, which could result in a discharge of hydrocarbons or chemicals to the marine environment are:

- loss of well containment (blow out), which is a continuous release that could last for a measurable period of time; and
- single-event instantaneous operational spills.

Eni is committed to minimising the release of hydrocarbons and hazardous chemical discharge into the marine environment and avoiding unplanned spills through the development and implementation of an Oil and Chemical Spill Response Plan. In case of accidental events, adverse effects to the environment are minimised by:

i) Incorporating oil and chemical spill prevention into the drilling plans; and
ii) Ensuring that the necessary contingency planning has taken place to respond effectively in the event of an incident.

2.7. Project Alternatives

In relation to a proposed activity “alternatives” means different ways of meeting the general purposes and requirements of the proposed activity. Different categories of alternatives can be identified, e.g. location alternatives, type of activity, design or layout alternatives, technology alternatives and operational alternatives. The 'No Go' or 'No Project' alternative must also be considered.

Details of the alternatives considered in this EIA are provided in the overall EIA and will not be repeated here.

3. DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

The Project Area comprises the various biophysical receptors that may be affected both directly and indirectly by the project activities. The Project Area is separated into Areas of Direct Influence (ADI) and Areas of Indirect Influence (AII) depending on the source and causes of the impacts, and these will vary in extent depending on the type of receptor affected.

The descriptions of the physical and biological environments focus primarily on the area between Port Shepstone and Richard's Bay on the KwaZulu-Natal (KZN) coast, and equate to the Area of Direct Influence. The Area of Indirect Influence includes the whole of the KZN coastline, extending down the East Coast to as far as Port Elizabeth and is included in the event of an unplanned event such as an oil spill. The summaries presented below are based on information provided in the Generic EMPRs for Oil and Gas Prospecting off the Coast of South Africa (CCA & CMS 2001) and more recent scientific studies undertaken in the general area.

3.1. The Physical Environment

3.1.1 Bathymetry and Sediments

The orientation of the coastline along the East Coast is relatively uniform, and north-northeast trending. A significant topographical feature is the Natal Bight, a coastal indentation between Cape Vidal and Durban, which is sheltered from the main force of the southward flowing Agulhas Current. The majority of the East Coast region within the area of direct influence has a narrow continental shelf and a steep continental slope. A prominent feature on the continental shelf is the Tugela Bank located along the KwaZulu-Natal coast between 28° 30' S and 30° 20' S. Here the continental shelf widens to 50 km offshore, the maximum width reached along the East Coast (Lutjeharms *et al.* 1989), and the continental slope is more gentle (Martin & Flemming 1988). To the south, the continental margin descends into the Natal Valley, while to the north-eastwards it develops into the Central Terrace (refer to Figure 1).

The Tugela Bank is interrupted by two canyons; the large and prominent Tugela Canyon and the smaller Goodlad Canyon (also referred to as 29°25' S). The northern area of interest for well drilling lies east of the Natal Bight in >1,500 m water depth, adjacent and to the north of the Goodlad Canyon. There is no overlap, however, of the northern area of interest for well drilling with the canyon. The southern area of interest lies off Port Shepstone in excess of 2,500 m water depth, to the south of the Tugela Canyon. A further canyon is located to the south of the Bank where the continental shelf narrows and the continental margin descends into the Natal Valley. There is no overlap of the southern area of interest with these canyons. The Tugela Canyon is an example of a large submarine canyon restricted to the mid-lower continental slope. Unlike those off the Greater St Lucia Wetland Park (GSLWP) further north, this canyon lacks connection to the upper continental slope and shelf. The canyon head is located at ~600 m depth with the thalweg ending in the Natal Valley at ~2,800 m (Wiles *et al.* 2013). Sporadic high relief basement outcrops occur in the canyon head, with terraces developing along the western canyon wall beyond depths of ~1,500 m. With increasing distance from the continental shelf, and increasing depth, the canyon increases in width and relief. Information on the Goodlad Canyon is sparse. It is reported to start as a small 20 m deep valley (Martin & Flemming 1988) deepening to 250 m while becoming a 50 km wide, shallow valley at a depth of 1,400 m. It emerges from the Tugela

Bank at 2,320 m (Goodlad 1986). The gradient of the canyon walls are less steep than those of the Tugela Canyon and limited tributaries occur (Young 2009). No information specific to the canyon off Durban could be sourced.

These Canyons therefore differs significantly in morphology from those in northern KwaZulu-Natal, where coelacanths have been reported. Firstly, the canyon heads lack the amphitheatre-shaped head morphology. Secondly, they are located at far greater depth than the Sodwana canyons and lack connectivity to the shelf, and finally, they show no significant tributary branches (Wiles *et al.* 2013). Although terraces are present and may provide shelter in the form of caves and overhangs, they occur at depths (>1,500 m) well beyond those at which coelacanths have been recorded to date.

The Tugela Bank is the major sedimentary deposition centre of the KZN continental shelf, being characterised by fluvial deposits of Tugela River and Mgeni River origin. Sediment dispersal in the Bight is controlled by the complex interaction of shelf morphology, the Agulhas Current, wave regime, wind-driven circulation, sediment supply and the presence of the semi-permanent gyre. The seabed is thus sedimentary in nature but varies in the degree to which it is consolidated (CBD 2013; see also Green & MacKay 2016). North of Durban, the shelf region is dominated by terrigenous sand (0.063 – 2 mm), with patches of gravel (>2 mm) occurring throughout the area. Areas on the mid-shelf contain sediments comprising up to 60% terrigenous mud. Two large mud depo-centres are found off the Tugela River mouth, while a smaller one is located off St Lucia. These mud depo-centres are a rare environment along the east coast of South Africa, comprising only about 10% of the shelf area (Demetriades & Forbes 1993). The muds and their associated elevated organic contents provide habitat to a unique fauna dominated by benthic and deposit feeders that favour muddy sediments and turbid waters. Despite being primarily a soft-sediment habitat, low profile beachrock outcrops (Fennessy 1994a, 1994b; Lamberth *et al.* 2009) occur just offshore of the 50 m contour off Durban and around the 200 m contour off Richard’s Bay.

South of Durban, sand dominates both the inshore and offshore surficial sediments, although a substantial gravel component is present on the middle and outer shelf to as far as Port St Johns, occurring as coarse lag deposits in areas of erosion or non-deposition. Traces of mud are present on most areas of the shelf, although significant mud depo-centres are absent. The Agulhas Current and/or waves affect the sediment bedform patterns on the KZN continental shelf. North and south of the Tugela Bank, the Agulhas Current generates active dune fields at the shelf edge (Flemming & Hay 1988). In contrast, sediments on the shelf area of the Tugela Bank to a depth of 100 m are affected mostly by wave action (CSIR 1998; Green & MacKay 2016). South of the Ilovo River the inner shelf comprises sand sheets, while sand ribbons and streamers occur on the mid-shelf comprises, with gravel pavements dominating the outer shelf.

The outer shelf is dominated by gravels of shell-fragment and algal-nodule origin (Heydorn *et al.* 1978). Outer shelf sediments are influenced solely by the strong Agulhas Current, forming large-scale subaqueous dunes with a southwesterly transport direction. Subaqueous dunes in the inner and mid shelf are prone to current reversals (Uken & Mkize 2012). Benthic habitats in the northern area of interest for well drilling comprise Southwest Indian Upper and Lower Bathyal, whereas Southern Indian Lower Bathyal sediments dominate in the southern area if interest

(Figure 4). Both these habitat types have been assigned an ecosystem threat status of 'least threatened' in the SANBI 2011 National Biodiversity Assessment (Sink *et al.* 2011) reflecting the great extent of these habitats within the South African Exclusive Economic Zone (EEZ). Inshore of the 200 m contour, the benthic habitats are primarily rated as 'vulnerable', with the mud depo-centres rates as 'endangered' (Sink *et al.* 2012) (Figure 5).

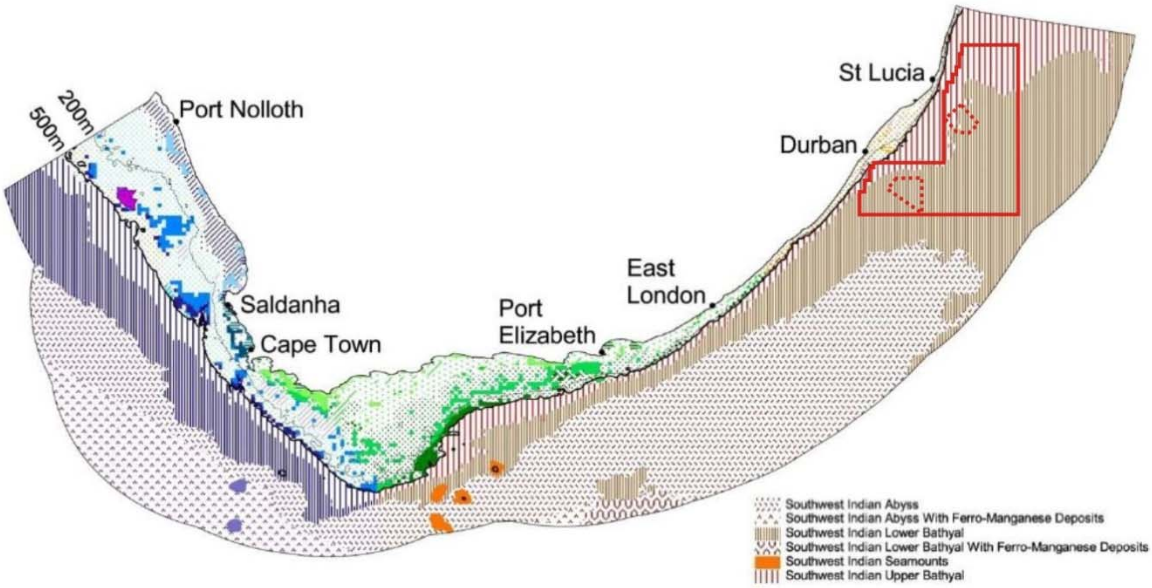


Figure 4: Coastal and offshore benthic habitat types off the South African East Coast, with particular reference to Block ER 236 (red polygon) and the areas of interest for well drilling (red dotted lines) (adapted from Sink *et al.* 2012).

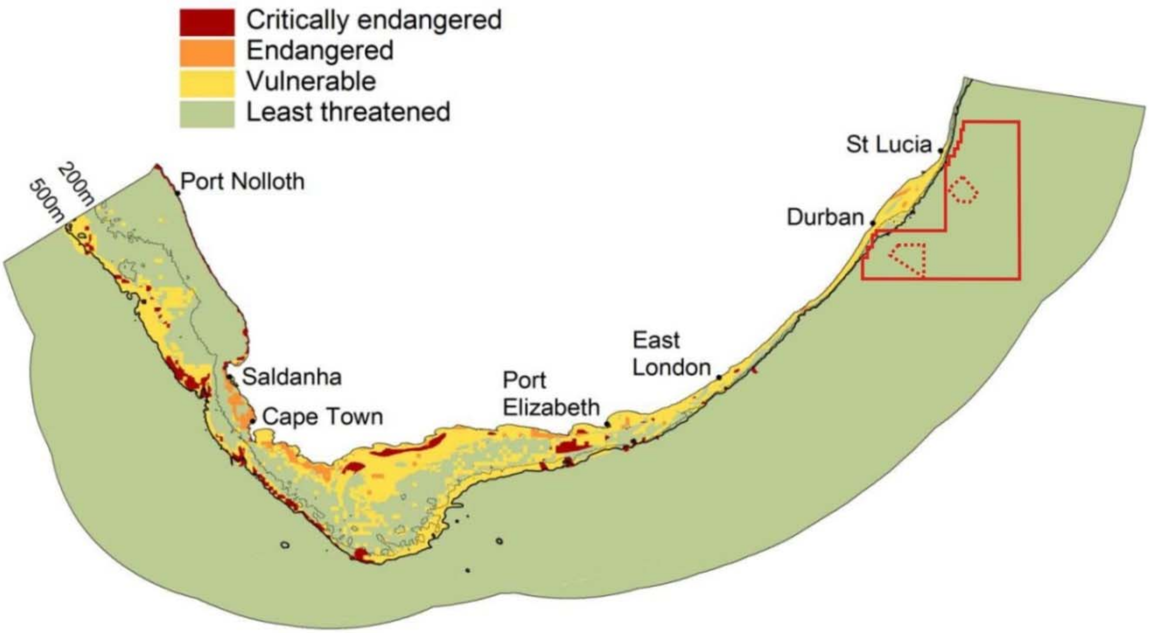


Figure 5: The ecological threat status of coastal and offshore benthic habitat types off the South African East Coast, with particular reference to Block ER236 (red polygon) and the areas of interest for well drilling (red dotted lines) (adapted from Sink *et al.* 2012).

3.1.2 Water Masses and Circulation

The oceanography of this coast is almost totally dominated by the warm Agulhas Current that flows southwards along the shelf edge (Schumann 1998) (Figure 6). The Agulhas Current forms between 25° and 30° S, its main source coming from recirculation in a South-West Indian Ocean subgyre. Further contributions to the Agulhas Current come from the Mozambique Current and the East Madagascar Current in the form of eddies that act as important perturbations to the flow (Lutjeharms 2006). It flows southwards at a rapid rate following the shelf edge along the East Coast, before retroflecting between 16° and 20° E (Shannon 1985). It is a well-defined and intense jet some 100 km wide and 2,300 m deep (Schumann 1998; Bryden *et al.* 2005). Current speeds of 2.5 m/s or more have been recorded (Pearce *et al.* 1978).

Where it meets the northern part of the Tugela Bank near Cape St Lucia, the inertia of the Agulhas Current carries it into deep water. This generates instability in the current (Gill & Schumann 1979) resulting in meanders and eddies (Pearce *et al.* 1978; Guastella & Roberts 2016; Roberts *et al.* 2016). Three eddy types have been identified in the Agulhas Current (Gründlingh 1992):

- Type I meanders that comprise smaller shear/frontal features to a depth of at least 50 m, which dissipate over a period of days.
- Type II meanders comprising the large clockwise loops generated within the Natal Bight. Of these the extremely transient Natal Pulse occurs when meanders move the southward flow offshore, enabling sluggish and occasional northward flow to develop close inshore (Schumann 1988; Roberts *et al.* 2016). The larger Natal Gyre is a clockwise circulation cell that extends from Durban to Richard's Bay, resulting in northward flow inshore (Pearce 1977a, 1977b). The Natal Gyre, however, is temporally and spatially variable (CSIR 1998; Roberts *et al.* 2016), being affected by a number of Type I disturbances (Gründlingh 1992). More recently, Guastella & Roberts (2016) identified that the Durban Eddy, a meso-scale, lee-trapped cold-core feature, which develops in the south between Durban and Sezela causing strong north-eastward flow inshore, is present off Durban approximately 55% of the time, with an average lifespan of 8.6 days, and inter-eddy periods of 4 to 8 days. Combined with the southerly flow on the outer shelf, the effect is the development of a semi-permanent cyclonic circulation ('swirl') over the entire southern bight.
- Type III meanders, which are the larger meanders that originate north of St Lucia.

South of Durban, the continental shelf again narrows and the Agulhas Current re-attaches itself as a relatively stable trajectory to the coast, until off Port Edward it is so close inshore that the inshore edge (signified by a temperature front) is rarely discernible (Pearce 1977a). At Port St Johns, however, there exists a semi-permanent eddy, which results in a northward-flowing coastal current and the movement of cooler water up the continental slope onto the centre of the very narrow shelf (Roberts *et al.* 2010). Further south, when the Agulhas Current reaches the wider Agulhas Bank, where the continental slopes are weaker, it starts to exhibit meanders, shear edge eddies and plumes of warm surface waters at the shelf edge, before retroflecting eastwards as the Agulhas Return Current to follow the Subtropical Convergence (Lutjeharms 2006) (Figure 6).

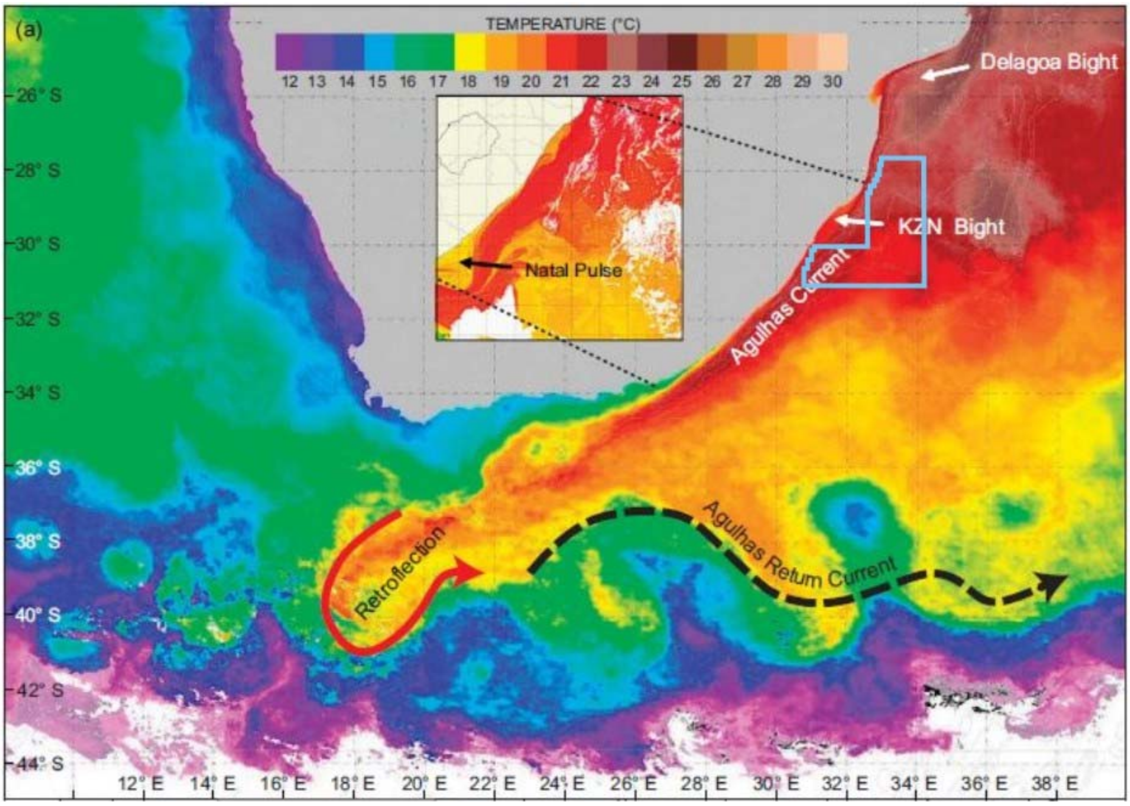


Figure 6: The predominance of the Agulhas current in the oceanography of Block ER236 (pale blue outline) (adapted from Roberts *et al.* 2010).

In common with other western boundary currents, a northward (equatorward) undercurrent — termed the Agulhas Undercurrent — is found on the continental slope of the East Coast at depths of between 800 m and 3,000 m (Beal & Bryden 1997).

As the Agulhas Current originates in the equatorial region of the western Indian Ocean its waters are typically blue and clear, with low nutrient levels and a low frequency of chlorophyll fronts. On the Tugela Bank, however, nutrient concentrations are characterised by short-term temporal variations, but are higher than in areas where the continental shelf is narrower (Carter & d'Aubrey 1988). This is attributed in part, to the topographically induced upwelling that occurs in the area as a result of the bathymetric arrangement of the Natal Bight (Gill & Schumann 1979; Schumann 1986; Lutjeharms *et al.* 1989). Recently, however, Roberts & Nieuwenhuys (2016) identified that upwelling in the northern KZN Bight is common, and that almost all major and minor cold-water intrusions coincided with upwelling-favourable north-easterly winds that simultaneously force a south-westerly coastal current. Major upwelling events last for 5-10 days, whereas shorter duration events persist for 1-2 days. Wind-driven upwelling also occurs in the inner bight between Richards Bay and Port Durnford. Furthermore, the canyons of northern bight may also play a role in enhancing upwelling. Upwelling has also been reported in the southern bight 'swirl'. The cold nutrient-rich upwelled waters are a source of bottom water for the entire Natal Bight (Lutjeharms *et al.* 2000a, b). However, from all other perspectives, the Bight may be considered a semi-enclosed system (Lutjeharms & Roberts 1988) as the strong Agulhas Current at the shelf edge forms a barrier to exchanges of water and biota with the open ocean. The location of the areas of interest for well drilling offshore and to the east and south of the Tugela Banks, however, suggests that nutrient concentrations will be comparatively low.

The surface waters are a mix of Tropical Surface Water (originating in the South Equatorial Current) and Subtropical Surface Water (originating from the mid-latitude Indian Ocean). Surface waters are warmer than 20°C and have a lower salinity than the Equatorial Indian Ocean, South Indian Ocean and Central water masses found below. Surface water characteristics, however, vary due to insolation and mixing (Schumann 1998). Seasonal variation in temperatures is limited to the upper 50 m of the water column (Gründlingh 1987), increasing offshore towards the core waters of the Agulhas Current where temperatures may exceed 25° C in summer (21° C in winter) (Schumann 1998). Further offshore of the core waters, and thus across most of the Block ER236, temperatures again decrease.

3.1.3 Winds and Swells

The main wind axis off the KZN coast is parallel to the coastline, with north-north-easterly and south-south-westerly winds predominating for most of the year (Schumann & Martin 1991) and with average wind speeds around 2.5 m/s (Schumann 1998) (Figure 7).

In the sea areas off Durban, the majority of swells are from the South and South-southwest, with the largest attaining >7 m. During summer and autumn, some swells also arrive from the east (Figure 8). The less regular weather patterns affecting the East Coast (e.g. low pressure cells present NE of Durban, cut-off low pressure cells and tropical cyclones) strongly influence the wave climate, resulting in swells in excess of 10 m (Hunter 1988; Schumann 1998). The giant waves (>20 m high) that are at times encountered within the Agulhas Current (Heydorn & Tinley 1980), arise from the meeting of the south-westerly swells and the southerly flowing Agulhas Current, and may be a navigation hazard at times.

In the Area of Indirect Influence along the South Coast, westerly winds predominate in winter, frequently reaching gale force strengths. During summer, easterly wind directions increase markedly resulting in roughly similar strength/frequency of east and west winds during that season (Jury 1994). The strongest winds are observed at capes, including Agulhas, Infanta, Cape Seal, Robberg and Cape Recife (Jury & Diab 1989). Calm periods are most common in autumn (CCA & CSIR 1998).

Wind-driven upwelling occurs inshore along the South Coast, especially during summer when easterly winds prevail (Schumann *et al.* 1982; Walker 1986; Schumann 1998). Such upwelling usually begins at the prominent capes and progresses westwards (Schumann *et al*. 1982; Schumann 1988), and can result in temperature changes of up to 8° C within a few hours (Hutchings 1994).

Intensive upwelling of Indian Ocean Central Water occurs periodically over the shelf and shelf edge, along the inner boundary of the Agulhas Current (Schumann 1998). This process is primarily due to frictional interactions between the Agulhas Current and bottom topography (Hutchings 1994), and is most intense at the eastern boundary of the South Coast, where the cold bottom layer breaks the surface. Such shelf-edge upwelling largely defines the strong thermocline and halocline topography of the Agulhas Bank region, particularly in summer. A cool ridge of upwelled water that extends in a north-east (NE) – south-west (SW) direction over the mid-shelf regions between the shelf-edge upwelling and inshore waters close to the coast. (Swart & Largier 1987; Boyd & Shillington 1994; Schumann 1998), dividing the waters of the Agulhas Bank into the two-layered structure in the inshore region and a partially mixed structure in the eastern offshore region.

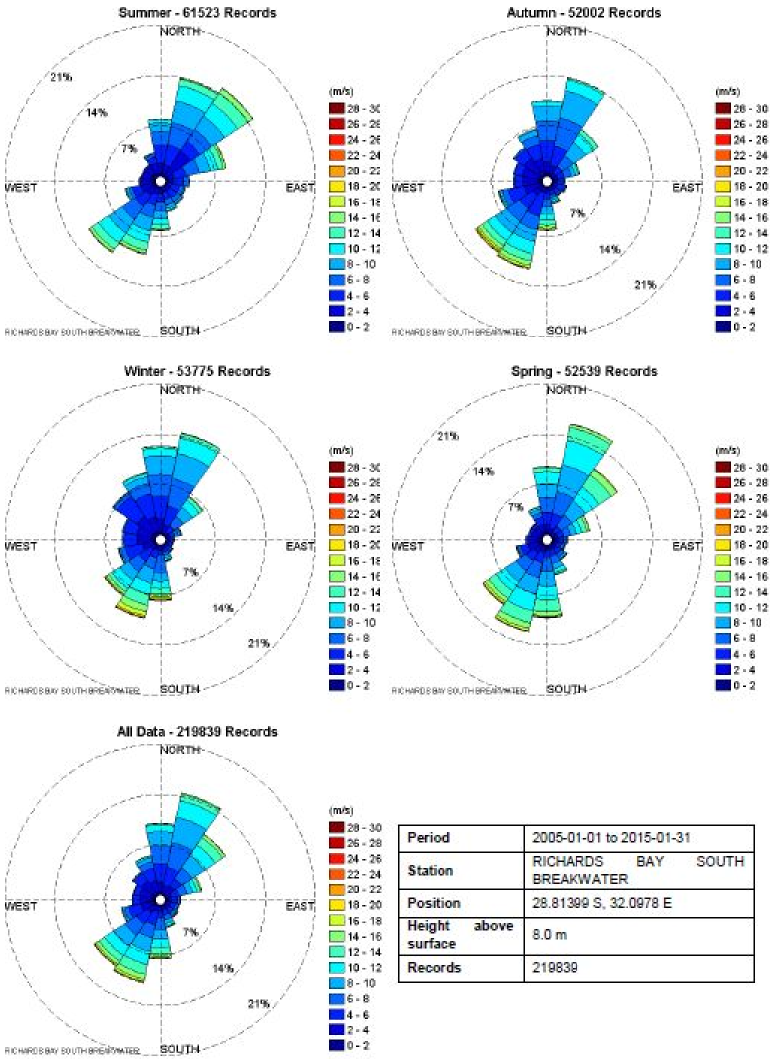
On the South Coast, the majority of waves arrive from the south-west quadrant (Whitefield *et al*. 1983), dominating wave patterns during winter and spring (Carter & Brownlie 1990). Waves from this direction frequently exceed 6 m (Swart & Serdyn 1981, 1982) and can reach up to 10 m (Heydorn 1989). During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

3.1.4 Nutrients

Nutrient inputs on the Tugela Banks are thought to originate from a combination of an upwelling cell off Richards Bay, the Tugela River, and a cyclonic lee eddy off Durban. The marine nutrients are derived from a topographically-induced upwelling cell just south of Richards Bay (Gill & Schumann 1979; Schumann 1988; Lutjeharms *et al.* 1989). The cold nutrient-rich upwelled waters are a source of bottom water for the entire Natal Bight (Lutjeharms *et al.* 2000a, b). The region is generally oligotrophic, with nutrients (silicates, phosphates and nitrates) occurring in very low concentrations in the upper mixed layer, increased below the pycnocline (Muir *et al.* 2016). Nutrient levels show temporal and spatial variability, with elevated levels typically occurring near the Thukela River mouth (Barlow *et al.* 2015; de Lecea *et al.* 2015; van der Molen *et al.* 2016). The cyclonic eddy incorporates enrichment, retention and concentration mechanisms, and together with the upwelling and elevated phytoplankton production in the north of the Bight (Lutjeharms *et al.* 2000b), creates the necessary conditions for enhanced survivorship of early larvae and juveniles of pelagic spawners (Beckley & van Ballegooyen 1992; Hutchings *et al.* 2003).

River discharge also has profound effect on physical, chemical and biological processes in coastal waters, and in KZN the effect of catchment-derived nutrient supply onto the Tugela Banks is thought to be pronounced given that nutrient supply from upwelling events is limited (Lamberth *et al.* 2009; Scharler *et al.* 2016). The importance of localised fluvial processes (under normal flow, reduced flow and flood events) in driving marine food webs has recently received much research attention (DWAF 2004; Lamberth *et al.* 2009; Turpie & Lamberth 2010). Nutrient inputs into the coastal environment through river runoff is predicted to stimulate phytoplankton and zooplankton production, and ultimately the larval, juvenile and adult fish that depend on them as a food source. Proposed impoundments on the Tugela River may thus have cascade effects on ecosystem functioning of the Tugela Banks, with far-reaching consequences for the sustainability of local fisheries.

The turbid, nutrient-rich conditions are also important for the life-history phases (breeding, nursery and feeding) of many demersal and pelagic species. The area harbours the only commercial shallow-water prawn trawl fishery in the country and is thus of considerable socio-economic importance to KZN.



Period	2005-01-01 to 2015-01-31
Station	RICHARDS BAY SOUTH BREAKWATER
Position	28.81399 S, 32.0978 E
Height above surface	8.0 m
Records	219839

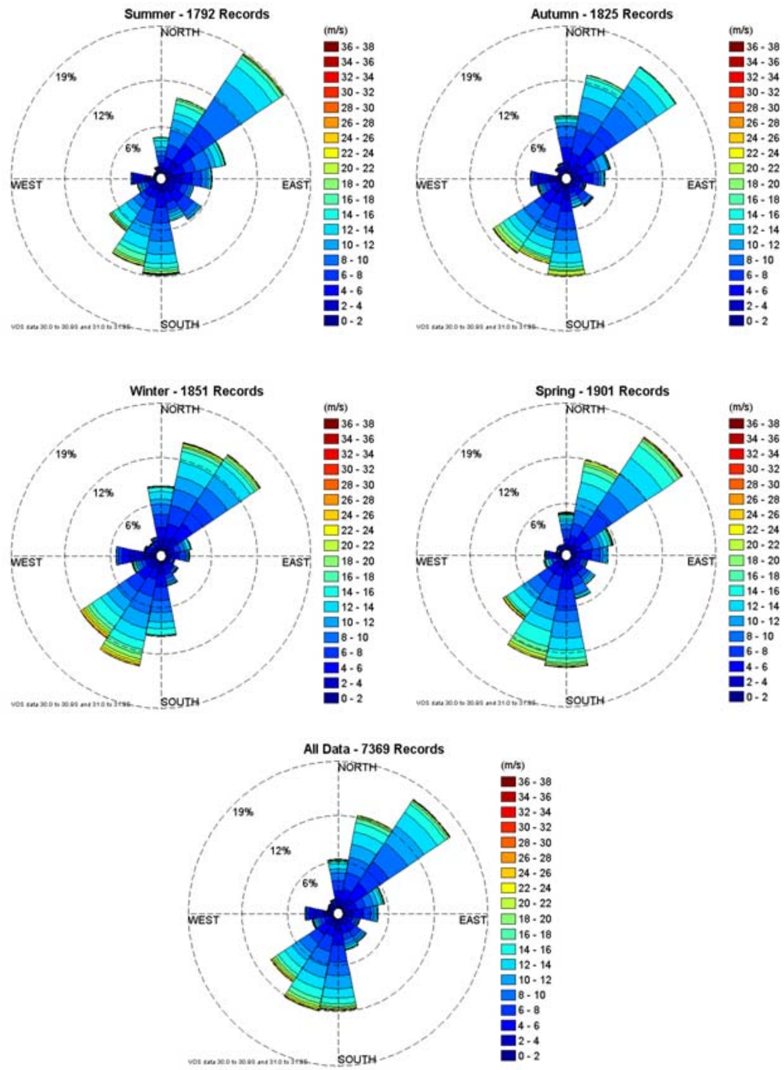
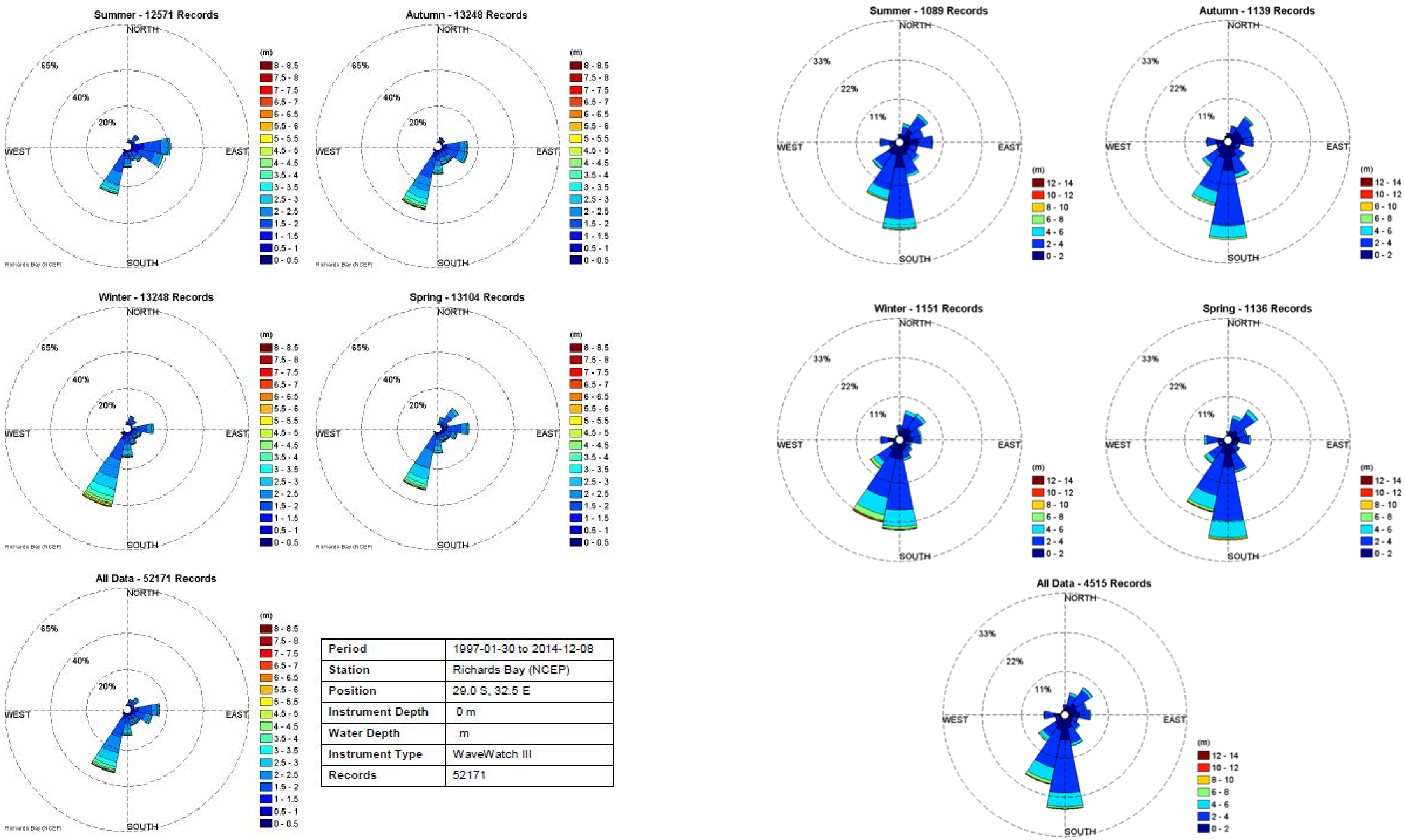


Figure 7: VOS Wind Speed vs Wind Direction for Richards Bay breakwater (28.8°S and 32.1° E) (left) and Port Shepstone (30.0° to 30.9° S and 31.0° to 31.9° E) (1960-02-15 to 2012-04-13; 7,369 records) (right) (from CSIR).



Period	1997-01-30 to 2014-12-08
Station	Richards Bay (NCEP)
Position	29.0 S, 32.5 E
Instrument Depth	0 m
Water Depth	m
Instrument Type	WaveWatch III
Records	52171

Figure 8: VOS Wave Height (Hmo) vs Wave Direction for a deepwater location offshore of Richards Bay (29.0°S and 32.5° E) (left) and for Port Shepstone (30.0° to 30.9° S and 31.0° to 31.9° E) (1960-02-15 to 2012-04-13; 4,515 records) (right) (from CSIR).

3.2. The Biological Environment

Biogeographically Block ER236 and the areas of interest for well drilling fall into the West Indian Offshore bioregion (Figure 9) (Lombard *et al.* 2004). The offshore areas comprise primarily deepwater benthic habitats and the water body. Due to limited opportunities for sampling, information on the pelagic and demersal communities of the shelf edge, continental slope, and upper and lower bathyal are very poorly known. Consequently, much of the information on the baseline environment provided below relates to the inshore (<50 m) and continental shelf (<200 m) regions, which fall within the Natal Bioregion (Figure 9).

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

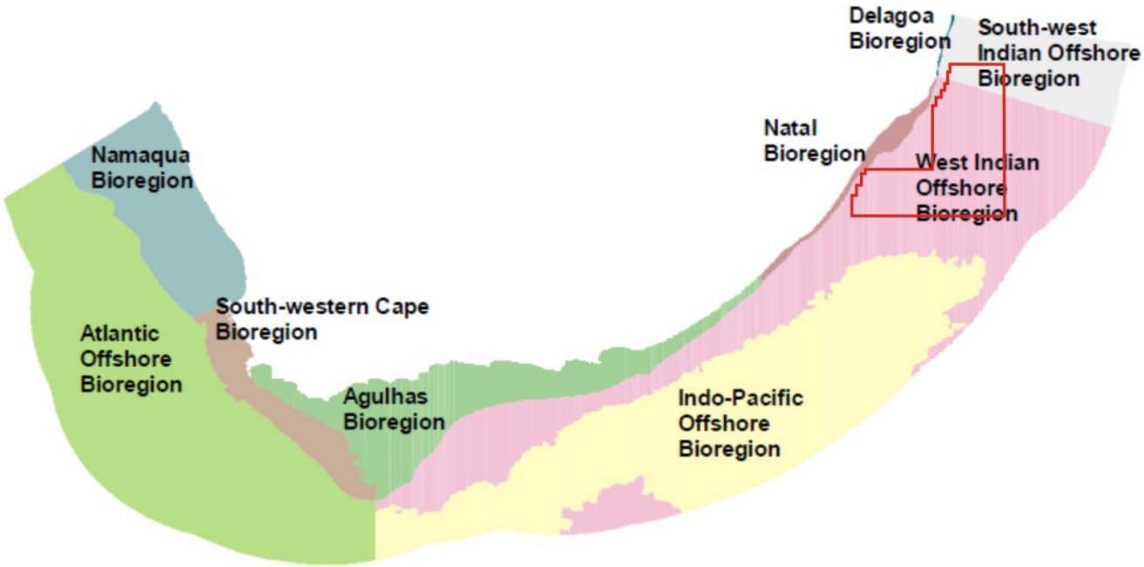


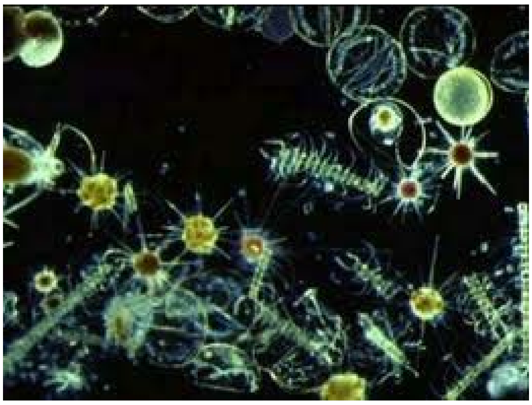
Figure 9: The South African inshore and offshore bioregions in relation to Block ER236 (red polygon) (adapted from Lombard *et al.* 2004).

3.2.1 Plankton

The nutrient-poor characteristics of the Agulhas Current water are reflected in comparatively low primary productivity in KwaZulu-Natal inshore areas, with chlorophyll a concentrations ranging between 0.03 and 3.88 µg/l (Carter & Schleyer 1988; see also Coetzee *et al.* 2010). Further offshore and in Block ER236, the pelagic environment is characterised by very low productivity, with the low variability in water-column temperature resulting in very low frequency of chlorophyll fronts. Phytoplankton, zooplankton and ichthyoplankton abundances in Block ER236 are thus expected to be extremely low. In contrast, on the Tugela Bank, short-term increases in productivity are associated with localised upwelling (Oliff 1973; Muir *et al.* 2016; Barlow *et al.* 2015), with phytoplankton being confined to the upper 100 m of the water column

(Muir *et al.* 2016). The distribution of phytoplankton and photosynthesis in the bight are, however, driven by temperature and irradiance, rather than nutrients (Barlow *et al*. 2013; Lamont & Barlow 2015). Continental shelf waters support greater and more variable concentrations of zooplankton biomass (Figure 10) than offshore waters (Beckley & Van Ballegooyen 1992), with species composition varying seasonally (Carter & Schleyer 1988). Copepods represent the dominant species group in shelf waters (Carter & Schleyer 1988), although chaetognaths are also abundant (Schleyer 1985). Zooplankton productivity appears associated with nutrient peaks from both the Durban Eddy as well as upwelling off Richards Bay (Pretorius *et al*. 2016), but dependence on nutrients derived from organic matter of marine origin (de Lecea *et al.* 2015) as well as terrestrial origin (de Lecea *et al.* 2013, 2016) has been demonstrated.

Similarly, primary productivity along the Eastern Cape Coast is comparatively low, with mean *chlorophyll a* concentrations averaging between 1-2 mg/m^3 over the whole year in the top 30 m of the water column. *Chlorophyll a* concentrations vary seasonally, being minimal in winter and summer (<1 – 2 mg/m^3), and maximal (2 - 4 mg/m^3) in spring and autumn (Brown 1992). Along the eastern half of the South Coast phytoplankton concentrations are usually higher than on the Agulhas Bank further west, comprising predominantly large cells (Hutchings 1994). This eastwards increase in *chlorophyll a* concentrations determines the increase in the biomass of mesozooplankton from ~0.5-~1.0 g C/m^2 in the west to ~1.0-~2.0 g C/m^2 further east. Dense swarms of euphausiids dominate this zooplankton component, and form an important food source for pelagic fishes (Cornew *et al*. 1992; Verheye *et al*. 1994).



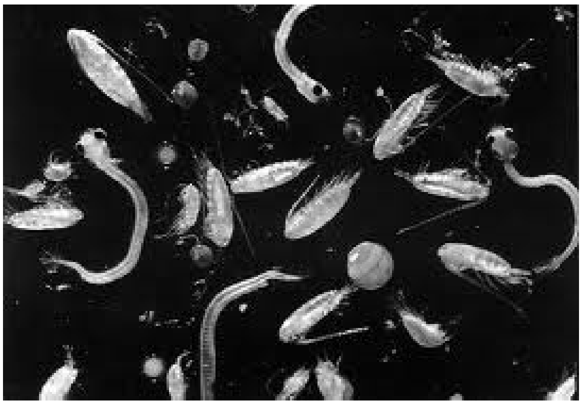


Figure 10: Phytoplankton (left, photo: hymagazine.com) and zooplankton (right, photo: mysciencebox.org) is associated with upwelling cells on the Tugela Bank.

Pilchard (*Sardinops sagax*) eggs occur in inshore waters (< 50 m) along the Eastern Cape and the southern KwaZulu-Natal coast with the onset of the 'sardine run' between May and July (Anders 1975; Connell 1996). The sardine and other clupeid eggs persist in inshore waters throughout winter – spring, before disappearing in early summer as the shoals break up and move northwards and further offshore (Connell 2010). Recent evidence suggests that the inshore areas of the KZN coast may also function as a nursery area for these small pelagic species during the winter months (Connell 2010; Coetzee *et al.* 2010) as freshwater flows from the large rivers serve as cues for spawning and the recruitment of juveniles (Lamberth *et al.* 2009). Anchovy (*Engraulis* *encrasicolus*) eggs were reported in the water column during December as far north as St Lucia (Anders 1975).

Numerous other fish species (e.g. squaretail kob and various sciaenids (snapper, sin croaker, beareded croaker)) use the Tugela Banks as a nursery area due to suitable food sources and protection from predators in the turbid water (Fennesy 1994a). For example, juvenile squaretail kob and snapper kob are seasonally abundant as a bycatch in the shallow-water prawn fishery from January to March, before moving from their feeding areas on the trawling grounds to low reef areas where their diet changes to include more teleosts (Fennessey 1994a). The Tugela Banks also serve as a nursery area for the endangered scalloped hammerhead shark, slinger and black mussel cracker (CBD 2013), and five species of dasyatid rays (Fennessy 1994b). The Banks serve as a spawning area for (amongst others) bull shark, sand tiger shark, black mussel cracker and king mackerel, as a spawning and migration route for sardine ('sardine run') (Haupt 2011; Harris *et al.* 2011; Sink *et al.* 2011; Ezemvelo KZN Wildlife 2012; CBD 2013). Numerous linefish species (e.g. dusky kob *Argyrosomus japonica*, elf *Pomatomus saltatrix*, seventy-four *Polysteganus undulosus*, steenbras *Petrus rupestrus*, black musselcracker *Cymatoceps nasutus*, white musselcracker *Sparodon durbanensis*, silverbream *Rhabdosargus holubi* and strepie *Sarpa salpa* leervis *Lichia amia*, geelbek *Atractoscion aequidens* and garrick *Lichia amia*) undertake spawning migrations along the inshore areas of the coast into KwaZulu-Natal waters during the winter months (Van der Elst 1976, 1981; Griffiths 1988; Garret 1988). Many of the species listed have been identified as either 'threatened' or listed as priority species for conservation due to over-exploitation (Sink & Lawrence 2008).

Following spawning during spring and summer (November to April), the eggs and larvae <u>of these linefish species</u> are subsequently dispersed southwards by the Agulhas Current (Connell 2010) (Figure 11), with juveniles occurring on the inshore Agulhas Bank (Van der Elst 1976, 1981; Garret 1988). Ichthyoplankton likewise is confined primarily to inshore waters (<200 m), with larval concentrations varying between 0.005 and 4.576 larvae/m^3. Concentrations, however, decrease rapidly with distance offshore (Beckley & Van Ballegooyen 1992). The areas of interest for well drilling lie offshore of major <u>linefish</u> spawning and migration routes, and ichthyoplankton abundance is likely to be low.

3.2.2 Soft-sediment Benthic Macro- and Meiofauna

The benthic biota of unconsolidated marine sediments constitutes invertebrates that live on (epifauna), or burrow within (infauna), the sediments, and are generally divided into megafauna (animals >10 mm), macrofauna (>1 mm) and meiofauna (<1 mm). While some species live at the water/sediment interface, others burrow into the sediment, usually to depths not exceeding 30 cm. The benthic fauna of the outer shelf, continental slope and beyond into the abyss are very poorly known, largely due to limited opportunities for sampling. To date very few areas of the continental slope off the East Coast have been biologically surveyed. Due to the lack of information on benthic macrofaunal communities beyond the shelf break, no description can be provided for the deeper portions (Lower Bathyal) of Block ER236. However, with little sea floor topography and hard substrate, such areas are likely to offer minimal habitat diversity or niches for animals to occupy. Detritus-feeding crustaceans, holothurians and echinoderms tend to be the dominant epi-benthic organisms of such habitats, with polychaete worms, molluscs, echinoderms and a variety of crustaceans typical of the infauna. The meiobenthos includes the smaller species such as nematode worms, flat worms, harpacticoid copepods, ostracods and gastrotriches. Some of the meiofauna are adept at burrowing while others live in the interstitial spaces between the sand grains. Also associated with soft-bottom substrates are demersal communities that comprise bottom-dwelling invertebrate species, many of which are dependent on the invertebrate benthic macrofauna as a food source.

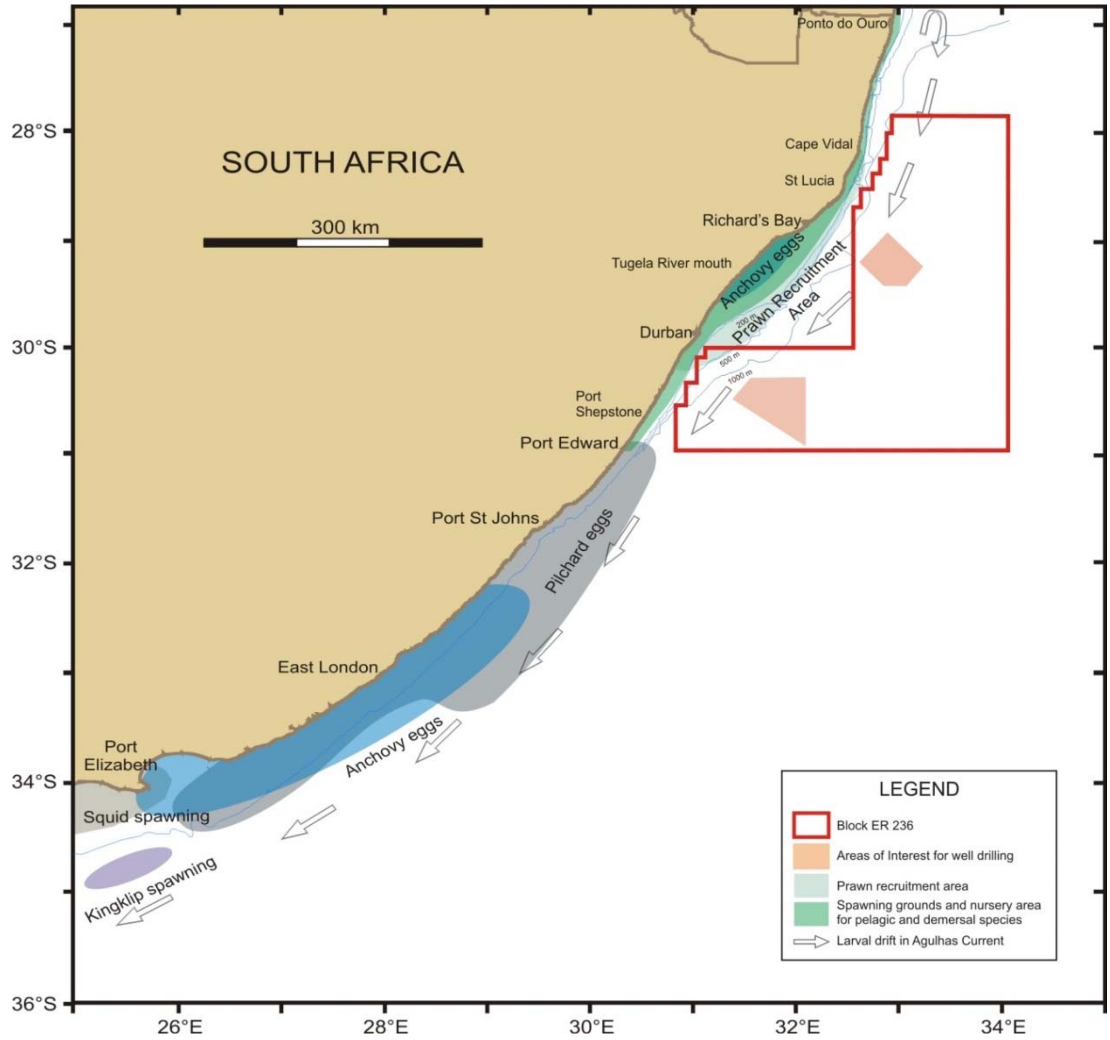


Figure 11: Major fish spawning, nursery and recruitment areas along the KwaZulu-Natal coast in relation to Block ER236 (red polygon) and the areas of interest for well drilling (orange squares).

The community structure of benthic biota is shaped by the prevailing physical (abiotic) conditions such as sediment grain size, temperature, salinity, turbidity and currents. Further shaping is derived from biotic factors such as predation, food availability, larval recruitment and reproductive success. The naturally high spatial and temporal variability for these factors results in seabed communities being both patchy and variable. The offshore soft-sediment habitat characterising the Thukela Banks is home to a unique fauna dominated by benthic and deposit feeders that favour muddy sediments and turbid waters. The offshore soft-sediment habitat characterising the Thukela Banks is home to a unique fauna dominated by benthic and deposit feeders that favour muddy sediments and turbid waters. In particular, the seabed in the nearshore areas off the KwaZulu-Natal coast tends to be patchy in terms of sediment composition, with significant sediment movement being frequently induced by the typically dynamic wave and current regimes (Fleming & Hay 1988). Consequently, the benthic macrofauna of inshore regions will be adapted to typically harsh conditions and frequent disturbance. Further offshore where near-bottom conditions are more stable, the macrofaunal communities will primarily be determined by sediment characteristics and depth.

A number of larger crustacean species form the basis for a small multispecies trawl fishery on the Tugela Bank and the shallow-water mud banks along the north east coast of KZN, well inshore of the areas of interest for well drilling. The species in question include various penaeid prawns, particularly *Fenneropenaeus indicus* (white prawn), *Metapenaeus monoceros* (brown prawn) and *Penaeus monodon* (tiger prawn) (Figure 12, left), as well as pink and red prawns (*Haliporoides triarthrus* and *Aristaeomorpha foliacea*), langoustines (*Metanephrops mozambicus* and *Nephropsis stewarti*) and red crab (*Chaceon macphersoni*). Most of the prawn species are fast-growing and short-lived (~1 year), and dependent on estuarine environments (e.g. Amatigkula and Tugela River mouths, St Lucia) during the early phase of their life cycle. Juveniles move out of estuaries in January and start recruiting onto the mud banks (and into the fishery) from February onwards, where they subsequently mature and reproduce (Wilkinson & Japp 2010). Abundance of these crustaceans varies seasonally and for shallow water species is strongly dependent on recruitment from estuarine nursery areas and river discharges (M&CM 2007). Prolonged closure of estuary mouths due to reduced river flow thus has important implications for the recruitment success of these crustacean. The shallow-water penaeid prawns typically occur on unconsolidated sandy to muddy sediments in <50 m depth on the Tugela and St Lucia Banks, whereas the deep-water species occur at depths between 360-460 m.

Figure 12: The tiger prawn *Panaeus monodon* (left) occur on shallow-water mud banks along the KwaZulu-Natal coast, whereas the Natal deep-sea rock lobster *Palinurus delagoae* (right) occurs on mud and rubble at depths of 100-600 m (Photos: platinum-premium.com; visualsunlimited.photoshelter.com).

Other deep-water crustaceans that may occur in the proposed areas of interest for well drilling are the shovel-nosed crayfish (*Scyllarides elisabethae*) and the Natal deep-sea rock lobster (*Palinurus delagoae*)(Figure 12, right). The shovel-nosed crayfish occurs primarily on gravelly seabed at depths of around 150 m, although it is sometimes found in shallower water. Its distribution range extends from Cape Point to Maputo. The Natal rock lobster similarly occurs on open areas of mud and rubble at depths of 100-600 m (Groeneveld & Melville-Smith 1995). Larvae settle offshore with juveniles and adults migrating inshore as they age. This species primarily occurs north of Durban. Other rock lobster species occurring on the east coast include the East Coast rock lobster (*Palinurus homarus*) and the painted spiny lobster (*Palinurus versicolor*), all of which, however, are typically associated with shallow-water reefs (Branch *et al.* 2010).

The deep-water rock lobster (*Palinurus gilchristi*) occurs on rocky substrate in depths of 90 - 170 m between Cape Agulhas and southern KwaZulu-Natal. Larvae drift southwards in the Agulhas Current, settling in the south of the Agulhas Bank before migrating northwards again against the current to the adult grounds (Branch *et al*. 2010). The species is fished commercially along the southern Cape Coast between the Agulhas Bank and East London, with the main fishing grounds being in the 100 – 200 m depth range south of Cape Agulhas on the Agulhas Bank, and off Cape St Francis, Cape Recife and Bird Island.

3.2.3 Reef Communities

The intertidal and shallow subtidal reefs along the East Coast of South Africa support a wide diversity of marine flora and fauna and a relatively high percentage of endemic species (Turpie *et al*. 2000, Awad *et al*. 2002). The subtidal shallow reefs of the East Coast range from rich, coral-encrusted sandstone reefs in the north to the more temperate rocky reefs further south. To the north of Block ER236, the Maputaland Coral Reef system, which extends from Kosi Bay to Leven Point (27°55'40"S, 32°35'40"E), constitute the southernmost coral-dominated reefs of Africa (UNEP-WCMC 2011). South of the iSimangaliso Wetland Park (St Lucia) reef habitat is provided by rock outcrops, although both hard and soft corals still occur. Known reefs inshore of the 200 m depth contour on the Thukela Bank were mapped by Turpie & Lamberth (2010). These fall well inshore of Block ER236. Both reef types (i.e. coral and rock outcrops) are characterised by diverse invertebrate and ichthyofaunal biota of Indo-Pacific origin (Figure 13, left). The invertebrate benthic communities associated with hard substrata boast a high diversity of hard and soft corals, sponges, tunicates and bivalve molluscs. Mobile benthic organisms associated with the reefs include a wide variety of echinoderms (urchins, starfish and sea cucumbers), gastropod molluscs and crustaceans. The coral reef habitat also provides shelter and a food source for the highly diverse Indo-Pacific reef fish community.

Both the coral-dominated reefs off Sodwana Bay (to the north of Block ER236) and the sandstone reefs off Durban and the KZN South Coast (inshore of Block ER236) are popular amongst divers for their wealth of invertebrate and fish diversity.

Figure 13: The reefs in KwaZulu-Natal are characterized by highly diverse invertebrate benthic communities and their associated fish fauna (Left, photo: www.sa-venues.com). The annual 'sardine run' attracts a large number of pelagic predator, which follow the shoals along the coast (Right, photo: www.sea-air-land.com).

In recent years there has also been increasing interest in deep-water corals and sponges because of their likely sensitivity to disturbance and their long generation times. These benthic filter-feeders generally occur at depths exceeding 150 m. Some coral species form reefs while others are smaller and remain solitary. Corals and sponges add structural complexity to otherwise uniform seabed habitats thereby creating areas of high biological diversity (Breeze *et al.* 1997; MacIssac *et al.* 2001). Their frameworks offer refugia for a great variety of invertebrates and fish (including commercially important species) within, or in association with, the living and dead frameworks. The canyons and feeder valleys on the shelf edge host a diversity of sponges, black corals, gorgonians, alcyonarian soft corals and stylasterine lace corals, which support a diverse epifauna including basket- and brittlestars, winged oysters and other molluscs (Sink *et al.* 2006). These invertebrates 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. The occurrence of such potentially vulnerable marine ecosystems in Block ER236 and the areas of interest for well drilling is unknown.

In the area of indirect influence, information about benthic reef communities and hard grounds is limited to descriptions of reef ecosystems in the Pondoland area (Celliers *et al*. 2007), and the Goukamma area on the south coast (Götz *et al*. 2009). The following description is summarised from these studies and from descriptions of South Africa's reef types provided in SANBI's Reef Atlas Project.

The nearshore reefs of the Pondoland coast shelter a mix of subtropical and warm-temperate fauna that manifest both a latitudinal and longitudinal shift in benthic composition over a relatively short distance. There is a change from low-diversity macroalgae dominated communities on the shallow high-profile reefs in the north to high-diversity (and comparatively high total living cover and high biomass) communities dominated by sponges, ascidians and bryozoans, on low-profile deeper reefs and reefs to the south. The shallow-water algae-dominated habitats also harbour hard corals (*Stylophora pistillata*), with wave action strongly influencing the community structure. This shift is concomitant with a reduction in available light associated with increased water turbidity. The shift from a habitat defined primarily by phototropism to a benthic community dominated by suspension-feeders is probably driven by higher sediment loads and the greater availability of nutrients coming from the numerous rivers along this portion of the coast. The reduction in available light with depth similarly allows non-phototrophic species – such as sponges and ascidians – to compete with algae for space on the reef.

Further south in the Port Elizabeth area, inshore reefs to -30 m depth also show relatively distinct changes in community structure, being characterised by diverse reef assemblages dominated by cauliflower soft coral (Sink *et al*. 2011). Further south off Goukamma, the reefs are characterised by equally distributed high and low profile areas. The benthic taxa were dominated by bryozoans and sponges (22.9% and 21.1% respectively), followed by gorgonians (16.4%), ascidians (13.7%) and algae (10.1%). Crinoids (8.4%) and hydrozoans (7.5%) constituted <10% of the overall occurrence. Community composition in this area was found to be strongly affected by linefishing, with higher abundance of algae and crinoids at fished sites, and higher sponge cover on reefs within the Goukamma Marine Protected Area (MPA).

3.2.4 Pelagic Invertebrates

Pelagic invertebrates that may be encountered in Block ER236 include the giant squid *Architeuthis* sp., a deep dwelling species usually found near continental and island slopes all around the world's oceans (Figure 14). Giant squid could thus potentially occur in Block ER236, although the likelihood of encounter is extremely low. Growing to in excess of 10 m in length, they are the principal prey of the sperm whale, and are also taken by beaked whaled, pilot whales, elephant seals and sleeper sharks. Nothing is known of their vertical distribution, but data from trawled specimens and sperm whale diving behaviour suggest they may span a depth range of 300 – 1,000 m.

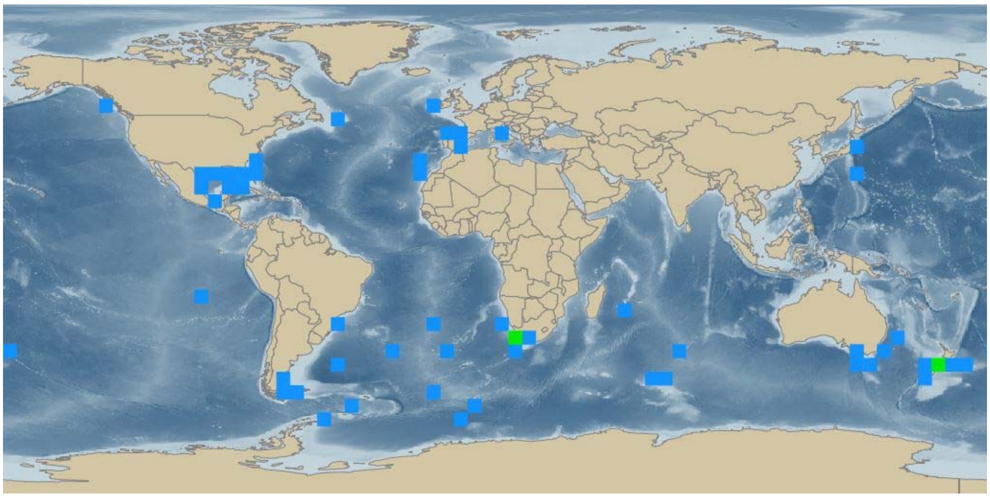


Figure 14: Distribution of the giant squid (http://iobis.org). Blue squares <5 records, green squares 5-10 records.

In the area of indirect influence, information on invertebrates occurring beyond -30 m depth along the South Coast is sparse. The squid (*Loligo vulgaris reynaudii*) occurs extensively on the Agulhas Bank out to the shelf edge (500 m depth contour) increasing in abundance towards the eastern boundary of the South Coast, especially between Plettenberg Bay and Algoa Bay (Augustyn 1990; Sauer *et al*. 1992; Augustyn *et al*. 1994). Adults are normally distributed in waters >100 m, except along the eastern half of the South Coast where they also occur inshore, forming dense spawning aggregations at depths between 20 - 130 m. These spawning aggregations are a seasonal occurrence reaching a peak in November and December.

3.2.5 Pelagic and Demersal Fish

Pilchards (*Sardinops sagax*) are a small pelagic shoaling species typically found in shelf water between 14 °C and 20 °C. Spawning occurs on the Agulhas Bank during spring and summer (November to April). During the winter months of June to August, the penetration of northerly-flowing cooler water along the Eastern Cape coast and up to southern KZN effectively expands the suitable habitat available for this species, resulting in a 'leakage' of large shoals northwards along the coast in what has traditionally been known as the 'sardine run'. Other pelagic shoaling species 'running' with the sardines but often occupying different depths in the water column include anchovy *Engraulis encrasicolus,* West Coast round herring *Etrumeus whiteheadi*,East Coast round herring *Etrumeus teres* and chub mackerel *Scomber japonicus* (Coetzee *et al.* 2010). The cool band of inshore water is critical to the 'run' as the sardines will either remain in the south or only move northwards further offshore if the inshore waters are above 20 °C. The shoals can attain lengths of 20-30 km and are typically pursued by Great White Sharks, Copper Sharks, Common Dolphins (Figure 13, right), Cape Gannets and various other large pelagic predators (www.sardinerun.co.za; O'Donoghue *et al.* 2010a, 2010b, 2010c). Recent studies have indicated that the annual 'sardine run' constitutes a migration to localised upwelling centres inshore of the Agulhas Current (East London and Cape St Lucia) that provide a favourable temperate spawning environment for these small pelagic fish species during and subsequent to their annual migration along the East Coast (Beckley & Hewitson 1994; Coetzee *et al.* 2010). The sardine run occurs along the continental shelf well inshore of Block ER236 and the areas of interest for well drilling.

Catch rates of several important species in the recreational shoreline fishery of KZN have been shown to be associated with the timing of the 'sardine run' (Fennessey *et al.* 2010). Other pelagic species that migrate along the KZN south coast include elf/shad (*Pomatomus saltatrix*), geelbek (*Atractoscion aequidens*), yellowtail (*Seriola lalandi*), kob (*Argyrosomus* sp.), seventy-four (*Cymatoceps nasutus*), strepie/karanteen (*Sarpa salpa*), Cape stumpnose (*Rhabdosargus holubi*), red steenbras (*Petrus rupestrus*), poenskop (*Cymatoceps nasutus)* and mackerel (*Scomber japonicus*), which are all regular spawners within KZN waters (Van der Elst 1988; Hutchings *et al.* 2003). Both the Tugela Bank (located inshore of Block ER236), as well as the many estuaries along the KZN coastline, serve as important nursery areas for many of these species. From an ecological perspective, the Thukela Banks are thought by some to function as an estuary, as freshwater flows from the large rivers are likely to provide cues for spawning and the recruitment of juveniles that use the bank as a nursery area (Lamberth *et al*. 2009).

A wide variety of demersal fishes and megabenthic invertebrates have been recorded in experimental trawls off Richards Bay (CSIR 2009) and between the Mlalazi River and Durban

(Fennessy 2016), inshore of the areas of interest for well drilling (Figure 15). Long-term datasets shows wide spatio-temporal variability in the diversity and abundance of trawl catches over the years (CSIR 2009). Similar variability has been reported from other regions of the world, and it appears to be an inherent feature of demersal fish and megabenthic invertebrate communities from near-shore soft-sediment habitats (Otway *et al.* 1996). Similarly, a high diversity of pelagic Teleosts (bony fish) and Chondrichthyans (cartilaginous fish) is associated with the numerous inshore reefs and shelf waters inshore of Block ER236. Many of the fishes are endemic to the Southern African coastline and form an important component of the commercial and recreational linefisheries of KZN (Table 4).

The shallower inshore areas (<100 m) along the South and East Coasts in the area of indirect influence comprise a varied habitat of rocky reefs and soft-bottom substrates, which support a high diversity of endemic sparid and other teleost species (Smale *et al*. 1994), some of which move into inshore protected bays to spawn (Buxton 1990) or undertake spawning migrations up the coast to KwaZulu-Natal.

Figure 15: A trawl sample taken 7 km off Richards Bay showing the wide variety of demersal fish and megabenthic invertebrates occurring in nearshore areas (CSIR 2009).

Fennessy (2016) reports on demersal fish communities across the KZN Bight to depths of 575 m. Species composition was structured mainly by depth (with diversity increasing with depth), substratum type (which in turn influences invertebrate macrofaunal community structure) and proximity to the Thukela River. The Thukela River itself was particularly influential species composition on the adjacent Thukela Bank that harbours a unique community. The fish communities were dominated by the Sparidae (five species), Triglidae (four species), Acropomatidae (three species), Macrouridae (eight species). Information on other neritic and demersal fish and megabenthic invertebrates beyond 600 m depth and in the areas of interest for well-drilling is lacking and no description of these communities can be can be provided for Block ER236.

Table 4: Some of the more important linefish species landed by commercial and recreational boat fishers along the East Coast (adapted from CCA & CMS 2001).

Common Name	Species Name
Demersal teleosts	
Blue hottentot	*Pachymetopon aeneum*
Cape stumpnose	*Rhabdosargus holubi*
Dageraad	*Chrysoblephus christiceps*
Englishman	*Chrysoblephus anglicus*
Mini kob	*Johnius dussumieri*
Natal stumpnose	*Rhabdosargus sarba*
Poenskop	*Cymatoceps nasutus*
Pompano	*Trachinotus africanus*
Red steenbras	*Petrus rupestris*
Red stumpnose	*Chrysoblephus gibbiceps*
River bream	*Acanthopagrus berda*
Rockcod	*Epinephalus* spp.
Santer	*Cheimerius nufar*
Scotsman	*Polysteganus praeorbitalis*
Slinger	*Chrysoblephus puniceus*
Snapper salmon	*Otolithes ruber*
Spotted grunter	*Pomadasys commersonnii*
Squaretail kob	*Argyrosomus thorpei*
White steenbras	*Lithognathus lithognathus*
Pelagic species	
Elf	*Pomatomus saltatrix*
Garrick/leerfish	*Lichia amia*
Geelbek	*Atractoscion aequidens*
Green jobfish	*Aprion virescens*
King mackerel	*Scomberomorus commerson*
Kob	*Argyrosomus* spp
Kingfish species	*Caranx* spp.
Queenfish	*Scomberoides commersonianus*
Queen mackerel	*Scomberomorus plurilineatus*
Tenpounder	*Elops machnata*
Wahoo	*Acanthocybium solandri*
Yellowtail	*Seriola lalandi*
Chondrichthyans	
Bronze whaler shark	*Carcharhinus brachyurus*
Dusky shark	*Carcharhinus obscurus*
Hammerhead shark	*Sphyrna* spp.
Sandshark	Rhinobatidae
Milkshark	*Rhizoprionodon acutus*
Skates	Rajiformes
Stingray	Dasyatidae

The fish most likely to be encountered on the shelf, beyond the shelf break and in the offshore waters of Block ER236 are the large migratory pelagic species, including various tunas (Figure 16, left), billfish (Figure 16, right) and sharks (Figure 17), many of which are considered threatened by the International Union for the Conservation of Nature (IUCN), primarily due to overfishing (Table 5). Tuna and swordfish are targeted by high seas fishing fleets and illegal overfishing has severely damaged the stocks of many of these species. Similarly, pelagic sharks, are either caught as bycatch in the pelagic tuna longline fisheries, or are specifically targeted for their fins, where the fins are removed and the remainder of the body discarded.

Figure 16: Large migratory pelagic fish such as longfin tuna (left) and blue marlin (right) occur in offshore waters (photos: www.samathatours.com; www.osfimages.com).

Table 5: Some of the more important large migratory pelagic fish likely to occur in the offshore regions of the East *Coast. The* Global IUCN Conservation Status and NEMBA listing are also provided.

Common Name	Species	IUCN Conservation Status	NEMBA Marine TOPS
Tunas			
Southern Bluefin Tuna	*Thunnus maccoyii*	Critically Endangered	
Bigeye Tuna	*Thunnus obesus*	Vulnerable	
Longfin Tuna/Albacore	*Thunnus alalunga*	Near Threatened	
Yellowfin Tuna	*Thunnus albacares*	Near Threatened	
Frigate Tuna	*Auxis thazard*	Least concern	
Eastern Little Tuna/Kawakawa	*Euthynnus affinis*	Least concern	
Skipjack Tuna	*Katsuwonus pelamis*	Least concern	
Billfish			
Blue Marlin	*Makaira nigricans*	Vulnerable	
Striped Marlin	*Kajikia audax*	Near Threatened	
Sailfish	*Istiophorus platypterus*	Least concern	
Swordfish	*Xiphias gladius*	Least concern	
Black Marlin	*Istiompax indica*	Data deficient	
Pelagic Sharks			
Great Hammerhead Shark	*Sphyrna mokarran*	Endangered	Endangered
Scalloped Hammerhead	*Sphyrna lewini*	Endangered (SWIO subpop.)	Endangered
Smooth Hammerhead	*Sphyrna zygaena*	Vulnerable	
Pelagic Thresher Shark	*Alopias pelagicus*	Vulnerable	
Bigeye Thresher Shark	*Alopias superciliosus*	Vulnerable	

Common Name	Species	IUCN Conservation Status	NEMBA Marine TOPS
Common Thresher Shark	*Alopias vulpinus*	Vulnerable	
Oceanic Whitetip Shark	*Carcharhinus longimanus*	Vulnerable	
Dusky Shark	*Carcharhinus obscurus*	Vulnerable	
Great White Shark	*Carcharodon carcharias*	Vulnerable	Vulnerable
Shortfin Mako	*Isurus oxyrinchus*	Vulnerable	
Longfin Mako	*Isurus paucus*	Vulnerable	
Whale Shark	*Rhincodon typus*	Endangered	Vulnerable
Blue Shark	*Prionace glauca*	Near Threatened	
Tiger Shark	*Galeocerdo cuvier*	Near Threatened	Protected

Two species likely to be encountered in the areas of interest for well-drilling are singled out for further discussion, namely the great white shark *Carcharodon carcharias* (Figure 17, left) and the whale shark *Rhincodon typus* (Figure 17, right). Both species have a cosmopolitan distribution and although not necessarily threatened with extinction, the great white shark is described as 'vulnerable' and the whale shark as 'endangered' in the IUCN Red listing, and are listed in Appendix II (species in which trade must be controlled in order to avoid utilization incompatible with their survival) of CITES (Convention on International Trade in Endangered Species) and Appendix I and/or II of the Bonn Convention for the Conservation of Migratory Species (CMS). The great white shark and whale shark are both also listed as 'vulnerable' in the List of Marine Threatened or Protectes Species (TOPS) as part of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA).

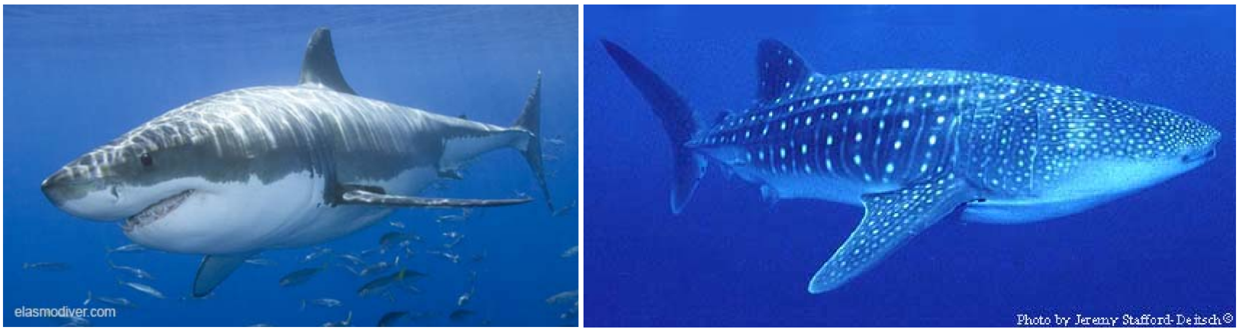


Figure 17: The great white shark *Carcharodon carcharias* (top left) and the whale shark *Rhincodon typus* (bottom right) (photos: www.flmnh.ufl.edu).

The great white shark is a significant apex predator along the South African south and east coasts, and was legislatively protected in South Africa in 1991 in response to global declines in abundance. Long-term catch-per-unit-effort data from protective gillnets in KwaZulu-Natal, however, suggest a 1.6% annual increase in capture rate of this species following protection, although high interannual variation in these data lessen the robustness of the trend (Dudley & Simpfendorfer 2006).

White sharks migrate along the entire South African coast, typically being present at seal colonies during the winter months, but moving nearshore during summer (Johnson et al. 2009). Recent research at Mossel Bay into the residency patterns of white sharks revealed that male sharks display low site fidelity, often rapidly moving in an out of the area. Females in contrast, display high site fidelity and may remain resident in the area for up to two months (Koch & Johnson 2006). Great white sharks are, however, capable of transoceanic migrations (Pardini *et al.* 2001; Bonfil *et al.* 2005; Koch & Johnson 2006), with recent electronic tag data suggesting links between widely separated populations in South Africa and Australia and possible natal homing behaviour in the species. Although during transoceanic migrations they appear to spend most of the time just below the sea surface, frequent deep dives to a much as 980 m are made whilst *en route*. Long-distance return migrations along the South African coast are also frequently undertaken (Figure 18), particularly by immature individuals (Bonfil *et al.* 2005). These coastal migrations, which are thought to represent feeding-related events, potentially traverse Block ER236.

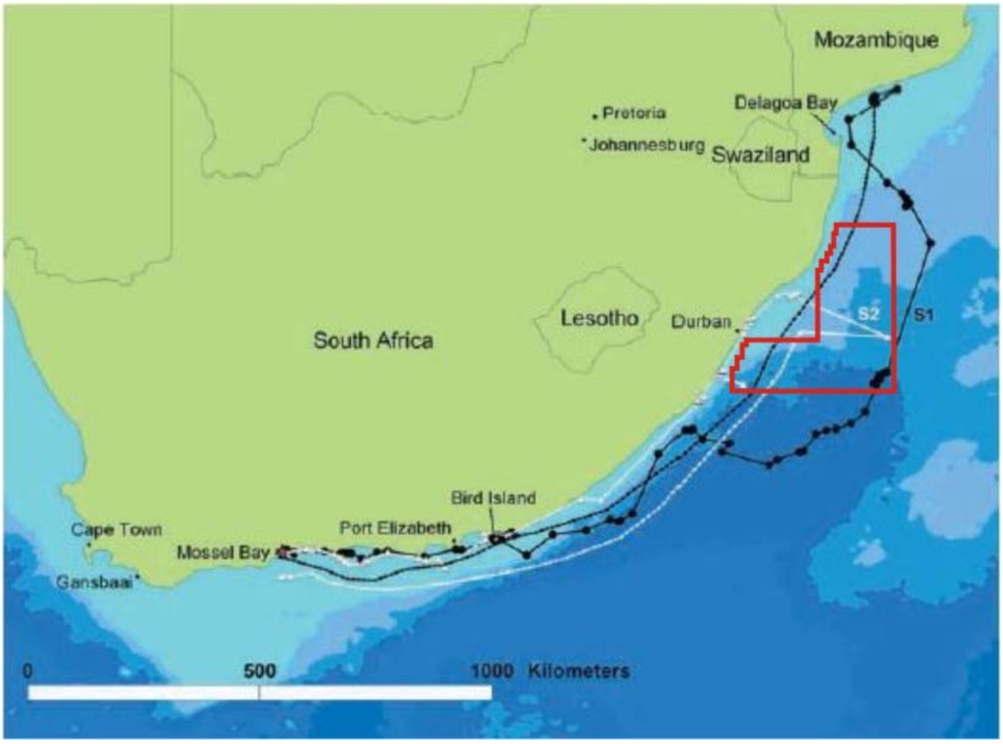


Figure 18: Long-distance return migrations of two tracked great white sharks along the South African coast in relation to Block ER236 (red polygon). The black trace shows a migration from 24 May – 2 November 2003; the white trace shows a migration from 31 May – 1 October 2004 (adapted from Bonfil *et al.* 2005)

Whale sharks are regarded as a broad ranging species typically occurring in offshore epipelagic areas with sea surface temperatures of 18–32°C (Eckert & Stewart 2001). Adult whale sharks reach an average size of 9.7 m and 9 tonnes, making them the largest non-cetacean animal in the world. They are slow-moving filter-feeders and therefore particularly vulnerable to ship strikes (Rowat 2007). Although primarily solitary animals, seasonal feeding aggregations occur at several coastal sites all over the world, those closest to the project area being off Sodwana

Bay in the Greater St. Lucia Wetland Park, Tofo Reef near Inhambane in Mozambique, Nosy Be off the northwest coast of Madagascar, and the Tanzanian islands of Mafia, Pemba, and Zanzibar (Cliff *et al.* 2007). Off the KZN coast, whale shark abundance in nearshore waters increases in late October-early November, with most animals moving in a northwards direction, possibly *en route* to the aggregation area around Ponta Tofo in Mozambique, where numbers peak between November and May.

Satellite tagging of whale sharks has revealed that individuals may travel distances of tens of 1,000s of kms (Eckert & Stewart 2001; Rowat & Gore 2007; Brunnschweiler *et al.* 2009). Recently the movements of a whale shark tagged in southern coastal Mozambique were monitored crossing the Mozambique Channel, passing the southern tip of Madagascar and into the Madagascar Basin. Although the fish spend most time in the upper 25 m of the water column while on the continental shelf, once in deep water, the occurrence of dives into mesopelagic and bathypelagic zones increased, with dives to a depth of 1,286 m being recorded. These dives were thought to represent search behaviour for feeding opportunities on deep-water zooplakton (Brunnschweiler *et al.* 2009). While there is a possibility of whale sharks migrating through the areas of interest for well drilling, the likelihood of an encounter is relatively low.

3.2.6 Coelacanths

Location, History and Distribution

For over four decades the Comores Archipelago was assumed to be the only natural habitat of the living Africa coelacanth *Latimeria chalumnae*, with their distribution restricted to depths of ~120-300 m on relatively sediment-poor, steep volcanic (basalt) dropoffs with caves.

The discovery by SCUBA divers of a group of coelacanths in the relatively shallow waters (90–140 m depth) of a submarine canyon off the Greater St Lucia Wetland Park (GSLWP) World Heritage Site in November 2000 (Venter *et al*. 2000), however, demonstrated that the fish were not confined only to the Comoros Islands. Since then captures have been made in bottom trawl and deep-set gillnets off Kenya (De Vos & Oyugi 2002) and Tanzania (Nyandwi 2006; Benno *et al*. 2006). In Tanzania, 21 confirmed catches were made between September 2003 and July 2005 (with a further 8 reported since), mostly from the outer reefs south of Tanga area in the north of the country (Benno *et al*. 2006). Although the habitats in which these specimens were caught are ill-defined, simple bathymetric surveys have suggested that the bottom profile in the Tanga region consists of a series of 10–15-m-high terraces between 70–140 m depth (Benno *et al*. 2006) whereas in the south, submarine depressions interpreted as canyons have been observed at depths of 400 m (Nyandwi 2010).

In contrast, those fish caught off East London (1938), Mozambique (1991: Bruton *et al.* 1992), Madagascar (1995: Heemstra *et al*. 1996; also 1997, 2001 along with other rumored and newly reported Madagascar catches, some of them from canyons) and Kenya (2001: De Vos & Oyugi 2002) were reported to have been captured over predominantly sandy, low-relief seabed. Assuming that steep dropoffs with caves are the required habitat for the species, these catches were thought to be drifters swept away from the Comores by the strong currents typical of the African East Coast.

Schartl *et al.* (2005) suggested that the scattered groups of African coelacanths probably originate from a single remote population, possibly the Comoros or other, unknown habitats in the Indian Ocean. Recent genetic studies, however, suggest that the coelacanths from Northern Tanzania and Kenya are genetically distinct from the population in southern Tanzania and the Comores (Nikaido *et al*. 2011).

Coelacanth Discoveries from Other Areas

Coelacanth discoveries have also been made in Indonesia, but genetic tissue analyses have revealed that these are a separate species, *Latimeria menadoensis*. The first Indonesian coelacanths were similarly caught by deep-set shark gillnets off a volcanic island famed for its steep coral reef dropoffs into over 2,000 m depth (Erdmann 2006). Subsequent, submersible dives found the fish in caves within steep carbonate rocks (Fricke *et al*. 1991; Fricke & Hissmann 2000; Fricke *et al*. 2000), thus resembling the habitats of their African counterparts.

Habitat Requirements and Characteristics

From the pioneering studies in the Comoros by Hans Fricke and associates using the submersible *Jago*, it was predicted that coelacanths have a narrow habitat-tolerance range, namely :

- They require caves and overhangs in steep dropoffs in which to shelter,
- They are sensitive to temperatures above 21°C,
- Being slow swimmers (~5 cm/s), they avoid strong currents,
- They require water with a high oxygen concentration, and
- They emerge from their cave shelters at night to hunt, typically in deeper water.

Following the coelacanth discovery off the GSLWP, numerous bathymetric and submersible surveys were undertaken between 2002 and 2004 as part of the African Coelacanth Ecosystem Project (ACEP) thus providing opportunities to compare the ecological requirements, lifestyle and activity patterns of coelacanths from different areas, and to investigate genetic similarities and differences between and within populations. Together with the discoveries of coelacanths from other areas, the surveys revealed that coelacanths :

- appear to be more widely distributed than originally thought,
- are more tolerant of variations in temperature, oxygen, light and depth than initially perceived,
- exhibit a broader tolerance range of different structural habitats than concluded from Comoran data, and on the East African coast appear to favour submarine canyons, but
- are not necessarily present where these conditions are met, suggesting that the population size in the GSLWP may be lower than formerly predicted.

The results of the studies conducted as part of the ACEP are summarised below.

Bathymetry and Geolomorphology

Multibeam bathymetric surveys were undertaken off the Maputaland coast, with the objective of defining potential coelacanth habitats within submarine canyons in the area (Ramsay & Miller 2006). A total of 23 submarine canyons, including six mature-phase (large, steep-sided features breaching the continental shelf), 17 youthful-phase (smaller, deepwater features occurring near the continental margin) and numerous incipient (shallow linear depressions on the seafloor) canyons that run approximately perpendicular to the shore, were identified along the northern KwaZulu-Natal coastline. The canyon heads breach the relatively narrow (2-4 km) shelf at depths of 90-120 m, and their thalwegs (bottoms) have depths of several hundred metres. The northern margins of the canyon heads are typically steeper and more stable than the southern margins. Stratified sedimentary rock outcrops occur as cliffs and intermittent sandy terraces at depths of between 40-130 m. Dissolution of the sedimentary rock during geological periods of lower sea level resulted in the formation of caves and overhangs below the steep canyon edge (~100 m depth) and along the canyon walls down to 160 m (Ramay & Miller 2006). In terms of canyon morphology, the terraces located at 110 -130 m below current sea level are thought to be optimal coelacanth habitats. In contrast, canyons occurring in close proximity to active subaqueous dune fields are thought to be suboptimal habitats for coelacanths, as excessive sediment movement is expected to result in slumping along unstable canyon margins, with the erosive effect of sediments likely having a negative impact on coelacanth populations through destruction of their preferred cave habitats.

Despite these canyon habitats in the GSLWP differing considerably from those of the volcanic Comoros, overhangs and caves occur in both areas, providing sheltered habitats for coelacanths to occupy during the day. The caves in the canyon edge and walls vary in size and shape; some larger caves penetrate >6 m horizontally into the slope and may be several metres wide and high, while others are lower and less spacious. Cave entrances are typically as wide as the main compartment, with smaller chambers in the ceiling or walls occurring on occasion. The roofs and walls of the caves are of karstic carbonate rock characterized by a rugged surface with sharp ledges and grooves, while the cave floors are rocky or sandy, and sometimes covered with soft silt (Hissmann *et al*. 2006).

Data from the Comoros, which indicated that coelacanths live in deep cool water, led to an initial expectation that coelacanths in the Maputaland canyons would be numerous, assuming that those found in the shallow canyon heads were representative of a deeper, more extensive population. However, the coelacanths sighted off Sodwana were confined to the narrow belt (90–140 m depth) in the canyons where caves, overhangs or broken boulder areas offering shelter were abundant. Coelacanths occurred singly or in groups of up to seven individuals in the caves, and although they showed site fidelity, they appear to use several different caves within their home range. The sizes of home ranges in the canyons off the GSLWP have not been defined, but individuals are known to move the 4 km distance between the Jesser and Wright canyons in the Sowdana Cayon complex (Hissman *et al*. 2006). In the Comoros, a home range might extend for about eight kilometres. Some of the Sodwana coelacanths are known to be resident within the canyon habitat for at least four years. Aggregations of these fish in caves are not thought to be a seasonal occurrence.

Green *et al*. (2006) used pre-existing bathymetric data sets and geo-referenced charts to identify further potential canyons on the southeast African continental shelf and slope. They concluded that further coelacanth habitats could be expected on the continental shelf off the Port Shepstone–Port St Johns stretch of coastline (the expected southernmost limit to coelacanth distribution) and on the outer shelf area between Olumbe and Porto Amelia, and Pemba, Nacala, Mossuril and Vilanculos in northern Mozambique. These areas are characterised by a high density of submarine canyons, and based on the regional geological setting, good cave development in the canyon heads is expected. Although off Tanzania submarine canyons seem to be less well developed, the sparse data identified canyon features off Mtwara, Lindi and Mchinga. In Madagascar, submarine canyons occur off the west coast at Toliara (where a coelacanth was found) and north of Morondava. Submarine canyons are more prevalent on the Madagascan east coast with examples occurring at Antsiranana and Ankerika, between Ambohitralanana and Masoala and between Fenerive and Ankirihiry (north of Toamasina).

Physical Requirements

The Agulhas Current consitutes a confluence of flows from the Mozambique Channel and southern Madagascar. Satellite imagery suggests that from its position further offshore in the Delagoa Bight, it shifts towards the coast near Ponto do Ouro, becoming fully formed in the vicinity of Sodwana Bay and propagating south-westwards as cyclonic and anti-cyclonic eddies. The narrow shelf area of the Maputaland coast is thus characterised by a stong, dominant, southward current, which commonly reaches 0.5-0.75 m/s. On occasions, however, the Agulhas current can be moved away from the shelf by the formation of cyclonic eddies, which induce shelf-edge upwelling (Roberts *et al.* 2006).

Current velocities off Sodwana, however, decrease rapidly with depth, but also exhibit horizontal velocity gradients along the shelf edge. The vertical velicity structure observed along the slope ranged from 20-80 cm/s in the 100-140 m depth zone at which coelacanths occur (Roberts *et al.* 2006). Within the submarine canyons themselves, submersible and Trimix dives have detected weak or the relative absence of currents beyond 50 m depth and near the seabed. The presence of a layer of silt on ledges along canyon walls, and occurrence of fragile glass sponges on steep cliffs, were also indicative of low current velocities near the seabed (Hissmann *et al.* 2006; Sink *et al*. 2006). These calm seabed conditions would enable the coelacanths, which are sluggish fish, to migrate easily within and between canyons. Current velocities measured in coelacanth habitats in the Comoros (Hissmann *et al*. 2000) ranged from 4.9 cm/s at ~160 m to 3.1 cm/s at 270 m. Under these conditions coelacanths were able to leave their caves at night to slowly swim along the volcanic slopes for distances of up to 10 km, before returning to their caves.

The normal temperature range for coelacanths in the Comoros, South Africa and Indonesia is 15-20°C. The upper threshold limit for coelacanths is thought to be 22–23°C (Fricke *et al.* 1991), although fish have been sighted resting in caves at a temperature above 24°C. The optimum temperature for oxygen uptake in coelacanths is 15°C (Hughes & Itazawa 1972), with higher temperatures resulting in respiratory distress. The Sodwana coelacanths would thus be expected to occur at depths beyond 200 m, but as there appear to be fewer adequate shelters beyond 140 m, their occurrence within caves in the 90-140 m depth range may be due to a necessity to remain quiescent in order to keep metabolic rate and oxygen consumption low (Roberts *et al*. 2006). South African coelacanths can tolerate a (tidally induced) temperature range of 6°C within a single day. Off the Maputaland coast, the 16 – 20°C isotherms typically lie at between 100-140 m depth, which is ~100 m shallower than in the Comoros (200-300 m). The shallowest depth at which a coelacanth has been recorded was at 54 m, below an overhang in a deep reef complex on the shelf south of Diepgat Canyon (Hissmann *et al*. 2006; Roberts *et al*. 2006) south of Sodwana Bay. This occurrence was, however, coincident with a significant upwelling event, when temperatures at this depth decreased to 17–19°C (Roberts *et al*. 2006).

Surface dissolved oxygen levels off the GSLWP were found to be in the order of 3.6 ml/l. A shallow oxygen minimum (a characteristic found throughout most of the South-West Indian Ocean) occurred at between 100-250 m depth, where levels dropped to 3.2 ml/l. Immediately below this oxygen minimum layer, concentrations increased again to resemble those at the surface before declining with depth to 3.2 ml/l at 1,000 m. The minimum oxygen layer thus correspondes with the depths at which the Sodwana coelacanths occur (Roberts *et al.* 2006; Hissmann *et al*. 2006). Off the Comoros, the shallow oxygen minimum of 2.9 ml/l occurs between 200-320m, which likewise corresponds to depths at which coelacanths occur there.

Potential Food Sources

Coelacanths are nocturnal drift hunters, feeding opportunistically on benthic, epibenthic and mesopelagic fish and cuttlefish found in their deep reef and volcanic slope habitats. No attempts of coelacanths feeding on species considered potential prey have been observed off Sodwana, although the density and diveristy of fish at the canyon edges and within the caves was high (Hissmann *et al*. 2006). Transmitter tracking experiments off Sodwana indicated nocturnal activity between 70 – 130 m which was at or above the depth of the daytime refuges, and the depth at which potential prey species were most abundant. Comoran coelacanths in contrast are most active between 200 m to 300 m depth, which is below their resting depth. Larger coelacanths off the Comoros regularly traverse the 100-500 m depth range with the deepest record at almost 700 m. This is in response to increasing abundance of bentho-pelagic and nocturnally active prey with depth (Fricke & Hissmann 2000).

Submersible and Trimix dives in the Sodwana submarine canyons have identified at least 54 species of fish from 18 taxa (Heemstra *et al*. 2006a; Sink *et al*. 2006). An additional 94 fish species are known from depths of 100-200 m along the KwaZulu-Natal coast (Heemstra *et al*. 2006a). The abundance of planktivorous species (fusiliers and lutjanids) along the canyon margins are indicative of the topographic upwelling that drives primary production in the canyon habitat. Other shoaling and commercially important sparids such as slinger, *Chrysoblephus puniceus*, Englishman, *Chrysoblephus anglicus*, Scotsman, *Polysteganus praeorbitalis*, and blueskin, *P. caeruleopunctatus*, as well as large predatory fish, including serranids, were also reported (Sink *et al*. 2006). These fish are all thought to consitute potential prey for coelacanths. The known coelacanth habitat in South Africa thus supports a greater density of large, transient and resident fish than their habitat in the Comoros, where the distribution of prey species has been cited as a factor limiting the distribution and abundance of the coelacanth (Bruton & Armstrong 1991; Fricke & Plante 1988; Fricke & Hissmann 2000). The biomass of fish in the Sodwana canyon habitat is estimated to be three to four times higher than in similar coelacanth habitat in the Comoros (Heemstra *et al*. 2006b). Comprehensive lists of known and potential prey species off the Comoros and Sodwana are provided in Heemstra *et al*. (2006a; 2006b).

Coelacanth Morphology and Behaviour

Coelacanths are large, lobe-finned fish that grow up to 1.8 m in length, can weigh 95 kg and may live as long as 60 years. Unique anatomical feature of coelacanths include:

- the retention of a notochord, a hollow, fluid-filled tube underlying the spinal cord and extending the length of the body. In most other vertebrates this is replaced by the vertebral column early in embryonic development. The fluid in the notochord is a low

viscosity lipid, under slight pressure, and similar to the lipids that fill the sinuses and organs of the fish's body.
- the presence of a rostral organ in the snout that is part of the electrosensory system to help in the location of prey;
- an intracranial joint in the skull that allows the anterior portion of the cranium to swing upwards, greatly enlarging the gape of the mouth;
- vertebrae that are incompletely formed or totally lacking bony centra;
- an oil-filled gas bladder, which together with the lipid-filled body provides buoyancy and enables the animal to undertake considerable vertical movement in the water column;
- a braincase containing only 1.5% brain tissue, the remainder being filled with fat; and
- well-developed eyes with reflecting tapita to enhance night vision.

Coelacanths are ovoviparous, giving birth to as many as 26 live pups which develop from eggs in the oviduct, feeding off a large yolk sac until birth (Smith *et al*. 1975). The gestation period estimated at 3 years, which would be the longest known in vertebrates (Froese & Palomares 2000). Although their reproductive behaviour is poorly known, recent data suggest that coelacanths have a monogamous mating system and that individual relatedness is not important for mate choice (Lampert *et al*. 2013).

Coelacanths typically occur singly or in groups, congregating in caves and under overhangs during the day, with as many as 14 fish reported crowded together in a single cave. Although several individuals occupy overlapping home ranges, no aggressive encounters between individiuals have been observed. A single fish may frequent several caves within its home range, and three individuals were sighted within the same home range over a period of two years. After sunset, the fish leave their caves and drift slowly, 1-3 metres off the bottom, presumably looking for food. During their nightly foraging swims, they have been observed to perform head-stands, with the body in a vertical position, the head near the bottom, holding this position for a few minutes at a time. This behaviour is thought to be used when scanning the bottom for prey with their rostal organs. (http://scienceinafrica.com/old/index. php?q=2002/ february/coela.htm).

Block ER236 in perspective

Block ER236 overlaps with two canyon systems (see Figure 1). Of these the Tugela and Goodlad Canyons, lie in close proximity to the southern and northern areas of interest for drilling, respectively. The Tugela Canyon is an example of a large submarine canyon restricted to the mid-lower continental slope. Unlike those off the GSLWP, this canyon lacks connection to the upper continental slope and shelf. The canyon head is located at ~600 m depth with the thalweg ending in the Natal Valley at ~2,800 m (Wiles *et al*. 2013). Sporadic high relief basement outcrops occur in the canyon head, with terraces developing along the western canyon wall beyond depths of ~1,500 m. With increasing distance from the continental shelf, and increasing depth, the canyon increases in width and relief. The Tugela Canyon therefore differs significantly in morphology from those in northern KwaZulu-Natal, where coelacanths have been reported. Firstly, the canyon head lacks the amphitheatre-shaped head morphology. Secondly, it is located at far greater depth to the Sodwana canyons, and finally, it shows no significant tributary branches (Wiles *et al*. 2013). Although terraces are present and may provide shelter in the form of caves and overhangs, they occur at depths (>1,500 m) well beyond those at which coelacanths have been recorded to date.

Information on the Goodlad (29°25' S) Canyon is sparse. It is reported to start as a small 20 m deep valley (Martin & Flemming 1988) deepening to 250 m while becoming a 50 km wide, shallow valley at a depth of 1,400 m. It emerges from the Thukela Cone at 2,320 m (Goodlad 1986). The gradient of the canyon walls are less steep than those of the Thukela Canyon and limited tributaries occur (Young 2009).

Other than the study by Roberts *et al*. (2006) on the Maputaland Coast, there are currently no data available on temperature or dissolved oxygen on, or beyond the shelf edge. Extrapolating these temperature and dissolved oxygen data to the Tugela Canyon region suggests that temperatures in the canyon heads at depths of 600 m the are likely to be <10°C, with dissolved oxygen concentrations of <3.4 ml/l. Although the oxygen concentrations would be suitable for coelacanths, the declining water temperatures beyond 600 m depths are well below the known tolerance for coelacanths (15°C). Together with the fact that these canyons lack connectivity to the shelf, and suitable food sources are likely to be limited at those depths, this suggests that the Tugela and Goodlad Canyons are unlikely to offer suitable habitat for coelacanths.

Conclusions and Data Gaps

As they are considered to be rare fish, coelacanths are in Appendix I (Endangered Species) of CITES, which prohibits international trade in specimens. In the IUCN Red listing <u>and List of Marine TOPS as part of the NEMBA</u>, they are listed as 'critically endangered'. Coelacanths are given additional protection in South Africa, Comoros and Indonesia by specific legislation. A coelacanth MPA is currently also being developed in Tanzania. In South Africa, coelacanths are given additional protection by specific legislation, which protect all coelacanths in South African waters, and tightens the control of diving in coelacanth habitats in the St Lucia and Maputaland Marine Protected Areas (MPAs) (DEAT *et al.* 2004).

Despite the substantial contributions by Fricke and his team of research in the Comoros and Indonesia and the research focus on coelacanths off the KwaZulu Natal Coast over the past decade, several of the fundamental questions related to evolutionary life history, ecology, physiology, behavioural adaptations, demographics and interactions with both the physical and biological environments in which coelacanths live remain either unanswered or only partially answered. In particular, questions regarding population structure, site fidelity, migration patterns and feeding are awaiting comprehensive answers from further detailed studies. A sound understanding of the relationship between coelacanths and their physical, chemical and biological environment is a prerequisite to an informed management and conservation strategy for this species (Ribbink & Roberts 2006). The sensitivity of coelacanths to hydrocarbon pollution is unknown.

3.2.7 Turtles

Five species of sea turtles occur along the East coast of South Africa; the green turtle (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*) (Figure 19, left), hawksbill (*Eretmochelys imbricata*) and loggerhead (*Caretta caretta*)(Figure 19, right). Green turtles are non-breeding residents often found feeding on inshore reefs. They nest mainly along the coast of Mozambique and on both Europa and Tromelin Islands (Lauret-Stepler *et al.*

2007). Hawksbills also occur on inshore reefs but nest along the coastlines of Madagascar and the Seychelles (Mortimer 1984). Olive ridleys are infrequent visitors to South African waters and nest throughout the central and northern regions of Mozambique (Pereira *et al.* 2008). Leatherback turtles inhabit the deeper waters of the Atlantic Ocean and are considered a pelagic species. They travel the ocean currents in search of their prey (primarily jellyfish) and may dive to over 600 m and remain submerged for up to 54 minutes (Hays *et al.* 2004; Lambardi *et al.* 2008). They come into coastal bays and estuaries to mate, and lay their eggs on the adjacent beaches. Loggerheads tend to keep more inshore, hunting around reefs, bays and rocky estuaries along the African East Coast, where they feed on a variety of benthic fauna including crabs, shrimp, sponges, and fish. The Tugela Bank, inshore of Block ER236, serves as an important feeding area for this critically endangered turtle species. In the open sea their diet includes jellyfish, flying fish, and squid (www.oceansafrica.com/turtles.htm).

Figure 19: Leatherback (left) and loggerhead turtles (right) occur along the East Coast of South Africa (Photos: Ketos Ecology 2009; www.aquaworld-crete.com).

Loggerheads and leatherbacks nest along the sandy beaches of the northeast coast of KwaZulu-Natal, South Africa, as well as southern Mozambique during summer months. These loggerhead and leatherback nesting populations are the southern-most in the world (Nel *et al.* 2013). Even though these populations are smaller (in nesting numbers) than most other populations, they are genetically unique (Dutton *et al.* 1999; Shamblin *et al.* Submitted) and thus globally important populations in terms of conservation of these species.

Loggerhead and leatherback females come ashore to nest from mid-October to mid-January each year. They crawl up the beach and deposit an average of ~100 (loggerheads) or ~80 (leatherback) eggs in a nest excavated with their hind flippers. The eggs incubate for two months and hatchlings emerge from their nests from mid-January to mid-March. The mean hatching success for loggerheads (73%) and leatherbacks (76%) on the South African nesting beaches (de Wet 2013) is higher than reported at other nesting sites globally. Nevertheless, eggs and emerging hatchlings are nutritious prey items for numerous shoreline predators, resulting in the mean emergence success and hatchling success being slightly lower than the hatching success. However, emergence and hatchling success for both species is similarly higher in South Africa than reported at other nesting beaches as mortality is largely limited to natural sources due to strong conservation presence on the nesting beach, which has reduced incidents of egg poaching and female harvesting to a minimum (Nel 2010). The production of both loggerhead and leatherback hatchlings is thus remarkably high in South Africa, making the nesting beaches in northern KZN some of the most productive (relative to nesting numbers) in the world.

Those hatchlings that successfully escape predation on their route to the sea, enter the surf and are carried ~10 km offshore by coastal rip currents to the Agulhas Current (Hughes 1974b). As hatchlings are not powerful swimmers they drift southwards in the current. Hatchlings and juveniles may therefore be encountered in the inshore regions of the northern portion of Block ER236, but abundances in the areas of interest for well drilling are expected to be low. During their first year at sea, the post-hatchlings feed on planktonic prey items (Hughes 1974a), with their activities largely remaining unknown (Hughes 1974a). After ~10 years, juvenile loggerheads return to coastal areas to feed on crustaceans, fish and molluscs and subsequently remain in these neritic habitats (Hughes 1974b). In contrast, leatherbacks remain in pelagic waters until they become sexually mature and return to coastal regions to breed. Loggerheads reach sexual maturity at about 36 years of age whereas leatherbacks reach maturity sooner, at approximately 15 years (Tucek *et al.* Submitted). It has been estimated that only 1 to 5 hatchlings survive to adulthood (Hughes 1974b; de Wet 2013).

Sea turtles are highly migratory and travel extensively throughout their entire life cycle. Adult turtles migrate thousands of kilometres between foraging and breeding grounds, returning to their natal beaches (Hughes 1996; Papi *et al.* 2000; Schroeder *et al.* 2003) by using geomagnetic (Lohmann *et al.* 2007) and olfactory cues (Grassman *et al.* 1984), hearing (Wyneken & Witherington 2001) as well as vision (Witherington 1992) to find their way back to the beach. The Maputaland loggerheads appear to use the higher sulphide concentrations along that particular stretch of coast as a chemical cue for nesting (Brazier 2012). Post-nesting females and hatchlings use natural ambient light to orientate towards the ocean (Bartol & Musick 2002). Artificial light, however, acts as deterrents for nesting females (Witherington 1992; Salmon 2003; Brazier 2012) and brightly lit beaches thus have reduced female emergences. In contrast, hatchlings are attracted to light even if the source is inland and may consequently suffer higher mortality rates due to desiccation and increased predation (Witherington & Bjorndal 1991; Salmon 2003).

Satellite tracking of female loggerhead and leatherback turtles during inter-nesting periods revealed that loggerheads remained close to the shore (within the boundaries of the iSimangaliso Wetland Park) between nesting events (Figure 20) whereas leatherbacks travelled greater distances (more than 300 km) and beyond the borders of the MPA. Consequently, a southward extension of the MPA was proposed in order to include a greater portion of the core range of inter-nesting leatherbacks and provide better protection. The southward and offshore extention of the iSimangaliso Wetland Park MPA was one of the network of MPAs approved by Cabinet on 24 October 2018. The inshore regions of the northern portion of Block ER236, coincide with the inter-nesting migrations for leatherbacks, but the areas of interest for well drilling lie offshore and to the south of the inter-nesting range.

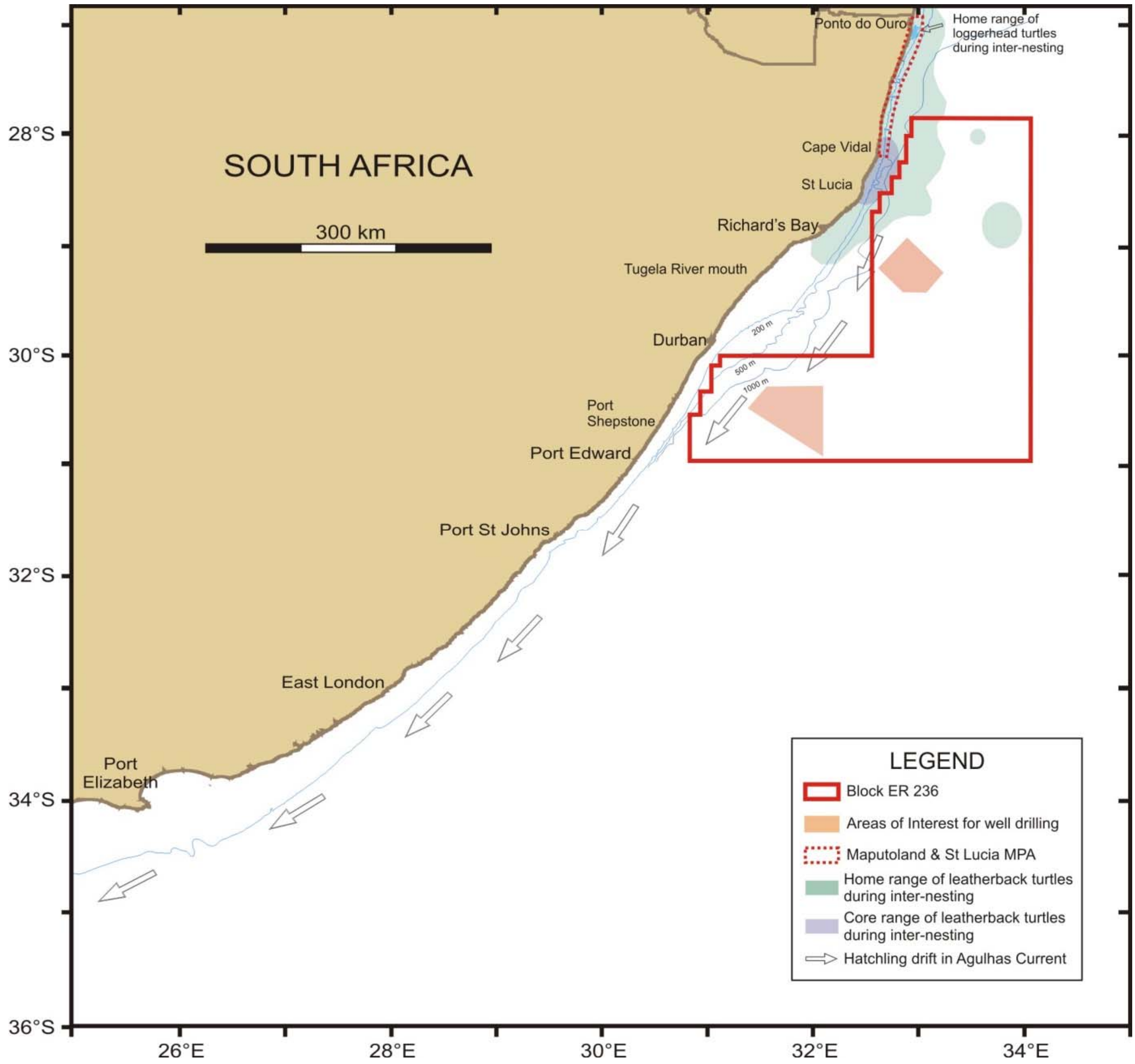


Figure 20: The home and core ranges of loggerheads and leatherbacks during inter-nesting relative to the MPA (orange outline) and the areas of interest for well drilling (orange rectangles) within Block ER236 (red polygon) (Oceans and Coast, unpublished data).

Female turtles do not nest every year due to the high energetic costs of reproduction (Wallace & Jones 2008). During this remigration interval they travel thousands of kilometres (particularly leatherbacks) with ocean currents in search of foraging grounds (Luschi *et al.* 2003a; Luschi *et al.* 2003b). Turtles marked with titanium flipper tags have revealed that South African loggerheads and leatherbacks have a remigration interval of 2 – 3 years, migrating to foraging grounds throughout the South Western Indian Ocean (SWIO) as well as in the eastern Atlantic Ocean. They follow different post-nesting migration routes (Hughes *et al.* 1998; Luschi *et al.* 2006), with loggerheads preferring to stay inshore whilst travelling northwards to foraging grounds along the southern Mozambican coastline or crossing the Mozambique Channel to forage in the waters off Madagascar (Figure 21). In contrast, leatherbacks move south with the Agulhas Current to deeper water in high-sea regions to forage (Hughes *et al.* 1998; Luschi *et al.* 2003b;

Luschi *et al.* 2006), with some individuals following the Benguela Current along the west coast of South Africa, as far north as central Angola (Figure 22, de Wet (2013)). Both species are thus likely to be encountered in Block ER236 during their foraging migrations.

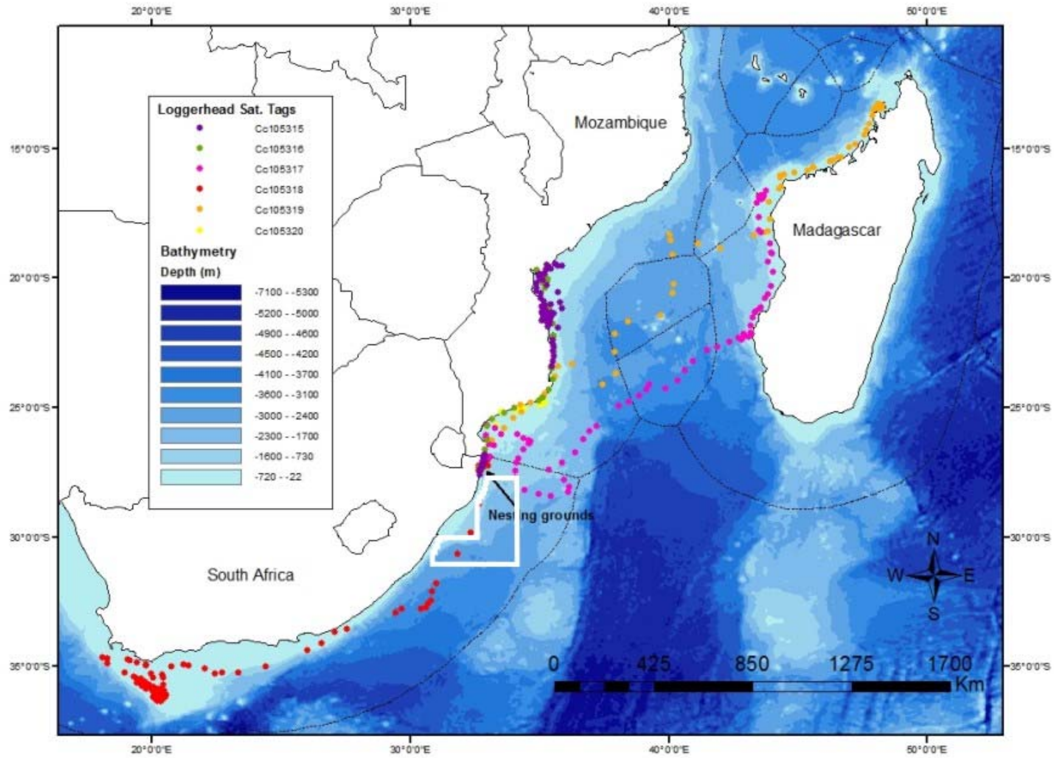


Figure 21: Spatial distribution of satellite tagged loggerhead females (2011/2012; Oceans and Coast, unpublished data) in relation to Block ER236 (white polygon).

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

In the IUCN Red listing, the hawksbill turtle is described as 'Critically Endangered', the green turtle is 'Endangered' and Leatherback, Loggerhead and Olive Ridley are 'Vulnerable' on a global scale. The most recent conservation status, which assessed the species on a sub-regional scale, is provided in Table 6.

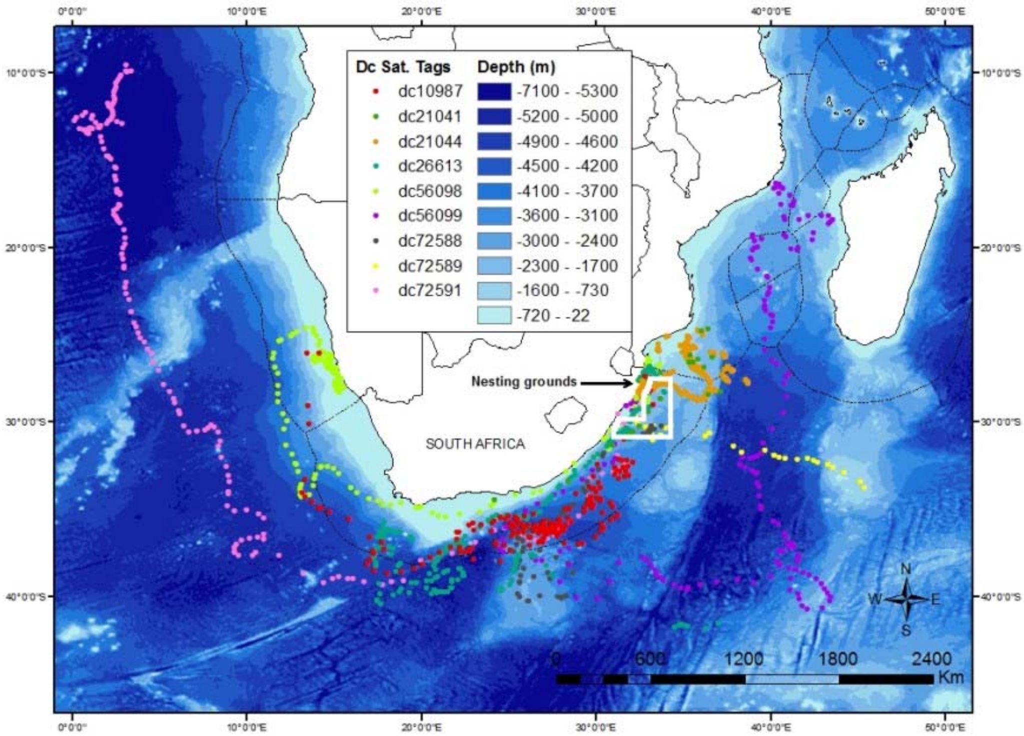


Figure 22: The post-nesting distribution of nine satellite tagged leatherback females (1996 – 2006; Oceans and Coast, unpublished data) in relation to Block ER236 (white polygon).

Table 6: Global and Regional Conservation Status of the turtles occurring off the South African coastline showing variation depending on the listing used.

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

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

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

3.2.8 Seabirds

Twenty-nine seabird species occur commonly along the KwaZulu-Natal coast (Table 7). As the East Coast provides few suitable breeding sites for coastal and seabirds, only three species (Grey-headed gull, Caspian tern and Swift tern) (Figure 23) breed regularly along the coast (CSIR 1998). Many of the river mouths and estuaries along the East Coast, however, serve as important roosting and foraging sites for coastal and seabirds birds, especially those at St Lucia and Richards Bay (Underhill & Cooper 1982; Turpie 1995).

Figure 23: Typical plunge-diving seabirds on the East Coast are the Swift Tern (left) and the Cape Gannet (right) (Photos: www.johanngrobbelaar.co.za; www.oceanwideimages.com).

In the offshore environment of Block ER236, the birds most likely to be encountered are the pelagic migrant species such as albatross, petrels and shearwaters. Encounter rates are likely to be higher during winter months and during the inshore sardine 'run', when many of the pelagic species come inshore to follow the shoals northwards up the coast (O'Donoghue *et al.* 2010a, 2010b, 2010c). Coastal species may be encountered in the inshore areas Block ER236, particularly in the vicinity of larger estuaries (Richards Bay, St Lucia).

In the area of indirect influence along the South Coast South, 60 species are known or thought likely to occur. South Coast seabirds can be categorised into three categories: 'breeding resident species', 'non-breeding migrant species' and 'rare vagrants' (Shaughnessy 1977; Harrison 1978; Liversidge & Le Gras 1981; Ryan & Rose 1989). Fifteen species breed within the South Coast region (Table 8), including Cape Gannets (Algoa Bay islands), African Penguins (Algoa Bay islands), Cape Cormorants (a small population at Algoa Bay islands and mainland sites), White-breasted Cormorant, Roseate Tern (Bird and St Croix Islands), Swift Term (Stag Island) and Kelp Gulls.

Table 7: Resident and fairly-common to common visiting seabirds present along the KwaZulu-Natal coast (from CSIR 1998).

Species name	Common name	Status
Diomedea exulans	Wandering albatross	Non-breeding winter visitor. Most abundant off continental shelf
Diomedea cauta	Shy albatross	Non-breeding winter visitor
Diomedea melanophris	Blackbrowed albatros	Non-breeding winter visitor
Diomedea chlororhynchos	Yellownosed albatross	Non-breeding winter visitor
Macronectes giganteus	Southern giant petrel	Non-breeding winter visitor
Macronectes halli	Northern giant petrel	Non-breeding winter visitor
Daption capense	Pintado petrel	Non-breeding visitor, mainly in winter
Pterodroma macroptera	Greatwinged petrel	Non-breeding winter visitor
Pterodroma mollis	Softplumaged petrel	Non-breeding visitor, mainly in winter
Pachyptila vittata	Broadbilled prion	Non-breeding visitor, mainly in winter
Procellaria aequinoctialis	Whitechinned petrel	Non-breeding visitor, mainly in winter
Calonectris diomedea	Cory's shearwater	Summer visitor
Puffinus gravis	Great shearwater	Summer vagrant
Puffinus griseus	Sooty shearwater	Non-breeding visitor, mainly in winter
Hydrobates pelagicus	European storm petrel	Non-breeding visitor, mainly in summer
Oceanodroma leucorhoa	Leach's storm petrel	Summer vagrant (NEMBA: Critically Endangered)
Oceanites oceanicus	Wilson's storm petrel	Non-breeding visitor, common year round
Morus capensis	Cape gannet	Common, follows 'sardine run'
Stercorarius parasiticus	Arctic skua	Summer visitor from Palaearctic
Catharacta skua	Antarctic skua	Present all year, more abundant in winter
Larus dominicanus	Kelp gull	Year-round visitor from South & West Coast
Larus cirrocephalus	Greyheaded gull	Coastal breeding resident
Hydroprogne caspia	Caspian tern	Coastal breeding resident
Sterna bergii	Swift tern	Coastal breeding resident
Sterna paradisaea	Arctic tern	Summer visitor from Palaearctic
Sterna sandvicensis	Sandwich tern	Summer visitor from Palaearctic
Sterna bengalensis	Lesser crested tern	Visitor to the coast, mainly in summer
Sterna albifrons	Little tern	Palaearctic migrant, common in summer
Sterna hirundo	Common tern	Summer visitor from Palaearctic

Table 8: Breeding resident seabirds present along the South Coast (adapted from CCA & CMS 2001).

Species name	Common name	Global IUCN Status	NEMBA Marine TOPS*
Haematopus moquini	African black oystercatcher	Lease Concern	Protected
Spheniscus demersus	African Penguin	Endangered	Endangered
Phalacrocorax carbo	Great Cormorant	Least Concern	
Phalacrocorax capensis	Cape Cormorant	Near Threatened	
Phalacrocorax neglectus	Bank Cormorant	Endangered	
Phalacrocorax coronatus	Crowned Cormorant	Least Concern	Protected
Phalacrocorax lucidus	White-breasted Cormorant	Not assessed	
Morus capensis	Cape Gannet	Endangered	Vulnerable
Larus dominicanus	Kelp Gull	Least Concern	
Larus cirrocephalus	Greyheaded Gull	Least Concern	
Larus hartlaubii	Hartlaub's Gull	Least Concern	Protected
Hydroprogne caspia	Caspian Tern	Endangered	Vulnerable
Sterna bergii	Swift Tern	Least Concern	Protected
Sterna dougallii	Roseate Tern	Least Concern	
Sterna balaenarum	Damara Tern	Vulnerable	Critically Endangered

3.2.9 Marine Mammals

The marine mammal fauna of the East Coast comprise between 28 and 38 species of cetaceans (whales and dolphins) known (historic sightings or strandings) or likely (habitat projections based on known species parameters) to occur here (Table 9) (Findlay 1989; Findlay *et al.* 1992; Ross 1984; Peddemors 1999; Best 2007), with seals occurring only occasionally in the form of vagrant Cape fur seals (*Arctocephalus pusillus pusillus*) (CSIR 1998). The offshore areas have been particularly poorly studied with almost all available information from deeper waters (>200 m) based on historic whaling records, and information on smaller cetaceans being particularly poor. Table 9 lists the cetaceans likely to be found within Block ER236. Of the 36 species listed, the Blue Whale is 'critically endangered', the Indo-Pacific humpback dolphin, fin whale and sei whale are considered 'endangered' and the Ifafi-Kosi Bay sub-population of the Indo-Pacific bottlenose dolphin, Sperm whale and Bryde's whale (inshore population) are considered 'vulnerable' in the South African Red List Assessment (Child *et al.* 2016). Altogether 9 species are listed as 'data deficient' underlining how little is known about cetaceans, their distributions and population trends.

The distribution of whales and dolphins on the East Coasts can largely be split into those associated with the continental shelf and those that occur in deep, oceanic waters. Species from both environments may, however, be found associated with the shelf (200 – 1,000 m), making this the most species-rich area for cetaceans. Cetacean density on the continental shelf is usually higher than in pelagic waters as species associated with the pelagic environment tend to be wide-ranging across 1,000s of kilometres. The most common species within Block ER236 (in terms of likely encounter rate not total population sizes) are likely to be the common bottlenose dolphin

(Figure 24, left), Indo-pacific humpback dolphin (Figure 24, right), short-finned pilot whale and humpback whale (Figure 25, left).

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


Figure 24: Toothed whales that occur on the East Coast include the Bottlenose dolphin (left) and the Indo-pacific humpback dolphin (right) (Photos: www.fish-wallpapers.com; www.shutterstock.com).

Mysticete (Baleen) whales

The majority of baleen whales fall into the family Balaenidae. Those occurring in the offshore waters of the East Coast include the blue, fin, sei, minke, dwarf minke, inshore Bryde's, Pygmy Right, Humpback and Southern Right. Most of these species occur in pelagic waters, with only occasional visits into shelf waters. These species show some degree of migration either to, or through, the Block ER236 when *en route* between higher-latitude feeding grounds (Antarctic or Subantarctic) and lower-latitude breeding grounds. Depending on the ultimate location of these feeding and breeding grounds, seasonality off South Africa can be either unimodal (usually in June-August, e.g. minke and blue whales) or bimodal (usually May-July and October-November, e.g. fin whales), reflecting a northward and southward migration through the East Coast area. As whales follow geographic or oceanographic features, the northward and southward migrations may take place at different distances from the coast, thereby influencing the seasonality of occurrence at different locations. Due to the complexities of the migration patterns, each species is discussed in further detail below.

Table 9: Cetaceans occurrence off the East Coasts of South Africa, their seasonality and likely encounter frequency with well-drilling operations (adapted from Best 2007). IUCN Conservation Status is based on the SA Red List Assessment (2014) (Child *et al.* 2016). The Global IUCN Conservation Status is also provided.

Common Name	Species	Shelf	Offshore	Seasonality	Likely encounter freq.	IUCN Conservation Status	Global IUCN Status
Delphinids							
Common bottlenose dolphin	*Tursiops truncatus*	Yes	Yes	Year round	Monthly	Least Concern	Least Concern
Indo-Pacific bottlenose dolphin	*Tursiops aduncus*-Ifafa-Kosi Bay subpopulation	Yes		Year round	Weekly	Vulnerable	
	Tursiops aduncus-Ifafa-False Bay subpopulation	Yes		Year round	Weekly	Near threatened	
	Tursiops aduncus-Seasonal subpopulation	Yes		Year round	Monthly	Data Deficient	Data Deficient
Common (short-beaked) dolphin	*Delphinus delphis*	Yes	Yes	Year round	Monthly	Least Concern	Least Concern
Common (long-beaked) dolphin	*Delphinus capensis*	Yes		Year round	Monthly	Least Concern	Data Deficient
Fraser's dolphin	*Lagenodelphis hosei*		Yes	Year round	Occasional	Least Concern	Least Concern
Pan tropical Spotted dolphin	*Stenella attenuata*	Yes	Yes	Year round	Occasional	Least Concern	Least Concern
Striped dolphin	*Stenella coeruleoalba*		Yes	Year round	Occasional	Least Concern	Least Concern
Spinner dolphin	*Stenella longirostris*	Yes		Year round	Occasional	Data Deficient	Data Deficient
Indo-Pacific humpback dolphin	*Sousa chinensis*	Yes		Year round	Monthly	Endangered	Vulnerable
Long-finned pilot whale	*Globicephala melas*		Yes	Year round	<Weekly	Least Concern	Data Deficient
Short-finned pilot whale	*Globicephala macrorhynchus*		Yes	Year round	<Weekly	Least Concern	Data Deficient
Killer whale	*Orcinus orca*	Occasional	Yes	Year round	Occasional	Least Concern	Data Deficient
False killer whale	*Pseudorca crassidens*	Occasional	Yes	Year round	Monthly	Least Concern	Data Deficient
Risso's dolphin	*Grampus griseus*	Yes (edge)	Yes	Year round	Occasional	Least Concern	Least Concern
Pygmy killer whale	*Feresa attenuata*		Yes	Year round	Occasional	Least Concern	Data Deficient

Common Name	Species	Shelf	Offshore	Seasonality	Likely encounter freq.	IUCN Conservation Status	Global IUCN Status
Sperm whales							
Pygmy sperm whale	*Kogia breviceps*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Dwarf sperm whale	*Kogia sima*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Sperm whale	*Physeter macrocephalus*		Yes	Year round	Occasional	Vulnerable	Vulnerable
Beaked whales							
Cuvier's	*Ziphius cavirostris*		Yes	Year round	Occasional	Least Concern	Least Concern
Arnoux's	*Berardius arnouxii*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Southern bottlenose	*Hyperoodon planifrons*		Yes	Year round	Occasional	Least Concern	Least Concern
Hector's	*Mesoplodon hectori*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Strap-toothed whale	*Mesoplodon layardii*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Longman's	*Mesoplodon pacificus*		Yes	Year round	Occasional	Data Deficient	Data Deficient
True's	*Mesoplodon mirus*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Gray's	*Mesoplodon grayi*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Blainville's	*Mesoplodon densirostris*		Yes	Year round	Occasional	Data Deficient	Data Deficient
Baleen whales							
Antarctic minke	*Balaenoptera bonaerensis*	Yes	Yes	AMJJASO	Monthly	Least Concern	Near Threatened
Dwarf minke	*Balaenoptera acutorostrata*	Yes		Year round	Occasional	Least Concern	Least Concern
Fin whale	*Balaenoptera physalus*		Yes	MJJASON	Occasional	Endangered	Endangered
Antarctic Blue whale	*Balaenoptera musculus intermedia*		Yes	MJJASON	Occasional	Critically Endangered	Ctrically Endangered
Sei whale	*Balaenoptera borealis*		Yes	MJJASON	Occasional	Endangered	Endangered
Bryde's (inshore)	*Balaenoptera brydei (subspp)*		Yes	Year round	Occasional	Vulnerable	least Concern
Pygmy right	*Caperea marginata*	Yes		Year round	Occasional	Least Concern	Data Deficient
Humpback	*Megaptera novaeangliae*	Yes	Yes	AMJJASOND	Daily	Least Concern	Least Concern
Southern right	*Eubalaena australis*	Yes		MJJASOND	Daily	Least Concern	Least Concern

Southern right whales (*Eubalaena australis*)

The Southern African population of Southern right whales (Figure 25, right) historically extended from Southern Mozambique (Maputo Bay) (Banks *et al.* 2011) to Southern Angola (Baie dos Tigres) and is considered a single population within this range (Roux *et al.* 2015). Winter concentrations have been recorded along the Southern and Eastern Coasts of South Africa as far north as Maputo Bay, with the most significant concentration currently on the South Coast between Cape Town and Port Elizabeth. They typically occur in coastal waters off the South Coast between June and November, although animals may be sighted as early as April and as late as January. They migrate to the southern African sub-region to breed and calve, inhabiting shallow coastal waters in sheltered bays (90% were found <2 km from shore; Best 1990; Elwen & Best 2004). While in local waters, southern rights are found in groups of 1-10 individuals, with cow-calf pairs predominating in inshore nursery areas. From July to October, animals aggregate and become involved in surface-active groups, which can persist for several hours.

The most recent (2008) abundance estimate for this population is ~4,600 individuals, which is thought to be approximately 23% of the pre-exploitation population size. The population has been increasing at about 7% per year (Brandaõ *et al.* 2011); however, the annual aerial surveys off the South African South Coast between Lambert's Bay on the West Coast and Nature's Valley (Plettenberg Bay) conducted in October 2015 and 2016 revealed a considerable drop in numbers throughout their range. Data analyses have not yet been completed for the 2015 and 2016 surveys, but the low numbers are a cause for concern. In recent years there has also been a decline in the number of cow-calf pairs encountered along the coast, a drop in the number of unaccompanied adults, as well as a reduced inter-calf-interval (Findlay, K., pers comm.). Preliminary results from the 2016 survey suggest high reproductive failure or movement away from the area (Findlay, K., pers comm. 2016). Increased entanglements have also been recorded in the shark nets off KZN in recent years, indicating that the animals are utilising their old migration routes more as the populations continue to increase.

Southern right whales will pass through Block ER236 in July and August and again on their southward migration in October/November. Disturbance during these times should be avoided, especially due to the recent unexplained decline in numbers.

Figure 25: The humpback whale (left) and the southern right whale (right) migrate along the East Coast during winter (Photos: www.divephotoguide.com; www.aad.gov.au).

Humpback whales (*Megaptera novaeangliae*)

Humpback whales (Figure 25, left) are known to migrate between their Antarctic feeding grounds and their winter breeding grounds in tropical waters. The main winter concentration areas for Humpback whales on the African east coast include Mozambique, Madagascar, Kenya and Tanzania on the east coast. During this migration they use subtropical coastal areas as important migratory corridors (Best 2007). Although they have a cosmopolitan distribution (Best 2007) they exhibit a distinct seasonality in occurrence along the South African east coast. This species can be observed between May and February, with peak sightings in June and November/December (Banks 2013). These peaks correspond to the northward migration, as animals pass through Block ER236 *en-route* to their breeding grounds off Mozambique and Madagascar, and the southward migration when they migrate back to their Southern Ocean feeding grounds. Cow-calf pairs can be seen closer to the coast during the southward migration than groups without calves. Humpback whales utilise the relatively protected bays along the South-East Coast of South Africa to rest during their migration.

Three principal migration routes for Humpbacks in the south-west Indian Ocean have been proposed. On the first route up the East Coast, the northern migration reaches the coast in the vicinity of Knysna continuing as far north as central Mozambique. The second route approaches the coast of Madagascar directly from the south, possibly *via* the Mozambique Ridge. The third, less well established route, is thought to travel up the centre of the Mozambique Channel to Aldabra and the Comore Islands (Findlay *et al.* 1994; Best *et al.* 1998).

The population of humpback whales that migrate through Block ER236 likely belong to breeding stock C, one of two populations that occur off southern Africa (IWC 1998). Their migration stream along the east coast of South Africa has been shown to begin at, or near, Knysna in the west (23° E) from where they travel inshore of the Agulhas current to the breeding grounds off Mozambique (Best *et al.* 1998; Banks 2013). A study conducted in Plettenberg Bay and Knysna, well to the south of the project area, calculated the width of the migration stream to extend a minimum of 16.5 km offshore of the Robberg peninsula (Banks 2013), with anecdotal reports from sailing and fishing vessels operating in the area reporting humpback whales at least 40 km from the coast.

Humpbacks have a bimodal distribution off the East coast, most reaching southern African waters around April, continuing through to September/October when the southern migration begins and continues through to December and as late as February (Banks 2013). The calving season for Humpbacks extends from July to October, peaking in early August (Best 2007). Cow-calf pairs are typically the last to leave southern African waters on the return southward migration, although considerable variation in the departure time from breeding areas has been recorded (Barendse *et al.* 2010). Off Cape Vidal whale abundances peak around June/July on their northward migration, although some have been observed still moving north as late as October. Southward moving animals on their return migration were first seen in July, peaking in August and continuing to late October (Findlay & Best 1996a, 1996b). More recent analysis of occurrence data from Plettenberg Bay/Knysna indicate a shift in temporal occurrence by 2 months in the last 100 years; with the northward migration starting later (end of May) and the southbound migration extending into late February (Banks 2013).

The most current estimated population size for the C1 population is 7,035 (CI 5,742 – 8,824) individuals, thought to indicate a post-whaling recovery to approximately 80% of pre-exploitation levels (IWC 2010). This estimate is, however, given with caution and may be an overestimate of the level of recovery (Banks 2013) and new information on the linkage between various sub-populations suggests this may need revision. The highest concentrations of humpback whales in or near Block ER236 can be expected in June - July and October - December.

Sei whales (*Balaenoptera borealis*)

Sei whales migrate through South African waters, where they were historically hunted in relatively high numbers, to unknown breeding grounds further north. Their migration pattern thus shows a bimodal peak with numbers on the east coast highest in June (on the northward migration), and with a second larger peak in September. All whales were caught in waters deeper than 200 m with most deeper than 1,000 m (Best & Lockyer 2002). This species is thus unlikely to occur in Block ER236. Almost all information is based on whaling records 1958-1963 and there is no current information on abundance or distribution patterns in the region.

Fin whales (*Balaenoptera physalus*)

Fin whales were historically caught off the East Coast of South Africa, with a unimodal winter (June-July) peak in catches off Durban. However, as northward moving whales were still observed as late as August/September, it is thought that the return migration may occur further offshore. Some juvenile animals may feed year-round in deeper waters off the shelf (Best 2007). There are no recent data on abundance or distribution of fin whales off Southern Africa.

Blue whales (*Balaenoptera musculus*)

Blue whales were historically caught in high numbers off Durban, showing a single peak in catches in June/July. Sightings of the species in the area between 1968-1975 were rare and concentrated in March to May (Branch *et al.* 2007) and only from far offshore (40-60 nautical miles). However, scientific search effort (and thus information) in pelagic waters is very low. The chance of encountering the species in Block ER236 is considered low.

Minke whales

Two forms of minke whale occur in the southern Hemisphere, the Antarctic minke whale (*Balaenoptera bonaerensis*) and the dwarf minke whale (*B. acutorostrata* subsp.); both species occur off the East coast (Best 2007). Antarctic minke whales range from the pack ice of Antarctica to tropical waters and are usually seen more than ~50 km offshore. Although adults of the species do migrate from the Southern Ocean (summer) to tropical/temperate waters (winter) where they are thought to breed, some animals, especially juveniles, are known to stay in tropical/temperate waters year-round. Off Durban, Antarctic minke whales were reported to increase in numbers in April and May, remaining at high levels through June to August and peaking in September (Best 2007).

The dwarf minke whale has a more temperate distribution than the Antarctic minke and they do not range further south than 60-65°S. Dwarf minke whales have a similar migration pattern to Antarctic minkes with at least some animals migrating to the Southern Ocean in summer months. Dwarf minke whales occur closer to shore than Antarctic minkes and have been seen <2 km from shore on several occasions around South Africa, particularly on the East Coast during the 'sardine run' (O'Donoghue *et al.* 2010a, 2010b, 2010c). Historic whaling records indicate that off Durban they were taken mainly between April and June. Both species are generally solitary and densities in Block ER236 are likely to be low.

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

Pygmy right whales

The smallest of the baleen whales, the pygmy right whale, occurs along the southern African East Coast to as far north as 30°S. There are no data on the abundance or conservation status of this species, but it was not subjected to commercial whaling, so the population is expected to be near to original numbers. Sightings of this species at sea are rare (Best 2007) due in part to their small size and inconspicuous blows. Density in Block ER236 is likely to be low.

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

Two types of Bryde's whales are recorded from South African waters - a smaller neritic form which recent research indicates is a subspecies of the larger pelagic form described as *Balaenoptera brydei* (Olsen 1913; Penry 2010). The migration patterns of Bryde's whales differ from those of all other baleen whales in the region as they are not linked to seasonal feeding or breeding patterns (Best 1977). The inshore population is unique in that it is resident year-round on the Agulhas Bank, with a few individuals undertaking occasional seasonal excursions up the East Coast in winter during the annual sardine migration. Sightings over the last two decades suggest that the distribution of this population off the South African South Coast has shifted eastwards, most likely in response to a shift in their prey distribution (Best 2001, 2007; Penry *et al.* 2011). This is a small population (~600 individuals), which is possibly decreasing in size; an abundance estimate of 150 – 250 individuals was calculated for Bryde's whales using the Plettenberg Bay/Knysna area in 2005-2008 (Best *et al.* 1984; Penry 2010). The recent South African National Red Data list assessment has also reclassified this population as 'Vulnerable' (Penry *et al.* 2016). Its current distribution implies that it is highly likely to be encountered in Block ER236 throughout the year, with peak encounter rates in late summer and autumn (Mar – May) (Penry *et al.* 2011; Melly *et al.* in press).

The offshore population of Bryde's whale occurs predominantly on the West Coast, beyond the continental shelf (>200 m depth), and migrates between wintering grounds off equatorial West Africa (Gabon) and summering grounds off the South African West Coast (Best 2001). Its seasonality within South African waters is thus contrary to most of the balaenopterids, with abundance on the West Coast highest in January-February. This population of Bryde's whales is unlikely to be encountered in Block ER236.

Odontocetes (toothed) whales

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

Sperm whales (*Physeter macrocephalus*)

All information about sperm whales in the southern African subregion results from data collected during commercial whaling activities prior to 1985 (Best 2007). Sperm whales are the largest of the toothed whales and have a complex, well-structured social system with adult males behaving differently from younger males and female groups. They live in deep ocean waters usually >1,000 m, but occasionally come inshore on the shelf into depths of 500-200 m (Best 2007). Seasonality of catches off the East Coast suggest that medium- and large-sized males are more abundant during winter (June to August), while female groups are more abundant in summer (December - February), although animals occur year round (Best 2007). Although considered relatively abundant worldwide (Whitehead 2002), no current data are available on density or abundance of sperm whales in African waters. They are likely to be the most frequently encountered large cetacean in Block ER236. Sperm whales feed at great depth, during dives in excess of 30 minutes, making them difficult to detect visually. The regular echolocation clicks made by the species when diving, however, make them relatively easy to detect acoustically using Passive Acoustic Monitoring (PAM).

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

Figure 26: 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).

Humpback dolphins (*Sousa plumbea*)

Humpback dolphins (Figure 24, right) occur along the South African South and East Coasts, from Danger Point in the Western Cape to Mozambique, Tanzania, Kenya, the Comoros Islands and the western coast of Madagascar. Due to the recent recognition of the Western Indian Ocean population as a separate species, their conservation status is internationally regarded as 'vulnerable' and within South Africa as 'endangered', and the species is accepted to be South

Africa's most endangered marine mammal. Overall, it is expected that the distribution of the species in the Indian Ocean is not continuous, but rather consists of many subpopulations that should be regarded as separate management units (Durham 1994; Karczmarski 1996; Keith 1999; Karczmarski *et al.* 2000).

Humpback dolphins are coastal animals, preferring water depths less than 20 m and are usually observed within 500 m from shore, predominantly within 10 km of river mouths (Melly 2011; Koper *et al.* 2016). This is similar to findings from the early 1990s, where 87% of sightings were observed within 400 m of land, and almost all the sightings were in waters less than 15 m deep (Karczmarski 1996; Karczmarski *et al.* 2000). Localised populations on the South Coast are concentrated around shallow reefs, whereas those off Richard's Bay appear to prefer large estuarine systems. It appears that the species is more closely associated with estuaries and rivers than other inshore cetaceans. The species is caught accidentally in the shark nets, with 3 animals being killed on average annually, most of which are caught in Richard's Bay (S. Plön, pers com.).

Seasonal movements and migrations are not characteristic of the species, but sightings rate and group size appear to increase between January and April, and again in September. The population off KZN is estimated at 160 individuals, with that for South Africa numbering no more than 1,000. Recent studies on the South Coast have indicated a decrease in sightings by approximately 50% and a reduction in mean group sizes from 7 to 4 individuals in the last decade (Greenwood 2013; Koper *et al.* 2016). Several hypotheses have been suggested as likely reasons for the decline: a decrease in prey availability, prolonged disturbance from whale and dolphin watching tourism and other marine recreation, coastal development and sustained pollution that contaminates the prey on which this species depends.

Due to their limited spatial distribution (restricted to shallow, coastal areas) this species is unlikely to occur in Block ER236.

Indo-Pacific Bottlenose dolphins (*Tursiops aduncus*)

The Indo-Pacific bottlenose dolphin (Figure 24, left) occurs throughout coastal and shallow offshore waters of the temperate and tropical regions of the Indian Ocean and South-West Pacific. The species inhabits waters less than 50 m deep between the Mozambique border in the east and False Bay in west (Ross 1984; Ross *et al.* 1987). It is found year-round in the coastal habitat inshore of Block ER236, with peak sightings being recorded in April/May (autumn) and October/November (spring) in Algoa Bay (Melly *et al.* in press).

Although their distribution is essentially continuous from Cape Agulhas eastwards to southern Mozambique, the Indo-Pacific bottlenose dolphin seems to have 'preferred areas' along the KZN coast (Ross *et al.* 1987; Ross *et al.* 1989; Cockcroft *et al.* 1990, 1991). Areas in which it is more frequently encountered are about 30 km apart, and are thought to correspond to discrete home ranges. Genetic assessments have identified a resident population North of Ifafa (KZN coast, listed as 'vulnerable'), a resident population south of Ifafa (listed as 'near threatened'), as well as a migratory population South of Ifafa ('data deficient'), which appears to undertake seasonal migrations into KZN waters in association with the 'sardine run' (Natoli *et al.* 2008; Cockcroft *et al.* 2016). On average, 15 animals die annually as bycatch in the shark nets set along the KZN coast to protect bathers. Little is known about the offshore form of the species, and nothing about their population size or conservation status. They sometimes occur in association with other species, such as pilot whales or false killer whales (Best 2007) and are likely to be present year-round in waters deeper than 200 m.

Indo-Pacific bottlenose dolphins are often seen in large groups of 10s to 100s of animals (Saayman *et al.* 1972; Ross 1984; Melly 2011) with calves seen year-round along the South-East Coast (Cockcroft & Peddemors 1990; Best 2007). Due to their shallow habitat preferences, they are unlikely to occur in Block ER236.

Common dolphins (*Delphinus spp.*)

Two species of common dolphin are currently recognised, the short-beaked common dolphin (*Delphinus delphis*) and the long-beaked common dolphin (*Delphinus capensis*). The long-beaked common dolphin (*D. capensis*) is resident to the temperate Agulhas Bank with sightings extending as far up the West Coast as St Helena Bay and up the East coast to Richards Bay, in waters less than 500 m deep. Individuals of this species are wide ranging within this area and may move hundreds of kilometers in short periods of time. They are not known to show any degree of residency to coastal areas. Group sizes in this species tend to be large: 100s to even 1000s of animals. No population estimate is available for the two species, but they are thought to be large (15,000 – 20,000; Cockcroft & Peddemors 1990; Peddemors 1999).

The short-beaked common dolphin prefers offshore habitats and is likely to be encountered in Block ER236. Estimates of the population size and seasonality for the subregion are lacking. A few studies have suggested that common dolphins inhabit the Eastern Cape coastline during summer, with movements towards the KwaZulu-Natal coastline during winter (Ross 1984; Cockcroft & Peddemors 1990; O'Donoghue *et al.* 2010a, 2010b, 2010c), although sightings off KZN have also been made during summer. These movements are associated with the annual sardine migration up the east coast in winter (Best 2007). Patterns in their spatial and temporal distribution along the coast are unclear, but long-beaked common dolphins may be observed off the East Coast year round, and are likely to be encountered in Block ER236.

As with the common bottlenose dolphins, an average of 39 animals die annually through entanglement in the shark nets (Best 2007).

<u>Other species</u>

Killer whales, false killer whales and common bottlenose dolphins are regularly reported by fishermen operating in deeper waters off East Coast of South Africa. These species are therefore likely to occur in Block ER236. Rarely encountered dwarf and pygmy sperm whales, pygmy killer whales, Risso's and Frazer's dolphins, striped, spinner and Pan-tropical spotted dolphins, and several beaked whale species have distributions that overlap with the project area (Findlay *et al.* 1992; Best 2007); their occurrence is thought to be rare, but insufficient data is available on the abundance and spatio-temporal distribution of these species to make an accurate assessment of their susceptibility to human disturbance.

The genus *Kogia* currently contains two recognised species, the pygmy (*K. breviceps*) and dwarf

(*K. sima*) sperm whales. Due to their small body size, cryptic behaviour, low densities and small school sizes, these whales are difficult to observe at sea, and morphological similarities make field identification to species level problematic. The majority of what is known about Kogiid whales in the southern African subregion results from studies of stranded specimens (e.g. Ross 1979; Findlay *et al.* 1992; Plön 2004; Elwen *et al.* 2013). *Kogia* species most frequently occur in pelagic and shelf edge waters, and are thus likely to occur in Block ER236 at low levels; seasonality is unknown. Dwarf sperm whales are associated with warmer tropical and warm-temperate waters. However, abundance in Block ER236 is likely to be very low.

Killer whales (Figure 26, right) have a cosmopolitan distribution, being found in all oceans from the equator to the ice edge (Best 2007). Killer whales occur year-round in low densities off the South Africa coast (Best *et al.* 2010) although on the East Coast whaling grounds their abundance was reported to be correlated with that of baleen whales, especially sei whales on their southward migration. Killer whales are found in all water depths from the coast to deep open ocean environments and may thus be encountered in Block ER236at low levels.

Although the false killer whale is globally recognized as one species, clear differences in morphological and genetic characteristics between different study sites show that there is substantial difference between populations and a revision of the species' taxonomy may be needed (Best 2007). The species has a tropical to temperate distribution and most sightings off Southern Africa have occurred in waters deeper than 1,000 m but with a few close to shore as well (Findlay *et al.* 1992). False killer whales usually occur in groups ranging in size from 1-100 animals (mean 20.2) (Best 2007), and are thus likely to be fairly easily seen in most weather conditions. However, the strong bonds and matrilineal social structure of this species makes it vulnerable to mass stranding (8 instances of 4 or more animals stranding together have occurred in the western Cape, between St Helena Bay and Cape Agulhas), which may exaggerate the consequences of any injury or harassment by seismic sounds (e.g. during Vertical Seismic Profiling of the well) or associated activities. There is no information on population numbers or conservation status and no evidence of seasonality in the region (Best 2007).

Short-finned pilot whales display a preference for warmer tropical waters than their counterparts, the long-finned pilot whales. Although distinguishing between the two pilot whale species at sea is difficult, those occurring in Block ER236 are most likely to be the short-finned pilot whales (Best 2007). The species is usually associated with the continental shelf or deep water adjacent to it, and is likely to be among the most commonly encountered odontocete in the project area.

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. They are all considered to be true deep water species, usually being seen in waters in excess of 1,000 - 2,000 m in depth (see various species accounts in Best 2007). With recorded dives of well over an hour to depths in excess of 2 km, beaked whales are amongst the most extreme divers of air breathing animals (Tyack *et al.* 2011). All the beaked whales that may be encountered in Block ER236 are pelagic species that tend to occur in small groups of usually less than five individuals, although larger aggregations of some species are known (MacLeod & D'Amico 2006; Best 2007). The long, deep dives of beaked whales make them difficult to detect visually, but PAM will increase the probability of detection as animals are frequently echo-locating when on foraging dives. Beaked whales are particularly vulnerable to certain types of man-made noise, particularly mid-frequency naval sonar. The exact reason why is not yet fully understood, but necropsy of stranded animals has revealed gas embolisms and haemorrhage in the brain, ears and acoustic fat - injuries consistent with decompression sickness (acoustically mediated bubble formation) may also play a role (Fernadez *et al.* 2005).

In summary, the majority of data available on the seasonality and distribution of large whales in Block ER236 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. Whaling data indicates that several other large whale species are also abundant on the East Coast for much of the year: fin whales peak in May-July and October-November and sei whale numbers peak in May-June and again in August-October. Data on the abundance, distribution or seasonality of the smaller odontocetes (including the beaked whales and dolphins) known to occur in oceanic waters off the shelf of eastern South Africa is lacking. Beaked whales are all considered to be true pelagic species usually being seen in small groups in waters in excess of 1,000 - 2,000 m depth. Their presence in the area may fluctuate seasonally, but insufficient data exist to define this clearly.

All whales and dolphins are given protection under the South African Law. The Marine Living Resources Act, 1998 (No. 18 of 1998) states that no whales or dolphins may be harassed[1], killed or fished. No vessel or aircraft may approach closer than 300 m to any whale and a vessel should move to a minimum distance of 300 m from any whales if a whale surfaces closer than 300 m from a vessel or aircraft. Whales and dolphins are also listed as 'protected' in the List of Marine Threatened or Protectes Species (TOPS) as part of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA).

3.2.10 Marine Protected Areas

KwaZulu-Natal boasts three existing Marine Protected Areas and four recently approved offshore MPAs, of which three fall within Block ER236, iSimangaliso Extension MPA, uThukela Banks MPA and Protea Banks MPA (Figure 28). iSimangaliso Extension MPA stretches 150 km from the Mozambique boundary to approximately 1 km south of Cape Vidal. The iSimangaliso Wetland Park Maputaland and St Lucia Marine Reserves, together with the proposed southward extension of the St Lucia MPA are components of the iSimangaliso MPA, and form the iSimangaliso Wetland Park. . The MPA protects a large number of turtle nesting sites; the migration of whales, dolphins and whale-sharks offshore; coelacanths in the submarine canyons; and a considerable number of waterfowl associated with the iSimangaliso Wetland Park, including large breeding colonies of pelicans, storks, herons and terns.

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

The Aliwal Shoal MPA is situated on the south coast between Umkomaas and Ocean View. The Aliwal Shoal MPA is 125 km^2 in size, approximately 18 km long and stretches ~4 nautical miles offshore. Further south lies the small Trafalgar Marine Reserve, which stretches for only 6 km along the KwaZulu-Natal south coast adjacent to the Mpenjati Nature Reserve, and extends 500 m offshore.

The uThukela Banks MPA is located between the Mlalazi and Seteni estuary. The purpose of this MPA is to protect coastal habitats including sandy beaches, rocky shores and estuaries as well as offshore habitats including the soft sediment and reef systems, submarine canyons, the shelf edge and slope ecosystems (Government Gazette 39646, 2016).

The Protea Banks Marine Protected Area is an offshore Area in the 20m to 3,000m depth range with the southern portion lying adjacent to the existing Trafalgar Marine Protected Area. The purpose of this MPA is to conserve and protect submarine canyons, deep reefs, cold water coral reefs and other habitats of the shelf edge and slope (Government Gazette 39646, 2016).

MPAs in the area of indirect influence include the Amathole MPA in the vicinity of East London, and the Dwesa-Cwebe, Hluleka and Pondoland MPAs located on the Wild Coast. The Amathole MPA comprised the three former closed areas, namely from Christmas Rock to the Gxulu River mouth, from Nahoon Point to Gonubie Point, and from the Nyara River mouth to the Kei River mouth.

World Heritage Site

The iSimangaliso Wetland Park is recognised as a wetland of international importance under the Ramsar Convention and has been designated a World Heritage Site in terms of the World Heritage Convention Act (No. 49 of 1999). The iSimangaliso Wetland Park covers an area on 324 441 ha, including 230 km of coastline from Kosi Bay (bordering Mozambique) to south of Maphelane and three nautical miles out to sea. The Park is governed by the National Environmental Management Protected Areas Act (No. 57 of 2003). In terms of Section 48(1) no person may conduct commercial prospecting or mining activities within a World Heritage Site. In addition, Section 50(5) states that no development is permitted in a World Heritage Site without prior written approval from the management authority, namely iSimangaliso Wetland Park Authority. The proposed areas of interest for well-drilling lie well to the south of the World Heritage Site (Figure 28).

Critical Biodiversity Areas

The objectives of the KwaZulu-Natal Coastal and Marine Biodiversity Plan (previously referred to as the SeaPLAN project) were to 1) provide a systematic framework for assessment of the status of biodiversity protection in KZN, and 2) enable planning for marine biodiversity protection by identifying spatial priorities for ongoing and future marine conservation efforts. Using systematic conservation planning (SCP) principles, and SCP software (C-Plan and Marxan), KZN's Coastal and Marine Biodiversity Plan assessed the state of protection of biodiversity, and identified key areas that required increased protection within existing protected areas, as well as areas outside of these protected areas that are important for future conservation management actions.

The final spatial product of the Plan was a map of Focus Areas for additional marine biodiversity protection (Harris et al. 2012). These were made up of Critical Biodiversity Areas (CBAs) that are considered either "irreplaceable" or "optimal" (Figure 27). Irreplaceable CBAs representing areas of significantly high biodiversity value and in some cases the areas are the only localities for which the conservation targets for one or more of the biodiversity features can be achieved i.e. there are few, or no, alternative sites available. Optimal CBAs are areas representing the best option, out of a potentially larger selection of options, of a selection of planning units that meet biodiversity targets. The optimal CBAs equate to the "Best solution" output minus the irreplaceable CBAs described above (Harris et al. 2012). The key drivers determining the selection of each focus area are provided in Table 10. Block ER236 overlaps with three CBAs, namely iSimangaliso Wetland Park extension, and Offshore Areas 20 and 21. Of these the iSimangaliso Wetland Park extension, and Offshore Area 20 have irreplaceable CBAs, which fall within Block ER236. The southern area of interest for well drilling falls within the irreplaceable portion of Offshore Area 20.

The Focus Areas of the Plan were subsequently used to guide South Africa's National Protected Area Expansion Strategy, which had identified a need to increase the protection in the Natal Bioregion as well as in the offshore areas. The CBAs map was thus used to help determine exact boundaries and zonation of any new proposed offshore MPAs in KZN.

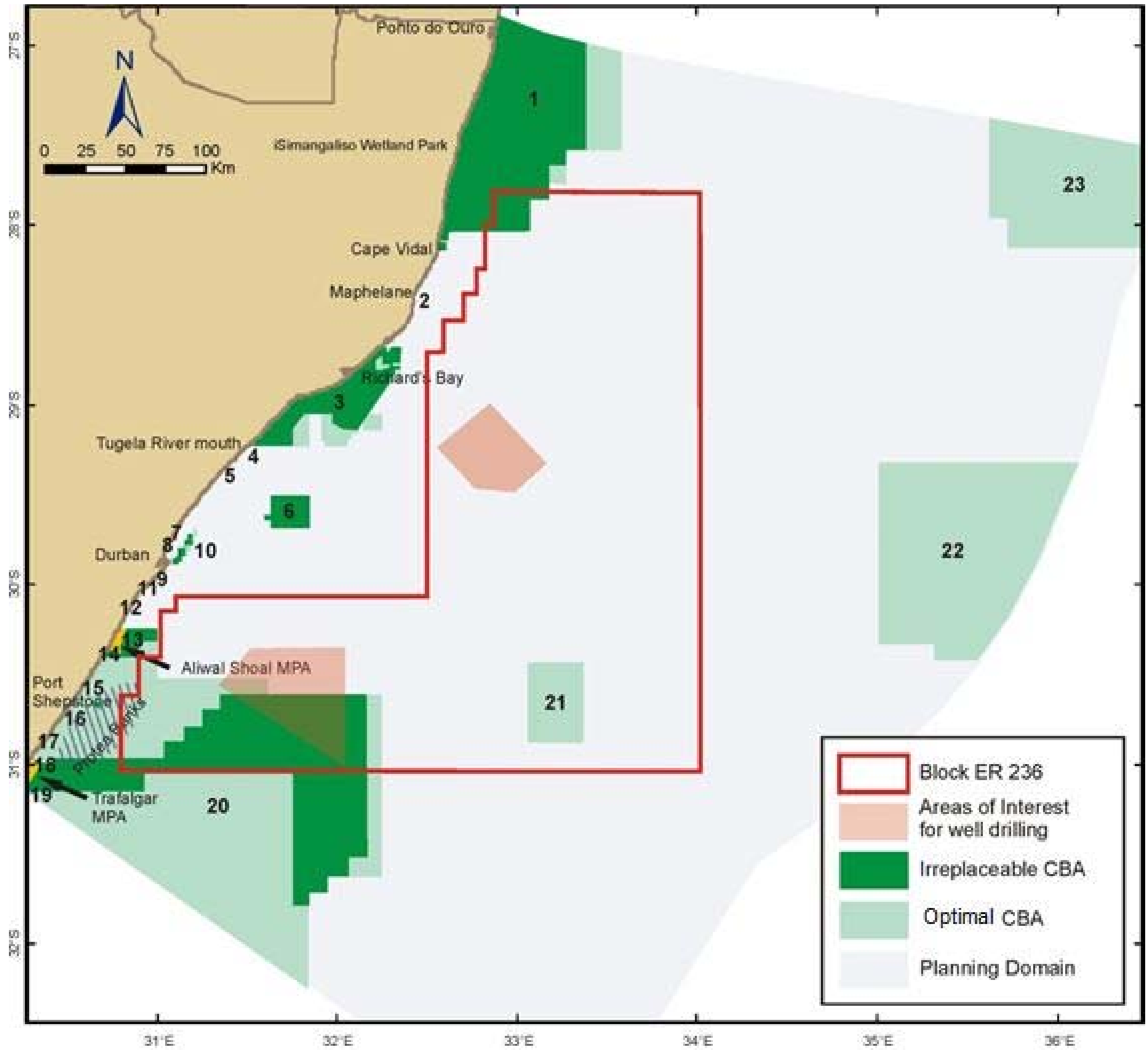


Figure 27: Critical Biodiversity Areas (CBAs) within the Exclusive Economic Zone off the KwaZulu-Natal coast in relation to Block ER236 and the areas of interest for well drilling. The numbers represent the various biodiversity focus areas provided in Table 10.

Table 10: The key drivers determining the selection of each focus area (Harris *et al*. 2012). Those areas coincident with the areas of interest for drilling are highlighted.

Focus Area Number	Area	Key Drivers
1	iSimangaliso Wetland Park extension	Offshore extension of iSimangaliso, Offshore habitats, processes and fish species
2	Cape St Lucia area	Southern extension of iSimangaliso, Shoreline habitats, high rock ledges, broken rocks and rock boulders; fish species
3	Tugela Banks Area	Shoreline habitats: estuaries, vegetated dune hummocks, intermediate sandy shores; Offshore soft Sediment habitat and reefs, fish, sharks and mammals
4	Zinkwazi Estuary and shoreline area	Shoreline habitats: dissipative sandy shore, rock ledges and scattered rocks
5	Mhlali estuary and shoreline	Mhlali Estuary and mixed shore
6	KZN Bight	Offshore area near continental shelf edge of the KZN Bight consisting of offshore habitats; Chl-a and SST fronts; fish species
7	Beachwood Mangroves	Shoreline habitats: vegetated dune hummocks, rock boulders and the Mgeni estuary
8	Durban	Subtidal fish species
9	Bluff Area	Shoreline habitats: Vegetated Dune hummocks, broken ledges: subtidal fish species, rocky reefs
10	KZN Bight	Subtidal fish species
11	iSipingo	iSipingo estuary and shoreline habitats: mixed shores plus intermediate sandy shore
12	Karridene	Shoreline area south of Karridene between the Msimbazi and Mgababa Rivers mixed shores plus intermediate sandy shore
13	Aliwal Shoal	Shoreline habitats: mixed shores, rock ledges, dissipative and intermediate sandy shores; offshore habitats: rocky reefs; number of fish species
14	Umdoni	Shoreline habitats: high rock ledges, solid rocks and boulder shores+
15-19	Hibiscus Coast	Shoreline habitats: high rock ledges, solid rocks and boulder shores and a number of estuaries
20	Offshore areas	Offshore habitat: biozones, offshore processes: SST and Chl-a fronts; fish, shark and mammal species
21-23	Offshore areas	Offshore habitat: biozones, SST fronts and Eddys

The KZN Marine Biodiversity Plan is scheduled to be updated every five years with any new information that becomes available. Future analyses aim to produce separate benthic and pelagic biodiversity plans, thereby streamlining conservation efforts and allowing for more specific protection and management for particular habitats, species and processes, with the use of a suite of management tools such as MPAs, temporally closed areas, harvesting quotas, fishing gear restrictions, bycatch management, improved industry standards for particular activities, etc.

Ecologically and Biologically Significant Areas (EBSAs)

Following application of the Conservation on Biological Diversity's (CBD) Ecologically or Biologically Significant marine Areas (EBSA) criteria2, a number of areas around the South African coast were identified as potentially requiring enhanced conservation and management. These were presented at the CBD regional workshop for the description of marine EBSAs in the Southern Indian Ocean (July/August 2012) (CBD 2013).

Three Ecologically or Biologically Significant Areas (EBSA) have been proposed and inscribed for the East Coast under the Convention of Biological Diversity (CBD) (CBD 2013), namely Protea Banks and the Sardine Route, the Natal Bight and the Delagoa Shelf Edge. In meeting the EBSA criteria various endemic and rare chondrychthian and teleost species were listed for the Natal Bight and Tugela Bank, and IUCN listed species and threatened habitat types identified. The Protea Banks area includes submarine canyons, an area of steep shelf edge and a unique deep-reef system, all of which may support fragile habitat-forming cold-water coral species. This area also includes a major component of the migration path for several species undertaking the 'sardine run'. The Delagoa Shelf Edge, Canyons and Slope is a transboundary EBSA that includes the iSimangaliso Wetland Park, a Ramsar and World Heritage Site in South Africa, and Ponta do Ouro Partial Marine Reserve in Mozambique. This EBSA supports a variety of fish, sharks, turtles, whales and other marine mammals by including their migratory routes, nursery areas, spawning/breeding areas, and foraging areas, and notably provides nesting habitat for Loggerhead and Leatherback turtles. Many of the species in the EBSA are threatened, such as: coelacanths, Seventy-Four seabream, marine mammals, turtles, and sharks. Potential VMEs include numerous submarine canyons, paleo-shorelines, deep reefs, and hard shelf edge, with reef-building cold-water corals also recovered at depths of more than 900 m.

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[2] In 2008, the Conference of the Parties to the Convention on Biological Diversity (COP 9) adopted the following scientific criteria for identifying ecologically or biologically significant marine areas in need of protection in open-ocean waters and deep-sea habitats (further details available at http://www. cbd.int/marine/doc/azores-brochure-en.pdf):

1. Uniqueness or Rarity
2. Special importance for life history stages of species
3. Importance for threatened, endangered or declining species and/or habitats
4. Vulnerability, Fragility, Sensitivity, or Slow recovery
5. Biological Productivity
6. Biological Diversity
7. Naturalness

In 2010, COP 10 noted that the application of the EBSA criteria was a scientific and technical exercise, and that areas found to meet the criteria may require enhanced conservation and management measures, and that this could be achieved through means such as marine protected areas and impact assessments. It was emphasised that the identification of EBSAs and the selection of conservation and management measures was a matter for States and competent intergovernmental rganisations, in accordance with international law , including the UN Convention on the Law of the Sea.

Although focussed primarily on the conservation of benthic biodiversity and threatened benthic habitats, the EBSA also considers the pelagic habitat. The pelagic habitat of the Natal Bight is characterized by cool productive water that is advected onto the shelf in this sheer-zone through Agulhas Current-driven upwelling cells. In the Protea Banks EBSA, the dynamic pelagic environment and the sardine run also contribute to the high diversity in the pelagic ecosystems.

Following new research conducted in the area since the original description of these EBSAs, the boundaries, names, descriptions and criteria ranks have recently been updated. No specific management actions have as yet been formulated for these EBSAs, although the uniqueness of the areas contributed to the development of the recently approved offshore MPAs.

Offshore Marine Biodiversity Protection Areas

Using biodiversity data mapped for the 2004 and 2011 National Biodiversity Assessments a systematic biodiversity plan was developed for the South African coast with the objective of identifying both coastal and offshore priority areas for MPA expansion. To this end, numerous offshore focus areas were identified for protection between 30°E and 35°E, and these carried forward through Operation Phakisa for the proposed development of offshore MPAs. This network of 20 MPAs was approved by Cabinet on 24 October 2018, thereby increasing the ocean protection within the South African Exclusive Economic Zone (EEZ) to 5%. The existing and recently approved MPAs within the project area are shown in Figure 28[3]. Although Block ER236 overlaps with the Protea Banks, Aliwal Shoal Expansion and iSimangaliso Wetland Park Extension MPAs, there is no overlap of the areas of interest for well drilling with the protection areas.

Hope Spots are defined by Mission Blue of the Sylvia Earle Alliance as special conservation areas that are critical to the health of the ocean. The first six Hope Spots were launched in South Africa in 2014 and include Aliwal Shoal in KZN, Algoa Bay, Plettenberg Bay, Knysna, the Cape Whale Coast (Hermanus area) and False Bay in the Western Cape. Of these, the Aliwal Shoal Hope Spot is located adjacent to (inshore) the southwestern corner of Block ER236, but well to the southwest (~250 km) of the area of northern interest for well drilling, and ~100 km inshore and west of the southern area of interest.

[3] The MPA boundaries illustrated are based on those provided on the Operation Phakisa map and may change following finalisation of the Draft Notice declaring the various MPAs released in February 2016.

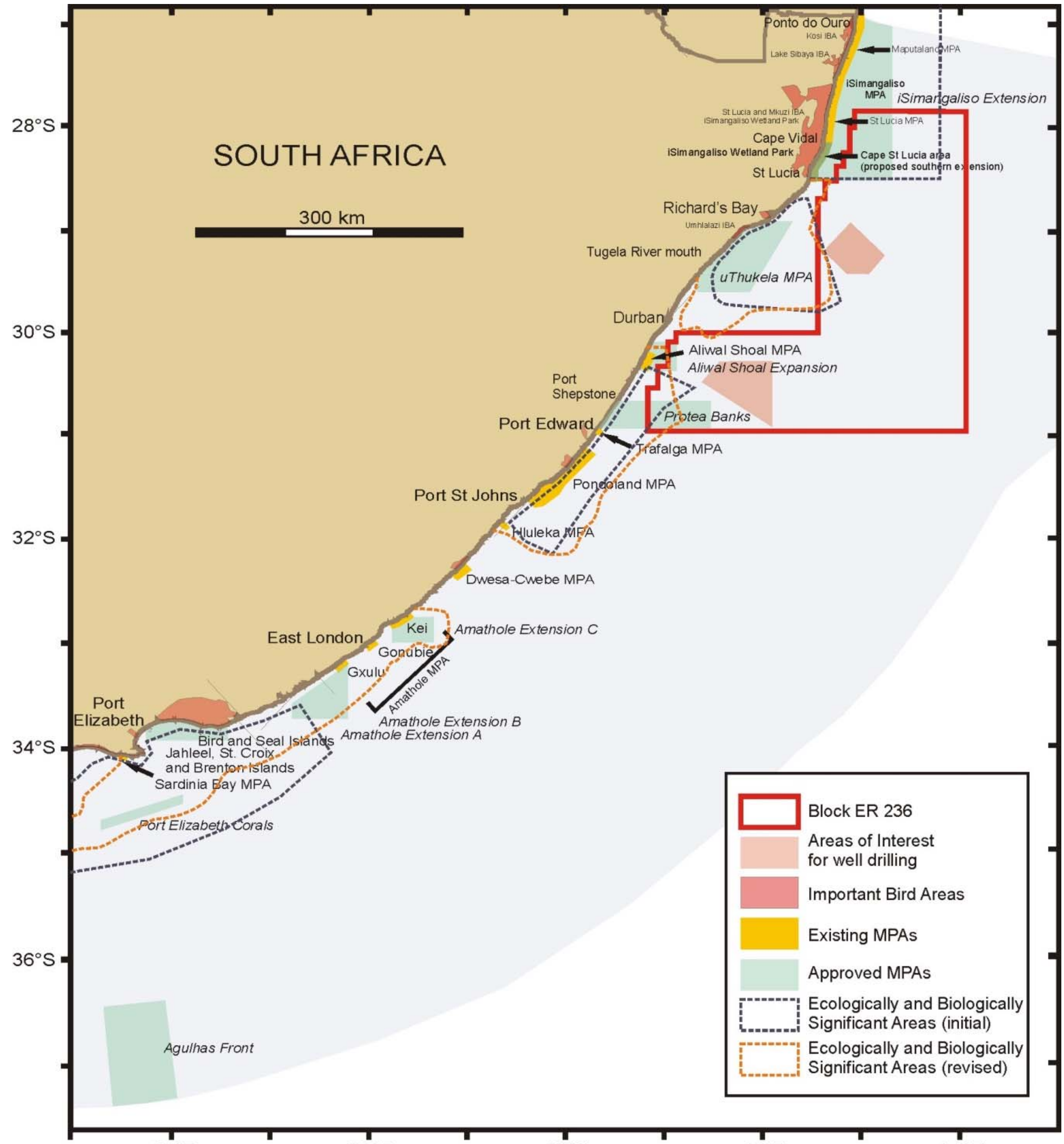


Figure 28: Marine Protected Areas, Important Bird Areas (IBAs), recently approved and existing Marine Protected Area (MPA) within the Exclusive Economic Zone (grey shading) off the KwaZulu-Natal coast in relation to Block ER236 (red polygon) and the proposed areas of interest for well drilling (orange shading).

4. ASSESSMENT OF PLANNED IMPACTS OF EXPLORATION WELL DRILLING ON MARINE FAUNA

4.1. Impact Assessment Methodology

An EIA methodology should minimise subjectivity as far as possible and accurately assess the planned project impacts. To achieve this ERM has followed the methodology defined below.

4.1.1 Impact Identification and Characterisation

An 'impact' is any change to a resource or receptor caused by the presence of a project component or by a project-related activity. Impacts can be negative or positive.

Impacts are described in terms of their characteristics, including the impact type and the impact spatial and temporal features (namely extent, duration, scale and frequency). Table 11 describes the terms used in this EIA.

Table 11: Impact Characteristics

Characteristic	Definition	Terms
Type	A descriptor indicating the relationship of the impact to the project (in terms of cause and effect).	**Direct** - Impacts that result from a direct interaction between the project and a resource/receptor (eg between occupation of the seabed and the habitats which are affected). **Indirect** - Impacts that follow on from the direct interactions between the project and its environment as a result of subsequent interactions within the environment (eg viability of a species population resulting from loss of part of a habitat as a result of the project occupying the seabed). **Induced** - Impacts that result from other activities (which are not part of the project) that happen as a consequence of the project. **Cumulative** - Impacts that arise as a result of an impact and effect from the project interacting with those from another activity to create an additional impact and effect.
Duration	The time period over which a resource / receptor is affected.	**Temporary** - impacts are predicted to be of short duration and intermittent/occasional. **Short term** - impacts that are predicted to last only for the duration of the drilling and well testing phase, i.e. 6 months or less. **Medium term** - impacts that are predicted to extend beyond the drilling phase but not longer than three years. **Long term** - impacts that will continue beyond three years but within 10 years. **Permanent** - impacts that cause a permanent change in the affected receptor or resource or ecological process, and which endures beyond 10 years.

Characteristic	Definition	Terms
Extent	The reach of the impact (i.e. physical distance an impact will extend to)	**On-site** - impacts that are limited to the site area only, i.e. within 500 m of drilling well (exclusion zone). **Local** - impacts that are limited to the project site and within the block. **Regional** - impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries, habitat type/ecosystems, ie extend to areas outside the block. **National** - impacts that affect nationally important environmental resources or affect an area that is nationally important/ or have macro-economic consequences. **Trans-boundary/International** - impacts that affect internationally important resources such as areas protected by international conventions or impact areas outside of South Africa.
Scale	Quantitative measure of the impact (eg the size of the area damaged or impacted, the fraction of a resource that is lost or affected, etc.).	Quantitative measures as applicable for the feature or resources affects. No fixed designations as it is intended to be a numerical value.
Frequency	Measure of the constancy or periodicity of the impact.	No fixed designations; intended to be a numerical value or a qualitative description.

4.1.2 Determining Impact Magnitude

Once impacts are characterised they are assigned a 'magnitude'. Magnitude is typically a function of some combination (depending on the resource/receptor in question) of the following impact characteristics:

- Extent;
- Duration;
- Scale; and
- Frequency.

Magnitude (from small to large) is a continuum. Evaluation along the continum requires professional judgement and experience. Each impact is evaluated on a case-by-case basis and the rationale for each determination is noted. Magnitude designations for negative effects are: negligible, small, medium and large.

The magnitude designations themselves are universally consistent, but the definition for the designations varies by issue. In the case of a positive impact, no magnitude designation has been assigned as it is considered sufficient for the purpose of the impact assessment to indicate that the project is expected to result in a positive impact.

Some impacts will result in changes to the environment that may be immeasurable, undetectable or within the range of normal natural variation. Such changes are regarded as having no impact, and characterised as having a negligible magnitude.

In the case of impacts resulting from unplanned events, the same resource/ receptor-specific approach to concluding a magnitude designation is used. The likelihood factor is also considered, together with the other impact characteristics, when assigning a magnitude designation.

4.1.3 Determining Magnitude for Biophysical Impacts

For biophysical impacts, the semi-quantitative definitions for the spatial and temporal dimension of the magnitude of impacts used in this assessment are provided below.

High Magnitude Impact affects an entire area, system (physical), aspect, population or species (biological) and at sufficient magnitude to cause a significant measureable numerical increase in measured concentrations or levels (to be compared with legislated or international limits and standards specific to the receptors) (physical) or a decline in abundance and/ or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would not return that population or species, or any population or species dependent upon it, to its former level within several generations (physical and biological). A high magnitude impact may also adversely affect the integrity of a site, habitat or ecosystem.

Medium Magnitude Impact affects a portion of an area, system, aspect (physical), population or species (biological) and at sufficient magnitude to cause a measurable numerical increase in measured concentrations or levels (to be compared with legislated or international limits and standards specific to the receptors) (physical) and may bring about a change in abundance and/or distribution over one or more plant/animal generations, but does not threaten the integrity of that population or any population dependent on it (physical and biological). A medium magnitude impact may also affect the ecological functioning of a site, habitat or ecosystem but without adversely affecting its overall integrity. The area affected may be local or regional.

Small Magnitude Impact affects a specific area, system, aspect (physical), group of localised individuals within a population (biological) and at sufficient magnitude to result in a small increase in measured concentrations or levels (to be compared with legislated or international limits and standards specific to the receptors) (physical) over a short time period (one plant/animal generation or less, but does not affect other trophic levels or the population itself), and localised area.

4.1.4 Determining Receptor Sensitivity

In addition to characterising the magnitude of impact, the other principal step necessary to assign significance for a given impact is to define the sensitivity of the receptor. There are a range of factors to be taken into account when defining the sensitivity of the receptor, which may be physical, biological, cultural or human. Where the receptor is physical (for example, a water body) its current quality, sensitivity to change, and importance (on a local, national and international scale) are considered. Where the receptor is biological or cultural (i.e. the marine environment or a coral reef), its importance (local, regional, national or international) and sensitivity to the specific type of impact are considered. As in the case of magnitude, the sensitivity designations themselves are universally consistent, but the definitions for these designations will vary on a resource/receptor basis. The universal sensitivity of a receptor is rated as low, medium or high.

For ecological impacts, sensitivity is assigned as low, medium or high based on the conservation importance of habitats and species. For the sensitivity of individual species, Table 12 presents the criteria for deciding on the value or sensitivity of individual species.

Table 12: Biological and Species Value / Sensitivity Criteria

Value / Sensitivity	Low	Medium	High
Criteria	Not protected or listed as common / abundant; or not critical to other ecosystem functions (eg key prey species to other species).	Not protected or listed but may be a species common globally but rare in South Africa with little resilience to ecosystem changes, important to ecosystem functions, or one under threat or population decline.	Specifically protected under South African legislation and/or international conventions e.g. CITES Listed as rare, threatened or endangered e.g. IUCN

Note: The above criteria should be applied with a degree of caution. Seasonal variations and species lifecycle stage should be taken into account when considering species sensitivity. For example, a population might be deemed as more sensitive during the breeding/spawning and nursery periods. This table uses listing of species (e.g. IUCN) or protection as an indication of the level of threat that this species experiences within the broader ecosystem (global, regional, local). This is used to provide a judgement of the importance of affecting this species in the context of project-level changes.

4.1.5 Assessing Significance

Once magnitude of impact and sensitivity of a receptor have been characterised, the significance can be determined for each impact. The impact significance rating will be determined, using the matrix provided in Table 13.

Table 13: Impact Significance

		Sensitivity/Vulnerability/Importance of Resource/Receptor		
		Low	**Medium**	**High**
Magnitude of Impact	**Negligible**	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	High	Moderate	Major	Major

The matrix applies universally to all resources/receptors, and all impacts to these resources/receptors, as the resource/receptor-specific considerations are factored into the assignment of magnitude and sensitivity/vulnerability/ importance designations that enter into the matrix. A context for what the various impact significance ratings signify is provided below.

4.1.6 Mitigation Potential and Residual Impacts

An impact of **negligible** significance is one where a resource/receptor (including people) will essentially not be affected in any way by a particular activity or the predicted effect is deemed to be 'imperceptible' or is indistinguishable from natural background variations.
An impact of **minor** significance is one where a resource/receptor will experience a noticeable effect, but the impact magnitude is sufficiently small and/or the resource/receptor is of low sensitivity/ vulnerability/ importance. In either case, the magnitude should be well within applicable standards.
An impact of **moderate** significance has an impact magnitude that is within applicable standards, but falls somewhere in the range from a threshold below which the impact is minor, up to a level that might be just short of breaching a legal limit. Clearly, to design an activity so that its effects only just avoid breaking a law and/or cause a major impact is not best practice. The emphasis for moderate impacts is therefore on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable (ALARP). This does not necessarily mean that impacts of moderate significance have to be reduced to minor, but that moderate impacts are being managed effectively and efficiently.
An impact of **major** significance is one where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. An aim of IA is to get to a position where the project does not have any major residual impacts, certainly not ones that would endure into the long-term or extend over a large area. However, for some aspects there may be major residual impacts after all practicable mitigation options have been exhausted (i.e. ALARP has been applied). An example might be the visual impact of a facility. It is then the function of regulators and stakeholders to weigh such negative factors against the positive ones, such as employment, in coming to a decision on the project.

A key objective of an EIA is to identify and define socially, environmentally and technically acceptable and cost effective measures to manage and mitigate potential impacts. Mitigation measures are developed to avoid, reduce, remedy or compensate for potential negative impacts, and to enhance potential environmental and social benefits.

The approach taken to defining mitigation measures is based on a typical hierarchy of decisions and measures, as described in Table 14

The priority is to first apply mitigation measures to the source of the impact (i.e. to avoid or reduce the magnitude of the impact from the associated project activity), and then to address the resultant effect to the resource/receptor via abatement or compensatory measures or offsets (i.e. to reduce the significance of the effect once all reasonably practicable mitigations have been applied to reduce the impact magnitude).

Once mitigation measures are declared, the next step in the impact assessment process is to assign residual impact significance. This is essentially a repeat of the impact assessment steps discussed above, considering the assumed implementation of the additional declared mitigation measures. The approach taken to defining mitigation measures is based on a typical hierarchy of decisions and measures, as described in Table 14.

Table 14: Mitigation Hierarchy

Avoid at Source; Reduce at Source:
avoiding or reducing at source through the design of the Project (eg avoiding by siting or re-routing activity away from sensitive areas or reducing by restricting the working area or changing the time of the activity).
Abate/Minimize on Site:
add something to the design to abate the impact (eg pollution control equipment).
Abate/Minimize at Receptor:
if an impact cannot be abated on-site then control measures can be implemented off-site (eg traffic measures).
Repair or Remedy:
some impacts involve unavoidable damage to a resource (eg material storage areas) and these impacts require repair, restoration and reinstatement measures.
Compensate in Kind; Compensate through Other Means:
where other mitigation approaches are not possible or fully effective, then compensation for loss, damage and disturbance might be appropriate (eg financial compensation for degrading agricultural land and impacting crop yields).

As required by the South African EIA Regulations (as amended in 2017) the following additional items will be considered in the assessment of impacts and risks identified:

- The degree to which the impact and risk can be **reversed** (this will be rated on a scale of high, medium, or low);

- The degree to which the impact and risk may cause **irreplaceable loss of resources** (this will be rated on a scale of high, medium, or low).

This will inform the residual impact significance.

4.1.7 Residual Impact Assessment

Once mitigation measures are declared, the next step in the impact assessment process is to assign residual impact significance. This is essentially a repeat of the impact assessment steps discussed above, considering the assumed implementation of the additional declared mitigation measures.

4.1.8 Cumulative Impacts

A cumulative impact is one that arises from a result of an impact from the Project interacting with an impact from another activity to create an additional impact. How the impacts and effects are assessed is strongly influenced by the status of the other activities (e.g. already in existence, approved or proposed) and how much data is available to characterise the magnitude of their impacts.

The approach to assessing cumulative impacts is to screen potential interactions with other projects on the basis of:

- projects that are already in existence and are operating;
- projects that are approved but not as yet operating; and
- projects that are a realistic proposition but are not yet built.

4.2. Identification of Impacts

The identification and assessment of impacts relating specifically to the marine ecology cover the four main activity phases (refer to the Aspects and Impacts Matrix for an outline of the activities in these phases) of the proposed well-drilling project, namely:

1 The Mobilisation Phase (MP)
2 Operational Phase (OP)
3 In the Demobilisation Phase (DP)
4 Unplanned Activities (UA)

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

- Physical disturbance of the seabed during ROV surveys, discharge of residual cement and well installation (OP), or loss of equipment (UA)
  - Disturbance and loss of seabed habitat and associated benthic macrofauna
- Accumulation of excess cement (from cementing) and disposed drill cuttings on the seabed (OP)

  - Smothering of seabed habitat and associated benthic fauna
  - Toxicity and bioaccumulation effects on marine fauna
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
- Discharge of drilling fluids and product water (OP)
  - Increased water turbidity and reduced light penetration
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
- Alteration of the seabed habitat through the physical presence of subsea structures (placement and abandonment of wellhead) (OP), solidified excess cement (OP, DP), or loss of equipment (UA)
  - Increase in benthic and demersal biodiversity and biomass
- Introduction of invasive alien species in the ballast water of the drilling units (MP)
  - Threats to ecosystem biodiversity
- Increase in underwater and atmospheric noise levels by drilling unit, support vessels and helicopters (MP, OP, DP)
  - Disturbance / behavioural changes of coastal and marine fauna
  - Avoidance of key feeding areas (e.g. Tripp Seamount)
  - Effects on key breeding areas (e.g. coastal birds and cetaceans)
  - Abandonment of nests (birds) and young (birds and seals)
- Discharge of waste to sea (e.g. deck and machinery space drainage, sewage and galley wastes) from drilling unit and support vessels, and local reduction in water quality (MP, OP, DP)
  - Reduced physiological functioning of marine organisms due to the biochemical effects on the water column and seabed sediments
  - Increased food source for marine fauna
  - Fish aggregation and increased predator-prey interactions
- Increase in ambient lighting from drilling unit and support vessels (OP)
  - Disorientation and mortality of marine birds
  - Physiological and behavioural effects on marine fauna
  - Fish aggregation and increased predator-prey interactions
- Localised reduction in water quality due to accidental release of fuel into the sea, discharge of fuel during bunkering and discharge of hydraulic fluid due to pipe rupture (UA)
  - Toxic effects on marine biota and reduced faunal health
- Uncontrolled release of oil/gas from the well (UA)
  - Toxic effects on marine biota and reduced faunal health
  - Pollution and smothering of coastal habitats

4.3. Assessment of Impacts

The possible impacts of petroleum extraction activities on marine benthic communities in South Africa’s Exclusive Economic Zone (EEZ) have to date not been comprehensively investigated (Atkinson & Sink 2008). Although not directly comparable to the South African East Coast, several studies have been conducted in other parts of the world, (USA, Mexico, North Sea) where there has been full oil and gas field production since the 1970s (Neff 2005; OGP 2003; Trefry *et al.* 2013; IOGP 2016, to name a few). These studies provide an indication of possible impacts to benthic habitats that might be expected in future petroleum production activities off the East Coast. The identified environmental aspects and the related potential impacts are discussed and assessed below using information from the international literature.

4.3.1 Physical disturbance of the seabed sediments

Description of the source of impact

The table below summarises the project activities that may physically disturb the seabed.

Activity phase	Activity
Mobilisation	n/a
Operation	Pre-drilling ROV seabed survey
	Drilling and spudding of the exploration well
	Discharge of residual cement during riserless stage
	Removal of BOP
Demobilisation	n/a
Unplanned Activities	Accidental loss of equipment to the seafloor (which is irretrievable)

These activities are described further below:

- During pre-drilling surveys, a ROV is deployed to obtain video footage of the seabed at the proposed well location. The ROV is also used to support drilling operations, monitoring the wellhead and BOP. At the end of the drilling activities the ROV is used to conduct a final survey of the wellhead and wellsite prior of demobilization of operations. Although the standard operating procedure is not to land or rest the ROV on the seabed, the ROVs thrusters can stir up the soft or silty sediments when operating close to the seabed. This resuspension of fine sediments would temporarily disturb seabed communities and result in localised increased turbidity.
- The current well-design parameter is to have a wellbore diameter of 42 inch (107 cm) during spudding. The penetration of the seabed by the drill bit during the riserless phase would physically disturb a surface area of 0.91 m^2, and displace deeper sediments (~400 m^3 of rock cuttings) into a conical cuttings pile around the wellhead. Casing of the hole and installation of the wellhead and BOP would potentially also result in localised direct disturbance of an area of about 3 m^2 around the well site.
- After a casing string is set in a well, specially designed cement slurries are pumped into the annular space between the outside of the casing and the borehole wall. To ensure effective cementing, an excess of cement is usually used. This excess (100 m^3 in the worst case) emerges out of the top of the well onto the cuttings pile, where (depending on its mix) it either does not set and dissolves slowly into the surrounding seawater, or if it remains in a pile, may act as an artificial reef, be colonised by epifauna and attract fish and other mobile predators (Buchanan *et al.* 2003).
- During the riser phase, ~220 m^3 (583 MT) of drill cuttings will be discharged overboard from the drillship and would settle on the seabed.
- Before demobilisation, the well(s) will be plugged (cement plug), tested for integrity and abandoned, irrespective of whether hydrocarbons have been discovered in the reservoir sections. The plug will create a permanent barrier to avoid future fluid release from the

well bore and across any reserve sections. Residual cement slurry in cement lines will be similarly discarded overboard.
- The accidental loss of equipment (which is irretrievable) onto the seafloor could physically damage the seabed and/or disturb sediments within the footprint of the lost item.

Description of the environmental aspects

Drilling of exploration wells within the two areas of interest in the ER236 area would result in the direct physical disturbance and removal of sediments during drilling activities, potential changes in sediment characteristics and condition. Physical disturbance of the seabed may also occur during ROV surveys, discharge of residual cement, or the accidental loss of equipment.

Description of the potential impacts

Any benthic fauna present on the seabed and in the sediment in the disturbance footprint, would be either completely eliminated or may potentially be disturbed or crushed. Resuspension of seabed sediments by ROV thrusters may also result in increased turbidity near the seabed, potentially with physiological effects on benthic faunal communities.

Disturbance of seabed sediments during pre-drilling ROV surveys could potentially increase turbidity of the near-bottom water layers. This may place transient stress on sessile and mobile benthic organisms, by negatively affecting filter-feeding efficiency of suspension feeders or through disorientation of mobile species due to reduced visibility (reviewed by Clarke and Wilber 2000). However, in most cases sub-lethal or lethal responses occur only at concentrations well in excess of those anticipated due to resuspension of sediments by ROV thrusters.

Sensitive Receptors

Disturbance of seabed sediments would result in direct damage to, and disturbance of, the invertebrate benthic communities living on the seabed or within the sediments. The benthic infauna inhabiting unconsolidated sediments of the outer shelf and continental slope are very poorly known, but at the depths of the proposed well are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic macro-infaunal communities usually comprise relatively fast-growing species able to recruit into areas that have suffered natural environmental disturbance. However, epifauna living on the sediment typically comprise urchins, burrowing anemones, molluscs, seapens and sponges, many of which are longer lived and therefore more sensitive to disturbance. In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. Video footage from the submarine canyons and feeder valleys on the shelf edge in the Maputaland and St Lucia Marine Reserves has identified vulnerable communities including sponges, black corals, gorgonians, alcyonarian soft corals and stylasterine lace corals (Sink *et al.* 2006). Although the occurrence of such potentially vulnerable marine ecosystems in Block ER236 and the areas of interest for well drilling is unknown, the potential presence of such sensitive deep-water ecosystems in the project area cannot be excluded. Such sensitive communities would be expected to occur in the submarine canyons within ER236, which are located to the immediate south of the northern area of interest and some 30 km northeast of the southern area of interest. As no drilling operations will be performed in canyons, direct and indirect impacts on sensitive receptors associated with such habitats would be avoided.

Project Controls and Industry Objectives

The proposed drilling operations will be undertaken by Eni in a manner consistent with good international industry practice.

Performance objectives

- Minimise disturbance to the seabed during pre-drilling ROV surveys, during drilling of the well and as a consequence of accidental loss of equipment.
- Avoid sensitive hard substrate areas by locating well-site in unconsolidated sediments.

Impact assessment

Disturbance of sediments due to ROV surveys

The impact of increased turbidity and elevated suspended sediment concentrations would be extremely localised (a few metres around the ROV and/or ROV flight track) and would persist only over the very short term (hours or minutes, based on sediment consistency). When the ROV is operating close to the seabed ROV the thrusters will disturb seabed sediments. The magnitude of any potential adverse effects on sessile benthos would be negligible. The impact is considered to be fully reversible and can thus confidently be rated as being of **NEGLIGIBLE** significance without mitigation.

Mitigation

Objective: to minimise sediment disturbance during ROV surveys.
Actions: the following measures are recommended to manage sediment disturbance by ROVs.

No.	Mitigation measure	Classification
1	Implement procedures for ROVs that stipulate that the ROV does not land or rest on the seabed as part of normal operations	Abate on site

Residual impact

This potential impact cannot be eliminated due to the necessity for pre-drilling ROV seabed surveys. Thus the significance of the impact remains **NEGLIGIBLE**.

Impacts of sediment resuspension by ROV thrusters		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to a few metres around the ROV and/or ROV track	Local
Duration	Short-term: intermittently for duration of ROV surveys	Short-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Negligible	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	None	

Disturbance of sediments due to drilling

The immediate effect of the physical disturbance and removal of seabed sediments on the benthos depends on their degree of mobility, with sedentary and relatively immobile species likely to be physically damaged or destroyed during the disturbances associated with well drilling or the accidental loss of irretrievable equipment. Considering the available area of similar habitat on and off the edge of the continental shelf in the West Indian Offshore bioregion, this disturbance of and reduction in benthic biodiversity can be considered negligible, and no cumulative effects on higher order consumers are expected.

Further loss or disturbance of the benthos due to smothering under the spoil mounds generated by disposal of drilling muds and cuttings are discussed further under Section 4.3.3.

The physical disturbance and/or removal of unconsolidated sediments and their associated benthic macrofaunal communities during drilling and spudding would be extremely localised and persist only over the short term. The impact is fully reversible and of small magnitude and can confidently be rated as being of **MINOR** significance without mitigation.

Mitigation

Objective: to reduce the disturbance to sediments through drilling.

Actions: the following measures are recommended to reduce and manage the disturbance to sediments through drilling:

No.	Mitigation measure	Classification
1	Review ROV footage of pre-drilling surveys to identify potential vulnerable habitats within 500 m of the drill site	Avoid / reduce at source
2	Ensure drill site is located more than 500 m from any identified vulnerable habitats	Avoid / reduce at source

Residual impact

This potential impact cannot be eliminated due to the nature of the drilling approach. Thus the impact remains of **MINOR** significance.

Impacts on benthic macrofauna of unconsolidated sediments through removal or crushing		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to well site	Local
Duration	Short-term: recovery of affected benthic fauna expected within 2-5 years	Short-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	Very Low	

4.3.2 Accumulation of residual cement on the seabed

Description of the source of impact

The table below summarises the project activities that will result in accumulation of excess cement on the seabed.

Activity phase	Activity
Mobilisation	n/a
Operation	Discharge of residual cement to the seabed during the riserless stage
	Discharge of unused cement slurry to the water column during the risered stage
Demobilisation	n/a

These activities are described further below:

- During riserless operations, after a casing string is set in a well, specially designed cement slurries are pumped into the annular space between the outside of the casing and the borehole wall. To ensure effective cementing, an excess of cement is usually used. This excess (100 m^3 in the worst case) emerges out of the top of the well onto the cuttings pile, where, due to the low temperatures and high pressures at the proposed well depth, it will dissolve slowly into the surrounding seawater.
- For cementing jobs subsequent to riser installation, excess cement is returned to the drilling vessel *via* the riser and treated using the solids control system. Unused cement slurry that has already been mixed is discharged overboard.

Description of the environmental aspects

The discharge of residual cement during cementing (this only occurs when cementing the first string – surface casing) would result in the physical disturbance of the seabed sediments and accumulation of cement on the seabed, where it will dissolve. The discharge of unused cement slurry to the water column would potentially reduce water quality.

Description of the potential impacts

The discharge of residual cement would result in the direct physical disturbance and smothering of the invertebrate benthic communities both during initial cementing. Any benthic fauna present on the seabed, may potentially be disturbed or crushed (direct impact) by the residual cement or suffer indirect toxicity and bioaccumulation effects due to leaching of potentially toxic cement additives. Pelagic biota may potentially suffer indirect toxicity and bioaccumulation effects due to leaching of potentially toxic cement additives in the excess slurry discharged overboard from the drillship.

Sensitive Receptors

The discharge of excess cement slurry at the seabed and from the drillship could affect a wide range of fauna; from benthic invertebrates and demersal species residing on the seabed in the vicinity of the wellhead, to those invertebrates and vertebrates occurring throughout the water column and in the pelagic habitat near the surface. The benthic fauna inhabiting unconsolidated sediments of the outer shelf and continental slope are very poorly known, but at the depths of the proposed well are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise urchins, burrowing anemones, molluscs, seapens and sponges, many of which are longer lived and therefore more sensitive to disturbance. No rare or endangered benthic species are known. In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. Video footage from the submarine canyons and feeder valleys on the shelf edge in the Maputaland and St Lucia Marine Reserves has identified vulnerable communities including sponges, black corals, gorgonians, alcyonarian soft corals and stylasterine lace corals (Sink *et al.* 2006). Although the occurrence of such potentially vulnerable marine ecosystems in Block ER236 and the areas of interest for well drilling is unknown, the potential presence of such sensitive deep-water ecosystems in the project area cannot be excluded. Such sensitive communities would be expected to occur in the submarine canyons within ER236, which are located to the immediate south of the northern area of interest and some 30 km northeast of the southern area of interest. As no drilling operations will be performed in canyons, direct and indirect impacts on sensitive receptors associated with such habitats would be avoided.

Project Controls and Industry Objectives

Eni has no project controls specifically governing the accumulation of residual cement on the seabed during initial cementing or the discharge into the water column of unused cement slurry. However, Eni would monitor cement returns and would terminate pumping if returns are observed on the seafloor.

Performance objectives

Although no specific targets, standards or legislation exist regarding disturbance of the seabed through the discharge and accumulation of residual cement, or the discharge to the water column of excess cement slurry, Eni should:

- Strive to minimise the discharge of cement to the seabed and water column;
- Avoid sensitive hard substrate areas by locating well-site in soft unconsolidated sediments.

Impact assessment

Disturbance and/or smothering due to cementing

Considering the available area of similar habitat on and off the edge of the continental shelf in the West Indian Offshore bioregion, the disturbance of and reduction in benthic biodiversity due to cementing can be considered moderate, and no cumulative effects on higher order consumers is expected.

Disturbance and smothering of benthic macrofauna due to the release of excess cement around the wellbore is of medium magnitude as the cement would be discharged in an area already affected by drill cuttings. Any potential impacts would be extremely localised (i.e. confined to the wellbore footprint) and would persist over the long term. The impact is partially reversible. The direct impact of smothering benthic communities can thus be rated as being of **MODERATE** significance.

Mitigation

Objective: to minimise the discharge of cement to the seabed and water column.

Actions: the following measures are recommended to reduce the discharge of excess cement.

No.	Mitigation measure	Classification
1	Reduce excess of cement slurry during riserless drilling by monitoring cement return with ROV	Avoid / reduce at source

Residual impact

This potential impact cannot be eliminated due to the nature of the drilling approach and the necessity for cementing. The residual impact would thus remain **MINOR**.

Disturbance and/or smothering of benthic communities due to cementing		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to well site	Local
Duration	Long-term: as recovery of benthic communities may take up to 10 years	Long-term
Scale	Small	Small
Reversibility	Medium	
Loss of resource	Low	
Magnitude	Medium	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium	Medium
Significance of Impact	**Moderate**	**Minor**
Mitigation Potential	Low	

Toxicity and bioaccumulation effects on marine fauna

Various chemical additives are used in the cementing programme to control its properties, include setting retarders and accelerators, surfactants, stabilisers and defoamers. The formulations are adapted to meet the requirements of a particular well. Their concentrations, however, typically make up <10 % of the overall cement used. Furthermore, the additives have a low toxicity to marine life (Ranger 1993; Chevron 1994).

The indirect impact of leaching of the additives into the surrounding water column and their potential toxic effects on pelagic, demersal and benthic communities, or the potential for bioaccumulation is of small maginitude and extremely localised (*i.e.* confined to the wellbore footprint or immediate vicinity of the drillship) and would likely persist only over the short term. As physiological effects would be fully reversible, the biochemical impacts can thus be rated as being of **NEGLIGIBLE** significance without mitigation.

Mitigation

Objective: to manage the biotoxicity of residual cement.

Actions: the following measures are recommended to manage the biotoxicity of residual cement.

No.	Mitigation measure	Classification
1	Ensuring that only low-toxicity and partially biodegradable cement additives are used.	Avoid / reduce at source

Residual impact

This potential impact cannot be eliminated due to the nature of the drilling approach and the necessity for cementing. With the implementation of the above-mentioned mitigation measure, the residual impact would have a lower probability, and the significance level would remain as **NEGLIGIBLE**.

Toxicity and bioaccumulation effects of residual cement on marine fauna		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to well site	Local
Duration	Short-term: for duration of drilling operation	Short-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	Low	

4.3.3 Accumulation of disposed drill cuttings on the seabed

Description of the source of impact

The table below summarises the project activities that will result in accumulation of drill cuttings on the seabed.

Activity phase	Activity
Mobilisation	n/a
Operation	Discharge of drill cuttings at the well bore during the riserless stage
	Discharge of drill cuttings from the drillship
Demobilisation	n/a

These activities are described further below:

- The current well-design parameter is to have a wellbore diameter of 42 inch (107 cm) during spudding. The cuttings from the top-hole sections of the well (drilled with WBMs) are discharged onto the seafloor where they would accumulate in a conical cuttings pile around the wellhead. In the order of 400 m^3 of cutting will be generated at the well bore.
- During the risered drilling phase of the well(s), the primary discharge from the drillship would be the drill cuttings. For the current project, these are expected to comprise muds and sands ranging in size from 0.02 mm to 60 mm. The chemistry and mineralogy of the rock particles reflects the types of sedimentary rocks penetrated by the bit. Cuttings from lower-hole sections (drilled with WBMs) are lifted up the marine riser to the drilling unit

and separated from the drilling fluid by the on-board solid control systems. The solids waste stream is fluidised with seawater and discharged overboard through the cutting chute, which is typically located a few metres below the sea surface. Cuttings released from the drillship would be dispersed more widely around the drill site by prevailing currents. In the order of 220 m^3 (583 MT) of cuttings will be discharged from the drillship.

- Should there be spent WBM remaining at the end of the drilling operation, this will either be stored onboard and shipped to shore for disposal/recycling or will be discharged overboard but only if in compliance with specific standards.

Description of the environmental aspects

Discharge of drill cuttings would result in the disturbance of the seabed around the wellbore and the accumulation of drill cuttings on the seabed.

Description of the potential impact

The potential impacts associated with the discharge of drill cuttings include:

- Direct smothering of benthic fauna by both the discharge of cuttings onto the seabed from the top-hole section of the well, as well as discharge of treated cuttings from the drillship;
- Increased water turbidity and reduced light penetration through discard of treated cuttings from the drillship resulting in indirect physiological effects on marine fauna or indirect effects on primary productivity in surface waters; and
- Physiological effects on marine fauna due to toxicity and/or bioaccumulation.

Sensitive Receptors

The discharge of cuttings at the seabed would have both direct and indirect effects on benthic faunal communities in the vicinity of the well head and within the fall-out footprint of the cuttings plume discharged from the drill ship. Disturbance of seabed sediments would result in direct damage to, and disturbance of, the invertebrate benthic communities living on the seabed or within the sediments. The benthic fauna inhabiting unconsolidated sediments of the outer shelf and continental slope are very poorly known, but at the depths of the proposed well are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise urchins, burrowing anemones, molluscs, seapens and sponges, many of which are longer lived and therefore more sensitive to disturbance. No rare or endangered species are known to occur here. In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. Video footage from the submarine canyons and feeder valleys on the shelf edge in the Maputaland and St Lucia Marine Reserves has identified vulnerable communities including sponges, black corals, gorgonians, alcyonarian soft corals and stylasterine lace corals (Sink *et al.* 2006). Although the occurrence of such potentially vulnerable marine ecosystems in Block ER236 and the areas of interest for well drilling is unknown, the potential presence of such sensitive deep-water ecosystems in the project area cannot be excluded. Such sensitive communities would be expected to occur in the submarine canyons within ER236, which are located to the immediate south of the northern area of interest and some 30 km northeast of the southern area of interest. As no drilling operations will be performed in canyons, direct and indirect impacts on sensitive receptors associated with such habitats would be avoided.

Cuttings discharged from the drillship would also have both direct and indirect effects on primary producers (phytoplankton) in surface waters, and pelagic fish and invertebrate communities in the water column. Due to the offshore location of the area of interest, the abundance of phytoplankton and pelagic fish and invertebrate fauna is likely to be very low. Being dependent on nutrient supply, plankton abundance is typically spatially and temporally highly variable and is thus considered to have a low sensitivity. Higher productivity and the concomitant development of detritivore-based food-webs can, however, be expected in the vicinity of the submarine canyons.

Project Controls and Industry Objectives

Eni's specifications for discharge of drill cuttings includes:

- Discharge of cuttings via a caisson in >15 m depth;
- Discharge of cuttings only in water >30 m depth;
- Only use of NADFs with < 1 mg/kg Hg and <3 mg/kg Cd;
- Treatment of cuttings to reduce the oil content to 5% (C16-C18 internal olefins) or 9.4% (C12-C14 ester or C8 esters) on wet cuttings; and
- Ship-to-shore if none of the above is achievable.

Performance objectives

Eni should strive to:

- reduce and manage the potential smothering effects of cuttings discharges;
- avoid and minimise the impacts of discharged cuttings on sensitive hard substrata.

Impact assessment

Smothering of seabed habitat and associated benthic fauna

The effects of drilling mud and cuttings discharges on the benthic environment are related to the total mass of drilling solids discharged, whether these are discharged at the seabed or off the drilling unit, and the relative energy of the water column and benthic boundary layer at the discharge site. The total volume of cuttings discharged during the drilling of a well would be dependent upon the well depth and the drilling conditions encountered. With increasing well depth and concomitant decrease in both penetration rate and wellbore diameter, the rate of cuttings discharge decreases.

The cuttings discharged at the seabed during the spudding of a well would form a highly localised spoil mound around the wellbore, thinning outwards. In contrast, the cuttings discharged from the drillship form two plumes as they are discharged. The heavier cuttings and flocculated clay/barite particles (>0.2 mm), which constitute 88.75 % of the discharge, settle to the seabed near the wellbore while the fine-grained unflocculated solids and dissolved components of the mud (11.25 % of the discharge) are dispersed in the water column at increasing distances from the drillship (Figure 29). The dispersion pattern and degree of accumulation depends on water depth, current strength and the frequency of storm surges (Buchanan *et al.* 2003).

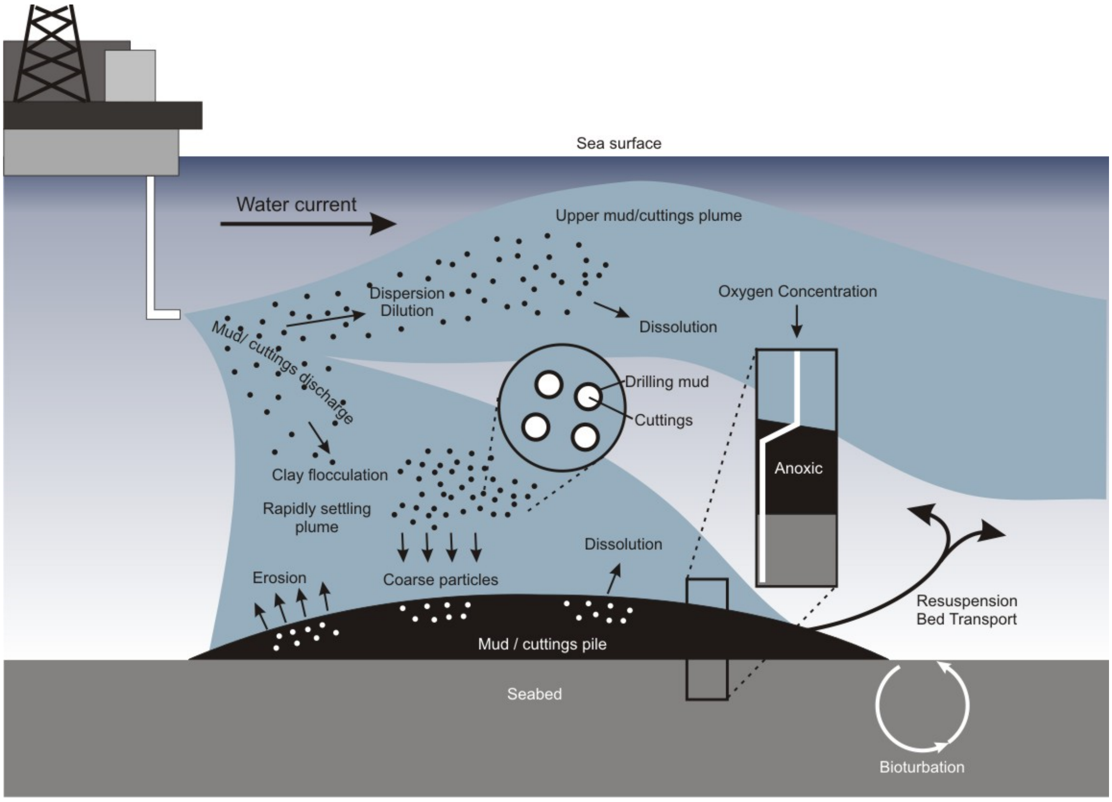


Figure 29: Hypothetical dispersion and fates of cuttings following discharge to the ocean, irrespective of drilling unit used. The solids undergo dispersion, dilution, dissolution, flocculation, and settling in the water column. If the discharge contains a high concentration of organic matter, the cuttings pile may become anaerobic near the surface, before being altered by redox cycling, bioturbation, and bed transport (adapted from Neff 2005).

In high energy environments, accumulation of drilling waste on the seabed is minimal as the drilling solids are rapidly dispersed and redistributed. Under such conditions adverse effects of the discharges on benthic community composition are difficult to detect above the natural variability (Lees & Houghton 1980; Houghton *et al.* 1980; Bothner *et al.* 1985; Neff *et al.* 1989; Daan & Mulder 1993, 1996). Where changes in abundance and diversity of macrofaunal communities were detected, these were typically restricted to within about 100 m of the discharge, but did not persist much beyond 6 months after drilling operations had ceased (Chapman *et al.* 1991; Carr *et al.* 1996; Currie & Isaacs 2005).

In low-energy, deep-water environments, however, the effects of drilling waste discharges on benthic ecosystems are more severe and long-lasting. Typically, the coarse cuttings accumulate within 200 m of the drilling unit, although depending on the strength of prevailing current, some may disperse as far as 800 m from the drilling unit. Some authors report that cuttings piles near a rig can be 1-2 m high (Hinwood *et al.* 1994; Hartley *et al.* 2003; Neff 2005), but these were usually associated either with the disposal of NADF cuttings, which tend to aggregate once discharged and thus disperse less readily resulting in a smaller area but thicker deposition on the seabed, or with cuttings shunted to and discharged near the seabed. The results of recent international modelling studies and physical sampling exercises have indicated that the majority of discharges would have a maximum accumulated height of less than 8 cm, with a fine cover of less than 2 mm thickness likely to extend to ~0.5 km from the discharge point (Perry 2005).

Studies have found that changes in abundance and diversity of macrofaunal communities in response to depositing cuttings were typically detected within a few 100 m of the discharge (Neff *et al.* 1992; Ranger 1993; Montagna & Harper 1996; Schaanning *et al.* 2008), with recovery of the benthos observed to take from several months to several years (most likely within 1 year) after drilling operations had ceased (Husky 2000, 2001a, 2001b; Buchanan *et al.* 2003; Neff 2005; Currie & Isaacs 2005). The potential environmental effects of drilling solids discharges have been discussed in several studies (Morant 1999; Husky 2000, 2001a; CAPP 2001; Hurley & Ellis 2004), all of which concluded that exploratory drilling has no measureable environmental effect on the marine environment.

The main impacts associated with the disposal of drilling solids would be smothering of sessile benthic fauna, physical alteration of the benthic habitat (changes in sediment properties) in the immediate vicinity (<200 m) of the well. The effects of smothering on the receiving benthic macrofauna are determined by 1) the depth of burial; 2) the nature of the depositing sediments; and 3) the tolerance of species (life habitats, escape potential, tolerance to hypoxia etc.) (Kranz 1974; Maurer *et al.* 1981a, 1981b, 1982, 1986; Bijkerk 1988; Hall 1994; Baan *et al.* 1998; Harvey *et al.* 1998; Essink 1999; Schratzberger *et al.* 2000b; Baptist *et al.* 2009).

Many benthic infaunal species are able to burrow or move through the sediment matrix, and some infaunal species are able to actively migrate vertically through overlying deposited sediment thereby significantly affecting the recolonisation and subsequent recovery of impacted areas (Maurer *et al.* 1979, 1981a, 1981b, 1982, 1986; Ellis 2000; Schratzberger *et al.* 2000a; but see Harvey *et al.* 1998; Blanchard & Feder 2003). Maurer *et al.* (1979) reported that some animals are capable of migrating upwards through 30 cm of deposited sediment. In contrast, consistent faunal declines were noted during deposition of mine tailings from a copper mine in British Columbia when the thickness of tailings exceeded 15-20 cm (Burd 2002), and Schaffner (1993) recorded a major reduction in benthic macrofaunal densities, biomass, and species richness in shallow areas in lower Chesapeake Bay subjected to heavy disposal (>15 cm) of dredged sediments. Similarly, Roberts *et al.* (1998) and Smith & Rule (2001) found differences in species composition detectable only if the layer of instantaneous applied overburden exceeded 15 cm. In general, mortality tends to increase with increasing depth of deposited sediments, and with speed and frequency of burial.

The survival potential of benthic infauna, however, also depends on the nature of the deposited non-native sediments (Turk & Risk 1981; Chandrasekara & Frid 1998; Schratzberger *et al.* 2000a). Although there is considerable variability in species response to specific sediment characteristics (Smit *et al.* 2006), higher mortalities were typically recorded when the deposited sediments have a different grain-size composition from that of the receiving environment (Cantelmo *et al.* 1979; Maurer *et al.* 1981a, 1981b, 1982, 1986; Smit *et al.* 2006; Smit *et al.* 2008), which would be the case in the discharge of drill cuttings. Migration ability and survival rates of organisms are generally lower in silty sediments than in coarser sediments (Hylleberg *et al.* 1985; Ellis & Heim 1985; Maurer *et al.* 1986; Romey & Leiseboer 1989, cited in Schratzberger *et al.* 2000a; Schratzberger *et al.* 2000b). Some studies indicate that changes to the geomorphology and sediment characteristics may in fact have a greater influence on the recovery rate of invertebrates than direct burial or mortality (USDOI/FWS 2000). The availability of food in the depositional sediment is, however, also influential.

The duration of burial, would also determine the effects on the benthos. Here a destinction must be made between incidental deposition, where species are buried by deposited material within a short period of time (as would occur during drilling solids disposal), and continuous deposition, where species are exposed to an elevated sedimentation rate over a long period of time (e.g. in the vicinity of river mouths). Provided the sedimentation rate of incidental deposition is not higher than the velocity at which the organisms can move or grow upwards, such deposition need not necessarily have negative effects. The sensitivity to short-term incidental deposition is species dependent and also dependent on the sediment type, with deposition of silt being more lethal than a deposition of sand.

The nature of the receiving community is also of importance. In areas where sedimentation is naturally high (e.g. wave-disturbed shallow waters) the ability of taxa to migrate through layers of deposited sediment is likely to be well developed (Roberts *et al.* 1998). The life-strategies of organisms is a further aspect influencing the susceptibility of the fauna to mortality. Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat may be negatively affected by the smothering effects of drill cuttings. Studies on the burrowing habits of 30 species of bivalves showed that mucous-tube feeders and labial palp deposit-feeders were most susceptible to sediment deposition, followed by epifaunal suspension feeders, boring species and deep-burrowing siphonate suspension-feeders, none of which could cope with more than 1 cm of sediment overburden. Infaunal non-siphonate suspension feeders were able to escape 5 cm of burial by their native sediment, but normally no more than 10 cm (Kranz 1972, cited in Hall 1994). The most resistant species were deep-burrowing siphonate suspension-feeders, which could escape from up to 50 cm of overburden. Meiofaunal species appear to be less susceptible to burial than macrofauna (Menn 2002).

There has recently been increasing focus on the potential impacts of drilling solids disposal on vulnerable deep-water coral communities in the Northeast Atlantic (Rogers 1999; Colman *et al.* 2005; www.coralreef.noaa.gov/deepseacorals/threats). As deep-water corals tend to occur in areas with low sedimentation rates (Mortensen *et al.* 2001), these benthic suspension-feeders and their associated faunal communities are likely to show particular sensitivity to increased turbidity and sediment deposition associated with cuttings discharges. Exposure of corals to drilling solids can result in mortality of the colony due to smothering, alteration of feeding behaviour and consequently growth rate, disruption of polyp expansion and retraction, physiological and morphological changes, and disruption of calcification. While tolerances to increased suspended sediment concentrations will be species specific, drilling mud concentrations as low as 100 mg/l have been shown to have noticeable effects on coral function (Roger 1999). Lepland & Mortensen (2008) identified that deep-water corals on the Norwegian shelf, downcurrent of a test well discharge, did not show clear differences in health status, although barite crystals derived from the drilling mud were present among trapped sediments in the skeleton cavities of dead coral polyps older than six years, with highest barite concentration found in a polyp older than 13 years. Although the occurrence of such potentially vulnerable marine ecosystems in Block ER236 and the areas of interest for well drilling is unknown, the potential presence of such sensitive deep-water ecosystems in the project area cannot be excluded. Such sensitive communities would be expected to occur in the submarine canyons within ER236, which are located to the immediate south of the northern area of interest and some 30 km northeast of the southern area of interest As video footage has identified vulnerable communities including sponges, black corals, gorgonians, alcyonarian soft corals and stylasterine lace corals (Sink *et al.* 2006) in submarine canyons off the KZN coastline, the potential occurrence of such sensitive deep-water ecosystems in the ER236 area cannot be excluded.

The results of the cuttings dispersion modelling studies undertaken as part of this project (ERM 2018a) largely confirm the reports of international studies that predicted that the effects of discharged cuttings are localised (see Perry 2005). For the current project, ~620 m^3 (1,643 MT) of rock cuttings would be generated, of which 400 m^3 (1,060 MT) of uncontaminated cuttings would be discharged at the seafloor (~65% of the total volume of cuttings generated), with the remaining 220 m^3 (583 MT) discharged off the drillship to the water column, from where they will be redistributed by currents before settling back onto the seabed. The cuttings discharged at the seabed were predicted to create a cone in the order of 1,000 mm thick close to the wellbore, thinning outwards to a thickness of 5 mm at a radius of <50 m (total area of 0.008 km^2), regardless of the well position (N1, N2 and S) or whether minimum or maximum average monthly current conditions were considered. Areas of deposition of <5 mm thickness were mainly isolated to within a 100 m radius of the wellhead, although isolated deposition extended to distances well beyond 1 km, primarily down-current of the well. The maximum area of deposition >50 mm (the threshold thickness adopted by the modelling study) remains restricted to an area of less than 0.003 km^2 at each location.

Once the marine riser has been set, cuttings would be released continuously near the sea surface from the drilling platform at a water depth deeper than 15 m through a caisson. These discharges would continue throughout the entirety of the drilling campaign and would experience greater dispersion as they settle through the water column resulting in a patchy deposit that extends ~1.5 km from the wellhead. Although the variations in current direction between the well locations and between the minimum and maximum average monthly current condition scenarios modelled result in different directional spread of the particles, the overall footprint deposition >1 mm covers a maximum total predicted area that extends ~7 km^2 around the well site. The differences apply primarily for the settlement patterns of the finer fractions (<0.2 mm), which would remain in the water column for longer. The large depths at the well sites in combination with the strong current speeds therefore result in a high dispersion of the discharged drill cuttings. This is, however, offset by the relatively low deposition thicknesses (<5 mm) predicted for distances beyond ~50 m from the well location. Relatively rapid recolonisation of benthic fauna can thus be expected (see for example Kingston 1987, 1992; Trefry *et al.* 2013), with subsequent bioturbation playing an important role in the physical recovery of the seabed (Munro *et al.* 1997).

Information on benthic communities beyond the shelf break is lacking, but the structure of the recovering communities will thus likely be highly spatially and temporally variable. The community developing after an impact depends on (1) the nature of the impacted substrate, (2) environmental factors such as bedload transport, near-bottom dissolved oxygen concentrations etc., and (3) differential re-settlement of larvae into the area, migration of mobile species into the area and from burrowing species migrating upwards back to the surface.

The smothering effects resulting from the discharge of drilling solids at the wellbore is assessed to have an impact of medium magnitude on the benthic macrofauna of unconsolidated sediments in the cuttings footprint, whereas discharges from the drillship would have a low magnitude impact. In both cases, the impact is localised and recovery of benthic communities is expected within a few years (5 - 10 years). As the impact is partially reversible, it can thus be considered to be of **MINOR** significance without mitigation for discharges at the wellbore. For discharges from the drilling unit, the impact is fully reversible and can thus be considered **NEGLIGIBLE**. However, should the cuttings footprint overlap with vulnerable communities on hard ground, the smothering effects would potentially have an impact of high magnitude, and recovery would only be expected over the medium- to long-term due to their long generation times. As Eni has ensured that the areas of interest for well drilling are located some distance from submarine canyons and the potential presence of sensitive deepwater corals would be checked during the pre-drilling ROV survey, these habitats and their associated sensitive receptors should not in any way be affected by the cuttings discharge. Should the impact on vulnerable communities on hard ground occur, it would be partially reversible and can thus be considered to be of **MODERATE** significance before mitigation.

Mitigation

Objective: to further reduce and manage the potential smothering, and toxicity and bioaccumulation effects of cuttings discharges.

Actions: the following measures are recommended to reduce and manage the potential smothering effects of cuttings discharges on vulnerable seabed communities:

No.	Mitigation measure	Classification
1	Review ROV footage of pre-drilling surveys to identify potential vulnerable habitats within 500 m of the drill site	Avoid / reduce at source
2	Ensure drill site is located more than 500 m from any identified vulnerable habitats	Avoid / reduce at source

Residual impact

This potential impact cannot be eliminated due to the need for and nature of the cuttings discharge. With the implementation of the above-mentioned mitigation measures, the residual impact on vulnerable seabed communities would drop to **MINOR**.

Smothering effects of drilling solids discharge onto the seabed at the wellbore on soft sediment macrofauna

Characteristic	Impact	Residual Impact
Extent	Local: limited to within a few 10s of meters of the well site	Local
Duration	Long-term: recovery is expected within 10 years	Long-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Medium	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Minor**	**Minor**
Mitigation Potential	None	

Smothering effects of drilling solids discharged at the surface on soft sediment macrofauna

Characteristic	Impact	Residual Impact
Extent	Local: limited to within a few 100s of meters of the well site	Local
Duration	Long-term: recovery is expected within 10years	Long-term
Scale	Medium	Medium
Reversibility	High	
Loss of resource	Low	
Magnitude	Small; some biota will be smothered, but many will be capable of burying up through the deposited drilling solids	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	None	

Smothering effects of drilling solids discharge on vulnerable seabed communities

Characteristic	Impact	Residual Impact
Extent	Local: limited to within a few 100s of meters of the well site	Local
Duration	Long-term	Short-term
Scale	Medium	Medium
Reversibility	Medium	
Loss of resource	Low	
Magnitude	High	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High	High
Significance of Impact	**Moderate**	**Minor**
Mitigation Potential	Medium	

Toxicity and bioaccumulation effects on marine fauna

The disposal of cuttings at the wellbore and from the drillship would have various direct and indirect biochemical effects on the receiving environment. The direct effects are associated with the contaminants contained in the drilling muds, sweeps and cements used during drilling operations. The indirect effects result from changes to water and sediment quality and are discussed separately below. The cuttings themselves are generally considered to be relatively inert, but may contribute small amounts of trace metals and/or hydrocarbons to receiving waters (Neff *et al.* 1987). However, most of the metals associated with cuttings are in immobile forms in minerals from the geologic strata, and their composition will thus resemble that of natural marine sediments. The drilling muds on the other hand, are a specially formulated mixture of natural clays, polymers, weighting agents and/or other materials suspended in a fluid medium. The constituents and additives of the discharged muds may potentially have ecotoxicological effects on the water column and sediments. These are discussed further below.

Toxicity and bioaccumulation effects of Water-Based Muds (WBMs)

Sea water and high viscous pills (sweeps) composed of bentonite would be used to drill the first 630 m section of the well. Bentonite, is a naturally occurring clay mineral (predominantly montmorillonite with minor amounts of other smectite group minerals), which is insoluble and non-biodegradable and is added to provide viscosity. The 900 m^3 of sweeps would be discharged at the seabed together with the drill cuttings, where they would primarily have smothering effects through burial. No toxicity or bioaccumulation effects of sweeps occur.

If WBMs are used for drilling during the risered stage, it is estimated that some 29.2 MT of residual WBMs may be discharged at the surface with the cuttings (see Table 1). As WBM-cuttings disperse more readily than NADF-cuttings, the areas of seabed affected by deposition in excess of 50 mm thickness, would be somewhat larger than the estimated 0.003 km^2 around the wellhead modelled for the the NADF discharges (ERM 2018a; Drill Cuttings and Discharge Modelling Report). The primary issues related to the discharge of WBMs include bioaccumulation. Typically, the major ingredients that make up over 90% of the total mass of the WBMs are fresh or sea water, barium sulphate (barite), bentonite clay, lignite, lignosulphonate, and caustic soda. Others substances are added to gain the desired density and drilling properties. Toxicity effects of WBMs are thus negligible.

Toxicity and bioaccumulation effects of residual NADFs on drill cuttings

WBMs are, however, not well suited for use in demanding drilling operations, such as highly deviated and horizontal wells, or for drilling the deeper sections of offshore wells. For the current project, the deeper sections of the well may therefore be drilled using a NADF comprising barite, calcium chloride, a synthetic base oil, lime, and a mixture of surfactants, emulsifiers, thinners and viscosifiers. The drilling fluid and cuttings would be isolated from the marine environment by the marine riser and would be circulated back to the drillship between the well casing and riser pipe. Although most of the drilling fluids would be mechanically separated from the drilling cuttings, some NADF would remain adhered to the cuttings and would therefore reach the ocean. It is estimated that the discharged cuttings may contain up to 5% by weight of drilling fluid (see Table 1-2 in ERM 2018a; Drill Cuttings and Discharge Modelling Report). During drilling of the deeper sections of the well, in the order of 29.2 MT of NADF would be discharged to the sea from the drillship with treated cuttings.

The fate of these drilling fluids in the marine environment differs from that of the WBMs used in the initial section of the well. NADF cuttings tend to aggregate once discharged and thus disperse less readily resulting in a smaller area of seabed impact, but thicker deposition on the seabed around the wellhead. The resulting cuttings mounds tend to be more significant compared to those produced when drilling with WBMs, and can consequently hamper biodegradation (Getliff *et al.* 1997). The heavier cuttings and particles settle near the wellbore where a localised smothering effect can be expected (see previous Section). The fines generate a plume in the upper water column, which is dispersed away from the drilling unit by prevailing currents, diluting rapidly to background levels at increasing distances from the drill unit. Despite the widespread dispersion of the cuttings, minor toxicity effects may occur in the water column and in the seabed sediments from the potential solution of the constituents and additives of the discharged muds.

The primary issues related to the discharge of NADFs thus include bioaccumulation and toxicity. The disposal of mud into the marine environment and its subsequent fate has been extensively investigated through field and laboratory studies (reviewed by Neff 2005). In general, it has been found that the impacts are insignificant in the open marine environment (Thomson *et al.* 2000; Hurley & Ellis 2004). The results of the studies are summarised below, focussing primarily on the constituents of WBMs as these would form the bulk of the discharge at the surface, with anticipated loss amounting to ~29 MT.

Bioaccessibility of Metals

Several metals typically occur in significantly higher concentrations in drilling muds discharges than background concentrations in uncontaminated marine sediments. Barium (from drilling mud barite) is usually the most abundant metal in WBMs and NADFs, and is thus used most frequently as an indicator of drilling muds in sediments (Neff 2005). Increased levels of barium in the sediments surrounding wells have been recorded up to 65 km from drill sites (Neff *et al.* 1989), and persisting in the sediments for up to 1.5 years post-drilling (Steinhauer *et al.* 1994). Other metals, most of them associated with barite, often present at substantially higher concentrations in drilling muds than in natural marine sediments are chromium, lead, and zinc (Neff *et al.* 1989; Neff 2005 and references therein), with elevated concentrations of cadmium, arsenic, copper and mercury in near-field sediments (<500 m) also being recorded in some cases (Buchanan *et al.* 2003). However, due to the low solubility of barite in seawater and in anoxic marine sediments, these metals do not dissolve from the barite and leach into sediment pore water and are thus not bioavailable to benthic fauna and do not bioaccumulate in the marine food chain (Neff 2005 and references therein). Lead appears to be the only metal that is bioavailable in some cuttings piles.

Bioaccessibility of Drilling Mud Ingredients

The requirements for toxicity testing differ worldwide, with some countries requiring testing on whole muds, whereas others require testing of the individual mud components. The overall conclusion drawn from these tests is that the majority of the components of WBMs currently used in offshore drilling operations constitute a low risk of chemical toxicity to marine communities.

As the most abundant solid ingredient in both WBMs and NADFs particulate barite is almost insoluble and non-biodegradable, and thus essentially inert toxicologically to marine organisms. In chronic exposure studies with benthic shrimp *Palaemonetes pugio* barite accumulated in the exoskeleton, hepatopancreas, and muscle tissue, with ingestion damaging the epithelial tissue of the gut (Neff 2005). Tagatz & Tobia (1978) reported that although barite-rich sediments did not prevent recruitment of several planktonic larvae of polychaetes and mussels, fewer individuals and species colonised sediments covered by a thin layer of barite. No adverse effects on faecal production, growth, and adults tube production were observed in the polychaete *Mediomastus ambiseta* living in barite-covered sediments, although migration out of patches of 100 % barite was observed (Starczak *et al.* 1992). Olsgard & Gray (1995) suggested that the effects of barite are more likely to be detected at a community level than at individual species levels.

Most toxicological studies have determined that sensitivity to barite was related to physical interactions with gills, the gastrointestinal tract, and integument due to elevated concentrations of particulate barite in suspension, rather than to direct chemical toxicity (see for example Barlow & Kingston 2001). Dilute suspensions have been shown to inhibit gonad development (Cranford *et al.* 1999), and food ingestion rates in the scallop *Placopecten magellanicus* leading to reduced growth rates and increased mortality (Muschenheim & Milligan 1996). In contrast, Cranford *et al.* (1998) reported no significant effect on survivorship or growth following acute and chronic exposure of scallops to 100 mg/l water based drilling mud. At concentrations >1,000 mg/l, Barium (as barite) was toxic to embryos of the crab *Cancer anthonyi* (MacDonald *et al.* 1988). Most bioassays have produced effects at median lethal concentrations >7,000 mg/l suspended barite (National Research Council 1983, in Neff 2005).

Bentonite, the second most abundant ingredient of WBMs, is a naturally occurring, insoluble and non-biodegradable clay added to drilling muds to provide viscosity. When in suspension, the clay-sized bentonite solids have smothering effects through burial and clogging of the gills, ultimately leading to mortality (Cabrera 1971; Sprague & Logan 1979). It may cause physical damage through abrasion and erosion (Sprague & Logan 1979), or shading effects reducing photosynthesis in the alga (Neff 2005). In particular, clay additives have been found to induce changes in respiratory and cardiac activities in cod, haddock, salmon and rays exposed to concentrations up to 40 mg/l for 2-5 minutes (Shparkovski *et al* 1989) with reduced survival in cod and flounder at 5 mg/l for exposures of 10-30 days (Kozak & Shparkovski 1991). Dethlefsen *et al.* (1996) also reported some indications of effects of WBMs on fish embryos and larvae. However, once the clay settles to the bottom, no further effects were observed (Carls & Rice 1984). Most 96-h acute toxicity studies have thus found bentonite to be non-toxic, with LC_{50}s ranging from 22,000 to >100,000 ppm for various organisms.

In modern WBMs, bentonite has been supplemented or replaced by organic polymers (e.g. carboxymethyl cellulose, hydroxyethyl cellulose, guar gum), which are primarily used in shallow parts of a well due to their poor thermal stability. These organic polymers are similarly non-toxic to aquatic organisms, but being highly biodegradable, require a biocide to control bacterial growth. The biocide most frequently used is gluteraldehyde (a liquid derivative of glutaric acid), which is a toxic irritant. However, when discharged to the marine environment, it is rapidly destroyed by biological degradation and reduction by oxidation of organic matter. Gluteraldehyde is moderately toxic to non-toxic to various freshwater and marine animals with LC_{50}s ranging from >6-2,200 ppm for several crustaceans. If used in excess in polymer muds, sufficient gluteraldehyde could persist in the mud/cuttings plume to be toxic to pelagic organisms.

Some of the inorganic salts added to WBM for alkalinity/pH or shale control are slightly toxic to freshwater plants and animals due to their ionic or pH effects. Caustic soda is corrosive. Because of the high ionic strength and buffer capacity of seawater, it is unlikely that these salts would be toxic to marine organisms at the concentrations at which they occur in drilling muds.

Some chrome and ferrochrome lignosulfonate thinners used in WBMs are slightly toxic to marine organisms (Neff 2005). Chronic toxicity testing identified that their effects include alterations in feeding behaviour of lobsters; cessation of swimming by crab and mysid larvae, inhibition of shell formation, reduced rate of shell regeneration, and damage to gills in various molluscs; reduction in calcification, respiration, and growth rates of corals; and a decrease in growth rate, depressed heart rate, developmental abnormalities, and reduced survival of several marine fish species. Whether these effects would be manifested under conditions of exposure to discharged drilling muds and cuttings is uncertain, as field studies have generally failed to find evidence of the long-lasting ecological impacts of lignosulfonate muds near WBM and cuttings discharges. Nonetheless, chrome lignosulfonates have to some extent been replaced with less-toxic chrome-free lignosulfonate salts. Other clay thinners, such as lignites and tannins, are not toxic.

Of the minor additives (based on volumes discharged) sometimes used in WBMs, the most toxic include diesel fuel, corrosion inhibitors, detergents, defoamers, and emulsion breakers. Toxicity of whole drilling mud was attributed primarily to chrome, in cases where chromate and chrome lignosulfonate concentrations in the mud were very high (Conklin *et al.* 1983). Other additives such as zinc-based H_2S scavengers, tributyl phosphate surfactant defoamers, and fatty acid high-temperature lubricants are also toxic, but are usually not present in concentrations high enough to contribute significantly to whole mud toxicity. Where hydrocarbons are added to the mud to aid in lubricating the drill string or to free stuck pipes, the toxicity of WBM to water column and benthic marine animals increases significantly (Breteler *et al.* 1988). Although common in the past, this practice is seldom implemented today. Drilling fluids containing a high-sulfur diesel fuel (Group I NADFs containing 25 % total aromatic hydrocarbons) are the most toxic, followed by those containing a low-sulfur diesel (containing 8.7 % total aromatics); drilling fluids containing a low-aromatic mineral oil (Group III NADFs) were the least toxic.

In addition to the multitude of ecotoxicological studies undertaken to date, many field monitoring studies have been performed since the 1970s to determine short- and long-term impacts of drilling discharges on the marine environment (e.g. Neff *et al.* 1989; Daan *et al.* 1992; Steinhauer *et al.* 1994; Hyland *et al.* 1994; Olsgard & Gray 1995, amongst others). Most of the monitoring conducted prior to 1993, focused on the impacts of Oil-based muds (OBMs) cuttings discharges. Some of these earlier studies (e.g. Neff *et al.* 1989; Steinhauer *et al.* 1994; Hyland *et al.* 1994) reported no detectable changes in benthic communities that could be attributed to oil and gas extraction, possibly due to dispersal of drilling mud solids over a wide area in the high-energy environment in which the drilling occurred (Neff *et al.* 1989). Many monitoring studies, however, showed a clear chemical contamination gradient of sediment within a few hundred metres of the well, decreasing beyond 750 m (Daan *et al.* 1992; Hernandez Arana *et al.* 2005), but in some cases still being detectable at distances of several kilometres from the well (Olsgard & Gray 1995), and persisting over the long term (>15 years) (OSPAR 2008). These contamination gradients manifested themselves as reduced abundance and biomass of dominant faunal species that serve as food for demersal fish, declines in diversity and loss of sensitive macrofaunal species, with an increase in abundance of opportunistic species (OGP 2003; IOGP 2016). The effects were shown to be predominantly linked to the presence of total hydrocarbons, barium and strontium. Although taint studies on fish caught near North Sea platforms discharging OBM cuttings where unable to determine an off taste (reviewed in Davies *et al.* 1983), Husky (2001b) reported external lesions (indicative of contaminant stress) in fish in the vicinity of drilling sites. Similarly, cod and haddock from a Norwegian oil field were found to have different lipid content or lipid composition of the cell membranes, possibly due to the fish feeding on old NADF cuttings piles (OSPAR 2008). The physical and physiological impacts to benthic fauna, were found to be greater at depths of <600 m, whereas at at depths >600 m impacts tend to be lower as increased water depths allow small particles to disperse over greater distances, thereby lessening the effects on the benthos (IOGP 2016).

Table 15 below provides a summary of acute toxicities of the ingredients of WBMs and SBMs to marine algae and animals. Neff (2005) notes that the requirements for toxicity testing of drilling mud and drilling mud ingredients differ in different regions of the world. In the U.S., a mysid (crustacean), *Americamysis [Mysidopsis] bahia*, is used for toxicity tests with dispersions of used whole drilling muds. In contrast, the North Sea countries test the individual drilling mud components with at least three organisms from different taxonomic levels: alga, crustacean, fish. In Russia, toxicity testing is undertaken with several species on individual drilling mud components.

Table 15: Acute toxicities, measured as median lethal concentration (LC_{50}) after 48 – 96 hours, and expressed as mg/l (ppm) of the ingredient or its suspended particulate phase (summarized from Neff 2005).

Ingredient	Range of LC_{50} for different species (mg/l)
Weighting Materials	
Barite (barium sulfate: $BaSO_4$)	385[a] - >100,000
Hematite (iron oxide: $Fe2O_3$)	>100,000
Siderite (iron carbonate: $FeCO_3$)	>100,000
Viscosifiers	
Bentonite (montmorillonite clay)	9,600[a] - >100,000
Hydroxyethyl cellulose (HEC) polymer/viscosifier	7,800 – 29,000
Sodium carboxymethyl cellulose (CMC)	500[a] - >100,000
Polyanionic cellulose	60,000 – 100,000
Organic polymers	7,800 - >100,000
Xanthan gum	420

Ingredient	Range of LC_{50} for different species (mg/l)
Salts for pH and Shale Control	
Potassium chloride (KCl: muriate of potash)	2,100[b]
Lime (CaO)	70 - 450[b]
Calcite (calcium carbonate: $CaCO_3$)	>100,000
Sodium hydroxide (NaOH: caustic soda)	105 - 110[b]
Lost Circulation Materials	
Mica	>7,500
Jellflake® shredded cellophane	>7,500
Thinners, Clay Dispersants	
Ferrochrome lignosulfonate	12 - 1,500
Chrome lignosulfonate	12,200 - 100,000
Chrome-treated lignosulfonate	465 - 12,200
Chrome-free lignosulfonate	31,000 - 100,000
Iron lignosulfonate	2,100
Modified chrome lignite	20,100
Potassium lignite	>100,000
Carbonox® lignitic material	6,500 - >7,500
Generic lignite	>15,000
Sulfomethylated tannin	33,900 - >100,000
Sodium acid pyrophosphate ($Na_4P_2O_7$)	870[b] - >100,000
Lubricants	
Diesel fuel	0.1 - 1,112
Fatty acid high pressure lubricant	3,500 - >100,000
Blended organic ester lubricant	10,400 - 49,400
Graphite	86,500
Other Additives	
Corrosion inhibitors (several types)	2.0 - 7,000
Ammonium bisulfite corrosion inhibitor	75,000
H_2S scavengers (zinc salts)	235 - 7,800
Low MW polyacrylate reverse breaker	3,500
Polyacrylate scale inhibitor	77,300
Scale inhibitors	>10,000
Glutaraldehyde (biocide) (25 %)	41 - 465
Flocculant WT-40	5,300
Surfactants	40 - 429
Detergents	0.4 - 340
Defoamers	5.4 - 84
Tributyl phosphate surfactant defoamer	5,100

Ingredient	Range of LC_{50} for different species (mg/l)
Emulsion breakers	3.6 - 930
Oxygen scavenger (sodium bisulfite)	175 – 185

LC_{50} median lethal concentration; measure of toxicity that will kill 50 % of a given population of organisms in a specified period.

[a] microalgal test; effects probably caused by turbidity.

[b] Freshwater species used in test; marine species expected to be more tolerant due to high ionic strength and buffer capacity of seawater

In summary, although several metals typically occur in significantly higher concentrations in drilling muds than in uncontaminated marine sediments, most of these are not bioavailable to benthic fauna and thus do not bioaccumulate in the marine food chain. Toxicity testing of WBMs and SBMs in use today has indicated that they constitute a low risk of chemical toxicity to marine communities. The two most abundant ingredients in WBMs, barite and bentonite, are insoluble and non-biodegradable. Other additives such as gluteraldehyde, inorganic salts and lignosulfonate thinners are only mildly toxic to marine life, but are present in such low concentrations that evidence of long-lasting ecological impacts are lacking. The most toxic additives include diesel fuel, corrosion inhibitors, detergents, defoamers, and emulsion breakers, but are usually not present in concentrations high enough to contribute significantly to whole mud toxicity. Similarly, the potential for significant bioaccumulation of SBMs in the marine environment is unlikely due to their extremely low water solubility and consequent low bioavailability. Due to the high dilution and wide dispersal of the dissolved and particulate components of SBMs, the biological effects associated with their use typically do not extend beyond 250 – 500 m from the drilling unit, with complete recovery of impacted communities being predicted within 3 – 5 years.

For the current project, the total predicted area affected by seabed discharges of WBMs would be in the order of 0.003 km^2, whereas deposition following surface discharges of NADF cuttings were anticipated to cover a maximum area of ~7 km^2 (ERM 2018a). The larger footprint of the surface-discharged cuttings was, however, offset by the relatively low deposition thicknesses (<5 mm) predicted for distances beyond ~50 m from the well location.

Assuming that the WBMs to be used in drilling the deeper sections of the well do not contain spotting fluids or lubricating hydrocarbons, the impacts of discharges of these drilling fluids to both the water column and the sediments are considered of low intensity. The area affected by discharged drilling fluids would be extremely localised (~0.003 km^2), with impacts persisting only over the short term. The impacts would be fully reversible any potential adverse effects on sessile benthos of WBMs would be of **NEGLIGIBLE** significance, before mitigation. In the case of residual NADFs on the drill cuttings, the impacts of discharges are considered of medium magnitude. The area affected by discharged drilling fluids would be larger, but by definition still localised (~7 km^2), persisting over the short term. Any adverse effects on sessile benthos would be partially reversible and the impact can thus be rated as being of **MINOR** significance before mitigation.

Mitigation

Objective: to further reduce and manage potential toxicity and bioaccumulation effects of cuttings discharges.

Actions: the following measures are recommended to reduce and manage potential toxicity and bioaccumulation effects of cuttings discharges:

No.	Mitigation measure	Classification
1	Careful selection of fluid additives taking into account their concentration, toxicity, bioavailability and bioaccumulation potential; Ensure only low-toxicity and partially biodegradable additives are used	Avoid / reduce at source
2	Use high efficiency solids control equipment to reduce the need for fluid change out and minimise the amount of residual fluid on drilled cuttings	Avoid / reduce at source
3	Ensure regular maintenance of the onboard solids control package	Abate on site
4	Store all recovered NADF mud on board and take to shore for treatment and reuse	Abate on and off site
5	If delivery to shore is not possible, residual WBM will be discharged overboard, but only if in compliance with specific standards[4]	Abate on and off site

Residual impact

This potential impact cannot be eliminated due to the nature of the drilling approach and the necessity for the use of WBMs and SBMs in the drilling process. With the implementation of the above-mentioned mitigation measures, the residual impact on marine fauna, would have a lower intensity and probability, and the level would drop to **INSIGNIFICANT** for the effects of WBMs but remain at **VERY LOW** significance for SBMs.

Monitoring

Drilling fluids to be discharged to sea (including residual material on drilled cuttings) must be subject to tests for toxicity, barite contamination, and oil content (in the case of NADFs).

[4] 96 hr LC-50 of suspended Particulate Phase (SPP) – 3% vol. toxicity test first for drilling fluids or alternatively testing based on standard toxicity assessment species

Biochemical impacts of sweeps and water-based drilling muds on marine organisms		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to drill site (0.003 km^2)	Local
Duration	Short-term; recovery is expected within 5 years	Short-term
Scale	Medium	Medium
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	Low	

Biochemical impacts on marine organisms of residual non-aqueous drilling fluids on drill cuttings		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to drill site (~7 km^2)	Local
Duration	Short-term; recovery is expected within 5 years	Short-term
Scale	Medium	Medium
Reversibility	Medium	
Loss of resource	Low	
Magnitude	Medium	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Minor**	**Minor**
Mitigation Potential	Very Low	

Increased water turbidity and reduced light penetration

Apart from the main biophysical (smothering and alteration in sediment characteristics) and biochemical (ecotoxicological effects of drilling mud constituents) impacts of the dispersed and settling cuttings on the marine environment, indirect impacts (i.e. impacts arising indirectly from biochemical effects on the water column) associated with cuttings disposal and discharge of WBMs include changes in water turbidity in the vicinity of the discharge point.

The heavier cuttings and particles discharged at the seabed or from the drillship would settle near the wellbore where a localised smothering effect can be expected (see previous Section). The finer components of the surface discharge generate a plume in the upper water column, which is dispersed away from the drillship by prevailing currents, diluting rapidly to background levels at increasing distances from the drill unit. Several studies have shown that in areas where current speeds are high, cuttings discharges are diluted rapidly (within an hour) to very low concentrations, within 1,000 – 2,000 m down-current of the drilling unit (see Neff 2005 for references). Morant (1999) reported that a typical near-surface plume is 30-40 m in vertical height, 40-60 m wide and can extend in excess of 10 km from the drilling unit. Similarly, the plume modelling undertaken for the current project (ERM 2018a) identified that at the seabed, exceedance of the 35 mg/l threshold concentrations of Total Suspended Solids (TSS) was limited to an area of less than 0.01 km^2 around the wellhead, regardless of well location or monthly average current strength. Concentrations of TSS generated at the surface through the discharge of cuttings off the drillship did not exceed the threshold, although turbidity plumes above ambient (5-35 mg/l) could extend up to 1,000 m from the discharge location. Similarly, for the overboard discharge of waste WBMs from the drillship, a plume of elevated TSS concentrations would occur at the surface (or just below the surface if discharged through a chute or caisson), potentially extending beyond 1,000 m from the discharge location due to the anticipated higher volumes of fine particles in the muds.

One of the more apparent effects of increased concentrations of suspended sediments and consequent increase in turbidity, is a reduction in light penetration through the water column with potential adverse effects on the photosynthetic capability of phytoplankton (Poopetch 1982; Kirk 1985; Parsons *et al.* 1986a, 1986b; Monteiro 1998; O'Toole 1997) and the foraging efficiency of visual predators (Simmons 2005; Braby 2009; Peterson *et al.* 2001). However, due to the rapid dilution and widespread dispersion of settling particles, any adverse effects in the water column would be ephemeral. Any biological effects on nectonic and planktonic communities would thus be negligible (Aldredge *et al.* 1986). Turbid water is seasonally a natural occurrence along the southern African east coast, resulting from riverine inputs, resuspension of seabed sediments in the wave-influenced nearshore areas and seasonal phytoplankton production in upwelling zones. Further offshore where the proposed well(s) would be located, surface waters, however, tend to be clearer and less productive as they are beyond the influence of shelf-edge upwelling. Consequently, the major spawning areas are all located on the continental shelf, well inshore of the proposed well sites(s). Any potential effects of turbid water plumes generated during cutting disposal on phytoplankton and ichthyoplankton production, fish migration routes and spawning areas, or on benthic and demersal species in the area would thus be negligible. Increased turbidity of near-bottom waters through disposal of WBMs and cuttings at the wellbore, may place transient stress on sessile and mobile benthic organisms, by negatively affecting filter-feeding efficiency of suspension feeders or through disorientation due to reduced visibility (reviewed by Clarke & Wilber 2000). However, in most cases sub-lethal or lethal responses occur only at concentrations well in excess of those anticipated at the wellbore.

The impact of increased turbidity in the water column and elevated suspended sediment concentrations around the wellbore would be of small magnitude, persisting only over the very short term (days), and would be localised (~1 000 m radius of the well site). Any possible adverse effects on sessile benthos, or on the feeding, spawning and recruitment of mobile predators, will be fully reversible. The biochemical impact of reduced water quality through increased turbidity can thus be rated as being of **NEGLIGIBLE** significance without mitigation.

Mitigation

No mitigation measures for potential indirect impacts on the water column associated with cuttings discharge are proposed or deemed necessary. In the case of direct impacts on the water column through the discharge of waste WBMs:

Objective: to further reduce wastes and reuse/recycle products where possible.

Actions: the following measures are recommended to reduce wastes and reuse/recycle products where possible.

No.	Mitigation measure	Classification
1	If delivery to shore is not possible, residual WBM will be discharged overboard, but only if in compliance with specific standards.	Abate on and off site

Residual impact

The potential indirect impact on water column and bottom-water biochemistry cannot be eliminated due to the necessity of disposal of drill cuttings. Thus the impact remains **NEGLIGIBLE**. In the case of discharge overboard of waste WBMs, potential direct impacts on water quality could be eliminated through the transport of WBMs to land.

Impacts of drill cuttings discharge on water column and bottom-water biochemistry (turbidity and light)		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to drill site (<0.01 km^2)	Local
Duration	Short-term; intermittently for duration of drilling operations	Short-term
Scale	Medium	Medium
Reversibility	High	
Loss of resource	Low	
Magnitude	Small; rapid dispersion and dilution	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	None	

Impacts of discharge of WBM wastes on water column biochemistry (turbidity and light)		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to drill site (<0.01 km^2)	Local
Duration	Short-term; once-off at the close of drilling operations	Short-term
Scale	Medium	Medium
Reversibility	High	
Loss of resource	Low	
Magnitude	Small; rapid dispersion and dilution	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	Small	

Reduced physiological functioning of marine organisms due to indirect biochemical effects

A further indirect impact (i.e. impacts arising indirectly from biochemical effects on the sediments) associated with cuttings disposal is the potential development of hypoxic conditions in the near-surface sediment layers through bacterial decomposition of organic matter. Biodegradable organic matter in cuttings piles on the seabed often has a greater effect than sediment texture, deposition rate or, in some cases, chemical toxicity on the structure and function of benthic communities (Hartley *et al.* 2003). Bacterial decomposition of organic matter may deplete oxygen in the near-surface sediment layers, thereby changing the chemical properties of the sediments by generating potentially toxic concentrations of sulfide and ammonia (Wang & Chapman 1999; Gray *et al.* 2002; Wu 2002). The rapid biodegradation of drilling solids (particularly those containing NADFs) may therefore lead indirectly yet rapidly to sediment toxicity, particularly in fine-grained sediments (Munro *et al.* 1998; Jensen *et al.* 1999; Trannum *et al.* 2010). Organically enriched sediments are often hypoxic or anoxic, and consequently harbour markedly different benthic communities to oxygenated sediments (Pearson & Rosenberg 1978; Gray *et al.* 2002). Organic matter concentration in the sediments would decrease in response to microbial degradation, resulting in increases in oxygen concentration in the surface-sediment layers leading to succession in the benthic community structure toward a more stable state.

WBM cuttings piles typically contain low concentrations of biodegradable organic matter and do not support large populations of bacteria (Dow *et al.* 1990). As most of the organic chemicals in WBMs are biodegradable under aerobic conditions, sediments containing WBM cuttings show only slight and short-term reductions in redox potential. However, organic chemicals in settled solids from mineral oil- and diesel fuel-contaminated WBMs have a high chemical and biological oxygen demand (Breteler *et al.* 1988). Therefore, if cuttings piles contain WBMs contaminated with petroleum hydrocarbons, the sediments may experience the ecological effects of organic enrichment, particularly if the cuttings pile is large. Similarly, the synthetic fluids in NADFs typically degrade rapidly and can cause localised hypoxia in underlying sediments (EPA 2000; OGP 2003). In the case of sediments containing OBM cuttings, the anoxic conditions that developed not only persisted over the long term (>1 year), but stimulated production of hydrogen sulphide by anaerobic sulphate-reducing bacteria (Dow *et al.* 1990).

Oxygen depletion in the sediments around a well site may also develop in response to organic enrichment following fall-out of fouling organisms off submerged platform structures.

Marine organisms respond to hypoxia by first attempting to maintain oxygen delivery (e.g. increases in respiration rate, number of red blood cells, or oxygen binding capacity of haemoglobin), then by conserving energy (e.g. metabolic depression, down regulation of protein synthesis and down regulation/modification of certain regulatory enzymes), and upon exposure to prolonged hypoxia, organisms eventually resort to anaerobic respiration (Wu 2002). Hypoxia reduces growth and feeding, which may eventually affect individual fitness. The effects of hypoxia on reproduction and development of marine animals remains almost unknown. Many fish and marine organisms can detect, and actively avoid hypoxia. Some macrobenthos may leave their burrows and move to the sediment surface during hypoxic conditions, rendering them more vulnerable to predation. Hypoxia may eliminate sensitive species, thereby causing changes in species composition of benthic, fish and phytoplankton communities. Decreases in species diversity and species richness are well documented, and changes in trophodynamics and functional groups have also been reported. Under hypoxic conditions, there is a general tendency for suspension feeders to be replaced by deposit feeders, demersal fish by pelagic fish and macrobenthos by meiobenthos (see Wu 2002 for references). Further anaerobic degradation of organic matter by sulphate-reducing bacteria may additionally result in the production of hydrogen sulphide, which is detrimental to marine organisms (Brüchert *et al.* 2003).

Development of anoxic conditions beneath re-deposited cuttings is highly unlikely due to the low deposition thicknesses (<1 mm) predicted in the cuttings fallout footprint for distances beyond ~50 m from the well location. Should anoxic conditions develop, these would be limited to within the 0.003 km^2 footprint of the WBMs cuttings pile deposited on the seabed around the wellbore, where they would have an impact of low intensity on the benthic macrofauna, with recovery expected within a few months. The impact would be fully reversible. The impact is thus considered to be **INSIGNIFICANT** without mitigation.

Mitigation

No mitigation measures for potential indirect biochemical effects in seabed sediments are proposed or deemed necessary. Thus the impact remains **INSIGNIFICANT**.

Residual impact

This potential impact cannot be eliminated due to the necessity of disposal of drill cuttings.

Indirect impacts of cuttings discharges: development of anoxic sediments around the wellbore		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to well site	Local
Duration	Short-term; erosion and dispersal of cuttings and bioturbation of cuttings pile should occur within a few months	Short-term
Scale	Small	Medium
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	None	

4.3.4 Increase in Noise

Description of the source of impact

The table below summarises the project activities that will result in noise.

Activity phase	Activity
Mobilisation	Transit of drilling units and support vessels to the drill site
Operation	Operation of drilling unit and support vessels
	Operation of helicopters
	Vertical seismic profiling of the well, however these noise emissions are very short term and the impact is considered not significant and will not be assessed further.
Demobilisation	Drilling unit / support vessels leave drill site and transit to port or next destination

These activities are described further below:

- The operation of the drillship and support vessels during transit to the drill site, during the proposed drilling activities and during demobilisation will introduce a range of underwater noises into the surrounding water column that may potentially contribute to and/or exceed ambient noise levels in the area.
- Crew transfers by helicopter from Richards Bay or Durban to the drill unit will generate noise in the atmosphere that may disturb coastal species such as seabirds and seals.
- Vertical seismic profiling (VSP) is a standard method used during well logging and can generate noise that could exceed ambient noise levels. VSP source generates a pulse noise level around 190 dB re 1μPa at 1m in the 5 to 100 Hz range and decreases rapidly with distance from the source. VSP uses a small airgun array; volumes and the energy released into the marine environment are significantly smaller than what is required or generated during conventional seismic surveys. The airgun array would be discharged approximately five times at 20 second intervals. This process is repeated, as required, for different sections of the well. A VSP is expected to take approximately 8 to 10 hours per well to

complete, depending on the well's depth and number of stations being profiled. As standard industry mitigation measures would be implemented for VSP activities, and VSP operations are of very short duration, the impact is considered insignificant and will not be assessed further here.

Description of the environmental aspects

Generation of noise by support vessels, drilling units, VSP, well testing flares and helicopters.

Description of the potential impact

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

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

Sensitive Receptors

Underwater noise generated during the project could affect a wide range of fauna; from benthic invertebrates and demersal species residing on the seabed in the vicinity of the wellhead, to those invertebrates and vertebrates occurring throughout the water column and in the pelagic habitat near the surface. The taxa most vulnerable to noise disturbance are turtles, pelagic seabirds, large migratory pelagic fish, and both migratory and resident cetaceans many of which are considered globally 'Critically Endangered' (e.g. Southern Bluefin tuna, Blue whale, hawksbill turtle), 'Endangered' (e.g. whale shark, Fin and Sei whales) 'Vulnerable' (e.g. Leatherback turtle short-fin mako, whitetip sharks, sperm whale) 'Near threatened' (eg blue shark) and 'Least concern' (eg: Humpback and Southern Right Whales. As no drilling operations will be performed in canyons, direct and indirect impacts of noise on sensitive receptors associated with such habitats would be avoided.

Noise generated by helicopters undertaking crew transfers between Durban or Richard's Bay and the drillship could affect seabirds in breeding colonies and roosts on the mainland coast. Low altitude flights over the ocean could also affect marine mammals and turtles in surface waters.

Project Controls and Industry Objectives

The National Environmental Management: Protected Areas Act (2003) stipulate that the minimum over-flight height over nature reserves, national parks and world heritage sites is 762 m (2,500 ft). The Marine Living Resources Act (1998) prohibits aircraft to approach within 300 m of a whale. Therefore, except for when the aircraft lands on or takes off from the drillship and logistics base, the flight altitude would be >300 m.

The operation of helicopters and fixed-wing aircraft is governed by the Civil Aviation Act (No. 13 of 2009) and associated regulations.

Performance objectives

No specific targets, standards or legislation exist regarding underwater and atmospheric noise levels above the ocean. Eni should ensure that the following policies and procedures are implemented:

- Manage of VSP operations thereby minimising potential impacts on threatened and migratory cetaceans;
- Management of helicopter operations and flight paths.

Impact assessment

The ocean is a naturally noisy place and marine animals are continually subjected to both physically produced sounds from sources such as wind, rainfall, breaking waves and natural seismic noise, or biologically produced sounds generated during reproductive displays, territorial defence, feeding, or in echolocation (see references in McCauley 1994). Such acoustic cues are thought to be important to many marine animals in the perception of their environment as well as for navigation purposes, predator avoidance, and in mediating social and reproductive behaviour. Anthropogenic sound sources in the ocean can thus be expected to interfere directly or indirectly with such activities thereby affecting the physiology and behaviour of marine organisms (NRC 2003). Natural ambient noise will vary considerably with weather and sea state, ranging from about 80 to 120 dB re 1 µPa (Croft & Li 2017). Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping. Depending on size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 µPa at 1 m (NRC 2003). Especially at low frequencies between 5 to 100 Hz, vessel traffic is a major contributor to noise in the world's oceans, and under the right conditions, these sounds can propagate 100s of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al.* 2003). The sound level generated by vessels fall within the 160 to 170dB re 1 µPa range close to the vessel, with main frequencies from 1 to 500 Hz (McCauley 1994; NRC 2003). Other forms of anthropogenic noise include 1) aircraft flyovers, 2) multi-beam sonar systems, 3) seismic acquisition, 4) hydrocarbon and mineral exploration and recovery, and 5) noise associated with underwater blasting, pile driving, and construction (Figure 30).

Noise propagation represents energy travelling either as a wave or a pressure pulse through a gas or a liquid. Due to the physical differences between air and water (density and the speed at which sound travels), the decibel units used to describe noise underwater are different from those describing noise in air. Furthermore, hearing sensitivities vary between species and taxonomic groups. Underwater noise generated by drilling activities is therefore treated separately from noise generated in the air.

The cumulative impact of increased background anthropogenic noise levels in the marine environment is an ongoing and widespread issue of concern (Koper & Plön 2012). The sound level generated by drilling operations fall within the 120-190 dB re 1 µPa range at the drilling unit, with main frequencies less than 0.2 kHz. For the current project, noise would be generated by a number of sources (e.g. heavy lift vessel, drill ship in transit and operational, semi-submersible drill rig, support vessels, helicopters and drill ship maintenance) with the noise levels ranging from 170 – 190 dB re 1 µPa depending on the drill unit and support vessels used (Croft & Li 2017). The noise generated by well-drilling operations in general and by the current project in particular, thus falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges (in the order of tens of kms) before attenuating to below threshold levels (Table 16).

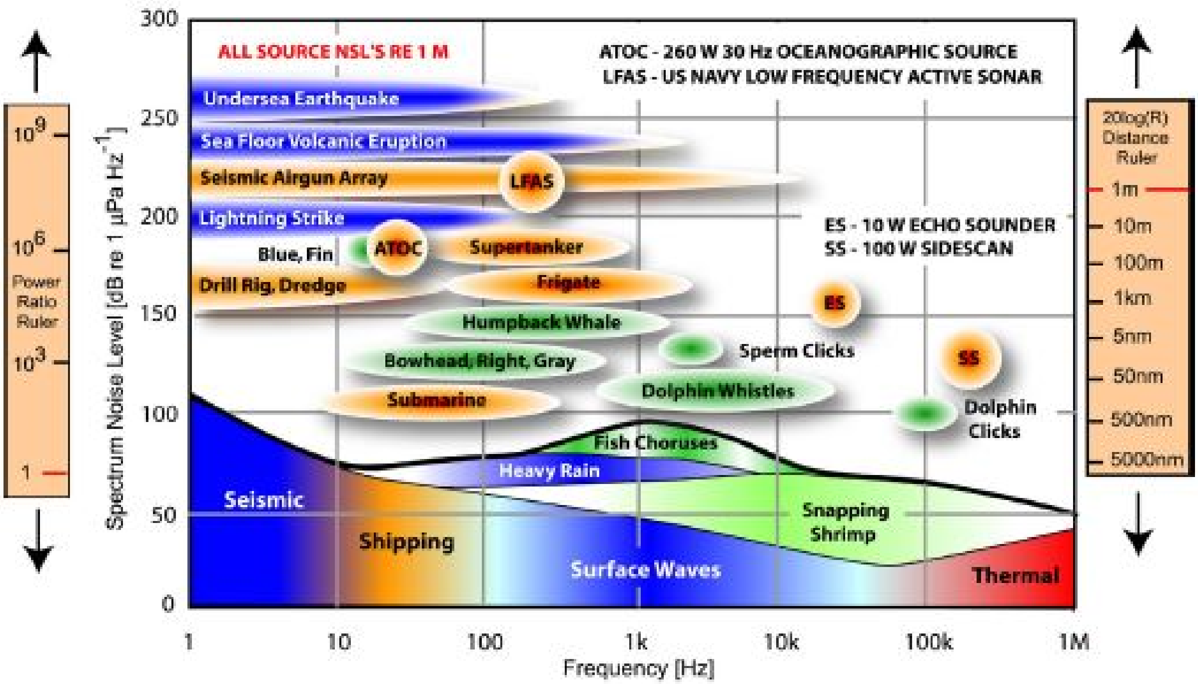


Figure 30: Comparison of noise sources in the ocean (Goold & Coates 2001).

Table 16: Known hearing frequency and sound production ranges of various marine taxa (Koper & Plön 2012).

Taxa	Order	Hearing frequency (kHz)	Sound production (kHz)
Shellfish	Crustaceans	0.1 - 3	
Snapping shrimp	*Alpheus/ Synalpheus* spp.		0.1 - >200
Ghost crabs	*Ocypode* spp.		0.15 - 0.8
Fish	Teleosts		0.4 - 4
Hearing specialists		0.03 - >3	
Hearing generalists		0.03 - 1	
Sea turtles	Chelonia	0.1 - 1	Unknown
Sharks and skates	Elasmobranchs	0.1 - 1.5	Unknown
Seals	Pinnipeds	0.25 - 10	1 - 4
Northern elephant seal	*Mirounga agurostris*	0.075 - 10	
Manatees and dugongs	Sirenians	0.4 - 46	4 - 25
Toothed whales	Odontocetes	0.1 - 180	0.05 - 200
Baleen whales	Mysticetes	0.005 - 30	0.01 - 28

Behavioural changes and masking of biologically-relevant sounds in marine fauna in response to underwater drilling noise

Unlike the noise generated by airguns during seismic surveys, the emission of underwater noise from drilling operations and associated drill unit and tender vessel activity is thus not considered to be of sufficient amplitude to cause direct physical injury or mortality to marine life, even at close range. The underwater noise from well drilling operations may, however, induce localised behavioural changes or masking of biologically relevant sounds in some marine fauna, but there is no evidence of significant behavioural changes that may impact on the wider ecosystem (Perry 2005). The responses of cetaceans to noise sources are often also dependent on the perceived motion of the sound source as well as the nature of the sound itself. For example, many whales are more likely to tolerate a stationary source than they are one that is approaching them (Watkins 1986; Leung-Ng & Leung 2003), or are more likely to respond to a stimulus with a sudden onset than to one that is continuously present (Malme *et al.* 1985; Southall *et al.* 2007; Abgrall *et al.* 2008).

For another deep water well-drilling project off the southern Namibian coast, it was estimated that noise from project activities would decrease to below the estimated median ambient background level (100 dB re 1μPa) within a distance of 14 - 32 km from the drill site, depending on the specific vessels used, the number of support vessels operating and the scenario. Maintenance activities represented the worst-case scenario for noise, although this would be expected to occur only for relatively short periods of time (Croft & Li 2017). The extent of the noise impacts would, however, also depend on the variation in the background noise level with weather and with the proximity of other vessel traffic (not associated with the project).

The effects of underwater noise generated during well-drilling and by the drillship and support vessels on marine fauna is considered to be of small magnitude in the drilling area and for the duration of the drilling campaign. While underwater noise may mask biologically significant sounds and cause behavioural changes, impacts are fully reversible once drilling operations are completed. The impact of underwater noise potentially masking biologically significant sounds is considered of **MODERATE** significance without mitigation, whereas the impact of underwater noise resulting in avoidance of feeding and/or breeding area is considered **NEGLIGIBLE** without mitigation due to the extreme offshore location of the areas of interest.

Mitigation

Objective: to further reduce and manage the generation of underwater noise.

Actions: the following measures are recommended to reduce and manage the generation of underwater noise during well drilling operations:

No.	Mitigation measure	Classification
1	As far as reasonably practicable, vessels used in the project should incorporate measures to reduce the amount of underwater noise generated by undergoing a regular maintenance regime to reduce noise ,which include the cleaning of propeller and underwater hull	Abate on site

Residual impact

The generation of noise from the drillship and support vessels cannot be eliminated due to the operating requirements of dynamic positioning. With the implementation of the above-mentioned mitigation measure, the scale of the impact would be reduced, and the level would drop to **MINOR**.

Behavioural changes and masking of biologically significant sounds in marine fauna due to noise from well-drilling operations		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to well site area	Local
Duration	Short-term: for duration of drilling operations	Short-term
Scale	Medium	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High	Medium
Significance of Impact	**Moderate**	**Minor**
Mitigation Potential	None	

Impacts of noise from well-drilling operations on marine fauna (avoidance of feeding and/or breeding areas)		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to well site area	Local
Duration	Short-term: for duration of drilling operations	Short-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	None	

Disturbance and behavioural changes in marine fauna in response to aircraft / helicopter noise

The dominant low-frequency components of aircraft engine noise (10-550 Hz) penetrate the water only in a narrow (26° for a smooth water surface) sound cone directly beneath the aircraft, with the angle of the cone increasing in Beaufort wind force >2 (Richardson *et al.* 1995). The peak sound level received underwater is inversely related to the altitude of the aircraft.

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

Most authors established that the reactions resulted from the animals presumably receiving both acoustic and visual cues (the aircraft and/or its shadow). As would be expected, sensitivity of whales to disturbance by an aircraft generally lessened with increasing distance, or if the flight path was off to the side and downwind, and if its shadow did not pass directly over the animals (Watkins 1981, 1986; Smultea *et al.* 2008). Smultea *et al.* (2008) concluded that the observed reactions of whales to brief overflights were short-term and isolated occurrences were probably of no long-term biological significance and Stewart *et al.* (1982) suggested that disturbance could be largely eliminated or minimised by avoiding flying directly over whales and by maintaining a flight altitude of at least 300 m. However, repeated or prolonged exposures to aircraft overflights have the potential to result in significant disturbance of biological functions, especially in important nursery, breeding or feeding areas (Richardson *et al.* 1995). Humpback whales were almost completely displaced from East Coast waters during historical whaling activities and have only recently returned on their migrations to calving sites off Mozambique. This species can be observed off the East Coast between May and February, with peak sightings in June and November/December (Banks 2013). The level of disturbance would also depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions.

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

Sensitivity of birds to aircraft disturbance are not only species specific, but generally lessened with increasing distance, or if the flight path was off to the side and downwind. However, the vertical and lateral distances that invoke a disturbance response vary widely, with habituation to the frequent loud noises of landing and departing aircraft without ill effects being reported for species such as gulls, lapwings, ospreys and starlings, amongst others (reviewed in Drewitt 1999). Further work is needed to examine the combined effects of visual and acoustic stimuli, as evidence suggests that in situations where background noise from natural sources (e.g. wind and surf) is continually high, the visual stimulus may have the greater effect. There is an IBA at Richards Bay, potentially within the flight path of aircraft commuting between Richard's Bay airport and the northern area of interest for well drilling (see Figure 28).

Indiscriminate low altitude flights over whales, seabird colonies and turtles by helicopters used to support the drillship could thus have an impact on behaviour and breeding success. The level of disturbance would depend on the distance and altitude of the aircraft from the animals (particularly the angle of incidence to the water surface) and the prevailing sea conditions and could range from small to large magnitude. Although such impacts would be localised and short term, impacts may have wider ramifications over the range of the affected species. As impacts may be only partially reversible, the significance of the potential impact is considered to be of **MINOR** significance without mitigation, and **NEGLIGIBLE** with mitigation.

Mitigation

Objective: to further reduce and manage noise disturbance associated with helicopter operations.

Actions: the following measures are recommended to reduce and manage noise disturbance associated with helicopter operations:

No.	Mitigation measure	Classification
1	• Pre-plan flight paths to ensure that no flying occurs over IBAs; • Avoid extensive low-altitude coastal flights (<3,000 ft and within 1 nautical mile of the shore); • The flight path between the onshore logistics base and drillship should be perpendicular to the coast; • A flight altitude >1,000 ft be maintained at all times, except for when the aircraft lands on or takes off from the drillship and logistics base; • Maintain an altitude of at least 3,000 ft within MPAs; • Contractors should comply fully with aviation and authority guidelines and rules; • Brief all pilots on the ecological risks associated with flying at a low level along the coast or above marine mammals.	Avoid / Abate offsite/at receptor

Residual impact

The generation of noise from helicopters cannot be eliminated due to the necessity of aerial crew transfers between the drillship and either Durban or Richard's Bay. With the implementation of the above-mentioned mitigation measures, the residual impact on marine fauna would have a lower magnitude and probability, and the level would drop to **NEGLIGIBLE**.

Disturbance and behavioural changes in seabirds, turtles and cetaceans due to support aircraft		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to immediate area around drillship	Local
Duration	Short-term and intermittent	Short-term
Scale	Small	Small
Reversibility	Medium	
Loss of resource	Low	
Magnitude	Small to Large	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High	Medium
Significance of Impact	**Minor**	**Negligible**
Mitigation Potential	Medium	

4.3.5 Discharge of waste to sea (e.g. deck and machinery space drainage, sewage and galley wastes) and local reduction in water quality

Description of the source of impact

The table below summarises the project activities that will result in discharges of wastes to the sea.

Activity phase	Activity
Mobilisation	Transit of drilling units and support vessels to the drillsite
Operation	Operation of drilling unit and support vessels
Demobilisation	Drilling unit / support vessels leave drill site and transit to port or next destination

These activities are described further below:

- **Deck drainage**: all deck drainage from work spaces is collected and piped into a sump tank on board the drilling unit to ensure MARPOL compliance (15 ppm oil in water). The fluid would be analysed and any hydrocarbons skimmed off the top prior to discharge. The oily substances would be added to the waste (oil) lubricants and disposed of on land.
- **Sewage**: sewage discharges will be comminuted and disinfected. In accordance with MARPOL Annex IV, the effluent must not produce visible floating solids in, nor causes discolouration of, the surrounding water. The treatment system must provide primary settling, chlorination and dechlorination before the treated effluent can be discharged into the sea. The discharge depth is variable, depending upon the draught of the drilling unit / support vessel at the time, but would not be less than 5 m below the surface.
- **Vessel machinery spaces, mud pit wash residue and ballast water**: the concentration of oil in discharge water from vessel machinery space or ballast tanks may not exceed 15 ppm oil in water (MARPOL Annex I). If the vessel intends to discharge bilge or ballast water at sea, this is achieved through use of an oily-water separation system. Oily waste substances must be shipped to land for treatment and disposal.
- **Food (galley) wastes**: food wastes may be discharged after they have been passed through a comminuter or grinder, and when the drilling unit is located more than 3 nautical miles from land. Discharge of food wastes not comminuted is permitted

beyond 12 nautical miles. The ground wastes must be capable of passing through a screen with openings <25 mm.

- **Detergents**: detergents used for washing exposed marine deck spaces are discharged overboard. The toxicity of detergents varies greatly depending on their composition, but low-toxicity, biodegradable detergents are preferentially used. Those used on work deck spaces would be collected with the deck drainage and treated as described above.
- **Cooling Water:** electrical generation on drilling units is typically provided by large diesel-fired engines and generators, which are cooled by pumping water through a set of heat exchangers. The cooling water is then discharged overboard. Other equipment is cooled through a closed loop system, which may use chlorine as a disinfectant. Such water would be tested prior to discharge and would comply with relevant Water Quality Guidelines.
- **Opening and closing of BOP:** A further operational discharge is associated with routine well opening and closing operations. As part of these operations, the subsea BOP stack elements will vent between 500 to 1,000 litres per month of oil-based hydraulic fluid into the ocean at the seafloor. Concentrated BOP fluids, which are usually mineral oil- or glycol-water mixes are mildly toxic to crustaceans and algae (96 h LC_{50} 102-117 ppm) but are completely biodegradable within 28 days.

Description of the environmental aspects

The discharge of wastes to sea has the potential to create local reductions in water quality, both during transit and at the drill site.

Description of the potential impact

The potential impact of such operational discharges from the drilling unit would include reduced physiological functioning of marine organisms due to the biochemical effects on the water column, increased food source for marine fauna due to discharge of galley wastes potentially leading to fish aggregation around drilling units and increased predator-prey interactions.

Sensitive Receptors

The operational waste discharges from the activities described above would primarily take place at the well locations and along the route taken by the support vessels between the drillship and either Durban or Richard’s Bay. The drilling activities would be located in the offshore marine environment, ~100 km offshore, far removed from any sensitive coastal receptors (e.g. bird colonies or turtle nesting sites), but could still directly affect migratory pelagic species transiting through the area of interest for drilling. The taxa most vulnerable to waste discharges are turtles, pelagic seabirds, large migratory pelagic fish, and both migratory and resident cetaceans, many of which are considered globally ‘Critically Endangered’ (e.g. Southern Bluefin tuna, Blue whale, hawksbill turtle), ‘Endangered’ (e.g. whale shark, Fin and Sei whales), ‘Vulnerable’ (e.g. Leatherback turtle, short-fin mako, whitetip sharks, sperm whale) or ‘Near threatened’ (e.g. blue shark). As no drilling operations will be performed in canyons, direct and indirect impacts of operational discharges on sensitive receptors associated with such habitats would be avoided.

Project Controls and Industry Objectives

It is the intention of Eni to ensure that the proposed drilling operation is undertaken in a manner consistent with good international industry practice. Eni’s standards require that project vessels comply with the applicable requirements in MARPOL 73/78, as summarised below.

Sewage and grey water discharges from vessels are regulated by MARPOL 73/78 Annex IV, which stipulates that vessels must have:

- A valid International Sewage Pollution Prevention Certificate;
- An onboard sewage treatment plant providing primary settling, chlorination and dechlorination before discharge of the treated effluent;
- A sewage comminuting and disinfecting system;
- A sewage holding tank;
- A discharge located not less than 5 m below the surface;

Furthermore,

- Discharge of sewage beyond 12 nm requires no treatment. However, sewage effluent must not produce visible floating solids in, nor cause the discolouration of, the surrounding water;
- Sewage must be comminuted and disinfected for discharges between 3 nm (± 6 km) and 12 nm (± 22 km) from the coast. This would require an onboard sewage treatment plant or a sewage comminuting and disinfecting system;
- The effluent must have a minimal residual chlorine concentration of 1.0 mg l-1;
- The biological oxygen demand of the effluent should be <25 mg l-1 (if the treatment plant was installed after 1/1/2010) or <50 mg l-1 (if installed before this date); and
- Disposal of sewage originating from holding tanks must be discharged at a moderate rate while the ship is proceeding *en route* at a speed not less than 4 knots.

The discharge of biodegradable wastes from vessels is regulated by MARPOL 73/78 Annex V, which stipulates that biodegradable wastes:

- Must be passed through a grinder so that it is capable of passing through a 25 mm screen;
- No disposal to occur within 3 nm (± 5.5 km) of the coast; and
- Disposal between 3 nm (± 5.5 km) and 12 nm (± 22 km) needs to be comminuted to particle sizes smaller than 25 mm.

Discharges of water (deck drainage, bilge and mud pit wash residue) to the marine environment are regulated by MARPOL 73/78 Annex I, which stipulates that vessels must have:

- Shipboard Oil Pollution Emergency Plan;
- A valid International Oil Pollution Prevention (IOPP) Certificate, as required by vessel class;
- Equipment for the control of oil discharge from machinery space bilges and oil fuel tanks (e.g. oil separating/filtering equipment [15 ppm] and oil content meter);
- Oil residue holding tanks;
- Standard discharge connections.

Performance objectives

Eni would ensure that waste discharges from the contracted vessel and their toxicity are minimised, and comply with MARPOL 73/78.

Impact assessment

The potential impact of such operational discharges from the drilling unit would include reduced physiological functioning of marine organisms due to the biochemical effects on the water column, increased food source for marine fauna due to discharge of galley wastes potentially leading to fish aggregation around drilling units and increased predator-prey interactions. Given the offshore location of the area of interest for drilling, waste discharges are expected to disperse rapidly and there is no potential for accumulation of wastes leading to any detectable long-term impact.

The majority of the discharged wastes are not unique to the project vessels, but rather common to the numerous vessels that operate in or pass through South African coastal waters daily. As volumes discharged would be low, any associated impacts would be of low intensity and limited to the drilling location over the short-term.

For support vessels travelling from Durban or Richard's Bay operational discharges would likewise be restricted to the immediate vicinity of the vessel over the short-term. This impact is considered to be fully reversible as waste discharges and the potential impact would cease after demobilisation. The significance of the potential impacts is therefore considered to be **MINOR** without mitigation.

Mitigation

Objective: to further reduce and manage routine waste discharges.

Actions: In addition to compliance with MARPOL 73/78 regulations regarding the various waste discharges mentioned above, the following measures are recommended to reduce wastes at the source:

No.	Mitigation measure	Classification
1	Implement a waste management system that addresses all wastes generated at the various sites, shore-based and marine. This should include: – Separation of wastes at source; – Recycling and re-use of wastes where possible; – Treatment of wastes at source (maceration of food wastes, compaction, incineration, treatment of sewage and oily water separation).	Avoid / reduce at source
2	Implement leak detection and repair programmes for valves, flanges, fittings, seals, etc.	Avoid / reduce at source

Residual impact

This potential impact cannot be eliminated because the drillship and support vessels are needed to undertake the drilling programme and will generate wastes during routine operations. With the implementation of the above-mentioned mitigation measures, the residual impact would decrease to being **NEGLIGIBLE**.

Impacts of operational discharges to the sea from drilling units and support vessels		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to immediate area around drillship or support vessels	Local
Duration	Short-term	Short-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	Low	

4.3.6 Impact of Drill Unit Lighting on Turtles, Birds and Fish

Description of the source of impact

The table below summarises the project activities that will result in an increase in ambient lighting.

Activity phase	Activity
Mobilisation	Transit of drilling units and support vessels to the drill site
Operation	Operation of drillship and support vessels
	Flaring during production tests
Demobilisation	Drilling unit / support vessels leave drill site and transit to port or next destination

These activities are described further below.

- Transit and operation of the drillship and support vessels. The operational lighting of drillship and support vessels can be a significant source of artificial light in the offshore environment.
- During well testing it may be necessary to vent or flare off some of the oil and gas brought to the surface. Flaring and venting is also an important safety measure used to ensure gas and other hydrocarbons are safety disposed of in the event of an emergency, power or equipment failure or other plant upset conditions. Flaring and venting produces a flame of intense light at the drill unit. Well testing is expected to last approximately 48 hours with clean-up and main flow accounting for approximately 36 hours within this period.

Description of the environmental aspects

The strong operational lighting used to illuminate the offshore installations at night or the light from the flaring of gas and oil during a production test will increase the ambient lighting in offshore areas.

Description of the potential impact

The strong operational lighting used to illuminate the offshore installations at night or the light from the flaring of gas and oil during a production test may disturb and disorientate pelagic seabirds feeding in the area. Operational lights may also result in physiological and behavioural effects of fish and cephalopods as these may be drawn to the lights at night where they may be more easily preyed upon by other fish and seabirds.

Sensitive Receptors

The drilling activities would be located in the offshore marine environment, more than 62 km offshore, far removed from any sensitive coastal receptors (e.g. bird colonies), but could still directly affect migratory pelagic species (pelagic seabirds, marine mammals and fish) transiting through the areas of interest for drilling. The light impacts from the activities described above would primarily take place at the well location and along the route taken by the support vessels between the drillship and either Durban or Richard's Bay. The drilling activities would be located in the offshore marine environment, ~100 km offshore, far removed from any sensitive coastal receptors (e.g. bird colonies), but could still directly affect migratory pelagic species transiting through the area of interest for drilling. The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans may also be attracted by the lights. Many of these are considered globally 'Critically Endangered' (e.g. Southern Bluefin tuna, Blue whale, hawksbill turtle), 'Endangered' (e.g. whale shark, Fin and Sei whales), 'Vulnerable' (e.g. Leatherback turtle, short-fin mako, whitetip sharks, sperm whale) or 'Near threatened' (e.g. blue shark).

Project Controls and Industry Objectives

Eni does not have specific applicable requirement regarding light emmisions during transit of vessels or rig operations when on site.

Performance objectives

Performance objectives would be to minimise disturbance of marine fauna by increased ambient lighting in the offshore environment as far as practicable.

Impact assessment

Although little can be done at the offshore installation to prevent seabird collisions, reports of collisions or death of seabirds on drilling units are rare. It is expected that seabirds and marine mammals in the area become accustomed to the presence of the installations within a few days, thereby making the significance of the overall impact on these populations negligible. The significance to the populations of fish and squid of increased predation as result of being attracted to an installation's lights is deemed to be insignificant.

The increase in ambient lighting in the offshore environment would be of negligible magnitude and limited to the drilling location over the short-term. For support vessels travelling from

Durban or Richard's Bay increase in ambient lighting would likewise be restricted to the immediate vicinity of the vessel over the short-term. This impact is considered to be fully reversible. The significance of the potential impacts is therefore considered to be of **NEGLIGIBLE** significance without mitigation.

Mitigation

Objective: All lighting equipment on the drillship potentially emitting light outside the physical boundary of the vessel should be assessed to determine whether the light is essential for safety reasons and whether there is the potential for reducing external emissions. As part of the monitoring process, photographs should be taken each night from the platform of the drillship's supply vessels to detect significant light sources emitting light to the surrounding environment.

Actions: the following measures are recommended to reduce and manage increased ambient lighting from the drillship and support vessels:

No.	Mitigation measure	Classification
1	The lighting on the drilling unit and support vessels should be reduced to a minimum compatible with safe operations whenever and wherever possible. Light sources should, if possible and consistent with safe working practices, be positioned in places where emissions to the surrounding environment can be minimized.	Avoid / reduce at source
2	Keep disorientated, but otherwise unharmed, seabirds in dark containers for subsequent release during daylight hours. Injured birds should be returned to shore where feasible to allow for treatment. Where it is not feasible to take the birds to shore, they are to be humanely euthanized. Ringed/banded birds should be reported to the appropriate ringing/banding scheme (details are provided on the ring).	Repair or restore

Residual impact

The use of lighting on the drillship cannot be eliminated due to safety, navigational and operational requirements. With the implementation of the above-mentioned mitigation measures, the residual impact remains **NEGLIGIBLE**.

Monitoring

Trained personnel shall record information on patterns of bird reaction to lights and real incidents of injury/death, including stray land birds resting on the rig, during the drilling operation.

Impacts of increased ambient lighting from drilling units and support vessels		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to immediate area around drillship or support vessels	Local
Duration	Short-term	Short-term
Scale	Small	Small
Reversibility	High (fully reversible)	
Loss of resource	Low	
Magnitude	Negligible	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	None	

4.3.7 Well testing

Description of the source of impact

The table below summarises the project activities that would result in well testing.

Activity phase	Activity
Mobilisation	n/a
Operation	Well testing
Demobilisation	n/a

These activities are described further below:

- If hydrocarbons are encountered, a subsequent "appraisal" well may be drilled. This well could be flow-tested, dependent on subsurface results to determine the economic potential of the discovery. If flow testing is required, hydrocarbons would be burned *via* a flare boom to maximise combustion of the hydrocarbons. The amount of hydrocarbons produced would depend on the quality of the reservoir but is kept to a minimum to minimise the impact on the environment and avoid wasting potentially marketable oil and/or gas.
- No produced water is anticipated. However, if water does flow with the hydrocarbons to the surface it would be burned off via the flare booms.

Description of the environmental aspects

Inefficient combustion of hydrocarbons can result in the release of unburnt hydrocarbons, which 'drop-out' onto the sea surface and may form a visible slick of oil.

Description of the potential impact

The slick of oil produced during 'drop-out' can result in direct localised physiological effects on seabirds and marine animals.

Sensitive Receptors

Flaring during well testing could directly and indirectly affect migratory pelagic species (pelagic seabirds, marine mammals and fish) transiting through the area of interest for drilling. The taxa most vulnerable to disturbance would be pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans may also be affected by the 'drop-out'. Many of these are considered globally 'Critically Endangered' (e.g. Southern Bluefin tuna, Blue whale, hawksbill turtle), 'Endangered' (e.g. whale shark, Fin and Sei whales), 'Vulnerable' (e.g. Leatherback turtle, short-fin mako, whitetip sharks, sperm whale) or 'Near threatened' (e.g. blue shark).

Project Controls and Industry Objectives

It is the intention of Eni to ensure that the proposed drilling operation is undertaken in a manner consistent with good international industry practice. Eni's standards require that flow testing complies with IFC guidelines.

Performance objectives

Performance objectives would be to minimise hydrocarbon 'drop-out' during flaring and well testing.

Impact assessment

The impact of hydrocarbon 'drop-out' during flaring would be of small magnitude and limited to the drilling location over the short-term. The impacts resulting from the slick of oil produced during 'drop-out' are fully reversible and therefore **NEGLIGIBLE** without mitigation.

Mitigation

Objective: to further reduce and manage 'drop-out' onto the sea surface during flaring.
Actions: the following measures are recommended to reduce and manage 'drop-out' onto the sea surface during flaring[5]:

No.	Mitigation measure	Classification
1	Use high efficiency burners for flaring to optimise combustion of the hydrocarbons in order to minimise emissions and hydrocarbon 'drop-out' during well testing.	Avoid / reduce at source
2	Maximise flare combustion efficiency by controlling and optimising flare fuel/air/stream flow rates.	Reduce at source/Abate on site

Residual impact

Should flow-testing be required, the need for flaring cannot be eliminated. With the implementation of the above-mentioned best management practices, the residual impact would have a lower magnitude and lower probability, but would remain **NEGLIGIBLE**.

[5] Based on the International Finance Corporation's (IFC) Environmental, Health and Safety Guidelines for offshore oil and gas development, April 2007

Impacts of hydrocarbon 'drop-out' during flaring on offshore areas		
Characteristic	**Impact**	**Residual Impact**
Extent	Local: limited to immediate area around drillship	Local
Duration	Short-term	Short-term
Scale	Small	Small
Reversibility	High	
Loss of resource	Low	
Magnitude	Small	
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low	Low
Significance of Impact	**Negligible**	**Negligible**
Mitigation Potential	Very Low	

4.3.8 Cumulative impacts

The primary impacts associated with the drilling of exploration wells in the West Indian Offshore Bioregion off the coast of KZN, relate to physical disturbance of the seabed, discharges of drilling solids to the water column and their settlement into the benthic environment, the presence of infrastructure remaining on the seabed and associated drillship presence and the noise generated during operations. The development of the proposed exploration well(s) in this assessment would impact a maximum cumulative area of ~0.003 km^2 (per well) in the West Indian Bioregion, which can be considered an insignificant percentage of the bioregion as a whole. Vessel activity and helicopter support during drilling operations would contribute to ambient levels of underwater noise caused by marine traffic in the region, but even sensitive species (cetaceans, turtles and certain fish species) are unlikely to be significantly affected by thecumulative effects of the drilling operation. Cumulative impacts from other hydrocarbon ventures in the area may increase in future. The cumulative impacts of the proposed drilling of exploration wells off the KZN coast can be considered of **LOW** significance.

5. ASSESSMENT OF IMPACTS OF ACCIDENTAL EVENTS ON MARINE FAUNA

An unplanned/ accidental event is defined as ‘a reasonably foreseeable incident that is not anticipated to occur as part of the proposed project, but which may conceivably occur as a result of project activities (e.g. vessel accidents and loss of well containment/blowout), but with a low probability’. Accidental events may occur during any phase of the project. This Section describes the potential accidental events associated with the project and provides an assessment of the risk significance of the impact on the receiving environment based on an assessment of likelihood vs consequence.

5.1 Assessment Methodology for Unplanned Events

The methodology used to assess the significance of the risks associated with accidental events differs from the impact assessment methodology in that the risk significance is based on a combination of the likelihood (or frequency) of the incident occurring and the consequences of the incident should it occur. The assessment of likelihood and consequence of the event also includes the existing control and mitigation measures for this project.

The assessment of likelihood takes a qualitative approach based on professional judgement, experience from similar projects and interaction with the technical team.

The assessment of consequence is based on specialists’ input and their professional experience gained from similar projects, and informed by the results of the various modelling studies undertaken to confirm the extent and duration of an oil spill. In order to determine the potential extent and duration of accidental oil spills (in the unlikely event that they occur) an oil spill modelling study was conducted for this project.

Definitions used in the assessment for likelihood and consequence are set out in Table 17 below.

Table 17: Risk Significance Criteria for Accidental events

Characteristic	Definition	Terms
Likelihood	Describes the probability of an event or incident actually occurring or taking place	**Low** - the event or incident is reported in the oil and gas industry, but rarely occurs. **Medium** - the event or incident does occur but is not common. **High** - the event or incident is likely to occur several times during the project's lifetime.
Consequence	A combination of those factors that determine the magnitude of the unplanned impact (in terms of the extent, duration and intensity of the impact).	**Minor consequence** - impacts of Low intensity to receptors/resources across a local extent, that can readily recover in the short term with little or no recovery/remediation measures required . **Moderate consequence** - impacts of Low to Medium intensity across a local to regional extent, to receptors/resources that can recover in the short term to medium term with the intervention of recovery/remediation measures . **Major consequence** - exceeds acceptable limits and standards, is of Medium to High intensity affecting receptors/resources across a regional to international extent that will recover in the long term only with the implementation of significant/remediation measures.

Once a rating is determined for likelihood and consequence, the risk matrix in Table 18 is used to determine the risk significance for accidental events. The prediction takes into account the mitigation and/or risk control measures that are already an integral part of the project design, and the management plans to be implemented by the project.

Table 18: Accidental Events Risk Significance

Risk Significance Rating				
Likelihood		Low	Medium	High
Consequence	Minor	Minor	Minor	Moderate
	Moderate	Minor	Moderate	Major
	Major	Moderate	Major	Major

Description of the source of impact

The table below summarises the project activities that could potentially result in small instantaneous spills, loss of fuel during a vessel accident and loss of well control. These would all be unplanned activities that could potentially occur during all phases of the project.

Activity phase	Activity
Mobilisation	Loss of fuel from vessel accident
	Small instantaneous spills
Operation	Loss of fuel from vessel accident
	Small instantaneous spills
	Loss of well control / well blow-out
Demobilisation	Loss of fuel from vessel accident
	Small instantaneous spills

These activities are described further below:

- Instantaneous spills of marine diesel and/or hydraulic fluid at the surface of the sea can potentially occur during all project activity phases, both from the drilling unit or from support vessels. Such spills are usually of a low volume and occur accidentally during fuel bunkering or as a result of hydraulic pipe leaks or ruptures.
- Larger volume spills of marine diesel would occur in the event of a vessel collision or vessel accident.
- During the drilling of the deeper sections of the well using NADFs, accidental disconnection of the riser could occur resulting in the spill of low-toxicity oil-based muds (LTOBMs) from the drillship.
- The primary safeguard against a blow-out is the column of drilling fluid in the well, which exerts hydrostatic pressure on the wellbore. Under normal drilling conditions, this pressure should balance or exceed the natural rock formation pressure to help prevent an influx of gas or other formation fluids. As the formation pressures increase, the density of the drilling fluid is increased to help maintain a safe margin and prevent "blowouts." However, if the density of the fluid becomes too heavy, the formation can break down. If drilling fluid is lost in the resultant fractures, a reduction of hydrostatic pressure occurs. Maintaining the appropriate fluid density for the wellbore pressure regime is therefore critical to safety and wellbore stability. Abnormal formation pressures are detected by primary well control equipment (pit level indicators, return mud-flow indicators and return mud gas detectors) on the drill unit. The drilling fluid is also tested frequently during drilling operations and its composition can be adjusted to account for changing downhole conditions. The likelihood of a blow-out is further minimised by installation of a blow-out preventer (BOP) on the wellhead at the start of the risered drilling stage. The BOP is a secondary control system, which contain a stack of independently-operated cut-off mechanisms, to ensure redundancy in case of failure. The BOP is designed to close in the well to prevent the uncontrolled flow of hydrocarbons from the reservoir. A blow-out occurs in the highly unlikely event of these pressure control systems failing.

<u>Description of the environmental aspects</u>

The environmental aspects associated with spills include the :

- Release of fuel into the sea following a vessel collision and localised reduction in water quality;
- Discharge of fuel into sea during bunkering and localised reduction in water quality;
- Discharge of hydraulic fluid into sea due to pipe rupture and localised reduction in water quality;

- Discharge of LTOBM onto the seabed resulting in localised reduction in sediment and water quality;
- Uncontrolled release of oil / gas from the well; and
- Acute toxicological effects on aquatic organisms (i.e. from narcosis) of the dissolved aromatic hydrocarbons (DAHs) in marine diesel and NADFs.

Description of the potential impact

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 habitat loss or contamination (CSIR 1998; Perry 2005).

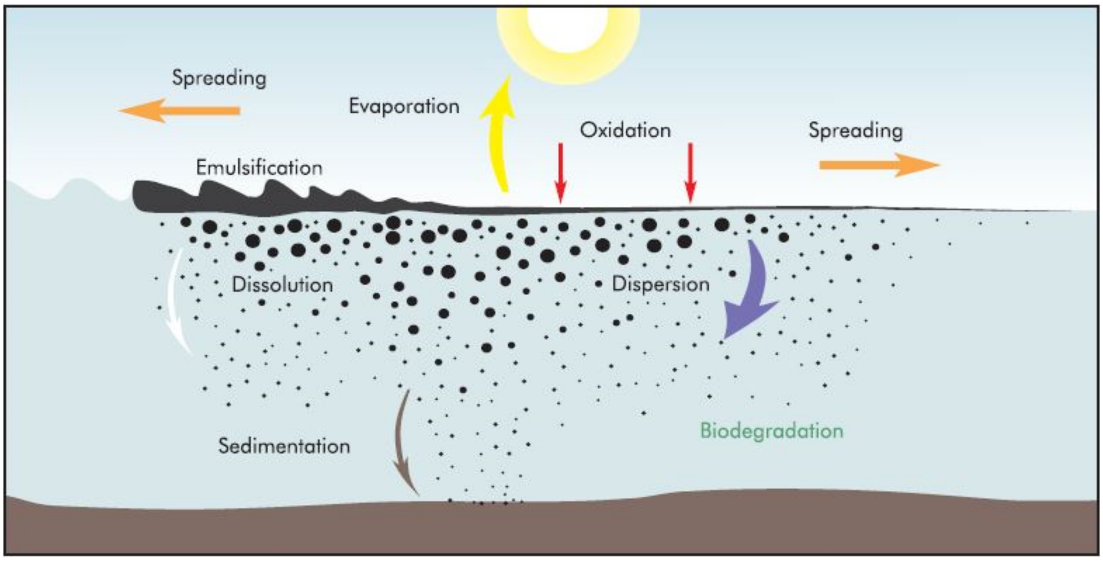
Various factors determine the impacts of oil released into the marine environment. The physical properties and chemical composition of the oil, local weather and sea state conditions and currents greatly influence the transport and fate of the released product. The physical properties that affect the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

As soon as oil is spilled, various weathering processes (Figure 31A) come into play. Although the individual processes may act simultaneously, their relative importance varies with time (Figure 31B). Whereas spreading, evaporation, dispersion, emulsification and dissolution are most important during the early stages of a spill, the ultimate fate of oil is determined by the longer term processes of oxidation, sedimentation and biodegradation.

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

Oil spilled in the marine environment will have an immediate detrimental effect on water quality. Most of the toxic effects are associated with the monoaromatic compounds and low molecular weight polycyclic hydrocarbons (also referred to as Dissolved-phase Aromatic Hydrocarbons : DAHs), as these are the most water-soluble components of the oil. Oil is most toxic in the first few days after the spill, losing some of its toxicity as it begins to weather and emulsify. The time of year during which a large spill takes place will significantly influence the magnitude of the impact on plankton and pelagic fish eggs and larvae. Should the spill coincide with a major spawning peak, it could result in severe mortalities and consequently a reduction in recruitment (Baker *et al.* 1990). However, spawning and recruitment success is temporally variable and environmental conditions are likely to have a far greater impact than a single large spill (Neff 1991). Sensitivity of fish eggs and larvae are primarily associated with exposure to fresh (unweathered) oils (Teal & Howarth 1984), with little mortality attributable to exposure to weathered product (Neff 1991). Because of their mobility and ability to avoid floating oil masses and the associated hydrocarbon contamination, adult pelagic fish are considered less at risk from exposure to oil spills than benthic or inshore species.

A)



B)

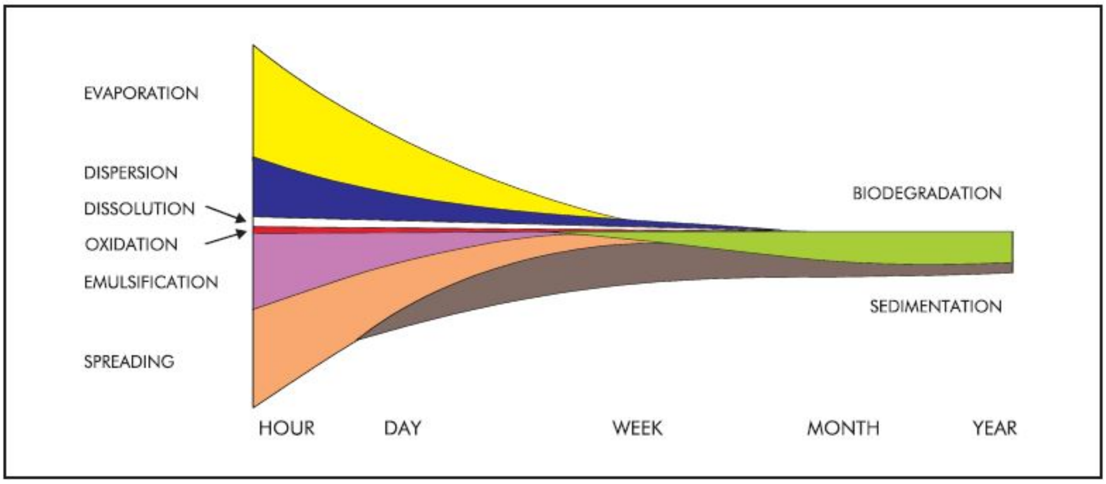


Figure 31: A) The weathering processes acting on spilled crude oil, and B) the fate of a typical medium crude oil under moderate sea conditions showing changes in the relative importance of weathering processes with time - the width of each band indicates the importance of the process (ITOPF 2002).

Surface spills in the offshore environment are unlikely to have an immediate effect on the seabed. However, oil in sediments as a result of accidental spillage near the coast or the loss of LTOBMs and oil-contaminated drill cuttings following accidental disconnection of the riser, can result in physical smothering of the benthos and chronic pollution of the sediments. A wide range of effects of oil on benthic invertebrates has been recorded, with much of the research focussing on the various life stages of polychaetes, molluscs and crustaceans (Volkman *et al.* 1994). However, as tolerances and sensitivities vary greatly, generalisations cannot be confidently made. Some burrowing infauna (e.g. polychaetes and copepods) show high tolerances to oils, as the weathered product serves as a source of organic material that is suitable as a food source. Polychaetes in particular can take advantage of bioturbation and degradation of oiled sediments (Scholtz *et al.* 1992). This results in highly modified benthic communities with (potentially lethal) 'knock-on' effects for higher order consumers. Bioaccumulation of petroleum hydrocarbons by fish through oil-contaminated prey and sediments is a well-described phenomenon (CSIR & CIME 2011).

Volkman *et al.* (1994) suggest that some epifauna produce complex responses to oiling and that bioaccumulation of petroleum hydrocarbons can in some cases readily occur. Sessile and motile molluscs (e.g. mussels and crustaceans) are frequent victims of direct oiling or coating. Filter-feeders in particular are susceptible to ingestion of oil in solution, in dispersion or adsorbed on fine particles. Chronic oiling is known to cause a multitude of sub-lethal responses in taxa at different life stages, variously affecting their survival and potential to re-colonise oiled areas. Tolerances to oil vary between life stages, with larvae and juvenile stages generally being more sensitive to the water-soluble fractions of oil than adults (Volkman *et al.* 1994; CSIR & CIME 2011).

Impacts of oil on juvenile and adult fish can be lethal, as gills may become coated with oil. Sub-lethal and long-term effects can include disruption of physiological and behavioural mechanisms, reduced tolerance to stress, and incorporation of carcinogens into the food chain (Thomson *et al.* 2000). However, being mobile, fish are likely to be able to avoid a large spill.

Chronic and acute oil pollution is a significant threat to both pelagic and inshore seabirds. Diving sea birds that spend most of their time on the surface of the water are particularly likely to encounter floating oil and will die as a result of even moderate oiling which damages plumage and eyes. The majority of associated deaths are as a result of the properties of the oil and damage to the water repellent properties of the birds' plumage. This allows water to penetrate the plumage, decreasing buoyancy and leading to sinking and drowning. In addition, thermal insulation capacity is reduced requiring greater use of energy to combat cold. Oil is also ingested as the birds preen in an attempt to clear oil from plumage and may furthermore be ingested over the medium to long term as it enters the food chain (Munro 2004). The effects of ingested oil include anaemia, pneumonia, intestinal irritation, kidney damage, altered blood chemistry, decreased growth, impaired osmoregulation, and decreased production and viability of eggs (Scholz *et al.* 1992). Furthermore, even small concentrations of oil transferred from adult birds to the eggs can cause embryo mortalities and significantly reduce hatching rate. Oil spills can thus have an effect on birds that may be some distance from the spill site, which can be attributed to the parent's feeding habits.

Impacts of oil spills on turtles is thought to primarily affect hatchling survival (CSIR & CIME 2011). Turtles encountered in the project area would mainly be migrating adults and vagrants. Similarly, little work has been done on the effect of an oil spill on fur seals, but they are expected to be particularly vulnerable as oil would clog their fur and they would die of hypothermia (or starvation, if they had taken refuge on land).

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

Sensitive Receptors

Being highly toxic, oil from a 'blow-out', a riser disconnection or marine diesel released during an operational spill would negatively affect any marine fauna it comes into contact with. The drilling activities would be located in the offshore marine environment, ~100 km offshore, and removed from most sensitive coastal receptors (e.g. bird colonies, coral reefs) or MPAs. However, due the the proposed well(s) being situated within the influence of the strong Agulhas Current, spilled hydrocarbons would be rapidly transported considerable distances, both within the water column and on the surface, with visible surface slicks potentially reaching the shore to the southwest of the proposed well locations. Depending on the nature of the spill, sensitive coastal receptors and MPAs could thus likely be affected to a greater or lesser degree by surface oil.

The benthic fauna inhabiting unconsolidated sediments of the outer shelf and continental slope are very poorly known, but at the depths of the proposed well are expected to be relatively ubiquitous, varying only with sediment grain size, organic carbon content of the sediments and/or near-bottom oxygen concentrations. These benthic communities usually comprise fast-growing species able to rapidly recruit into areas that have suffered natural environmental disturbance. Epifauna living on the sediment typically comprise taxa which are longer lived and therefore more sensitive to disturbance. No rare or endangered benthic species are known. In contrast, the benthos of deep-water hard substrata are typically vulnerable to disturbance due to their long generation times. As video footage has identified vulnerable communities including sponges, black corals, gorgonians, alcyonarian soft corals and stylasterine lace corals (Sink *et al.* 2006) in submarine canyons off the KZN coastline, the potential occurrence of such sensitive deep-water ecosystems in the ER236 area, and specifically the areas of interest for well drilling, cannot be excluded.

In the offshore environment, the taxa most vulnerable to surface spills are pelagic seabirds, although turtles, large migratory pelagic fish, and both migratory and resident cetaceans may also be affected. Many of these are considered globally 'Critically Endangered' (e.g. Southern Bluefin tuna, Blue whale, hawksbill turtle), 'Endangered' (e.g. whale shark, Fin and Sei whales), 'Vulnerable' (e.g. Leatherback turtle, short-fin mako, whitetip sharks, sperm whale) or 'Near threatened' (e.g. blue shark).

The majority of the oil from a blowout would, however, remain entrained in the water column as droplets and by way of DAHs. Where threshold concentrations for dissolved aromatics are exceeded, these could negatively impact both demersal and pelagic marine fauna through acute narcosis. Of particular interest in this regard is the African coelacanth, which is known to occur in the Wright, Jesser and Chaka Canyons off the GSLWP World Heritage Site, with further potential habitats being located in Leven Canyon off St Lucia (Hissman *et al.* 2006) and on the continental shelf off the stretch of coastline between Port Shepstone and Port St Johns (Green *et al.* 2006). As the effects of hydrocarbons on these rare fish is unknown, the potential impacts of a blow out on this species (and other sensitive demersal and pelegic receptors) need to be considered.

Although the areas of interest for well drilling do not overlap with any existing MPAs or proposed EBSAs, there are numerous MPAs, recently approved MPAs, EBSAs and Hope Spots in the Area of Indirect Influence. These include the Amathole MPA in the vicinity of East London, and the Dwesa-Cwebe, Hluleka and Pondoland MPAs located on the Wild Coast. Biota protected within these areas could be impacted by surface oil slicks following a major blow out.

Project Controls and Industry Objectives

The purpose of the Eni performance standards is to reduce the risk of pollution and oil spills for projects to As Low As Reasonably Practicable (ALARP). The objectives of Eni's policies and procedures are to:

- Apply the hazard management process
- Design and install equipment and/or implement Procedures to reduce the likelihood of discharges to the environment
- Assess the Maritime Safety Risks and put controls in place to manage these risks to ALARP
- Establish and maintain procedures for managing the risk of maritime operations that comply with the Eni Maritime Safety Requirements for Design, Engineering and Operation

Eni's standard controls and responses are summarised below.

Barriers and Controls (Avoidance/Prevention Actions)	
Design and Technical Integrity	The Eni wells standard defines HSSE and technical requirements for wells. It also details assurance and competency requirements for well engineering and completion and well intervention personnel. This covers the well design, procurement of materials, and identification of risks.
Barriers and Controls (Avoidance/Prevention Actions)	
Multiple Barriers	**Casing:** Casings would be designed to withstand a variety of forces, such as collapse, burst or tensile failure, as well as chemically aggressive brines. They would be run to prevent caving-in of formations and to provide strong foundations for continued drilling operations.
	Wellbore pressure: Subsurface pressures above and within the hydrocarbon-bearing strata would be controlled by the use of weighted drilling mud. The hydrostatic pressure of the drilling mud in the well would be adjusted to ensure that it is greater than the formation pressure to prevent the undesired influx of fluids into the wellbore (known as a 'kick'). Pressure monitoring would be undertaken during drilling to ensure that kicks are avoided or managed to prevent escalation into a blowout.
	Blow-out Preventer (BOP) stack: BOP stacks are used to control the pressure of a well through mechanical devices designed to rapidly seal the well (or "shut in") in an emergency.

Barriers and Controls (Avoidance/Prevention Actions) (cont.)	
Competent Staff	Eni has competent and certified staff who would design the well and conduct independent sign-off for its design. During operations Eni can transmit real-time information, such as pressure and temperature, back to operations centres around the world for additional quality control and advise when needed.
Testing and Certification	Safety critical equipment would be subject to testing and certification to ensure that it meets design specifications. The well design, drilling and completion plans would go through several stages of review involving experts from Eni and the drilling contractor prior to the commencement of drilling operations.
Response and Recovery (Mitigation Actions)	
Oil Spill Response Plan	Despite the prevention measures and management procedures built into the design of the project there is always a risk that a spill can occur. Thus, as standard practice, an Oil Spill Response Plan is prepared and put in place at all times during the drilling operation. There are three principal components underpinning an Oil Spill Response Plan: • Crisis management (Emergency Command and Control Management); • Spill response, containment and clean-up; and • Well control.
Emergency Command and Control Management	Emergency Command and Control Management arrangements range from the On-scene Commander, normally at the source of the incident, to the main Emergency Control Centre (ECC) Incident Commander who takes over control. As each level is activated the level of response would equally escalate.
Well Control	Whilst the Oil Spill Response Plan defines the approach and strategy required to manage the containment, removal and clean up following a major spill, the well control process is focussed on stopping the source of the leak. A Well Control Contingency Plan (WCCP) would be put in place for each well.
Cap and Containment Equipment	If the BOP does not successfully shut off the flow from the well, the drilling rig would disconnect and move away from the well site while crews mobilise a capping system. The capping system would be lowered into place from its support barge and connected to the top of the BOP to stop the flow of oil or gas. Eni is a member of OSRL, which operates advanced well intervention and capping equipment from Saldanha Bay for deployment in the event of a subsea well control incident. This would significantly reduce the spill period. All of Eni's wells are designed to allow for capping.
Containment and clean-up equipment	Project vessels would be equipped with appropriate spill containment and clean-up equipment, e.g. booms, dispersants and absorbent materials. All relevant vessel crews would be trained in spill clean-up equipment use and routine spill clean-up exercises. Logistical arrangements for the integration of additional support would be in place (e.g. from OSRL).

Performance objectives

The specific performance objective is "zero leaks and spills".

Brief Summary of Oil Spill Modelling Results

The oils spill modelling undertaken by ERM (2018b) considered three oil spill scenarios, namely:

1) Small operational surface spill of marine diesel (795 m^3) just below the sea surface at the well site due to a vessel collision, where the dominant weathering processes are evaporation and dispersion.
2) Blow-out of medium crude oil for two events, namely:
   – Release of 750 m^3 /day at the seabed (1,623 m depth) at the north well (N1) under a 7-day blow-out scenario before hole collapse, and

   - Release of 1,050 m^3 /day at the seabed (2,883 m depth) at the south well (S) under a 20-day blow-out scenario before well capping.

   For crude oil the weathering processes over the short-term (hours to weeks) include evaporation, dispersion, dissolution, photo-oxidation, emulsification and spreading, whereas biodegration and sedimentation dominate the weathering processes over the medium- to long-term (weeks to years).

3) Instantaneous release of LTOBMs and contaminated cuttings (300 m^3 - 530 m^3) from the drillship following the accidental disconnection of the riser during drilling of the deeper well sections. LTOBMs comprise primarily alkanes, with aromatics comprising less than 0.01% of the oil by mass. The base oil comprises 60% by volume of the LTOBM, with the remaining 40% being solids (typically barium sulfate with other minerals and crystals such as calcium chloride, calcium hydroxide, silica, etc.). The muds comprise particles of <77 μm, with the largest representation by particles in the 12-28 μm size range. As with marine diesel, the dominant weathering processes are evaporation and dispersion.

These three spill scenarios were modeled in order to simulate the:

- Spill trajectories;
- Potential locations of the surface slicks and their potential to impact wildlife;
- Potential shoreline locations at risk of oiling;
- Travel times for the slick to arrive at various locations; and
- Magnitudes of the oil's dissolved-phase aromatic hydrocarbon (DAH) component concentrations, assuming a threshold of 5 parts per billion (ppb).
- The separate modelling of the settling rate of the solid particles in the released LTOBMs to simulate the size, location and thickness of the deposits on the seafloor and the concentration of TSS added to the water column.

The spill scenarios were based on historical meteorological and oceanographic data to simulate the most realistic surface and subsurface conditions. As currents are usually strong compared to the wind intensity in the region, these will have a controlling role on surface transport of floating slicks. As the small operational spills due to a vessel collision or riser disconnect would typically occur near the sea surface and involve the light volatile fraction of aromatics and other oil components with a low molecular weight, the spills would disperse rapidly from the point source and remain at the sea surface for no more than a few days. During this time the DAHs can, however, have toxicological effects on marine fauna.

In contrast, in the case of a large blow-out, the discharge of crude oil would leave the seabed under momentum, which together with the buoyancy of the oil/gas mixture would result in a rapid rise of the oil-gas plume in the water column driven by the expanding gas bubbles. However, gas hydrate formation and the entrainment of ambient water would likely result in the plume being trapped a few 100 m above the seabed (see also Spaulding *et al*. 2000). Thereafter, the oil particles would rise towards the surface as a function of oil droplet diameter and the differences in oil and water density being transported away from the discharge, both vertically and horizontally, by advection and diffusion. The larger fractions would reach the surface within a few hours after initial release, potentially forming a floating slick that would drift rapidly due to winds and currents at the surface. The smaller fractions would likely remain entrained and decay before they surface, being subjected to subsurface advection-diffusion transport. The lower rise velocities of the smaller oil particles, however, results in longer residence times of droplets in the water column, thereby affecting a larger volume of water and longer durations of exposure of aquatic organisms to the dissolved aromatic components. The amount of crude oil entrained in the water column is, however, very sensitive to the properties of the oil and the prevailing wind speed at the time of the blow out. At the lowest wind speeds, entrainment is minimal and nearly all the oil either evaporates or remains in the surface slick. At mid-high wind speeds the evaporation and vertical entrainment processes compete in removing floating oil from the water surface, whereas at high wind speeds vertical entrainment processes dominate and almost no oil reaches the surface. The model results and consequently the assessment of impacts thus have an element of uncertainty associated with them, namely the unknown characteristics of the crude oil itself and uncertainties regarding the long-term weathering behaviour of oil from a deepwater blow out.

The results of the oil spill modelling exercise are summarised below:

Scenario	Result
795,000 litres of marine diesel spilled just below the surface at the well site over a 1 hr period	• Slick of thickness >1.0 µm (thickness for smothering of aquatic biota), travels as a narrow swath to a distance of 230 km (N1 well site), 215 km (N2 well site) and 320 km (S well site) south-westwards from the source, remaining beyond 20 km of the coastline, • diesel remains on the sea surface for 1 - 2 days before oil dispersion and spreading reduces the oil thickness below the minimum smothering thickness of 1.0 µm within 50 km of the point of release, • the maximum total area contacted at some point by a smothering thickness >1.0 µm was 1,896 km^2 (N1 well site), 1,684 km^2 (N2 well site) and 2,848 km^2 (S well site), • the maximum area affected by a >10 µm slick was 210 km^2 (N1 well site), 147 km^2 (N2 well site) and 243 km^2 (S well site), • no significant shoreline oiling (<100 g/m^2) occurred, although under the worst case scenario oil would reach the shore within 2-3 days potential affecting a 280 km (N1 well site), 160 km (N2 well site) and 310 km (S well site) stretch of shoreline between Durban and East London, • the probability of the spill reaching the shoreline is low (<7.5%).

Scenario	Result
7-day blow-out of 5,250 m^3 (33,019 barrels) of crude oil before hole collapse	• once the oil surfaces it generally moves in a south-westerly direction as a widening plume due to the prevailing near-surface currents and winds, • a slick of minimum smothering thickness (1.0 µm) is unlikely to come ashore before weathering away into a thin sheen, • the maximum total area contacted at some point by a smothering thickness >1.0 µm occurred during summer and autumn, and was 410 km^2 (N1 well site) and 3,049 km^2 (2 well site), • no regions exceeded the 10 µm threshold for risks to birds and wildlife, • significant oiling (>100 g/m^2) is unlikely to reach the shoreline, • should oil reach the shore it would do so within 4-6 days during the summer/autumn in the areas between Port Shepstone and Port St Johns (N1 and S well sites), and at St Lucia (N1 well site) and Port Edward (S well site) during winter/spring, • maximum area of DAH above the 5 ppb threshold for worst case oiling ranged from 324 km^2 (southern well location during summer/autumn) to 5,874 km^2 (northern well location during winter/spring).
20-day blow-out of 21 000 m^3 (132,080 barrels) of crude oil before cap install	• once the oil surfaces it generally moves in a south-westerly direction as a widening plume due to the prevailing near-surface currents and winds, • a slick of minimum smothering thickness (1.0 µm) is unlikely to come ashore before weathering away into a thin sheen, • at the N1 well site, the maximum total area contacted at some point by a smothering thickness >1.0 µm occurred during winter and spring, and was 695 km^2, • at the S well site, the maximum total area contacted at some point by a smothering thickness >1.0 µm occurred during summer and autumn, and was 4,386 km^2, • no regions exceeded the 10 µm threshold for risks to birds and wildlife, • significant oiling (>100 g/m^2) is unlikely to reach the shoreline, • should oil reach the shore it would do so within 5-7 days during the summer/autumn in the areas between Port Shepstone and Port St Johns (N1 and S well sites), and at St Lucia (N1 well site) and Port Edward (S well site) during winter/spring.

Scenario	Result
Riser disconnect and loss of 178,000 – 317,000 litres of base oil just below the sea surface	• the surface oil patch travels as a narrow swath of 215 km (N1 well site), 160 km (N2 well site) and 305 km (S well site) south and south-westwards from the source before weathering into a thinner sheen, remaining beyond 25 km of the coastline, • base oil remains on the sea surface for 1 - 2 days before weathering into a thin sheen within 25 km of the point of release, • the maximum total area contacted at some point by a smothering thickness >1.0 µm was 1,232 km^2 (N1 well site), 870 km^2 (N2 well site) and 2,050 km^2 (S well site), • slicks >10 µm thickness did not occur, • no significant shoreline oiling (>100 g/m^2) occurred, although under the worst case scenario oil would reach the shore within 4 days potential affecting 220 km (N1 well site), 145 km (N2 well site) and 320 km (S well site) of shoreline between Durban and East London, • 8.3% probability of the spill reaching the coastline, • surface plumes of elevated TSS would extend up to 6 km down-current of the point of release under maximum average current conditions, but concentrations remain below the threshold of 35 mg/l, • particles in the solid fraction of the LTOBMs did not settle on the seabed within a 10 km radius of their release.

Risk assessment

The environmental risks associated with the various oil spill scenarios modelled by ERM (2018b) are assessed below, based on the footprints for the probability of surface oiling from spill events, as well as the modelled footprint of the entrained fraction.

Major Spills

While the probability of a major spill happening is low, the impact nonetheless needs to be considered as it could have devastating effects on the marine environment. The risk assessment below assumes the worst-case scenario of a 20-day blow out of medium crude oil. The intensity of the potential impact of a surface slick varies depending on the faunal group affected ranging from low for benthic macrofauna, marine mammals and turtles, to high for seabirds, likely persisting over the medium- to long-term. Results of the oil spill modelling study indicated that surface oil from the spill would spread in a south-westerly direction, with a very low likelihood of reaching the shoreline thus being of regional extent for all but benthic macrofaunal communities. Oil droplets and DAHs may also persist throughout the water column due to the rising plume from the release, as well as in the top few meters of the water column beneath the slick for a number of days, potentially resulting in acute toxicological effects in marine fauna coming in contact with the entrained slick for extended periods. The modelling results indicated that at the end of the simulation, ~40% of the oil remains in the water column as droplets and ~40% remained as the dissolved component, with only around 10% reaching the surface. For a surface slick, the risk significance is considered to be **MINOR** for benthic invertebrates, plankton, pelagic fish and larvae, for marine mammals and turtles and for MPAs, but of **MODERATE** significance for seabirds. Due to their high sensitivity to oiling and the elevated threat status of many of the coastal avifaunal species, the impacts of an oil spill on seabirds would be of **HIGH** significance. Although the risk of a surface spill on coelacanths and coelacanth habitat has been assessed below, using modelling results for surface spill trajectories has little meaning for a species found in 90-140 m depth.

Mitigation

Objective: to further reduce and manage impacts associated with blow-outs.

Actions: In addition to the best industry practices and Eni's project standards, the following measures are recommended to manage the impacts associated with blow-outs:

No.	Mitigation measure	Classification
1	Prepare and implement a Shipboard Oil Pollution Emergency Plan and an Oil Spill Contingency Plan. In doing so take cognisance of the South African Marine Pollution Contingency Plan, which sets out national policies, principles and arrangements for the management of emergencies including oil pollution in the marine environment.	Avoid / reduce at source
2	As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill.	Abate on and off site
3	Use low toxicity dispersants that rapidly dilute to concentrations below most acute toxicity thresholds. Use dispersants only with the permission of DEA.	Abate on and off site
4	Ensure adequate resources are available to collect and transport oiled birds to a cleaning station.	Restore

Risk of surface oiling from a major spill following a blow out impacting deepwater benthic macrofauna

Characteristic	Risk Significance
Type of Impact	Direct
Likelihood	Low
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of surface oiling from a major spill following a blow out impacting plankton	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium

Risk of surface oiling from a major spill following a blow out impacting pelagic fish and larvae	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of surface oiling from a major spill following a blow out impacting seabirds	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Major
Risk Significance	**Moderate**
Reversibility	Partially Reversible
Loss of resource	Medium
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High

Risk of surface oiling from a major spill following a blow out impacting marine mammals and turtles	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of surface oiling from a major spill following a blow out impacting MPAs and EBSAs	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of surface oiling from a major spill following a blow out impacting coelacanths and coelacanth habitat	
Characteristic	**Risk Significance**
Type of Impact	Indirect
Likelihood	Low
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High

In the case of a 7-day deep water blow out, the entrained fraction would travel in a different direction to suface slicks as it is subjected to subsurface currents rather than the wind's sheer stress. Distributions of current speed and direction indicate that at the northern well site, currents flow towards the west, southwest and south for 89% of the time, with north, north-northwest and northwest flows occurring only 2% of the time. At the southern well site, currents flow towards the west, southwest and south for 83% of the time, with north and north-northwest flows occurring only 3% of the time. Concentrations of DAHs above the threshold would thus affect a larger volume of water and result in longer durations of exposure of aquatic organisms to the dissolved components than the DAH footprints for surface slicks. Dissolved aromatic 96-hour LC_{50} values range between 100 and 1,000 ppb (ANZECC & ARMCANZ 2000). Concentrations below which no toxic effects occur are assumed to be 10 to 100 times less than the 96-hour LC_{50}. In the modelling study undertaken for this project (ERM 2018b) a highly conservative value of 5 ppb was chosen as a 96-hour Low Reliability Trigger threshold to enable a significant margin of safety for sensitive organisms. Only the plumes for a 7-day blow out were modelled.

Modelling results indicate that for a blow out at the northern well site in summer/autumn, the DAH plume above the 5 pbb threshold would tend to travel in a southerly direction for ~ 200 km before turning west. The plume travels independently and further than the surface slick and, regardless of depth, was estimated to affect an area of 4,403 km^2. The plume would cross the feeder valley of the Goodlad Canyon at ~2,000 m depth and the feeder valley of the Tugela Canyon at between 2,500 m and 3,000 m depth. The probability of northward transport of the plume towards the canyons off the GSLWP and St Lucia was very low. In contrast, the DAH plume from a blow out at the southern well site remains confined to within ~30 km west of the well location, only affecting an area of 324 km^2 (Figure 32, top). The canyons off Port Shepston would not be affected.

DAH plume footprints for a blow out at the northern well location during winter/spring would tend to travel mostly eastwards for ~100 km before turning southwards, affecting an area of some 5,874 km^2. The plume would cross the feeder valley (>2,500 m) of the Goodlad Canyon and its confluence with the base of the Sodwana feeder valley at ~2,500 m depth. The probability of northward transport of the plume towards the canyons off the GSLWP was very low. The DAH plume from a blow out at the southern well site would tend to travel mostly southwest for ~100 km, affecting an area of 2,033 km^2 before diluting and degrading away (Figure 32, bottom). The canyons off Port Shepston would not be affected. The probability of northward transport of the plume towards the Tugela Canyon was very low. The plumes would again travel independently and further than surface slicks.

For a sub-surface slick, the risk significance is considered to be **MINOR** for benthic invertebrates, plankton, pelagic fish and larvae, seabirds and for marine mammals and turtles.

Risk of sub-surface oiling from a major spill following a blow out impacting deepwater benthic macrofauna	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of sub-surface oiling from a major spill following a blow out impacting plankton	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

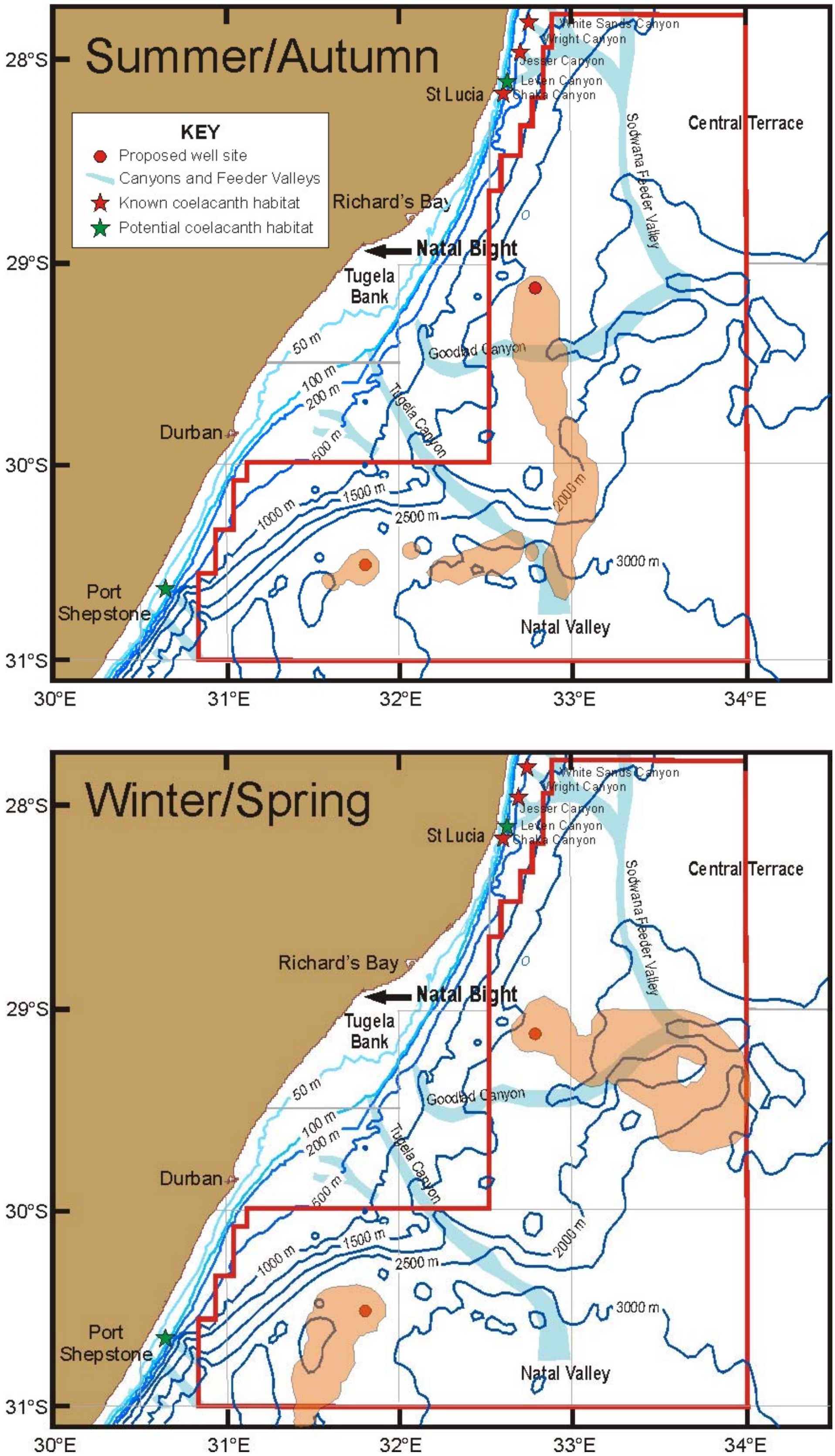


Figure 32: Extent of the modelled DAH plume footprints >5 ppb (orange shading) from the northern and southern well sites during summer/autumn (top) and winter/spring (bottom) in relation to submarine canyons and feeder valleys off the KwaZulu-Natal coast.

Risk of sub-surface oiling from a major spill following a blow out impacting pelagic fish and larvae	
Characteristic	Risk Significance
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of sub-surface oiling from a major spill following a blow out impacting seabirds	
Characteristic	Risk Significance
Type of Impact	Direct
Likelihood	Low
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Medium
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High

Risk of sub-surface oiling from a major spill following a blow out impacting marine mammals and turtles	
Characteristic	Risk Significance
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of sub-surface oiling from a major spill following a blow out impacting MPAs and EBSAs	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Low
Consequence	Moderate
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Medium
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium

When considering the risks of subsurface oiling to coelacants and coelacanth habitat in particular, the subsurface slicks from a potential blow out in both the northern and southern areas of interest for well drilling are more likely (89% and 83%, respectively) to occur well to the south of the known and potential coelacanth habitat off the GSLWP and St Lucia. Although the paths of the plumes cross the Goodlad and Tugela Canyons, the overlap occurs in the feeder valleys where the canyons are in excess of 2,000 m deep and thus well beyond the depths at which coelacanths are known to occur. Based on the distribution of current speeds and direction across all depths, the modelling results predicted that the probability of northward transport of the plume towards the canyons off the GSLWP and off St Lucia was very low as north, north-northwest and northwest flows occur only 2% of the time. Similarly, the potential coelacanth habitats on the continental shelf off the stretch of coastline between Port Shepstone and Port St Johns are located well inshore of the anticipated path of the DAH plume (see Figure 32). It must also be kept in mind that the light oil or gas expected in the well(s) (°API gravity >31.1) is less persistent and droplets would thus dissolve more rapidly and not deposit as readily as heavy oil particles. Should any sedimentation of oil droplets occur in submarine canyons off the KZN coast, concentrations are thus likely to be well below threshold levels.

For a subsurface slick, the risk significance is thus considered to be **MINOR** for coelacanths and known or expected coelacanth habitat.

Risk of sub-surface oiling from a major spill following a blow out impacting coelacanths and coelacanth habitat	
Characteristic	**Risk Significance**
Type of Impact	Indirect
Likelihood	Low
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	High

Operational Spill and Riser Disconnect

There is a far greater probability of a minor spill of hydrocarbons (a common risk for all marine traffic) or the loss of drilling muds through accidental disconnection of the riser, than of a blow out and major spill.

The potential impact on the marine environment of such operational spills at the well site would be of low intensity for most faunal groups, with the exception of seabirds, where it would be of high intensity. In all cases impacts would likely only persist over the short-term (days). The risk significance of an operational spill or loss of LTOBMs at the well site is dependent on the biota likely to be affected the impact. For benthic fauna, plankton, pelagic fish and larvae, marine mammals and turtles and MPAs and EBSAs the risk is considered **MINOR**, but for seabirds the risk is **MODERATE**. Results of the oil spill modelling study indicated that an offshore diesel spill or slick resulting from a riser disconnect would spread in a south-westerly direction and would not reach the shore. Dissolved aromatic concentrations may, however, persist in the top few meters of the water column beneath the slick for a number of days, potentially resulting in acute toxicological effects in marine fauna coming in contact with the slick for extended periods. Should they occur, impacts would be partially (seabirds) or fully reversible (benthic macrofauna, fish and larvae and marine mammals and turtles).

Mitigation

Objective: to further reduce and manage impacts associated with operational spills.

Actions: In addition to the best industry practices and Eni's project standards, the following measures are recommended to manage the impacts associated with operational spills:

No.	Mitigation measure	Classification
1	Prepare and implement a Shipboard Oil Pollution Emergency Plan and an Oil Spill Contingency Plan. In doing so take cognisance of the South African Marine Pollution Contingency Plan, which sets out national policies, principles and arrangements for the management of emergencies including oil pollution in the marine environment.	Avoid / reduce at source
2	As far as possible, and whenever the sea state permits, attempt to control and contain the spill at sea with suitable recovery techniques to reduce the spatial and temporal impact of the spill.	Abate on and off site
3	Use low toxicity dispersants that rapidly dilute to concentrations below most acute toxicity thresholds. Use dispersants only with the permission of DEA.	Abate on and off site
4	Ensure adequate resources are available to collect and transport oiled birds to a cleaning station.	Restore

Operational Spill at the well site

Risk of an operational spill at the well site impacting deepwater benthic macrofauna	
Characteristic	**Risk Significance**
Type of Impact	Indirect
Likelihood	Medium
Consequence	Minor (Negligible)
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of an operational spill at the well site impacting plankton	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor (Negligible)
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of an operational spill at the well site impacting pelagic fish and larvae	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of an operational spill at the well site impacting seabirds	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Moderate
Risk Significance	**Moderate**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of an operational spill at the well site impacting marine mammals and turtles	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of an operational spill at the well site impacting MPAs and EBSAs	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium

Accidental Riser Disconnect

Risk of a riser disconnect impacting benthic macrofauna	
Characteristic	**Risk Significance**
Type of Impact	Indirect
Likelihood	Medium
Consequence	Minor (Negligible)
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of a riser disconnect impacting plankton	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor (Negligible)
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of a riser disconnect impacting pelagic fish and larvae	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of a riser disconnect impacting seabirds	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Moderate
Risk Significance	**Moderate**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of a riser disconnect impacting marine mammals and turtles	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Low

Risk of a riser disconnect impacting MPAs and EBSAs	
Characteristic	**Risk Significance**
Type of Impact	Direct
Likelihood	Medium
Consequence	Minor
Risk Significance	**Minor**
Reversibility	Partially Reversible
Loss of resource	Low
Sensitivity/Vulnerability/Importance of the Resource/Receptor	Medium

6. CONCLUSIONS

Studies investigating benthic communities, habitats or ecosystems in the offshore environments of southern Africa's East Coast are lacking and no knowledge exists of seabed communities at the depths of the proposed well(s).

The impacts on marine habitats and communities associated with the proposed drilling of 2-3 exploratory wells in the area of interest in ER236 are summarised in the Table below (Note: * indicates that no mitigation is possible and / or considered necessary, thus significance rating remains). The total area to be impacted by the proposed exploration drilling can be considered negligible with respect to the total area of the West Indian Offshore bioregion.

Impact	Significance (before mitigation)	Significance (after mitigation)
Sediment resuspension by ROV thrusters	Negligible	Negligible*
Removal or crushing of benthic macrofauna in unconsolidated sediments during well installation	Negligible	Negligible*
Disturbance and/or smothering of benthic macrofauna in unconsolidated sediments by residual cement	Negligible	Negligible*
Toxicity and bioaccumulation effects of residual cement on marine fauna	Negligible	Negligible*
Smothering of benthic macrofauna by drilling solids discharged directly onto the seabed during well spudding and drilling of the initial section with sweeps	Minor	Minor*
Smothering of soft-sediment benthic macrofauna by drilling solids discharged from the drillship	Negligible	Negligible*
Smothering of vulnerable reef communities by drilling solids discharged at the surface depositing onto the seabed	Moderate	Minor
Biochemical effects on marine fauna of Sweeps and Water-Based drilling muds	Negligible	Negligible*
Biochemical effects on marine fauna of drill cuttings containing residual NADFs	Minor	Minor
Increased water column turbidity due to discharge of cuttings near the surface	Negligible	Negligible*
Increased water column turbidity due to discharge of waste WBMs near the surface	Negligible	Negligible
Reduced physiological functioning of marine organisms due to the development of anoxic sediments in the cuttings depositional footprint due to biodegradation of the organic constituents of WBMs	Negligible	Negligible*
Behavioural changes and masking of biologically-relevant sounds in marine fauna in response to underwater drilling noise	Moderate	Minor
Avoidance of feeding and/or breeding areas in response to underwater noise	Negligible	Negligible*
Disturbance of seabirds, seals, turtles and cetaceans through noise generated by support aircraft	Minor	Negligible
Pollution of the marine environment through operational discharges to the sea from drillship and support vessels	Negligible	Negligible
Disturbance of marine fauna due to increased ambient lighting	Negligible	Negligible*
Toxic effects of hydrocarbon 'drop-out' during flaring on offshore areas	Negligible	Negligible*

Impact	Risk Significance
Toxic effects on benthic macrofauna of surface oiling from a major spill following a blow out	Minor
Toxic effects on plankton of surface oiling from a major spill following a blow out	Minor
Toxic effects on pelagic fish and larvae of surface oiling from a major spill following a blow out	Minor
Toxic effects on seabirds of surface oiling from a major spill following a blow out	Moderate
Toxic effects on marine mammals and turtles of surface oiling from a major spill following a blow out	Minor
Toxic effects on MPAs and EBSAs of surface oiling from a major spill following a blow out	Minor
Toxic effects on coelacanths and coelacanth habitat of surface oiling from a major spill following a blow out	Minor
Toxic effects on benthic macrofauna of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on plankton of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on pelagic fish and larvae of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on seabirds of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on marine mammals and turtles of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on MPAs and EBSAs of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on coelacanths and coelacanth habitat of sub-surface oiling from a major spill following a blow out	Minor
Toxic effects on benthic macrofauna of an operational spill at the wellsite	Minor
Toxic effects on plankton of an operational spill at the wellsite	Minor
Toxic effects on pelagic fish and larvae of an operational spill at the wellsite	Minor
Toxic effects on seabirds of an operational spill at the wellsite	Moderate
Toxic effects on marine mammals and turtles of an operational spill at the wellsite	Minor
Toxic effects on MPAs and EBSAs of an operational spill at the wellsite	Minor
Toxic effects on benthic macrofauna of a riser disconnect	Minor
Toxic effects on plamkton of a riser disconnect	Minor
Toxic effects on pelagic fish and larvae of a riser disconnect	Minor
Toxic effects on seabirds of a riser disconnect	Moderate
Toxic effects on marine mammals and turtles of a riser disconnect	Minor
Toxic effects on MPAs and EBSAs of a riser disconnect	Minor

If all environmental guidelines, and appropriate mitigation measures advanced in this report, and the EMP for the proposed exploration drilling project as a whole, are implemented, there is no reason why the proposed well drilling should not proceed.

6.1. Mitigation and Management Plan

The mitigation measures are based largely on the guidelines currently accepted for exploratory well drilling in South Africa, but have been revised to include salient points from international guidelines and industry practices discussed above.

The mitigation measures proposed below are the outcome after having defined the performance objectives, indicators and targets in the various assessments. Performance objectives are influenced by international standards, legal requirements and scientific knowledge.

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
1. Mobilisation Phase											
1.1	Discharge of waste to sea	Local reduction in water quality	Offshore marine fauna	Minimise discharges and ensure discharges from vessels are in accordance with MARPOL 73/78 standards	n/a	n/a	Compile and implement the following plans and certificates: • Waste Management Plan. • Shipboard Oil Pollution Emergency Plan (SOPEP). • Ballast Water Management Plan. • A valid International Sewage Pollution Prevention Certificate, as required by vessel class. • International Oil Pollution Prevention (IOPP) Certificate, as required by vessel class	Project Control	Drilling/support vessel contractors	Prior to mobilisation and during transit	Copy of all plans and certificates
1.2					Sewage	n/a	Ensure vessels have: • an onboard sewage treatment plant; • a sewage comminuting and disinfecting system, and/or • a sewage holding tank.	Project Control			Correct operation of sewage treatment system (compliance with MARPOL 73/78 standards)
1.3						Discharge depth: 5 m	Ensure a sewage discharge depth of not less than 5 m below the surface.	Project Control			
1.4						Biological Oxygen Demand (BOD): <25 mg l^{-1}or <50 mg l^{-1} Chlorine (Cl): ≤1 mg l^{-1}	Ensure sewage discharges comply with : • a BOD of <25 mg l^{-1} (if the treatment plant was installed after 1/1/2010,) or <50 mg l^{-1} (if installed before this date); and • minimal residual chlorine concentration of 1 mg l^{-1}.	Project Control		Continuous during transit	Correct operation of sewage treatment system (compliance with MARPOL 73/78 standards)

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
1.5						No treatment: > 12 nm of coast Treatment: 3 nm – 12 nm of coast	Sewage discharge to comply with the following: • Discharge of sewage beyond 12 nm requires no treatment. However, no visible floating solids must be produced or discolouration of the surrounding water must occur. • Sewage must be comminuted and disinfected for discharges between 3 nm and 12 nm from the coast. • Disposal of sewage from holding tanks must be discharged at a moderate rate while the ship is proceeding *en route* at a speed not less than 4 knots.	Project Control		During transit	
1..6					Galley (biodegradable) wastes	No disposal: < 3 nm of coast No treatment: > 12 nm of coast Treatment: 3 nm – 12 nm of coast	Galley waste discharge to comply with the following: • No disposal to occur within 3 nm of the coast. • Disposal between 3 nm and 12 nm needs to be comminuted to particle sizes smaller than 25 mm. • Discharge beyond 12 nm requires no treatment.	Project Control	Drilling/support vessel contractors	During transit	• Correct operation of macerator • Volume of waste discharged
1.7							Minimise the discharge of waste material should obvious attraction of fauna be observed.	Reduce at Source	Drilling/support vessel contractors	During transit	
1.8					Discharge of deck and machinery drainage	n/a	Ensure all deck and machinery drainage is routed to: • equipment for the control of oil discharge from machinery space bilges and oil fuel tanks, e.g. oil separating/filtering equipment and oil content meter. • oil residue holding tanks; and • oil discharge monitoring and control system	Project Control	Drilling/support vessel contractors	Prior to mobilisation	

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
1.9						Oil concentration: 15 ppm	Oil in water concentration must be less than 15 ppm prior to discharge overboard	Project Control		Continuous during transit	Correct operation of macerator of oil separating/filtering equipment and oil content meter (compliance with MARPOL 73/78 standards)
1.10						Zero spills	Ensure all process areas are bunded to ensure drainage water flows into the closed drainage system.	Avoid		During transit	Type and volume of spill
1.11							Use low-toxicity biodegradable detergents in cleaning of all deck spillage.	Reduce at source		During transit	
1.12							• Mop up any spills immediately with biodegradable low toxicity detergents. • Use oil absorbent.	Reduce at source		During transit	
1.13							Use drip trays to collect run-off from equipment that is not contained within a bunded area and route contents to a closed drainage system.	Avoid / reduce at source		During transit	
1.14							Ensure all crew is trained in spill management.	Reduce at source		Prior to mobilisation	
1.14					General waste	Zero discharge	Initiate a waste minimisation system.	Avoid	Drilling/support vessel contractors	During transit	• Volume of waste generated • Volume transferred for onshore disposal / incinerated • Waste receipts
1.15							No disposal overboard.				
1.16							Ensure on-board solid waste storage is secure.				
1.17							Incinerate (non-hazardous) or transport ashore for disposal/recycling. Retain waste receipts.				
1.18							Recycle metal waste onshore				

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
1.19					Hazardous waste (incl. oil and medical)	Zero discharge	Hazardous waste will be segregated on-board the drilling unit and all wastes will be appropriately classified, labelled, and stored in suitable receptacles in order to ensure the safe containment and transportation of waste. A specific waste management storage and segregation area shall be provided at the onshore base. The waste facility shall have specific infrastructure for waste oil storage (in a bunded enclosure) and separate areas for sorting and storage of all waste brought back to the base from the offshore drill ship. The final treatment and disposal of generated wastes will be managed in alignment with the Waste Management Plan. All wastes transferred shall be disposed of to a facility that is appropriately licensed and accredited.	Avoid	Drilling/support vessel contractors	During transit	• Record types and volumes of chemical and hazardous wastes and destination thereof • Waste receipts
1.20		Introduction of non-indigenous invasive marine species	Marine fauna, specifically coastal benthic fauna	Minimise the discharge of ballast water into the sea and risk of the introduction of non-indigenous invasive marine species	Ballast water	n/a	Compile a Ballast Water Management Plan, which aims to ensure that de- and re-ballasting is undertaken in terms of the IMO 2004 International Convention for the Control and Management of Ships' Ballast Water and Sediments.	Project Control	Drilling/support vessel contractors	During ballast water discharge	Copy of Ballast Water Management Plan
1.21						n/a	Use adequate filtration procedures during loading in order to avoid the uptake of potentially harmful aquatic organisms, pathogens and sediment that may contain such organisms.	Avoid / reduce at source			
						Discharge 200 nm from the nearest land and in water of at least 200 m depth	Whenever possible, conduct the exchange of ballast water at least 200 nm (± 370 km) from the nearest land and in water of at least 200 m depth. Where this is not feasible, the exchange should be as far from the nearest land as possible, and in all cases a minimum of 50 nm (± 93 km) from the nearest land and preferably in water at least 200 m in depth.	Project Control			Volumes of ballast water disposed, and distance and water depth ballast water was disposed
1.22						Minimise discharge	Avoid unnecessary discharge of ballast water.	Reduce at source			

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
1.23						Clean ballast tanks in mid-ocean or in port or dry dock	Ensure that routine cleaning of the ballast tank to remove sediments should be carried out, where practicable, in mid-ocean or under controlled arrangements in port or dry dock, in accordance with the provisions of the ship's Ballast Water Management Plan.	Avoid / reduce at source		During ballast tank cleaning	Frequency and location of ballast tank cleaning
1.24	Vessel lighting	Increased ambient lighting	Marine fauna, especially seabirds	Minimise disturbance of marine fauna by increased ambient lighting in the offshore environment	Marine fauna attractions	Minimise as far as possible	Reduce lighting to a minimum compatible with safe operations whenever and wherever possible by: • Minimising the number of lights and the intensity of the lights. • Automatically or manually controlling lighting in areas where it is not a continuous requirement through the process control system. • Positioning light sources in places where emissions to the surrounding environment are minimised.	Avoid / reduce at source	Drilling/support vessel contractors	During transit at night	
1.25					Seabirds	At least four staff members receive Marine Observer training before deployment on sea birds, seals and cetaceans (whales and dolphins)	Assign relevant staff for observation, distance estimation and reporting, to perform marine mammal observations and notifications.	Abate on site	Eni		Record information on patterns of bird reaction to lights and real incidents of injury/death, including stray land birds resting on the rig, during the drilling operation
						Zero incidents	Keep disorientated, but otherwise unharmed, seabirds in dark containers for subsequent release during daylight hours.	Repair or restore	Eni		
1.26							Euthanise of injured birds humanly.	Repair or restore	Eni		
1.27							Report ringed/banded birds to the appropriate ringing/banding scheme (details are provided on the ring.	Repair or restore	Eni		

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
2. Operation Phase											
2.1	Emissions to the atmosphere	Reduction in local air quality	Settlements and bird / seal colonies	Minimise emissions to the atmosphere and compliance with MARPOL 73/78 Annex VI	Well testing / Flaring	Maximise combustion	Use a high-efficiency burner for flaring to maximise combustion of the hydrocarbons in order to minimise emissions and hydrocarbon 'drop-out' during well testing.	Abate on site	Drilling contractor	During Well (flow) testing	Volume of oil / gas flared
2.2	Discharge of waste to sea	Local reduction in water quality	Offshore marine fauna	Minimise discharges and ensure discharges from vessels are in accordance with MARPOL 73/78 standards	n/a	n/a	Implement the following plans: • Waste Management Plan. • Shipboard Oil Pollution Emergency Plan (SOPEP). • Ballast Water Management Plan.	Project Control	Drilling/support vessel contractors	During operation	Copy of all plans
2.3					Sewage	Discharge depth: 5 m	Ensure a sewage discharge depth of not less than 5 m below the surface.	Project Control			
2.4						Biological Oxygen Demand (BOD): <25 mg l^{-1} or <50 mg l^{-1} Chlorine (Cl): ≤1 mg l^{-1}	Ensure sewage discharges comply with : • a BOD of <25 mg l^{-1} (if the treatment plant was installed after 1/1/2010,) or <50 mg l^{-1} (if installed before this date); and • minimal residual chlorine concentration of 1 mg l^{-1}.	Project Control		Continuous during operation	Correct operation of sewage treatment system (compliance with MARPOL 73/78 standards)
2.5						No treatment: > 12 nm of coast Treatment: 3 nm – 12 nm of coast	Sewage discharge to comply with the following: • Discharge of sewage beyond 12 nm requires no treatment. However, no visible floating solids must be produced or discolouration of the surrounding water must occur. • Sewage must be comminuted and disinfected for discharges between 3 nm and 12 nm from the coast. • Disposal of sewage from holding tanks must be discharged at a moderate rate while the ship is proceeding *en route* at a speed not less than 4 knots.	Project Control		During operation	

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
2.6					Galley (biodegradable) wastes	No disposal: < 3 nm of coast No treatment: > 12 nm of coast Treatment: 3 nm – 12 nm of coast	Galley waste discharge to comply with the following: • No disposal to occur within 3 nm of the coast. • Disposal between 3 nm and 12 nm needs to be comminuted to particle sizes smaller than 25 mm. • Discharge beyond 12 nm requires no treatment.	Project Control	Drilling/support vessel contractors	During operation	• Correct operation of macerator • Volume of waste discharged
2.7							Minimise the discharge of waste material should obvious attraction of fauna be observed.	Reduce at Source	Drilling/support vessel contractors	During operation	
2.8					Discharge of deck and machinery drainage	Oil concentration: 15 ppm	Oil in water concentration must be less than 15 ppm prior to discharge overboard	Project Control	Drilling/support vessel contractors	Continuous during operation	Correct operation of macerator of oil separating/filtering equipment and oil content meter (compliance with MARPOL 73/78 standards)
2.9						Zero spills	Ensure all process areas are bunded to ensure drainage water flows into the closed drainage system.	Avoid		During operation	Type and volume of spill
2.10							Use low-toxicity biodegradable detergents in cleaning of all deck spillage.	Reduce at source		During operation	
2.11							• Mop up any spills immediately with biodegradable low toxicity detergents. • Use oil absorbent.	Reduce at source		During operation	
2.12 2.13							Use drip trays to collect run-off from equipment that is not contained within a bunded area and route contents to a closed drainage system.	Avoid / reduce at source		During operation	
2.13					General waste	Zero discharge	Initiate a waste minimisation system.	Avoid	Drilling/support vessel contractors	During operation	• Volume of waste generated • Volume transferred for onshore
2.14							No disposal overboard.				
2.15							Ensure on-board solid waste storage is secure.				
2.16							Incinerate (non-hazardous) or transport ashore for disposal/recycling. Retain waste receipts.				

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
2.17							Recycle metal waste onshore				disposal / incinerated • Waste receipts
2.18					Hazardous waste (incl. oil and medical)	Zero discharge	Send hazardous waste to designated onshore hazardous disposal site.	Avoid	Drilling/support vessel contractors	During operation	• Record types and volumes of chemical and hazardous wastes and destination thereof • Waste receipts
2.19	Vessel lighting	Increased ambient lighting	Marine fauna, especially seabirds	Minimise disturbance of marine fauna by increased ambient lighting in the offshore environment	Marine fauna attractions	Minimise as far as possible	Reduce lighting to a minimum compatible with safe operations whenever and wherever possible by: • Minimising the number of lights and the intensity of the lights. • Adapting the spectrum of lights to bird-friendly lighting systems, if possible. • Automatically or manually controlling lighting in areas where it is not a continuous requirement through the process control system. • Positioning light sources in places where emissions to the surrounding environment are minimised.	Avoid / reduce at source	Drilling/support vessel contractors	During operation at night	
2.20					Seabirds	At least four staff members receive Marine Observer training before deployment on sea birds, seals and cetaceans (whales and dolphins)	Assign relevant staff for observation, distance estimation and reporting, to perform marine mammal observations and notifications.	Abate on site	Eni		Record information on patterns of bird reaction to lights and real incidents of injury/death, including stray land birds resting on the rig, during the drilling operation
						Zero incidents	Keep disorientated, but otherwise unharmed, seabirds in dark containers for subsequent release during daylight hours.	Repair or restore	Eni		

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
2.21							Euthanise of injured birds humanly.	Repair or restore	Eni		
2.22							Report ringed/banded birds to the appropriate ringing/banding scheme (details are provided on the ring.	Repair or restore	Eni		
2.23	Operation of helicopters	Increased ambient noise levels	Sensitive coastal receptors, including key faunal breeding / feeding areas, bird or seal colonies	Minimise disturbance to marine and coastal fauna	Flight path	Avoid sensitive receptors	Pre-plan flight path to ensure it avoids (except in medical emergency): • Important bird areas; and • Turtle nesting areas.	Avoid / abate offsite/at receptor	Eni Logistics Manager and Helicopter contractor	All flights between drilling unit an Lüderitz airport	• Copy of set flight path. • Helicopter logs • Deviations from set flight paths
2.24							Maintain an altitude of at least 1 000 m (3 000 ft) within MPAs and a cruising altitude of greater than 300 m, except when taking off and landing or in a medical emergency.	Avoid / abate offsite/at receptor	Helicopter contractor		
2.25							Avoid extensive flights parallel to the coast by ensuring that the flight path is perpendicular to the coast, as far as possible.	Avoid / abate offsite/at receptor			
2.26					Environmental awareness	All pilots are briefed	Comply with aviation and authority guidelines and rules.	Avoid / abate offsite/at receptor			
2.27							As part of the HSSE induction for all pilots incorporate awareness training on the ecological risks associated with flying at a low level along the coast or above marine mammals.	Avoid / abate offsite/at receptor	Eni Logistics Manager and Helicopter contractor		
2.28	Pre-drilling seabed survey	Sediment disturbance	Benthic fauna	Minimise disturbance to the seabed during pre-drilling ROV surveys	ROV	Minimise disturbance of seabed	Avoid landing or resting the ROV on the seabed during the seabed survey.	Abate on site	Drilling contractor	During ROV survey	

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
2.29	Spudding	Physical disturbance of the seabed sediments	Benthic fauna	Minimise disturbance to sensitive hard substrates	Hard substrates	Avoid spudding on and adjacent to hard substrates, which house sensitive benthic communities	Adjust the well location to avoid spudding on or in close proximity to potential vulnerable habitats (identified in pre-drilling ROV surveys).	Avoid	Drilling contractor / Eni	Prior to spudding	ROV footage
2.30	Discharge of drill cuttings	Physical disturbance of the seabed sediments and accumulation on the seabed, as well as result in an increase of sediment in the water column	Marine fauna, specifically benthic fauna	Minimise extend of deposition footprint and toxicity of drill cuttings	Smothering of hard substrates	Deposition footprint to avoid hard substrates	• Review ROV footage of pre-drilling surveys to identify potential vulnerable habitats within 500 m of the drill site • Ensure drill site is located more than 500 m from any identified vulnerable habitats.	Avoid / reduce at source	Drilling contractor / Eni	Prior to spudding	ROV footage
2.31						Minimise dispersion as far as possible	Discharge of cuttings via a caisson at greater than 15 m water depth	Project Control	Drilling contractor	During risered drilling	
2.32					Toxicity	Minimise toxicity	Ensure only low-toxicity and partially biodegradable additives are used in drilling fluid.	Avoid / reduce at source	Drilling contractor	Prior to drilling	
2.33						Oil content: ≤6.9% PAH: 0.001 Hg: <1 mg/kg Cd: <3 mg/kg	Treatment of cuttings to reduce the: • Oil content to 6.9% or less of dry cutting weight; • PAH to less than 0.001; • Hg to less than 1 mg/kg; and • Cd to less than 3 mg/kg.	Project Control	Drilling contractor	During risered drilling	• Volume discharged • Toxicity, barite contamination and oil content of SBM drill cuttings
2.34						Minimise residual SBM in cuttings	Use high efficiency solids control equipment to reduce the need for fluid change out and minimise the amount of residual fluid on drilled cuttings.	Avoid / reduce at source	Drilling contractor	During risered drilling	
2.35							Ensure regular maintenance of the onboard solids control package	Abate on site	Drilling contractor	During risered drilling	
2.36						Zero discharge over board	Ensure all recovered SBM is taken to shore for treatment and reuse	Abate on and off site	Drilling contractor	During demobilisation	Waste receipts

Ref. No.	Activity	Aspect	Receptor	Environmental and Social Performance Objective	Indicators	Targets	Mitigation and Management action	Type of Mitigation Option	Responsibility	Frequency / timing	Monitoring and record keeping requirements
2.37	Discharge of residual cement	Physical disturbance of the seabed sediments and accumulation on the seabed, as well as result in an increase of sediment in the water column	Marine fauna, specifically benthic fauna	Minimise extend of deposition footprint and toxicity of cement	Smothering	Minimise residual discharge volume	Avoid excess cement usage by monitoring (by ROV) for discharges during cementing	Project Control	Drilling contractor	During cementing	Volume discharged
2.38					Toxicity	Minimise toxicity	Ensuring that only low-toxicity and partially biodegradable cement additives are used	Reduce at source	Drilling contractor	Prior to cementing	
2.39	Discharge of residual WBMs	Physical disturbance of the seabed sediments and accumulation on the seabed, as well as result in an increase of sediment in the water column	Marine fauna, specifically pelagic fauna	Minimise discharge of WBMs	Smothering	Minimise residual discharge volume	Discharge WBMs overboard only if in compliance with MARPOL standards	Project Control	Drilling contractor	At close of drilling	Volume discharged
3. Demobilisation Phase											
Refer to "Mobilisation Phase" for: • Discharge of waste to sea and • Vessel lighting											

7. LITERATURE CITED

ABGRALL, P., MOULTON, V.D. and W.R. RICHARDSON. 2008. Updated Review of Scientific Information on Impacts of Seismic Survey Sound on Marine Mammals, 2004-present. LGL Rep. SA973-1. Rep. from LGL Limited, St. John's, NL and King City, ON, for Department of Fisheries and Oceans, Habitat Science Branch, Ottawa, ON. 27 p. + appendices.

ALDREDGE, A.L., M. ELIAS and C.C. GOTSCHALK, 1986. Effects of drilling muds and mud additives on the primary production of natural assemblages of marine phytoplankton. *Mar. Environ. Res*. **19**: 157-176.

ANDERS, A.S., 1975. Pilchard and anchovy spawning along the Cape east coast. *S. Afr. ship. news fish. ind. rev*. **30 (9)**: 53-57.

ANZECC & ARMCANZ, 2000. Australian and New Zealand guidelines for fresh and marine water quality. October 2000. National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra, Australia.

ATKINSON, L.J. and K. SINK, 2008. User profiles for the South African offshore environment. SANBI Biodiversity Series 10. South African Biodiversity Institute, Pretoria.

AUGUSTYN, C.J. 1990. Biological studies on the chokker squid *Loligo vulgaris reynaudii* (Caphalopoda: Myopsida) on spawning grounds off the south-east coast of South Africa. *S. Afr. J. mar. Sci*., **9**: 11-26.

AUGUSTYN, C.J., LIPINSKI, M.R., SAUER, W.H.H., ROBERTS, M.J. and MITCHELL-INNES, B.A. 1994. Chokka squid on the Agulhas Bank: life history and ecology. *S. Afr. J. Sci*., **90**: 143-153.

AWAD, A.A., GRIFFITHS, C.L. and TURPIE, J.K. 2002. Distribution of South African marine benthic invertebrates applied to the selection of priority conservation areas. *Diversity and Distributions* **8**: 129–145

AWBREY, F.T. and B.S. STEWART, 1983. Behavioural responses of wild beluga whales *(Delphinapterus leucas*) to noise from oil drilling. *Journal of the Acoustical Society of America, Suppl*. 1, 74: S54.

BAAN, P.J.A., MENKE, M.A., BOON, J.G., BOKHORST, M., SCHOBBEN, J.H.M. and C.P.L. HAENEN, 1998. R*isico Analyse Mariene Systemen (RAM). Verstoring door menselijk gebruik*. Waterloopkundig Laboratorium, Delft.

BAKER, J.M., CLARK, R.B., KINGSTON, P.F. and R.H. JENKINS, 1990. Natural recovery of cold water marine environments after an oil spill. 13th Annual Arctic and Marine Oil spill Program Technical Seminar, Edmonton, Alberta. pp 1-111.BAPTIST, M.J., TAMIS, J.E., BORSJE, B.W. and J.J. VAN DER WERF, 2009. *Review of the geomorphological, benthic ecological and biogeomorphological effects of nourishments on the shoreface and surf zone of the Dutch coast.* Report IMARES C113/08, Deltares Z4582.50, pp69.

BANKS, A.M., 2013. The seasonal movements and dynamics of migrating humpback whales off the east coast of Africa. PhD Thesis. School of Biology, University of St Andrews. http://hdl.handle.net/10023/4109.

BANKS, A. BEST, P.B., GULLAN, A., GUISSAMULO, A., COCKCROFT, V. & K. FINDLAY, 2011. Recent sightings of southern right whales in Mozambique. Document SC/S11/RW17 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

BAPTIST, M.J., TAMIS, J.E., BORSJE, B.W. and J.J. VAN DER WERF, 2009. Review of the geomorphological, benthic ecological and biogeomorphological effects of nourishments on the shoreface and surf zone of the Dutch coast. Report IMARES C113/08, Deltares Z4582.50, pp69.

BARENDSE, J., BEST, P.B., THOMTON, M., POMILLA, C. CARVALHO, I. & H.C. ROSENBAUM, 2010. Migration redefined ? Seasonality, movements and group composition of humpback whales *Megaptera novaeangliae* off the west coast of South Africa. *Afr. J. mar. Sci.*, **32(1)**: 1-22.

BARLOW, M.J. and P.F. KINGSTON, 2001. Observations on the effects of barite on the gill tissues of the suspension feeder *Cerastoderma edule* (Linne) and the deposit feeder *Macoma balthica* (Linne). *Mar. Pollut. Bull*. **42**: 71-76.

BARLOW, R., LAMONT, T., BRITZ, K. and H. SESSIONS, 2013. Mechanisms of phytoplankton adaptation to environmental variability in a shelf ecosystem. *Estuarine Coastal and Shelf Science* 133: 45–57.

BARLOW, R.G., LAMONT, T., GIBBERD, M.J., VAN DEN BERG, M. and K. BRITZ, 2015. Chemotaxonomic investigation of phytoplankton in the shelf ecosystem of the KwaZulu-Natal Bight, South Africa. *African Journal of Marine Science* 37: 467–484.

BARTOL, S.M. & J.A. MUSICK, 2002. 3 Sensory Biology of Sea Turtles. *The biology of sea turtles*, **79**.

BAX, N, WILLIAMSON, A., AGUERO, M., GONZALEZ, E. and W. GEEVES, 2003. Marine invasive alien species: a threat to global biodiversity. *Marine Policy* **27**: 313-323.

BEAL, L. M. & H. L. BRYDEN, 1997, Observations of an Agulhas Undercurrent. *Deep-Sea Res*. I, 44: 1715 – 1724.

BECKLEY, L.E. & J.D. HEWITSON, 1994. Distribution and abundance of clupeoid larvae along the east coast of South Africa in 1990/1991. *South African Journal of Marine Science* **14**: 205–212.

BECKLEY, L.E. and VAN BALLEGOOYEN, R.C. 1992. Oceanographic conditions during three ichthyoplankton surveys of the Agulhas Current in 1990/91. *S. Afr. J. mar. Sci.*, **12**: 83-93.

BENNO, B., VERHEIJ, E., STAPLEY, J., RUMISHA, C., NGATUNGA, B., ABDALLAH, A. and H. KALOMBO, 2006. Coelacanth (*Latimeria chalumnae* Smith, 1939) discoveries and conservation in Tanzania. *S. Afr. J. Sci.* 102, 486–490.

BEST, P.B., 1977. Two allopatric forms of Bryde's whale off South Africa. Report of the International Whaling Commission (Special Issue 1), 10-38.

BEST, P.B., 1990. Trends in the inshore right whale population off South Africa, 1969-1987. *Marine Mammal Science*, **6**: 93-108.

BEST, P.B., 2001. Distribution and population separation of Bryde's whale *Balaenoptera edeni* off southern Africa. *Mar. Ecol. Prog. Ser.*, 220: 277 – 289.

BEST, P.B., 2007. Whales and Dolphins of the Southern African Subregion. Cambridge University Press, Cape Town, South Africa.

BEST, P.B., BUTTERWORTH, D.S. & L.H. RICKETT, 1984. An assessment cruise for the South African inshore stock of Bryde's whale (*Balaenoptera edeni*). *Report of the International Whaling Commission*, **34**: 403-423.

BEST, P.B., FINDLAY, K.P., SEKIGUCHI, K., PEDDEMORS, V.M., RAKOTONIRINA, B., ROSSOUW, A. AND D. GOVE, 1998. Winter distribution and possible migration routes of humpback whales *Megaptera novaeangliae* in the southwest Indian Ocean. *Mar. Ecol. Prog. Ser.* **162**: 287 - 299.

BEST, P.B. & C.H. LOCKYER, 2002. Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa in the 1960s. *South African Journal of Marine Science*, **24**: 111-133.

BEST P.B., MEŸER, M.A. & C. LOCKYER, 2010. Killer whales in South African waters – a review of their biology. *African Journal of Marine Science*. **32**: 171–186.

BIJKERK, R., 1988. Ontsnappen of begraven blijven. De effecten op bodemdieren van een verhoogde sedimentatie als gevolg van baggerwerkzaamheden., RDD Aquatic Systems.

BLANCHARD, A.L. and H.M. FEDER, 2003. Adjustment of benthic fauna following sediment disposal at a site with multiple stressors in Port Valdez, Alaska. *Marine Pollution Bull*etin, **46**: 1590-1599.

BONFIL, R., MEYER, M., SCHOLL, M.C., JOHNSON, R., O'BRIEN, S., OOSTHUIZEN, H., SWANSON, S., KOTZE, D. and PATERSON, M., 2005. Transoceanic migration, spatial dynamics, and population linkages of white sharks. *Science* **310**: 100-103.

BOTHNER, M.H., RENDIGS, R.R., CAMPBELL, E.Y., DOUGHTON, M.W., PARMENTER, C.M., O'DELL, C.H., DILISIO, G.P., JOHNSON, R.G., GILSON, J.R. and N. RAIT. 1985. The Georges Bank Monitoring Program: analysis of trace metals in bottom sediments during the third year of monitoring. Final report submitted to the U.S. Dept. of the Interior, Minerals Management Service, Vienna, VA. Prepared by the U.S. Geological Survey, Woods Hole, MA. 99 pp.

BOYD, A.J. and SHILLINGTON, F.A. 1994. Physical forcing and circulation patterns on the Agulhas Bank. *S. Afr. J. Sci*., **90**: 114-120.

BRABY, J., 2009. The Damara Tern in the Sperrgebiet: Breeding productivity and the impact of diamond mining. Unpublished report to Namdeb Diamond Corporation (Pty) Ltd.

BRANCH, G.M., GRIFFITHS, C.L., BRANCH, M.L., and BECKLEY, L.E. 2010. *Two Oceans*. Struik Nature, Cape Town, South Africa, revised edition, 456pp

BRANCH, T.A., STAFFORD, K.M., PALACIOS, D.M., ALLISON, C., BANNISTER, J.L., BURTON, C.L.K., CABRERA, E., CARLSON, C.A., GALLETTI VERNAZZANI, B., GILL, P.C., HUCKE-GAETE, R., JENNER, K.C.S., JENNER, M.-N.M., MATSUOKA, K., MIKHALEV, Y.A., MIYASHITA, T., MORRICE, M.G., NISHIWAKI, S., STURROCK, V.J., TORMOSOV, D., ANDERSON, R.C., BAKER, A.N., BEST, P.B., BORSA, P., BROWNELL JR, R.L., CHILDERHOUSE, S., FINDLAY, K.P., GERRODETTE, T., ILANGAKOON, A.D., JOERGENSEN, M., KAHN, B., LJUNGBLAD, D.K., MAUGHAN, B., MCCAULEY, R.D., MCKAY, S., NORRIS, T.F., OMAN WHALE AND DOLPHIN RESEARCH GROUP, RANKIN, S., SAMARAN, F., THIELE, D., VAN WAEREBEEK, K. & R.M. WARNEKE, 2007. Past and present distribution, densities and movements of blue whales in the Southern Hemisphere and northern Indian Ocean. *Mammal Review*, **37 (2)**: 116-175.

BRANDÃO, A., BEST, P.B. & D.S. BUTTERWORTH, 2011. Monitoring the recovery of the southern right whale in South African waters. Paper SC/S11/RW18 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

BRAZIER, W., 2012. *Environmental cues and sensory preferences directing the nesting process in loggerhead turtles, Caretta caretta, nesting in Maputaland, South Africa*. MSc, Nelson Mandela Metropolitan University.

BREEZE, H., DAVIS, D.S. BUTLER, M. and KOSTYLEV, V. 1997. Distribution and status of deep sea corals off Nova Scotia. Marine Issues Special Committee Special Publication No. 1. Halifax, NS: Ecology Action Centre. 58 p.

BRETELER, R.J., REQUEJO, A.G. and J.M. NEFF, 1988. Acute toxicity and hydrocarbon composition of a water-based drilling mud containing diesel fuel or mineral oil additives. Pages 375-390 In: LICHTENBERG, J.J., WINTER, F.A., WEBER, C.I. and L. FRADKIN, Eds., Chemical and Biological Characterization of Municipal Sludges, Sediments, Dredge Spoils and Drilling Muds. American Society for Testing and Materials, Philadelphia, PA.

BROWN, P.C. 1992. Spatial and seasonal variation in chlorophyll distribution in the upper30m of the photic zone in the southern Benguela/Agulhas region. *S. Afr. J. mar. Sci.*, **12**: 515-525.

BRÜCHERT, V., BARKER JØRGENSEN, B., NEUMANN, K., RIECHMANN, D., SCHLÖSSER M. and H. SCHULZ, 2003. Regulation of bacterial sulfate reduction and hydrogen sulfide fluxes in the central Namibian coastal upwelling zone. *Geochim. Cosmochim. Acta*, **67(23)**: 4505-4518.

BRUNNSCHWEILER, J.M., BAENSCH, H., PIERCE, S.J. & D.W. SIMS, 2009. Deep-diving behaviour of a whale shark *Rhincodon typus* during long-distance movement in the western Indian Ocean. *Journal of Fish Biology*, **74**: 706–714.

BRUTON, M.N. and ARMSTRONG, M.J., 1991. The demography of the coelacanth *Latimeria chalumnae. Environ. Biol. Fishes* 32, 301–311.

BRUTON, M.N., CABRAL, A.J.P. and H.W. FRICKE, 1992. First capture of a coelacanth, *Latimeria chalumnae* (Pisces, Latimeriidae), off Mozambique. *South African Journal of Science*, 88, 225-227

BRUTON, M.N. and R.E. STOBBS, 1991. The ecology and conservation of the coelacanth *Latimeria chalumnae. Environ. Biol. Fishes* 32, 313–339.

BRYDEN, H.L., BEAL, L.M. & L.M. DUNCAN, 2005. Structure and transport of the Agulhas Current and its temporal variability. *Journal of Oceanography* **61**: 479–492.

BUCHANAN, R.A., COOK, J.A. and A. MATHIEU, 2003. Environmental Effects Monitoring for Exploration Drilling. Report for Environmental Studies Research Funds, Alberta. Solicitation No. ESRF – 018. Pp 182.

BULL, A.S. and J.J. KENDALL, Jr., 1994. An indication of the process: offshore platforms as artificial reefs in the Gulf of Mexico. *Bull. Mar. Sci*. **55**: 1086-1098.

BURD, B.J., 2002. Evaluation of mine tailings effects on a benthic marine infaunal community over 29 years. *Marine Environmental Research*, **53**: 481-519.

CABRERA, J., 1971. Survival of the oyster *Crassostrea virginica* (Gmelin) in the laboratory under the effects of oil drilling fluids spilled in the Laguna de Tamiahua, Mexico. *Gulf Research Reports* **3**: 197-213.

CANTELMO, F.R., TAGATZ, M.E. and K.R. RAO, 1979. Effect of barite on meiofauna in a flow-through experimental system Mar. EnVirOn. Res., 2: 301-309.

CARLS, M.G. and S.D. RICE. 1984. Toxic Contributions of Specific Drilling Mud Components to Larval Shrimp and Crabs. *Marine Environmental Research* **12**: 45-62.

CARTER, R.A. and BROWNLIE, S. 1990. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 34: Kafferkuils (CSW 24) and Duiwenshok (CSW 23). Heydorn, A.E.F. and Morant, P.D. (eds). Stellenbosch, CSIR Research Report 43, 86pp.

CAPP (Canadian Association of Petroleum Producers), 2001. Technical Report. Offshore Drilling Waste Management Review. Report 2001-0007 from Canadian Association of Petroleum Producers, Halifax, Nova Scotia, Canada. 240 pp.

CARR, R.S., CHAPMAN, D.C., PRESLEY, B.J., BIEDENBACH, J.M., ROBERTSON, L., BOOTHE, P., KILADA, R., WADE, T. and P. MONTAGNA, 1996. Sediment pore water toxicity assessment studies in the vicinity of offshore oil and gas production platforms in the Gulf of Mexico. *Can. J. Fish. Aquat. Sci*., **53**: 2618-2628.

CARTER, R.A. and D'AUBREY, J. 1988. Inorganic nutrients in Natal continental shelf waters. In: Coastal ocean sciences of Natal, South Africa (Ed. E.H. Schumann). Springer-Verlag, Berlin., 131-151.

CARTER, R.A. and SCHLEYER, M.H. 1988. Plankton distributions in Natal coastal waters. In: Coastal ocean sciences of Natal, South Africa (Ed. E.H. Schumann). Springer-Verlag, Berlin., 152-177.

CELLIERS, L., MANN, B.Q., MCDONALD, A.H.H. and SCHLEYER, M.H. 2007. A benthic survey of the rocky reefs off Pondoland, South Africa. *African Journal of Marine Science* **29**: 65–77.

CHANDRASEKARA, W.U. and C.L.J. FRID, 1998. A laboratory assessment of the survival and vertical movement of two epibenthic gastropod species, *Hydrobia ulvae* (Pennant) and *Littorina littorea* (Linnaeus), after burial in sediment. *Journal of Experimental Marine Biology and Ecology*, **221**: 191-207.

CHAPMAN, P.M., POWER, E.A., DESTER, R.N. and H.B. ANDERSON, 1991. Evaluation of effects associated with an oil platform, using the sediment quality triad. *Environ. Toxicol. Chem*., **10**: 407-424.

CHEVRON, 1994. Environmental Impact Assessment for Exploration Drilling in offshore Area 2815, Namibia. Impact Assessment Report. Chevron Overseas (Namibia) Limited, 55 pp.

CHILD, M.F., ROXBURGH, L., DO LINH SAN, E., RAIMONDO, D. and DAVIES-MOSTERT, H.T. (editors). 2016. The Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa. (https://www.ewt.org.za/Reddata/Order%20Cetacea.html).

CLARKE, R., 1956. Marking whales from a helicopter. *Norsk Hvalfangst-Tidende* **45**: 311-318.

CLARKE, D.G. and D.H. WILBER, 2000. Assessment of potential impacts of dredging operations due to sediment resuspension. DOER Technical Notes Collection (ERDC TN-DOER_E9). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

CLIFF, G., ANDERSON-READE, M.D., AITKEN, A.P., CHARTER, G.E. & V.M. PEDDEMORS, 2007. Aerial census of whale sharks (*Rhincodon typus*) on the northern KwaZulu-Natal coast, South Africa. *Fisheries Research* **84**: 41–46.

COCKCROFT, V.G. & V.M. PEDDEMORS, 1990. Seasonal distribution and density of common dolphins *Delphinus delphis* off the south-east coast of southern Africa. *S. Afr. J. mar. Sci.* **9:** 371-377.

COCKCROFT, V.G., ROSS G.J.B. & V.M. PEDDEMORS, 1990. Bottlenose dolphin *Tursiops truncatus* distribution in Natal's coastal waters. *South African Journal of Marine Science* **9:** 1-10.

COCKCROFT, V.G., ROSS G.J.B. & V.M. PEDDEMORS, 1991. Distribution and status of bottlenose dolphin *Tursiops truncatus* on the south coast of Natal, South Africa. *S. Afr. J. mar. Sci.* **11:** 203-209.

COCKCROFT, V., NATOLI, A., REISINGER, R., ELWEN, S., HOELZEL, R., ATKINS, S. and PLÖN, S., 2016. A conservation assessment of *Tursiops aduncus*. In CHILD, M.F., ROXBURGH, L., DO LINH SAN, E., RAIMONDO, D., DAVIES-MOSTERT, H.T., editors. The Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa.

COETZEE, J.C., MERCKLE, D., HUTCHINGS, L., VAN DER LINGEN, C.D., VAN DEN BERG, M. & M.D.DURHOLTZ, 2010. The 2005 KwaZulu-Natal sardine run survey sheds new light on the ecology of small fish off the east coast of South Africa. *African Journal of Marine Science* **32**: 337–360.

COLEY, N.P. 1994. *Environmental impact study: Underwater radiated noise.* Institute for Maritime Technology, Simon's Town, South Africa. pp. 30.

COLEY, N.P. 1995. *Environmental impact study: Underwater radiated noise II*. Institute for Maritime Technology, Simon's Town, South Africa. pp. 31.

COLMAN, J.G., GORDON, D.M., LANE, A.P., FORDE, M.J. and J.J. FITZPATRICK, 2005. Carbonate mounds off Mauritania, Northwest Africa: status of deep-water corals and implications for management of fishing and oil exploration activities. In: *Cold-water Corals and Ecosystems*, Freiwald, A and Roberts, J. M. (eds). Springer-Verlag Berlin Heidelberg pp 417-441.

CONKLIN, P.J., DRYSDALE, D., DOUGHTIE, D.G., RAO, K.R., KAKAREKA, J.P., GILBERT, T.R. and R. SHOKES, 1983. Comparative toxicity of drilling muds: role of chromium and petroleum hydrocarbons. *Mar. Environ. Res*., **10**: 105-125.

CONNELL, A.D. 1996. Seasonal trends in sardine spawning at Park Rynie, KwaZulu-Natal south coast. Workshop on South African sardine: Proceedings and recommendations. BARANGE, M. and VAN DER LINGEN (ed.). *BEP Rep. 29*, 29-33.

CONNELL, A.D., 2010. A 21-year ichthyoplankton collection confirms sardine spawning in KwaZulu-Natal waters. *African Journal of Marine Science* **32**: 331–336.

CONVENTION ON BIOLOGICAL DIVERSITY (CBD), 2013. Report of the Southern Indian Ocean regional workshop to facilitate the description of ecologically or biologically significant marine areas. UNEP/CBD/RW/EBSA/SIO/1/4. www.cbd.int/doc/?meeting=EBSA-SIO-01

CORNEW, S., STUART, V. and BECKLEY, L.E. 1992. Population structure, biomass and distribution of *Nyctiphanes capensis* (Euphausiacea) in the vicinity of Algoa Bay, South Africa. *S. Afr. J. Zoo*., **27 (1)**: 14-20.

CRANFORD, P.J., QUERBACH, K., MAILLET, G., LEE, K., GRANT, J. and C. TAGGART, 1998. Sensitivity of larvae to drilling wastes (Part A): Effects of water-based drilling mud on early life stages of haddock, lobster, and sea scallop. Report to the Georges Bank Review Panel, Halifax NS, Canada. 22 pp.

CROFT, B. and B. LI, 2017. Shell Namibia Deepwater Exploration Drilling: Underwater Noise Impact Assessment. Prepared by SLR Consulting Australia Pty Ltd. for SLR Consulting (Cape \Town) Pty Ltd. 19pp.

CROWTHER CAMPBELL & ASSOCIATES CC AND CENTRE FOR MARINE STUDIES (CCA & CMS). 2001. Generic Environmental Management Programme Reports for Oil and Gas Prospecting off the Coast of South Africa. Prepared for Petroleum Agency SA, October 2001.

CROWTHER CAMPBELL & ASSOCIATES and CSIR, 1998. Environmental Impact Assessment for the proposed extension of the ORIBI oil production facility and hydrocarbon exploration off the Southern Cape Coast. Report No. SOE01OE/2.

CSIR, 1998. Environmental Impact Assessment for the Proposed Exploration Drilling in Petroleum Exploration Lease 17/18 on the Continental Shelf of KwaZulu-Natal, South Africa. CSIR Report ENV/S-C 98045.

CSIR, 2009. Environmental studies in the Richards Bay offshore outfalls region. Report No. 22. Surveys made in 2008/2009. CSIR Report CSIR/NRE/CO/ER/2010/0010/B.

CSIR and CIME, 2011. Environmental Impact Assessment for Exploration Drilling Operations, Yoyo Mining Concession and Tilapia Exploration Block, Offshore Cameroon. CSIR Report no. CSIR/CAS/EMS/ER/2011/0015/A.

CURRIE, D.R. and L.R. ISAACS, 2005. Impact of exploratory offshore drilling on benthic communities in the Minerva gas field, Port Campbell, Australia. *Mar. Environ. Res.*, **59**: 217-233.

DAAN, R. and M. MULDER, 1993. A study on possible environmental effects of WBM cuttings discharge in the North Sea, one year after termination of drilling. NIOZ Report 1993-16 from the Netherlands Institute of Sea Research, Texel, the Netherlands. 17 pp.

DAAN, R. and M. MULDER, 1996. Long-term effects of OBM cutting discharges at 12 locations on the Dutch Continental Shelf. NIOZ-report 1996-6, NIOZ, Texel, The Netherlands: 1-36.

DAAN, R., VAN HET GROENEWOUD, H., DE JONG, S.A., and M. MULDER, 1992. Physico-chemical and biological features of a drilling site in the North Sea, 1 year after discharges of oil-contaminated drill cuttings. *Marine Ecology Progress Series*, **91**: 37-45.

DAVIES, J., ADDY, J., BLACKMAN, R., BLANCHARD, J., FERBRACHE, J., MOORE, D., SOMMERVILLE, H., WHITEHEAD, A. and T. WILKINSON, 1983. Environmental effects of oil based mud cuttings. UKOOA, Aberdeen, Scotland. 24 pp. plus appendices.

DE LECEA, A.M., COOPER, R. and A.J. SMIT, 2015. Identifying the drivers of the pelagic ecosystem of an oligotrophic bight (KwaZulu-Natal, South Africa) using stable isotopes (δ13C, δ15N) and C:N ratio analysis. *Marine and Freshwater Research*. DOI:org/10.1071/MF15256.

DE LECEA, A.M., FENNESSY, S.T. and A.J. SMIT, 2013. Processes controlling the benthic food-web of a mesotrophic bight (KwaZulu-Natal, South Africa) revealed by stable isotope analysis. *Marine Ecology Progress Series* 484: 97–114.

DE LECEA, A.M., SMIT, A.J. and S.J. FENNESSY, 2016. Riverine dominance of a nearshore marine demersal food web: evidence from stable isotope and C/N ratio analysis. *African Journal of Marine Science* 38(Supplement): S181–S192.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM, GREATER ST LUCIA WETLAND PARK AUTHORITY and MARINE AND COASTAL MANAGEMENT, 2004. Management Plan for the conservation of coelacanths in the Greater St Lucia Wetland Park. Coelacanth Management Plan GSLWP, Edition 2, 14/04/04, pp13.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY, SOUTH AFRICA, 2004. DWAF Report No. PBV000-00-10310. Thukela Bank: Impacts of Flow Scenarios on Prawn and Fish Catch. Report - Reserve Determination Study – Thukela River System. Prepared by IWR Source-to-Sea as part of the Thukela Water Project Decision Support Phase. Pp76.

DEMETRIADES N.T. & A.T. FORBES, 1993. Seasonal changes in the species composition of the penaeid prawn catch on the Tugela Bank, Natal, South Africa. *South African Journal of Marine Science* **13**: 317-322.

DETHLEFSEN, V., SOFFKER, K., BUTHER, H. and U. DAMM, 1996. Organochlorine compounds in marine organisms from the international North Sea incineration area Arch. *Fish. Mar. Res*., **44(3)**: 215-242.

DEVOS L. and D. OYUGI, 2002. First capture of a coelacanth, *Latimeria chalumnae* Smith, 1939 (Pisces: Latimeriidae), off Kenya. S. Afr. J. Sci. 98, 345–347.

DE WET, A. 2013. *Factors affecting survivorship of loggerhead (Caretta caretta) and leatherback (Dermochelys coriacea) sea turtles of South Africa.* MSc, Nelson Mandela Metropolitan University.

DOW, F.K., DAVIES, J.M. and D. RAFFAELI, 1990. The effects of drilling cuttings on a model marine sediment system. *Mar. Environ. Res*., **29**: 103-124.

DREWITT, A., 1999. Disturbance effects of Aircraft on birds. English Nature. Birds Network Information Note. 14pp.

DUDLEY, S.F.J. & C.A. SIMPFENDORFER, 2006. Population status of 14 shark species caught in the protective gillnets off KwaZulu-Natal beaches, South Africa, 1978 – 2003. *Marine and Freshwater Research* **57**: 225 – 240.

DURHAM, B., 1994. The distribution and abundance of the humpback dolphin (Sousa chinensis) along the Natal coast, South Africa. University of Natal.

DUTTON, P. H., BOWEN, B. W., OWENS, D. W., BARRAGAN, A. & DAVIS, S. K. 1999. Global phylogeography of the leatherback turtle (Dermochelys coriacea). *Journal of Zoology,* 248**,** 397-409.

ECKERT, S.A. & B.S. STEWART, 2001. Telemetry and satellite tracking of whale sharks, *Rhincodon typus*, in the Sea of Cortez, Mexico, and the north Pacific Ocean. *Environmental Biology of Fishes*, **60**: 299–308.

ELLIS, D.V., 2000. Effect of Mine Tailings on The Biodiversity of The Seabed: Example of The Island Copper Mine, Canada. In: SHEPPARD, C.R.C. (Ed), Seas at The Millennium: An Environmental Evaluation. Pergamon, Elsevier Science, Amsterdam, pp. 235-246.

ELLIS, D.V. and C. HEIM, 1985. Submersible surveys of benthos near a turbidity cloud. *Marine Pollution Bulletin*, **16**: 197-202.

ELLIS, M.S., WILSON-ORMOND, E.A. and E.N. POWELL, 1996. Effects of gas-producing platforms on continental shelf macroepifauna in the northwestern Gulf of Mexico: abundance and size structure. *Can. J. Fish. Aquat. Sci.*, **53**: 2589-2605.

ELWEN, S. & P.B. BEST, 2004. Environmental factors influencing the distribution of southern right whales (*Eubalaena australis*) on the South Coast of South Africa I: Broad scale patterns. *Mar. Mammal Sci.*, **20 (3)**: 567-582.

ELWEN, S.H., GRIDLEY, T., ROUX, J.-P., BEST, P.B. and M.J. SMALE, 2013. Records of Kogiid whales in Namibia, including the first record of the dwarf sperm whale (*K. sima*). *Marine Biodiversity Records*. 6, e45 doi:10.1017/S1755267213000213.

ENVIRONMENTAL PROTECTION AGENCY (EPA), 2000. Environmental assessment of fun] effluent limitations guidelines and standards for synthetic-based drilling fluids and other non-aqueous drilling fluids in the oil and gas extraction point source category. EPA-821-B-00-014. December 2000.

ERDMANN, M.V., 2006. Lessons learned from the conservation campaign for the Indonesian coelacanth, *Latimeria menadoensis*. *S. Afr. J. Sci.*, 102, 501-5-4.

ERM, 2018a. Environmental Impact Assessment: Drill Cuttings and Muds Discharge Modeling Report. Exploration of Block ER236, South Africa. May 2018. Pp31.

ERM, 2018b. Environmental Impact Assessment: Oil Spill Modelling Report. Exploration of Block ER236, South Africa. May 2018. Pp104.

ESSINK, K., 1999. Ecological effects of dumping of dredged sediments; options for management. *Journal ofCoastal Conservation*, **5**: 12.

EZEMVELO KZN WILDLIFE, 2012. Focus areas for additional marine biodiversity protection in KwaZulu-Natal, South Africa. Unpublished Report - Jan 2012. Scientific Services, Ezemvelo KZN Wildlife: Durban. Pp 62.

FECHHELM, R.G., GALLAWAY, B.J., HUBBARD, G.F., MACLEAN, S. and L.R. MARTIN, 2001. Opportunistic sampling at a deep-water synthetic drilling fluid discharge site in the Gulf of Mexico. *Gulf of Mexico Science*, **2**: 97-106.

FENNESSY, S.T., 1994a. The impact of commercial prawn trawlers on linefish off the north coast of Natal, South Africa. *South African Journal of Marine Science* **14**: 263-279.

FENNESSY, S.T., 1994b. Incidental capture of elasmobranchs by commercial prawn trawlers on the Tugela Bank, Natal, South Africa. *South African Journal of Marine Science* **14**: 287-296.

FENNESSY, S.T., 2016. Subtropical demersal fish communities on soft sediments in the KwaZulu-Natal Bight, South Africa, *African Journal of Marine Science*, 38:sup1, S169-S180, DOI: 10.2989/1814232X.2016.1140677

FENNESSY, S.T, PRADERVAND, P. & P.A. DE BRUYN, 2010. Influence of the sardine run on selected nearshore predatory teleosts in KwaZulu-Natal. *African Journal of Marine Science* **32(2)**: 375–382.

FERNANDEZ, A., EDWARDS, J.F., RODRIGUEZ, F., ESPINOSA DE LOS MONEROS, A., HERRAEZ, P., CASTRO, P., JABER, J., *et al.*, 2005. "'Gas and Fat Embolic Syndrome'" Involving a Mass Stranding of Beaked Whales (Family Ziphiidae) Exposed to Anthropogenic Sonar Signals. *Veterinary Pathology*, **457**: 446–457.

FINDLAY, K.P., 1989. The distribution of cetaceans off the coast of South Africa and South West Africa/Namibia. Unpublished MSc. Thesis, University of Pretoria Town. 110pp.

FINDLAY, K.P., 1996. The impact of diamond mining noise on marine mammal fauna off southern Namibia. Specialist Study #10. In: Environmental Impact Report. Environmental Evaluation Unit (ed.) Impacts of deep sea diamond mining, in the Atlantic 1 Mining Licence Area in Namibia, on the natural systems of the marine environment. No. 11-96-158, University of Cape Town. Report to De Beers Marine (Pty) Ltd. pp. 370

FINDLAY, K.P. & P.B. BEST, 1996a. Estimates of the numbers of humpback whales observed migrating past Cape Vidal, South Africa, 1988-1991. *Mar Mammal Sci.,* **12(3)**: 354-370.

FINDLAY, K.P. & P.B. BEST, 1996b. The Migrations of Humpback Whales past Cape Vidal, South Africa, and a Preliminary Estimate of the Population Increase Rate. *Rep Int Whal Commn*. SC/A06/HW16

FINDLAY, K.P., BEST, P.B., PEDDEMORS, V.M. and D. GOVE, 1994. The distribution and abundance of humpback whales on the southern and central Mozambique winter grounds. *Rep Int Whal Commn* **44**: 311-320.

FINDLAY, K.P., BEST, P.B., ROSS, G.J.B. and COCKCROFT, V.G. 1992. The distribution of small odontocete cetaceans off the coasts of South Africa and Namibia. *S. Afr. J. mar. Sci.*, **12**: 237-270.

FLEMMING, B. and HAY, R., 1988. Sediment distribution and dynamics on the Natal continental shelf. In: *Coastal ocean sciences of Natal, South Africa* (Ed. E.H. SCHUMANN). Springer-Verlag, Berlin., 47-80.

FOSTER, B.A. and R.C. WILLAN, 1979. Foreign barnacles transported to New Zealand on an oil platform. *New Zealand Journal of Marine and Freshwater Research* 13(1): 143-149.

FRICKE, H. and K. HISSMANN, 2000. Feeding ecology and survival of the living coelacanth. *Mar. Biol*. 136, 379–386.

FRICKE, H., HISSMANN, K., SCHAUER, J., REINICKE, O., KASANG, L. and R. PLANTE, 1991. Habitat and population size of the coelacanth *Latimeria chalumnae* at Grande Comoro. *Environ. Biol. Fishes* 32, 287–300.

FRICKE, H., HISSMANN, K., SCHAUER, J., ERDMANN, M., MOOSA, M.K. and R. PLANTE, 2000. Biogeography of the Indonesian coelacanths. *Nature* 403, 38.

FRICKE, H. and R. PLANTE, 1988. Habitat requirements of the living coelacanth *Latimeria chalumnae* at Grande Comore, Indian Ocean. *Naturwissenschaften* 15, 149–151.

FRITTS, T.H., IRVINE, A.B., JENNINGS, R.D., COLLUM, L.A., HOFFMAN, W. and M.A. McGEHEE, 1983. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. FWS/OBS-82/65. Technical Report. U.S. Fish and Wildlife Service, Washington, D.C., USA.

FROESE, R. and M.L.D. PALOMARES, 2000. Growth, natural mortality, length-weight relationship, maximum length and length-at-first-maturity of the coelacanth *Latimeria chalumnae*. *Environ. Biol. Fish*. 58(1):45-52.

GAMBELL, R., 1968. Aerial observations of sperm whale behaviour. *Norsk Hvalangst-Tidende* **57**: 126-138.

GARRATT, P.A., 1988. Notes on seasonal abundance and spawning of some important offshore linefish in in Natal and Transkei waters, southern Africa *South African Journal of Marine Science* **7**: 1-8

GETLIFF, J., ROACH, A., TOYO, J. and J. CARPENTER, 1997. An overview of the environmental benefits of LAO based drilling fluids for offshore drilling. Report from Schlumberger Dowell. 10 pp.

GILL, A.E. and SCHUMANN, E.H. 1979. Topographically induced changes in the structure of an inertial jet: Application to the Agulhas Current. *Journal of Physical Oceanography*, **9**: 975-991.

GOOLD, J. and R. COATES, 2001. Acoustic Monitoring of Marine Wildlife. Seiche.Com Ltd. 182pp.

GOODLAD, S.W., 1986. Tectonic and sedimentary history of the mid-Natal Valley (South West Indian Ocean). *Joint GSO/UCT Marine Geoscience Unit Bulletin* **15**: 414 pp.

GÖTZ, A., KERWATH, S.E., ATTWOOD, C.G. and SAUER, W.H.H. 2009. Effects of fishing on a temperate reef community in South Africa 2: benthic invertebrates and algae. *African Journal of Marine Science* **31**: 253-262.

GRASSMAN, M.A., OWENS, D.W. and J.P.McVEY, 1984. Olfactory-based orientation in artificially imprinted sea turtles. *Science*, **224**: 83-84.

GRAY, J.S., WU, R.S. and Y.Y. OR, 2002. Effects of hypoxia and organic enrichment on the coastal marine environment. *Mar. Ecol. Prog. Ser*., **238**: 249-279.

GRIFFITHS, M.H. 1988. Aspects of the biology and population dynamics of the geelbek *Atractoscion aequidens* (Curvier) (Pisces: Sciaenidae) off the South African coast. *M.Sc. thesis, Rhodes University, Grahamstown*: 149.

GREEN, A., UKEN, R., RAMSAY, P., LEUCI, R . and S. PERRITT, 2006. Potential sites for suitable coalacanth habitat using bathymetric sata from the western Indian Ocean. *S. Afr. J. Sci.* **102**: 151–154.

GREEN, G.A., BRUEGGEMAN, J.J., GROTEFENDT, R.A., C.E. BOWLBY, C.E., M.L. BONNELL, M.L. and K.C. BALCOMB III., 1992. Cetacean distribution and abundance off Oregon and Washington, 1989-1990. In: J.J. BRUEGGEMAN, ed. Oregon and Washington Marine Mammal and Seabird Surveys. OCS Study MMS 91-0093. Minerals Management Service, Pacific OCS Region, Los Angeles, CA, USA, p. 1-100.

GREEN, A.N. and C.F. MACKAY, 2016. Unconsolidated sediment distribution patterns in the KwaZulu-Natal Bight, South Africa: the role of wave ravinement in separating relict versus active sediment populations, African Journal of Marine Science, 38:sup1, S65-S74, DOI: 10.2989/1814232X.2016.1145138

GREENWOOD, G., 2013. Population changes and spatial distribution of Indo-pacific humpback dolphins (*Sousa plumbea*) within the Plettenberg Bay area. BSc Honours, Department of Zoology, Faculty of Science, Nelson Mandela Metropolitan University.

GROENEVELD, J.C. & R. MELVILLE-SMITH, 1995. Spatial and temporal availability in the multispecies crustacean trawl fishery along the east coast of South Africa and southern Mozambique, 1988–93. *South African Journal of Marine Science,* **15**: 123-136.

GRÜNDLINGH, M.L., 1987. On the seasonal temperature variation in the southwestern Indian Ocean. *S. Afr. Geogr. J.*, **69 (2)**: 129-139.

GRÜNDLINGH, M.L. 1992. Agulhas Current meanders: review and case study. *S. Afr. Geogr. J.*, **74 (1)**: 19-29.

GUASTELLA, L.A. and M.J. ROBERTS, 2016. Dynamics and role of the Durban cyclonic eddy in the KwaZulu-Natal Bight ecosystem, *African Journal of Marine Science*, 38:sup1, S23-S42, DOI: 10.2989/1814232X.2016.1159982

HALL, S.J., 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanography and Marine Biology: An Annual Review*, **32**: 179-239.

HALL, S.J., 2001. Is offshore oil exploration good for benthic conservation? *Trends in Ecology and Evolution*, 16(1): 58.

HARRIS, J.M., LIVINGSTONE, T., LOMBARD, A.T., LAGABRIELLE, E., HAUPT, P., SINK, K., MANN, B. & M. SCHLEYER, 2011. Marine Systematic Conservation Assessment and Plan for KwaZulu-Natal - Spatial priorities for conservation of marine and coastal biodiversity in KwaZulu-Natal. Ezemvelo KZN Wildlife.

HARRIS, J.M., LIVINGSTONE, T., LOMBARD, A.T., LAGABRIELLE, E., HAUPT, P., SINK, K., SCHLEYER, M., MANN, B.Q., 2012. Coastal and Marine Biodiversity Plan for KwaZulu-Natal. Spatial priorities for the conservation of coastal and marine biodiversity in KwaZulu-Natal. Ezemvelo KZN Wildlife Scientific Services Technical Report.

HARRISON, P., 1978. Cory's Shearwater in the Indian Ocean. *Cormorant*. **5**: 19-20.

HARTLEY, J., TRUEMAN, R., ANDERSON, S., NEFF, J., FUCIK, K. and P. DANDO, 2003. Drill Cuttings Initiative: Food Chain Effects Literature Review. United Kingdom Offshore Operators Association, Aberdeen, Scotland. 118 pp + Appendices.

HARVEY, M., GAUTHIER, D. and J. MUNRO, 1998. Temporal changes in the composition and abundance of the macro-benthic invertebrate communities at dredged material disposal sites in the Anse a Beaufils, Baie des Chaleurs, Eastern Canada. *Marine Pollution Bull*etin, **36**: 41-55.

HAUPT, P., 2011. The use of fish species in a marine conservation plan for KwaZulu-Natal. MSc Thesis, Nelson Mandela Metropolitan University, South Africa.

HAYS, G.C. HOUGHTON, J.D.R., ISAACS, C. KING, R.S. LLOYD, C. & P. LOVELL, 2004. First records of oceanic dive profiles for leatherback turtles, *Dermochelys coriacea*, indicate behavioural plasticity associated with long-distance migration. *Animal Behaviour,* **67**: 733-743.

HEEMSTRA, P.C., FREEMAN, A.L.J., WONG, H.Y., HENSLEY, D.A. and H.D. RABESANDRATANA, 1996. First authentic capture of a coelacanth, *Latimeria chalumnae* (Pisces: Latimeriidae), off Madagascar. *South African Journal of Science*, 92: 150-151.

HEEMSTRA P.C., FRICKE H., HISSMANN, K., SCHAUER J. and K. SINK, 2006a. Interactions of fishes with particular reference to coelacanths in the canyons at Sodwana Bay and the St Lucia Marine Protected Area of South Africa. *S. Afr. J. Sci*. **102**: 461–465.

HEEMSTRA P.C., HISSMANN, K., FRICKE H., SMALE M. and J. SCHAUER, 2006b. Fishes of the deep demersal habitat at Ngazidja (Grand Comoro) Island, Western Indian Ocean. *S. Afr. J. Sci*. **102**: 444–460.

HERNANDEZ ARANA, H.A., WARWICK, R.M., ATTRILL, M.J., RODEN, A.A. and G. GOLD-BOUCHOT, 2005. Assessing the impact of oil-related activities on benthic macroinfauna assemblages of the Campeshe shelf, southern Gulf of Mexico. *Marine Ecology Progress Series,* **289**: 89-107.

HEWITT, C.L., GOLLASCH, S. and D. MINCHIN, 2009. Biological Invasions in Marine Ecosystems: Ecological, Management and Geographic Perspectives - The Vessel as a Vector – Biofouling, Ballast Water and Sediments In: *Ecological Studies* 204 (eds) G. Rilov and J. A. Crooks.

HEYDORN, H.J. 1989. Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 39: Quko (CSE 56). HEYDORN, A.E.F. and MORANT, P.D. (eds). Stellenbosch, CSIR Research Report 437, 66pp.

HEYDORN, A.E.F. and TINLEY, K.L. 1980. Estuaries of the Cape, Part I. Synopsis of the Cape coast. Natural features, dynamics and utilization. Stellenbosch, CSIR Research Report 380, 97 pp.

HEYDORN, A.E.F., BANG, N.D., PEARCE, A.F., FLEMMING, B.W., CARTER, R.A., SCHLEYER, M.H., BERRY, P.F., HUGHES, G.R., BASS, A.J., WALLACE, J.H. VAN DER ELST, R.P., CRAWFORD, R.J.M. AND SHELTON, P.A. 1978. Ecology of the Agulhas Current region: an assessmnet of biological responses to environmental parameters in the south- west Indian ocean. *Trans. roy. Soc. S. Afr*., **43(2)** : 151-190.

HINWOOD, J.B., POOTS, A.E., DENNIS, L.R., CAREY, J.M., HOURIDIS, H., BELL, R.J., THOMSON, J.R., BOUDREAU, P. and A.M. AYLING, 1994. Drilling activities. Pages 123-207 In: SWAN, J.M., NEFF, J.M. and P.C. YOUNG, Eds., Environmental Implications of Offshore Oil and Gas Development In Australia – Findings of an Independent Scientific Review. Australian Petroleum Production and Exploration Association, Canberra, Australia.

HISSMANN K., FRICKE H., SCHAUER J., RIBBINK A.J., ROBERTS M., SINK K. and P. HEEMSTRA, 2006. The South African coelacanths – an account of what is known after three submersible expeditions. *S. Afr. J. Sci.* **102**: 491–501.

HISSMANN, K., FRICKE, H. and J. SCHAUER, 2000. Patterns of time and space utilisation in coelacanths (*Latimeria chalumnae*) determined by ultrasonic telemetry. *Mar. Biol.* 136, 943-952.

HOUGHTON, J.P., BEYER, D.L. and E.D. THIELK, 1980. Effects of oil well drilling fluids on several important Alaskan marine organisms. pp 1017-1044, In: Proceedings of Symposium, Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, January 21-24, 1980, Lake Buena Vista, Florida. Vol. II. American Petroleum Institute, Washington, DC.

HUGHES, G.M. and Y. ITAZAWA, 1972. The effect of temperature on the respiratory function of coelacanth blood. *Experientia*, 18, 1247.

HUGHES, G.R. 1974a. The Sea Turtles of South East Africa I. Status, morphology and distributions. I*nvestl. Rep. Oceanogr. Res. Inst.* 35.

HUGHES, G. R. 1974b. *The sea turtles of south east Africa.* PhD, University of Natal.

HUGHES, G.R., 1996. Nesting of the Leatherback turtle (*Dermochelys coriacea*) in Tongaland, KwaZulu-Natal, South Africa 1963-1995. *Chelonian Conservation and Biology*, 2, 153 - 158.

HUGHES, G.R., 2012. Between the Tides: In Search of Sea Turtles, Jacana.

HUGHES, G.R., LUSCHI, P., MENCACCI, R. & F. PAPI, 1998. The 7000 km journey of a leatherback turtle tracked by satellite. *Journal of Experimental Marine Biology and Ecology*, **229**: 209 - 217.

HUGHES, G. And R. NEL, 2014[a]. Family Cheloniidae. In: BATES, M.F., BRANCH, W.R., BAUER, A.M., BURGER, M., MARAIS, J., ALEXANDER, G.J., DE VILLIERS, M.S. (eds) Atlas and Red List of the Reptiles of South Africa, Lesotho and Swaziland. Suricata 1, SANBI, Pretoria.

HUGHES, G. and R. NEL, 2014b. Family Dermochelyidae. In: BATES, M.F., BRANCH, W.R., BAUER, A.M., BURGER, M., MARAIS, J., ALEXANDER, G.J., DE VILLIERS, M.S. (eds) Atlas and Red List of the Reptiles of South Africa, Lesotho and Swaziland. Suricata 1, SANBI, Pretoria.

HUNTER, I.T., 1988. Climate and weather off Natal. In: Coastal ocean sciences of Natal, South Africa (Ed. E.H. Schumann). Springer-Verlag, Berlin, 81-100.

HURLEY, G. and J. ELLIS, 2004. Environmental Effects of Exploratory Drilling Offshore Canada: Environmental Effects Monitoring Data and Literature Review - Final Report. Prepared for the Canadian Environmental Assessment Agency - Regulatory Advisory Committee.

HUSKY OIL OPERATIONS LIMITED, 2000. White Rose Oilfield Comprehensive Study. Submitted by Husky Oil Operations Limited as Operator, St. John's, NL.

HUSKY OIL OPERATIONS LIMITED, 2001a. White Rose Oilfield Comprehensive Study Supplemental Report Responses to Comments from Canada-Newfoundland Offshore Petroleum Board, Department of Fisheries and Oceans, Environment Canada, Natural Resources Canada and Canadian Environmental Assessment Agency. Submitted by Husky Oil Operations Limited (Operator). 265 pp. + Appendices.

HUSKY OIL OPERATIONS LIMITED, 2001b. White Rose baseline characterization data report June 2001. Prepared by Jacques Whitford Environment Limited for Husky Oil Operations Limited. St. John's. NL. 109 p. — App.

HUTCHINGS, L. 1994. The Agulhas Bank: a synthesis of available information and a brief comparison with other east-coast shelf regions. *S. Afr. J. Sci.*, **90**: 179-185.

HUTCHINGS, L., BECKLEY, L.E., GRIFFITHS, M.H., ROBERTS, M.J., SUNDBY, S. and VAN DER LINGEN C. 2003. Spawning on the edge: spawning grounds and nursery areas around the southern African coastline. *Marine and Freshwater Research* **53**: 307-318.

HYLAND, J., HARDIN, D., STEINHAUER, M., COATS, D., GREEN, R.H., and J. NEFF, 1994. Environmental impact of offshore oil development on the outer continental shelf and slope off Point Arguello, California. *Marine Environmental Research*, **37**: 195-229.

HYLLEBERG, J., NATEEWATHANA, A. and B. CHATANANTHAWEJ, 1985. Temporal changes in the macrobenthos on the west coast of Phuket Island, with emphasis on the effects of offshore tin mining. *Research Bulletin of the Phuket Marine Biological Center*, **38**: 32 pp.

INTERNATIONAL WHALING COMMISSION (IWC), 1998. Report of the Scientific Committee of the International Whaling Commission, 1998.

INTERNATIONAL WHALING COMMISSION (IWC), 2010. Report of the sub-committee on other Southern Hemisphere whale stocks. Journal of Ceatacean Research and Management, 11: 218-251.

IOGP (International Association of Oil and Gas Producers), 2003. Environmental Aspects of use and disposal of non-aqueaous drilling fluids associated with offshore oil & gas operations. IOGP Report 342, IOGP, London, UK, pp114.

IOGP (International Association of Oil and Gas Producers), 2016. Environmental fates and effects of ocean discharge of drill cuttings and associated drilling fluids from offshore oil and gas operations. IOGP Report 543, pp144.

ITOPF (International Tanker Owners Pollution Federation Limited), 2002. *Technical Information Paper: Fate of Marine Oil Spills.* www.itopf.com.

JENSEN, T., PALERUD, R., OLSGARD, F. and S.M. BAKKE, 1999. Dispersion and effects of synthetic drilling fluids in the Environment. Technical Report to the Ministry of Oil and Energy. Report no. 99-3507. 49pp.

JOHNSON, R., BESTER M.N., DUDLEY, S.F.J., OOSTHUIZEN, W.H., MEŸER, M., HANCKE, L. & E. GENNARI, 2009. Coastal swimming patterns of white sharks (*Carcharodon carcharias*) at Mossel Bay, South Africa. *Environ Biol Fish*, **85**: 189–200.

JURY, M.R. 1994. Meteorology of eastern Agulhas Bank. *S. Afr. J. Sci.*, **90**: 109-113.

JURY, M.R. and DIAB, R., 1989. Wind energy potential in the Cape coastal belt. *S. Afr. Geogr. J.*, **71**: 3-11.

KARCZMARSKI, L., 1996. Ecological studies of humpback dolphins Sousa chinensis in the Algoa Bay region, Eastern Cape, South Africa. University of Port Elizabeth.

KARCZMARSKI, L., COCKCROFT, V.G., McLACHLAN, A., 2000. Habitat use and preferences of Indo-Pacific humpback dolphins *Sousa chinensis* in Algoa Bay, South Africa. *Marine Mammal Science*, 16(1): 65–79.

KEITH, M., 1999. Population biology of humpback dolphins in Richards Bay, South Africa. Population (English Edition). University of Pretoria.

KETTEN, D.R., 1998. Marine mammal auditory systems: A summary of audiometric and anatomical data and its implications for underwater acoustic impacts. NOAA Technical Memorandum NMFS-SWFSC-256:1-74.

KINGSTON, P.F., 1987. Field effects of platform discharges on benthic macrofauna. *Philosophical Transactions of the Royal Society of London*, Series B 317, 545–565.

KINGSTON, P.F., 1992. Impact of offshore oil production installations on the benthos of the North Sea. *ICES J. Mar. Sci.*, **49**: 45-53.

KIRK, J.T.O., 1985. Effects of suspensoids on penetration of solar radiation in aquatic ecosystems. *Hydrobiologia*, **125**: 195-208.

KOCH, A. & R. JOHNSON, 2006. White Shark abundance: not a causative factor in numbers of shark bite incidents. In NEL, D.C. & T.P. PESCHAK (eds) Finding a balance: White shark conservation and recreational safety in the inshore waters of Cape Town, South Africa; proceedings of a specialist workshop. WWF South Africa Report Series - 2006/Marine/001.

KOPER, R.P., KARCZMARSKI, L., DU PREES, D., PLÖN S., 2016. Sixteen years later: Occurrence, group sizes, and habitat use of humpback dolphins (*Sousa plumbea*) in Algoa Bay, South Africa.

KOPER, R.P and S. PLÖN, 2012. *The potential impacts of anthropogenic noise on marine animals and recommendations for research in South Africa.* EWT Research & Technical Paper No. 1. Endangered Wildlife Trust, South Africa.

KOZAK, N.V. and I.A. SHPARKOVSKI, 1991. Testing Drilling Muds and their Components with the Use of Fish from the Barents Sea. In Theses of the Second. *All-Union Conference on Fisheries Toxicology*, **1**: 272-273

KRANZ, P.M., 1974. The anastrophic burial of bivalves and its paleoecological significance. *Journal of Geology*, **82**:29

LAMBARDI, P., LUTJEHARMS, J.R.E., MENACCI, R., HAYS, G.C. & P. LUSCHI, 2008. Influence of ocean currents on long-distance movement of leatherback sea turtles in the Southwest Indian Ocean. *Marine Ecology Progress Series*, **353**: 289–301.

LAMBERTH, S.J., DRAPEAU, L & G.M. BRANCH, 2009. The effects of altered freshwater inflows on catch rates of non-estuarine-dependent fish in a multispecies nearshore linefishery. *Estuarine, Coastal and Shelf Science* **84**: 527–538.

LAMONT, T. and R.G. BARLOW, 2015. Environmental influence on phytoplankton production during summer on the KwaZulu-Natal shelf of the Agulhas ecosystem. *African Journal of Marine Science* 37: 485–501.

LAURET-STEPLER, M., BOURJEA, J., ROOS, D., PELLETIER, D., RYAN, P., CICCIONE, S. and H. GRIZEL, 2007. Reproductive seasonality and trend of Chelonia mydas in the SW Indian Ocean: a 20 yr study based on track counts. *Endangered Species Research,* 3: 217-227.

LAMPERT, K.P., BLASSMANN, K., HISSMANN, K., SCHAUER, J., SHUNULA, P., KHAROUSY, Z., NGATUNGA, B.P., FRICKE, H. and M. SCHARTL, 2013. Single male paternity in coelacanths. Nature Communications, published online 18.09.2013, doi: 10.1038/ncomms3488

LEATHERWOOD, S., AWBREY, F.T. and J.A. THOMAS, 1982. Minke whale response to a transiting survey vessel. *Report of the International Whaling Commission* **32**: 795-802.

LEES, D.C. and J.P. HOUGHTON, 1980. Effects of drilling fluids on benthic communities at the Lower Cook Inlet C.O.S.T. well. pp309-350. In: Proceedings of Symposium, Research on Environmental Fate and Effects of Drilling Fluids and Cuttings, Vol. I, January 21-24, 1980, Lake Buena Vista, Florida. American Petroleum Institute, Washington, DC.

LEPLAND, A. and P.B. MORTENSEN, 2008. Barite and barium in sediments and coral skeletons around the hydrocarbon exploration drilling site in the Traena Deep, Norwegian Sea. *Environ. Geol.,* **56**: 119–129.

LEUNG-NG, S. and S. LEUNG, 2003. Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Mar. Env. Res.*, **56**: 555-567.

LIVERSIDGE, R. and LE GRAS, G.M. 1981. Observations of seabirds off the eastern Cape, South Africa, 1953-1963. In: *Proceedings of the symposium on birds of the sea and shore, 1979*. COOPER, J. (Ed.). 149-167.

LOHMANN, K. J., LOHMANN, C. M. & PUTMAN, N. F. 2007. Magnetic maps in animals: nature's GPS. *Journal of Experimental Biology,* 210**,** 3697-3705.

LOMBARD, A.T., STRAUSS, T., HARRIS, J., SINK, K., ATTWOOD, C. and HUTCHINGS, L. 2004. *National Spatial Biodiversity Assessment 2004: South African Technical Report Volume 4: Marine Component.*

LOVE, M.S. and A. YORK, 2006. The relationships between fish assemblages and the amount of bottom horizontal beam exposed at California oil platforms: fish habitat preferences at man-made platforms and (by inference) at natural reefs. *Fisheries Bulletin,* **104**: 542-549.

LOVE, M.S., SCHROEDER, D.M. and W.H. LENARZ, 2005. Distribution of bocaccio (*Sebastes paucispinis*) and cowcod (*Sebastes levis*) around oil platforms and natural outcrops off California with implications for larval production. *Bulletin of Marine Science,* **77(3)**: 397-408.

LUSCHI, P., HAYS, G.C. & F. PAPI, 2003a. A review of long-distance movements by marine turtles, and the possible role of ocean currents. *Oikos*, 103, 293 – 302.

LUSCHI, P., LUTJEHARMS, J.R.E., LAMBARDI, P., MENCACCI, R., HUGHES, G.R. & G.C. HAYS, 2006. A review of migratory behaviour of sea turtles off southeastern Africa. *South African Journal of Science*, 102, 51 - 57.

LUSCHI, P., SALE, A., MENCACCI, R., HUGHES, G.R., LUTJEHARMS, J.R.E. & F. PAPI, 2003b. Current transport of leatherback sea turtles (*Dermochelys coriacea*) in the ocean. *Proceedings of the Royal Society: Biolgical Sciences*, 270, 129 - 132.

LUTJEHARMS, J.R.E., (ed.). 2006. *The Agulhas Current*. Heidelberg, Berlin: Springer-Verlag.

LUTJEHARMS, J.R.E. & H.R. ROBERTS, 1988. The Agulhas Pulse: an extreme transient on the Agulhas Current. *Journal of Geophysical Research*, **93**: 631-45.

LUTJEHARMS, J.R.E., GRÜNDLINGH, M.L. & R.A. CARTER, 1989. Topographically induced upwelling in the Natal Bight. *S. Afr. J. Sci.*, **85 (5)**: 310-316.

LUTJEHARMS, J.R.E, VALENTINE, H.R. & R.C. VAN BALLEGOOYEN, 2000a. The hydrography and water masses of the Natal Bight, South Africa. *Continental Shelf Research*, **20**: 1907-39.

LUTJEHARMS J.R.E., COOPER, J. & M. ROBERTS, 2000b. Dynamic upwelling at the inshore edge of the Agulhas Current. *Continental Shelf Research*, **20**: 737761.

MacDONALD, J.M., SHIELDS, J.D., and R.K. ZIMMER-FAUST, 1988. Acute toxicities of eleven metals to early lift-history stages of the yellow crab *Cancer anthonyi*. *Mar. Biol*., **98**: 201-207.

MacLEOD, C.D. & A. D'AMICO, 2006. A review of beaked whale behaviour and ecology in relation to assessing and mitigating impacts of anthropogenic noise. *Journal of Cetacean Research and Management* **7(3)**: 211–221.

MacISSAC, K., BOURBONNAIS, C., KENCHINGTON, E.D., GORDON JR. & S. GASS, 2001. Observations on the occurrence and habitat preference of corals in Atlantic Canada. *In:* (eds.) J.H.M. WILLISON, J. HALL, S.E. GASS, E.L.R. KENCHINGTON, M. BUTLER, AND P. DOHERTY. Proceedings of the First International Symposium on Deep-Sea Corals. Ecology Action Centre and Nova Scotia Museum, Halifax, Nova Scotia.

MALME, C.I., MILES, P.R., TYACK, P., CLARK, C.W. and J.E. BIRD, 1985. Investigation of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. *BBN Report 5851, OCS Study MMS 85-0019.* Report from BBN Laboratories Inc., Cambridge, MA, for U.S. Minerals Management Service, NTIS PB86-218385. Bolt, Beranek, and Newman, Anchorage, AK.

MARINE & COASTAL MANAGEMENT (M&CM). 2007. Recommendations for the Sustainable Management of the KwaZulu-Natal Trawl Fishery in 2007. Unpublished Memorandum for Ministerial Approval.

MARTIN, A.K. and FLEMMING, B.W. 1988. Physiography, structure and geological evolution of the Natal continental shelf. In: *Coastal ocean sciences of Natal, South Africa* (Ed. E.H. Schumann). Springer-Verlag, Berlin., 11-46.

MAURER, D., KECK, R.T., TINSMAN, J.C. and W.A. LEATHEM, 1981a. Vertical migration and mortality of benthos in dredged material: Part I – Mollusca. *Marine Environmental Research*, **4**: 299-319.

MAURER, D., KECK, R.T., TINSMAN, J.C. and W.A. LEATHEM, 1981b. Vertical migration and mortality of benthos in dredged material: Part II – Crustacea. *Marine Environmental Research*, **5**: 301.317.

MAURER, D., KECK, R.T., TINSMAN, J.C. and W.A. LEATHEM, 1982. Vertical migration and mortality of benthos in dredged material: Part III – Polychaeta. *Marine Environmental Research*, **6**: 49-68.

MAURER, D.L., LEATHEM, W., KINNER, P. and J. TINSMAN, 1979. Seasonal fluctuations in coastal benthic invertebrate assemblages. *Estuarine and Coastal Shelf Science*, 8: 181-193.

MAURER, D., KECK, R.T., TINSMAN, J.C. and W.A. LEATHAM, 1986. Vertical migration and mortality of marine benthos in dredged material: A synthesis. *Int. Revue Ges. Hydrobiol*ogia, **71**: 49-63.

McCAULEY, R.D. 1994. Seismic surveys. In: Swan, J.M., Neff, J.M., Young, P.C. (Eds.). Environmental implications of offshore oil and gas development in Australia - The findings of an Independent Scientific Review. APEA, Sydney, Australia, 695 pp.

MELLY, B., 2011. The zoogeography of the cetaceans in Algoa Bay. Rhodes University. Retrieved from http://eprints.ru.ac.za/2489/1/MELLY-MSc-TR11-.pdf

MELLEY, B.L., MCGREGOR, G., HOFMEYR, G.J.G. and S. PLÖN, in press. Spatio-temporal distribution and habitat preferences of cetaceans in Algoa Bay, South Africa. Journal of the Marine Biological Association of the United Kingdom.doi:10.1017/S0025315417000340

MENN, I., 2002. Ecological comparison of two sandy shores with different wave energy and morphodynamics in the North Sea. *Berliner Polarforschung und Meeresforschung*, **417**: 1-174.

MONTAGNA, P.A. and D.E. HARPER, Jr., 1996. Benthic infaunal long-term response to offshore production platforms in the Gulf of Mexico. *Can. J. Fish. Aquat. Sci*., **53**: 2567-2588.

MONTEIRO, P.M.S., 1998. Assessment of sediment biogeochemical characteristics in the Espirito Santo Estuary-Maputo, Bay system in order to devise a low risk dredging-disposal management plan linked to the proposed MOZAL Matola Terminal. CSIR Report No: ENV/s-C98131 A. pp 39.

MORANT, P.D., 1999. Synthesis and assessment of information on the BCLME. BCLME Thematic Report 4: Integrated overview of the offshore oil and gas industry in the Benguela Current Region. CSIR Report. ENV-S-C 99057.

MORTENSEN, P.B., HOVLAND, T., FOSSÅ, J.H. and D.M. FUREVIK, 2001. Distribution, abundance and size of *Lophelia perusa* coral reefs in mid-Norway in relation to seabed characteristics. *Journal of the Marine Biological Association of the UK* 81(4): 581-597.

MORTIMER, J., 1984. Marine Turtles in the Republic of the Seychelles: Status and Management Report on Project 1809 (1981-1984). International Union for Conservation of Nature and Natural Resources World Wildlife Fund.

MUIR, D., KUNNEN, T. and U.M. SCHARLER, 2016. A seasonal comparison of prokaryote numbers, biomass and heterotrophic productivity in waters of the KwaZulu-Natal Bight, South Africa. In: Roberts MJ, Fennessy ST, Barlow RG (eds), Ecosystem processes in the KwaZulu-Natal Bight. *African Journal of Marine Science* 38(Supplement): S123–S138.

MULLIN, K., HOGGARD, W., RODEN, C., LOHOEFENER, R., ROGERS, C. and B. TAGGART, 1991. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. OCS Study MMS 91-0027. Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA, USA.

MUNRO, G., 2004. Falkland Islands Environmental Baseline Survey 2004. A report to the Falklands Island Government by Falklands Conservation.

MUNRO, P.D., CROCE, B., MOFFAT, C.F., BROWN, N.A., MCINTOSH, A.D., HIRD, S.J.and R.M. STAGG, 1998. Solid-phase test for comparison of degradation rates of synthetic mud base fluids used in the off-shore drilling industry. *Environmental Toxicology and Chemistry*, **17(10)**: 1951-1959.

MUNRO, P., CROCE, B., MOFFIT, C., BROWN, N., McINTOSH, A., HIRD, S. and R. STAGG, 1997. Solid-Phase Test for Comparison of Degradation Rates of Synthetic Mud Base Fluids Used in the Off-Shore Drilling Industry. *Environmental Toxicology and Chemistry,* **17(10)**: 1951-1959.

MUSCHENHEIM, D.K. and T.G. MILLIGAN, 1996. Flocculation and accummulation of fine drilling waste particulates on the Scotian Shelf (Canada). *Marine Pollution Bulletin* 32 (10): 740-745.

NATOLI, A., PEDDEMORS, V.M. & A.R. HOELZEL, 2008. Population structure of bottlenose dolphins (*Tursiops aduncus*) impacted by bycatch along the east coast of South Africa. *Conservation Genetics* **9**: 627–636.

NEFF, J.N., 1991. *Water Quality in Prince William Sound and the Gulf of Alaska*. Arthur D Little, Cambridge, Massachusetts.

NEFF, J.M., 2005. Composition, Environmental Fates, and Biological Effects of Water Based Drilling Muds and Cuttings Discharged to the Marine Environment: A Synthesis and Annotated Bibliography. Prepared fro Petroleum Environmental Research Forum (PERF) and American Petroleum Institute. 83pp.

NEFF, J.M., RABALAIS, N.N. and D.F. BOESCH, 1987. Offshore oil and gas development activities potentially causing long-term environmental effects. pp 149-174. In: BOESCH D.F. and N.N. RABALAIS, Eds., Long Term Effects of Offshore Oil and Gas Development. Elsevier Applied Science Publishers, London.

NEFF, J.M., BOTHNER, M.H., MACIOLEK, N.J. and J.F. GRASSLE, 1989. Impacts of exploratory drilling for oil and gas on the benthic environment of Georges Bank. *Marine Environmental Research*, **27**: 77-114.

NEFF, J.M., SAUER, T.C. and N. MACIOLEK, 1992. Composition, fate and effects of produced water discharges to nearshore waters. pp371-386. In: RAY, J.P. and F.R. ENGELHARDT, Eds., Produced Water: Technological/Environmental Issues. Plenum Publishing Co., New York.

NEFF, J.M., McKELVIE, S. and R.C. AYERS, Jr., 2000. Environmental Impacts of Synthetic Based Drilling Fluids. OCS Study MMS 2000-64. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Program, New Orleans, LA. 118 pp.

NEL, R. 2010. Sea turtles of KwaZulu-Natal: Data report for the 2009/10 season. *In:* HUGHES, G. R. & BACHOO, S. (eds.). Ezemvelo.

NEL, R., PUNT, A. E. & HUGHES, G. R. 2013. Are coastal protected areas always effective in achieving population recovery for nesting sea turtles? *PloS one,* 8, e63525.

NIKAIDO M., SASAKIA T., EMERSONB J.J., AIBARAA M., MZIGHANIA S.I., BUDEBAC Y.L., NGATUNGAC B.P, IWATAD M., ABED Y., LIE W-H. and N. OKADAA, 2011. Genetically distinct coelacanth population off the northern Tanzanian coast. www.pnas.org/cgi/doi/10.1073/ pnas.1115675108.

NRC, 2003. *Ocean noise and marine mammals*. National Academy Press, Washington, DC.

NYANDWI, N., 2006. Coastal Tanzania, a new home to the living coelacanth: an oceanographic analysis, *Tanzania Journal of Science*, 32(2), 33-38.

NYANDWI, N., 2010. Geomorphological potential of coelacanth habitat across Mozambique-Tanzania border. *Tanzania Journal of Science*, Short Communication, 36, 113-118.

O'DONOGHUE, S.H., DRAPEAU, L., DUDLEY, S.F.J. & V.M. PEDDEMORS, 2010a. The KwaZulu-Natal sardine run: shoal distribution in relation to nearshore environmental conditions, 1997 to 2007. *African Journal of Marine Science* **32**: 293–307.

O'DONOGHUE, S.H., DRAPEAU, L. & V.M. PEDDEMORS, 2010b. Broad-scale distribution patterns of sardine and their predators in relation to remotely sensed environmental conditions during the KwaZulu-Natal sardine run. *African Journal of Marine Science* **32**: 279–291.

O'DONOGHUE, S.H., WHITTINGTON, P.A., DYER, B.M. & V.M. PEDDEMORS, 2010c Abundance and distribution of avian and marine mammal predators of sardine observed during the 2005 KwaZulu-Natal sardine run survey. *African Journal of Marine Science* **32**: 361–374.

OGP, 2003. Environmental aspects of the use and disposal of non aqueous drilling fluids associated with offshore oil and gas operations. Report prepared by the International Association of Oil and Gas Producers No. 342 pp.103.

OLIFF, W.D. 1973. Chemistry and productivity at Richards Bay. CSIR/NPRC Oceanography Division Contract Report CFIS 37B. Durban, South Africa.

OLSEN, O., 1913. On the External Characters and Biology of Bryde's Whale (Balaenoptera brydei*) a new Rorqual from the coast of South Africa. Proceedings of the Zoological Society of London, 1073-1090.

OLSGARD, F. and J.S. GRAY, 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. *Marine Ecology Progress Series,* **122**: 277–306.

OSPAR, 2008. OSPAR List of Substances / Preparations Used and Discharged Offshore which Are Considered to Pose Little or No Risk to the Environment (PLONOR).

O'TOOLE, M.J., 1997. A baseline environmental assessment and possible impacts of exploration and mining of diamond deposits (Prospecting Grants Areas M46/3/1946, 1950) off the coast of Namibia. In: LANE, S and CMS, 1996. Environmental Assessment and Management Plan report for deep sea diamond mining in Namibia by Arena Mining (Pty) Ltd.

OTWAY, N.M., GRAY, C.A., CRAIG, J.R., MCVEA, T.A. & J.E. LING, 1996. Assessing the impacts of deepwater sewage outfalls on spatially- and temporally-variable marine communities. *Marine Environmental Research* **41**: 45-71

PAGE, H.M., DUGAN, J.E., CULVER, C.S. and J.C. HOESTEREY, 2006. Exotic invertebrate species on offshore oil platforms. *Marine Ecology Progress Series,* **325**: 101-107.

PAPI, F., LUSCHI, P., AKESSON, S., CAPOGROSSI, S. & G. HAYS, 2000. Open-sea migration of magnetically disturbed sea turtles. *Journal of Experimental Biology*, **203**: 3435-3443.

PARDINI, A.T., JONES, C.S., NOBLE, L.R., KREISER, B., MALCOLM, H., BRUCE, B.D., STEVENS, J.D., CLIFF, G., SCHOLL, M.C., FRANCIS, M., DUFFY, C.A.J. and MARTIN, A.P., 2001. Sex-biased dispersal of great white sharks. *Nature* **412**: 139 – 140.

PARSONS, T.R., KESSLER T.A. and L. GUANGUO, 1986a. An ecosystem model analysis of the effect of mine tailings on the euphotic zone of a pelagic ecosystem. *Acta Oceanol. Sin.*, **5**: 425-436.

PARSONS, T.R., THOMPSON, P., WU YONG, LALLI, C.M., HOU SHUMIN and XU HUAISHU, 1986b. The effect of mine tailings on the production of plankton. *Acta Oceanol. Sin.*, **5**: 417-423.

PATENAUDE, N.J., RICHARDSON, W.J., SMULTEA, M.A., KOSKI, W.R., MILLER, G.W., WÜRSIG, B. and C.R. GREENE, JR., 2002. Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. *Marine Mammal Science* **18**: 309-335.

PEARCE, A.F. 1977a. The shelf circulation off the east coast of South Africa. *CSIR Professional Research Series*, **1**, 220 pp.

PEARCE, A.F. 1977b. Some features of the upper 500 m of the Agulhas Current. Journal of Marine Research. 35: 731-753.

PEARCE, A.F., SCHUMANN, E.H. and LUNDIE, G.S.H. 1978. Features of the shelf circulation off the Natal Coast. *S. Afr. J. Sci.*, **74**: 328-331.

PEARSON, T.H. and R. ROSENBERG. 1978. Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. Oceanogr. Mar. Biol. Ann. Rev. 16: 229-311.

PEDDEMORS, V.M. 1999. Delphinids of southern africa. A review of their distribution, status and life history. *J. Cetacean Res. Manage.*, **1(2)**: 157-166.

PENRY, G.S., 2010. *Biology of South African Bryde's whales*. PhD Thesis. University of St Andrews, Scotland, UK.

PENRY, G.S., COCKCROFT, V.G., HAMMOND, P.S., 2011. Seasonal fluctuations in occurrence of inshore Bryde's whales in Plettenberg Bay, South Africa, with notes on feeding and multispecies associations, African Journal of Marine Science, 33/3: 403-414.

PENRY, G., FINDLAY, K., BEST, P., 2016. A Conservation Assessment of Balaenoptera edeni. In: M.F. CHILD, L. ROXBURGH, D. RAIMONDO, E. DO LINH SAN, J. SELIER AND H. DAVIES-MOSTERT (eds), The Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa.

PEREIRA, M. A. M., VIDEIRA, E. J. S. & LOURO, C. M. M. 2008. Sea turtles of Mozambique: Report. *In:* PEREIRA, M. A. M. (ed.). Cabo Delgado Biodiversity and Tourism.

PERRY, J., 2005. Environmental Impact Assessment for Offshore Drilling the Falkland Islands to Desire Petroleum Plc. 186pp

PETERSON, C.H., LANEY, W. and T. RICE, 2001. Biological impacts of beach nourishment. Workshop on the Science of Beach Renourishment, May 7-8, 2001. Pine Knoll Shores, North Carolina.

PIDCOCK, S., BURTON, C. and M. LUNNEY, 2003. *The potential sensitivity of marine mammals to mining and exploration in the Great Australian Bight Marine Park Marine Mammal Protection Zone.* An independent review and risk assessment report to Environment Australia. Marine Conservation Branch. Environment Australia, Cranberra, Australia. pp. 85.

PLÖN, S., 2004. The status and natural history of pygmy (*Kogia breviceps*) and dwarf (*K. sima*) sperm whales off Southern Africa. PhD Thesis. *Department of Zoology & Entomology* (Rhodes University), p. 551.

POOPETCH, T. 1982. Potential effects of offshore tin mining on marine ecology. Proceedings of the Working Group Meeting on environmental management in mineral resource development, *Mineral Resource Development Series*, **49**: 70-73.

RAMSAY, P.J. and W.R. MILLER, 2006. Marine geophysical technology used to define coelacanth habitats on the KwaZulu-Natal shelf, South Africa. *S. Afr. J. Sci.*, 102, 427–435.

RANGER, 1993. Exploration Drilling Phase Environmental ImpactAssessment; Licence Area 2213, Namibia. Ranger Oil Limited.

RIBBINK, A.J. and M. ROBERTS, 2006. African Coelacanth Ecosystem Programme: An overview of the conference contributions. *S. Afr. J. Sci.*, 102, 409-415.

RICHARDSON, W.J., GREENE, C.R., JR., KOSKI, W.R. and M.A. SMULTEA, 1991. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska-1990 phase: Sound propagation and whale responses to playbacks of continuous drilling noise from an ice platform, as studied in pack ice conditions. Unpublished report to U.S. Minerals Management Service, Procurement Operations, Herndon, Virginia: Contract 14-12-0001-30412 (LGL Report TA848-)

RICHARDSON, W.J., GREENE, C.R., MALME, C.I. and THOMSON, D.H. 1995. *Marine Mammals and Noise*. Academic Press, San Diego, CA.

RICHARDSON, W.J. and B. WÜRSIG, 1997. Influences of man-made noise and other human actions on cetacean behaviour. *Marine and Freshwater Behaviour and Physiology* **29**: 183-209.

RICHTER, C.F., DAWSON, S.M. and E. SLOOTEN, 2003. Sperm whale watching off Kaikoura, New Zealand: Effects of current activities on surfacing and vocalisation patterns. Science for Conservation Report No. 219. Department of Conservation, Wellington, New Zealand.

RICHTER, C., DAWSON, S. and E. SLOOTEN, 2006. Impacts of commercial whale watching on male sperm whales at Kaikoura, New Zealand. *Marine Mammal Science* **22**: 46-63.

ROBERTS, M.J., RIBBINK, A.J., MORRIS, T., VAN DEN BERG, M.A., ENGELBRECHT, D.C. and R.T. HARDING, 2006. Oceanographic environment of the Sodwana Bay coelacanths (*Latimeria chalumnae*), South Africa. *S. Afr. J. Sci.*, 102, 435-443.

ROBERTS, M.J., VAN DER LINGEN, C.D. & M. VAN DEN BERG, 2010. Shelf currents, lee-trapped and transient eddies on the inshore boundary of the Agulhas Current, South Africa: their relevance to the KwaZulu-Natal sardine run. *African Journal of Marine Science* **32**: 423–447.

ROBERTS, R.D., MURRAY, S., GREGORY, R. and B.A. FOSTER, 1998. Developing an efficient macrofauna monitoring index from an impact study - A dredge spoil example. *Mar. Pollut. Bull.*, **36**: 231-235.

ROBERTS, M.J. and C. NIEUWENHUYS, 2016. Observations and mechanisms of upwelling in the northern KwaZulu-Natal Bight, South Africa, *African Journal of Marine Science*, 38:sup1, S43-S63, DOI: 10.2989/1814232X.2016.1194319

ROBERTS, M.J., NIEUWENHUYS, C. AND L.A. GUASTELLA, 2016. Circulation of shelf waters in the KwaZulu-Natal Bight, *South Africa, African Journal of Marine Science*, 38:sup1, S7-S21, DOI: 10.2989/1814232X.2016.1175383

ROGERS, A.D., 1999. The biology of Lophelia pertusa (Linnaeus 1758) and other deep-water reef-forming corals and impacts from human activities. *International Review of Hydrobiology*, 84 (4): 315-406.

ROSS, G.J.B. 1984. The smaller cetaceans of the east coast of southern Africa. A*nn. Cape. Prov. Mus. (nat. Hist.)*, **15 (2)**.

ROSS, G.J.B., 1979. Records of pygmy and dwarf sperm whales, genus *Kogia*, from southern Africa, with biological notes and some comparisons. *Annals of the Cape Province Museum (Natural History)* **11**: 259-327.

ROSS, G.J.B. 1984. The smaller cetaceans of the east coast of southern Africa. A*nn. Cape. Prov. Mus. (nat. Hist.)*, **15 (2)**.

ROSS, G.J.B., COCKCROFT V.G. & D.S. BUTTERWORTH, 1987. Offshore distribution of bottlenosed dolphins in Natal coastal waters and Algoa Bay, Eastern Cape. *S. Afr. J. Zool.* **22:** 50-56.

ROSS, G.J.B., COCKCROFT, V.G., MELTON D.A. & D.S. BUTTERWORTH, 1989. Population estimates for bottlenose dolphins *Tursiops truncatus* in Natal and Transkei waters. *S. Afr. J. mar. Sci.* **8**: 119-129.

ROUX, J-P., BRADY, R. & P.B. BEST, 2011. Southern right whales off Namibian and their relationship with those off South Africa. Paper SC/S11/RW16 submitted to IWC Southern Right Whale Assessment Workshop, Buenos Aires 13-16 Sept. 2011.

ROUX, J.-P., BRABY, R.J. & BEST, P.B., 2015. Does disappearance mean extirpation? The case of right whales off Namibia. *Marine Mammal Science*, 31(3): 1132–1152.

ROWAT, D. 2007. Occurrence of the whale shark (*Rhincodon typus*) in the Indian Ocean: a case for regional conservation. *Fisheries Research*, **84**: 96-101.

ROWAT, D. & M. GORE, 2007. Regional scale horizontal and local scale vertical movements of whale sharks in the Indian Ocean off Seychelles. *Fisheries Research* **84**: 32–40.

RYAN, P.G. & B. ROSE, 1989. Migrant seabirds. In: Oceans of life off southern Africa. PAYNE, A.I.L. and CRAWFORD, R.J.M. (Eds.). Cape Town. Vlaeberg Publishers, pp. 274-287.

SAAYMAN, G.S., BOWER, D., TAYLER, C.K., 1972. Observations on inshore and pelagic dolphins on the south-eastern cape coast of south Africa. *Koedoe* 15: 1-24.

SALMON, M., 2003. Artificial night lighting and sea turtles. *Biologist*, **50**: 163 - 168.

SAUER, W.H.H., SMALE, M.J. & M.R. LIPINSKI, 1992. The location of spawning grounds, spawning and shoaling behaviour of the squid *Loligo vulgaris reynaudii* (D'Orbigny) off the eastern Cape coast, South Africa. *Mar. Biol.*, **114**: 97-107.

SCHAANNING, M.T., TRANNUM, H.C., OXNEVAD, S., CARROLL, J. and T. BAKKE, 2008. Effects of drill cuttings on biogeochemical fluxes and macrobenthos of marine sediments. *Journal of Experimental Marine Biology and Ecology,* **361**: 49–57.

SCHAFFNER, L.C., 1993. *Baltimore Harbor and channels aquatic benthos investigations at the Wolf Alternate Disposal Site in lower Chesapeake Bay.* Final report prepared by the College of William and Mary and the Virginia Institute of Marine Science for the US Army Corps of Engineers, Baltimore District: pp. 120.

SCHARLER, U.M., AYERS, M.J., DE LECEA, A.M., PRETORIUS, M., FENNESSY, S.T., HUGGETT, J.A., MACKAY, C.F. and D. MUIR, 2016. Riverine influence determines nearshore heterogeneity of nutrient (C, N, P) content and stoichiometry in the KwaZulu-Natal Bight, South Africa, African Journal of Marine Science, 38:sup1, S193-S203, DOI: 10.2989/1814232X.2016.1150347

SCHARTL, M., HORNUNG, U., HISSMANN, K., SCHAUER, J. and H. FRICKE, 2005. Relatedness among east African coelacanths. *Nature*, 435, 901.

SCHLEYER, M.H., 1985. Chaetognaths as indicators of water masses in the Agulhas Current system. Investl. Rep. Oceanogr. Res. Inst., Durban, 61, 20 pp.

SCHOLZ, D., MICHEL, J., SHIGENAKA, G. and R. HOFF, 1992. Biological resources. In: An Introduction to Coastal habitats and Biological Resources for Oil Spill Response. Report HMRAD 92-4 pp (4)-1-66. NOAA Hazardous Materials Response and Assessment Division, Seattle.

SCHRATZBERGER, M., REES, H.L. and S.E. BOYD, 2000a. Effects of simulated deposition of dredged material on structure of nematode assemblages - the role of burial. *Mar. Biol.*, **136**: 519-530.

SCHRATZBERGER, M., REES, H.L. and S.E. BOYD, 2000b. Effects of simulated deposition of dredged material on structure of nematode assemblages - the role of contamination. *Mar. Biol.*, **137**: 613-622.

SCHROEDER, B.A., FOLEY, A.M. & D.A. BAGLEY, 2003. Nesting patterns, reproductive migrations, and adult foraging areas of loggerhead turtles. *Loggerhead sea turtles*, 114-124.

SCHUMANN, E.H., 1986. Bottom boundary layer observations inshore of the Agulhas Current. *S. Afr. J. mar. Sci.*, **4:** 93-102.

SCHUMANN, E.H. 1988. Physical oceanography off Natal. In: Coastal ocean sciences of Natal. South Africa (Ed. E.H. Schumann). Springer Verlag, Berlin. 101-130.

SCHUMANN, E.H. 1998 . The coastal ocean off southeast Africa, including Madagascar coastal segment (15, W). In: The Sea, Vol.11. Robinson, A.R. and Brink, K. (eds). John Wiley & Sons, Inc.

SCHUMANN, E.H., PERRINS, L.-A. & I.T. HUNTER, 1982. Upwelling along the south coast of the Cape Province, South Africa. *S. Afr. J. Sci.*, **78**: 238-242.

SCHUMANN, E.H. and MARTIN, J.A. 1991. Climatological aspects of the coastal wind field at Cape Town, Port Elizabeth and Durban. *South African Geography Journal*, **73**: 48-51.

SHAMBLIN, B. M., BOLTEN, A. B., ABREU-GROBOIS, F. A., BJORNDAL, K. A., CARDONA, L., CARRERAS, C. C., CLUSA, M., MONZÓN-ARGÜELLO, C., NAIRN, C. J., NIELSEN, J. T., NEL, R., SOARES, L. S., STEWART, K. R., TÜRKOZAN, O. & DUTTON, P. H. Submitted. Loggerhead turtle phylogeography and stock structure revisited with expanded mitochondrial control region sequences. *PLoS ONE*.

SHANNON, L.V. 1985. The Benguela ecosystem Part I. Evolution of the Benguela, physical features and processes. *Oceanogr. Mar. Biol. Ann. Rev.*, **23**: 105-182.

SHAUGHNESSY, P.D. 1977. Flock size in Sabine's Gull. *Cormorant*. **3**: 17.

SHPARKOVSKI, I.A., PETROV, V.S. and N.V. KOZAK, 1989. Physiological Criteria [for] Assessment of the Ecological Situation During Drilling on the Shelf. In: *Theses of the First All-Union Conference on Fisheries Toxicology*, **2**:199-200 Riga.

SIMMONS, R.E., 2005. Declining coastal avifauna at a diamond mining site in Namibia: comparisons and causes. *Ostrich*, **76**: 97-103.

SINK, K., BOSHOFF, W., SAMAAI, T., TIMM, P.G. & S.E. KERWATH, 2006. Observations of the habitats and biodiversity of the submarine canyons at Sodwana Bay. *S. Afr. J. Sci*. **102**: 466–474.

SINK, K.J., ATTWOOD, C.G., LOMBARD, A.T., GRANTHAM, H., LESLIE, R., SAMAAI, T., KERWATH, S., MAJIEDT, P., FAIRWEATHER, T., HUTCHINGS, L., VAN DER LINGEN, C., ATKINSON, L.J., WILKINSON, S., HOLNESS, S. & T. WOLF, 2011. Spatial planning to identify focus areas for offshore biodiversity protection in South Africa. Unpublished Report. Cape Town: South African National Biodiversity Institute.

SINK, K., HOLNESS, S., HARRIS, L., MAJIEDT, P., ATKINSON, L., ROBINSON, T., KIRKMAN, S., HUTCHINGS, L., LESLIE, R., LAMBERTH, S., KERWATH, S., VON DER HEYDEN, S., LOMBARD, A., ATTWOOD, C., BRANCH, G., FAIRWEATHER, T., TALJAARD, S., WEERTS, S., COWLEY, P., AWAD, A., HALPERN, B., GRANTHAM, H. and T. WOLF, 2012. National Biodiversity Assessment 2011: Technical Report. Volume 4: Marine and Coastal Component. South African National Biodiversity Institute, Pretoria.

SINK, K. and C. LAWRENCE, 2008. Threatened Marine and Coastal Species in Southern Africa. SANBI Report, pp16.

SMALE, M.J., KLAGES, N.T., DAVID, J.H.M. & V.G. COCKROFT, 1994. Predators of the Agulhas Bank. *S. Afr. J. Sci*., **90**: 135-142.

SMIT, M.G.D., HOLTHAUS, K.I.E., TAMIS, J.E., JAK, R.G., KARMAN, C.C., KJEILEN-EILERTSEN, G., TRANNUM, H. and J. NEFF, 2006. *Threshold levels and risk functions for non-toxic sediment stressors: burial, grain size changes, and hypoxia - summary report – TNO*.

SMIT, M.G.D., HOLTHAUS, K.I.E., TRANNUM, H.C., NEFF, J.M., KJEILEN-EILERTSEN, G., JAK, R.G., SINGSAAS, I., HUIJBREGTS, M.A.J. and A.J. HENDRIKS, 2008. Species sensitivity distributions for suspended clays, sediment burial, and grain size change in the marine environment. *Environmental Toxicology and Chemistry*, **27**: 1006-1012.

SMITH, C.L., RAND, R.S., SCHAEFFER, B. and J.W. ATZ, 1975. *Latimeria*, the living coelacanth, is ovoviviparous. *Science* 190:1105-1106.

SMITH, S.D.A. and M.J. RULE, 2001. The effects of dredge-spoil dumping on a shallow water soft-sediment community in the Solitary Islands Marine Park, NSW, Australia. *Mar. Pollut. Bull.*, **42**: 1040-1048.

SMULTEA, M.A., KIECKHEFER, T.R. and A.E. BOWLES, 1995. Response of humpback whales to an observation aircraft as observed from shore near Kauai, Hawaii, 1994. Final Report for the 1994 Marine Mammal Research Program of the Acoustic Thermometry of Ocean Climate (ATOC) study. Prepared by the Bioacoustics Research Program of the Cornell Laboratory of Ornithology, Cornell University, Ithaca, NY, USA. 46 p.

SMULTEA, M.A., MOBLEY, J.R., FERTL, D. and G.L. FULLING, 2008. An unusual reaction and other observations of sperm whales near fixed-wing aircraft. *Gulf and Caribbean Research* **20**: 75-80.

SOUTHALL, B.L., A.E. BOWLES, W.T. ELLISON, J.J. FINNERAN, R.L. GENTRY, C.R. GREENE, JR., D. KASTAK, D.R. KETTEN, J.H., MILLER, P.E. NACHTIGALL, W.J. RICHARDSON, J.A. THOMAS and P.L. TYACK, 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquatic Mammals*, **33(4)**: 411-522.

SPRAGUE, J.B. and W.J. LOGAN, 1979. Separate and joint toxicity to rainbow trout of substances use in drilling fluid for oil exploration. *Environ. Pollut.*, **19**: 269-281.

STARCZAK, V.R., FULLER, C.M. and C.A. BUTMAN, 1992. Effects of barite on aspects of ecology of the polychaete *Mediomastus ambiseta*. *Marine Ecology Progress Series*, **85**: 269-282.

STEINHAUER, M., CRECELIUS, E. and W. STEINHAUER, 1994. Temporal and spatial changes in the concentrations of hydrocarbons and trace metals in the vicinity of an offshore oil-production platform. *Marine Environmental Research*, **37**: 129-163.

STEWART, B.S., EVANS, W.E. and F.T. AWBREY, 1982. Effects of man-made waterborne noise on behaviour of belukha whales (Delphinapterus leucas) in Bristol Bay, Alaska. Unpublished report for National Oceanic and Atmospheric Administration, Juneau, Alaska, by Hubbs/Sea World Research Institute, San Deigo, California. HSWRI Technical Report 82-145.

SWART, V.P. and LARGIER, J.L. 1987. Thermal structure of Agulhas Bank water. In: The Benguela and Comparable Ecosystems, PAYNE, A.I.L., GULLAND, J.A. and BRINK, K.H. (Eds.), *S. Afr. J. mar. Sci.*, **5**: 243-254.

SWART, D.H. and SERDYN, J. de V. 1981. Statistical analysis of visually observed wave data from voluntary observing ships (VOS) for the South African east coast. Stellenbosch. NRIO. Unpublished data.

SWART, D.H. and SERDYN, J. de V. 1982. Statistical analysis of visually observed wave data from voluntary observing ships (VOS) for the South African east coast. CSIR Report T/ (to be published).

TAGATZ, M.E. and M. TOBIA, 1978. Effect of barite ($BaSO_4$) on development of estuarine communities. *Estuarine and Coastal Marine Science,* **7**: 401-407.

TEAL, J.M. and R.W. HOWARTH, 1984. Oil spill studies: a review of ecological effects. *Environmental Management*, **8**: 27-44.

THOMSON, DR., DAVIS, R.A., BELLORE, R., GONZALEZ, E., CHRISTIAN, J., MOULTON, V. and K HARRIS, 2000. Environmental assessment of exploration drilling off Nova Scotia. Report by LGL Limited for Canada-Nova Scotia Offshore Petroleum Board. Mobil Oil Canada Properties Ltd.. Shell Canada Ltd.. Imperial Oil Resources Ltd.. Gulf Canada Resources Ltd.. Chevron Canada Resources, PanCanadian Petroleum. Murphy Oil Ltd.. and Norsk Hydro. 278 p.

TRANNUM, H.C., NILSSON, H.C., SCHAANNING, M.T. and S. ØXNEVAD, 2010. Effects of sedimentation from water-based drill cuttings and natural sediment on benthic macrofaunal community structure and ecosystem processes. *Journal of Experimental Marine Biology and Ecology,* **383**: 111-121.

THOMSON, DR., DAVIS, R.A., BELLORE, R., GONZALEZ, E., CHRISTIAN, J., MOULTON, V. and K HARRIS, 2000. Environmental assessment of exploration drilling off Nova Scotia. Report by LGL Limited for Canada-Nova Scotia Offshore Petroleum Board. Mobil Oil Canada Properties Ltd.. Shell Canada Ltd.. Imperial Oil Resources Ltd.. Gulf Canada Resources Ltd.. Chevron Canada Resources, PanCanadian Petroleum. Murphy Oil Ltd.. and Norsk Hydro. 278 p.

TREFRY, J.H., DUNTON, K.H., TROCINE, R.P, SCHONBERG, S.V., MCTIGUE, N.D., HERSH E.S. and T.J. McDONALD, 2013. Chemical and biological assessment of two offshore drilling sites in the Alaskan Arctic. *Marine Environmental Research*, **86**: 35-45.

TUCEK, J., NEL, R., GIRANDOT, M. & G. HUGHES, (Submitted). Estimating reproductive age and size of loggerhead sea turtles. *Endangered Species Research*.

TURK, T.R. and M.J. RISK, 1981. Effects of sedimentation of infaunal invertebrate populations in Cobequid Bay, Bay of Fundy. *Can. J. Fish. Aquat. Sci.*, **38**: 642-648.

TURPIE, J.K., 1995. Prioritizing South African estuaries for conservation: A practical example using waterbirds. *Biol. Cons.*, **74**: 175-185.

TURPIE, J.K. & S.J. LAMBERTH, 2010. Characteristics and value of the Thukela Banks crustacean and linefish fisheries, and the potential impacts of changes in river flow. *African Journal of Marine Science* **32**: 613-624.

TURPIE, J.K., BECKLEY, L.E. and KATUA, S.M. 2000. Biogeography and selection of priority areas for conservation of South African coastal fishes. *Biological Conservation* **92**: 59–72.

TYACK, P.4L., ZIMMER, W.M.X., MORETTI, D., SOUTHALL, B.L., CLARIDGE, D.E., DURBAN, J.W., CLARK, C.W., *et al.*, 2011. Beaked Whales Respond to Simulated and Actual Navy Sonar, 6(3). doi:10.1371/journal.pone.0017009

UKEN, R & N. MKIZE, 2012. Unconsolidated sediment distribution within the KwaZulu-Natal Bight. Extended Abstract, ACEP. Pp4.

UNDERHILL, L.G. and COOPER, J. 1982. Counts of waterbirds at coastal wetlands in southern Africa. 1978 to 1981. Unpublished MS. PFIAO.

UNEP-WCMC, 2011. Isimangaliso Wetland park KwaZulu-Natal, South Africa. http://www.unep-wcmc.org/medialibrary/2011/06/29/0efed969/iSimangaliso.pdf.

U.S. DEPARTMENT OF THE INTERIOR. MMS GULF OF MEXICO OCS REGION. 2000. Press Release: Deepwater Production in the Gulf of Mexico Jumps Dramatically. 26 June, 2000. <http://www.gomr.mms.gov/homepg/whatsnew/newsreal/000626s.html>.

VAN DER ELST, R. 1976. Game fish of the east coast of southern Africa. I: The biology of the elf *Pomatomus saltatrix* (Linneaus) in the coastal waters of Natal. *ORI Investl. Rep.*, 44. 59pp.

VAN DER ELST, R. 1981. A Guide to the Common Sea Fishes of Southern Africa. Struik, Cape Town: 367pp.

VAN DER ELST, R. 1988. Shelf ichthyofauna of Natal. In: Coastal ocean sciences of Natal, South Africa (Ed. E.H. Schumann). Springer-Verlag, Berlin: 209-225.

VAN DER MOLEN, J.S., SCHARLER, U.M. and D. MUIR, 2016. Species composition, abundance and biomass of microphytoplankton in the KwaZulu-Natal Bight on the east coast of South Africa. In: ROBERTS, M.J., FENNESSY, S.T., BARLOW, R.G. (eds), Ecosystem processes in the KwaZulu-Natal Bight. *African Journal of Marine Science* 38(Supplement): S139–S153.

VENTER P., TIMM P.,GUNN G., LE ROUX E., SERFONTEIN C., SMITH P., SMITH E., BENSCH M., HARDING D. and P. HEEMSTRA, 2000. Discovery of a viable population of coelacanths (*Latimeria chalumnae* Smith, 1939) at Sodwana Bay, South Africa. *S. Afr. J. Sci*,. **96**: 567–568.

VERHEYE, H.M., HUTCHINGS, L., HUGGETT, J.A., CARTER, R.A., PETERSON, W.T. and PAINTING, S.J. 1994. Community structure, distribution and trophic ecology of zooplankton on the Agulhas Bank with special reference to copepods. *S. Afr. J. Sci.*, **90**: 154-165.

VOLKMAN, J.K., MILLER, G.J., REVILL, A.T. and D.W. CONNELL, 1994. Environmental implications of offshore oil and gas development in Australia – oil spills. In: SWAN, J.M., NEFF, J.M. and P.C. YOUNG (eds), Environmental implications of offshore oil and gas development in Australia. The findings of an independent scientific review. Australian Exploration Association, Sydney. pp 509-695.

WALLACE, B.P. & T.T. JONES, 2008. What makes marine turtles go: a review of metabolic rates and their consequences. *Journal of Experimental Marine Biology and Ecology*, **356**: 8-24.

WANG, F. and P.M. CHAPMAN, 1999. Biological implications of sulfide in sediment—a review focusing on sediment toxicity. *Environ. Toxicol. Chem.*, **18**: 2526-2532.

WATKINS, W.A., 1981. Activities and underwater sounds of fin whales. *Scientific Reports of the Whales Research Institute* **33**: 83-117.

WATKINS, W.A., 1986. Whale reactions to human activities in Cape Cod waters. *Mar. Mamm. Sci.*, **2(4)**: 251-262.

WATKINS, W.A. and W.E. SCHEVILL, 1977. Sperm whale codas. *Journal of the Acoustical Society of America* **62**: 1485-90 + disk in pocket.

WHITE, R.W., GILLON, K.W., BLACK, A.D. and J.B. REID, 2001. Vulnerable concentrations of seabirds in Falkland Islands waters.. JNCC, Peterborough.

WHITEFIELD, A.K., ALLANSON, B.R. and HEINECKEN, T.J.E. 1983 Estuaries of the Cape, Part II: Synopses of available information on individual systems. Report No. 22: Swartvlei (CMS 11). HEYDORN, A.E.F. and GRINDLEY, J.R. (eds). Stellenbosch, CSIR Research Report 421, 62pp.

WHITEHEAD, H., 2002. Estimates of the current global population size and historical trajectory for sperm whales. *Marine Ecology Progress Series*, **242**: 295-304.

WILES, E., GREEN, A., WATKEYS, M., JOKAT, W. & R. KROCKER, 2013. The evolution of the Tugela Canyon and submarine fan: A complex interaction between margin erosion and bottom current sweeping, southwest Indian Ocean, South Africa. *Marine and Petroleum Geology* **44**: 60-70.

WILKINSON, S. & D.W. JAPP, 2010. Proposed 2D Seismic Survey within Blocks 2931c, 2931d, 2932a and 2932c (East Coast, South Africa). Specialist Study on the Impact on the Fishing Industry. pp19.

WITHERINGTON, B.E., 1992. Behavioral responses of nesting sea turtles to artificial lighting. *Herpetologica*, 31-39.

WITHERINGTON, B.E. & K.A. BJORNDAL, 1991. Influences of wavelength and intensity on hatchling sea turtle phototaxis: implications for sea-finding behavior. *Copeia*, 1060-1069.

WITHROW, D.E., 1983. Gray whale research in Scammon's Lagoon (Laguna Ojo de Liebre). *Cetus* **5(1)**: 8-13.

WOLFSON, A., VAN BLARICOM, G., DAVIS, N. and G.S. LEWBE, 1979. The marine life of an offshore oil platform. *Marine Ecology Progress Series,* **1**: 81-89.

WU, R.S.S., 2002. Hypoxia: from molecular responses to ecosystem responses. *Mar. Pollut. Bull.*, **45**: 35-45.

WÜRSIG, B., LYNN, S.K., JEFFERSON, T.A. and K.D. MULLIN, 1998. Behaviour of cetaceans in the northern Gulf of Mexico relative to survey ships and aircraft. *Aquatic Mammals* **24**: 41-50.

WYNEKEN, J. & D. WITHERINGTON, 2001. The anatomy of sea turtles, Southeast Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, US Department of Commerce.

YOUNG, P.M., 2009. An integrated marine GIS bathymetric dataset for KwaZulu-Natal. M.Sc. Thesis University of KwaZulu-Natal. pp212.

ZONFRILLO, B., 1992. The menace of low-flying aircraft to Ailsa Craig. Scottish Bird News, 28 :4.

APPENDIX A

Curriculum Vitae

Dr Andrea Pulfrich

Dr Andrea Pulfrich is the founder, director, sole employee and share holder of Pisces Environmental Services (Pty) Ltd. The company was established in January 1998 to help fill the growing need for an expert interface between users of the coastal and marine environment and the various national and provincial management authorities. Since then, PISCES has been providing a wide range of information, analyses, environmental assessments, advice and management recommendations to these user groups, particularly the South African and Namibian marine diamond mining and hydrocarbon industries.

Personal Details

Born:	Pretoria, South Africa on 11 August 1961
Nationality and Citizenship:	South African and German
Languages:	English, German, Afrikaans
ID No:	610811 0179 087

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	PO Box 31228, Tokai, 7966, South Africa
Tel:	+27 21 782 9553
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Academic Qualifications

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

Membership in Professional Societies

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

Employment History and Professional Experience

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

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

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

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

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

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

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

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

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

Annex D1.2

Marine Ecology Specialist Details

environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

	(For official use only)
File Reference Number:	12/12/20/ or 12/9/11/L
NEAS Reference Number:	DEA/EIA
Date Received:	

Application for integrated environmental authorisation and waste management licence in terms of the-

(1) National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2014; and

(2) National Environmental Management Act: Waste Act, 2008 (Act No. 59 of 2008) and Government Notice 921, 2013

PROJECT TITLE

Specialist:	Dr Andrea Pulfrich		
Contact person:	Dr Andrea Pulfrich		
Postal address:	PO Box 302, McGregor		
Postal code:	6708	Cell:	082 7818152
Telephone:	021 7829553	Fax:	n/a
E-mail:	apulfrich@pisces.co.za		
Professional affiliation(s) (if any)	South African Council for Natural Scientific Professions (Pr.Sci.Nat. No: 400327/06) SA Institute of Ecologists and Environmental Scientists International Association of Impact Assessment (South Africa) Registered Environmental Assessment Practitioner (Certification Board for Environmental Assessment Practitioners of South Africa).		

Project Consultant:			
Contact person:			
Postal address:			
Postal code:		Cell:	
Telephone:		Fax:	
E-mail:			

4.2 The specialist appointed in terms of the Regulations_

I, Dr Andrea Pulfrich, declare that -- General declaration:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

Andrea Pulfrich

Signature of the specialist:

Pisces Environmental Services (Pty) Ltd

Name of company (if applicable):

06/09/2018

Date:

CONTENT OF THE SPECIALIST REPORT CHECKLIST

The content of this report has been prepared in terms of Regulation GNR 326 of 2014, as amended, Appendix 6, as shown below.

Specialist Report Checklist

Contents of this report in terms of Regulation GNR 982 of 2014, Appendix 6	**Cross-reference in this report**
(a) details of— the specialist who prepared the report; and the expertise of that specialist to compile a specialist report including a curriculum vitae;	Appendix A
(b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	Pg i
(c) an indication of the scope of, and the purpose for which, the report was prepared;	Section 1.1
(cA) an indication of the quality and age of base data used for the specialist report;	Section 1.2
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 4.3
(d) the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	n/a
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Sections 4.1 and 5.1
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;;	Section 4.3
(g) an identification of any areas to be avoided, including buffers;	Sections 3.2 and 4.3
(h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Chapter 3
(i) a description of any assumptions made and any uncertainties or gaps in knowledge;	Chapter 3 and Chapter 5
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity or activities.	Chapter 4
(k) any mitigation measures for inclusion in the EMPr;	Chapter 4
(l) any conditions for inclusion in the environmental authorisation;	n/a
(m) any monitoring requirements for inclusion in the EMPr or environmental authorisation;	n/a
(n) a reasoned opinion— (i) whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and (ii) if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Chapter 6
(o) a description of any consultation process that was undertaken during the course of preparing the specialist report;	n/a
(p) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	n/a
(q) any other information requested by the competent authority.	n/a