BASIC ASSESSMENT FOR THE INSTALLATION OF PROPOSED BYPASS PIPELINES AND REPOSITIONING OF A SINGLE-POINT MOORING (SPM) BUOY, MOSSEL BAY

Marine Ecology Specialist Statement

Prepared for:

srk consulting

On behalf of

PetroSA

October 2022

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ABBREVIATIONS and UNITS

BCC	Benguela Current Commission
CBA	Critical Biodiversity Area
CBM	Central Buoy Mooring
CITES	Convention on International Trade in Endangered Species
CMS	Conservation of Migratory Species
CSIR	Council for Scientific and Industrial Research
DEFF	Department of Environment, Forestry and Fisheries
EBSA	Ecologically or Biologically Significant Area
ESA	Ecological Support Area
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Oragnisation
IUCN	International Union for the Conservation of Nature
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NEMBA	National Environmental Management: Biodiversity Act
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Services
NRC	National Research Council
PIM	Particulate Inorganic Matter
PLEM	pipeline end manifold
POM	Particulate Organic Matter
SPM	Single Point Mooring
TSPM	Total Suspended Particulate Matter

Units used in the report

cm	centimetres
dB	decibels
Hz	Herz
kHz	kiloHerz
km	kilometres
m	metres
m^2	square metres
m^3	cubic metres
mg/ℓ	milligrams per litre
mm	millimetres
NTU	nephelometric turbidity units
µm	micron
µPa	micro Pascal
ppm	parts per million
″	inch
%	percentage

~	approximately
<	less than
>	greater than

EXPERTISE AND DECLARATION OF INDEPENDENCE

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

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

This specialist report was compiled on behalf of SRK Consulting (South Africa) (Pty) Ltd (SRK) for their use in preparing a Basic Assessment for the proposed installation of two new pipelines between the single point mooring and the onshore tank farm in Mossel Bay. I do hereby declare that Pisces Environmental Services (Pty) Ltd is financially and otherwise independent of the Applicant and SRK.

Dr Andrea Pulfrich

1. GENERAL INTRODUCTION

PetroSA operates and owns a Gas to Liquids Refinery in Voorbaai, Mossel Bay to import and export gas using a Central Buoy Mooring (CBM) and Single Point Mooring (SPM) facility. Three pipelines of varying diameters connect the pipeline end manifold (PLEM) at the SPM to the onshore tank farm in a single 36˝ carrier pipeline 2.95 km in length. The CBM connects to the carrier pipeline through a tie-in structure located ~1,400 m from the SPM. Due to corrosion over an 800 m section of the existing 12 ˝ and 14 ˝ pipelines and the 36 ˝ carrier bundle pipeline linking the PLEM to the tie-in structure, two new bypass steel pipelines need to be installed, and both the PLEM and tie-in structure replaced.

The bundle was constructed and installed in 1991 to export distillate (Kerosene and diesel) from the Voorbaai tank farm to the offloading point at the SPM. The pipelines' service was updated in 2012 to export petrol *via* the 12 ˝ line and import reformate and condensate *via* the 14 ˝ line. The 12 ˝ pipeline was decommissioned in 2019 due to severe corrosion. The 14 ˝ pipeline has also suffered metal loss and is in need of repair. The new dual pipeline will be installed on the seabed, parallel to and 15 m from the existing housing structure, and will terminate in a new PLEM that will tie in to the existing SPM buoy (once repositioned) and the existing operating pipeline bundle.

1.1. Description of Development

The proposed installation method involves the towing of the two pipelines as a single twin pipeline pair from an onshore fabrication facility. The pipeline assembly will be terminated with a lead and trail towhead structure with temporary buoyancy to assist with the tow operations. The structures also provide fixed tie-in points to the bundle and SPM at either end. Connection of the newly installed pipelines to the existing bundle and SPM will be undertaken with diver support. Weights will be temporarily landed onto the pipeline to anchor it to the seabed. The pipeline will be jetted in below the seabed surface (buried) and sediment allowed to backfill naturally. It is also proposed to install mechanical protection (concrete or bitumen mattresses, or burial) over exposed rigid tie-in spools and flange connections.

The replacement pipeline-pair will be positioned 15 m south and parallel to the existing bundle pipeline and will be connected *via* the replacement tie-in structure to the existing operational bundle section that runs ashore. The pipeline pair will be buried along their length between the replacement tie-in structure and the replacement PLEM to ensure on-seabed stability, with transition from seabed to burial depth starting ~20 m from each structure. Both the cut and abandoned bundle pipelines and the abandoned PLEM and tie-in structures will be recovered.

It is proposed that the replacement pipeline sections will be welded together in string lengths of approximately 200 m, stored on an elevated pipe rack on land, and pulled to sea across a launch-way on the beach using a tugboat. Once the first section of pipeline is towed out, the next section will be welded on and towed. The pipeline will be fitted with temporary installation aids in the form of buoyancy tanks, trimming chains to counterbalance buoyancy and ballast weight chains to keep the pipeline on the seabed in the nearshore. Once the required length of the pipeline has been reached, a trail head is welded on to the final 12 ˝ and 14 ˝ sections and the pipeline will be 'parked' on the seabed until a suitable weather window occurs. Once the weather window is favourable, the ballast weight chains are removed and the pipe assumes an off-bottom position ready for towing to site. Once in position, the pipes are flooded, pigged to remove any biofouling organisms and hydrotested before being positioned on the seabed for tie-in of the replacement pipeline pair to the existing operational pipeline bundle section going ashore. The pipeline will be buried along most of its length to maintain on-bottom stability by jetting it into the unconsolidated sediments and allowing natural back-filling of sediments.

This Marine Ecological Specialist Study deals only with the potential marine impacts of the proposed pipeline installation.

1.2 Scope of Work

This specialist report was compiled as a desktop study on behalf of SRK, for submission with the Baseline Assessment Report for the proposed installation of two new pipelines between the single point mooring and the onshore tank farm in Mossel Bay

The Specialist ToRs for the Marine Ecology Specialist Statement are as follows:

- Provide a general description of the marine biodiversity and ecosystem goods and services in the project area, including their current condition, trends and uses, based on current available literature.
- Describe the habitats that are likely to be affected by the installation of the pipeline and associated infrastructure.
- Identify sensitive marine species (receptors).
- Confirm the presence and/or status of priority biodiversity features, habitats and species in the impact area, and contextualise the assessment within local, regional and national conservation priorities.
- Highlight the implications of gaps in information, uncertainty and/or risks in terms of irreversibility of impacts, irreplaceable loss of resource, etc.
- Assess whether there are any secondary, indirect, induced and/or cumulative impacts.
- Identify, describe and assess the significance of potential impacts of the proposed installation of the pipeline and associated infrastructure on Biodiversity and Ecosystem Services.
- Systematically apply the Mitigation Hierarchy for avoidance and reduction of any negative impacts across all phases of the project.
- When making recommendations, specify and identify all mitigation with reference to the options in the Mitigation Hierarchy.

1.3 Approach to the Study

As determined by the terms of reference, this study has adopted a 'desktop' approach. Further descriptions of the natural baseline environment in the study area are based on a review and collation of existing information and data from scientific literature, and internal reports. The sources consulted are listed in the Reference chapter.

All identified marine and coastal impacts are summarised, categorised and ranked in appropriate impact assessment tables.

1.3.1 Assumptions, Limitations and Information Gaps

This study has adopted a 'desktop' approach. Consequently, the description of the natural baseline environment in the study area is based largely on the previous reports prepared for various other projects undertaken in the area. No new data have been collected.

The assumptions made in this specialist assessment are:

- The study is based on the **project description made available to the specialists at the time of the commencement of the study** (engineering designs, construction approaches, discharge temperatures *etc*.).
- Potential changes in the marine environment such as sea-level rise and/or increases in the severity and frequency of storms related to climate change are not included in the terms of reference and therefore not dealt with in this report.

1.3.2 Impact Assessment Methodology

SRK's prescribed impact assessment methodology was used to assess the significance of potential impacts. Using this methodology, the **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact was rated as set out below:

Step 1 - The **consequence** rating for the impact was determined by assigning a score for each of the three criteria (A-C) listed below and then **adding** them.

Rating	Definition of Rating	Score
A. *Extent* *– the area over which the impact will be experienced*		
None		0
Local	Confined to project or study area or part thereof (e.g. site)	1
Regional	The region, which may be defined in various ways, e.g. cadastral, catchment, topographic	2
(Inter) national	Nationally or beyond	3
B. *Intensity* *– the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources*		
None		0
Low	Site-specific and wider; natural functions and processes are negligibly altered	1
Medium	Site-specific and wider; natural functions and processes continue albeit in a modified way	2
High	Site-specific and wider; natural functions or processes are severely altered	3

C. *Duration* *– the timeframe over which the impact will be experienced and its reversibility*		
None		0
Short-term	Up to 2 years (i.e. reversible impact)	1
Medium-term	2 to 15 years (i.e. reversible impact)	2
Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	0-2	3 - 4	5	6	7	8 - 9
Consequence Rating	Insignificant	Very low	Low	Medium	High	Very high

Step 2 -The **probability** of the impact occurring is assessed according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Step 3 -The overall **significance** of the impact is determined as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

The impact significance rating should be considered by authorities in their decision-making process based on the implications of ratings ascribed below:

- **Insignificant**: the potential impact is negligible and will not have an influence on the decision regarding the proposed activity/development.
- **Very Low:** the potential impact is very small and should not have any meaningful influence on the decision regarding the proposed activity/development.
- **Low**: the potential impact may not have any meaningful influence on the decision regarding the proposed activity/development.

- **Medium**: the potential impact should influence the decision regarding the proposed activity/development.
- **High:** the potential impact will affect the decision regarding the proposed activity/development.
- **Very High**: The proposed activity should only be approved under special circumstances.

Step 4 - The **status** of the impact is noted as being either negative or positive.

Step 5 -The level of **confidence** in the assessment of the impact is stated as high, medium or low.

Step 6 - Practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact are identified and described as either:

- **Essential**: best practice measures which must be implemented and are non-negotiable; and
- **Best Practice**: recommended to comply with best practice, with adoption dependent on the proponent's risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Having inserted *Essential* mitigation and optimisation measures, the impact is then re-assessed assuming mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures. *Best practice* measures are also inserted into the impact assessment table, but not considered in the "with mitigation" impact significance rating.

2. BRIEF DESCRIPTION OF THE BASELINE MARINE ENVIRONMENT

2.1. The Physical Environment

Mossel Bay is a log spiral bay terminating in the rocky Cape St Blaize headland. The coastline is characterised by a fairly continuous stabilised aeolian dune ridge at the back of the contemporary beach. The bay itself comprises thin, predominantly unconsolidated sediments underlain by calcareous cemented sandstone of Pleistocene age. North of the Klein Brak River mouth these calcarenites extend into the current beach as intertidal wave cut platform (referred to as "beach rock") and may continue under the dune ridge. In the nearshore regions they are evident as extensive low relief reefs, which appear to extend out to at least 30 m depth, and are relicts of wind-blown foredune systems and beach deposits from Quaternary low sea level stands (DEFF 2019).

The unconsolidated sediments similarly extend 20-30 km offshore (Melis & Du Plessis 1990), and may form ripples oriented coast-parallel and reaching amplitudes of 0.5 m with typical wavelengths of approximately 3 m. The nearshore sands are mobile because of wave resuspension and transport and are therefore an unstable habitat for benthic macrofauna.

The South Coast inner shelf is characterised by a general lack of terrigenous sediments. The sand delivered by rivers is transported eastwards by longshore drift, while suspended mud is distributed further offshore and transported west by bottom currents to form the South Coast mud belt (Cawthra 2014;Cawthra *et al.* 2015).

The bathymetry in the bay is relatively shallow with the 25 m depth contour in the area of the SPM buoy being located ~3.5 km offshore. The only bathymentric feature of note in the project area is Seal Island, which is part of an east-west striking elongated trough of rock of Cretaceous and Tertiary age. An eastward trending, sediment-filled paleo river channel skirts the northern side of Seal Island (Melis & Du Plessis 1990).

Mossel Bay lies on the Eastern Agulhas Bank where the shelf widens rapidly. This serves to insulate the inner shelf waters from the direct influence of the Agulhas Current. Wind-driven currents dominate in the inshore waters, with wave-driven currents strongly influencing the predominantly eastward flows in the typically narrower surf-zone. Shelf waters are, however, influence by the Agulhas Current, as topographically-driven upwelling on the Eastern Agulhas Bank results in cold upwelled water forming a cold basal layer that contributes to intense seasonal thermoclines in the area (Eagle & Orren 1985; Swart & Largier 1987). Wind-driven upwelling occurs in the summer to the west of Cape St Blaize under easterly wind conditions (Schumann *et al.* 1982) resulting in vertically sheared currents with high surface velocities and generally quiescent conditions deeper in the water column. Upon reversal of these winds, these colder waters may be forced eastwards into Mossel Bay (Goschen & Schumann 1995).

For Mossel Bay the mean significant wave height is 1.21 m and extreme wave height is 2.8 m, indicating the relatively sheltered nature of the western regions of the coastal embayment. Due to the significant reduction in easterly waves these western regions of the bay remains sheltered year round, suggesting that locations may exist where there is a significant risk of the long-term accumulation of organic material on the seabed (DEFF 2019). Heaviest seas and swells are predominantly south easterly in response to the south east winds. South westerly winds seldom cause swell problems. In common with the rest of the southern African coast, tides are semi-diurnal, with a total range of some 1.5 m at spring tide, but only 0.6 m during neap tide periods.

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulate matter. Total Suspended Particulate Matter (TSPM) can be divided into Particulate Organic Matter (POM) and Particulate Inorganic Matter (PIM), the ratios between them varying considerably. The POM usually consists of detritus, bacteria, phytoplankton and zooplankton, and serves as a source of food for filter-feeders. On the Agulhas Bank, seasonal microphyte production associated with upwelling events, both inshore and along the shelf edge, will play an important role in determining the concentrations of POM. PIM, on the other hand, is primarily of geological origin consisting of fine sands, silts and clays. The PIM loading in nearshore waters is strongly related to natural riverine inputs and resuspension and bedload transport of seabed sediments. As there are no major rivers entering the Southeast coast, PIM loading in the offshore regions of the Reconnaissance Permit Area would be negligible. Offshore of the continental shelf, and within the Reconnaissance Permit Area, the oceanic surface waters are clear and background concentrations are typically <1 mg/ℓ (Emery *et al.* 1973).

A feature of continental shelf waters off the Southeast coast is the benthic nepheloid layer (Zoutendyk & Duvenage 1989; Dorfler 2002). This layer can be up to 10 m thick and may have Total Suspended Particulate Matter (TSPM) values of up to 38 mg/ℓ. It is usually located below the thermocline at a depth of between 20 m and 30 m (Zoutendyk & Duvenage 1989). Although thought to originate from detrital fallout from surface waters, Zoutendyk & Duvenage (1989) reported that Particulate Organic Matter (POM) contributed <10% of the TSPM in the turbid layer. The dynamics of the nepheloid layer are complex, and appear to be driven by a combination of wind, waves and currents. The benthic nepheloid layer plays a significant role in the benthic community structure of nearshore reefs (Zoutendyk & Duvenage 1989).

2.2. The Ecological Environment

Mossel Bay falls within the warm temperate Agulhas ecoregion. The ecosystem type within the bay is classified as Western Agulhas Bay (Figure 1), which is considered poorly protected (Figure 2) and has been assigned an ecosystem threat status of 'Endangered' (Figure 3) (Sink *et al.* 2019). The shoreline of the project area comprised primarily Agulhas Dissipative-Intermediate Sandy Shores, with Agulhas Mixed Shores and Agulhas Sheltered Rocky Shores becoming more prevalent towards Cape St Blaize. To the north towards the Klein Brak River mount, the wave-cut platforms contribute to Agulhas Mixed Shore substratum. These habitats are considered 'Moderately Protected' and 'Well Protected'. The shore crossing of the pipeline is located in a 'Well Protected' habitat that has been assigned a threat status of 'Least Concern'. The shoreline crossing lies adjacent to the Gericke estuary and just south of the Tweekuilen estuary, both of which have been assigned a threat staus of 'Least Concern' (van Niekerk *et al.* 2019).

The biota of nearshore marine habitats on the South Coast are relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. Communities within this region are largely ubiquitous, particular only to substrate type (i.e. hard vs. soft bottom), exposure to wave action, or water depth. Habitats specific to the study area include:

- Sandy intertidal and subtidal substrates,
- Intertidal rocky platforms and subtidal reefs, and
- The water body

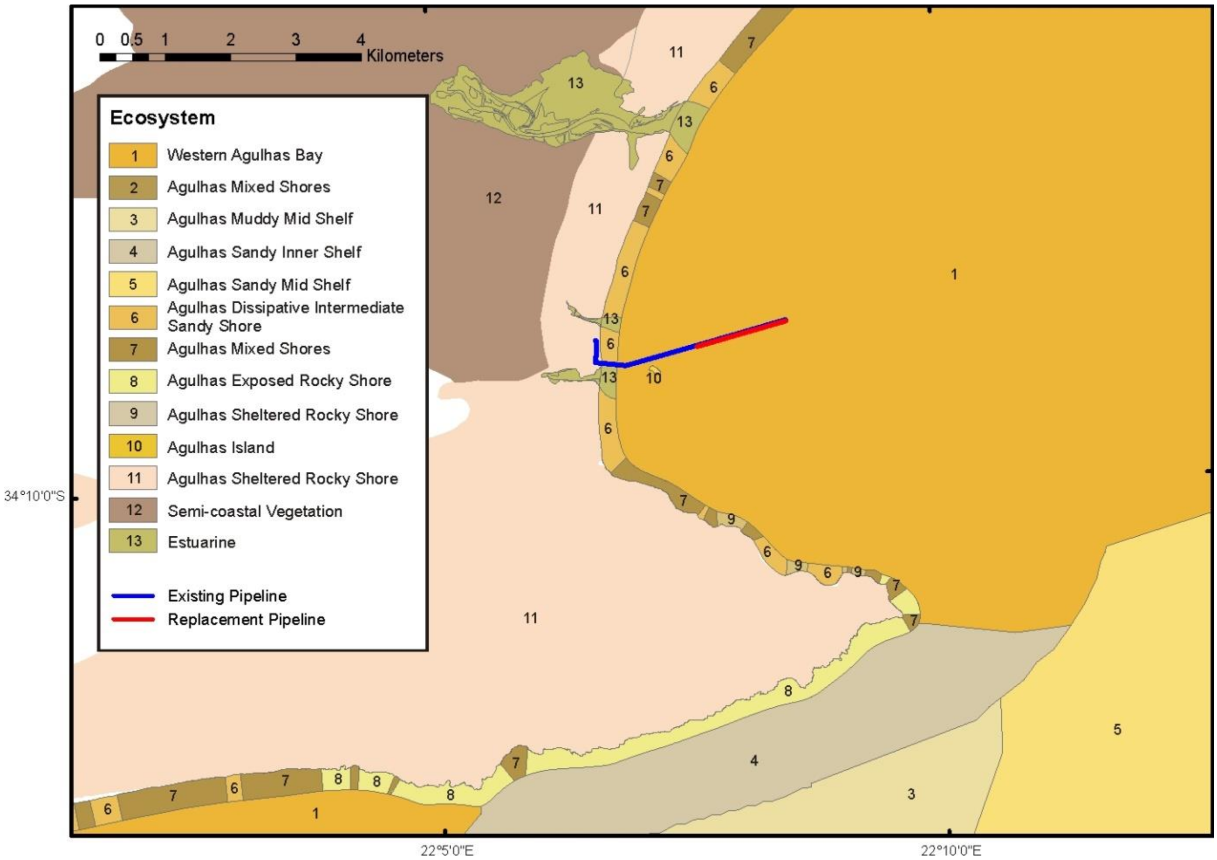

Figure 1: Ecosystem types within Mossel Bay and around Cape St. Blaize (adapted from Sink *et al.* 2019).

The biological communities of these environments consist of many hundreds of species, often displaying considerable temporal and spatial variability (even at small scales). No rare or endangered species have been recorded (Awad *et al.* 2002). The biological communities 'typical' of these habitats are described briefly below, focussing both on dominant, commercially important and conspicuous species, as well as potentially threatened or sensitive species, which may be affected by the proposed pipeline replacement.

2.2.1 Sandy Substrate Habitats and Biota

The benthic biota of soft bottom substrates constitutes invertebrates that live on, or burrow within, the sediments, and are generally divided into megafauna (>10 cm), macrofauna (animals >1 mm) and meiofauna (<1 mm).

Intertidal Sandy Beaches

The faunal community composition of sandy beaches is largely dependent on the interaction of wave energy, beach slope and sand particle size (beach morphodynamics). There are three general morphodynamic beach types: dissipative, reflective and intermediate beaches (McLachlan *et al.* 1993). Dissipative beaches are wide and flat with fine sands and high wave energy. Waves start to break far from the shore in a series of spilling breakers that 'dissipate' their energy across a broad surf zone. This generates slow swashes with long periods, resulting in less turbulent conditions on the gently sloping beach face. These beaches usually harbour the richest intertidal faunal communities. Reflective beaches have low wave energy, are coarse grained (>500 μm sand) and have narrow and steep intertidal beach faces. The relative absence of a surf zone causes the waves to break directly on the shore causing a high turnover of sand. The result is depauperate faunal communities. Intermediate beach conditions exist between these extremes and have a very variable species composition (McLachlan *et al*. 1993, Jaramillo *et al*. 1995, Soares 2003). This variability is mainly attributable to the amount and quality of food available. Virtually all the beaches in Mossel Bay are classified as dissipative-intermediate sandy shores comprised of dune and medium-grained marine sands. Considerable small-scale spatial and temporal variability in the physical state can, however, occur and beaches and their associated macrofaunal communities should therefore be viewed as extremely dynamic.

The beach and surf-zones together are considered a functional ecosystem, which interacts with the terrestrial environment through the movement of sand, and with the nearshore through the activity of rip currents (McLachlan *et al*. 1981; McLachlan *et al*. 1984; Talbot 1986). In this semi-enclosed ecosystem, surf-zone phytoplankton are the producers, macrofauna the consumers and the interstitial meiofauna the decomposers.

Numerous methods of classifying beach zonation have been proposed, based either on physical or biological criteria. The general scheme proposed by Branch & Griffiths (1988) is used below (Figure 4).

The high shore between the base of the dunes and the high water mark is typically dominated by the semi-terrestrial isopod *Tylos capensis* and the beach hopper *Talorchestia capensis*. Scavenging whelks such as *Bullia rhodostoma* are common in the midshore zone while *B. pura* and *B. digitalis* occur in the surf zone (McLachlan 1977), feeding on almost any carion cast up on the shore. Several cirolanid isopod species occur across the intertidal moisture gradient (De Ruyck *et al*. 1992) with the genus *Eurydice* being the most common from the midshore and extending into the low shore.

The isopods *Pontegeloides latipes* and *Excirolana natalensis* occur in lower numbers above mid-tidal level extending also into the lowshore. The nemertean worm *Cerebratulus* sp. and polychaete *Nephtys* sp. are typical of the mid- and lowshore, extending into the surf-zone.

In the lowshore, the macrofauna is dominated by the filter feeding sand mussel *Donax serra*, with the smaller *D. sordidus* dominating the surf-zone (McLachlan & Bate 1984). Sand mussels in the region are thought to dependent largely on *Anaulus* and consequently reach their highest biomasses where surf diatom (*Anaulus)* blooms are most frequent. Such blooms occur in the northern portions of Mossel Bay (Harris *et al*. 2022). Sand mussels are key organisms in the foodwebs and are preyed on by a variety of animals including gulls, oystercatchers, crabs, sandsharks, rays and fish. The surf-zone swimming crab *Ovalipes punctatus*, is an important invertebrate predator on Southern Cape beaches, feeding predominantly on *Donax* and *Bullia* (Du Preez 1984).

A brief beach survey undertaken for the ecological assessment as part of a previous EIA for the installation of the pipeline in Voorbaai noted numerous crustacean isopods, but no molluscs or polychaetes were found. The sand dollar (*Echinodiscus bisperforatus*) is also found in the area, but populations are reported to be concentrated in the area between the harbour and Dias beach to the south of the sub-sea pipeline (SRK 2001).

Figure 2: The protection levels of marine ecosystem types in Algoa Bay as assessed by Sink *et al.* (2019).

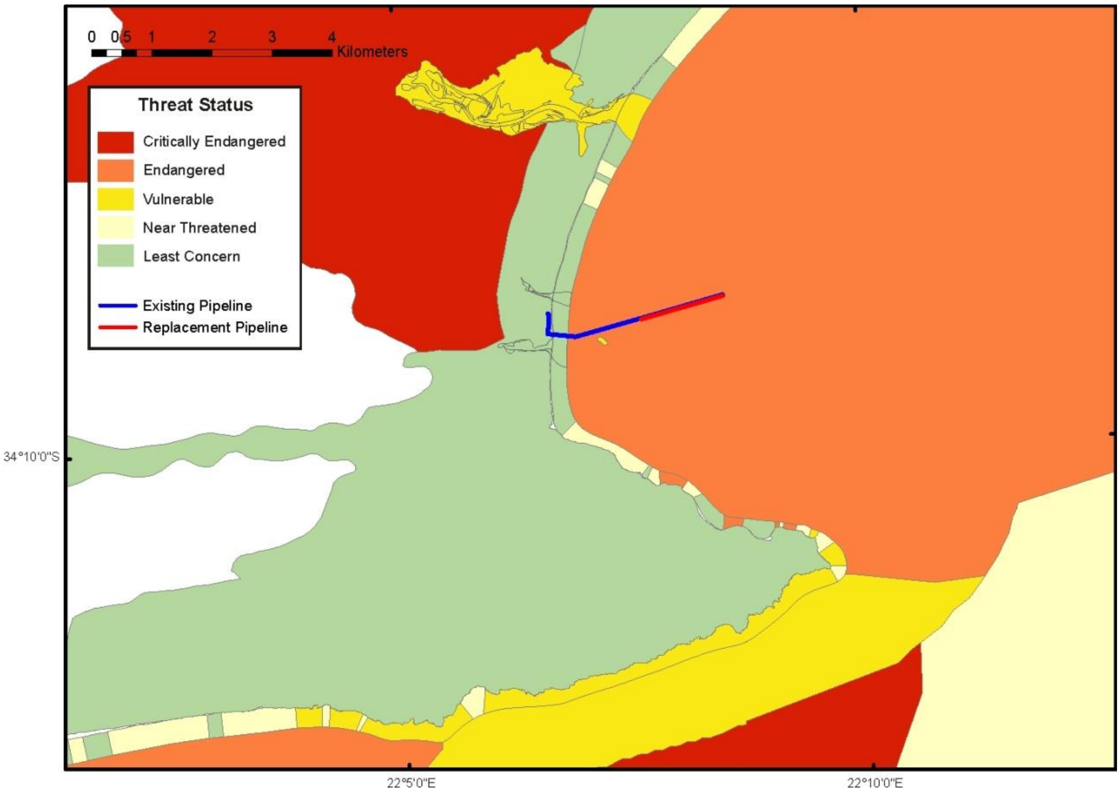

Figure 3: Ecosystem threat status for coastal and offshore benthic habitat types around Mossel Bay (adapted from Sink *et al.* 2019).

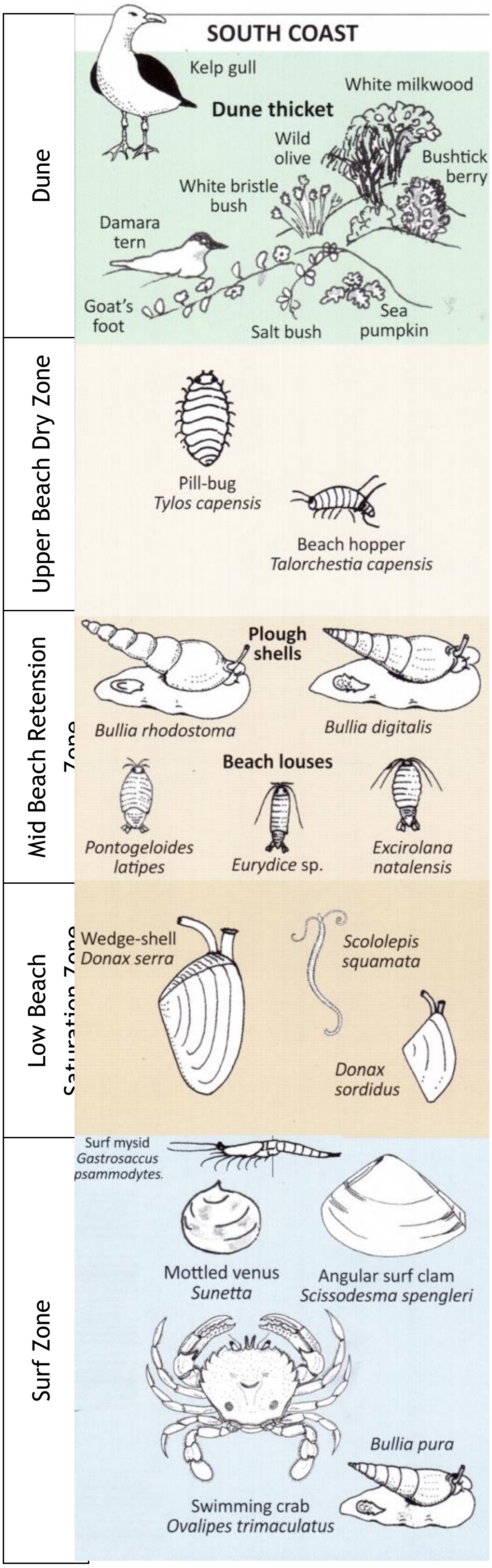

Figure 4: Schematic representation of the South Coast intertidal zonation on sandy beaches (adapted from Branch & Branch 2018).

Meiofaunal organisms (<1 mm in size), which occur within the sediment, are dominated by nematodes and harpacticoid copepods, with turbellarians, mystacocarids, archiannelids, oligochaetes and other minor groups constituting the rest (McLachlan *et al*. 1981). Nematodes dominate where the sand is finer and the oxygen level lower, while harpacticoid copepods prefer coarser well-drained sands.

A number of fish species occur in and just beyond the surf zone, namely galjoen (*Dichistius capensis*) and white steenbras (*Lithognathus lithognathus*), which swim over submerged beaches at high tide and feed on small crabs and macrofauna (Branch & Branch 2018). Elf (*Pomatomus saltatrix*), leervis (*Lichia amia*), sand shark (*Rhinobatos annulatus*) and white sea catfish (*Galeichthys feliceps*), are some of the characteristic species that favour the sandy surf-zone.

Nearshore and Offshore unconsolidated habitats

On intertidal beaches, species diversity peaks just above the low tide mark, declining with distance through the inner turbulent zone and reaching a minimum at the break point of the waves (Figure 5). Within the surf zone, the inner turbulent zone extends to 2 m depth and the transition zone spans approximately 2 - 5 m depth. Extreme turbulence is experienced in this zone, and as a consequence this zone typically harbours the lowest diversity. The outer turbulent zone extends below 5 m depth, where turbulence is significantly decreased and species diversity is again much higher and abundance and biomass generally increase with depth.

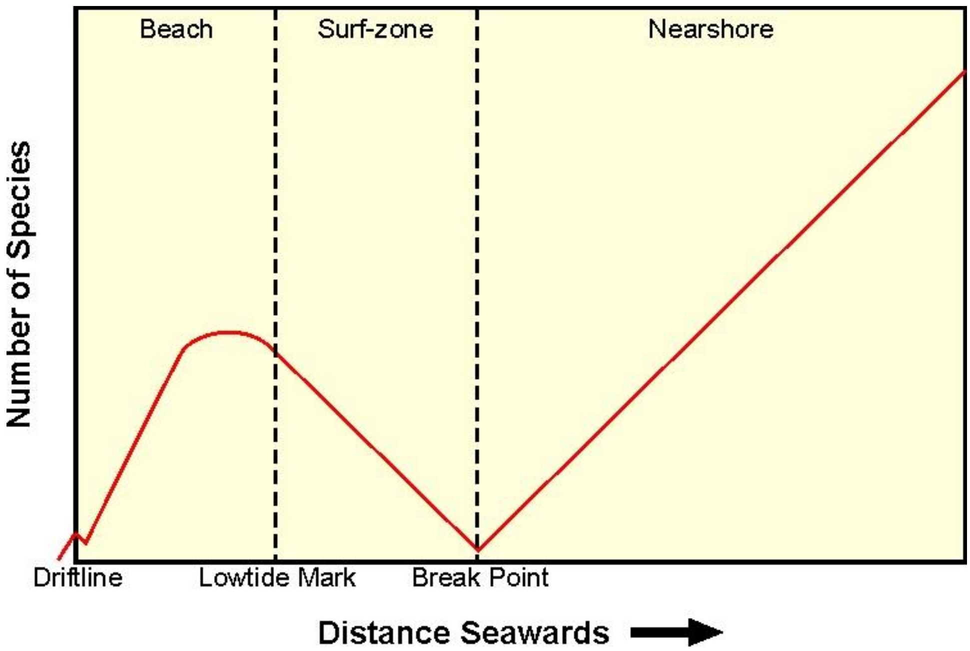

Figure 5: Hypothetical pattern of species diversity across a beach/surf-zone system (from Brown & McLachlan 1994).

The bentho-pelagic mysid *Gastrosaccus psammodytes* is most abundant in the swash and surf-zone of sandy beaches and occurs in densities of up to 55 individuals/m^2, forming an important link between the primary food supply and higher levels of the macrofaunal foodweb (Wooldridge 1983; Wooldridge *et al*. 1997). Other macrofauna typical of the inner turbulent zone include the ribbon worm

Cerebratulus fuscus (Nemertea), cumaceans and a variety of polychaetes. Seawards of the breaker zone, the scavenging polychaete worm Goniadopsis incerta is abundant (McLachlan & Bate 1984).

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

Resuspension, mobilisation and transport of sands in the nearshore of the project area by wave action results in a dynamic and unstable habitat where macrofauna are likely to be poorly represented (DEFF 2019). A survey of this habitat immediately offshore of the Klein Brak River (CCA 2008) found that all of the dominant macrofaunal groups were present, with polychaetes and crustaceans being numerically dominant. Although the taxonomic resolution of this study was too coarse to determine whether there are unique species in the area, benthic taxonomic abundance data from similar depth horizons in Algoa Bay (Klages & Bornman 2003; Masikane 2011; Dawson *et al*. 2019), highlighted both Amphipoda and Polychaeta as the dominant groups in terms of abundance. Masikane (2011) reported an exceptionally rich macrofaunal diversity in Algoa Bay comprising 187 species from 137 different genera. The taxa that occur in the study are should thus similarly have wide distributions, at least along the South African coast, and diversity in Mossel Bay may be higher than previously expected.

Chokka squid (*Loligo vulgaris reynaudii*) may occur in <50 m water depths in Voorbaai (Augustyn *et al*. 1994). The species occurs extensively on the Agulhas Bank out to the shelf edge (500 m depth contour) increasing in abundance towards the eastern boundary of the South Coast, especially between Plettenberg Bay and Algoa Bay (Augustyn 1990; Sauer *et al*. 1992; Augustyn *et al*. 1994). Adults are normally distributed in waters >100 m, except along the eastern half of the South Coast where they also occur inshore, forming dense spawning aggregations at depths between 20 - 130 m (Augusty 1990; Roberts *et al*. 2012; Downey 2014). The most important spawning grounds are between Plettenberg Bay and Algoa Bay (Augustyn 1990), these having been linked to specific spawning habitat requirements (Roberts & Sauer 1994; Roberts 2005). Spawning aggregations are a seasonal occurrence, reaching a peak between September and December (Augustyn *et al*. 1992). Eggs are typically laid on sand and low relief reefs in large and sheltered bays, with environmental conditions playing an important role in the migration of the adults into the spawning areas.

2.2.2 Rocky Habitats and Biota

The majority of the off-shore zone of Mossel Bay consists of a sandy sea bed although various rocky outcrops exist (Melis & Du Plessis 1990; Cawthra 2014; Cawthra *et al*. 2015). Reefs in similar water depths, further along the coastline, predominantly contain red-bait (*Pyura stolonifera*), encrusting monaxonid type sponges, sea-anemones, soft corals and, to a limited extent, star fish.

The low-lying rocky outcrops within sandy floor environments such as Mossel Bay will be strongly influenced by periodic sand inundation, which will limit the successful colonisation, establishment and maintenance of benthic communities, with those functional groups present representing opportunistic and sand-tolerant species whose presence is determined by their abilities to withstand physical smothering by sand. Many of the more sand-tolerant and opportunistic foliose algal genera have mechanisms of growth, reproduction and perennation that contribute to their persistence on sand-influenced shores (Daly & Matheison 1977; Airoldi *et al.* 1995; Anderson *et al.* 2008).

CSIR (1988) reported that the biological community on the western end of the subtidal reef extending eastwards from the Klein Brak river mouth was dominated by Porifera (sponges), Bryozoa (moss or lace animals), Cnidaria (hydroids and sea fans) and Tunicata (sea squirts) with other fauna such as annelids (worms) also being present along with algae). This community structure appears to be relatively uniform for the nearshore reefs along the South Coast, as Götz *et al.* (2009a) found, in terms of frequency of occurrence, the important taxa on the reefs in the Goukamma area, were Bryozoa, Porifera (~20% each), sea fans (16%), Tunicata (14%), Algae (10%), feather stars (8%) and hydroids (8%). Algae and sea squirts were mainly distributed in shallower regions of the reefs (~10 m depth) with sponges, lace animals and sea fans dominant in the deeper areas (10-30 m depths) (Lwandle 2009; Götz *et al.* 2009a). Intrusions of cold, high turbidity water have been implicated as being an important controlling factor limiting the amount of algae and, therefore, excluding grazers from the fauna.

The aeolianite reefs are also important for fish, with 34 species being observed during underwater video surveys off Goukamma (Götz *et al.* 2009b). These included species such as Roman, Santer, Red stumpnose, Red steenbras, Poenskop, Panga, Yellowtail, Geelbek, Kob, Dageraad and Carpenter, several of which are classed as globally 'Critically Endangered' (Dageraad), 'Endangered' (Red stumpnose, Red Steenbras), 'Vulnerable' (Silver kob, Poenskop, Geelbek) or 'Near Threatened' (Roman, Carpenter) (Sink *et al.* 2019).

Another species known to frequent these reefs is the great white shark (*Carcharodon carcharias*), which apparently utilises the reefs for resting between hunting for seals around Seal Island in Voorbaai. The great white shark is a significant apex predator in the Mossel Bay Bay area, particularly in the vicinity of the seal colony at Seal Island. Currently there is no consensus on the number of white sharks in South Africa (Cliff *et al.* 1996; Towner *et al.* 2013; Andreotti *et al.* 2016; Irion *et al.* 2017). White sharks migrate along the entire South African coast, typically being present at seal colonies during the winter months, but moving nearshore during summer (Johnson *et al.* 2009). The species is known to seasonally aggregate at specific localities along the South African coast, including False Bay, Gans Bay, Struisbaai, Mossel Bay (Kock & Johnson 2006; Kock *et al.* 2013; Towner *et al.* 2013) and Algoa Bay (Dicken *et al.* 2013). Recent research at Mossel Bay into the residency patterns of white sharks revealed that male sharks display low site fidelity, often rapidly moving in an out of the area. Females in contrast, display high site fidelity and may remain resident in the area for up to two months (Koch & Johnson 2006; see also Jewell *et al.* 2013, 2014; Ryklief *et al.* 2014). 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, particularly by immature individuals (Bonfil *et al.* 2005).

Although not necessarily threatened with extinction, the great white shark is described as 'Vulnerable' in the IUCN Red listing, and is 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 is also listed as 'Vulnerable' in the List of Marine Threatened or Protected Species (TOPS) as part of the National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEMBA). In response to global declines in abundance, white sharks were legislatively protected in South Africa in 1991. Long-term catch-per-unit-effort data from protective gillnets in KwaZulu-Natal, however, suggest a 1.6% annual increase in capture rate of this species following protection, although high interannual variation in these data lessen the robustness of the trend (Dudley & Simpfendorfer 2006). In Mossel Bay three different business activities make commercial use of the presence of these sharks, namely, boat viewing trips around Seal Island, shark cage diving off Seal Island and helicopter flights along the coastline to Hartenbos to view the sharks off the back breakers of the shoreline.

2.2.3 The Pelagic Habitat

Various sharks are known to occur in coastal waters along the South Coast (Harris *et al*. 2022), many of which are considered globally threatened (Table 1).

Table 1: Some of the chondrichthyan species occurring along the South Coast (CCA & CMS 2001; Harris *et al*. 2022).

Name	Species Name	National Assessment	Global Assessment
Great white shark	*Carcharodon carcharias*	Least Concern	Vulnerable
Ragged-tooth shark	*Odontaspis taurus*	Data deficient	Near Threatened
Bronze whaler shark	*Carcharhinus brachyurus*	Data deficient	Vulnerable
Dusky shark	*Carcharhinus obscurus*	Data deficient	Endangered
Lesser Guitarfish	*Acroteriobatus annulatus*	Least Concern	Vulnerable
Spotted Gully shark	*Triakis megalopterus*	Data deficient	Least Concern
Biscuit skate	*Raja straeleni*	Not Assessed	Near Threatened
Spearnose skate	*Rostroraja alba*	Not Assessed	Endangered
Slime skate	*Dipturus pullopunctatus*	Not Assessed	Least Concern
Blue stingray	*Dasyatis chrysonota*	Data deficient	Near Threatened
Smooth Hammerhead	*Sphyrna zygaena*	Endangered	Vulnerable
Soupfin shark	*Galeorhinus galeus*	Endangered	Criticly Endangered
Sevengill cowshark	*Notorynchus cepedianus*	Least Concern	Vulnerable
Sixgill Sawshark	*Pliotrema warreni*	Not Assessed	Least Concern
Shortfin Mako	*Isurus oxyrinchus*	Vulnerable	Endangered
Tiger catshark	*Halaelurus natalensis*	Not Assessed	Vulnerable
African Angelshark	*Squatina africana*	Not Assessed	Near Threatened
Twineye skate	*Raja miraletus*	Not Assessed	Least Concern
Spotted spiney dogfish	*Squalus acanthias*	Least Concern	Vulnerable
Puffadder shyshark	*Haploblepharus edwardsii*	Not Assessed	Endangered

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

Five species of sea turtles occur along the South Coast; the green turtle (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*) and loggerhead (*Caretta caretta*). In the National Assessment (Hughes & Nel 2014a, 2014b), the leatherback is described as 'Endangered', the loggerhead as 'Vulnerable' and the Green and Hawksbill as 'Near Threatened'.

Five species of cetaceans are regularly seen in Mossel Bay; including southern right whales (*Eubalaena australis*), humpback whales (*Megaptera novaeangliae*), Bryde's whales (*Balaenoptera brydei*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), and Indian Ocean humpback dolphins (*Sousa chinensis*) (Levy 2017). Of these, the Bryde's whale, Indo-Pacific bottlenose dolphin and Indian Ocean humpback dolphin are resident, with southern rights and humpbacks being migratory. The Bryde's whale is considered 'Vulnerable' in the South African Regional Assessment (Child *et al*. 2016), with southern right and humpback whales assessed as being both regionally and internationally of 'Least Concern'. Southern right whales calve in Mossel Bay annually between June and November.

The population of Indo-Pacific bottlenose dolphin inhabiting the South Coast has been estimated as between 16,000 and 41,000 based on data collected within Algoa Bay (Reisinger & Karczmarski 2010). The species tends to occur in large groups of 10s to 100s of individuals. The Ifafi to False Bay subpopulation of the *aduncus* form is considered endemic and is listed as 'Near Threatened' in the South African Red Data Book, while the seasonal migratory subpopulation is considered 'Data Deficient' (Peddemors & Oosthuizen 2004; Child *et al*. 2016; Cockcroft *et al*. 2016).

The Indo-Pacific humpback dolphin is primarily a shallow-water species restricted to <30 m depth and are usually observed within 500 m from shore. Due to the recent recognition of the western Indian Ocean population as a separate species, their conservation status is regarded as 'Endangered', and the species is accepted to be South Africa's most endangered resident cetacean (Child *et al*. 2016) with <1,000 individuals occupying the South African coastline (James *et al*. 2015). Several lines of evidence suggest a decline in the population numbers and changes in behaviour (Peddemors *et al*. 2004; Plön *et al*. 2015; Vermeulen *et al*. 2017). Localised populations in the Plettenberg Bay - Algoa Bay region are concentrated around shallow reefs, 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*. 2000a). It appears that the species is more closely associated with estuaries and rivers than other shallow-water cetaceans. In Mossel Bay sightings rate appears to increase between November and April, with largest groups observed in winter (May – October) (James *et al.* 2015). In Mossel Bay the population was estimated at 125 individuals of all age groups, with within-year estimates of between 33 and 86 individuals. Half of the animals identified in Mossel Bay are considered 'transient' between the Mossel Bat, Plettenberg Bay and Algoa Bay populations, with 40% considered 'semi-resident' (James *et al.* 2015). The South Coast population is separated from all other populations of the species in South Africa, making them particularly vulnerable (Vermeulen *et al.* 2017). Recent studies in Plettenberg Bay and Algoa Bay indicated a decrease in sightings and group sizes in both locations by approximately 50% in the last decade and a reduction in mean group sizes from 7 to 4 individuals (Greenwood 2013; Koper *et al.* 2016). Several hypotheses have been 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.

The Cape fur seal (*Arctocephalus pusillus pusillus*) is the only seal species that has breeding colonies along the South Coast, namely on Seal Island in Mossel Bay, the northern shore of the Robberg Peninsula in Plettenberg Bay and at Black Rocks (Bird Island group) in Algoa Bay. The timing of the annual breeding cycle is very regular occurring between November and January, after which the breeding colonies break up and disperse. Seal Island in Mossel Bay hosts a population of approximately 3,000 to 4,000 seals.

2.3. Significance and Sensitivity

Marine Protected Areas

The only formally protected area in Mossel Bay is Seal Island, which is a provincial nature reserve that supports a Cape fur seal breeding colony. It is also an area where great white sharks congregate. Other marine protected areas (MPAs) in the broader project area are Robberg MPA in Plettenberg BayTsitsikamma MPA to the east of Mossel Bay, and the Stillbaai MPA and De Hoop MPA to the west of Mossel Bay.

Ecologically or Biologically Significant Areas (EBSAs)

As part of a regional Marine Spatial Management and Governance Programme (MARISMA 2014-2020), the Benguela Current Commission (BCC) and its member states have identified a number of Ecologically or Biologically Significant Areas (EBSAs) both spanning the border between Namibia and South Africa and along the South African West, South and East Coasts, with the intention of implementing improved conservation and protection measures within these sites. South Africa currently has 12 EBSAs solely within its national jurisdiction with a further three having been proposed. It also shares eight trans-boundary EBSAs with other countries (Namibia (3) and Mozambique (2)) and high seas (3). The principal objective of these EBSAs is the identification of features of higher ecological value that may require enhanced conservation and management measures.

There is no overlap of the proposed project with any of these EBSAs, with the closest being the Agulhas Bank Nursery Area EBSA, which estends from Cape St. Blaize westwards to the De Hoop MPA.

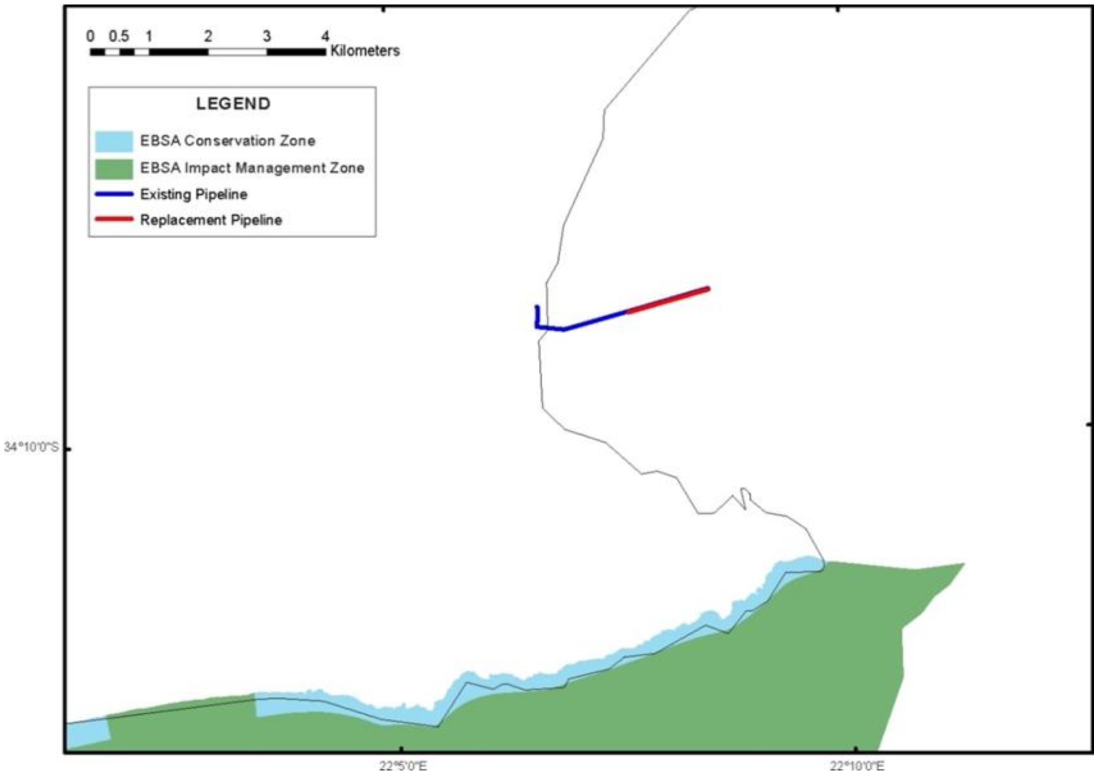

Figure 6: The PetroSA pipeline in Mossel Bay in relation to the Agulhas Bank Nursery Area Ecologically and Biologically Significant Area (EBSAs) on the South coast (adapted from Sink *et al.* 2019).

Biodiversity Priority Areas

The National Coastal and Marine Spatial Biodiversity Plan[1] comprises a map of Critical Biodiversity Areas (CBAs), Ecological Support Area (ESAs) and accompanying sea-use guidelines. The CBA Map presents a spatial plan for the marine environment, designed to inform planning and decision-making in support of sustainable development. The sea-use guidelines enhance the use of the CBA Map in a range of planning and decision-making processes by indicating the compatibility of various activities with the different biodiversity priority areas so that the broad management objective of each can be maintained. The intention is that the CBA Map (CBAs and ESAs) and sea-use guidelines inform the MSP Conservation Zones and management regulations, respectively.

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

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

The offshore portion of the existing PetroSA pipeline, as well as a portion of the proposed replacement pipeline falls within an area mapped as CBA 2 -Restore (Figure 7). CBA 2: restore indicates "best design sites" that are no longer in a natural ecological condition and that need to be restored. Together with MPAs, and other CBAs, these sites are required to meet biodiversity targets so that a representative sample of coastal and marine biodiversity can persist into the future. For CBA 2 sites there often alternative areas where feature targets can be met; however, these will be of higher cost to other sectors and / or will be larger areas.

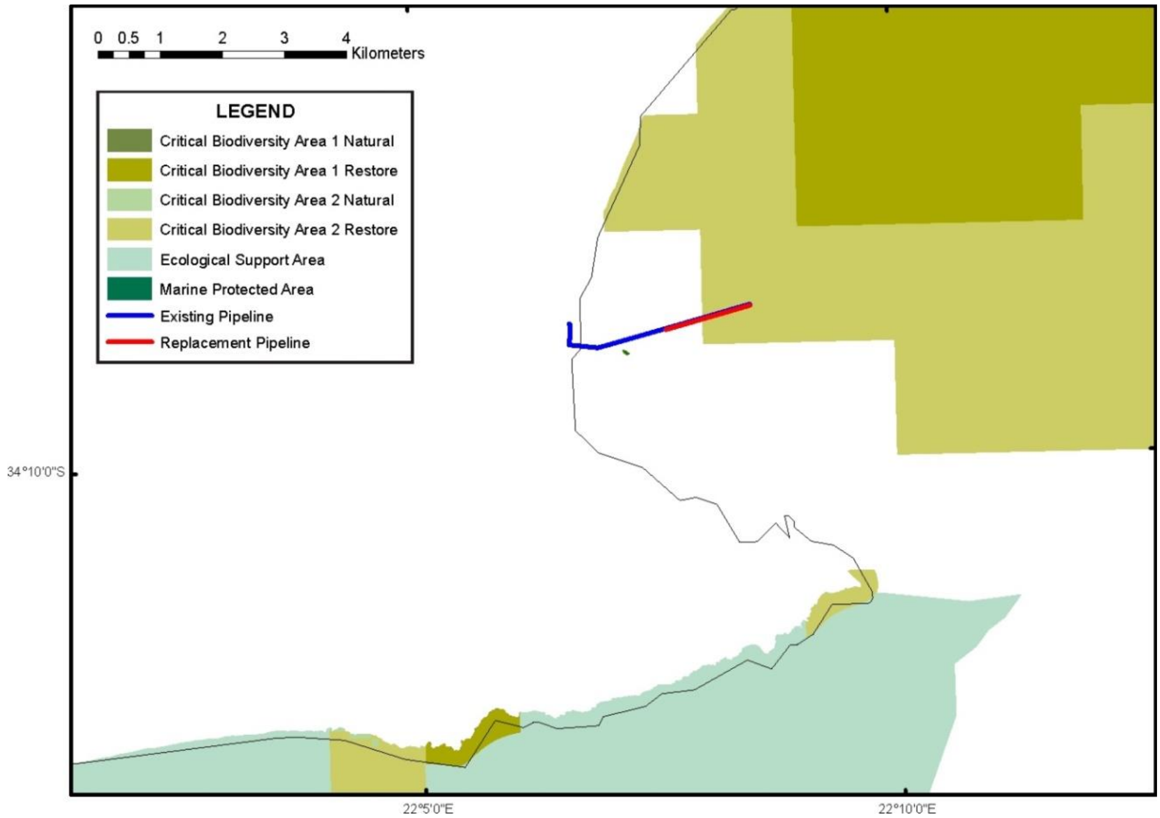

Figure 7: The PetroSA pipeline in Mossel Bay in relation to Critical Biodiversity Areas (CBAs) and Ecological Support Areas (ESAs) (version 1.2) (adapted from Harris *et al*. 2022).

Activities within these management zones are classified into those that are "compatible", those that are “not compatible”, and those that have “restricted compatibility”. Oil and gas pipelines are classified as being “not compatible” in both CBA-Natural and CBA-Restore areas, but with “restricted compatibility”. Activities with restricted compatibility require a detailed assessment to determine whether the recommendation is that they should be permitted (general), permitted subject to additional regulations (consent), or prohibited, depending on a variety of factors (Harris *et.al.* 2022). It should, however, be noted that this is a repair project for an existing pipeline, where a corroded section of the existing line is being replaced with a new bypass section. It is therefore not a new oil and gas pipeline.

3. ASSESSMENT OF IMPACTS ON MARINE FAUNA

3.1. Identification of Impacts

Marine environmental issues associated with the proposed project will focus around the installation of the marine pipeline and associated structures on the seabed, and effects on water quality, sediment redistribution and disturbance of benthic biota in the footprint of the pipeline and associated structures.

3.1.1 Construction Phase

Potential environmental impacts on the coastal and marine environment affected by the installation of a replacement pipeline and associated structures will include:

- Loss or disturbance of intertidal and subtidal sediments and associated communities;
- Reduced physiological functioning of marine organisms due to increased suspended sediment concentrations or turbidity;
- Loss of invertebrate macrofauna due to burial by displaced sediments;
- Temporary impacts on habitat health from noise and lighting during the installation activities;
- Creation of artificial hard substrata;
- Compromises to marine water quality and sediment quality through hydrocarbon pollution by marine construction infrastructure and plant.

3.1.2 Operational Phase

- Temporary impacts on habitat health from noise and lighting during maintenance activities;
- Loss or disturbance to marine fauna due to pollution of the marine environment (littering and / waste from Vessels).

3.1.3 Unplanned Events

- Faunal strikes;
- Release of diesel to the shore or the sea following a vessel accident;
- Loss of or disturbance to marine fauna as a result of a hydrocarbon leak in the bypass pipeline entering the marine environment during the operational phase.

3.2. Assessment of Potential Impacts

3.2.1 Loss or Disturbance of Intertidal and Subtidal Sediments and associated Communities

<u>**Source of Impact**</u>

The project activities and their associated aspects that will result in the disturbance of beach and seabed sediments are described below.

- Construction of the pipeline launchway across the beach, which will involve the excavation of upper beach dune sands and their transfer to the midshore beach area as infill material to achieve the required profile. Depending on the profile, roller support for the pipeline may be required on the lowshore;

- Establishment of beach welding stations where pipeline stalks will be welded together before successive pulls of the pipeline offshore;
- Attachment of the tow head, trimming chains and ballast weights to the pipeline to maintain an on-bottom position through and beyond the surf zone for the duration of the pipeline assembly operations;
- Parking of the assembled pipeline on the seabed through the nearshore corridor and along the installation corridor, and delivery of the assembly to an intermediate target route before final positioning in the pipeline corridor;
- Diver operations during installation of tie-in spools, flanges, and pipeline pigging operations;
- Excavation of sediments around work areas buried below the seabed and cutting and removing of sections of the carrier pipe and redundant pipelines. Active backfilling of excavated work areas to the original profile;
- Temporary removal and subsequent re-installation of the SPM and adjustments to the mooring system;
- Excavation of the seabed (by jetting) along the length of the replacement pipeline section to ensure adequate burial of the pipeline below the seabed surface. Backfilling of sediments around the pipeline will be through natural processes;
- Displacement of sand covering the new bypass pipelines and new PLEM by diver-operated airlift nozzles during routine maintenance of this infrastructure.

Impact Description

Installation of the new pipelines and removal of redundant sections will result in the disturbance and destruction of the intertidal and subtidal infaunal and epifaunal communities in the unconsolidated sediments of the construction footprint.

Where roller support is required for the pipeline in the low shore most of the biota inhabiting the sediments would be crushed. Similarly, where the pipeline and associated tow head and trail head are temporarily parked on the seabed or finally positioned in the pipeline corridor, most of the epifauna or infauna inhabiting the sediments would be smothered and crushed. During pipeline parking and towing this impact would be temporary as following repositioning of the pipeline, the disturbed area would be rapidly recolonised through immigration of macrofauna from adjacent undisturnbed areas. Similarly, within the pipeline corridor itself, this loss would be temporary as the pipeline will be buried along most of its length. Only in areas where the subsea infrastructure extends above the seabed would the loss be permanent as the unconsolidated sediments would be replaced by hard substrata, which in turn would offer alternative habitats for colonisation by a different suite of species (see section 3.2.5).

During construction of the launchway, relocation of dune sands to the midshore will result in the disturbance and removal of high shore beach macrofauna and the smothering of biota in the mid beach retension zone possibly extending into the low beach saturation zone. Trenching of the seabed by jetting to receive the new pipeline sections will result in the removal and redistribution of at least 2,000 m^3 of sand. Benthic macrofauna typically inhabit only the top 20 – 30 cm of sediment, and redistribution of the sediment by the jetting system will thus displace the benthic infaunal and epifaunal biota in the pipeline corridor footprint. Most biota affected by the low pressure water jet are expected to survive the displacement process, although some soft-bodied animals may die, resulting in a localised and temporary reduction in benthic biodiversity. Larger mobile invertebrates and fish will be capable of actively avoiding the construction area.

The ecological recovery of the disturbed seafloor is generally defined as the establishment of a successional community of species, which progresses towards a community that is similar in species composition, population density and biomass to that previously present (Ellis 1996). The rate of recolonization depends largely on the type of community that inhabits the deposits in the construction area, the extent to which the community is naturally adapted to high levels of sediment disturbances, the sediment structure (grain size) and physical factors such as depth and exposure (waves, currents) (Newell *et al.* 1998; Herrmann *et al.* 1999). Recolonization typically takes place by passive translocation of animals during storms or sediment infill from nearby unaffected areas, active immigration of mobile species, and immigration and settlement of pelagic larvae and juveniles (Hall 1994; Kenny & Rees 1994, 1996; Herrmann *et al.* 1999; Ellis 2000). Areas of undisturbed deposits adjacent to the construction area may also provide an important source of colonizing species that enable a faster recovery than might occur solely by larval settlement and growth (van Moorsel 1993, 1994).

Due to the intrinsic tolerance of the assemblages inhabiting the wave-influenced environment, declines in infaunal abundance, biomass, and diversity following disturbances are short term, with recolonisation following the cessation of disturbance on beaches occurring within weeks (Schoeman *et al.* 2000). Communities in the deeper subtidal show higher sensitivity to disturbance due to a higher abundance of long-lived species than in the highly dynamic wave-influenced zones (Parr *et al.* 1978; Brown & McLachlan 1994; Rakocinski *et al.* 1996; Menn 2002). Natural rehabilitation of the seabed following pipeline installation would occur through a process involving influx and redistribution of sediments, and subsequent recruitment of invertebrates. Recolonisation of disturbed areas will start rapidly after cessation of construction activities and takes place by passive translocation of animals from adjacent areas during successive tidal cycles or storms, active immigration of mobile species, and immigration and settlement of pelagic larvae and juveniles (Hall 1994; Kenny & Rees 1994, 1996; Herrmann et al. 1999; Ellis 2000). Usually, undisturbed sediments adjacent to the impacted site provide an important source of colonising species, enabling faster recovery (van Moorsel 1993, 1994; Cheshire & Miller 1999). In general, diversity and abundance largely recover within 1 year after the impact (Essink 1997; Jutte *et al.* 1999a, 1999b; USACE 2001; Menn 2002; Menn *et al.* 2003), with full recovery of the benthic community and age structure of long-lived species considered to take between 2 and 5 years (Kenny & Rees 1994, 1996; Hackney *et al.* 1996; Rakocinski *et al.* 1996; Essink 1997; Van Dalfsen & Essink 1997; van Dalfsen *et al.* 2000; Newell *et al.* 2004; Pulfrich *et al.* 2004; Boyd *et al.* 2005; Baptist *et al.* 2009; Pulfrich & Branch 2014; Pulfrich & Hutchings 2021).

In general, communities of short-lived species and/or species with a high reproduction rate (opportunists) recover more rapidly than communities of slow growing, long-lived species. Opportunists are usually small, mobile, highly reproductive and fast growing species. As the early colonizers, such species may already attain increased densities within months after sediment disturbance and/or removal. Fine mobile deposits, which are subjected to frequent disturbances, are typically inhabited by such opportunistic species. More stable habitats beyond the influence of waves or characterised by coarser sediments on the other hand, are typified by large, often burrowing, slow growing and long-lived species such as molluscs and echinoderms (Newell *et al*. 1998). Biomass therefore often remains reduced for several years.

Ellis (1996) provided typical recovery rates for different grained deposits based on several sources (

Table **2**). These average time scales conform to those from other studies (see Newell et al. 1998). From this it can be assumed that a period of 1-3 years is a realistic estimate for the time required for recovery of benthic communities in the fine to medium-grained deposits expected along the pipeline corridor.

Table 2: Timing for recovery of seabed habitats after dredging (after Ellis 1996).

Sediment type	Recovery time
Fine-grained deposits: muds, silts, clays, which can contain some rocks and boulders	1 year
Medium-grained deposits: sand, which can contain some silts, clay and gravel	1-3 years
Coarse-grained deposits: gravels, which can contain some finer fraction and some rock and boulders	5 years
Coarse-grained deposits: gravels with many rocks and boulders	>5 years

In summary, the intrinsic tolerance of the biota in wave influenced unconsolidated sediments will ensure that any declines in infaunal abundance, biomass, and diversity following disturbances of the sediments during pipeline installation and maintenance activities will be short term. Rapid immigration of biota from surrounding sediments will ensure that recovery of macrofaunal communities in disturbed areas are likely to return to functional similarity within one year.

Sensitivity of Receptors

The biota of nearshore marine habitats on the South Coast is relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. Consequently, faunal communities associated with wave-exposed coastlines are naturally variable, particularly over short to medium time frames (tidal cycles, storm events, seasons or inter-annual weather changes) (McLachlan 1990; Souza & Gianuca 1994; Löffler & Coosen 1995; Calliari *et al*. 1996; Newell *et al*. 1998, 2004). Most of the infaunal species are opportunistic, with a short life cycle and a large reproductive potential. Recolonisation starts rapidly following a disturbance, the early colonisers typically being small, abundant and mobile pioneer species with high reproductive and fast growth rates (e.g. small crustaceans and polychaetes). It is thus often difficult to identify trends in macrofaunal community structure over and above natural variation, particularly those due to anthropogenic disturbance (see also Gorzelany & Nelson 1987).

Impact Significance

The elimination of marine benthic communities in the structural footprint of the replacement pipeline sections is an unavoidable consequence of the proposed development, and no direct mitigation measures, other than the no-project alternative, are possible. The initial negative impacts are deemed of low intensity within the immediate vicinity of the pipeline route, replacement PLEM location and SPM mooring position. Furthermore, the negative impacts can be considered temporary, persisting over the short-term only as recolonization of unconsolidated sediments will be rapid and as the new structures extending above the seabed will offer a new settling ground for hard bottom species and will be rapidly colonised. The impact is therefore assessed to be of **VERY LOW** significance both without and with mitigation.

Impact: Loss or Disturbance of Intertidal and Subtidal Sediments and associated Communities

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Definite	**VERY LOW**	**- ve/ + ve**	High
Essential mitigation measures: • Restrict vehicles to clearly demarcated areas on the beach. **Best practice mitigation measures:** • Have good house-keeping practices in place during construction								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**- ve/ + ve**	High

Potential for Cumulative Effects

Any disturbance of sediments in the intertidal or subtidal regions will have cumulative impacts on the marine communities associated with those sediments. Over the lifetime of the pipeline installation process, these impacts are likely to be of very low significance, due to the naturally dynamic environment.

3.2.2 Sediment Resuspension and Increased Turbidity

Source of Impact

The project activities and their associated aspects that will generate suspended sediment plumes and an increase in turbidity are described below.

- The excavation of upper beach dune sands and their transfer to the mid and low shore beach area as infill material to achieve the required profile during launchway construction. Mobilisation of these sediments during high-tide periods could lead to increased turbidity in the surf zone;
- Attachment of the tow head, trimming chains and ballast weights to the pipeline to maintain an on-bottom position through and beyond the surf zone for the duration of the pipeline assembly operations;

- Parking of the assembled pipeline on the seabed through the nearshore corridor and along the installation corridor, and delivery of the assembly to an intermediate target route before final positioning in the pipeline corridor;
- Diver operations during installation of tie-in spools, flanges, and pipeline pigging operations;
- Excavation of sediments around work areas buried below the seabed and cutting and removing of sections of the carrier pipe and redundant pipelines. Active backfilling of excavated work areas to the original profile;
- Temporary removal and subsequent re-installation of the SPM and adjustments to the mooring system;
- Excavation of the seabed (by jetting) along the length of the replacement pipeline section to ensure adequate burial of the pipeline below the seabed surface. Backfilling of sediments around the pipeline will be through natural processes;
- Displacement of sand covering the new bypass pipelines and new PLEM by diver-operated airlift nozzles during routine maintenance of this infrastructure.

Impact Description

The coarser fractions of the sediments remobilised during excavation and jetting in the subtidal settle out rapidly, but any silts and clays in the material will remain in suspension longer and disperse further. The suspended sediment concentrations, the extent and area over which plumes disperse, and their duration, depend largely on the proportions of silts, muds and clays (<63 μm) in the remobilised sediments, as well as local sea conditions. The higher the proportion of fine material, the larger and more persistent the suspended sediment plume is likely to be (Newell *et al.* 1998; Johnson & Parchure 1999; Posford Duvivier Environment 2001; Greene 2002). Effects of suspended sediment are highly species-specific and can vary greatly. Although published data on suspended sediments effects on fish and bivalves are typically for species occurring elsewhere, they are summarised below.

Suspended sediments load the water with inorganic particles, which may have biological effects such as a reduction of invertebrate egg and larval survival (thereby potentially affecting the recovery rate of the impacted area), and diminish the filter-feeding efficiency of suspension feeders (reviewed by Clarke & Wilber 2000). However, in most cases sub-lethal or lethal responses occur only at concentrations well in excess to those of sediment plumes expected from jetting and underwater excavation operations. For fish, critical exposure levels can range from ~500 mg/ℓ for 24 hours to no effects at concentrations of >10,000 mg/ℓ over 7 days (Clarke & Wilber 2000). Direct long-term impacts for fish are, however, unlikely to occur as they are mobile and can actively avoid any area affected by increased sediment loadings. Short-term impacts may occur by reducing the ability to find prey by visual feeders (Hecht & van der Lingen 1992) and the loss of potential food items due to smothering. On the other hand, fish may be attracted by the 'odour stream' of crushed benthic organisms during dredging activities (Herrmann *et al.* 1999). Fish eggs and larvae are generally more susceptible to elevated concentrations of suspended sediments; hatching can be delayed and feeding of larvae may be impaired. The adhesion of particles to eggs may cause loss of buoyancy resulting in the eggs sinking to the bottom (ICES ACME 1997). Benthic and demersal species that spawn, lay eggs or have juvenile life stages dependent on the seafloor habitat (e.g. hake, squid) could therefore be negatively affected by the smothering effects of redepositing sediments. In general, however, the concentrations of suspended sediments that stimulate avoidance responses or result in mortality are orders of magnitude higher than would be expected in naturally turbid coastal waters, or from redistribution of sediments during pipeline installation operations. Being mobile, fish are also able to move away from areas of elevated turbidity or mobilised sediments, and thus less likely to suffer long-term or lethal effects.

Filter-feeders are generally more sensitive to suspended solids than deposit-feeders, since heavy sedimentation may clog the gills. However, research has shown that filter-feeders (particularly bivalves) living in coastal waters are highly adaptable, and can maintain their feeding activity over a wide range of inorganic particulate loads (Iglesias *et al.* 1996; Navarro *et al.* 1996). Suspended sediment effects on juvenile and adult bivalves occur mainly at the sub-lethal level with the predominant response being reduced filter-feeding efficiencies occurring generally at concentrations of about 100 mg/ℓ. Lethal effects are seen at much higher concentrations (>7,000 mg/ℓ) and at long-term (3 weeks) exposures (Clarke & Wilber 2000). For bivalve egg stages, critical suspended sediment concentration range from 188 mg/ℓ for oysters to 1,000 mg/ℓ for burrowing clams (Clarke & Wilber 2000) and larval stages show no effects at suspended sediment concentrations <750 mg/ℓ (Clarke & Wilber 2000).

Crustaceans appear similarly resistant to lethal effects with 25% mortality rate reported at 10,000 mg/ℓ for >240 h exposures (Clarke & Wilber 2000).

Increases in suspended material in the water column will diminish the light penetration with potential adverse effects on the photosynthetic capability of phytoplankton and other aquatic plants, or reduced feeding in zooplankton (Poopetch 1982; Kirk 1985; Parsons *et al*. 1986a, 1986b; Monteiro 1998; O'Toole 1997). On the other hand, resuspended nutrients may stimulate phytoplankton productivity (ICES 1992).

The presence of surface and sub-surface plumes has the potential to reduce the ability of visually-feeding marine mammals (e.g. seals and dolphins) and diving seabirds (e.g. Damara terns, Cape Cormorants, African Penguins) to locate their prey, thereby diminishing their feeding success and potentially negatively affecting reproductive success. This could potentially trigger cascade effects through the marine food web through emigration of higher order consumers from the area in search of food. The only study examining the possible effects of suspended sediment plumes on nearshore fish fauna in southern Africa is that of Clark *et al.* (1998), who showed that surf-zone fish seem to benefit from the turbidity plume produced by the fine tailings discharged from a diamond mine near Lüderitz in Namibia. Fish species richness and abundance in areas affected by the plume were higher than at control sites on the same beach, suggesting that the plume may provide a form of visual cover from predators (see also Blaber & Blaber 1980; Bruton 1985; Cyrus & Blaber 1987a, 1987b, 1987c).

A wide range of birds forage in or just behind the surf-zone. Seabirds are visual predators that forage by sight and therefore need clear water to locate their prey. Most pelagic fish species, which form a major component of the diet of some seabirds, tend to avoid turbid waters. Turbidity is likely to affect local feeding efficiency of seabirds either by obscuring their vision or by reducing prey availability through avoidance responses of prey species to turbid water areas. It is difficult to assess the significance of the potential impacts of construction-induced turbidity on seabird populations, as it will depend largely on the extent and duration of the sediment plumes. If the plumes are highly localised and disperse quickly, as would be the case during pipeline installation, then the consequences are likely to be negligible.

Furthermore, as marine communities on the South Coast (particularly in the Mossel Bay area) are frequently exposed to naturally elevated suspended-sediment levels as part of the coastal nepheloid layer, they can be expected to have behavioural and physiological mechanisms for coping with this feature of their habitat. Turbidity around the pipeline corridor is thus unlikely to exceed levels attained naturally during turn-over of nearshore sediments by wave action or seasonal inputs in the form of river discharges. Effects of suspended sediment are highly species-specific and can vary greatly. Although published data on suspended sediments effects on fish and bivalves are typically for species occurring elsewhere, they are summarised below.

Considering the ranges over which marine mammals and seabirds feed, and that prey abundance is likely to be lower in areas affected by plumes, the feeding ability or efficiency of pelagic mammals and seabirds is unlikely to be adversely affected by the highly localised sediments resuspended during construction activities (Posford Duvivier Environment 2001).

In summary, any increases in turbidity during pipeline installation and maintenance due to mobilization of sediments will be short-term only and suspended sediment concentrations are unlikely to attain levels that would have negative impacts on the receiving environment.

Sensitivity of Receptors

Considering that as Mossel Bay is periodically influenced by highly turbid nepheloid layer water it can be assumed that the benthic fauna and demersal species at least are naturally adapted to periodic elevated turbidity and suspended sediment concentrations.

Impact Significance

Elevated suspended sediment concentrations and increased turbidity due to construction activities is deemed of low intensity within the immediate vicinity of the pipeline corridor and construction site, with impacts persisting over the short-term only. The impact is assessed to be of **VERY LOW** significance both without and with mitigation. Although elevated suspended sediment concentrations are an unavoidable consequence of construction activities, impacts can be kept to a minimum through responsible construction practices.

Impact: Reduced physiological functioning of marine organisms due to increased suspended sediment concentrations or turbidity

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Definite	**VERY LOW**	**- ve**	High
Essential mitigation measures: • No direct mitigation possible other than the no-project alternative. **Best practice mitigation measures:** • All contractors must have an approved Environmental Management Plan in place that ensures that environmental impacts are minimised as far as practicable possible.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

As increased suspended sediment concentrations associated with construction activities are ephemeral, no long term cumulative impacts on marine organisms are expected.

3.2.3 Burial of Benthic Biota by relocated Sediments

Source of Impact

The project activities and their associated aspects that will result in relocation or redeposition of sediments are described below.

- The excavation of upper beach dune sands and their transfer to the mid and low shore beach area as infill material to achieve the required profile during launchway construction;
- Excavation of sediments around work areas buried below the seabed and cutting and removing of sections of the carrier pipe and redundant pipelines. Active backfilling of excavated work areas to the original profile;
- Excavation of the seabed (by jetting) along the length of the replacement pipeline section to ensure adequate burial of the pipeline below the seabed surface. Backfilling of sediments around the pipeline will be through natural processes.

Impact Description

The immediate impact of trench excavation using jetting will be the burial of the benthos adjacent to the excavation by displaced sands. Coarser sediments will settle out first around the outer edge of the excavation, progressively thinning radially outwards through subsequent redeposition of the finer sediment fractions. Depending on water depth, wave action and local current conditions, sediment redeposition may extend over an area of a few hundred metres around the excavation.

Factors known to determine the effect of burial on species are 1) the depth of burial; 2) the nature of depositing sediments; 3) burial time; 4) tolerance of species (life habitats, escape potential, tolerance to hypoxia etc.); 5) presence of contaminants in the depositing sediments, and 6) season (mortality rate by burial higher in summer than winter) (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; Janssen *et al.* 2011).

Many benthic invertebrates are able to burrow or move through the sediment matrix, and numerous studies have shown that 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; Lynch 1994; Ellis 2000; Schratzberger *et al.* 2000a; but see Harvey *et al.* 1998; Blanchard & Feder 2003). Lynch (1994) conducted vertical migration experiments with beach macrofauna to determine their tolerance to sand overburdens, and found that several species were capable of burrowing through sediments between 60 and 90 cm, and 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 difference 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, depends not only on their ability to migrate upwards through the deposited sediment, but also on the nature of the deposited sediments (Turk & Risk 1981; Chandrasekara & Frid 1998; Schratzberger *et al.* 2000a; Speybroeck *et al.* 2004). 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 (Maurer et al. 1981a, 1981b, 1982, 1986; Smit *et al.* 2006, 2008), migration ability and survival rates generally being 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.* 2000a). 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 also influential. Although some vertical gradients in particle size distribution may be expected, depositing sediments after jetting will be uncontaminated and native to the area. Substantial changes in the biophysical characteristics of the sediments are therefore not expected. The survival potential of affected communities should thus be comparatively high, recovery relatively rapid and community structure of recovering communities similar to that prior to the disturbance (Hayden & Dolan 1974; Culter & Mahadevan 1982; Gorzelany & Nelson 1987; Hurme & Pullen 1988; Nelson 1993; Löffler & Coosen 1995; Birklund *et al.* 1996; Le Roy *et al.* 1996; Rakocinski *et al.* 1996; Peterson *et al.* 2000; Van Dalfsen & Essink 2001;Menn 2002; Menn *et al.* 2003; Pulfrich *et al.* 2004; amongst other).

The burial time, or duration of burial, will also determine the effect on benthos. Here a distinction must be made between incidental deposition, where species are buried by deposited material within a short period of time, and continuous deposition, where species are exposed to an elevated sedimentation rate over a long period of time. Whereas the volumes deposited per unit time will likely be lower under conditions of continuous deposition, such deposition can nonetheless have negative effects when the sedimentation rate is higher than the velocity at which the organisms can move or grow upwards. The sensitivity to long-term continuous deposition is species dependent and also dependent on the sediment type, with continuous deposition of silt being more lethal than a deposition of sand.

Some studies have also reported that the recovery rate following deposition of non-native sediments on beaches is affected by the time of year in which the nourishment is undertaken. For most species, the oxygen consumption rate is lower in winter than in summer, resulting in higher survival rates following burial in winter. Movement of the organisms, however, is also slower, so it takes longer for the organism to escape from the smothering layer. The influence of the season on the effect of burial is therefore hard to predict and is likely dependent on individual species tolerances (Speybroek *et al.* 2005). Excessive sediment deposition during spring and summer when most macrofauna reproduce and recruit has been hypothesised to affect both the rate and timing of recovery, with recruitment failure of longer-lived species being possible if nourishment spans both their reproductive and recruitment periods (Peterson *et al.* 2000; Jongbloed *et al.* 2006; Baptist *et al.* 2009).

The nature of the receiving community is also of importance. In areas where sedimentation is naturally high (e.g. wave-disturbed shallow waters, proximity of major rivers) 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. Kranz (1972, cited in Hall 1994) studied the burrowing habits of 30 species of bivalves and 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. The most resistant species were deep-burrowing siphonate suspension-feeders, which could escape from up to 50 cm of overburden. Menn (2002) reported that meiofaunal species appeared less susceptible to burial than macrofauna.

The exact depth of sand through which biota can successfully migrate ('fatal depth') thus depends on the species involved (reviewed by Essink 1993). Although numerous studies have investigated the burrowing efficiency of local intertidal species under different swash conditions or grain size composition (e.g. Brown & Trueman 1991, 1995; Nel *et al.* 2001), information on successful upward migration and survival following heavy deposition of sediments is largely lacking (but see Trueman & Ansell 1969). However, benthic organisms living in nearshore wave influenced areas in the Benguela region are likely to be adapted to relatively high sedimentation rates. Nonetheless, it is safe to assume that at least some infauna may be smothered during the excavation process but that these effects are likely to remain limited to around the crater rim and in the immediate vicinity of excavation where depositional thickness may reach the 'fatal depth' for some species.

Burial can also lead to a chain of other stressors on benthic species communities like oxygen depletion and high sulphide concentrations. As the pipeline area is located in shallow water where sediments are naturally disturbed and turned over by wave action, such effects are highly unlikely.

In summary, the intrinsic tolerance of the biota in wave influenced unconsolidated sediments and the comparatively low volumes of sediment that would be redistributed during pipeline construction and maintenance will ensure that any declines in infaunal abundance, biomass, and diversity following redeposition of mobilised sediments will be short term and highly localised. Many species will be able to burrow up through the re-deposited sediments ensuring rapid recovery of disturbed areas.

Sensitivity of Receptors

The biota of nearshore marine habitats on the South Coast is relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. Consequently, faunal communities associated with wave-exposed coastlines are naturally variable, particularly over short to medium time frames (tidal cycles, storm events, seasons or inter-annual weather changes).

Impact Significance

Relocation of beach sands and redeposition of jet-excavated sediments due to construction activities is deemed of low intensity within the immediate vicinity of the launchway, pipeline corridor and construction site, with impacts persisting over the short-term only. The impact is assessed to be of **VERY LOW** significance both without and with mitigation. Relocation of sediments is an unavoidable consequence of construction activities, and no mitigation measures, other than the no-project alternative, are feasible.

Impact: Loss of invertebrate macrofauna due to burial by displaced sediments

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Definite	**VERY LOW**	**- ve**	High
Essential mitigation measures: • No direct mitigation possible other than the no-project alternative. **Best practice mitigation measures:** • All contractors must have an approved Environmental Management Plan in place that ensures that environmental impacts are minimised as far as practicable possible.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

As relocation of beach sediments and redeposition of excavated sediments by jetting are ephemeral, no long term cumulative impacts on marine organisms are expected.

3.2.4 Coastal and Underwater Noise and Vibrations Levels

Source of Impact

The project activities and their associated aspects that will generate underwater noise are described below.

- Construction of the pipeline launchway across the beach, establishment of beach welding stations, pipeline assembly and towing of the pipeline out though the surf zone will generate construction noise in the coastal zone;
- All underwater construction activities, and associated vessel support, will generate underwater noise and vibrations.

Impact Description

Of all human-generated sound sources, the most persistent in the ocean is the noise of shipping. The noise generated by large vessels is predominantly from cavitation bubbles at the tips of the propellers, as a result of a static pressure drop below ambient water pressure (Hildebrand 2009). Noise is, however, also generated by both the machinery onboard and hydraulic flow over the hull (Hildebrand 2005). Depending on size and speed, the sound levels radiating from vessels range from 160 to 220 dB re 1 µPa at 1 m (NRC 2003). Especially at low frequencies between 5 to 100 Hz, vessel traffic is a major contributor to noise in the world's oceans, and under the right conditions, these sounds can propagate 100s of kilometres thereby affecting very large geographic areas (Coley 1994, 1995; NRC 2003; Pidcock *et al.* 2003).

As the proposed pipeline is located within a bay and in close proximity to a harbour, the shipping noise component of the ambient noise environment is expected to be significant within and around the construction site. Given the local shipping traffic and relatively strong metocean conditions specific to the area, ambient noise levels are expected to be 90–120 dB re 1 µPa for the frequency range 10 Hz – 10 kHz (SLR Consulting Australia 2019). The noise generated by the vessels and underwater construction in general required for the replacement of the pipeline and associated infrastructure, falls within the hearing range of most fish and marine mammals, and would be audible for considerable ranges before attenuating to below threshold levels. However, pipeline installation will be conducted in comparatively shallow water, which restricts the propagation of low frequencies (>10°Hz, the spectrum that potentially propagates for long distances) to within a few kilometres. In contrast, under the right conditions, the low frequencies radiating from merchant vessels can propagate 100s of kilometres.

The potential effects of anthropogenic sounds on marine organisms include disturbance of normal behaviour resulting in possible displacement from areas, restricted detection of natural sounds (auditory "masking"), and temporary or permanent reductions in hearing sensitivity. Exposure to intense sounds for even a short period of time may result in permanent hearing loss, while lower sound levels often result in temporary or transient loss of hearing that may last for minutes, hours, or even days. Hearing, however, ultimately returns to the pre-exposure level.

The received level of noise (and risk of physiological injury or behavioural changes) would depend on the animal's proximity to the sound source. However, the noise and vibrations generated during underwater construction are unlikely to be injurious or reach lethal amplitudes, even at close range (SLR Consulting Australia 2019). The risk of temporary threshold shifts (TTS) close to continuous shipping sounds is generally low. The underwater noise from general construction activities 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).

Sensitivity of Receptors

There are no seabird breeding colonies within Mossel Bay, but a number of species breed along the adjacent mainland coast; a breeding colony of Cape Cormorant has recently established on Robberg Peninsula (Marnewick *et al*. 2015), kelp gulls breed in high numbers on the Keurbooms River estuary spit (Witteveen 2015, but see also Whittington *et al*. 2006) and African Black Oystercatcher, Caspian Tern and White-fronted Plover breed on many of the beaches between Plettenberg Bay and the eastern boundary of the Tsitsikamma Section of the Garden Route National Park (http://www.birdlife.org.za/component/k2/item/240-sa098-tsitsikamma-plettenberg-bay). African Black Oystercatchers breed as far east as East London while breeding of Whitefronted Plovers extends into KwaZulu-Natal (Hockey *et al*. 2005). Damara Terns breed inshore between Cape Agulhas and Cape Infanta on the South Coast, with the bulk of the South African population breeding in Algoa Bay (Taylor *et al*. 2015; Whittington *et al*. 2015). These colonies are all sufficiently far away from Mossel Bay for the species not to be influenced by localised construction noise. The foraging ranges of those species that feed at sea (e.g. Cape Cormorant, Cape Gannet, African Penguin) do not extend as far as Mossel Bay (Harris *et al*. 2022).

Any mobile marine fauna particularly sensitive to noise (e.g. seals, dolphins, turtles, seabirds and finfish species) are expected to avoid the construction area once activities commence, thereby moving away from the sound source before trauma could occur. The maximum radius over which the noise of underwater construction may influence is also comparatively small relative to the population distribution ranges of the potentially sensitive species.

The taxa most vulnerable to disturbance by underwater noise are fish, diving seabirds and marine mammals. Some of of the species potentially occurring in the project area are considered regionally or globally 'Endangered' (e.g. leatherback turtle, Indian Ocean humpback dolphin), 'Vulnerable' (e.g. loggerhead turtle, great white shark, Bryde's whale) or 'Near Threatened' (e.g. Indo-Pacific bottlenose dolphin) and may be affected by the underwater noise in the far-field.

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. Many whales, for example, 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).

Impact Significance

The underwater noise generated by project-associated vessels and general construction noise is deemed to be of low intensity but would remain localised and would persist over the short-term only. Although disturbance effects due to construction noise will definitely occur, the noise will be a reatively stationary source with likely habituation by affected groups. The significance of general construction noise is deemed to be of **VERY LOW** significance.

Impact: Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish, seabirds, seals and cetaceans due to noise generated by general construction

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Definite	**VERY LOW**	**- ve**	High
Essential mitigation measures: • Maintain all generators, vehicles, and other equipment in good working order to minimise exhaust fumes and excess noise. **Best practice mitigation measures:** • Have good house-keeping practices in place during construction.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Probable	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

Although noise and vibrations associated with construction activities are ephemeral, the cumulative impact of increased background anthropogenic noise levels in the oceans has been recognised as an ongoing and widespread issue of concern (Koper & Plön 2012). The long term cumulative impacts of noise on marine organisms are therefore predicted to be of medium significance before mitigation.

3.2.5 Creation of Artificial Hard Substrata

Source of Impact

The project activities and their associated aspects that will result in the habitat alteration and the creation of hard substrata are described below.

- Physical presence of replacement pipelines, PLEM, tie-in spools and trail head would provide an alternative substratum and additional hard surfaces for colonisation by biofouling communities (including alien species);
- Physical presence of replacement pipelines, PLEM, tie-in spools and trail head may act as an artificial reef, thereby attracting fish and mobile invertebrates.

Impact Description

The installation of subsea pipelines and associated infrastructure will result in the physical distrubance of subtidal soft-sediment habitats. Although the installation of some of these hard structures will result in a permanent net loss of soft-sediment habitat, this negative impact will be temporary only through the replacement by hard substrata offering alternative habitats for colonisation.

The composition of the fouling community on artificial structures depends on the age (length of time immersed in water) and the composition of the substratum, and usually differs from the communities of nearby natural rocky reefs (Connell & Glasby 1999; Connell 2001). Colonization of hard substratum goes through successional stages (Connell & Slayter 1977). Early successional communities are characterized by opportunistic algae (e.g. *Ulva* sp., *Enteromorpha* sp.). These are eventually displaced by slower growing, long-lived species such as mussels, sponges and/or coralline algae, and mobile organisms, such as urchins and lobsters, which feed on the fouling community. With time, a consistent increase in biomass, cover and number of species can usually be observed (Bombace *et al.* 1994; Relini *et al.* 1994; Connell & Glasby 1999). Depending on the supply of larvae and the success of recruitment, the colonization process can take up to several years. For example, a community colonising concrete blocks in the Mediterranean was found to still be changing after five years with large algae and sponges, in particular, increasing in abundance (Relini *et al.* 1994). Other artificial reef communities, on the other hand, were reported to reach similar numbers of species (but not densities and biomass) to those at nearby artificial reefs within eight months (Hueckel *et al.* 1989).

Sensitivity of Receptors

The area around the pipeline is dominated by unconsolidated seabed, with rocky outcrops being limited to the nearby Seal Island. The emergent portions of the existing pipeline and the moorings associated with the SPM all represent introduced artificial substrata and their succession communities will be in different stages of development and not necessarily representative of nearby natural rocky intertidal and subtidal habitats.

Impact Significance

Although artificial structures will provide a new settling habitat for reef dwellers, the biofouling community that will establish itself on the new artificial structures over the short-term will be different from that characterising the original unconsolidated sediments. The creation of artificial hard substrata through the placement of pipelines and the PLEM is thus deemed to be of low intensity. The impact can be considered positive as the developing successional biofouling communities would serve as a food source for reef-associated fish and invertebrate species thereby potentially enhancing the biodiversity and abundance in an otherwise comparatively uniform sandy seabed area. The effect will be highly localised and limited to the area of the artificial structures themselves. The impact is assessed to be of **VERY LOW** significance. No mitigation is possible other than the no-project alternative.

Impact: Creation of Artificial Hard Substrata through the physical presence of the replacement pipeline and associated infrastructure

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Definite	**VERY LOW**	**+ ve**	High
Essential mitigation measures: • No direct mitigation possible other than the no-project alternative.								
With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Definite	**VERY LOW**	**+ ve**	High

Potential for Cumulative Effects

Any developments that require the installation of hard structures will have a cumulative impact on the availability of hard substrata for colonisation by marine organisms. The long term cumulative impacts are, however, expected to be of low significance.

3.2.6 Impact of Vessel Lighting on Pelagic Fauna

Source of Impact

The project activities that will result in an increase in ambient nighttime lighting on marine fauna are:

- Operational vessel lighting on the tugs and diver support vessels can be an additional source of artificial light in the nearshore environment increasing the ambient lighting in marine and coastal areas;
- Divers may need to use underwater lighting during times of low visibility during construction activities thereby generating a source of artificial light in the subtidal environment.

Impact Description

The strong operational lighting used to illuminate tugs and diver support vessels at night may disturb and disorientate pelagic seabirds feeding in the area or attract turtles, marine mammals and fish. The response of marine organisms to artificial lights can vary depending on a number of factors such as the species, life stage and the intensity of the light. Strong lights could cause artificially induced biological aggregations. Operational lights may also result in physiological and behavioural effects on 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. Although some species may change their feeding habits based on these aggregations, the impacts on marine species are generally expected to be minor as the construction operations will be located close to shore where artificial lighting from the oil terminal will be of comparatively high intensity. It is expected, therefore, that seabirds and marine mammals in the area would become accustomed to the presence of the vessels within a few days.

Sensitivity of Receptors

The taxa most vulnerable to ambient lighting are pelagic seabirds, although turtles, shoaling pelagic fish, chokka squid and both migratory and resident cetaceans transiting through the area may also be attracted by the lights. Some of of the species potentially occurring in the project area are considered regionally or globally 'Critically Endangered' (e.g. Damara terns), 'Endangered' (e.g. leatherback turtles, Indian Ocean humpback dolphin), 'Vulnerable' (e.g. loggerhead turtle, great white shark, Bryde's whale) or 'Near Threatened' (e.g. Indo-Pacific bottlenose dolphin), and may be affected by the increase in ambient lighting generated during construction activities.

Impact Significance

The intensity of the impact of an increase in ambient lighting is considered low, with effects remaining localised. The impact would endure over the short term only. The impact of increased lighting is deemed to be of **VERY LOW** significance, both without and with mitigation. The use of lighting on the project-associated vessels and underwater cannot be eliminated due to safety, navigational and operational requirements.

Impact: Increase in ambient lighting

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Improbable	**VERY LOW**	**- ve**	High
Essential mitigation measures: • Reduce lighting in non-essential areas. • No direct light in water, exept during safety inspections. • Ensure vessel operators have a lighting management plan or procedure in place to minimize or avoid impacts associated with operational nighttime lighting on avian species, fish species, and marine mammals.								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**VERY LOW**	**- ve**	High

Potential for Cumulative Effects

No long term cumulative impacts on marine organisms are expected relative to the ambient light levels in the Mossel Bay area.

3.2.7 Impacts of Waste Discharges to Sea

Source of Impact

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

- Operation of the tugs and diver support vessels.

- Operation of vehicles and machinery on the beach.

The aspects associated with these activities are described further below:

- **Litter and construction wastes:** construction activities can lead to operational spills of diesel and hydraulic fluid into the marine environment from machinery and plant used on the beach. Construction activities can also result in the discard of litter into the marine environment.
- **Deck drainage, sewage, bilge and cooling water, food wastes**: all operational discharges from project vessels must comply with MARPOL standards.

Impact Description

The discharge of wastes to sea during marine construction operations could create local reductions in water quality. Deck and machinery space drainage may result in small volumes of oils, detergents, lubricants and grease, the toxicity of which varies depending on their composition, being introduced into the marine environment. Sewage and gallery waste will place a small organic and bacterial loading on the marine environment, resulting in an increased biological oxygen demand. Discharges to sea will result in a local reduction in water quality, which could impact marine fauna in a number of different ways:

- Physiological effects: Ingestion of hydrocarbons, detergents and other waste could have adverse effects on marine fauna, which could ultimately result in mortality.
- Increased food source: The discharge of galley waste and sewage will result in an additional food source for opportunistic feeders, speciality pelagic fish species.
- Increased predator-prey interactions: Predatory species, such as sharks and pelagic seabirds, may be attracted to the aggregation of pelagic fish attracted by the increased food source.

Sensitivity of Receptors

The operational waste discharges from the activities described above would primarily take place along the pipeline route and at the SPM. The project area lies close to shore within Mossel Bay and adjacent to Seal Island, and therefore in close proximity to sensitive coastal receptors (e.g. key faunal breeding/feeding areas, seal colonies and nursery areas for commercial fish stocks).

The taxa most vulnerable to waste discharges are pelagic seabirds, turtles, and marine mammals. Some of of the species potentially occurring in the project area, are considered regionally or globally 'Critically Endangered' (e.g. Damara terns), 'Endangered' (e.g. leatherback turtles, Indian Ocean humpback dolphin), 'Vulnerable' (e.g. loggerhead turtles, great white shark, Bryde's whale) or 'Near Threatened' (e.g. Indo-Pacific bottlenose dolphin), and may be affected by operational discharges associated with pipeline installation.

Impact Significance

The impacts associated with normal waste discharges from construction activities, and the tow- and diver support vessels are deemed to be of low intensity and would remain localised. The impacts would, however, persist over the long-term due to the extended biodegradability of plastic wastes and, based on the relatively small discharge volumes and compliance with MARPOL 73/78 standards, are considered of **LOW** significance.

Impact: Compromises to marine water quality due to Waste Discharges to Sea

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Long-term 3	**Low** 5	Probable	**LOW**	**- ve**	High
Essential mitigation measures: • Ensure vessel operators have a waste management procedure in place to avoid waste discharges to sea. • Continue to undertake regular maintenance inspections for all pipeline infrastructure. **Best practice mitigation measures:** • All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan. • Good house-keeping must form an integral part of any marine construction operations from start-up.								
With mitigation	Local 1	Low 1	Long-term 3	**Low** **5**	Possible	**VERY LOW**	**- ve**	High

<u>Potential for Cumulative Effects</u>

Although pollutant levels in the waters of Mossel Bay are currently low, compromised water quality over the long-term due to cumulative impacts resulting from vessel discharges can be expected. Over the lifetime of the project, these impacts are likely to be of low significance.

3.3. Unplanned events

3.3.1 Faunal Strikes

<u>Source of Impact</u>

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

- Transit of the diver support vessel between Mossel Bay harbour and the construction site. [due to the low towing speed of the tugs during transfer of the pipeline from the parked location near the beach to the final target installation route, faunal collisions are not expected].

Impact Description

Vessel traffic can affect large cartilaginous fish species, turtles and marine mammals by direct collisions or propeller injuries. The potential effects of vessel presence on turtles and cetaceans include behavioural disturbance, physiological injury or mortality.

Collisions between cetaceans and vessels are not limited to project associated vessels. In areas of heavy ship traffic, whales and dolphins can experience propeller or collision injuries, with most of these injuries caused by fast-moving vessels. Injuries and deaths resulting from direct ship collisions represent a significant threat to several whale populations (Laist *et al.* 2001; Jensen & Silber 2003). All types and sizes of vessels hit whales, but most lethal and serious injuries are caused by larger vessels and most vessel strikes occur on the continental shelf and when vessels were doing in excess of 10 knots (Laist *et al.* 2001). As diver support-vessels are unlikely to exceed a speed of 3 knots when transiting to and from the harbour and through sensitive areas, ship strikes are unlikely.

Ship strikes have been reported to result in medium-term effects such as evasive behaviour by animals experiencing stress, or longer-term effects such as decreased fitness or habitual avoidance of areas where disturbance is common and in the worst case death (see for example Constantine 2001; Hastie *et al.* 2003; Lusseau 2004, 2005; Bejder *et al.* 2006; Lusseau *et al.* 2009). Ship strikes have been documented from many regions and for numerous species of whales (Panigada *et al.* 2006; Douglas *et al.* 2008; Elvin & Taggart 2008) and dolphins (Bloom & Jager 1994; Elwen & Leeney 2010), with large baleen whales being particularly susceptible to collision.

Sensitivity of Receptors

The taxa most vulnerable to vessel strikes are large, slow-moving chondrichthyans (e.g. manta ray, whale shark), turtles and marine mammals. Some of of the species potentially occurring in the project area are considered regionally or globally 'Endangered' (e.g. leatherback turtles, Indian Ocean humpback dolphin), 'Vulnerable' (e.g. loggerhead turtles, Bryde's whale) or 'Near Threatened' (e.g. Indo-Pacific bottlenose dolphin), and may be affected by the transit of project-associated vessels from and to the harbour.

Impact Significance

The potential for strikes and collisions with large cartilaginous fish, turtles and cetaceans is highly dependent on the abundance and behaviour of these animals in the project area at the time. Due to their extensive distributions and feeding ranges, the number of large cetaceans encountered by project-associated vessels is expected to be low. As large cetaceans may occasionally enter the bay, encounters with the vessels may occur. However, as project-associated vessels will be travelling at low speeds the likelihood of a vessel strike is very low (improbable). However, should strikes occur, the impacts would be of high intensity for individuals but of LOW intensity for the population as a whole. Furthermore, as the duration of the impact would be limited to the short-term and be restricted to the survey area (LOCAL), the impact is considered to be **INSIGNIFICANT**.

Impact: Faunal strikes

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Low 1	Short-term 1	**Very Low** 3	Improbable	**INSIGNIFICANT**	**- ve**	High
Essential mitigation measures: • Conduct an environmental awareness programme amongst contracted vessel operators on best practice to avoid marine faunal strikes (e.g. reduced vessel speed, keeping watch for slow-swimming large pelagic fish, marine mammals and turtles in the path of the vessel). **Best practice mitigation measures:** • Report any collisions with whales to the International Whaling Commission (IWC) database, which has been shown to be a valuable tool for identifying the species most affected, vessels involved in collisions, and correlations between vessel speed and collision risk (Jensen & Silber 2003).								
With mitigation	Local 1	Low 1	Short-term 1	**Very Low** **3**	Improbable	**INSIGNIFICANT**	**- ve**	High

3.3.2 Release of diesel to the shore or the sea

<u>**Source of Impact**</u>

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

- Instantaneous spills of diesel on the shore by vehicles and machinery. Such spills are usually of a low volume;
- Instantaneous spills of marine diesel at the sea surface of the sea during operation of marine construction equipment. Such spills are usually of a low volume;
- Larger volume spills of marine diesel would occur in the event of a vessel collision or vessel accident.

<u>**Impact Description**</u>

Construction activities in the intertidal zone will involve extensive traffic on the shore by heavy vehicles and machinery, as well as the potential for accidental spillage or leakage of fuel, chemicals or lubricants. Any release of liquid hydrocarbons has the potential for direct, indirect and cumulative effects on the marine environment through contamination of the water and/or sediments. Any release of liquid hydrocarbons thus has the potential for direct, indirect and cumulative effects on the marine environment. These effects include physical oiling and toxicity impacts to marine fauna and flora, localised mortality of plankton (particularly copepods), pelagic eggs and fish larvae, and habitat loss or contamination (Perry 2005). Many of the compounds in petroleum products have been known to smother organisms, lower fertility and cause disease in aquatic organisms. Hydrocarbons are incorporated into sediments through attachment to fine dust particles, sinking and deposition in low turbulence areas. Due to differential uptake and elimination rates filter-feeders particularly mussels can bioaccumulate organic (hydrocarbons) contaminants (Birkeland *et al*. 1976).

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 oil spilled at sea are specific gravity, distillation characteristics, viscosity and pour point, all of which are dependent on the oils chemical composition (e.g. the amount of asphaltenes, resins and waxes). Spilled oil undergoes physical and chemical changes (collectively termed 'weathering'), which in combination with its physical transport, determine the spatial extent of oil contamination and the degree to which the environment will be exposed to the toxic constituents of the released product.

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

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

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

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

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

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

In summary, in the unlikely event of a vessel accident, heavy fuel oil or marine diesel spilled in the marine environment will have an immediate detrimental effect on water quality, with the toxic effects potentially resulting in mortality (e.g. suffocation and poisoning) of marine fauna or affecting faunal health (e.g. respiratory damage). If the spill reaches the coast, it can result in the smothering of sensitive coastal habitats.

Sensitivity of Receptors

Accidental spills and loss of marine diesel in the event of a vessel collision could take place offshore in the shipping lanes or within Mossel Bay. Diesel spills or accidents within Mossel Bay or on the beach could result in fuel loss closer to or on the shore, thereby potentially having an environmental effect on the sensitive coastal environments, Seal Island and the CBAs.

The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring in the survey area are considered regionally or globally 'Endangered' (e.g. African Penguin, Cape Gannet, Bank and Cape Cormorant) or 'Vulnerable' (e.g. Damara tern, Caspian Tern). As species considered regionally or globally threatened do not typically occur in Mossel Bay in large numbers and their breeding colonies are all located some distance away, their numbers in the project area will be low and any hydrocarbon spill is thus unlikely to have catastrophic consequences to the populations of these species. The population of African Penguins on Seal Island went extinct around 1926 (Shelton *et al.* 1984).

Impact Significance

In the unlikely event of an operational spill or vessel collision, the magnitude of the impact would depend on whether the spill occurred in offshore waters where encounters with pelagic seabirds, turtles and marine mammals would be low due to their extensive distribution ranges, or whether the spill occurred closer to the shore where encounters with sensitive receptors will be higher. In the case of a spill or collision within Mossel Bay and *en route* to the harbour, the spill would likely be contained within thesouthwestern portions of the bay, and would likely reach the shore affecting intertidal and shallow subtidal benthos and sensitive coastal bird species. Project associated vessels are unlikely to use heavy oil and so the impact of heavy oil will not be discussed further. In the case of marine diesel, which evaporates relatively quickly, the impact would only persist over the short-term and would likely remain localised but would be of medium intensity. It must be pointed out that the probability of a marine diesel spill or vessel collision is highly unlikely. Spills n the beach by vehicles and earth-moving machinery is, however, possible. As the duration of the impact would be limited to the short-term and be restricted to the construction area (LOCAL), the impact is considered to be **INSIGNIFICANT**.

Impact: Release of marine diesel into the marine environment

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>Medium
2</td><td>Short-term
1</td><td>Very Low
4</td><td>Possible</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
<tr><td colspan="9">Essential mitigation measures:
• Conduct an environmental awareness programme amongst contracted construction personnel on best practice to avoid hydrocarbon spills in the marine environment.
• For equipment maintained in the field, oils and lubricants to be contained and correctly disposed of off-site.
• Maintain vehicles and equipment to ensure that no oils, diesel, fuel or hydraulic fluids are spilled.
• Vehicles operating on the beach should have a spill kit (peatsorb/ drip trays) onboard in the event of a spill.
• All project-associated vessels must have an oil spill contingency plan in place.

Best practice mitigation measures:
• Have good house-keeping practices in place during construction.</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Medium
2</td><td>Short-term
1</td><td>Very Low
4</td><td>Improbable</td><td>INSIGNIFI-CANT</td><td>- ve</td><td>High</td></tr>
</table>

3.3.3 Release of hydrocarbons to the marine environment in the case of leaks in the pipeline

Source of Impact

The project activities that may result in the accidental release of hydrocarbons are listed below.

- During the operational phase, leaks may develop in the pipeline and associated infrastructure, resulting in release of hydrocarbons (petrol, diesel and condensate) to the marine environment.

Impact Description

Marine diesel spilled in the marine environment will have an immediate detrimental effect on water quality, with the toxic effects potentially resulting in mortality (e.g. suffocation and poisoning) of marine fauna or affecting faunal health (e.g. respiratory damage). Further impacts were detailed in section 3.3.3 above.

Condensate is a light, volatile, and acutely toxic (in concentrations less than 1 ppm) petroleum hydrocarbon mixture that behaves very differently from heavier crude oil when released into the marine environment in that it is not known to form distinct and visible surface slicks and is therefore not amenable to traditional spill response methodologies. The term applies equally to condensate pumped in its liquid form from a well ('lease' condensate) or processed and separated from natural gas at a gas plant ('plant' condensate) (Steiner 2018).

Condensates are generally moderately (and variably) soluble in water. The BTEX component contributes most of the solubility of condensates, with benzene being highly soluble. Solubility of a complex condensate mixture is often different than it is for the individual components alone. There is therefore a synergistic effect on solubility. The water-soluble fraction of condensate is similar to light crude oils, with light polycyclic aromatic hydrocarbons dominant. While the impact on the sea surface of a condensate spill may be less, the entrained and dispersed hydrocarbon plume would remain submerged, dilute with water currents and not be visible at the sea surface. Impacts in the subsurface water column ecosystem can potentially be acute and serious (Steiner 2018).

Studies have shown that spilled gasoline (a component of, and surrogate for, condensate) can have a half-life of up to 6 months in water. Some components, including the heavier aromatics, alkanes, and PAHs, have shown half-lives exceeding 6 months in water and more than a year in sediments. These heavier, lipophilic components are also prone to bioaccumulation. Weathered condensate on the sea surface and shoreline will degrade more slowly, and is known to be even more acutely toxic than fresh condensate. Acute toxicity is reported in some marine species exposed to concentrations of weathered condensate as low as 0.03 mg/L (0.04 ppm) (Steiner 2018).

Sensitivity of Receptors

Hydrocarbon leaks in the pipeline would occur in shallow water in Mosssel Bay and, depending on prevailing currents, the subsurface plume (condensate) or surface slick (diesel and petrol) could potentially have an environmental effect on the sensitive coastal environments, Seal Island and the CBAs.

The taxa most vulnerable to hydrocarbon spills are coastal and pelagic seabirds. Some of the species potentially occurring in the survey area are considered regionally or globally 'Endangered' (e.g.

African Penguin, Cape Gannet, Bank and Cape Cormorant) or 'Vulnerable' (e.g. Damara tern, Caspian Tern). As species considered regionally or globally threatened do not typically occur in Mossel Bay in large numbers and their breeding colonies are all located some distance away, their numbers in the project area will be low and any hydrocarbon spill is thus unlikely to have catastrophic consequences to the populations of these species. The population of African Penguins on Seal Island went extinct around 1926 (Shelton *et al.* 1984).

Impact Significance

In the unlikely event of a leak, the magnitude of the impact would depend on the hydrocarbon lost. In the case of marine diesel or petrol, which evaporate relatively quickly, the impact would only persist over the short-term and would likely remain localised but would be of medium intensity. In the case of condensate, the impact could persist for longer (months to years), with potential risks of bioaccumulation. It must be pointed out that the probability of a leak is highly unlikely. The duration of the impact would be limited to the short-term and be restricted to the area around the pipeline route area (LOCAL), the impact is considered to be **INSIGNIFICANT**.

Impact: Leaks of hydrocarbon from the pipeline into the marine environment

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local 1	Medium 2	Short-term 1	**Very Low** 4	Improbable	**INSIGNIFI-CANT**	**- ve**	High
Essential mitigation measures: • Compile an Emergency Procedure (or implement an existing procedure) to document the steps to be taken in the case of a hydrocarbon leak. • Continue to undertake regular maintenance inspections for all pipeline infrastructure.								
With mitigation	Local 1	Medium 2	Short-term 1	**Very Low** **4**	Improbable	**INSIGNIFI-CANT**	**- ve**	High

4. CONCLUSIONS

4.1. Impact Summary

The impact assessment identified that the marine environment will be impacted to some degree during the construction activities associated with the replacement of the pipeline, and with subsequent pipeline maintenance.

A summary of impacts is provided below.

Impact	Significance (before mitigation)	Significance (after mitigation)
Construction and Maintenance Phase		
Loss of and disturbance to invertebrate macrofaunal communities through sediment disturbance and redistribution, and increased turbidity during installation of infrastructure	Very Low	Very Low
Disturbance, behavioural changes and avoidance of feeding and/or breeding areas in fish, seabirds, seals, turtles and cetaceans due to noise generated by general construction and increases in ambient lighting	Very Low	Very Low
Loss of or disturbance to marine fauna due to pollution of the marine environment (littering and / waste)	Low	Very Low
Unplanned Events		
Release of diesel to the marine environment in event of a vessel accident	Insignificant	Insignificant
Faunal strikes with project vessels	Insignificant	Insignificant
Loss of or disturbance to marine fauna as a result of a hydrocarbon leak in the bypass pipeline entering the marine environment during the operational phase	Insignificant	Insignificant

4.2. Mitigation Measures

The essential mitigation measures for the construction and operation phases are:

- All contractors must have an approved Environmental Management Plan (EMP) in place that ensures that environmental impacts are minimised as far as practicably possible.
- Conduct an environmental awareness programme amongst contracted construction personnel and vessel operators.
- Restrict vehicles to clearly demarcated areas on the beach.
- Maintain all generators, vehicles, and other equipment in good working order to minimise exhaust fumes and excess noise.
- Reduce lighting in non-essential areas.

- No direct light in water, exept during safety inspections.
- Ensure vessel operators have a lighting plan or procedure in place to minimize or avoid impacts associated with operational nighttime lighting on avian species, fish species, and marine mammals.
- Ensure vessel operators have a waste management procedure in place to avoid waste discharges to sea.
- Continue to undertake regular maintenance inspections for all pipeline infrastructure.
- For equipment maintained in the field, oils and lubricants to be contained and correctly disposed of off-site.
- Maintain vehicles and equipment to ensure that no oils, diesel, fuel or hydraulic fluids are spilled.
- Vehicles operating on the beach should have a spill kit (peatsorb/ drip trays) onboard in the event of a spill.
- All project-associated vessels must have an oil spill contingency plan in place.

The essential mitigation measures for the operational phase are:

- Compile an Emergency Procedure (or implement an existing procedure) to document the steps to be taken in the case of a hydrocarbon leak during the operation of the bypass pipelines.
- Continue to undertake regular maintenance inspections for all pipeline infrastructure..

The best practice mitigation measures for the construction and maintenance phases are:

- Good house-keeping must form an integral part of any marine construction operations from start-up.
- All construction activities in the coastal zone must be managed according to a strictly enforced Environmental Management Plan.
- Report any collisions with whales to the International Whaling Commission (IWC) database, which has been shown to be a valuable tool for identifying the species most affected, vessels involved in collisions, and correlations between vessel speed and collision risk (Jensen & Silber 2003).

4.3. Cumulative Impacts and Climate Change

Anthropogenic activities in the coastal zone can result in complex immediate and indirect effects on the natural environment. Effects from disparate activities can combine and interact with each other in time and space to cause incremental or cumulative effects. Cumulative effects can also be defined as the total impact that a series of developments (both disparate and similar), either present, past or future, will have on the environment within a specific region over a particular period of time (DEAT IEM Guideline 7, Cumulative effects assessment, 2004).

To define the level of cumulative impact in the intertidal and subtidal environment within the pipeline route, it is therefore necessary to look beyond the environmental impacts of the current project and consider also the influence of other past, current or future developments in the area.

Cumulative impacts would relate specifically to:

- Physiological effects on marine fauna of increased turbidity;
- Increased background anthropogenic noise levels;

Considering the temporary nature of the impacts associated with the replacement of the pipeline, and the highly dynamic nature of the intertidal and subtidal habitats and communities that may be affected, cumulative effects on the marine ecology in response to the construction activities are not expected.

4.4. Conclusions

The pipeline and associated infrastructure is located on unconsolidated seabed in shallow water (<25 m). Although the Western Agulhas Bay ecosystem type in which the pipeline is located is considered 'Endangered' and 'poorly protected' there is no overlap of the project with MPAs or EBSAs and only marginal overlap with CBA2: Restore habitat. As there is already an existing pipeline in place, the habitats are by no means pristine and the assemblages inhabiting the wave-influenced nearshore environment are intrinsically tolerant to disturbance. There are no known rare or endangered species and the invertebrate macrofaunal communities present will be dominated by small, abundant and mobile species with high reproductive and fast growth rates. Recovery of such communities following temporary disturbance will therefore be rapid and any impacts resulting from pipeline replacement and maintenance will be highly localised and persist in the very short term (months to years) only. The impacts to such communities before mitigation was therefore rated as being of either low or very low significance.

Residual impacts associated with the proposed project have all been identified as being either INSIGNIFICANT or of VERY LOW significance. If all environmental guidelines, and appropriate mitigation measures recommended in this report are implemented, there is no reason why the proposed replacement of the subsea pipeline linking the SPM to the gas-to-liquid refinery onshore should not proceed.

5. LITERATURE CITED

Airoldi, L., Rindi, F. & F. Cinelli, 1995. Structure, seasonal dynamics and reproductive phenology of a filamentous turf assemblage on a sediment influenced, rocky subtidal shore. Botanica Marina, 38(3): 227-237.

Anderson, R.J., Anderson, D.R. & J.S. Anderson, 2008. Survival of sand-burial by seaweeds with crustose bases or life-history stages structures the biotic community on an intertidal rocky shore. Botanica Marina 51, 10-20.

Andreotti, S., Rutzen, M., Van Der Walt, S., Von Der Heyden, S., Henriques, R., Meÿer, M., Oosthuizen, H. & C.A. Matthee, 2016. An integrated mark-recapture and genetic approach to estimate the population size of white sharks in South Africa. Marine Ecology Progress Series, 552: 241-253.

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., Sauer, W.H.H. & M.R. Lipinski, 1992. Can the Loligo squid fishery be managed effectively? A synthesis of research on Loligo vulgaris reynaudii. S. Afr. J. mar. Sci., **12**: 903-918.

Augustyn, C.J., Lipinski, M.R., Sauer, W.H.H., Roberts, M.J. & B.A. Mitchell-Innes, 1994. Chokka squid on the Agulhas Bank: life history and ecology. S. Afr. J. Sci., **90**: 143-153.

Awad, A.A., Griffiths, C.L. & J.K. Turpie, 2002. Distribution of South African benthic invertebrates applied to the selection of priority conservation areas. Diversity and Distributions **8**: 129-145.

Baan, P.J.A., Menke, M.A., Boon, J.G., Bokhorst, M., Schobben, J.H.M. & C.P.L. Haenen, 1998. Risico Analyse Mariene Systemen (RAM). Verstoring door menselijk gebruik. Waterloopkundig Laboratorium, Delft.

Baptist, M.J., Tamis, J.E., Borsje, B.W. & 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.

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.

Bejder, L., Samuels, A., Whitehead, H. & N. Gales, 2006. Interpreting short-term behavioral responses to disturbance within a longitudinal perspective. Animal Behavior, 72: 1149-1158.

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

Birkeland, C., Reimer, A.A. & J.R. Young, 1976. Survey of marine communities in Panama and experiments with oil. US EPA Research Series, 600/3-76-028.

Birklund, J., Toxvig, H. & C. Laustrup, 1996. RIACON Evaluation of the nourishment and sand extraction of Torsminde Denmark. The Danish Coastal Authority in cooperation with the VKI, Draft Final Report: 65 pp

Blaber, S.J.M. & T.G. Blaber, 1980. Factors affecting the distribution of juvenile estuarine and inshore fish. Journal of Fish Biology 17:143-162

Blanchard, A.L. & H.M. Feder, 2003. Adjustment of benthic fauna following sediment disposal at a site with multiple stressors in Port Valdez, Alaska. Marine Pollution Bulletin, 46: 1590-1599.

Bloom, P. & M. Jager, 1994. The injury and subsequent healing of a serious propeller strike to a wild bottlenose dolphin (Tursiops truncatus) resident in cold waters off the Northumberland coast of England. Aquatic Mammals, 20(2): 59-64.

Bombace, G., Fabi, G., Fiorentini, L. and S. Speranza (1994). Analysis of the efficacy of artificial reefs located in five different areas of the Adriatic Sea. Bulletin of Marine Science, 55: 559-580.

Bonfil, R., Meyer, M., Scholl, M.C., Johnson, R., O'brien, S., Oosthuizen, H., Swanson, S., Kotze, D. & M. Paterson, 2005. Transoceanic migration, spatial dynamics, and population linkages of white sharks. Science **310**: 100-103.

Boyd, S.E., Limpenny, D.S., Rees, H.L. & K.M. Cooper, 2005. The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). ICES Journal of Marine Science, **62**: 145-162.

Branch, G. & M. Branch, 2018. Living Shores : Interacting with southern Africa's marine ecosystems. Struik Nature. Cape Town, South Africa.

Branch, G.M. & C.L. Griffiths, 1988. The Benguela ecosystem part V: the coastal zone. Oceanog. Marine Biology: An Annual Review, **26**: 395-486.

Brown, A.C. & A. McLachlan, 1994. Ecology of sandy shores, pp. 1-328 Amsterdam, Elsevier

Brown, A.C. & E.R. Trueman, 1991. Burrowing of sandy-beach molluscs in relation to penetrability of the substratum. Journal of Molluscan Studies, **57**: 134–136.

Bruton, M.N., 1985. The effect of suspensoids on fish. Hydrobiologia, **125**: 221-241.

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

Calliari, L.J., Klein, A.H.F. & F.C.R. Barros, 1996. Beach differentiation along the Rio Grande do Sul coastline (Southern Brazil). Revista Chilena de Historia Natural, **69**: 485-493.

Cawthra, H.C. 2014. The marine geology of Mossel Bay, South Africa, Phd Thesis, University of Cape Town, 284pp.

Cawthra, H., Compton, J., Fisher, E., Machutchon, M. & C. Marean, 2015. Submerged shorelines and landscape features offshore of Mossel Bay, South Africa. Geological Society, London, Special Publications. 411: 219-233.

CCA 2008. Mossel Bay currents and fish farm dispersal study. Report prepared for Irvin & Johnson Pty Ltd. 57 pp.

Chandrasekara, W.U. & 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.

Cheshire, A.C. & D.J. Miller, 1999. The impact of sand dredging on benthic community structure at Pt Stanvac Dredge Site 4: Final report on the results of surveys 1992 to 1999. Department of Environmental Biology, University of Adelaide.

Cliff, G., Van Der Elst, R.P., Govender, A., Witthuhn, T.K. & E.M. Bullen, 1996. Chapter 36 - First Estimates of Mortality and Population Size of White Sharks on the South African Coast, In Great White Sharks. eds A.P. KLIMLEY, D.G. AINLEY, pp. 393-400. Academic Press, San Diego.

Child, M.F., Roxburgh, L., Do Linh San, E., Raimondo, D. and H.T. Davies-Mostert (eds), 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).

Clark, B.M., Smith, C.E. & W.F. Meyer, 1998. Ecological effects of fine tailings disposal and marine diamond pumping operations on surf zone fish assemblages near Lüderitz, Namibia. Report to Namdeb Diamond Corporation (Pty) Ltd., Oranjemund, Namibia. 46pp.

Clarke, D.G. & 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.

Cockcroft, V., Natoli, A., Reisinger, R., Elwen, S., Hoelzel, R., Atkins, S. & S. Plön, 2016. A conservation assessment of Tursiops aduncus. In: Child, M.F., Roxburgh, L., Do Linh, San E., Raimondo, D. & H.T. 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.

Coley, N.P., 1994. Environmental impact study: Underwater radiated noise. Institute for Maritime Technology, Simon's Town, South Africa. pp30.

Coley, N.P., 1995. Environmental impact study: Underwater radiated noise II. Institute for Maritime Technology, Simon's Town, South Africa. pp31.

Connell, S.D., 2001. Urban structures as marine habitats: an experimental comparison of the composition and abundance of subtidal epibiota among pilings, pontoons and rocky reefs. Marine Environmental Research, 52: 115-125.

Connell, S.D. & T.M. Glasby, 1999. Do urban structures influence local abundance and diversity of subtidal epibiota? A case study from Sydney Harbour. Marine Environmental Research, 47: 373-387.

Connell, S.D. & R.O. Slayter, 1977. Mechanisms of succession in natural communities and their role on community stability and organisation. American Naturalist, 111: 1119-1144.

Constantine, R., 2001. Increased avoidance of swimmers by wild bottlenose dolphins (Tursiops truncatus) due to long-term exposure to swim-with-dolphin tourism. Marine Mammal Science, 17: 689-702.

CSIR 1988. East London outfall studies report no. 3: Physical data interpretation and summaries. CSIR Report C/SEA 8804, 20pp + Figs and App, 42 pp.

CSIR & 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.

Culter, J.K. & S. Mahadevan, 1982. Long-term Effects of Beach Nourishment on the Benthic Fauna of Panama City, Florida. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Misc. report. No. 82-2.

Cyrus, D.P. & S.J.M. Blaber, 1987a. The influence of turbidity on juvenile marine fishes in estuaries. Part 1: Field studies in Lake St. Lucia on the southeastern coast of Africa. Journal of Experimental Marine Biology and Ecology, **109**: 53-70.

Cyrus, D.P. & S.J.M. Blaber, 1987b. The influence of turbidity on juvenile marine fishes in estuaries. Part 2: Laboratory studies, comparisons with field data and conclusions. Journal of Experimental Marine Biology and Ecology, **109**: 71-91.

Cyrus, D.P. & S.J.M. Blaber, 1987c. The influence of turbidity on juvenile marine fish in the estuaries of Natal, South Africa. Continental Shelf Research, **7(11/12)**: 1411-1416.

Daly, M.A. & A.C. Mathieson, 1977. The effects of sand movements on intertidal seaweeds and selected invertebrates at Bound Rock, New Hampshire. Marine Biology 43: 45-55.

Dawson, J., Wright, A. & K. Hutchings, 2019. Benthic Mapping Assessment for the Proposed Algoa Bay Sea-based Aquaculture Development Zone. Report prepared for Department of Agriculture, Forestry & Fisheries by Anchor Research and Monitoring (PTY). Ltd. Report no. 1817/1. October 2019.

Department of Environment, Forestry and Fisheries [DEFF], 2019. Strategic Environmental Assessment for Marine and Freshwater Aquaculture Development in South Africa. ISBN: 978-0-7988-5646-1. CSIR Report Number: CSIR/IU/021MH/ER/2019/0050/A. Stellenbosch, Western Cape.

De Ruyck, A.M.C., Donn, T.E. & A. McLachlan, 1992. Distribution of three intertidal cirolanid isopods (Flabellifera: Cirolanidae) on a South African sandy beach. Cah. Biol. Mar., **33**: 147-168.

Dicken, M.L., Smale, M.J. & A.J. Booth, 2013. White sharks Carcharodon carcharias at Bird Island, Algoa Bay, South Africa. African Journal of Marine Science 35: 175–182.

Dorfler, K.A., 2002. The dynamics of turbidity on the spawning grounds of chokka squid Loligo vulgaris reynaudii and links to squid catches. MSc Thesis. University of Port Elizabeth. 157pp.

Douglas, A.B., Calambokidis, J., Raverty, S., Jeffries, S.J., Lambourn, D.M. and S.A. Norma (2008). Incidence of ship strikes of large whales in Washington State. Journal of the Marine Biological Association of the United Kingdom, 88: 1121-1132.

Downey, N.J., 2014. The Role of the Deep Spawning Grounds in Chokka Squid (Loligo reynaudi D'Orbigny, 1845) Recruitment. PhD Thesis, Rhodes University, Grahamstown, pp135.

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.

Du Preez, H.H., 1984. Molluscan predation by Ovalipes punctatus (De Haan) (Crustacea: Brachyura: Portunidae). J. Exp. Mar. Biol. Ecol., **84**: 55-71.

Eagle, G.A. & M.J. Orren, 1985. A seasonal investigation of the nutirents and dissolved oxygen in the water column along two lines of Stations south and West of South Africa., Res. Rep. CSIR, 567: 52pp + 126 pp of Tables and Figures.

Ellingsen, K.E., 2002. Soft-sediment benthic biodiversity on the continental shelf in relation to environmental variability. Marine Ecology Progress Series, **232**: 15-27.

Ellis, D.V., 1996. Practical mitigation of the environmental effect of offshore mining. Offshore Technology Conference, Houston Texas, 6-9 May 1996.

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. & C. Heim, 1985. Submersible surveys of benthos near a turbidity cloud. Marine Pollution Bulletin, **16**: 197-202.

Elvin, S.S. & C.T. Taggart, 2008. Right whales and vessels in Canadian waters. Marine Policy, 32(3): 379-386.

Elwen, S.H. & R.H. Leeney, 2010. Injury and Subsequent Healing of a Propeller Strike Injury to a Heaviside's dolphin (Cephalorhynchus heavisidii). Aquatic Mammals, 36(4): 382-387.

Emery, J.M., Milliman, J.D. & E. Uchupi, 1973. Physical properties and suspended matter of surface waters in the Southeastern Atlantic Ocean. J. Sed. Petr. **43**: 822-837.

Essink, K., 1993. Ecosystem effects of dredging and dumping in the Ems-Dollard estuary and the Wadden Sea, RWS, RIKZ.

Essink, K., 1997. Risk analysis of coastal nourishment techniques (RIACON). Final evaluation report. Rijkswaterstaat, National Institute for Coastal and Marine Management/RIKZ.

Essink, K., 1999. Ecological effects of dumping of dredged sediments; options for management. Journal ofCoastal Conservation, **5**: 12.

Flach, E. & L. Thomsen, 1998. Do physical and chemical factors structure the macrobenthic community at a continental slope in the NE Atlantic? Hydrobiologia, **375/376**: 265-285.

Gorzelany, J.F. & W.G. Nelson, 1987. The effects of beach replenishment on the benthos of a sub-tropical Florida beach. Marine Environmental Research, **21**: 75-94.

Goschen, W. & E.H. Schumann, 1995. Upwelling and the occurrence of cold water around Cape Recife. S. Afr. J. Sci., 16: 57-67.

Götz, A., Kerwath, S.E., Attwood, C.G. & W.H. Sauer, 2009a. Effects of fishing on a temperate reef community in South Africa 1: Ichthyofauna. African Journal of Marine Science 31(2): 241-251.

Götz, A., Kerwath, S.E., Attwood, C.G. & W.H. Sauer, 2009b. Effects of fishing on a temperate reef community in South Africa 2: Benthic invertebrates and algae. African Journal of Marine Science 31(2): 253-262.

Greene, K., 2002. Beach Nourishment: A Review of the Biological and Physical Impacts, ASMFC Habitat Management Series #7 (Atlantic States Marine Fisheries Commission). Pp 179

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.

Hackney, C.T., Posey, M.H., Ross, S.W. & A.R. Norris, (eds.), 1996. A Review and Synthesis of Data: Surf Zone Fishes and Invertebrates in the South Atlantic Bight and the Potential Impacts from Beach Nourishment. Prepared for U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

Hall, S.J., 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. Oceanography and Marine Biology: An Annual Review, 32: 179-239.

Harris, L.R., Holness, S.D., Kirkman, S.P., Sink, K.J., Majiedt, P. & A. Driver, 2022. National Coastal and Marine Spatial Biodiversity Plan, Version 1.2 (Released 12-04-2022): Technical Report. Nelson Mandela University, Department of Forestry, Fisheries and the Environment, and South African National Biodiversity Institute. South Africa. 280 pp.

Harvey, M., Gauthier, D. & 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 Bulletin, **36**: 41-55.

Hastie, G.D., Wilson, B., Tufft, L.H. & P.M. Thompson, 2003. Bottlenose dolphins increase breathing synchrony in response to boat traffic. Marine Mammal Science, 19: 74-84.

Hayden, B. & R. Dolan, 1974. Impact of beach nourishment on distribution of Emerita talpoida, the common mole crab. Journal of Waterways, Harbors, and Coastal Engineering Division, **100**: 123-132.

Hecht, T. & C.D. van der Lingen, 1992. Turbidity-induced changes in feeding strategies of fish in estuaries. S. Afr. J. Zool., 27: 95-107.

Herrmann, C., Krause, J. Chr., Tsoupikova, N. & K. Hansen, 1999. Marine Sediment extraction in the Baltic Sea. Status Report. Baltic Sea Env. Proc., 76: 1-29.

Hildebrand, J.A., 2005. Impacts of Anthropogenic Sound. Marine Mammal Research: Conservation beyond Crisis, 124: 101–124.

Hildebrand, J.A., 2009. Anthropogenic and natural sources of ambient noise in the ocean. Marine Ecology Progress Series, 395: 5–20.

Hueckel, G.J., Buckley, R.M. & B.L. Benson, 1989. Mitigating rocky habitat loss using artificial reefs. Bulletin of Marine Science, 44: 913-922.

Hughes, G. & R. Nel, 2014a. 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. & 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.

Hurme, A.K. & E.J. Pullen, 1988. Biological effects of marine sand mining and fill placement for beach replenishment: Lessons for other uses. Marine Mining, **7**: 123-136.

Hylleberg, J., Nateewathana, A. & 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.

ICES, 1992. Effects of extraction of marine sediments on fisheries, ICES Cooperative Research Report No. 182, Copenhagen 1992.

ICES ACME, 1997. ACME Report 1997: Effects of Extraction of Marine Sand and Gravel on the Baltic Ecosystem. Chapter 6.3: 49-59.

Iglesias, J.I.P., Urrutia, M.B., Navarro, E., Alvarez-Jorna, P., Larretxea, X., Bougrier, S. & M. Heral, 1996. Variability of feeding processes in the cockle Cerastoderma edule (L.) in response to changes in seston concentration and composition. J. Exp. Mar. Biol. Ecol., 197: 121-143.

Irion, D.T., Noble, L.R., Kock, A.A., Gennari, E., Dicken, M.L., Hewitt, A.M., Towner, A.V., Booth, A.J., Smale, M.J. & G. Cliff, 2017. Pessimistic assessment of white shark population status in South Africa: Comment on Andreotti et al. (2016). Marine Ecology Progress Series, 577: 251-255.

James, B.S., Bester, M.N., Penry, G.S., Gennari, E. & S.H. Elwen, 2015. Abundance and degree of residency of humpback dolphins Sousa plumbea in Mossel Bay, South Africa. Afr. J. Mar. Sci., 37(3)

Janssen, G.M., Leewis, L. & S. Marx, 2011. Mitigation of the ecological effects of nourishment on sandy shores, a case study. In: Bayed A (ed.). Sandy beaches and coastal zone management – Proceedings of the Fifth International Symposium on Sandy Beaches, 19th-23rd October 2009, Rabat, Morocco Travaux de l'Institut Scientifique, Rabat, série générale, **6**: 121-123.

Jaramillo, E., McLachlan, A. & J. Dugan, 1995. Total sample area and estimates of species richness in exposed sandy beaches. Marine Ecology Progress Series **119**: 311-314.

Jensen, A.S. & G.K. Silber, 2003. Large whale ship strike database. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-F/OPR 25. 37 pp.

Jewell, O.J., Johnson, R.L., Gennari, E. & M.N. Bester, 2013. Fine scale movements and activity areas of white sharks (Carcharodon carcharias) in Mossel Bay, South Africa. Environmental Biology of Fishes, 96: 881–894.

Jewell, O.J.D., Wcisel, M.A., Towner, A.V., Chivell, W., Van Der Merwe, L. & M.N. Bester, 2014. Core habitat use of an apex predator in a complex marine landscape. Marine Ecology Progress Series, 506, 231–242.

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.

Johnson, B.H. & T.M. Parchure, 1999. Estimating dredging sediment resuspension sources. DOER Technical Notes Collection (TN DOER-E6). U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army/mil/el/dots/doer.

Jongbloed, R.H., Dankers, N.M.J.A., Brinkman, A.G., Van Dalfsen, J.A., Smit, C.J. & J.E. Tamis, 2006. Effecten van storten van baggerspecie in het Marsdiep. Report No. C084/06, IMARES, Den Helder.

Jutte, P.C., Van Dolah, R.F. & M.V. Levisen, 1999a. An environmental monitoring study of the Myrtle Beach Renourishment Project: Physical and biological assessment of offshore sand borrow sites - Phase I.- Cherry Grove to North Myrtle Beach. Final Report. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U.S. Army Corps of Engineers, Charleston, S.C.

Jutte, P.C., Van Dolah, R.F. & M.V. Levisen, 1999b. An environmental monitoring study of the Myrtle Beach Renourishment Project: Intertidal benthic community assessment of Phase II.-Myrtle Beach. Supplemental Report. Prepared by the Marine Resources Division, South Carolina Department of Natural Resources for U.S. Army Corps of Engineers, Charleston, S.C.

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. & A. Mclachlan, 2000a. Habitat use and preferences of Indo-Pacific humpback dolphins Sousa chinensis in Algoa Bay, South Africa. Marine Mammal Science, 16(1): 65–79.

Karczmarski, L., Thornton, M. and V. Cockcroft (2000b). Daylight occurrence of humpback dolphins Sousa chinensis in Algoa Bay, South Africa. African Journal of Ecology, 38(1): 86 – 90.

Kenny, A.J. & H.L. Rees, 1994. The effects of marine gravel extraction on the macrobenthos: Early post-dredging recolonisation. Marine Pollution Bulletin, 28: 442-447.

Kenny, A.J. & H.L. Rees, 1996. The effects of marine gravel extraction on the macrobenthos: Results 2 years post-dredging. Marine Pollution Bulletin, 32: 615-622.

Kirk, J.T.O., 1985. Effects of suspensoids on penetration of solar radiation in aquatic ecosystems. Hydrobioligica, 125: 195-208.

Klages N.T.W. & T.G. Bornman 2003. Port of Ngqura Marine Biomonitoring Programme. Annual Report 2002-2003. Prepared for National Ports Authority. IECM Report C86: 1-65.

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.

Kock, A., O'riain, M.J., Mauff, K., Meÿer, M., Kotze, D. & C. Griffiths, 2013. Residency, habitat use and sexual segregation of white sharks, Carcharodon carcharias in False Bay, South Africa. PLoS ONE 8: e55048.

Koper, R.P., Karczmarski, L., Du Prees, D. & S. Plön, 2016. Sixteen years later: Occurrence, group sizes, and habitat use of humpback dolphins (Sousa plumbea) in Algoa Bay, South Africa.

Koper, R.P & S. Plön, 2012. The potential impacts of anthropogenic noise on marine animals and recommendations for research in South Africa. EWT Research and Technical Paper No. 1. Endangered Wildlife Trust, South Africa.

Kranz, P.M., 1974. The anastrophic burial of bivalves and its paleoecological significance. Journal of Geology, **82**:29

Laist, D. W., Knowlton, A. R., Mead, J. G., Collet, A. S. & M. Podesta, 2001. Collisions between ships and whales. Marine Mammal Science, 17: 35–75.

Le Roy, D., Degraer, S., Megaert, K., Dobbelaere, I., Vincx, M. & P. Vanhaecke, 1996. Risk of shoreface nourishment for the coastal marine benthic community. Evaluation of the nourishment of De Haan, Belgium. ECOLAS N.V., Antwerpen.

Leung-Ng, S. & S. Leung, 2003. Behavioral response of Indo-Pacific humpback dolphin (Sousa chinensis) to vessel traffic. Marine Environmental Research, 56: 555-567.

Levy, D., 2016. The environmental factors determining temporal distributions of cetaceans in Mossel Bay, South Africa. MSc Thesis, University of Cape Town, 57pp.

Löffler, M. & J. Coosen, 1995. Ecological Impact of Sand Replenishment. P.291-299. In: HEALY & DOODY (Eds). Directions in European Coastal Management. Samara Publishing Ltd., Cardigan.

Lusseau, D., 2004. The hidden cost of tourism: Effects of interactions with tour boats on the behavioral budget of two populations of bottlenose dolphins in Fiordland, New Zealand. Ecology and Society, 9(1): Part. 2.

Lusseau, D., 2005. Residency pattern of bottlenose dolphins Tursiops spp. in Milford Sound, New Zealand, is related to boat traffic. Marine Ecology Progress Series, 295: 265-272.

Lusseau, D., Bain, D.E., Williams, R. & J.C. Smith, 2009. Vessel traffic disrupts the foraging behavior of southern resident killer whales Orcinus orca. Endangered Species Research, 6: 211-221.

Lwandle, 2009. Proposed floating facility for offloading of liquid natural gas in Mossel Bay: Marine Ecology Specialist Study. Lwandle Report No. LT-08-059b. 30pp.

Lynch, A.E., 1994. Macrofaunal recolonization of Folly Beach, South Carolina, After Beach Nourishment. Unpublished master's thesis, University of Charleston, Charleston, S.C.

Malme, C.I., Miles, P.R., Tyack, P., Clark, C.W. & 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.

Masikane, N.F., 2011. Nearshore subtidal soft-bottom macrozoobenthic community structure in the western sector of Algoa Bay, South Africa. MSc Thesis, Nelson Mandela Metropolitan University

Maurer, D., Keck, R.T., Tinsman, J.C., Leathem, W.A., Wethe, C.A., Huntzinger, M., Lord, C. & T.M. Church, 1978. Vertical Migration of Benthos in Simulated Dredge Material Overburdens. Col. I: Marine Benthos. DMRP Technical Report D-78-35. Report prepared by University of Delaware, College of Marine Studies. Vicksburg, Miss.: U.S. Army Engineer Waterways Experiment Station, U.S. Army Corps of Engineers.

Maurer, D., Keck, R.T., Tinsman, J.C. & 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. & 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. & 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. & 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. & W.A. Leathem, 1986. Vertical migration and mortality of marine benthos in dredged material: A synthesis. Int. Revue Ges. Hydrobiologia, **71**: 49-63.

McLachlan, A. 1977. Studies on the psammolittoral meiofaun of Algoa Bay, South Africa. I. Physical and chemical evaluation of the beaches. Zoologica Africana **12**: 15-32.

McLachlan, A., 1990. Dissipative beaches and macrofaunal communities on exposed intertidal sands. Journal of Coastal Research, **6**: 57-71.

McLachlan, A. & G.C. BATE, 1984. Carbon budget of a high energy surf-zone. Vie et Milieu **34**: 67-77.

McLachlan, A., JARAMILLO, E., DONN, T.E. And F. WESSELS. 1993. Sandy beach macrofauna communities and their control by the physical environment: a geographical comparison. Journal of coastal Research, Special Issue, **15**: 27-38.

McLachlan, A., Cockcroft, A.C. & D.E. Malan, 1984. Benthic faunal response to a high energy gradient. Mar. Ecol. Prog. Ser., **16**: 51-63.

McLachlan, A., Wooldridge, T.H. & A.H. Dye, 1981. The ecology of sandy beaches in southern Africa. S. Afr. J. Zool. **16**: 219-231.

Melis & Du Plessis Geotechnical Consultants, 1990. Report on the Marine Geotechnical Study for the Product Export Pipeline Route and SPM Site at Voorbaai, Mossel Bay, Report Number MD364/1 March 1990, 54pp.

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

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.

Menn, I., Junghans, C. & K. Reise, 2003. Buried alive: Effects of beach nourishment on the infauna of an erosive shore in the North Sea. Senckenbergiana Maritima, **32**:125-145

Monteiro, P.M.S., 1997. Table Bay sediment study: Phase III. CSIR Report ENV/S-C97085. Prepared for Cape Metropolitan Council.

Navarro, E., Iglesias, J.I.P., Camacho, P.A. & U. Labarta, 1996. The effects of diets of phytoplankton and suspended bottom material on feeding and absorption of raft mussels (Mytilus galloprovincialis Lmk). J. Exp. Mar. Biol. Ecol., 198: 175-189.

Nedwell, J.R., Turnpenny, A.W.H., Lovell, J.M. and B. Edwards (2006). An investigation into the effects of underwater piling noise on salmonids. Journal of the Acoustical Society of America, 120: 2550-2554.

Nel, R., McLachlan, A. & D.P.E. Winter, 2001. The effect of grain size on the burrowing of two Donax species. Journal of Experimental Marine Biology and Ecology, **265,** 219-238.

Nelson, W.G., 1993. Beach restoration in the southeastern US: Environmental Effects and Biological Monitoring. Ocean Coastal Management, **19**: 157-182.

Newell, R.C., Seiderer, L.J. & D.R. Hitchcock, 1998. The impact of dredging work in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. Oceanogr. Mar. Biol. Ann. Rev., 36: 127–178.

Newell, R.C., Seiderer, L.J., Simpson, N.M. & J.E. Robinson, 2004. Impacts of Marine Aggregate Dredging on Benthic Macrofauna off the South Coast of the United Kingdom. Journal of Coastal Research, **20(1)**: 115–125.

NOAA, 1998. Fact Sheet: Small Diesel Spills (500-5000 gallons) Available at: http://response.restoration.noaa.gov/oilaids/diesel.pdf

NRC, 2003. Ocean noise and marine mammals. National Academy Press, Washington, DC.

NRC, 2005. Marine mammal populations and ocean noise, determining when noise causes biologically significant effects. The National Academy Press, Washington, DC.

Panigada, S., Pesante, G., Zanardelli, M., Capoulade, F., Gannier, A. & M.T. Weinrich, 2006. Mediterranean fin whales at risk from fatal ship strikes. Marine Pollution Bulletin, 52(10): 1287-98.

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, CMS, 1996. Environmental Assessment and Management Plan report for deep sea diamond mining in Namibia by Arena Mining (Pty) Ltd.

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. & A.P. Martin, 2001. Sex-biased dispersal of great white sharks. Nature **412**: 139 – 140.

Parr, T., Diener, D. & S. Lacy, 1978. Effects of Beach Replenishment on the Nearshore Sand Fauna at Imperial Beach, California. MR-78-4. U.S. Army Corps of Engineers Coastal Engineering Research Center.

Parsons, T.R., Kessler, T.A. & Li Guanguo, 1986a. An ecosystem model analysis of the effect of mine tailings on the production of phytoplankton. Acta Oceanologica Sinica, 5: 425-436.

Parsons, T.R., Thompson, P. & Wu Yong, 1986b. The effect of mine tailings on the production of phytoplankton. Acta Oceanologica Sinica, 5: 417-423.

Peddemors, V.M., Atkins S. & W.H. Oosthuizen, 2004. Sousa plumbea-Indian Ocean Humpback Dolphin. Pages 660-661. In: Friedmann Y. & B. Daly eds. Red Data Book of the Mammals of South Africa: A Conservation Assessment. CBSG Southern Africa, Conservation Breeding Specialist Group (SSC/IUCN), Endangered Wildlife Trust, South Africa.

Peddemors, V.M. & W.H. Oosthuizen, 2004. Tursiops aduncus- Indian Ocean Bottlenose Dolphin. Pages 666-667. In: Friedmann Y. & B. Daly eds. Red Data Book of the Mammals of South Africa: A Conservation Assessment. CBSG Southern Africa, Conservation Breeding Specialist Group (SSC/IUCN), Endangered Wildlife Trust, South Africa.

Perry, J., 2005. Environmental Impact Assessment for Offshore Drilling the Falkland Islands to Desire Petroleum Plc. 186pp

Peterson, C.H., Hickerson, D.H.M. & G.G. Johnson, 2000. Short-Term Consequences of Nourishment and Bulldozing on the Dominant Large Invertebrates of a Sandy Beach. Journal of Coastal Research, 16(2): 368-378.

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., Cockcroft, V.G. and W.P. Froneman, 2015. The Natural History and Conservation of Indian Ocean Humpback Dolphins (Sousa plumbea) in South African Waters. Advances in Marine Biology, 72:143–162.

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.

Posford Duvivier Environment (2001). Guidelines on the impact of aggregate extraction on European marine sites. Prepared for the UK Marine SACs Project, Task Manager, Dr Margaret Hill, Countryside Council for Wales.

Pulfrich, A. & G.M. Branch, 2014. Using diamond-mined sediment discharges to test the paradigms of sandy-beach ecology. Estuarine, Coastal and Shelf Science, 150: 165-178.

Pulfrich, A. & K. Hutchings, 2021. Sandy-Beach Macrofaunal Communities on the Sperrgebiet Coastline: Consolidated Beach Monitoring Report – 2020. Report to NAMDEB Diamond Corporation (Pty) Ltd., Oranjemund, Namibia. January 2022, 83pp.

Pulfrich, A., Nel, P. & A.J.Penney, 2004. Impacts of Beach Mining Operations on Sandy Beach Macrofaunal Communities on the Beaches of Geelwal Karoo: 2004 Beach Survey. Pisces Environmental Services (Pty) Ltd. Report to Trans Hex Operations (Pty) Ltd. October 2004, 42pp.

Rakocinski, C.F., Heard, R.W., Lecroy, S.E., Mclelland, J.A. & T. Simons, 1996. Responses by macrobenthic assemblages to extensive beach restoration at Perdido Key, Florida, U.S.A. Journal of Coastal Research, **12**: 326-353.

Reisinger, R. & L. Karczmarski, 2010. Population size estimate of Indo-Pacific bottlenose dolphins in the Algoa Bay region, South Africa. Journal of Marine Mammal Science, 26(1): 86–97.

Relini, G., Zamboni, N., Tixi, F. & G. Torchia, 1994. Patterns of sessile macrobenthos community development on an artificial reef in the Gulf of Genoa (northwestern Mediterranean). Bulletin of Marine Science, 55: 745-771.

Roberts, M.J., 2005. Chokka squid (Loligo vulgaris reynaudii) abundance linked to changes in South Africa's Agulhas Bank ecosystem during spawning and the early life cycle. ICES Journal of Marine Science, **62**: 33–55.

Roberts, M.J. & W.H.H. Sauer, 1994. Environment: the key to understanding the South African chokka squid (Loligo vulgaris reynaudii) life cycle and fishery? Antarctic Science, **6**: 249-258.

Roberts, M.J., Downey, N.J. & W.H.H. Sauer, 2012. The relative importance of shallow and deep shelf spawning habitats for the South African chokka squid (Loligo reynaudii). ICES Journal of Marine Science, doi:10.1093/icesjms/fss023.

Roberts, R.D., Murray, S., Gregory, R. & B.A. Foster, 1998. Developing an efficient macrofauna monitoring index from an impact study - A dredge spoil example. Mar. Pollut. Bull., 36: 231-235.

Ryklief, R., Pistorius, P.A. & R. Johnson, 2014. Spatial and seasonal patterns in sighting rate and lifehistory composition of the white shark Carcharodon carcharias at Mossel Bay, South Africa, African Journal of Marine Science, 36(4): 449-453,

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.

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.

Schoeman, D.S., McLachlan, A. & J.E. Dugan, 2000. Lessons from a Disturbance Experiment in the Intertidal Zone of an Exposed Sandy Beach. Estuarine and Coastal Shelf Science, **50(6)**: 869-884.

Scholz, D., Michel, J., Shigenaka, G. & 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. & 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. & 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.

Schumann, E.H., L-A. Perrins & I.T. Hunter. 1982. Upwelling along the South coast of the Cape Province, South Africa. South African Journal of Science, 78(6): 238-242.

Shelton, P.A., Crawford, R.J.M., Cooper, J. & R.K. Brooke, 1984. Distribution, population size and conservation of the jackass penguin Spheniscus demersus. South African Journal of Marine Science 2: 217–257.

Sink, K.J., Van Der Bank, M.G., Majiedt, P.A., Harris, L.R., Atkinson, L.J., Kirkman, S.P. and N. Karenyi (eds). 2019. South African National Biodiversity Assessment 2018 Technical Report Volume 4: Marine Realm. South African National Biodiversity Institute, Pretoria. South Africa.

SLR Consulting Australia, 2019. Proposed Offshore Exploration Drilling in PEL83, Orange Basin, Namibia. Underwater Noise Preliminary Modelling Prediction and Impact Assessment. Prepared for SLR Consulting (Namibia) (Pty) Ltd. July 2019. 47pp.

Smith, S.D.A. & 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.

Smit, M.G.D., Holthaus, K.I.E., Tamis, J.E., Jak, R.G., Karman, C.C., Kjeilen-Eilertsen, G., Trannum, H. & 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. & 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.

Snelgrove, P.V.R. & C.A. Butman, 1994. Animal-sediment relationships revisited: cause versus effect. Oceanography & Marine Biology: An Annual Review, **32**: 111-177.

Soares, A.G., 2003. Sandy beach morphodynamics and macrobenthic communities in temperate, subtropical and tropical regions - a macroecological approach. PhD, University of Port Elizabeth

Souza, J.R.B. & N.M. Guanuca, 1994. Zonation and seasonal variation of the intertidal macrofauna of a sandy beach of Parana, Brazil. Scienta Marina, **59(2)**:103-111.

Speybroeck, J., Bonte, D., Courtens, W., Gheskiere, T., Grootaert, P., Maelfait, J.-P., Mathys, M., Provoost, S., Sabbe, K., Stienen, E., Van Lancker, V., Vincx, M. & S. Degraer, 2004. Studie over de impact van zandsuppleties op het ecosysteem, Ministerie van de Vlaamse Gemeenschap. Afdeling waterwegen kust.

Speybroeck, J., Bonte, D., Courtens, W., Gheskiere, T., Grootaert, P., Maelfait, J.-P., Mathys, M., Provoost, S., Sabbe, K., Stienen, E., Van De Walle, M., Van Lancker, V., Wouter Van Landuyt, W., Vercruysse, E., Vincx, M. & S. Degraer, 2005. How may beach nourishment affect the sandy beach ecosystem? The case of Belgian beaches. In: Herrier J-L, Mees J, Salman A, Seys J, Van Nieuwenhuyse H, Dobbelaere I (Eds). Proceedings 'Dunes and Estuaries 2005' – International Conference on Nature Restoration Practices in European Coastal Habitats, Koksijde, Belgium, 19-23 September 2005. VLIZ Special Publication 19, xiv + 685 pp.

SRK Consulting (Pty) Ltd., 2001. Final Environmental Impact Report: Proposed Mosspar H (LAD) and Mosspar M (LAK) Storage Tanks and Sub-sea Pipeline. Voorbaai, Mossel Bay. SRK Report 278155/3, April 2001, 140pp.

Steiner, R., 2018. Environmental Risks of Condensate Releases - Leviathan Offshore Gas Project, Israel. Independent Expert Opinion. https://homelandguards.org › uploads › 2018/08 (accessed 18 October 2022).

Swart, V.P. & J.L. Largier, 1987. Thermal structure of the Agulhas Bank waters. South African Journal of Marine Science, 5: 243-253.

Talbot, M.M.B., 1986. The distribution of the surf-zone diatom Anaulus birostratis Grunow in relation to the nearshore circulation in an exposed beach/surf-zone ecosystem. PhD thesis, University of Port Elizabeth.

Towner, A.V., Underhill, L.G., Jewell, O.J.D. & M.J. Smale, 2013. Environmental influences on the abundance and sexual composition of white sharks Carcharodon carcharias in Gansbaai, South Africa. PLoS ONE 8: e71197.

Trueman, E.R. & A.D. Ansell, 1969. The mechanisms of burrowing into soft substrata by marine animals. Oceanography and Marine Biology: an Annual Review, **7**: 315–366.

Turk, T.R. & 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.

U.S. Department of the Interior/ Fish and Wildlife Service (USDOI/FWS), 2000. Draft Fish and Wildlife Coordination Act Report, Brunswick County Beaches Project. Ecological Services Raleigh Field Office, Raleigh, North Carolina. 175 pp.

U.S. Army Corp of Engineers (USACE), 2001. The New York Districts' Biological Monitoring Program for the Atlantic Coast of New Jersey, Asbury Park to Manasquan Section Beach Erosion Control Project. Final report. Waterways Experiment Station, Vicksburg, MS.

Van Dalfsen, J.A. & K. Essink, 1997. Risk analysis of coastal nourishment techniques in The Netherlands. Part A. The ecological effects of shoreface nourishment off the island of Terschelling, Part B. The ecological effects of subaqueous sand extraction North of the island of Terschelling, Part C. Literature references. National Institute for Coastal and Marine Management RIKZ.

Van Dalfsen, J.A. & K. Essink, 2001. Benthic community response to sand dredging and shoreface nourishment in Dutch coastal waters. Senckenbergiana Maritima, **31**: 329-332.

Van Dalfsen, J.A., Essink, K., Toxvig Madsen, H., Birklund, J., Romero, J. & M. Manzanera, 2000. Differential response of macrozoobenthos to marine sand extraction in the North Sea and the Western Mediterranean. ICES J. Mar. Sci., **57**: 1439–1445.

Van Moorsel, G.W.N.M., 1993. Long-term recovery of geomorphology and population development of large molluscs after gravel extraction at the Klaverbank (North Sea). Rapport Bureau Waardenburg bv, Culemborg, The Netherlands.

Van Moorsel, G.W.N.M., 1994. The Klaver Bank (North Sea), geomorphology, macrobenthic ecology and the effect of gravel extraction. Rapport Bureau Waardenburg and North Sea Directorate (DNZ), Ministry of Transport, Public Works & Water Management, The Netherlands.

Van Niekerk, L., Adams, J.B., Lamberth, S.J., Mackay, C.F., Taljaard, S., Turpie, J.K., Weerts S.P. & D.C. Raimondo, 2019 (eds). South African National Biodiversity Assessment 2018: Technical Report. Volume 3: Estuarine Realm. CSIR report number CSIR/SPLA/EM/EXP/2019/0062/A. South African National Biodiversity Institute, Pretoria. Report Number: SANBI/NAT/NBA2018/2019/Vol3/A. http://hdl.handle.net/20.500.12143/6373 (Unproofed version)

Vermeulen, E., Bouveroux, T., Plön, S., Atkins, S., Chivell, W., Cockcroft, V., Conry, D., Gennari, E., Hörbst, S., James, B.S., Kirkman, S., Penry, G., Pistorius, P., Thornton, M., Vargas-Fonseca, A. & S.H. Elwen, 2017. Indian Ocean humpback dolphin (Sousa plumbea) movement patterns along the South African coast. Aquatic Conservation, 28(1): 231-240.

Watkins, W.A., 1986. Whale reactions to human activities in Cape Cod waters. Marine Mammal Science, 2(4): 251-262.

White, R.W., Gillon, K.W., Black, A.D. & J.B. Reid, 2001. Vulnerable concentrations of seabirds in Falkland Islands waters. JNCC, Peterborough.

Whittington, P.A., Tree, A.J., Connan, M. and E.G. Watkins, 2015. The status of the Damara Tern in the Eastern Cape, South Africa. Ostrich, 86 (1&2): 65–73.

Wooldridge, T.H., 1983. Ecology of beach and surf-zone mysid shrimp in the Eastern Cape, South Africa. In: Sandy beaches as ecosystems, Eds: McLachlan, A. and Erasmus, T. Junk, The Hague, pp.449-460.

Wooldridge, T.H., Klages, N.T. & M.J. Smale, 1997. Proposed harbour development at Coega (Pre-feasibility Phase): Specialist report on the nearshore environment. Prepared for PORTNET.

Zoutendyk, P. & I.R. Duvenage, 1989. Composition and biological implications of a nepheloid layer over the inner Agulhas Bank near Mossel Bay, South Africa. Trans. Roy. Soc. S. Afr., **47**: 187-197.