2019
Strategic Environmental Assessment for Marine and Freshwater Aquaculture Development in South Africa

APPENDIX A

Specialist Assessments

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APPENDIX A-1

Marine Biodiversity and Ecology Specialist Assessment

Marine Biodiversity and Ecology Specialist Assessment

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ABBREVIATIONS & ACRONYMS

Biodiversity Act	National Environmental Management: Biodiversity Act (No. 10 of 2004)
CES	Coastal Environmental Services
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DWAFF	Department of Water Affairs and Forestry
E	Extreme
EFZ	Estuarine Functional Zone
EIA	Environmental Impact Assessment
EIF	Environmental Integrity Framework
EU	Extremely unlikely
FAO	Food and Agriculture Organization of the United Nations
H	High
ha	Hectare
ICM Act	National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008)
IUCN	International Union for Conservation of Nature
KZN	KwaZulu-Natal
L	Likely (in terms of Likelihood), Low (in terms of Risk)
M	Medium (in terms of Consequences), Moderate (in terms of Risk)
MLRA	Marine Living Resources Act (No. 18 of 1998)
MPA	Marine Protected Area
NEMA	National Environmental Management Act (No. 107 of 1998)
NL	Not likely
NPAES	National Protected Areas Expansion Strategy
RAS	Recirculating aquaculture system
SANBI	South African National Biodiversity Institute
SDF	Spatial development framework
Se	Severe
Sl	Slight
SPLUMA	Spatial Planning and Land-use Management Act (No. 16 of 2013)
VH	Very high
VL	Very likely
VU	Very unlikely
Water Act	National Water Act (No. 36 of 1998)

1 SUMMARY

Fish and shellfish farming in marine environments has a wide range of potential environmental impacts and risks posed to marine biodiversity and ecology are key issues that need to be investigated in considering the sustainability of marine aquaculture (mariculture). This chapters presents the results of assessment of risks associated with farming of five possible mariculture species and seven types of production system conducted in eight identified mariculture study areas along the South African coast.

Generically important, spatially explicit (mappable) ecological features and socio-economic uses in coastal and marine environments were identified as:

- ***Ecological***: Formally protected areas; estuaries (specifically marine environments adjacent to estuaries); fluvially-derived banks; aggregation areas for important marine species (e.g. seal, penguin colonies, islands); important fishery nurseries; critically endangered habitats; endangered habitats; vulnerable habitats; least threatened habitats;
- ***Socio-economic***: Important recreational areas (Blue Flag beaches and popular diving sites); high density urbanised areas; cultivated lands; commercial ports; small ports and fishing harbours.

These features and uses were rated in term of their sensitivity to anthropogenic (mariculture) pressures. This provided a means of identifying ecological and socio-economic sensitivities across each of the eight study areas, and representing these spatially in zones categorised as being of "Very High", "High", "Moderate", and "Low" sensitivity. In this way geo-referenced ecological and socio-economic attribute maps, as well as environmental sensitivity maps for the various mariculture study areas could be developed.

Having produced sensitivity maps, key impacts associated with the selected mariculture species and production systems were identified. These included:

- Alteration in water circulation patterns and wave regimes;
- Alteration in benthic habitat;
- Alteration of genetic structure of wild populations;
- Introduction of invasive alien species;
- Transmission of diseases and parasites to wild populations;
- Interactions with- and entanglement of marine biota;
- Destruction of terrestrial vegetation;
- Deterioration in water quality (pollution and eutrophication); and
- Socio-economic impacts (conflict of use).

Each of these impacts was briefly discussed, and possible mitigating measures were identified. For the purposes of Strategic Environmental Assessment a risk evaluation approach was then followed. This involved quantification of the likelihood of impacts (associated with each species/production system), and the consequences of impacts (as determined by the sensitivity of the receiving environment). This was performed for scenarios of unmitigated and mitigated impact. Likelihood and consequence ratings were finally used to determine overall risk (with and without mitigation) posed by each species/production system to the various ecological and socio-economical attributes, based on their sensitivities.

In the next phase of this study, risk assessment results produced here, together with the sensitivity maps for the various study areas, will be used to prepare production system-specific risk maps for various study areas.

2 INTRODUCTION

Fisheries and aquaculture are an important source of food, income and livelihoods for millions of people across the world. The world per capita fish supply reached a record of 20 kg in 2014 (FAO, 2016a). Fast growth in aquaculture has contributed markedly to this, and aquaculture now provides about 50% of all fish used for human consumption. Review of the world's fisheries and aquaculture (FAO, 2016a) has highlighted the tremendous potential for the oceans and inland waters to contribute to food security and to assist in providing adequate nutrition for the growing global population. For such potential to be realised, aquaculture developments need to be sustainable and should be conducted in accordance with the principles of "Blue Growth" (FAO, 2016a, 2016b) in supporting sustainable management of living aquatic resources, balancing their use and conservation in an economically, socially and environmentally responsible manner.

Contributions of marine aquaculture (hereafter referred to as mariculture) to socio-economic well-being vary in different parts of the world. In many places they have been viewed as positive, but in some Latin America and Caribbean regions this has not been the case. Here fast growing aquaculture production has not resulted in an increase in employment opportunities as several of the species cultivated are aimed at satisfying highly competitive foreign markets. Mariculture here has therefore required a focus on efficiency, quality, lower costs and greater reliance on technological developments rather than human labour (FAO, 2016a).

Integrated mariculture is a concept that has come to the fore in recent years, involving mariculture systems sharing resources (e.g. water, feeds, management) with other activities, most commonly agricultural, agro-industrial, and infrastructural development (e.g. wastewaters, power stations) (Soto, 2009). This field requires more research to be implemented optimally, but it shows significant potential to become an important tool in facilitating sustainable growth of mariculture.

Key to sustainable growth in aquaculture (including mariculture) production, is the need to strengthen aquatic ecosystem governance to deal with the competition for space and resources. Increasingly it is becoming necessary to coordinate various activities taking place in a specific area, specifically recognizing their cumulative impacts, and to align sustainability goals and legal frameworks. This will require effective, cross-sectoral coordination to ensure that sustainability goals such as environmental protection and ecosystem and biodiversity conservation align with social and economic sustainability goals (FAO, 2016a).

In South Africa, aquaculture production has increased significantly during the last 20 years. Marine operations are the main contributor to total aquaculture production, and in 2013 contributed about 70% of total production in South Africa (DAFF, 2017a). From 2000 to 2015 total marine aquaculture production increased by 2535.94 tons (240.16%, Figure 1, DAFF, 2016). Mariculture production (excluding seaweed) is highest in the Western Cape (92%) followed by the Eastern Cape (7%) (2015 figures, DAFF, 2016).

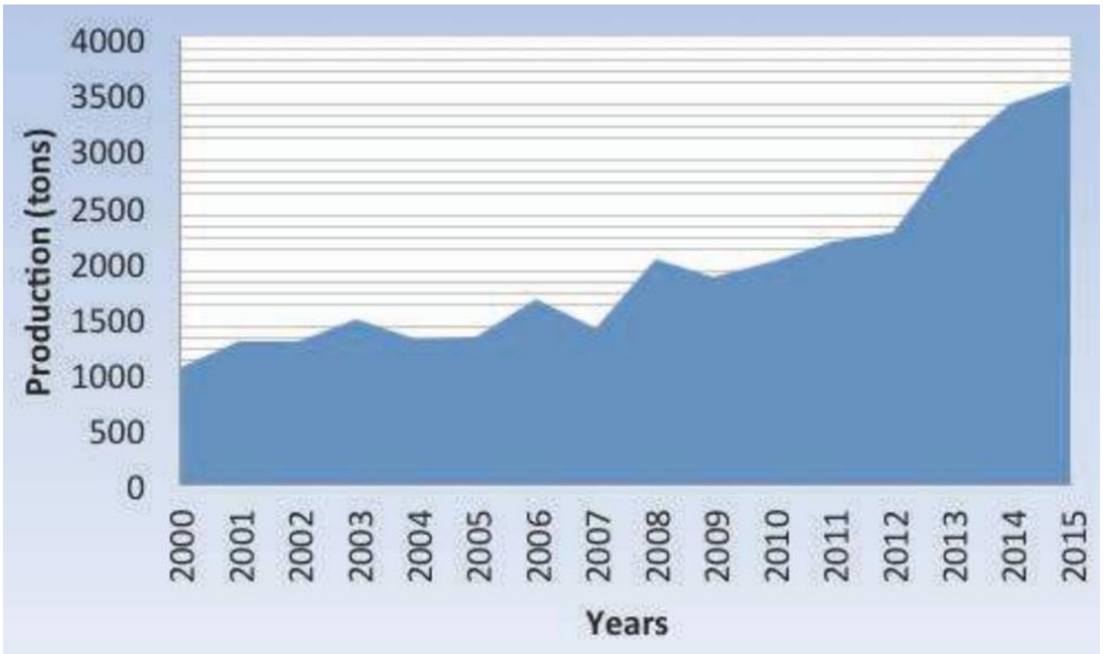

Figure 1. Growth in mariculture production in South Africa from 2000 to 2015 (Source: DAFF, 2016)

Mariculture relies on suitable environmental quality for efficient production, health of stocks and product quality. However, if not properly designed and operated, mariculture activities can detrimentally impact coastal environments and affect the value that other users derive from coastal resources. To promote sustainable development of the mariculture sector, South Africa's Department of Agriculture, Forestry and Fisheries (DAFF) introduced an Environmental Integrity Framework (EIF) for Marine Aquaculture in 2012 (DAFF, 2012). This is based on principles of sustainable development, and seeks optimisation and equity of human beneficiation from the use of natural resources, while maintaining biological diversity and ecosystem functioning. To achieve this the EIF provides a framework for setting objectives, indicators, mitigation measures, monitoring and performance standards, as the basis for responsible and sustainable development of marine aquaculture in South Africa.

Following the development of the EIF, DAFF prepared feasibility studies focusing on specific categories of mariculture species, namely marine finfish (Dusky kob and Atlantic salmon) (DAFF, 2017a) and oysters and mussels (DAFF, 2017b). These high-level, non-site specific studies evaluated the technical and financial feasibility of the various types of mariculture within the South African context. They provided background on the biology and environmental requirements of the mariculture species, different mariculture production systems, and investigated operational scales, timeframes, and financial requirements for commercially viable operations. While these feasibility studies had an economic focus, they also considered social aspects addressing potential stakeholders and community impacts. Aspects covered included:

- Descriptions of the biology of the selected species and applicable production systems (historical and current);
- Suitable regions where species could be farmed based on environmental and logistical criteria;

- The socio-economic context of mariculture in South Africa, with a focus on overall impacts;
- Market conditions for mariculture products in South Africa and internationally;
- Conceptual production system designs;
- Financial modelling;
- Risks associated with the culture of the selected species based on the viability assessment; and
- Recommendations on the best way forward for the sustainable development of the culture of these species in South Africa.

3 SCOPE OF THIS STRATEGIC ASSESSMENT

This study focusses on assessing risks associated with selected mariculture production systems involving five selected species at eight study areas on the South African coast (Table 1, Figure 2). Marine biodiversity and ecology were identified as key strategic issues that needed to be investigated. Key environmental attributes of each study area are identified along with potential impacts and possible mitigation measures for each species/production system permutation. Risks (unmitigated and mitigated) associated with key potential impacts are assessed. This is done, as far as possible, in a manner that is spatially explicit, with the intent that the outputs can be used to guide mariculture development. Scale of operation is clearly a primary determinant of impact. For the purposes of this work the assumed scales of different production systems are those listed in Table 2.

Table 1: Selection of species and production systems to be considered in each of the eight study areas for marine aquaculture

Species **Production system**	**KwaZulu-Natal**	**Eastern Cape**		**Western Cape**				**Northern Cape**
	Durban-Richards Bay	**East London-Kei**	**Port Elizabeth**	**Gouritz-George**	**Hermanus-Arniston**	**Velddrif-Saldanha**	**Strandfontein-Lamberts Bay**	**Orange-Hondeklip Bay**
Abalone								
Land-based flow-through		X	X	X	X	X	X	X
Mediterranean mussel								
Longlines				X	X			
Longlines/rafts			X			X	X	
Pacific oyster								
Land-based nurseries						X		X
Longlines				X	X		X	
Longlines/rafts			X			X		
Dusky kob								
Cage culture	X	X	X					
Pond culture	X	X	X					
Land-based RAS	X	X	X					
Atlantic salmon								
Cage culture					X	X		
Land-based RAS					X	X	X	X

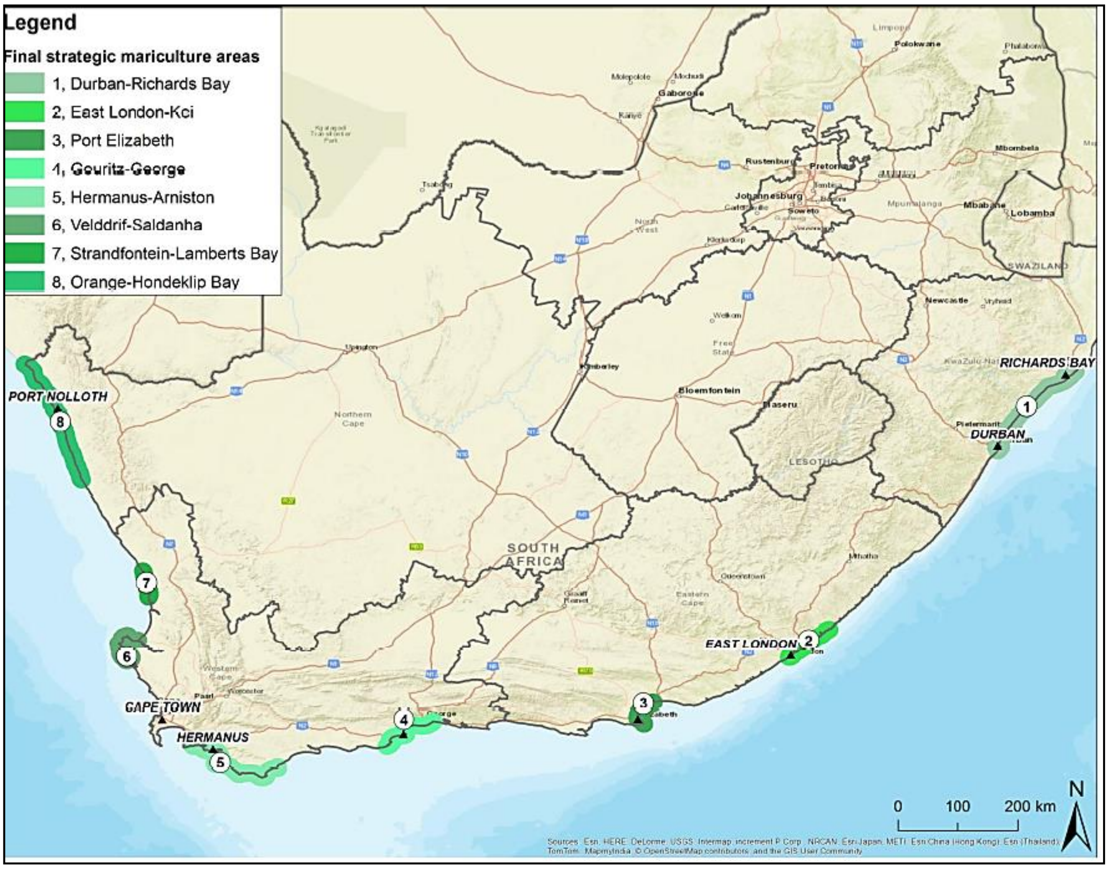

Figure 2. Eight study areas identified for mariculture assessment.

Table 2: Typical assumed scales (footprint area) of mariculture production systems

Production system	Culture environment	Types	Species commonly cultured	Generic farm footprint
Cage culture	Sea-based	Floating cages	Atlantic salmon, Dusky kob	70 - 80 ha comprising: 20 - 50 ha sea floor 10 - 20 ha sea surface 1000 - 2000 m² land-based
Longlines	Sea-based	Suspended culture, lines, racks and baskets	Oysters, mussels	60 ha (of which 1000 - 2000 m² is land-based)
Rafts	Sea-based	Floating rafts	Oysters, mussels	50 ha (of which 1000 - 2000 m² is land-based)
Flow-through	Land-based	Ponds and tanks	Abalone	10 ha
Recirculating aquaculture system (RAS)	Land-based	Ponds and tanks	Dusky kob, oysters, mussels	0.5 ha
Pond culture	Land-based	Ponds	Dusky kob	50 ha

4 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations apply to this assessment:

- This assessment only considers mariculture activities as listed in Table 1. It does not consider risks associated with related activities, such as product processing, packaging and transport.
- Given the primary focus of this specialist study, on marine biodiversity and ecology issues, it mainly identifies risks rather than opportunities associated with mariculture development. Any activity or development within an ecosystem has the potential to alter natural functioning (although not necessarily always be in a detrimental manner).
- A benefit of mariculture often cited is its potential role in alleviating harvesting pressure on wild populations (FAO, 2016a). In this regard both abalone and Dusky kob are indigenous species that are heavily over-exploited in South Africa. It is not certain however, that the culture of these species, or any of the others assessed here, will reduce demand for wild harvested (legally or illegally) species. For example, the main human pressures on the natural stocks of abalone (poaching) and Dusky kob (recreational fishing) in South Africa are unlikely to be alleviated by mariculture.
- Further to the above, there is some potential that mariculture may actually lead to increased pressure on natural stocks of some species. Elsewhere in the world, there are cases where a high end market for a wild harvested species has developed following successful farming of that species (e.g. in the case of Atlantic salmon, FAO, 2016a). In the case of Dusky kob and abalone, mariculture in South Africa may increase the difficulty in effectively implementing fisheries control measures. Farmed fish and shellfish are likely to be harvested and sold locally at sizes smaller than the size limit for wild caught commercial (and recreational) fisheries. Mariculture may therefore provide opportunity for illegally caught and undersized kob to be sold in local markets with no way of distinguishing wild caught fish from farmed fish. DAFF has developed traceability protocols to deal with local sales of undersized kob and abalone, but the effectiveness of these is as yet untested.
- South Africa's coast offers potentially favourable environments to support mariculture. Many areas are subject to high current flows that create dispersive environments. Water quality impacts can therefore be mitigated by locating mariculture development in areas with naturally high assimilative capacity. While the broad scale of this strategic assessment and lack of detailed oceanographic information precludes the identification of such areas, this should be considered in more detailed site specific feasibility studies. Some of the key considerations in this regard are highlighted in Section 9 (Best Practice Principles and monitoring requirements).
- Estuaries are excluded from this assessment as most South African systems are shallower than 5 m and are subject to high variability in river flow, floods and sediment loads. They are therefore unsuitable for most aquaculture infrastructure. Estuaries are also water bodies characterised by high retention, and are sensitive to organic and nutrient loading. They are important nursery areas for estuarine and marine species, including those supporting subsistence and recreational fisheries, and are also coastal focus points for recreational activities. Many larger estuaries are already hotspots in terms of user conflict. Given the above, South African estuaries are inherently sensitive to aquaculture development, and careful and

detailed assessment should be made of the suitability aquaculture in these systems. This includes development in the estuarine functional zone (EFZ). As per the National Environmental Management Act (NEMA), EIA Regulations (EIA Regulations Listing Notice 3, Government Gazette No. 33306, 18 June 2010) any development within the EFZ of an estuary is subject to an environmental impact assessment (EIA). The demarcation of the EFZ for all estuaries in South Africa is available from the South African National Biodiversity Institute (SANBI) (http://bgis.sanbi.org/estuaries/project.asp).

- Even though this assessment only focuses on eight marine study areas, these individually cover spatial scales extending over hundreds of kilometres. The high-level, strategic nature of this assessment necessitates that it be conducted at a low spatial resolution and that it address ecological and socio-economic characteristics pertinent at this coarser scale. A suite of appropriate generic environmental and socio-economic indicators was identified and used across the study areas to assess risks from typical impacts associated with mariculture.
- This assessment provides a broad scale sensitivity rating across each of the marine study areas. While the assessment attempted to be spatially explicit, several sensitivity indicators could only be identified as geo-referenced points. It was not possible, within the scope of this assessment, to accurately define all sensitive zones as GIS polygons. Spatially scaled sensitivity demarcations within the study areas will need to be refined prior to the use of these maps for mariculture rights or permit allocations.
- Consequence ratings applied in this assessment are associated with narrative qualitative statements, rather than detailed quantitative ratings (such as % loss of biota/habitat, or making reference to quantitative temporal or spatial extents). This was necessary given the scope and scale of this strategic environmental assessment.
- This assessment assumes risk associated with a single farming operation under each of the production systems, roughly resembling the farm footprints as provided in Table 2. It does not account for cumulative effects of multiple farms within close proximity to each another. Cumulative risk associated with multiple farms in close proximity depends on numerous factors, both environmental (e.g. circulation patterns, habitat types, etc.) and operational (e.g. size and density of farms). This level of detail could not be resolved within the scope of this strategic environmental assessment study. Cumulative risks will need to be assessed (e.g. using numerical modelling) where multiple mariculture operations in close proximity to each other is considered.
- This study did not consider the consequences of brood-stock harvesting of critically depleted stocks of Dusky kob, presently estimated at less than 2% of pristine spawner biomass (the total biomass of Dusky kob old enough to breed in the South African stock) (Winker *et al.* 2015). With a very restricted effective population size (successful breeders) throughout its South African distribution, this species is sensitive to the harvesting of large adults and current offtake should be limited. Industry's shift towards rearing offspring from wild caught parents to reproductive size and farming their offspring (F1 generation fish) is a positive step that will relieve pressure on wild populations. Note, however, use of second or later generation fish for this should be avoided to reduce risks of contamination of the wild population by genetic drift if offspring of these subsequent generations should escape and interbreed with wild stock. This initiative is compatible with the recent introduction of a slot-limit (minimum and maximum harvestable size) of 50-110 cm for this species.

- This work focuses on potential risks that mariculture will pose to coastal environments rather than assessing the suitability of different coastal areas for different mariculture production systems. Previous work (e.g. Hutchings *et al*., 2011 dealing specifically with marine finfish) provides good detail on logistical considerations and environmental suitability of South African marine coastal waters for mariculture development.
- This assessment makes use of available datasets that are dated in some cases. Specifically, information and datasets from the 2011 National Biodiversity Assessment (Sink *et al*., 2012) are used. The 2018 National Biodiversity Assessment is currently a work in progress.

5 KEY ENVIRONMENTAL ATTRIBUTES AND SENSITIVITIES OF STUDY AREAS

Available information was used to describe important environmental and socio-economic attributes within each of the marine study areas. These include a brief overview of the physical processes, as well as key biotic, habitat and socio-economic characteristics. The most appropriate approach to deal with the large spatial scales of this assessment was to select a generic suite of environmental and socio-economic indicators which could be mapped using existing knowledge and datasets, and which were suitable for assessing potential risks associated with mariculture. These are listed in Table 3.

Sensitivity base maps were produced for each study area demarcating the presence and locations of socially and ecologically sensitive areas. However, where there were areas within any of the study areas, other than those described by the generic indicators, that potentially posed site specific risk in terms of mariculture, these were also highlighted. Based on available information, as well as the authors' knowledge of estuarine and coastal ecosystem sensitivities to anthropogenic effects (such as those posed by mariculture), each of these indicators was allocated a sensitivity rating (very high, high, moderate, low, Table 3). This allowed for the translation of base maps into sensitivity maps for each of the study areas.

Table 3: Selected ecological and socio-economic sensitivity indicators and associated sensitivity ratings

Sensitivity Indicator		Brief description	Sensitivity Rating
Ecological sensitivity	Formally protected areas	Marine, estuarine and terrestrial areas within the study area boundaries that are under formal protection.	Very High
	Estuaries (specifically marine environments adjacent to estuaries)	Although this assessment does not consider mariculture activities in estuaries, impacts on the marine environment adjacent to these systems can result in detrimental effects through their connectivity with the sea. Estuaries (as demarcated by estuarine functional zones) are included as a sensitivity category in this assessment to caution against development in marine areas immediately adjacent to estuary mouths (i.e. development buffer zones).	High
	Fluvially-derived banks	Fluvially-derived banks and plumes typically develop in the marine environment where large rivers deliver high sediment loads to the coast. These banks and plumes fulfil an important ecological role as unique habitats in South African marine areas, as refugia for estuarine biota during times of high flow, and in providing cues for estuarine recruitment. These areas are characterised by fine sediments and are therefore prone to sediment quality impacts. Because plumes are important habitats (e.g. turbid, nutrient rich areas) for certain biota, they are also included here.	High
	Aggregation areas for important marine species	Areas where important marine fauna aggregate include significant breeding, nursery and feeding sites for marine biota (e.g. seals, penguins, Cape gannets), cetaceans (dolphins, whales), sharks, or rare and over-exploited species. For this assessment large seal and penguin colonies, as well as islands are used as key indicators of aggregation areas.	High
	Important fishery	Estuaries and adjacent marine areas that are important nursery areas	Very High

Sensitivity Indicator		Brief description	Sensitivity Rating
	nurseries	for fish and shellfish populations, and which support fisheries.	
	Critically endangered habitats	Natural habitats identified in the National Biodiversity Assessment (2011) as being critically endangered, and coastal forest and dune habitat as identified in SANBI (2012).	Very High
	Endangered habitats	Natural habitats identified in the National Biodiversity Assessment (2011) as being endangered.	High
	Vulnerable habitats	Natural habitats identified in the National Biodiversity Assessment (2011) as being vulnerable.	Moderate
	Least threatened habitats	Natural habitats identified in the National Biodiversity Assessment (2011) as being least threatened.	Low
Socio-economic sensitivity	Important recreational areas	Areas where direct use is made of coastal waters for recreational purposes. These include Blue Flag beaches which are places designated and valued as safe and clean swimming areas and popular diving sites. These areas generate (either directly or indirectly) tourism income for local municipalities and mariculture impacts may result in loss of revenue. Issues relate to aesthetics, water quality and competition for space.	High
	High density urbanised areas	Urbanised areas and cultivated lands where (especially) land-based mariculture may result in competition for terrestrial space with other users. Highly urbanised areas and cultivated lands (as per the 2014 Land Cover) are included as a sensitivity category.	High
	Cultivated lands		Low
	Commercial ports	Ports and harbours provide opportunity for mariculture (e.g. sheltered waters and proximity of land and infrastructure for processing and dispatching of products), but mariculture development can result in competition for space with port and harbour activities, as well as other industrial and commercial activities linked to ports and harbours.	High
	Small ports and fishing harbours		Moderate

5.1 Durban-Richards Bay

Important ecological and socio-economic attributes for this region are presented in Figure 3. The relative sensitivity of zones within the study area is illustrated in Figure 4.

5.1.1 Morphology, sediments and physical dynamics

The continental shelf off KwaZulu-Natal is generally narrow and steeply sloping. Its oceanography is dominated by the warm Agulhas Current flowing southwards along the shelf edge, seawards of the 200 m isobath (Schumann, 1989). The current is a well-defined, intense flow of water some 100 km wide and 1 000 m deep (Schumann, 1989), flowing at speeds of 2.5 m/s or more (Pearce *et al.*, 1978). Nearshore counter currents periodically occur, possibly generated by strong local winds, and during cold fronts that travel up the coast from the Cape (Gill and Schumann, 1979).

The Durban to Richards Bay study area covers an area known as the KZN Bight. This is the only significant topographical feature on the KZN coast, which is otherwise uniformly orientated on a south-west – north-east orientation with few bays or indentations. The coastal topography of this Bight interacts with the prevailing Agulhas Current to affect the regional oceanography, generating Natal Pulses (Lutjeharms and van Ballegooyen, 1988; Lutjeharms *et al.*, 2000a, Lutjeharms, 2006), and local current regimes. Together with large quantities of sediment delivered by the Thukela River it creates a unique sedimentological feature with a mud depositional centre - the Thukela Bank (Fennessy *et al*., 2016). While the wider KZN continental shelf between Durban and Richards Bay is dominated by sandy sediments the influence of the Thukela is clearly evident in mud deposits in inshore and mid-shelf areas directly off, and to the north of the river mouth (Green and MacKay, 2016).

South of Durban, the continental shelf again narrows and the Agulhas Current aligns in close proximity to the coast. Off Port Edward it is so close inshore that the inshore edge (signified by a temperature front) is rarely discernible (Pearce, 1977).

5.1.2 Important biota

Biogeographically the Durban-Richards Bay study area lies in the Natal Ecoregion (Sink *et al*., 2012), a subtropical zone extending from the Mbashe Mouth to Cape Vidal. Beaches comprise coarse grained sediments (Jackson and Lipschitz, 1984) and are typically exposed to high wave energy. They tend to be reflective and unstable, resulting in depauperate macrofaunal assemblages (CSIR, 1998). The macrofaunal assemblages are characterised by tropical crustaceans (Dye *et al*., 1981), with gastropods and isopods being comparatively poorly represented (Wooldridge *et al*., 1981).

The seabed off this part of the KZN coast tends to be patchy in terms of sediment composition, with significant sediment movement being frequently induced by the dynamic wave and current regimes (Fleming and Hay, 1988). The benthic macrofauna have adapted to these harsh conditions and frequent disturbance. Further offshore where near-bottom conditions are more stable, the macrofaunal communities are primarily determined by sediment characteristics and depth. Macrobenthic diversity varies across the area. Long-term studies in the Richard's Bay area (CSIR, 2017a) have identified that the benthic macrofaunal communities have a low diversity and abundance, particularly on sandy inshore substrates. Similar surveys undertaken off Durban, and on the KZN continental shelf in general, yield much richer communities (CSIR, 2017b). Muddy areas, with associated elevated organic content, in particular areas on the depositional banks off the Thukela River, provide habitat for distinct and important benthic communities (MacKay *et al*., 2016) and have historically supported a shallow water trawl fishery targeting penaeid prawns (Fennessy and Groeneveld, 1997, Turpie and Lamberth, 2010).

Rocky intertidal habitats comprise less than one third of the KZN coastline (Jackson and Lipschitz, 1984) most of which are regularly inundated by sand. Rocky intertidal shores on the southern African East Coast can be divided into distinct zones on the basis of their characteristic biological communities. Tolerance to physical stresses associated with life in the intertidal zone, as well as biological interactions such as herbivory, competition and predation interact to produce these zones. They correspond roughly to zones based on tidal heights. East Coast rocky intertidal fauna is comparatively diverse, with assemblages characterised by subtropical species. The subtidal shallow reefs of the East Coast range from rich, coral-encrusted sandstone reefs in the north to the more temperate rocky reefs further south. South of the iSimangaliso Wetland Park (St Lucia) reef habitat is provided by rock outcrops, although both hard and soft corals still occur.

A high diversity of fishes is associated with the inshore and shelf waters of the KZN study area. Many are endemic to the southern African coastline and form an important component of the commercial and recreational line-fisheries of KZN. Several species undergo migrations though KZN waters. The most widely recognised is the small pelagic shoaling pilchard *Sardinops sagax* which migrates in large numbers during winter months up the southern KZN coast from the Agulhas Bank, in what is traditionally known as the ”sardine run”. Shoals reaching lengths of 20 - 30 km are pursued by a variety of game fish, sharks, dolphins and birds (Fennessy *et al.*, 2010). This migration typically ends (in nearshore waters) near Durban, although sightings further north do occasionally occur.

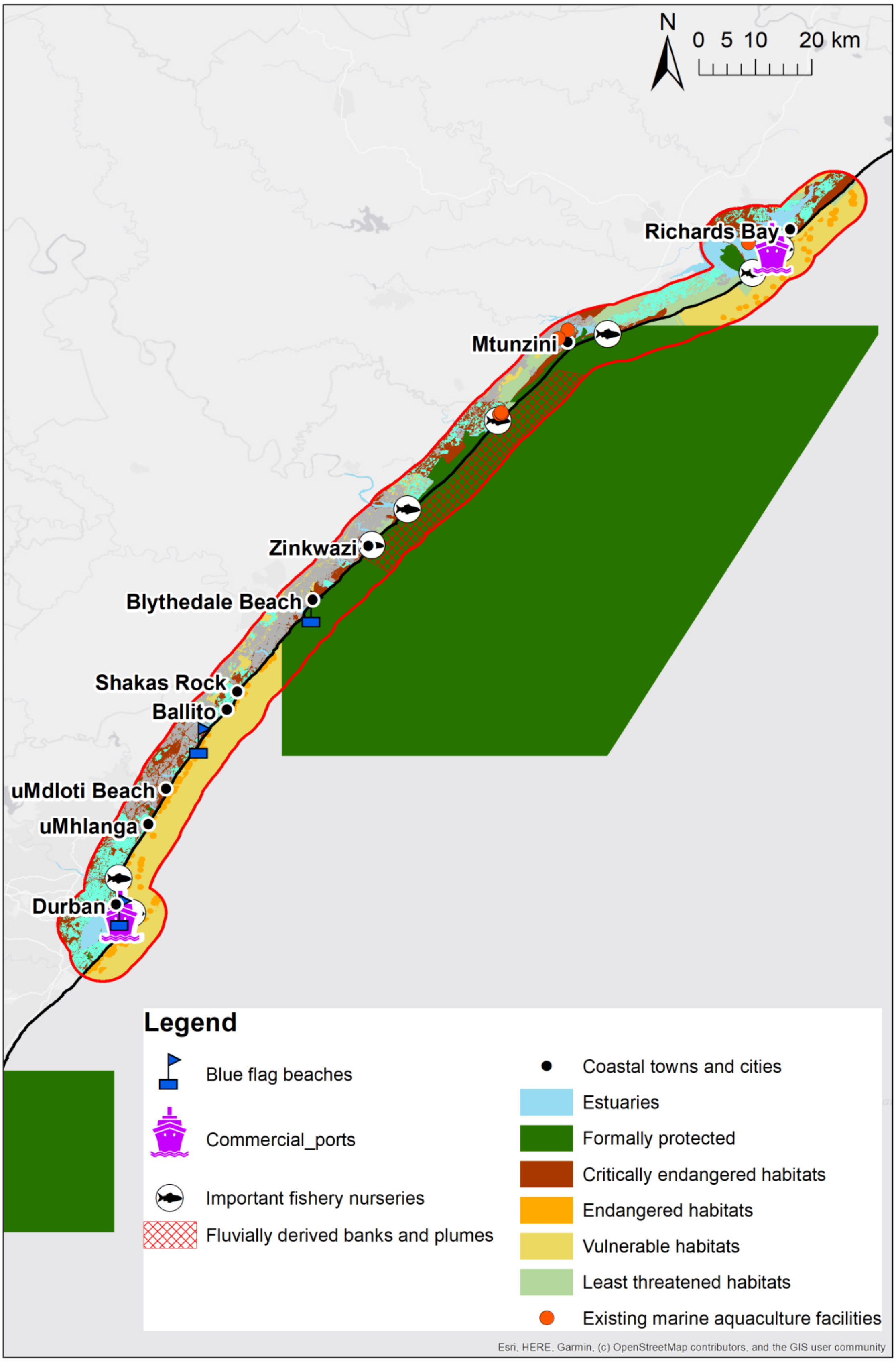

Figure 3. Durban-Richards Bay: Important ecological and socio-economic attributes

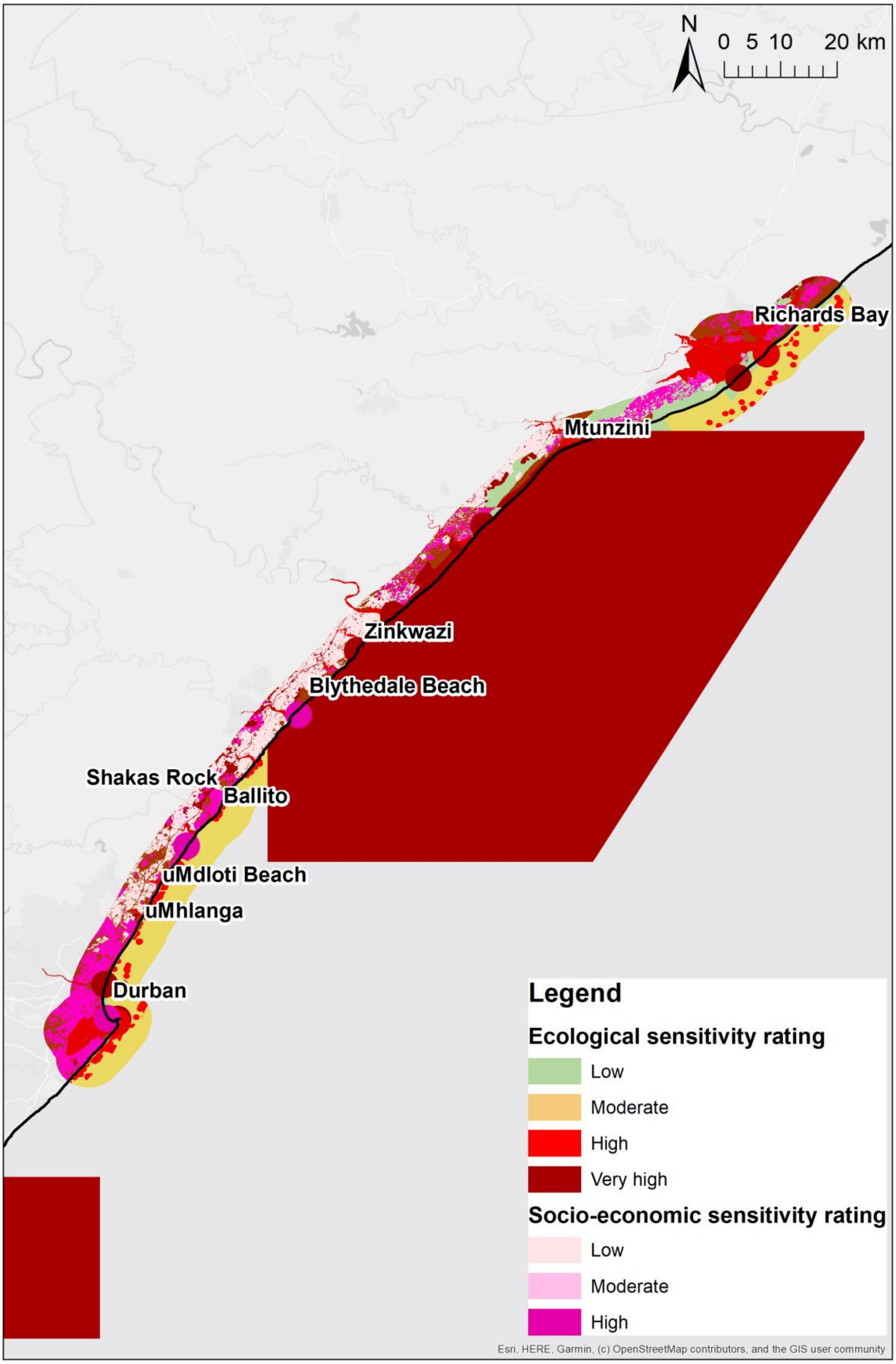

Figure 4. Durban-Richards Bay: Ecological and socio-economic sensitivity

Five species of sea turtles occur along the KZN coast; the green turtle (*Chelonia mydas*), Olive ridley (*Lepidochelys olivacea*), Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*) and Loggerhead (*Caretta caretta*). Green turtles, Hawksbills and Olive ridleys typically occur on inshore reefs as non-residents or visitors (Lauret-Stepler *et al.*, 2007, Mortimer, 1984, Pereira *et al.,* 2008). Leatherbacks and Loggerheads nest along the sandy beaches of KZN. Richards Bay is regarded as the southern limit of their nesting grounds (Harris *et al.*, 2012).

Although forty-six seabird species occur commonly along the KZN coast very few suitable nesting sites are available for seabirds, and only three species (Grey-headed Gull, Caspian Tern and Swift Tern) breed regularly along the coast (CSIR, 1998). Many of the river mouths and estuaries along the East Coast, however, serve as important roosting and foraging sites for coastal and seabirds birds, especially those at St Lucia and Richards Bay (Underhill and Cooper, 1982; Turpie, 1995).

Whales most commonly occurring in KZN coastal waters are the Humpback and Southern Right. They typically occur in small pods in the winter during migrations between higher-latitude feeding grounds and lower-latitude breeding grounds. Dolphin species include Indo-Pacific bottlenose dolphin, the larger Common bottlenose dolphin and the Indo-Pacific humpback dolphin. The latter is primarily a shallow-water species restricted to <50 m depth. There is considerable concern over the future of this species in the subregion resulting in it being listed as vulnerable (South African Red Data, Friedmann and Daly, 2004) or near-threatened (Reeves *et al.*, 2008). These dolphins occur over an area that covers the wider stretch of coast pertinent to the present study, but a resident pod is well known to favour an area in the immediate vicinity of the Port of Richards Bay (Atkins *et al.*, 2004).

5.1.3 Estuaries and fluvially-derived banks

There is an abundance of estuaries on the KZN coast, most of them temporarily open-closed systems. Between Richards Bay and Durban there are 19 estuaries (inclusive of the Ports of Richards Bay and Durban). Because of the nature of the coastal plain, estuaries in this area are generally larger and better connected (mouth open frequency) to the sea than systems south of Durban. Eight can be regarded as important fisheries systems, with high fish diversity and abundance, and/or as systems which generate plumes which are locally important as areas which are natural aggregation areas for estuarine fishes (such as Dusky kob, spotted grunter and Zambezi sharks) and which support fisheries. Of these the Thukela is the most significant. Areas adjacent to this estuary support populations of Dusky kob which are important to both the fishery and the conservation of the species. The Thukela plays an important role in delivering sediments to the coast. Offshore a large depositional feature, characterised by fine sands and muds, has formed (De Lecea and Cooper, 2016). This is important for ecological, biodiversity, and fisheries (e.g. prawn) reasons.

5.1.4 Protected areas

The Aliwal Shoal Marine Protected Area (MPA) is located on the KwaZulu-Natal South Coast near Umkomaas some 40 km south of Durban and well out of the study area. To the north are the Maputaland and St Lucia Marine Reserves, which fall into the iSimangaliso Wetland Park, a designated World Heritage Site. This protected area is more than 50 km north of Richards Bay, and therefore also well out of the study area. Therefore, no MPAs in this study area considered here. However, currently various initiatives are underway to increase MPAs in KZN, both in number and spatial extent. Ezemvelo-KZN Wildlife has applied systematic conservation planning to develop SeaPLAN to identify biodiversity areas needed to contribute to marine conservation in the province and to motivate their declaration as protected areas. Although not yet formally protected, future development on the KZN coast should consider these areas and account for their potential designation as MPAs. Outputs of SeaPLAN highlight an area (the Thukela Banks Area) from the Thukela River mouth to just south of Nhlabane Estuary (i.e. to include the wider Richards Bay study area under consideration here) as a focal area needed to meet marine biodiversity targets most practically and efficiently, and/or where critical biodiversity is in need of additional protection (Harris *et al*., 2012). This may have important implications for future mariculture developments.

Another conservation planning process of relevance is currently underway as part of Operation Phakisa. This process recognises the need to fast track the identification and promulgation of more MPAs in the light of planned increased development and use of South Africa's ocean and marine resource base for economic gain and national development. In this regard, areas on the Thukela Banks, within the study area are likely candidates for inclusion into a wider MPA network on the KZN coast.

There are a number of estuaries and terrestrial coastal areas that fall under the jurisdiction of Ezemvelo KZN Wildflife and can be regarded as protected areas. The Mhlathuze, Mlalazi, Siyaya, Amatikulu/Nyoni and Mhlanga estuaries (or sections thereof), as well as the Beachwood Mangroves at the Mgeni Estuary all fall under the jurisdiction of the Ezmvelo KZN Wildlife. Terrestrial coastal reserve areas include the Mlalazi Nature Reserve, the Siyaya Coastal Park, and the Amatikulu Nature Reserve.

5.1.5 Important socio-economic activities

Several crustacean species form the basis for a small multispecies trawl fishery on the shallow water mud banks along the north Coast of KZN (Fennessy and Groeneveld, 1997). The fishery targets various commercial penaeid prawn species, particularly white prawn, brown prawn and tiger prawn. The shallow water component targets the muddy/sandy inshore regions (5 - 40 m depth and within 10 nautical miles of the shore) of the Thukela Bank. Further offshore, at 100 - 600 m depth between Amanzimtoti and Cape Vidal, the deep water fishery targets pink and red prawns, langoustines, Natal deep-sea rock lobster and red crab. Offshore trawling takes place year-round. Inshore the East Coast rock lobster occurs on shallow-water reefs and supports a recreational dive fishery.

The highly diverse ichthyofauna along the KZN coastline supports commercial and recreational skiboat-based line fisheries which operate within two major fishing areas; a narrow zone of scattered reefs along the 50 m isobath and along deeper reefs south of Durban and north of the Thukela River (100 – 200 m) (Penney *et al*. 1999). Shore angling is the most common form of line fishing in KZN (Fennessey *et al*. 2010). While most angling activity is recreational, it is probable that subsistence fishing has become increasingly important and widespread, or at least more recognised over recent years. A wide range of fish species is targeted and harvested with at least some degree of overlap occurring with species targeted by the boat fisheries.

Marine waters in KZN are used for a variety of recreational activities which underpin significant social benefits and tourism value. These include swimming, snorkelling and SCUBA diving, board sports (e.g. surfing, kite boarding), paddling and sailing. These activities all inherently rely on good marine water quality. While it is beyond the scope of this work to identify all these areas, some specific locations can be highlighted where there is likelihood of conflict arising in the event of large scale mariculture development. In addition to ports (see below) these include high use areas along the Durban beachfront as well as at Richards Bay's Alkantstrand and Newark Beach. These are areas which are well used by beach goers and swimmers. Beaches with Blue Flag status in the study area are at Ushaka (Durban beachfront) Westbrook, and Blythedale.

Commercial ports exist at Richards Bay and Durban. They are respectively, South Africa's largest (by cargo tonnage handled) and busiest (by number of vessels handled) ports, controlled and managed by Transnet National Ports Authority. Both have large offshore anchorage areas. They are both areas where considerable activity other than shipping and cargo handling, occurs. This includes recreational (and subsistence) fishing, boating and various other recreational activities. Commercial marine sea cage finfish farming (Dusky kob) has recently been piloted in Richards Bay, but given conflicting uses and the fact that these ports are both estuaries, these areas are not likely to support any large scale mariculture development.

5.2 East London-Kei

Important ecological and socio-economic attributes for this region are presented in Figure 5. The relative sensitivity of zones within the study area is illustrated in Figure 6.

5.2.1 Morphology, sediments and physical dynamics

The study area comprises a relatively straight coastline with minor crenulations interrupted occasionally by rocky headlands and larger coastal embayments. The coastline is diverse with boulder beaches, largely rocky but mixed shores, pocket beaches, often associated with estuary mouths, and more extensive dissipative/intermediate beaches. A small stretch of cliff/rocky coastline occurs north of Morgan's Bay.

The continental shelf is fairly uniform and relatively narrow along this section of the coast. The inner shelf (<50 m water depth) is wave-dominated and, beyond the surf-zone is generally covered by sediments of between 1 - 10 m thick (Fleming, 1981). Offshore (>40 - 60 m) sediment movement is dominated by the Agulhas Current, with significant sediment dunes occurring on the outer shelf. The terrigenous inputs in the inshore region comprise bedload that is gradually worked alongshore and into deeper waters by waves and wind-driven currents. The fine suspended material (mainly silts and clays) from these terrigenous inputs generally does enter the shelf sediments, however this fine suspended material may be temporarily deposited offshore of major river mouths (e.g. Kei River) before being re-suspended and transported into deeper waters.

The surface flows associated with the Agulhas Current reach a maximum along the East coast of southern Africa in the vicinity of East London (Schumann, 1976; Duncan, 1976). As expected the Agulhas Current dominates the flows on the outer shelf and beyond, however due to the narrow shelf in this region even the inshore waters (<40 m) are strongly influenced by the Agulhas Current. There is clear evidence of this in data measured offshore of East London (Schumann and Brink, 1990; van Ballegooyen, 2014; van Ballegooyen *et al*., 2017). While the offshore flows are predominantly south-westward, in the inshore zone, regular current reversals occur due to the influence of strong or persistent south-westerly to westerly winds associated with the passing of coastal lows and mid-latitude cyclones over this region (Schumann, 1987, 1989; Schumann and Brink, 1990). However, due to the strong influence of the Agulhas Current south-westerly flows may prevail even under moderately strong south-westerly wind conditions and typically, current reversals are only observed after south-westerly winds have persisted for two to three days or longer (CSIR 1988, 1996) or with the passing of a Natal Pulse. The Natal Pulse is a large perturbation of the Agulhas Current that occurs at irregular time intervals of 50 to 240 days (de Ruijter *et al*., 1999), with a mean frequency of four to six per year (van Ballegooyen *et al*. 1996; Bryden *et al*., 2005; Lutjeharms, 2006). However more recent estimates suggest that only 1.6 to 1.7 Natal Pulses reach the shelf region offshore of Port Elizabeth yearly (Rouault and Penven, 2011; Krug *et al*., 2014). Smaller perturbations and meanders of the Agulhas Current are expected to influence the shelf currents more regularly but to a lesser extent. Close inshore the currents are wave-driven. These alongshore currents in the surf-zone are predominantly upcoast (i.e. in a north-easterly direction) and largely are a consequence of the prevailing wave conditions in the nearshore zone (CSIR, 1996). The fact that the currents in the nearshore zone are generally opposed to the prevailing strong deep water current results in complex flow patterns closer inshore between headlands and in the larger coastal embayments.

The close proximity of the Agulhas Current to the coast and the narrow shelf results in the upwelling of cold waters inshore of the Agulhas Current as far north as the Mbashee River (Lutjeharms and Roberts, 1988, Beckley and van Ballegooyen, 1992). This brings cold nutrient-rich water onto the shelf over an area that can extend as far downstream as Algoa Bay (Lutjeharms *et al*., 2000b). Major perturbations of the Agulhas Current also result in fairly extended periods of low seawater temperature conditions prevailing in the inshore waters (van Ballegooyen *et al*., 1996).

Along this stretch of the coast, the mean significant wave height (2.1 m), extreme wave height (4.6 m) and peak wave period (6 - 14 s) in the offshore region are similar to those further up the coast towards Durban but lower than those on the South and South-west coast of South Africa (CSIR, 2013). Closer inshore (in 27 m water depth), the mean significant wave height (1.7 m), and extreme wave height (3.5 m) are less than those observed offshore while peak wave periods range between 10 and14 s. The offshore waves are predominantly from a SW to SSW direction, but with a significant east to east-north-east wave component in spring and summer. As these offshore waves propagate shoreward they are refracted into a more shore-normal direction, resulting in an inshore wave climate dominated by southerly waves with a lesser south-south-east component. There exist some minor wave-sheltered regions immediately to the east of significant headlands, however the SSE waves occurring in spring and summer further limit the extent of these wave-sheltered regions. Recent modelling studies (van Ballegooyen *et al*., 2017) indicate that the accumulation of fine organic material is only likely to occur in very sheltered area such as inside the southern breakwater of the Port of East London. Few such sheltered areas exist along what is considered to be a wave exposed stretch of coastline.

5.2.2 Important biota

This study area lies primarily within the Agulhas inshore ecozone of the Agulhas Ecoregion but, in the north, extends into the southern extremity of the Natal inshore ecozone of the Natal Ecoregion (Sink *et al*., 2012). It therefore supports ecological elements of both ecoregions where they merge. The coastline is diverse with boulder beaches, mixed shores, dissipative/intermediate beaches and a small stretch of cliff/rocky coastline north of Morgan's Bay.

The intertidal and shallow subtidal rocky shores host a range of seaweed species with *Gelidium* being harvested commercially. Sessile filter feeders include brown mussel (*Perna perna*), rock oysters (*Striostrea margaritacea, Saccostrea cucullata*), ascidians including red bait (*Pyura stolonifera*) and organisms such as octopus, abalone (*Haliotis midae*) and other haliotid species, and spiny rock lobster (*Panulirus homarus*). Subtidal reefs support a wide variety of longer lived large finfish species. These have been exploited to very low population levels (Britz *et al*., 2001) and, outside of MPAs, their recovery is uncertain.

Information on the subtidal soft sediment fauna is sparse, being limited to benthic macrofaunal surveys conducted off East London (CSIR, 1999). On the open coast macrofaunal abundance and taxonomic composition was approximately uniform across depth horizons from the nearshore (~10 m depth) to deeper stations (~70 m depth) offshore where sand-sized sediments were dominant. Marked differences were observed within the sheltered waters within the Port of East London in terms of reduced diversity and abundance. This was attributed to the presence of muddy sediments, higher organic loads and the presence of sulphide below a shallow oxic layer. This was the result of increased deposition of fine sediments within the sheltered waters of the port along with particulate organic material derived from the adjacent coastal waters and the Buffalo River urban and rural catchment.

5.2.3 Estuaries and fluvial derived banks

Seven estuaries occur in this study area, the largest of which is the semi-permanently open Kei River in the north and the industrialised Buffalo River accommodating the Port of East London in the south. Other estuaries along this stretch are predominantly closed by sand bars across their mouths due to longshore drift (e.g. James and Harrison, 2016). Permanent or semi-permanent fluvially derived banks are rare in the region, the Kei fluvial fan being a noted exception. This areas provides spawning habitat for several fish species, including White steenbras *Lithognathus lithognathus* and Dusky kob *Argyrosomus japonicus*, and provides refuge areas for small pelagic species.

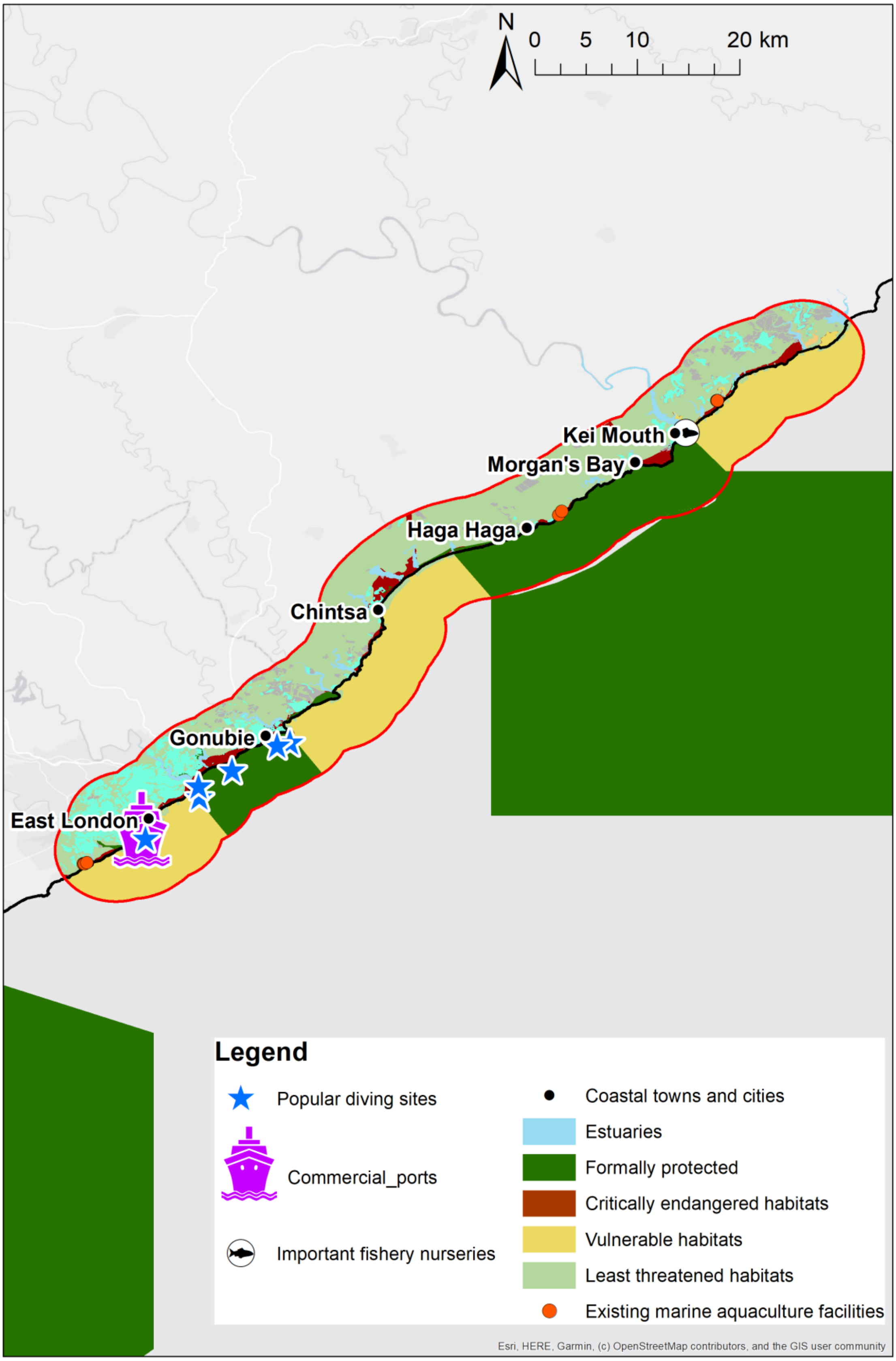

Figure 5. East London-Kei: Important ecological and socio-economic attributes.

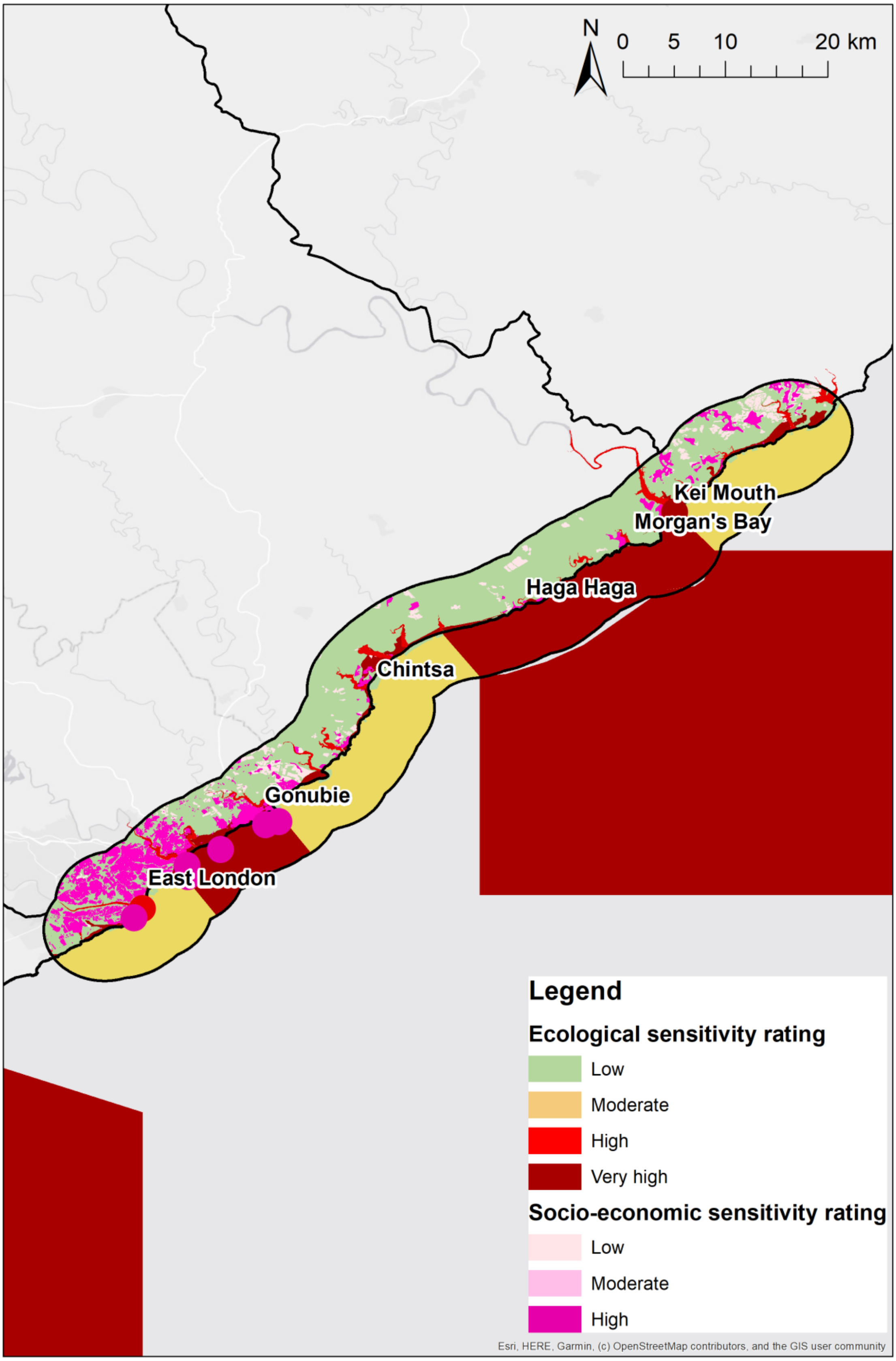

Figure 6. East London-Kei: Ecological and socio-economic sensitivity.

All of the estuaries play important roles in the life-histories of estuarine dependent fish in the region. Generally, the species dominating estuarine fish biomass include Dusky kob, Ladyfish, Blue spotted stingray, Ragged tooth shark, White sea-catfish, Estuarine roundherring, Leervis, White steenbras, various mullet species, Spotted grunter, Elf, and Cape stumpnose (James and Harrison, 2016). These fish generally recruit to estuaries in the region as juveniles and migrate into the adjacent nearshore marine environment as subadults or adults. The Great Kei estuary especially contributes significantly as a nursery area.

5.2.4 Protected areas

Marine Protected Areas in the study area include the Gonube and Kei (Figure 5). Together with the Gxulu MPA south of East London, these are collectively known as the Amathole MPA. The intention of their establishment is to protect marine biodiversity on this stretch of coastline and continental shelf (WWF, 2013).

5.2.5 Important socio-economic activities

The socio-economic activities in the study area include subsistence and recreational fishing, mainly from the shoreline, land-based abalone farming at Haga Haga, land-based fin fish production (RAS) trials at the East London Industrial Development Zone systems, surfing, swimming, and when sea conditions are suitable, diving at nearshore reef sites. Commercial activity is dominated by shipping, entering and leaving the Port of East London on the Buffalo River estuary.

5.3 Port Elizabeth

Important ecological and socio-economic attributes for this region are presented in Figure 7. The relative sensitivity of zones within the study area is illustrated in Figure 8.

5.3.1 Morphology, sediments and physical dynamics

Algoa Bay is a large log-spiral bay (Rust, 1991), anchored by rocky headlands at Cape Recife in the south-east, and Woody Cape and the Bird Island group in the north-east. Mixed rock and sand beaches occur west of Cape Recife, while the coastline from Cape Recife to the Port of Port Elizabeth comprises rocky-sandy shore interspersed with pocket beaches characterised by a narrow upper beach area underlain by rock. Rocky marine wave-cut platform remnants and rocky outcrops buffer these narrow sandy beaches (de Meillon, 1993; Molyneux, 2008). The shoreline extending from the western breakwater of the Port of Port Elizabeth to New Brighton Beach just south of the Swartkops River Mouth, is highly modified having been armoured with dolosse to prevent erosion. Mixed rock and sand beaches occur to the east of the Port of Ngqura, giving way to more expansive sandy beaches backed by largely unvegetated and mobile dunes to the east of the Sunday's River (Carter, 2006). The sandy beaches of the region, characteristic of mainly eastern Algoa Bay, are classified as intermediate in the dissipative/reflective continuum with typically large surf zones extending to 250 - 300 m wide in high wave conditions. The sediments of the beaches in the southern area of the western bay are largely fine-grained, increasing to fine- to medium-grained sands north of Brighton Beach and become only slightly coarser in the more wave-exposed eastern half of the bay (Theron *et al.*, 1991). Alongshore sediment transport in the vicinity of the Port Elizabeth harbour is estimated to be approximately 180 000 m^3 per annum (Goschen and Schumann, 2010) and an appreciably greater

200 000 to 350 000 m^3 per annum in the vicinity of the Port of Ngqura due to the generally higher wave conditions prevailing at this location (Theron, 2013).

The bathymetry of Algoa Bay slopes to the south-east at about 0.15° and has a maximum depth of approximately 70 m (Goschen and Schumann, 2010). The sediments of the bay are sandy (Bremner, 1991) comprising predominantly (>60%) terrigenous material. Numerous islands, depressions, ridges and scarps exist in the bay. The most rugged bathymetry in the bay comprises exposed bedrock off Cape Recife Riy Bank and Bird Island that are joined by a discontinuous ridge, the Recife Bird Ridge considered to be the dividing line between the bay and the adjacent shelf region. Other exposed rocky areas, St Croix Island, Brenton Island and Jahleel Island, occur in the northwest quadrant of the bay near the mouth of the Coega River. Fine-grained sand is dispersed right around the bay in shallow water, while generally coarse-grained sediments predominate in the deeper waters (Theron, 2013). Gravels and gravely sands are abundant in the vicinity of the islands (Bremner, 1991). In the inshore region of the western bay, shallow reefs occur along much of the coastline between Cape Recife and to just north of the Port Elizabeth harbour (Phipps, 1997). The shallow veneer of sand and the high mobility of sediments in this region mean that at times sand will cover the low reef areas and other times the reefs will be exposed, depending on prevailing wind, wave and current conditions.

The Agulhas Current dominates the flows on the outer shelf and beyond and has a strong influence on the upwelling conditions occurring in the eastern bay. Significant changes in water column structure within the bay can occur during major episodic perturbations of the Agulhas Current, such as the Natal Pulse (e.g. Goschen and Schumann, 1988; 1994; Goschen *et al.*, 2012). Strong upwelling, associated with easterly winds, is observed at Cape Recife (Goschen and Schumann, 1995). Upwelling observed at the eastern side of the bay is a combination of both the influence of large-scale flows and a local and more remote response to synoptic wind events (Goschen *et al.*, 2012, Goschen and Schumann 2010). While inshore wind-driven flows predominate particularly in the eastern part of the bay (Roberts, 2010), in the western part of the bay the correlation between local wind and currents is relatively weak (Schumann *et al.*, 2005). Measurement and hydrodynamic modelling studies have shown wind-driven flows to predominate in the nearshore waters around the Port of Ncgura (Roberts, 2010; van Ballegooyen and Newman, 2013). Wave-driven currents predominate in the surf-zone throughout the bay, but are generally more modest in the south-western region of the bay that is relatively sheltered from the predominant SW wave conditions.

Along this stretch of the coast, the offshore mean significant wave height and particularly the extreme wave height, are expected to increase slightly compared to those offshore of East London (CSIR, 2013). Inshore (in 21 m water depth in the vicinity of the Port of Ngqura), the mean significant wave height (1.2 m) and extreme wave height (3.0 m) are lower than those observed offshore of East London. This reduction, particularly in the extreme wave height, is a reflection of the sheltering from SW wave storm conditions that occurs in large parts of the bay. However this sheltering effect does not occur for the easterly offshore wave conditions that affect almost all sites in the bay. While wave shadow effects exist in the lee of the islands in the bay, the bimodal distribution between SW and E waves mean that few locations remain sheltered all year round. This is clearly shown in wave modelling studies for Algoa Bay (e.g. Theron, 2103; van Ballegoyen *et al.*, 2013; CSIR, 2013). The implication is that there exist few locations in the bay where there is a significant risk of the long-term accumulation of organic material on the seabed.

5.3.2 Important biota

This study area falls within the Agulhas Ecoregion (Sink *et al*., 2012). Important habitats in Algoa Bay are sandy beaches and surf zones, rocky shores on Islands, the islands themselves as bird breeding sites, the subtidal zone in the bay itself and the water body in Algoa Bay. The enclosed water body of the Port of Ngqura is important for various fish species.

The description of the nearshore ecology given below is based on a number of existing reports (e.g. CES, 2001; Wood, 2002).

A major ecological feature of the sandy shore surf zones is the development of dense patches of the diatom *Anaulus australis* which may comprise more than 95% of the total algal production. Consequently, this species is a critical component in the nearshore food web driving interstitial, microbial and macroscopic food chains. The partition of the energy is 20%, 40% and 20% respectively with the balance exported to the adjacent nearshore water column and benthic environments. Molluscs dominate the macrofaunal biomass with the dominant forms in the surf zone area being scavenging Plough snails (*Bullia* spp.) and the filter feeding Sand mussels *Donax serra* and *D. sordidus*. Sand mussels are apparently largely dependent on *Anaulus* and consequently reach their highest biomasses where *Anaulus* blooms are most frequent, north east of the Sundays River mouth, immediately outside of the defined study area. Swarming mysids (*Gastrosaccus spp* and *Mesopodopsis* spp.) are also important in the surf zone food web, and sand mussel and mysids specifically are important prey species for various fish including sand sharks, rays, mullet, Blacktail, White steenbras, White stumpnose etc., and the Three-spot swimming crab.

High concentrations of food organisms, *Anaulus* blooms and swarms of mysids, lead to north eastern Algoa Bay surf zones being important nursery areas for a wide range of fish species. Thirty species have been recorded of which approximately half also occupy surfzones as adults contributing to the more than 70 species of teleost and cartilaginous fish recorded from the surf zones and nearshore of Algoa Bay. The biological structure of Algoa Bay beaches and surfzones is unique in South Africa and is considered to merit a high conservation status. This is reflected in the establishment of a Marine Protected Area extending east of the eastern breakwater of the Port of Ngqura as part of the Greater Addo Elephant National Park.

Eastern Algoa Bay has isolated mixed shores east of the Coega river mouth and the island shores of Jahleel, St Croix and Brenton Rock. The Island shores have been quantitatively surveyed as part of the suite of environmental monitoring associated with the development of the Port of Ngqura (e.g. Klages and Bornman, 2003, 2005a, 2005b; Klages *et al.* 2006), but there is apparently no information available on isolated rocky shores that mainly comprise wave cut terraces located to the north east of the port.

The island shores exhibit characteristic zonation patterns extending down the intertidal zone; namely Littorina, Upper Balanoid, Lower Balanoid Mussel and Cochlear zones. Both the macroalgae and fauna appear to be typical of the warm temperate Agulhas Bioregion which extends from the Mbashe River mouth in the north to Cape Point in the south west (Bustamante and Branch 1996). The macroalgae are dominated by red algae genera (e.g. *Plocamium, Hypnea, Gigartina, Chondrococcus*) and articulated corralines (e.g. *Amphiroa, Cheilosporum*). Brown and green algae are also represented (Porter *et al*., 2012). Intertidal macrofauna include the winkle (Molluscan gastropod) *Nodilitorina africana*, the limpets *Patella cochlear*, *P. granularis*, *Siphonaria* sp and keyhole limpets (probably

Fissurella sp.), the brown mussel *Perna perna*, amphipod and isopod crustaceans, barnacles, primarily *Tetraclita serrata* and *Octomeris angulosa* and echinoderms.

The subtidal sea floor adjacent to the Port of Ngqura is dominated by low relief emergent rock reefs interspersed by various grades of sand. Mud, silt and clay sediments generally do not occur in this area, probably due to high shear stresses at the seafloor associated with waves. Although not well known, the available research/observation literature indicates that the major primary producers are phytoplankton and a fine macroalgal turf growing on the shallower emergent reef surfaces. The Coega River is apparently an important contributor of nutrients to the shallow subtidal as elevated phytoplankton biomasses have been recorded adjacent to the river mouth. The sand areas support a benthic macrofauna distribution expected for a nearshore depth gradient, i.e. suspension feeders dominate the shallow areas, predators and scavengers are most common at intermediate depths and deposit feeders dominate in the deeper areas. Biomass co-varies with lowest levels in the nearshore and highest levels at the deeper locations.

The benthic macrofauna include all of the major groups expected to be found in warm temperate inner continental shelf unconsolidated sediments. Crustaceans and polychaetes comprise the numerical dominants followed by molluscs and echinoderms. Subsidiary taxa such as sipunculids have also been recorded in the area. The pelagic fauna is perhaps different from other East and South-east coast beaches in that, aside from the ubiquitous fish species, the mysid *Mesopodopsis wooldridgei* forms dense swarms out to approximately 10 - 20 m depths and moves inshore to just behind the breaker line at night to feed. Here it consumes phytoplankton, including *Anaulus*, and is preyed on in turn by various fish. This mysid is probably instrumental in transporting primary production from the surf zone into the shallow and deeper subtidal regions.

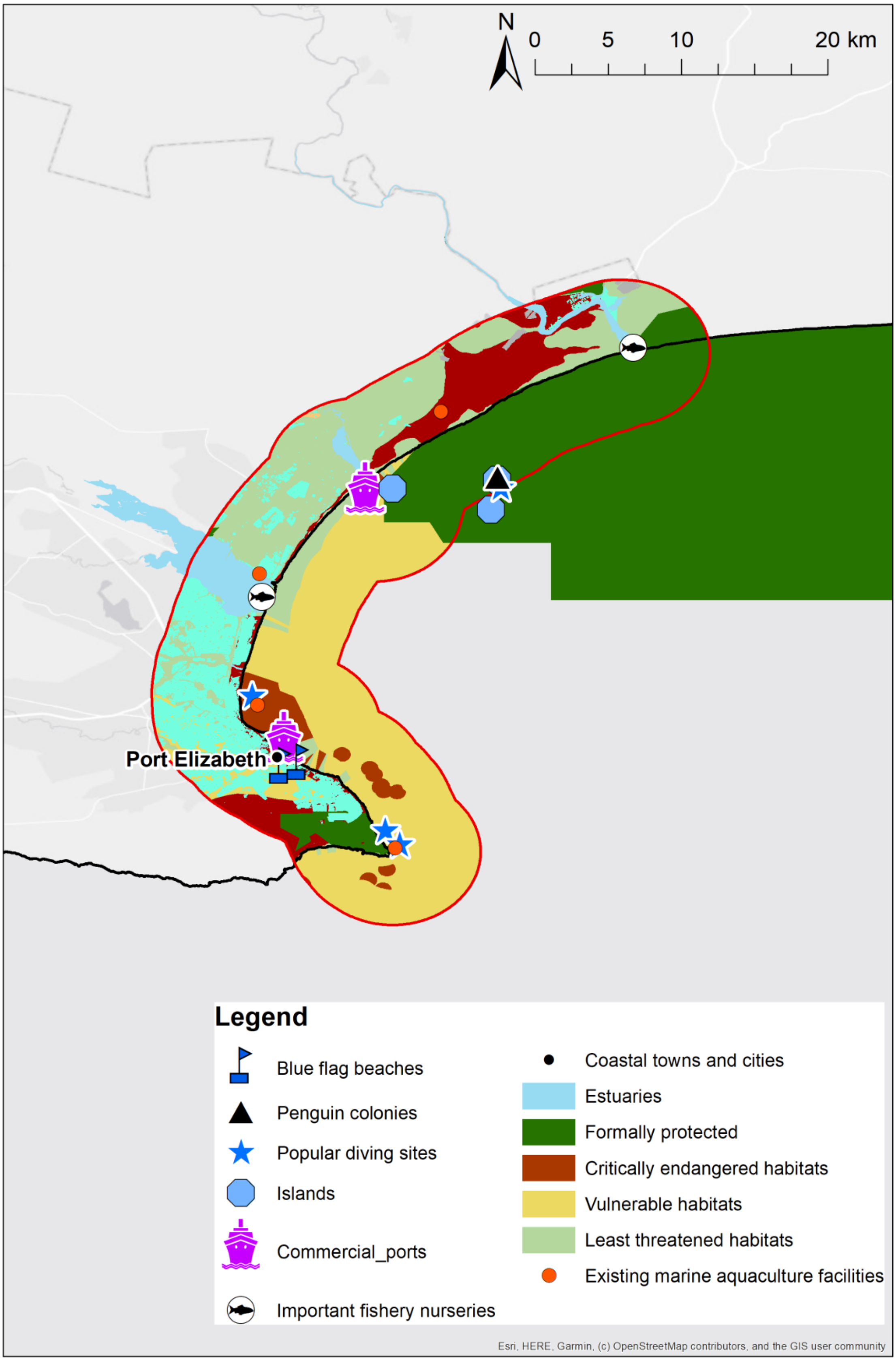

Figure 7. Port Elizabeth: Important ecological and socio-economic attributes.

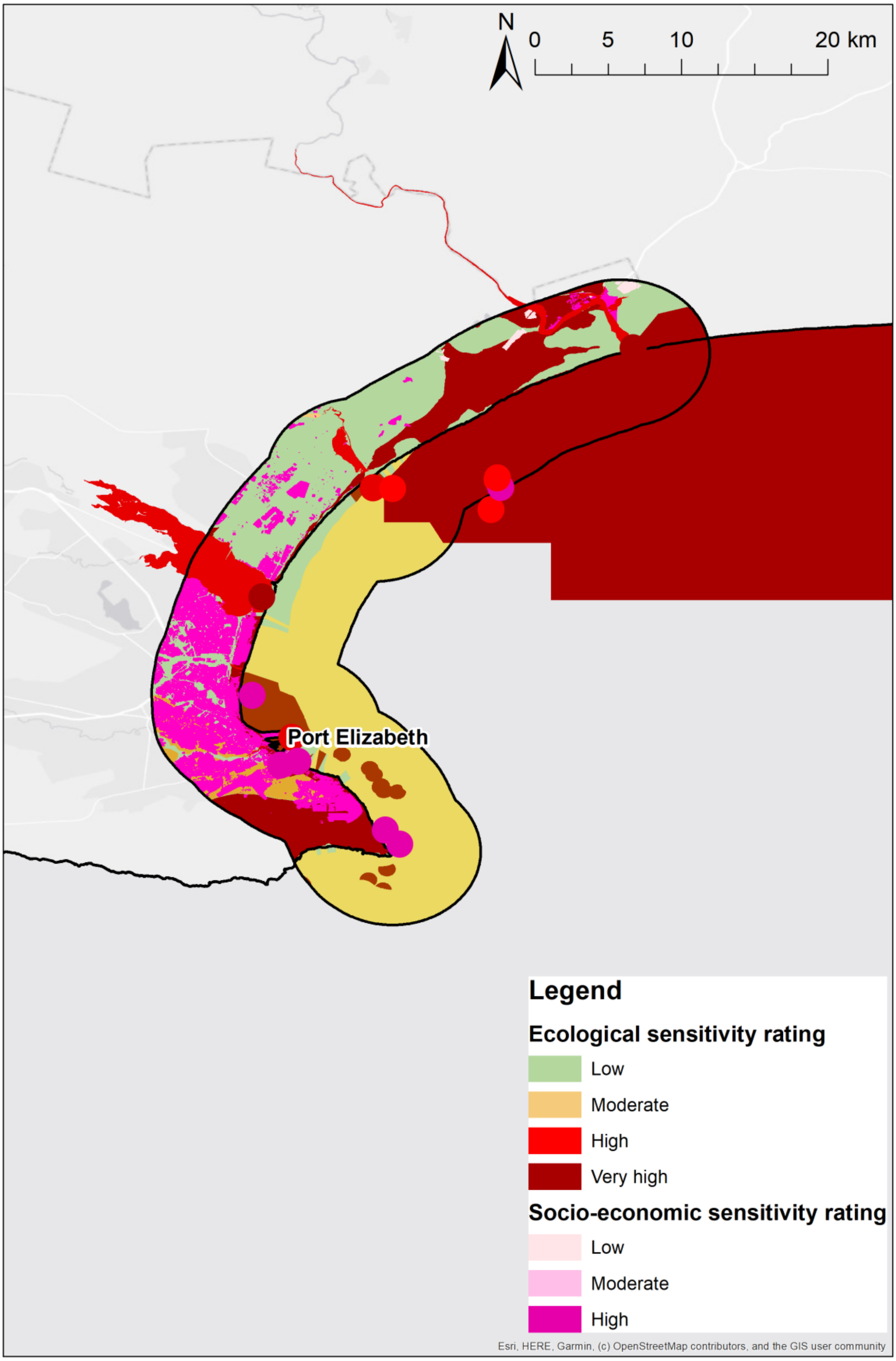

Figure 8. Port Elizabeth: Ecological and socio-economic sensitivity

The shallow subtidal zones of the mixed shores around Cape Recife support reef communities with sessile biota largely similar to that of the islands in Algoa Bay and that in the larger bioregion. Fauna include sea squirts such as *Pyura stolonifera*, colonial ascidians, sponges, soft corals and bryozoans (Porter *et al.*, 2012). The Port of Ngqura provides a range of substrates suitable for biological colonisation and associated varied subtidal environments. These range from the essentially undifferentiated quay walls of the container and general cargo berths through the refuge diverse dolosse armouring the breakwaters to the intertidal and subtidal sands inshore of the eastern breakwater on the eastern side of the port. Dicken (2010) showed that the port provided habitat for 47 fish species. Included here were mainly sub-adult Dusky kob, Elf, Leervis and Dusky sharks. Preferred locations for these species were sandy shores and associated subtidal areas (Leervis and Dusky shark) and dolosse/quay walls (Kob and Elf). Dolosse supported the most diverse fish assemblage as may be expected given the number of refuges for fish that dolosse provide. It is notable that the port system supports relatively large predators indicating that there are sufficient prey species such as Mugilidae and Sparidae for them to forage on. In subsequent work Dicken (2011) showed that the port water body was a regionally important habitat and core activity zone for neonate and juvenile Dusky sharks.

The islands in Algoa Bay are utilized by colonial breeding coastal seabirds as nesting sites and the St Croix Island group, incorporating Jahleel Island, held a significant proportion of the global African Penguin *Spheniscus demersus* population (~40%, Barnes (1998)) in the 1990's proportionally increasing to ~50% in this century but in the face of an overall 50% decline in the global population (Marnewick *et al*. 2015). These birds move between the islands and, although not as important as St Croix Island itself due to its size and terrain, Jahleel Island has hosted important numbers of penguins. Accordingly, islands in the St Croix Island group are denoted as important bird areas (Marnewick *et al*. 2015) and are currently provincial nature reserves. The reserve boundaries extend 500 m offshore of the islands as MPAs and its living marine species are protected under the Marine Living Resources Act (MLRA) of 1998 (Addo Elephant National Park, 2008). Birds include African Penguins, classified as Endangered by IUCN (2017), Cape Gannet, African Black Oystercatcher, and various tern species.

Other notable species that occur in the area include the southern African population of humpback dolphin of which 200 - 400 appear to be semi-resident in Algoa Bay. This is a substantial proportion of the estimated population size (<1 000 individuals). The individuals in Algoa Bay are mainly distributed around rocky reefs in the nearshore south west of the Sundays River mouth within 350 m of the shore in water depths <25 m (Karczmarski *et al*., 1999). According to Wooldridge *et al*. (1997) the surf zone off the Coega River mouth and around the St Croix Islands was an important foraging and socializing area for this species. Some of this habitat has been altered by the construction of the Ngqura Port breakwaters which has unknown consequences for the local (Algoa Bay) sub-population. Further, Cape fur seal forage in Algoa Bay and breeding on the islands has been recorded (Porter *et al*., 2012).

Inner continental shelf and nearshore habitats considered to be under threat are shown in Figure 8. Critically endangered habitats are sand seabed immediately north of the Port of Port Elizabeth extending to the Papenkuils discharge, and isolated reef areas offshore of Cape Recife. The balance of the study area has a lower threat status but, in common with almost all of South Africa's inner continental shelf, is still rated as vulnerable.

5.3.3 Estuaries and fluvial derived banks

There are three estuaries (Sundays, Coega and Swartkops) and one 'industrial drain' (Papenkuils) in the region. The Sundays and Swartkops are the largest of these and are tidal in their lower reaches.

The Zwartkops is characterised by extensive intertidal mudflats, islands and saltmarshes in its lower reaches. It is biologically productive with submerged aquatic vegetation (eelgrass e.g. *Zostera*, *Ruppia*), saltmarsh (such as cord grass, *Sarcocornia*) and reed beds (*Phragmites)* in its upper reaches (Enviro-Fish Africa, 2009). Marine migrant fish that utilise the estuary include Dusky kob, grunter, steenbras, Cape stumpnose and Leervis. Grunter is the most abundant of these. Estuary resident species include Estuarine roundherring, Cape silverside and River goby. The eelgrass beds are important nursery areas for these and some of the migrant species (Enviro-Fish Africa, 2009). Due to its productivity and diverse habitats the estuary is an important bird habitat, hosting migrant waders, terns and other species. Most of these birds utilise the intertidal habitat in the estuary.

In contrast to the Zwartkops estuary the Sundays estuary does not support salt marshes or extensive mudflats and the primary production supporting the food chain is primarily phytoplankton (Wooldridge and Bailey, 1982, Kotsedi *et al*., 2012). It does, however, support a similar fish community including grunter, Cape stumpnose and Dusky kob (Griffiths, 1997). Ichthyoplankton is dominated by four species with estuarine taxa (Estuarine roundherring and gobies) comprising >86% of the larval fish abundance. Seasonal variability in abundance is linked to seasonal peaks in zooplankton biomass in spring and summer which also accords with spawning cycles (Harrison and Whitfield, 1990). Both estuaries have flood tide deltas upstream of their mouths with no apparent fluvially derived banks offshore.

5.3.4 Protected areas

The Bird Island Marine Reserve (proclaimed in 2004) and MPA (Greater Addo Elephant National Park) are designated as 'no take' areas with all forms of fishing and associated activities being banned in the area. Further, each of the St Croix Island group, consisting of St Croix, Brenton and Jahleel islands are designated nature reserves with their reserve areas extending out to 500 m offshore, and all the Algoa Bay islands are declared Important Bird Areas as they are inhabited by threatened and endangered species (Wood, 2002).

5.3.5 Important socio-economic activities

Algoa Bay supports a diversity of fish and shellfish species which are targeted by commercial and recreational fisheries. The former include clupeids, although trawling for these is restricted to north of Woody Cape. Along with linefish, chokka squid are an important fisheries resource in the area. Squid spawn in Algoa Bay throughout the year with the apparent peak in spawning migration in the spring/summer period (Sauer *et al*., 1992). The squid attach their egg pods to the sea floor for egg maturation and hatching. Direct observations indicate that preferred substrate types for pod attachment are coarse sands and shell, flat and high profile reef and sand interspersed with reef (Roberts, 1998). Egg pods have not been observed in fine sands and silt, which is possibly due to insecure attachment. Unfavourable conditions (e.g. large swell or high turbidity) may result in the squid leaving the spawning site (Roberts and Sauer, 1994). There are a minimum of 26 individual spawning sites in Algoa Bay. During spawning squid are mainly benthic predators consuming larger polychaetes and crustaceans (Sauer and Lipinski, 1991).

Other environment dependent activities include diving, with dive sites off Cape Recife being popular, sailing (all forms), surfing and bathing. Beaches in Humewood and Summerstrand have been awarded Blue Flag status. The region also has two industrial ports and therefore is traversed by commercial shipping. Shipping lanes and anchorage areas have been set aside for these vessels.

5.4 Gouritz-George

Important ecological and socio-economic attributes for this region are presented in Figure 9. The relative sensitivity of zones within the study area is illustrated in Figure 10.

5.4.1 Morphology, sediments and physical dynamics

The coast line is characterized by log spiral bays terminating in rocky headlands. Beaches within these bays are classified as intermediate in the dissipative/refractive continuum. Mixed rock and sand beaches have restricted distributions lying immediately east of the Gouritz River, in Vlees Baai, Mossel Bay, east of the Klein Brak River and west of Herold's Bay. Cliffed coastline is extensive in the eastern sector but consists of isolated stretches of coast west of Mossel Bay.

This region lies on the Eastern Agulhas Bank where the shelf widens rapidly which has a strong influence on the oceanographic conditions of the region. Water depth increases from the shoreline to depths of approximately 50 m, whereafter the shelf slopes more gradually to water depth of approximately 100 m. The shelf slope is fairly gentle between water depths of 100 m to approximately 140 m. Beyond this the shelf slope increases again until the outer edge of the shelf at a depth of 200 m (De Wet, 2013). No major valleys or canyons transect this part of the South Coast continental shelf (Gentle, 1987).

A number of studies have characterized the shelf sediments in this region (e.g. Birch, 1980; De Decker, 1983), the most recent being a detailed study by Cawthra (2014) extending from Dana Bay in the west to the Groot Brak River in the east. Sediments of the South Coast generally tend to be trapped in the nearshore zone, forming an elongated sediment prism (De Decker, 1983) and may form ripples oriented coast-parallel and reaching amplitudes of 0.5 m with typical wavelengths of approximately 3 m. The sediment coverage in these inshore areas is greatest in the coastal embayments in the lee (east) of coastal headlands. There is a general lack of terrigenous sediments on the South Coast shelf. The sand that is delivered by rivers is transported eastwards by longshore drift, while suspended mud is likely distributed further offshore and transported west by bottom currents to form the South Coast mud belt (Cawthra, 2014).

The wider shelf in this region largely insulates the inner shelf waters from the direct influence of the Agulhas Current. As a consequence wind-driven currents dominate in the inshore waters, with wave-driven currents strongly influencing the predominantly eastward flows in the typically narrower surf-zone in this region. The influence of the Agulhas Current, does however affect the shelf waters as topographically-driven upwelling on the Eastern Agulhas Bank results in cold upwelled water forming a cold basal layer on the Agulhas Bank (Shannon, 1966; Bang, 1972) that contributes to intense seasonal thermoclines (Eagle and Orren, 1985; Swart and Largier, 1987). Wind-driven upwelling occurs to the west of the capes under easterly wind conditions (Schumann *et al.*, 1982, 1988) 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 the adjacent coastal embayments (Goschen and Schumann, 1995).

Along this stretch of the coast, the offshore mean significant wave height (2.7 m) and particularly the extreme wave height (~6.0 m), are significantly greater than for the East coast sites (CSIR, 2013). Despite the increase in wave height, the relatively modest mean significant wave height (1.21 m) and extreme wave height (2.8 m) reported for Mossel Bay are indicative of the relatively sheltered nature of the western regions of the coastal embayments along the South coast. Due to the significant reduction in easterly waves these western regions of the coastal embayment remain 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.

5.4.2 Important biota

The study area falls within Agulhas within the inshore eco-zone of the Agulhas Ecoregion (Sink *et al.*, 2012). No information could be sourced on biological features of the shorelines but they are expected to be similar throughout the Agulhas inshore ecoregion (Sink *et al.*, 2012) with the exception that surf zone *Anaulus* blooms appear to be rare. Oceanographically the Agulhas Bank is a transition zone between the major oceanographic features of the warm Agulhas Current to the east and the cooler Benguela Current to the west. It supports commercially important populations of pelagic fish (sardine, anchovy and Horse mackerel), demersal species (hake, Kingklip, Snoek, kob, seabreams, sole, gurnard and Monkfish), squid and large pelagic species such as tuna. The area is critically important in the life cycle of sardine and anchovy and associated predators such as African Penguin and Cape Gannet. Whales and dolphins resident on the Agulhas Bank include Bryde's whale, common dolphin, bottlenose and Indo-Pacific humpback dolphin and killer whale. Southern right and Humpback whales are seasonal visitors. A further 24 cetacean species have been recorded as occasional occurrences (Best, 2007; Findlay *et al.*, 1992). Clearly the area is immensely important for national marine biodiversity and goods and services dependent on this (mainly commercial fishing).

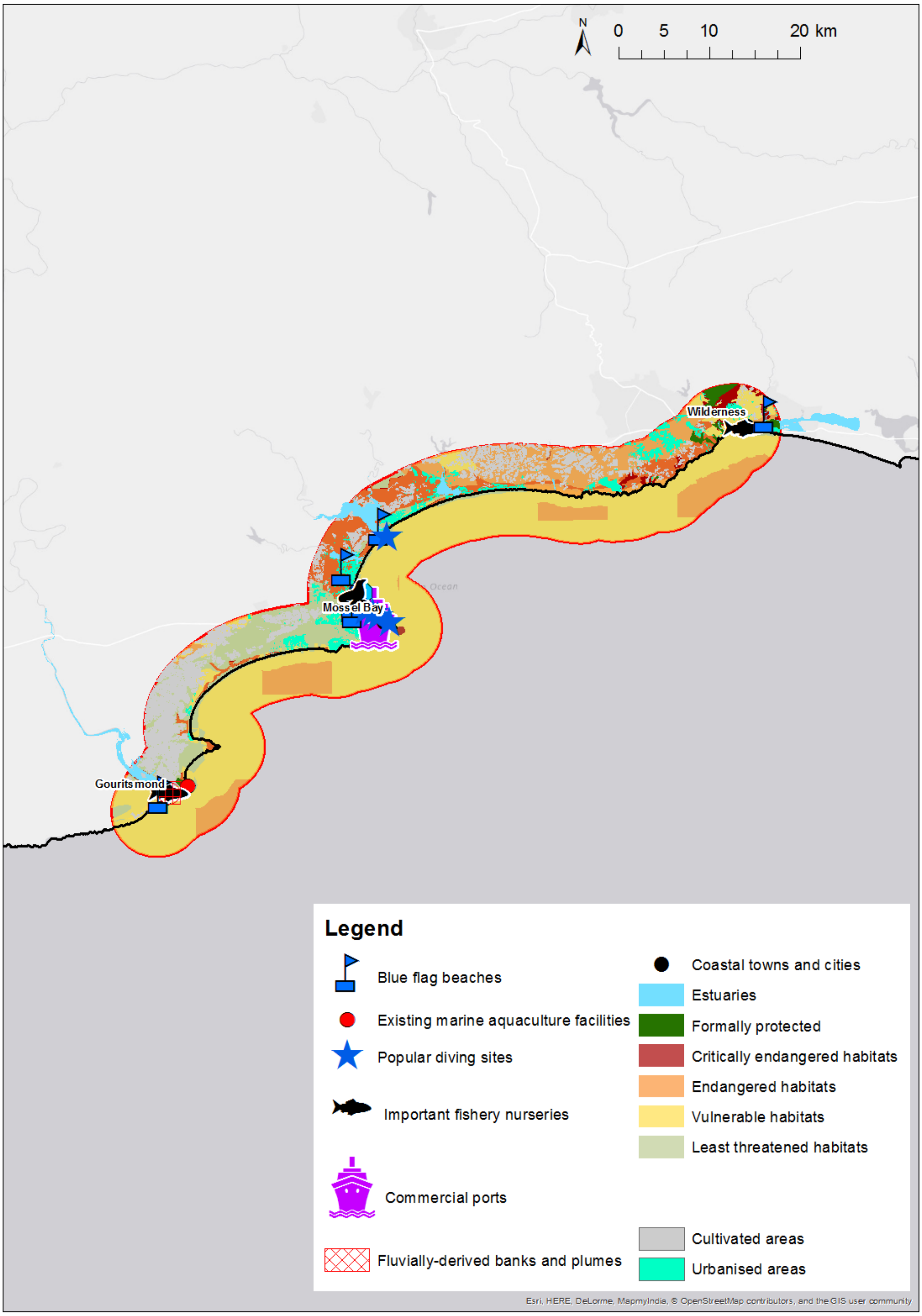

Figure 9. Gouritz-George: Important ecological and socio-economic attributes

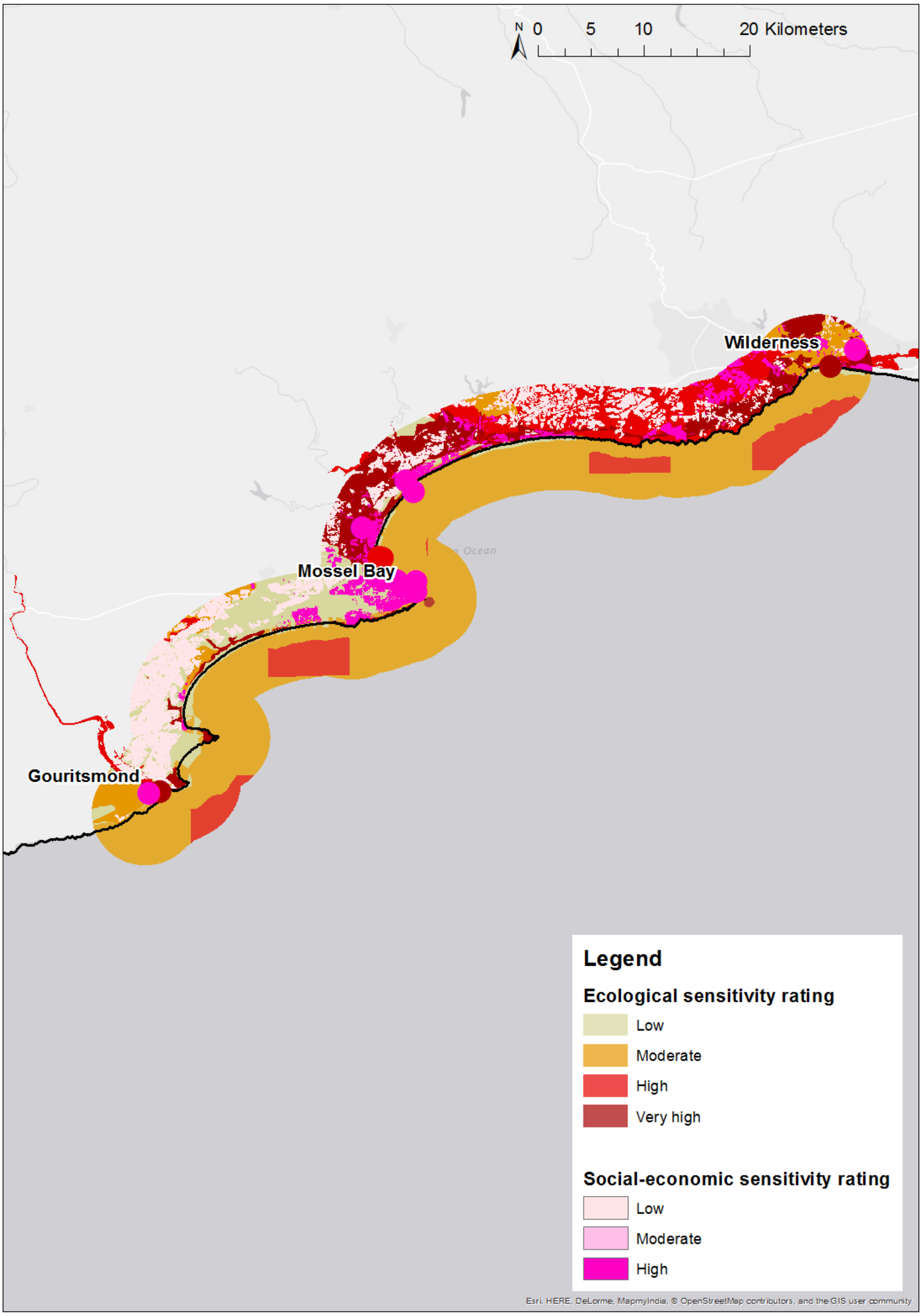

Figure 10. Gouritz-George: Ecological and socio-economic sensitivity

In the study area there is a nearshore sand prism bounded by a coast parallel mud belt. The fine sediments in this mud belt originate from the local rivers (Bree, Duiwenhoks, Gouko and Gourits) and the inshore boundary is controlled by wave action. In the nearshore west of Vleesbaai and north of the Klein Brak River mouth are extensive low relief aeolianite (sandstone) reefs (Badenhorst and Smale, 1991) but these are isolated and small in Vleesbaai and located mainly in the eastern end of the bay (Lwandle, 2009). These reefs are extensions of the intertidal wave cut platform evident at the Klein Brak River mouth (and further east) and are relicts of sand dunes from Quaternary low sea level stands (Bailey and Rogers, 1997). The reefs appear to extend out to at least 30 m depth (Lwandle, 2009; Götz *et al.*, 2009a,b).

The nearshore sands are mobile because of wave resuspension and transport and therefore are an unstable habitat where macrofauna (>1 mm) are likely to be poorly represented. A survey of this habitat immediately offshore of the Klein Brak River by CCA (2008) showed that, as expected from similar surveys in South African inner continental shelf areas, all of the dominant macrofauna groups are present but polychaetes and crustaceans are numerically dominant. Unfortunately the CCA (2008) survey was non-quantitative and the taxonomic resolution coarse so that no conclusions can be drawn on whether there are unique species in the area. However, benthos taxonomic count data from similar depth horizons in other South coast localities (Klages and Bornman, 2003) are broadly similar which implies that the taxa that do occur in the study area should have wide distributions, at least along the South African coast. This applies to organism morphology but not necessarily gene structure (e.g. von der Heyden, 2009).

The biological community on the western end of the subtidal reef extending eastwards from the Klein Brak river mouth is 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 (CSIR, 1988). This community structure appears to be uniform along the reef as Götz *et al*. (2009a) found that, in terms of frequency of occurrence, the important taxa in the Goukamma area, east of the study area, were Bryozoa, Porifera (~20% each), Cnidaria (sea fans, 16%), Tunicata (14%), Algae (10%), Crinoidea (feather stars, 8%) and Cnidaria (hydroids, 8%). Similar to Lwandle (2009), Götz *et al*. (2009a) found that 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). Both Lwandle (2009) and Götz *et al*. (2009a) implicate intrusions of cold, high turbidity water as being an important controlling factor limiting the amount of algae and, therefore, excluding grazers (e.g. marine snails) from the fauna.

The aeolianite reefs are also important for fish with Götz *et al*. (2009b) observing 34 species during underwater video surveys off Goukamma. These included subtidal reef fishery species such as Roman, Santer, Red stumpnose, Red steenbras, Black musselcracker, Panga, Yellowtail, Geelbek, Kob, Dageraad and Carpenter. Several species that occur (Dageraad, Black musselcracker, Galjoen and Red steenbras) are classed as vulnerable (i.e. facing a high risk of extinction in the wild in the medium term future; RSA National Environmental Management: Biodiversity Act, Section 56(1)). Another vulnerable species known to frequent these reefs is the great white shark, apparently utilising the reefs for resting between hunting for seals around Seal Island in Voorbaai.

The commercial important East coast sole occurs on the shore parallel mud belt offshore of Mossel Bay and extends west towards Cape Infanta. Chokka squid may occur in <50 m water depths in Voorbaai and Vleesbaai as well as in embayments to the west and east (Augustyn *et al*., 1994). These areas are used for spawning (which is when the squid are targeted by the fishery) with egg capsules being attached to gravel, sandy gravel, shelly sand or rock by stalks. Large, intertwined egg beds may be formed extending up to 6 m in diameter and containing >6 000 egg capsules. Squid eggs hatch within 10 - 45 days depending on ambient temperatures (Augustyn *et al.,* 1994).

5.4.3 Estuaries and fluvial banks

The estuaries in the region include the Touw, draining the Wilderness Lakes, Groot Brak, Klein Brak, Hartenbos and Gourits. The Touw, Groot and Klein Brak estuaries are temporarily open-closed systems, the Hartenbos to all intents and purposes can be regarded as permanently closed and the Gourits is permanently open but has high variability in flow.

The Wilderness Estuarine Lake system supports both euryhaline marine species, estuarine resident species and freshwater species. (Olds *et al*., 2016). The former include Cape stumpnose, Mugillidae species, Leervis, White steenbras, Oval moony, Ladyfish, Dusky kob and Spotted grunter. Recruitment of euryhaline marine species to the system is affected by the timing of the opening of the estuary mouth to the sea, with peak recruitment occurring in the winter/spring period (Olds *et al*., 2016). The numerically dominant species in the estuary zone was Cape silverside followed by Estuarine roundherring. Alien fresh water species also inhabit the estuary zone including common carp, western mosquitofish and Mozambique tilapia.

The fish communities in the Groot and Klein Brak estuaries are expected to be broadly similar to those described for the Wilderness as the euryhaline marine species are distributed in the nearshore throughout the region and will enter these systems when they are open to the sea. The fish community in the closed Hartenbos estuary includes euryhaline marine species (mullets, Moony, Dusky kob, Spotted grunter, Ladyfish and Leervis) but these appear to be present at low abundances (Harrison, 2002).

The Gouritz Estuary fish community is typical of high turbidity estuarine habitats derived from large catchments transporting Karoid sediments from South Africa's interior. Dusky kob, Estuarine roundherring, mullets, Spotted grunter and Cape stumpnose are abundant and, with White seacatfish, Leervis and White steenbras important contributors to fish biomass (Harrison 2002). The Gouritz River sediment load is high and the system deposits substantial muds and silt offshore forming an extensive muddy zone offshore of the mouth.

5.4.4 Protected areas

The only formally protected area in the marine zone under review is Seal Island in Mossel Bay which supports a Cape fur seal breeding colony. It is also an area where great white sharks congregate. A terrestrial protected area exists in the Wilderness area in the north of the study area (see Figure 9).

5.4.5 Important socio-economic activities

Sole is the target species of the inshore trawl fishery with effort focused on the inshore mud belt, west of Mossel Bay. Research surveys indicate that sole are mostly confined to water depths <100 m (Badenhorst and Smale, 1991) and are apparently preferentially distributed on fine sediments (Le Clus *et al*., 1996). Badenhorst and Smale (1991) report highest research catches adjacent to Cape St Francis east of Mossel Bay and near Cape Infanta to the west while Le Clus *et al*. (1996) show relatively high catches immediately adjacent to Mossel Bay.

Other species are targeted by the inshore trawl sector, notably hake (*Merluccius capensis*), but research trawl data indicate that this species occurs in higher densities west of Mossel Bay (Cape Infanta) and offshore in deeper water (>100 m) (Badenhorst and Smale, 1991).

Irvin & Johnson (I&J) has trialled an aquaculture development focused on finfish (Kob and Yellowtail) farming using offshore cages in the eastern extremity of Voorbaai, immediately offshore of the Klein Brak river mouth in 20 - 30 m water depth.

Great white sharks hunt seals around Seal Island and most of the shark viewing is focused on this area. Currently a single vessel is licensed for this activity (http://www.divesouthafrica.co.za). Sharks also appear to frequent the nearshore aeolianite reefs to the east of the Klein Brak River.

The region supports the full range of sea and shore-based recreational activities. Beaches at Gouritsmond, Mossel Bay, Hartenbos, Klein Brak Rivier and Wilderness have Blue Flag status. Surfing sites are distributed throughout and there are well known dive locations, primarily in and around Mossel Bay.

5.5 Hermanus-Arniston

Important ecological and socio-economic attributes for this region are presented in Figure 11. The relative sensitivity of zones within the study area is illustrated in Figure 12.

5.5.1 Morphology, sediments and physical dynamics

Shorelines in the study area comprise a mixture of sand beaches, limestone headlands and wave cut terraces in the eastern sector and Table Mountain sandstone headlands and rocky shores with pocket sand beaches in the west. The exception to the latter is the long sand beach between the Klein River estuary mouth and De Kelders immediately east of Hermanus.

This western Agulhas Bank shelf region has a width of approximately 100 km out to the 200 m isobath off Cape Agulhas and narrows upon moving westward to approximately 50 km off Cape Hangklip. The 100 m isobath lies some 50 km offshore over the whole region of interest. Major features closer inshore are the rocky ridges running in an approximate east-north-east to west-south-west direction off Cape Hangklip, Danger Point (Robklip, Dyer Island and Geyser Island), Sandy Point and to a lesser extent of Quoin Point (Bremner, 1987). Between Quoin Point and Cape Agulhas lie two extensive shallow regions, Six Mile Bank and Twelve Mile Bank. The outer and inner shelf are characterised by sandy sediments with muddy sediments occurring on the mid-shelf region (Birch *et al*., 1976 as cited by Shannon, 1985). Outside the major embayments, sediments are limited on the inner shelf.

Oceanographically the Western Agulhas Bank is a transition zone between the Agulhas and Benguela systems. The outer shelf is dominated by the larger and longer timescale dynamics of the Agulhas Current and shelf edge jet while the inner shelf is dominated by event-scale upwelling dynamics (Largier *et al*., 1992). This inshore upwelling extends from Cape Agulhas through to the West Coast (Lutjeharms and Stockton, 1987). The mid-shelf region is dominated by strong stratification that separates the warmer oceanic surface water from the upwelled bottom waters. This stratification being maintained largely by buoyancy inputs from the Eastern Agulhas Bank. Currents are polarised in an alongshore direction, however in the vicinity of headlands such as Danger Point, more complex flows occur, creating highly site-specific conditions where small scale re-circulations and stagnant conditions can occur (van Ballegooyen and Botes, 2003).

This stretch of the coastline is highly exposed to waves. The offshore mean significant wave height is approximately 2.6 m while the extreme wave height is of the order of 6.1 m. The coastal embayments typically face the incoming wave conditions, resulting in few sheltered areas and therefore there is minimal (localised at best) risk of the long-term accumulation of organic material on the seabed.

5.5.2 Important biota

The study area lies in the Agulhas Ecoregion (Sink *et al*., 2012). Intertidal rocky shores show typical temperate patterns with tidal height elevation, supporting littorina, upper balanoid, lower balanoid, cochlear and infratidal zones. Endemic species occur in these zones but all have extended ranges on the South African coastline (Griffiths *et al*., 2012). West of Cape Agulhas, extensive kelp beds occur in the infra- and shallow sub-tidal areas (Branch and Branch 1981). Dominant kelp species here are *Ecklonia maxima* and, in deeper water, *Laminaria pallida*. Smaller patches of *E. maxima* do occur east of Cape Agulhas at Koppie Alleen in the de Hoop MPA as a range extension from west of Cape Agulhas attributed to cooling seawater temperatures on this coast (Bolton *et al*., 2012).

Information on sandy beach biota in the region is sparse. A feature of the supratidal zone on beaches west of Cape Agulhas is kelp wrack and attendant kelp flies, isopods and amphipods. Wave swash zones can host plough snails and sand mussels along with the polychaete worm *Scololepis squamata* which can be locally abundant here (Griffiths *et al*. 2012).

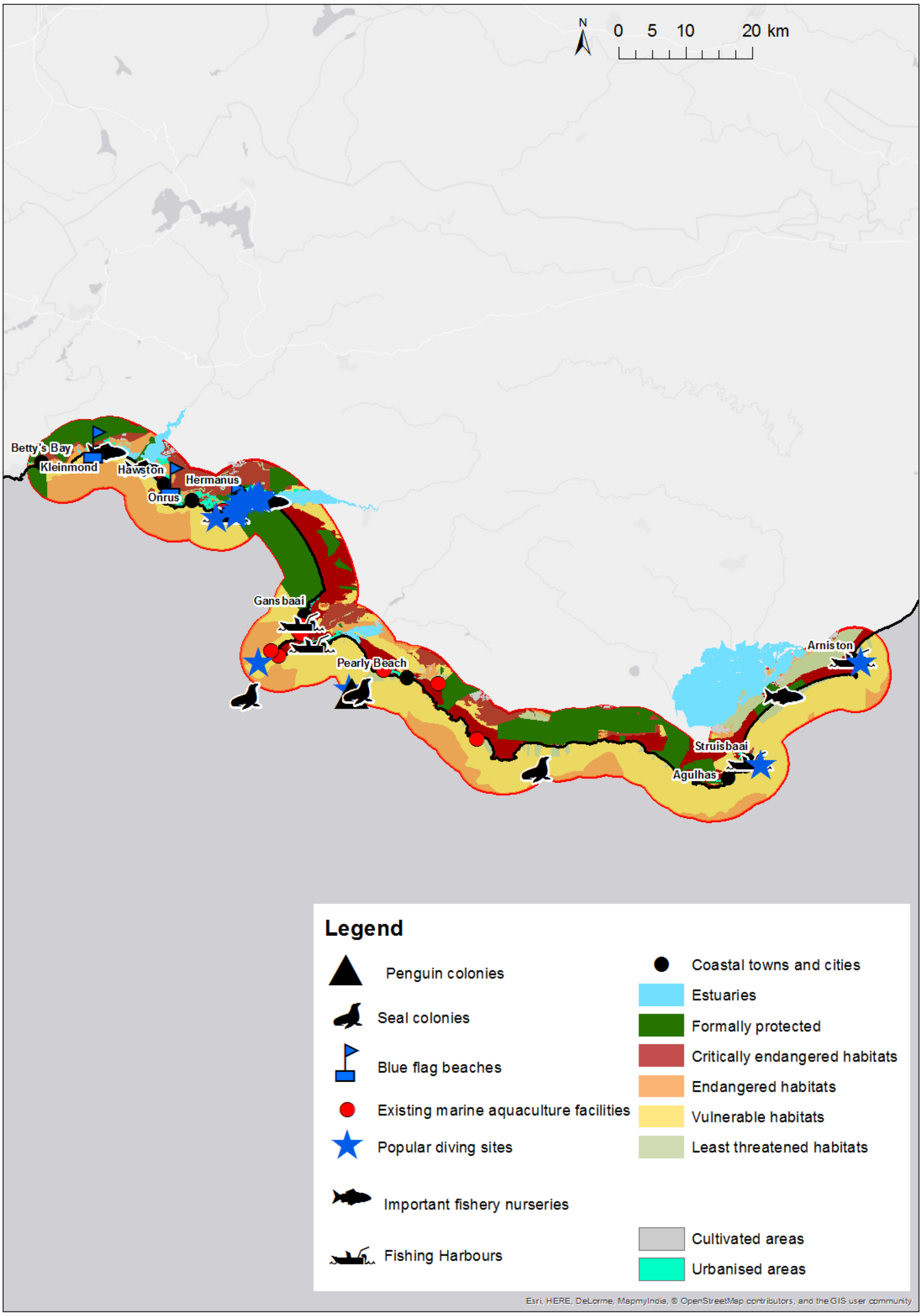

Figure 11. Hermanus-Arniston: Important ecological and socio-economic attributes

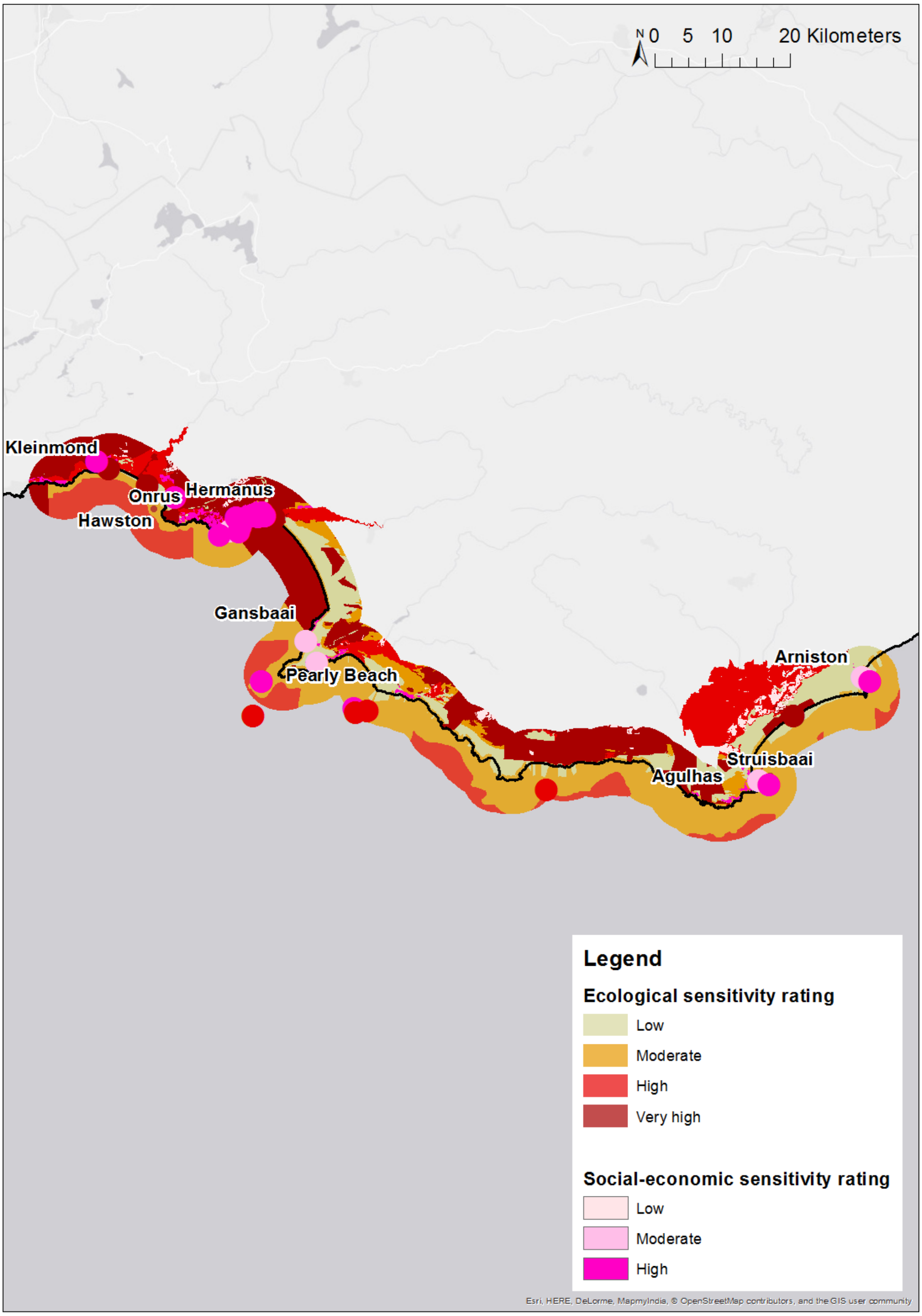

Figure 12. Hermanus-Arniston: Ecological and socio-economic sensitivity

The biological community structure of subtidal sediments in the region is not well known but is expected to be typical of sandy sediments, comprising crustaceans, molluscs and polychaete worms along with other taxa. Sharp gradients in these are not expected as fine sand/muddy areas in the shallower (<50 m) depth horizons would be limited by the vigorous wave action. Griffiths *et al.* (2012) consider that the presence of taxa of special conservation importance in subtidal sediments is unlikely.

Subtidal reef communities west of Cape Agulhas are depth partitioned. In shallow depths (<10 m) macroalgae *Ecklonia maxima* and *Laminaria pallida*, along with understorey algae, dominate and support associated grazers such as the commercially important abalone (*Haliotis midae*) and sea urchins. The red bait sea squirt (*Pyura stolonifera*) is prominent on tidally exposed rocks. In deeper water mussels are prolific along with carnivorous whelks and, in kelp areas rock lobster *Jasus lalandii*.

The fish community on the Agulhas Bank is known to be diverse (Japp *et al.*, 1994) and most of the species recorded are expected to occur in the study area. Important aggregation sites are the 6- and 12-mile reefs off Struisbaai (Cape Yellowtail amongst others) while juvenile smooth hammerhead and subadult great white sharks aggregate in the de Hoop area (Kraai *et al.*, 2009, CapeNature, 2016). These aggregations are apparently seasonal.

Further, Great white adults are abundant around the Cape fur seal colony on Geyser Rock, adjacent to Dyer Island, and Quoin Point to the south-east, and form the basis of tourism (cage diving) operations. These sharks also occur nearshore in this area having been recorded just outside of the surf zone east of Dyer Island. Kock and Johnson (2006) note that over 1 200 different individual sharks were identified in the area over the period 1998 - 2004, indicating significant population exchange with adjacent areas of great white shark habitat.

As stated above Cape fur seal breed at Geyser Rock and Quoin Point and juveniles forage in the nearshore region. No breeding colonies occur east of this in the study area. Numbers of seals peak during breeding season that extends from November to January.

Aside from seals the study area supports Indian Ocean bottlenose dolphin and Indo-Pacific humpback dolphin year-round. The southern right whale, is abundant in winter months, and humpback whale, Bryde's whale and long-beaked common dolphin also occur regularly, but usually further offshore (Griffiths *et al.*, 2012).

The size of the Southern right whale population seasonally present off South Africa was estimated to be ~4 600 individuals in 2008. (Brandão *et al.,* 2011). A wider section of coastal nearshore waters is now utilised for calving and mating by this species, extending east of San Sebastian Bay. The majority of Southern right whale sightings in this area occur from July to November, with calves being present predominantly from September to December.

Bottlenose and humpback dolphins occur year round in the nearshore of the study area. False Bay is considered the western limit for both species (Best, 2007). The population of Bottlenose dolphins living along the Cape South coast is considered to be large and healthy with few major threats (e.g. Reisinger and Karczmarski, 2010) with individuals likely to range along hundreds of kilometres of coastline. They are thus likely to be resilient to localised threats. Conversely, it is important to note threats do not occur in isolation and localised activities may impact a large portion of the population.

No recent published information is available on the humpback dolphin from the Cape South coast. However, indications for the species are not positive. Humpback dolphins naturally occur in small populations, which combined with their extremely coastal and occasionally estuarine distribution, makes them vulnerable to anthropogenic threats. The humpback dolphin population structure along the Cape South coast is not known (i.e. degree of isolation between the possibly geographically separate populations), but individual humpback dolphins in the Eastern Cape are known to move several hundreds of kilometres so the total population may be small.

Dyer Island supports breeding colonies of African Penguin, Roseate Terns, Cormorants (Whitebreasted, Cape, Bank and Crowned), Hartlaubs and Kelp gulls, Swift Terns and Leach's Storm Petrel (Griffiths *et al*., 2012). In addition, Common and Sandwich Terns roost on the island in summer and African Black Oystercatchers forage in the intertidal zone (as well as intertidal zones on the mainland).

African Penguins are classified as vulnerable according to IUCN (2017) criteria. They are particularly at risk due to mismatches in prey abundance and breeding island locations in the southern Benguela Current area. Sherley *et al*. (2017) show that climate change and fisheries have combined to reduce the probability of high pelagic fish abundance in high chlorophyll biomass areas where water temperatures are 14.5 - 17.5 °C. Penguins apparently use these as cues in the selection of their foraging areas and therefore juvenile penguin foraging success rates decrease as do survival rates. These factors mostly apply north of Cape Point and therefore penguin breeding islands east of this, including Dyer Island and those in Algoa Bay, become disproportionately important in maintaining the African Penguin population size. Therefore disturbances to these areas need to be avoided.

5.5.3 Estuaries and fluvial banks

The three main estuaries in the region are the Heuningnes in the east, the Klein in the west at Hermanus, and the Bot/Kleinmond system that drains through an estuary mouth at Kleinmond, but also intermittently following major floods or through artificial breaching, at Hawston. Remaining estuaries in this study area are small and intermittently open to the sea.

The Heuningnes opens to the sea at De Mond, west of Arniston. The estuary is linked to Soetendalsvlei and further upstream to Voelvlei. The system's mouth is sinuous and generally shallow, with the channel affected by wind-blown sand from the west. At present the system is kept open to the sea by artificial breaching. The Klein Estuary opens to the sea annually, although in some years low river flow does not allow this to occur naturally. During breaching events silt and sand is flushed from the lower estuary but these are insufficient to generate significant offshore fluvial banks. The extensive estuarine lake provides nursery areas to fish including White steenbras, Dusky kob, Leervis, Cape moony, Cape stumpnose, and flathead mullet, which are estuary-dependent for at least their first year of life (Whitfield, 1998). In recent years the poor water quality of the Klein has been a source of concern for abalone farms in Walker Bay. In the main the Bot Estuary behaves in a similar manner to the Klein except that there is usually some drainage through the attenuated discharge at Kleinmond. During floods and major outflows aerial imagery suggests that the Bot and Klein River plumes mix and provide a mechanism for the exchange of organisms between the two.

5.5.4 Protected areas

MPAs are located at De Hoop, Cape Agulhas to Quoin Point, Dyer Island/Geyser Rock, De Kelders to the Klein River Estuary, Onrus River Estuary and Betty's Bay in the western extremity of the study area.

5.5.5 Important socio-economic activities

Pelagic sardine and, to a lesser extent, Anchovy fishing operations are based in Gansbaai in the west along with commercial linefish boats that operate mainly east of the port. Linefishing is also conducted from launch sites at Pearly beach, Struisbaai and Arniston. Species landed include Cape Yellowtail, Panga, mackerel and, more rarely Dusky kob. Seaweed (*Ecklonia maxima*) is collected from beaches and fronds are directly harvested from kelp beds for supply to abalone farms on Danger Point and further east at Buffelsjag. Although the local population of wild abalone (*Haliotis midae*) has been decimated by overfishing and poaching and increased predation levels on juveniles by rock lobster (*Jasus lalandii*) the fishery is currently open even though abalone densities have declined by a factor of 10 since the 1990s (Griffiths *et al*., 2012).

This region is a major centre for abalone aquaculture in South Africa. Farms are located at Buffelsjag, on Danger Point, in Gansbaai Harbour and around the New Harbour in Hermanus. Further, offshore finfish cage farming for salmon was trialled off Danger Point but, apparently due to access problems, the cages were overgrown by biofouling and sank. This allowed a mass escape of fish but none appears to have been caught in the extensive line fishing that occurs in the study area.

Given its scale abalone aquaculture is a significant employer of local people and therefore an important contributor to socio-economic wellbeing.

Great white sharks hunt seals around Dyer Island/Geyser Rock and shark cage diving is prevalent in this area. Tour parties embark on viewing vessels at Pearly Beach, east of Gansbaai. The entire study area is suitable and utilized for whale (southern right whale) watching in winter/spring.

Blue Flag beaches are located primarily around Hermanus but the balance of the beaches in the study area are likely to be of similar status due to mostly low population densities and the absence of marine outfalls. Demarcated dive sites are located at Struisbaai (6- and 12-mile reef), Arniston, Danger Point and Betty's Bay. Both the Bot and Klein estuaries are used for boating activities, the later including keelboat and dinghy sailing.

5.6 Velddrif-Saldanha

Important ecological and socio-economic attributes for this region are presented in Figure 13, while the relative sensitivity of zones within the study area is illustrated in Figure 14.

5.6.1 Morphology, sediments and physical dynamics

The continental shelf along the West Coast is generally wide and deep, maintaining a general north-northwest trend, and widening north of Cape Columbine. Winds are one of the main physical drivers of the nearshore region, both on an oceanic scale, generating the heavy and consistent south-westerly swells that impact this coast, and locally, contributing to the northward-flowing longshore currents. Interaction of the coastal topography, prevailing southerly/south-easterly winds and the Benguela Current strongly affect the regional oceanography resulting in localised upwelling of nutrient-rich bottom waters. There are three upwelling centres in the southern Benguela, namely the Cape Point (34°S), Cape Columbine (33°S) and Namaqua (30°S) upwelling cells (Taunton-Clark, 1985). Upwelling in these cells is seasonal, with maximum upwelling occurring between September and March. St Helena Bay is positioned downstream of the Cape Columbine upwelling cell and is a retention zone for the nutrient rich water that is upwelled in this cell (Monteiro and Roychoudhury, 2005). Much of the coastline is exposed and impacted by heavy south-westerly swells generated in the roaring forties, as well as significant sea waves generated locally by the prevailing moderate to strong southerly winds characteristic of the region. The peak wave energy periods fall in the range 9.7 – 15.5 seconds. The Saldanha Bay-Langebaan Lagoon system and St Helena Bay offer some of the only protection from heavy swells along the entire West Coast.

As a result of erosion on the continental shelf, the unconsolidated sediment cover is generally thin, often less than 1 m. Sediments are finer seawards, changing from sand on the inner and outer shelves to muddy sand and sandy mud in deeper water. However, this general pattern has been modified considerably by biological deposition and localised river input.

Following an upwelling event, high phytoplankton productivity in the upper layers depletes the nutrients in the surface waters, resulting in a wind-related cycle of plankton production, mortality, sinking of plankton detritus and eventual nutrient re-enrichment occurring below the thermocline as the phytoplankton decays. The absolute rate of this is dependent upon the net organic material build-up in the sediments, with the carbon rich mud deposits playing an important role. Consequently, continental shelf waters are characterised by low oxygen concentrations with <40% saturation occurring frequently (e.g. Visser, 1969; Bailey *et al.*, 1985).

St Helena Bay is one of two main areas along the West Coast associated with the formation of low-oxygen water, with daily variability in the volume of hypoxic waters occurring as a result of downward flux of oxygen through thermoclines and short-term variations in upwelling intensity (Bailey and Chapman, 1991). Subsequent upwelling processes can move this low-oxygen water up into nearshore waters, and, extreme cases, lead to "black tide" events. These can have catastrophic effects on the marine communities as a result of large-scale stranding of rock lobsters, and mass mortalities of marine biota and fish (Newman and Pollock, 1971; Matthews and Pitcher, 1996; Pitcher, 1998; Cockcroft *et al.*, 2000).

An associated phenomenon ubiquitous to the Benguela system is red tides (dinoflagellate and/or ciliate blooms) (see Shannon and Pillar, 1986; Pitcher, 1998). Also referred to as Harmful Algal Blooms (HABs), these red tides can reach very large proportions, extending over 100s of kilometres of ocean. Toxic dinoflagellate species can cause extensive mortalities of fish and shellfish through direct poisoning, while degradation of organic-rich material derived from both toxic and non-toxic blooms can result in oxygen depletion of the entire water column in the neashore environment (Pitcher *et al.* 2014).

The Saldanha Bay-Langebaan Lagoon complex is a major feature on this section of the coast and is unique along the South African coast as a large coastal embayment. The system can be divided into Outer Bay, Inner Bay (comprising Big Bay and Small Bay) and Langebaan Lagoon (Smith and Pitcher 2015). It contains five offshore islands, namely Malgas, Jutten, Marcus, Meeuw and Schaapen. Coastal upwelling, strongly correlated with equatorward windstress, plays a strong role in the exchange of water between bay and coastal waters, and also influences phytoplankton communities in Saldanha Bay (Probyn *et al.*, 2000, Pitcher *et al.*, 2010).

Harmful (toxic) algal blooms have become a regular seasonal occurrence in the bay since 1994, however, these are transported into the system with exchanges of surface water with the adjacent continental shelf and have not yet been observed to develop in the Saldanha Bay (Probyn *et al.*, 2000). These blooms pose a risk to both the sensitive ecosystems in the area and beneficial uses, such as aquaculture operations, and recreation and tourism.

5.6.2 Important biota

Biogeographically the Saldanha Bay - Langebaan Lagoon system falls within the Southern Benguela Ecoregion (Sink *et al.*, 2012). The West Coast in general is characterised by low marine species richness and low endemicity (Awad *et al.*, 2002). The biota of nearshore marine habitats are relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. The majority of the open coastline in this study area is dominated by dissipative/intermediate beaches and mixed shores.

With the exception of a few beaches in large bay systems (St Helena Bay, Saldanha Bay), the beaches along the South African West coast are typically highly exposed. Exposed sandy shores consist of coupled surf-zone, beach and dune systems, which together form the active littoral sand transport zone (Short and Hesp, 1985). The composition of their faunal communities is largely dependent on the interaction of wave energy, beach slope and sand particle size, which is termed beach morphodynamics. Three morphodynamic beach types occur; dissipative, reflective and intermediate beaches (McLachlan *et al.*, 1993). Generally, dissipative beaches are relatively wide and flat with fine sands and low wave energy. These beaches usually harbour the richest intertidal faunal communities. Reflective beaches in contrast, have high wave energy, and are coarse grained (>500 µm sand) with narrow and steep intertidal beach faces. Waves break directly on the shore causing a high turnover of sand and resulting in 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). The macrofaunal communities of sandy beaches are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone. Due to the exposed nature of much of the coastline in the study area, most beaches are of the intermediate type, with dissipative beaches characterising the more sheltered bays.

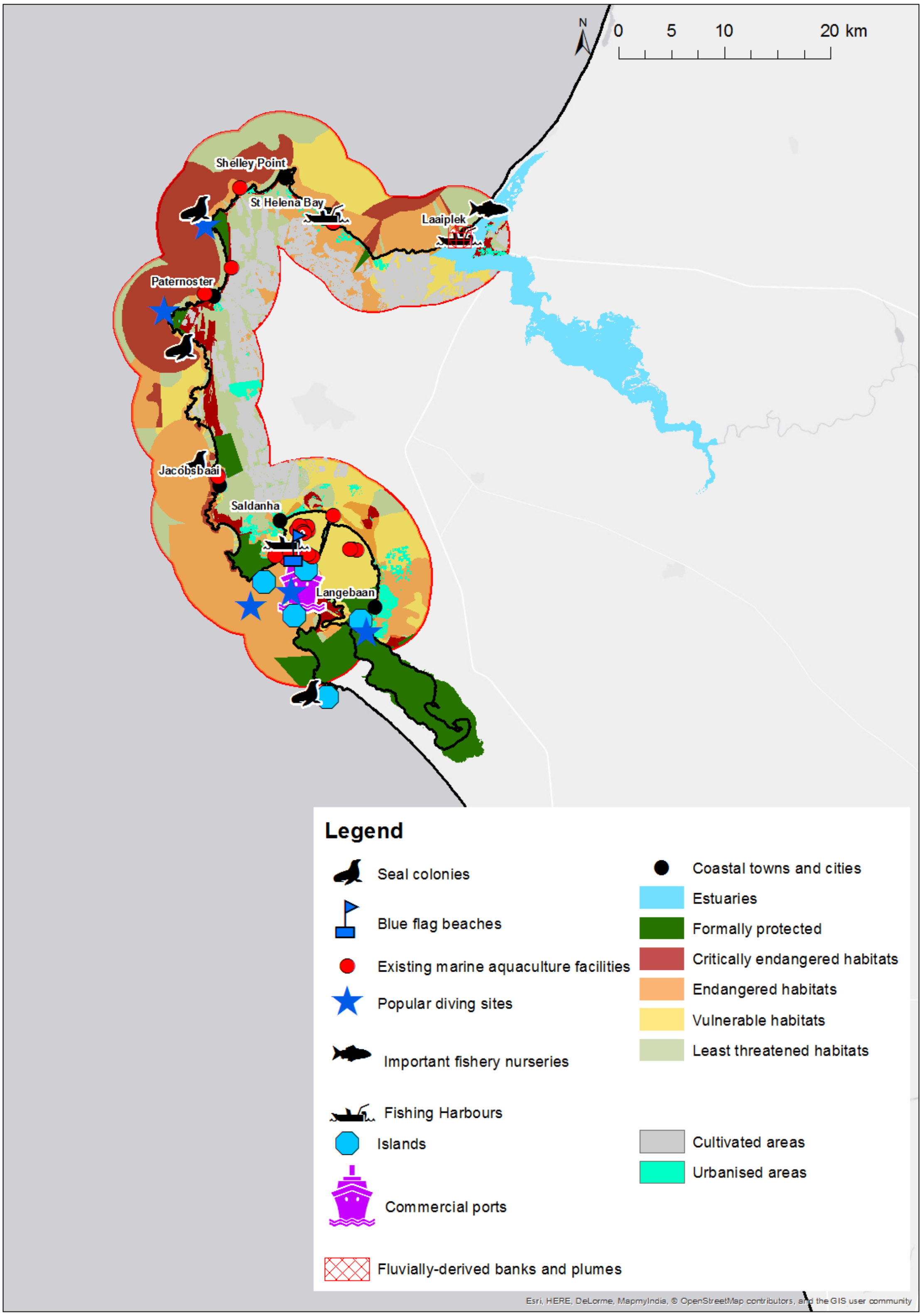

Figure 13. Velddrif-Saldanha Important ecological and socio-economic attributes

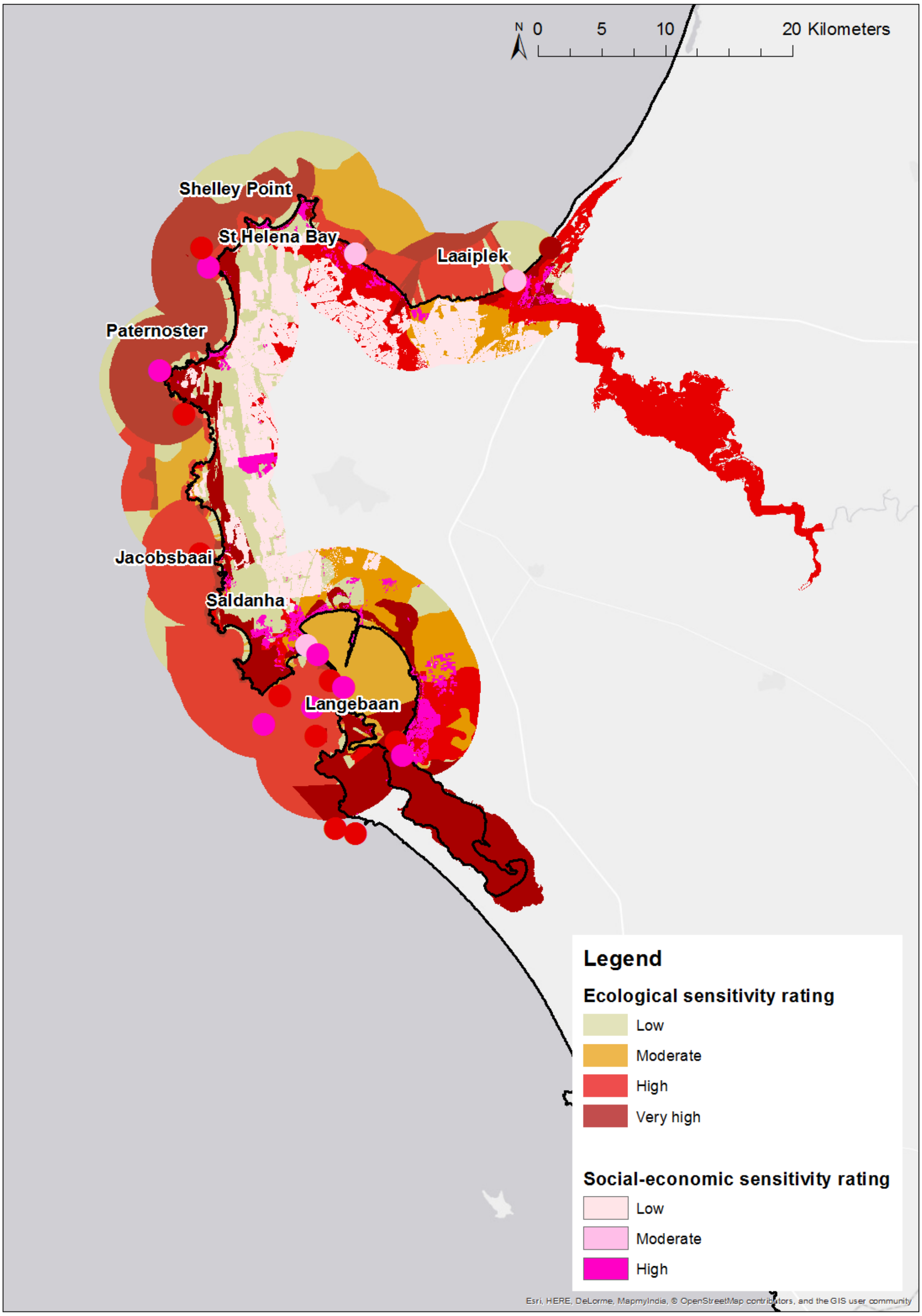

Figure 14. Velddrif-Saldanha Ecological and socio-economic sensitivity

There is a noticeable scarcity of published information on the intertidal beach biota of Saldanha Bay, as previous research on the West Coast has primarily focussed on 'open coast' beaches (e.g. Bally, 1987; Soares, 2003). Prior to the construction of the causeway and jetty, Day (1959) described an increase in species richness and a significant change in species composition with increasing shelter. Unpublished data from Langebaan Lagoon and Lynch Point (unpublished UCT student data: 1995 and 1996; provided by Prof. C. Griffiths) confirm the dramatic change in species richness and composition between the exposed Saldanha Bay beach and the sheltered lagoon beaches, the biota of the latter being characterised by either South Coast species known to occur on the West Coast only in Langebaan Lagoon, or typical estuarine species.

As with the rest of the southern African coastline, rocky intertidal shores on the West Coast can be divided into five zones on the basis of their characteristic biological communities. Tolerance to the physical stresses associated with life in the intertidal, as well as biological interactions such as herbivory, competition and predation interact to produce these five zones. The biological zones, however, also correspond roughly to zones based on tidal heights. On the West Coast, wave action plays an important role in the structure of intertidal rocky-shore communities. Specifically, wave action enhances filter-feeders by increasing the concentration and turnover of particulate food, leading to an elevation of overall biomass despite low species diversity (McQuaid and Branch, 1985; Bustamante *et al*., 1995a, 1995b; Bustamante *et al.,* 1997). Conversely, sheltered shores are diverse with a relatively low biomass, and only in relatively sheltered embayments does drift kelp accumulate and provide a vital support for very high densities of kelp trapping limpets that occur exclusively there (Bustamante *et al*., 1995b). In the subtidal, these differences diminish as wave exposure is moderated with depth.

Biological communities of the rocky sublittoral can be broadly grouped into an inshore zone from the sublittoral fringe to a depth of about 10 m dominated by flora, and an offshore zone below 10 m depth dominated by fauna. This shift in communities is not sharp, and rather represents a continuum of species distributions, merely with changing abundances. From the sublittoral fringe to a depth of between 5 and 10 m, the benthos is largely dominated by algae, in particular two species of kelp. The canopy-forming kelp *Ecklonia maxima* is the dominant species extending seawards to a depth of about 10 m forming extensive beds from west of Cape Agulhas to north of Cape Columbine. The smaller *Laminaria pallida* forms a sub-canopy to a height of about 2 m underneath *Ecklonia*, but continues its seaward extent to about 30 m depth (Velimirov *et al.* 1977; Jarman and Carter 1981; Stegenga *et al.* 1997; Rand 2006; Branch 2008).

Kelp beds absorb and dissipate much of the typically high wave energy reaching the shore, thereby providing important partially-sheltered habitats for a high diversity of marine flora and fauna, resulting in diverse and typical kelp-forest communities being established. Through a combination of shelter and provision of food, kelp beds support recruitment and complex trophic food webs of numerous species, including commercially important rock lobster stocks (Branch, 2008).

Both St Helena Bay and the Saldanha-Langebaan Lagoon system function as productive nursery areas to early life stages of various fish species (Bakun, 1998; Monteiro and Roychoudhury, 2005). The Langebaan Lagoon MPA has been shown to be an import refuge for a part of the spawning stock of White stumpnose, an important linefish in the area (Kerwath *et al*., 2009).

Seabird breeding sites in the project area are located on the Saldanha Bay islands and Dassen Island off Yzerfontein to the south of the project area (Crawford *et al*., 2015). There are also a number of Cape fur seal colonies within the study area: Paternoster Rocks, Paternoster Point and Jacobs Reef at Cape Columbine (Oosthuizen 1991).

5.6.3 Estuaries and fluvial banks

The Berg River Estuary, flowing into St Helena Bay, is one of three predominantly-open estuaries on the West Coast and is ecologically important for fish, fisheries, invertebrates and birds. Ecological functioning of the estuary is determined by seasonal changes in river discharge and consequent changes in salinity and turbidity. Covering an area of ~6 621 ha, the Berg is the only estuary in this study area. It accounts for about 30% of the estuarine fish nursery habitat on the West Coast and is regarded as the most important from an estuarine invertebrate, macrophyte and avifaunal perspective.

Langebaan Lagoon is a shallow tidal lagoon connected to Saldanha Bay. Originally considered to be a sheltered marine area (Day 1959), the system is more recently recognised as an extensive, warm, shallow-water areas that is markedly influenced by groundwater, and as such has a typical estuarine character (Whitfield, 2005).

5.6.4 Protected areas

The West Coast National Park, which was established in 1985 incorporates the Langebaan Lagoon and Sixteen Mile Beach MPAs, as well the Schaapen, Marcus, Malgas and Jutten islands. Langebaan Lagoon was designated as a Ramsar site in April 1988 under the Convention on Wetlands of International Importance especially as Waterfowl Habitat. The lagoon is divided into three different utilization zones namely: wilderness, limited recreational and multi-purpose recreational areas. The wilderness zone has restricted access and includes the southern end of the lagoon and the inshore islands, which are the key refuge sites of the waders and breeding seabird populations respectively. The limited recreation zone includes the middle reaches of the lagoon, where activities such as sailing and canoeing are permitted. The mouth region is a multi-purpose recreation zone for power boats, yachts, water-skiers and fishermen. However, no collecting or removal of abalone and rock lobster is allowed. The length of the combined shorelines of Langebaan Lagoon MPA and Sixteen Mile Beach is 66 km. Langebaan is unique in that it is a warm oligotrophic lagoon, along the cold, nutrient-rich and wave exposed West Coast.

No rock lobster may be caught in Saldanha Bay eastwards of a line between North Head and South Head. There is also a Rock Lobster Sanctuary in St Helena Bay. Further marine conservation areas in the Saldanha/Cape Columbine region include:

- Paternoster Rocks – Island reserves for seabirds and seals;
- Jacob's Reef - Island reserve for seabirds and seals;
- An area within the military base, SAS Saldanha; and
- Vondeling Island.

5.6.5 Important socio-economic activities

The Transnet National Ports Authority (TNPA) set aside a total of 395 ha of sea area within Saldanha Bay for mariculture activities, of which 200 ha are situated in Big Bay, 130 ha are located in Small Bay and a further 65 ha lie adjacent to the breakwater and Small Craft Harbour. There are currently nine mariculture operators that farm mussels, oysters, and various other species in the Bay. A total area of approximately 165 ha has been allocated to these operators (Pisces 2017).

The commercial fishery in Saldanha Bay consists mainly of line fishing from small boats and gill netting. Linefishing is conducted both within the bay and along the open coast to the north of Saldanha Bay, whereas gill-netting is confined to within the bay. Species such as White stumpnose, White steenbras, Kob, Elf, Steentjie, Yellowtail, Snoek, Hottentot and Smoothhound shark support the commercial line fisheries, and also a large shore angling and recreational boat fishery, which contributes significantly to the tourism appeal and regional economy of Saldanha Bay and Langebaan (Atkinson *et al*. 2006). Recreational line-fishing is confined largely to rock and surf angling within Saldanha Bay and the more accessible coastal stretches in the regions along the Cape Columbine coast. Stocks of several species are showing signs of decline through overexploitation (e.g. Hutchings and Lamberth, 2002, Parker *et al*., 2017).

Although no rock lobster may be caught in the entire Saldanha Bay area between North Head and South Head, recreational and commercial rock-lobster fishing takes place northwards along the coast to as far as the St Helena Bay Rock Lobster Sanctuary. Actual rock-lobster fishing, however, takes place only at discrete suitable reef areas along the shore within this broad depth zone. Lobster fishing is conducted from a fleet of small dinghies/bakkies. The majority of these work directly from the shore within a few nautical miles of the harbours, with only 30% of the total numbers of bakkies participating in the fishery being deployed from larger deck boats. As a result, lobster fishing tends to be concentrated close to the shore. Recreational rock lobster catches are made primarily by diving or shore-based fishing using baitbags (Cockcroft and McKenzie, 1997). The majority of the recreational take of rock lobster is made by locals resident in areas close to the resource.

St Helena Bay was the centre of the pelagic fishing industry when it began in the 1940s and has been an important part of the West Coast lobster fishing grounds (von Bonde and Marchand, 1935; Hutchings *et al*., 2011). The Bay still functions as a major node for industrial and small-scale fisheries on the West coast. Indeed, the fishing industry is the mainstay of St Helena Bay with the bulk of South Africa's fish production and processing being conducted in the St Helena Bay factories. The factories in the bay produce a variety of products including tinned fish, fresh and frozen hake, fish-meal and live crayfish for export. Other industries located around the periphery of the bay include mariculture, ship repair and shipbuilding.

As a deep water bay offering relative protection from the adjacent high energy coastline, Saldanha Bay is the only natural harbour of significant size on the West coast of South Africa. It hosts a substantial fishing industry and fish processing factories. In 1971 the harbour was upgraded into an international port, which was followed by two major developments:

- A causeway that linked Marcus Island to the mainland, providing shelter for ore-carriers; and
- The construction of the iron ore loading facility, which was later extended to provide for the import of oil.

A multipurpose terminal was later added to the iron-ore berth and a small-craft harbour was built to cater for the increase in recreational and tourism activities in the bay. The construction of the iron ore loading facility essentially divided Saldanha Bay into two sections: a smaller area bounded by the one berth, the northern shore and The Marcus Island breakwater (Small Bay); and an adjacent larger, more exposed area (Big Bay) which leads into Langebaan Lagoon.

There are numerous smaller harbour areas in and around Saldanha Bay and Langebaan Lagoon:

- Small craft harbours (also under the jurisdiction of the TNPA);
- Fishing harbours;
- Military harbours (SAS Saldanha)Langebaan and Donkergat;
- Yacht clubs of Saldanha Bay and Langebaan, and at Club Mykonos.

St Helena Bay hosts various smaller harbours associated with the various fish factories. The Laaiplek fishing harbour lies just inside the river mouth, with the Port Owen Marina located ~3 km upstream.

Other recent developments implemented in and around Saldanha Bay include the TNPA 2 400 m^3/day reverse-osmosis desalination plant constructed at the Iron Ore Terminal in Big Bay, which has been operational since August 2012. Effluents from a further desalination plant proposed by the West Coast District Municipality, and the proposed Frontier Saldanha Utilities (Pty) Ltd regional marine outfall, would be discharged into Danger Bay. Mainly fishing, sailing, kayaking, wind-surfing, and kite surfing occur in this area.

5.7 Strandfontein-Lamberts Bay

Important ecological and socio-economic attributes for this region are presented in Figure 15, while the relative sensitivity of zones within the study area is illustrated in Figure 16.

5.7.1 Morphology, sediments and physical dynamics

The continental shelf along the West Coast widens north of Cape Columbine. As with the Saldanha-Velddrif area, winds are one of the main physical drivers of the nearshore region, both on an oceanic scale, generating heavy south-westerly swells, and locally, contributing to the northward-flowing longshore currents. The wave climate is similar to that of the Velddrif to Saldanha area, and the coast is impacted by the heavy south-westerly swells. Lamberts Bay and Doring Bay offer only marginal protection from the prevailing swells. This study area is positioned downstream of the Cape Columbine upwelling cell, one of three main upwelling cells on the Cape West coast, and its waters are therefore prone to oxygen depletion(Jarre *et al.*, 2015). It also lies in an area subject to a localised narrow band of upwelling which leads to oxygen variability in shallow nearshore waters (<20 m) (Pitcher *et al.* 2014).

The coastline of the study area is dominated by dissipative/intermediate sandy beaches and mixed shores, with rocky coastline confined to the area immediately south of Strandfontein. Offshore sediments are mainly sandy (Sink *et al.*, 2012, Harris *et al.*, 2013).

Figure 15/...

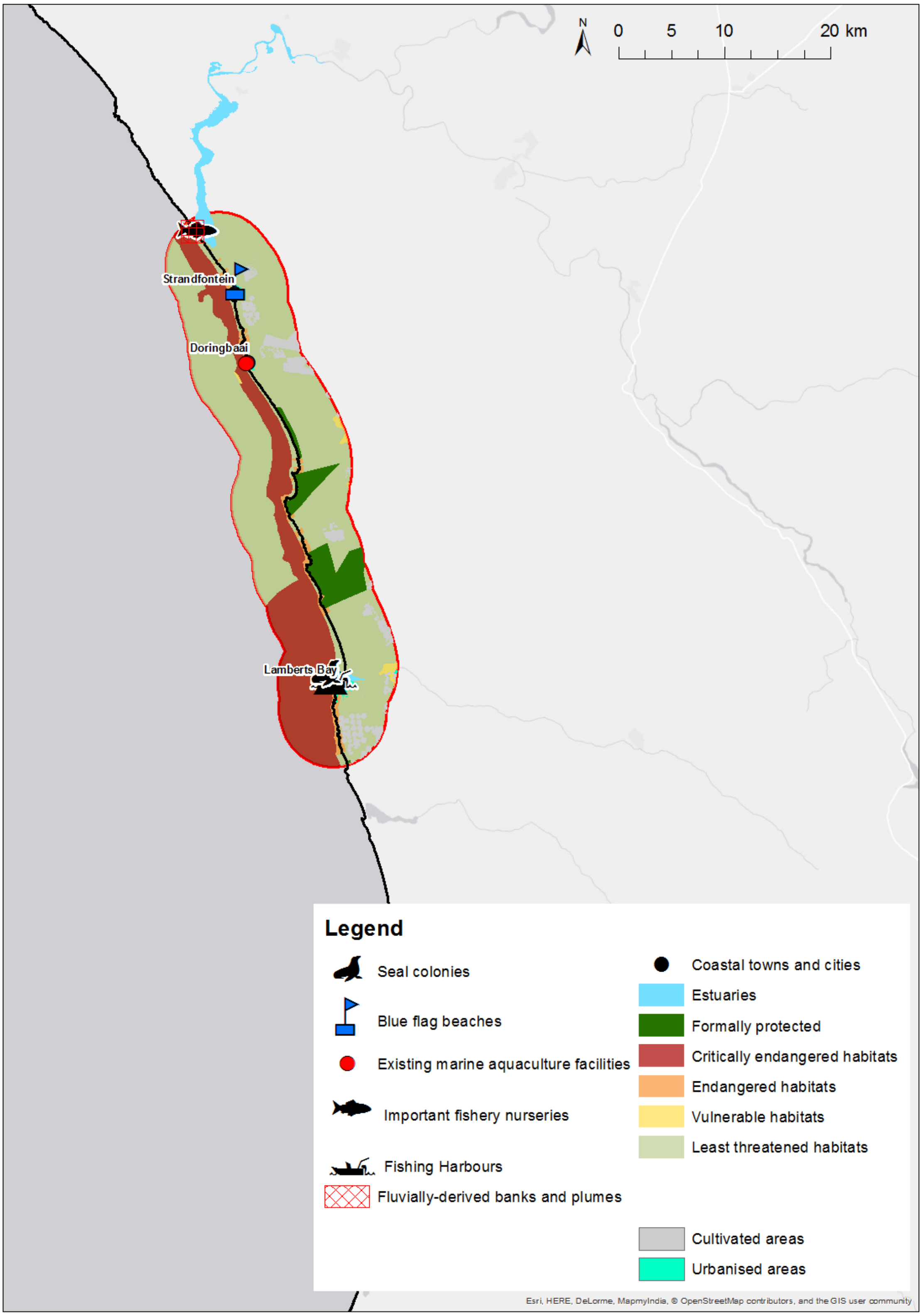

Figure 15. Strandfontein-Lamberts Bay: Important ecological and socio-economic attributes

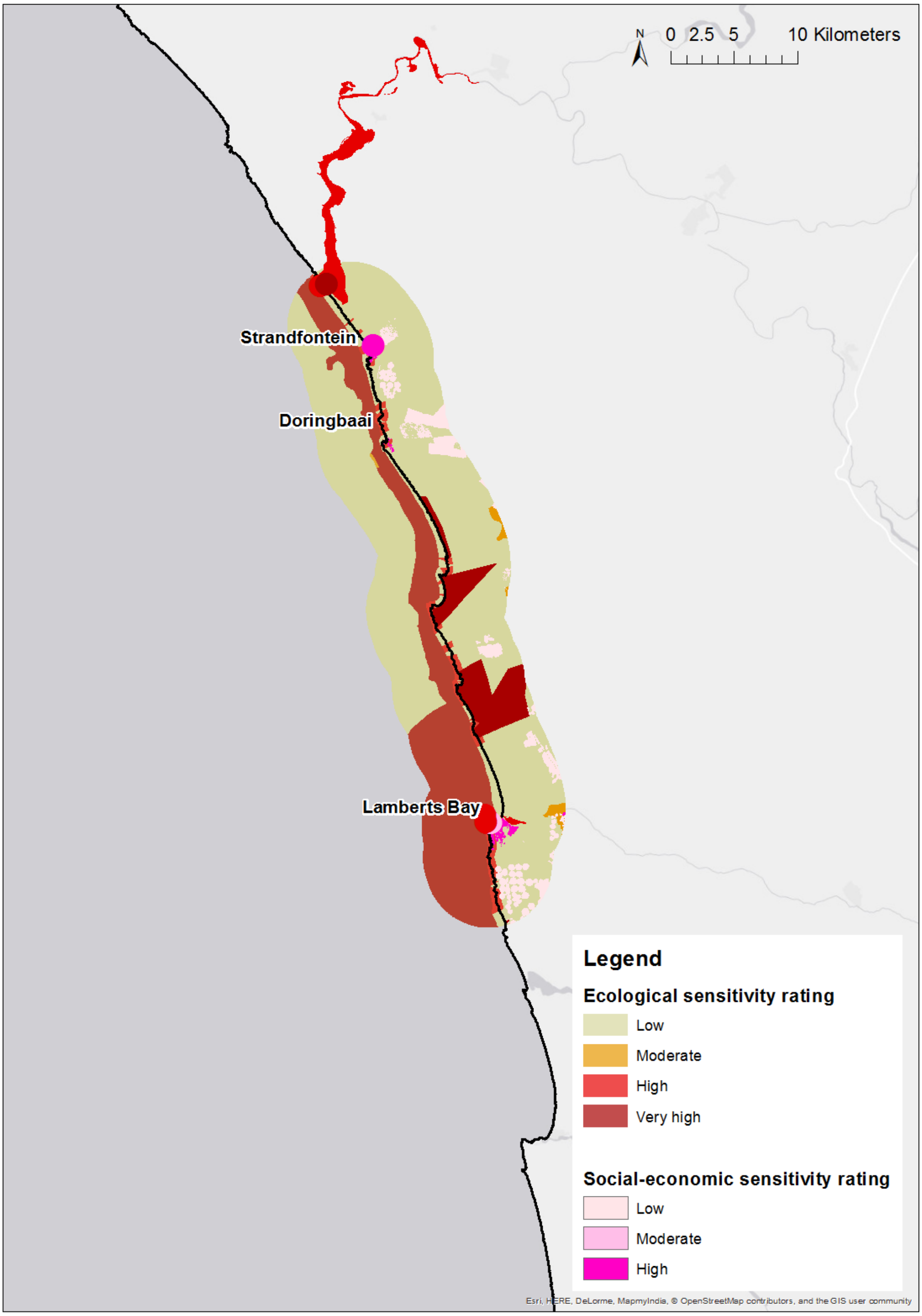

Figure 16. Strandfontein-Lamberts Bay: Ecological and socio-economic sensitivity

5.7.2 Important biota

Biogeographically the Strandfontein to Lamberts Bay area falls within the Southern Benguela Ecoregion (Sink *et al.*, 2012). The West Coast in general is characterized by low marine species richness and low endemicity (Awad *et al.*, 2002). The biota of nearshore marine habitats are relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace. The majority of the open coastline in this study area is dominated by dissipative/intermediate beaches and mixed shores.

With the exception of a few beaches in large bay systems (St Helena Bay, Saldanha Bay), the beaches along the South African West coast are typically highly exposed. The macrofaunal communities of sandy beaches are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone. Due to the exposed nature of much of the coastline in the study area, most beaches are of the intermediate type. Invertebrate macrofaunal communities characterising these beaches are typical of those occurring on the West Coast being dominated by a variety of isopods, amphipods and polychaete worms. Further offshore where near-bottom conditions are more stable, the macrofaunal communities of unconsolidated sediments are primarily be determined by sediment characteristics and depth. Macrobenthic diversity varies across the area.

Biological communities of the rocky sublittoral are similar to those in temperate study areas to the south, grouped into an inshore zone from the sublittoral fringe to a depth of about 10 m dominated by flora, and an offshore zone below 10 m depth dominated by fauna. Kelpbeds are formed by the canopy-forming kelp *Ecklonia maxima* and the smaller *Laminaria pallida*, but, due to the dominance of sandy coastline, kelpbed area within the region is comparatively small.

An important bird breeding site in the study area is Bird Island at Lamberts Bay. The island, which is almost 3 hectares in size, lies about 100 m off the shore and is connected to the mainland by a breakwater. It is an important breeding and roosting site for seabirds, particularly Cape Gannets and cormorants. It is also used as a haul-out site by Cape fur seals.

5.7.3 Estuaries and fluvial banks

There are two estuaries in the study area: the Jakkals Estuary at Lamberts Bay and the Olifants River Estuary north of Strandfontein. The Olifants is one of only four perennial estuaries on the West coast of southern Africa and covers an area of ~2 000 ha. The river's catchment is the second largest in South Africa after that of the Orange River. It is one of the most important estuaries in the country from a conservation perspective. The estuary is also noteworthy in that it is perhaps the least developed of the large permanently-open estuaries in South Africa, providing a valuable sanctuary for flora and fauna. The Olifants Estuary supports one of two commercial fisheries in estuaries in South Africa. The small Jakkals Estuary only opens to the sea during periods of high flow.

5.7.4 Protected areas

There are no MPAs in the Strandfontein to Lamberts Bay area, but four coastal protected areas exist as indicated in Figure 15.

5.7.5 Important socio-economic activities

The study area covers portions of marine diamond mining concessions although over the past decade there has been a substantial decline in small-scale shore- and vessel-based diver-assisted diamond mining operations along the coast due to the global recession and depressed diamond prices.

Line fishing effort in the region is centred on Doringbaai and the Olifants River mouth, targeting primarily Snoek and Hottentot. Fishing is conducted primarily from tiny rock lobster bakkies belonging to the local rock lobster factories, although larger deckboats from Lamberts Bay and further south may visit the area during the Snoek and Yellowtail seasons. Most of the fishing is undertaken after the rock lobster nets have been deployed, or during the rock lobster closed season. The boats typically operate very close to the shore. A treknet and drift net fishery in the region is centred around the Olifants River. Commercial catches of rock lobster in the area around Doringbaai are confined to shallower water (<30 m) with almost all the catch being taken in <15 m depth between Doringbaai and Donkin Bay. Lobster fishing is conducted with hoopnets from a fleet of small dinghies/bakkies. The majority of these work directly from the shore within a few nautical miles of the bays.

The West Coast is divided into numerous seaweed concession areas and two of these lie between Strandfontein and Lamberts Bay. The actual level of beach-cast kelp collection varies substantially through the year, being dependent on storm action to loosen kelp from subtidal reefs. Permit holders collect beach casts of both *Ecklonia maxima* and *Laminaria pallida* from the drift line of beaches. The kelp is initially dried just above the high water mark before being transported to drying beds in the foreland dune area.

Major recreational activities in the study area include recreational rock lobster fishing and angling and, to a lesser extent, beach activities, swimming and surfing. Recreational line-fishing is confined largely to rock and surf angling, with catches consisting mainly of Hottentot and Galjoen. Recreational rock lobster catches are made primarily by diving or shore-based fishing using baitbags. The majority of the recreational take of rock lobster is made by locals resident in areas close to the resource. Coastal tourism includes flower viewing, bird watching, seal and whale watching, hiking and mountain biking, canoe trips and 4x4 trails.

There are no major harbours in the project area. Lamberts Bay serves as an important fishing harbour along that stretch of coastline, with Doring Bay offering limited shelter to small fishing vessels and diamond boats. A 1.7 megalitres per day reverse osmosis desalination plant came into full operation in Lamberts Bay during the second quarter of 2014. The plant's infrastructure has been designed to accommodate future expansion of up to 5 megalitres per day, providing the capacity to supplement the region's water usage by approximately 50%.

5.8 Orange-Hondeklip Bay

Important ecological and socio-economic attributes for this region are presented in Figure 17, while the relative sensitivity of zones within the study area is illustrated in Figure 18.

5.8.1 Morphology, sediments and physical dynamics

As with the rest of the West Coast, winds are one of the main physical drivers of the nearshore region, affecting both swell and current conditions. Within this area of interest only Port Nolloth offers reasonable protection from prevailing swells, with marginal protection offered by Hondeklip Bay and Alexander Bay. Localised upwelling of nutrient-rich bottom waters occurs in common with other areas on the West Coast. This study area is positioned within the Namaqua upwelling cell. Upwelling in this cell is seasonal, with maximum upwelling occurring between September and March.

The coastline of the study area is dominated by rocky shoreline interspersed by dissipative/ intermediate sandy beaches and mixed shores. Nearshore sediments between Hondeklip Bay and Kleinzee are mainly muddy sand, whereas north of Kleinzee they are sandy. A long mud belt (up to 40 km wide, and of 15 m average thickness) is situated over the inner shelf of this study area (Birch *et al*., 1976).

5.8.2 Important biota

Biogeographically the Orange to Hondeklip Bay area falls within the Southern Benguela Ecoregion (Sink *et al*., 2012) with a generally low marine species richness and low endemicity (Awad *et al*,. 2002). The majority of the open coastline in this study area is dominated by dissipative/intermediate beaches and mixed shores. Biota of nearshore marine habitats are relatively robust, being naturally adapted to an extremely dynamic environment where biophysical disturbances are commonplace.

The beaches along this stretch of coast are typically highly exposed and of an intermediate type. The macrofaunal communities of sandy beaches are generally ubiquitous throughout the southern African West Coast region, being particular only to substratum type, wave exposure and/or depth zone. Invertebrate macrofaunal communities characterising these beaches are typical of those occurring on the West Coast being dominated by a variety of isopods, amphipods and polychaete worms. Further offshore where near-bottom conditions are more stable, the macrofaunal communities of unconsolidated sediments are primarily determined by sediment characteristics and depth. Macrobenthic diversity varies across the area.

Figure 17. Orange-Hondeklip Bay: Important ecological and socio-economic attributes

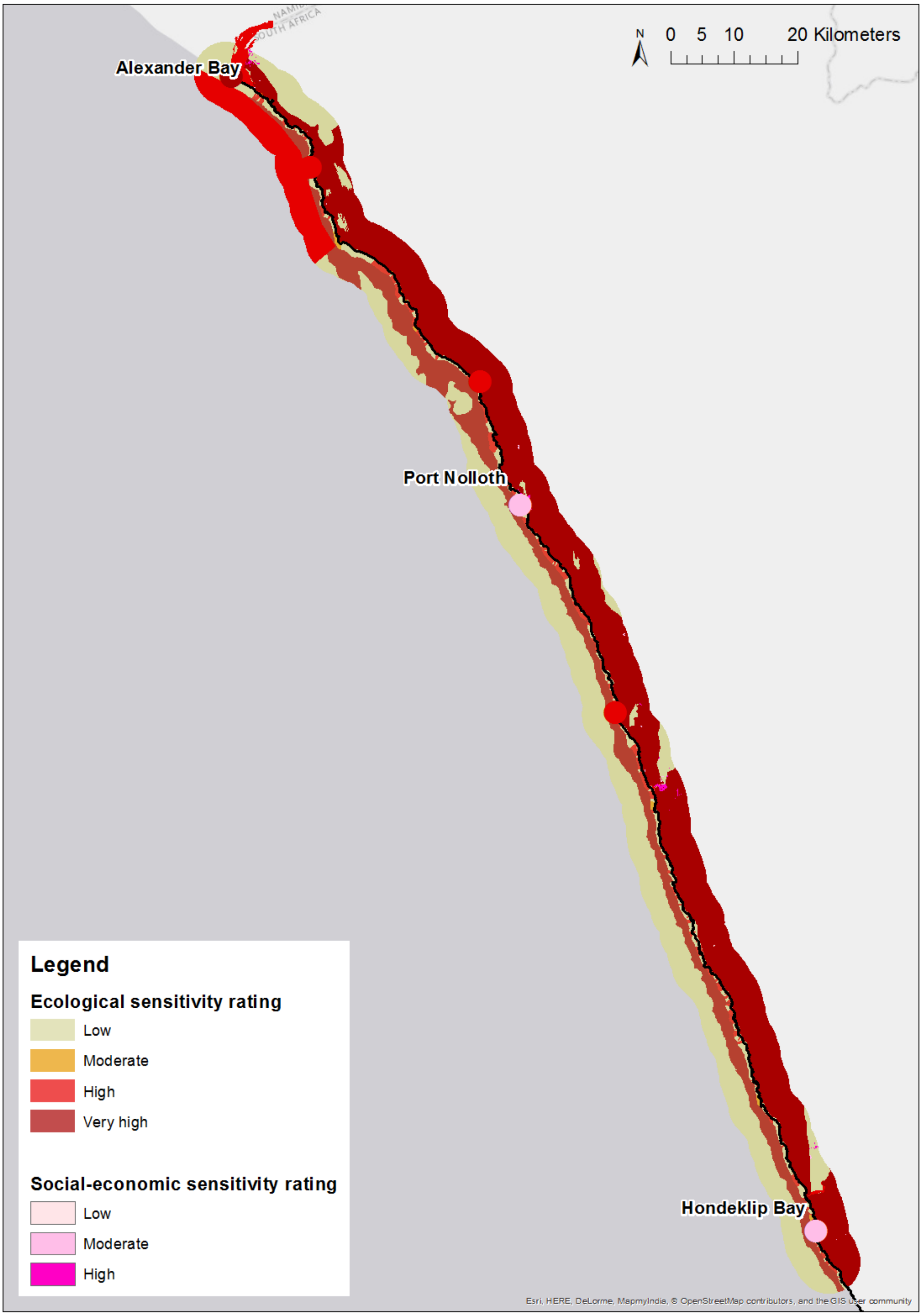

Figure 18. Orange-Hondeklip Bay: Ecological and socio-economic sensitivity

Similar to the Strandfontein Lamberts Bay area, biological communities of the rocky sublittoral can be broadly grouped into an inshore zone from the sublittoral fringe to a depth of about 10 m dominated by flora, and an offshore zone below 10 m depth dominated by fauna. This shift in communities is not sharp, and rather represents a continuum of species distributions, merely with changing abundances. From the sublittoral fringe to a depth of between 5 and 10 m, the benthos is largely dominated by algae, in particular two species of kelp; the canopy-forming kelp *Ecklonia maxima* and the smaller *Laminaria pallida*

There are a number of Cape fur seal colonies within the study area: at Kleinzee (incorporating Robeiland), at Bucchu Twins near Alexander Bay, and Strandfontein Point (south of Hondeklipbaai). The colony at Kleinzee has the highest population and produces the highest seal pup numbers on the South African Coast (Wickens, 1994). The colony at Buchu Twins, formerly a non-breeding colony, has also attained breeding status (M. Meyer, DAFF, pers. comm.). Bird breeding sites are absent along this stretch of coastline, although the estuaries of the ephemeral rivers do offer some roosting habitats.

5.8.3 Estuaries and fluvial banks

The Orange River Mouth forms the only perennial estuary in this study area. It was declared a Ramsar site in 1991, as was the Namibian side of the mouth in 1995. Together they form the Orange River Mouth Transboundary Ramsar Site. It is considered to be a critical coastal wetland in southern Africa because of the overall numbers of wetland birds it supports and because of its role as a migration stopover. All other rivers along this portion of the coastline are ephemeral and their estuaries intermittently, or seasonally, open.

An extensive sediment load is carried by the Orange River which nourishes the surrounding beaches and Orange River cone area up to a 100 km offshore of the mouth. A long mud belt (up to 40 km wide, and of 15 m average thickness) is situated over much of the inner shelf (Birch *et al.*, 1976).

5.8.4 Protected Areas

There are no MPAs in the Orange to Hondeklip Bay area. The only conservation area in the Northern Cape in which restrictions apply is the McDougall's Bay rock lobster sanctuary near Port Nolloth, which is closed to exploitation of rock lobsters. The sanctuary extends one nautical mile seawards of the high water mark between the promontory at the northern end of McDougall's Bay, and the promontory at the southern extremity of McDougall's Bay.

5.8.5 Important socio-economic activities

The project area overlaps with the 'a' and 'b' portions of marine diamond mining concessions 1 - 7. Over the past decade there has been a substantial decline in small-scale shore- and vessel-based diver-assisted diamond mining operations along the coast due to the global recession and depressed diamond prices. However, diver-assisted operations in Concessions 1a, 2a and 3a are again active with vessels based either in Alexander Bay or Port Nolloth.

Commercial catches of rock lobster in Area 1 are confined to shallower water (<30 m) with almost all the catch being taken in <15 m depth. Actual rock-lobster fishing, however, takes place only at discrete suitable reef areas along the shore within this broad depth zone. Lobster fishing is conducted from a fleet of small dinghies/bakkies. The majority of these work directly from the shore within a few nautical miles of the harbours, with only 30% of the total numbers of bakkies partaking in the fishery being deployed from larger deck boats. As a result, lobster fishing tends to be concentrated close to the shore within a few nautical miles of Port Nolloth and Hondeklip Bay.

There are four seaweed concession areas in this study area for the collection of beach-cast kelp. The actual level of beach-cast kelp collection varies substantially through the year, being dependent on storm action to loosen kelp from subtidal reefs. Permit holders collect beach casts of both *Ecklonia maxima* and *Laminaria pallida* from the driftline of beaches. The kelp is initially dried just above the high water mark before being transported to drying beds in the foreland dune area.

Poor road infrastructure and ownership of much of the land between Hondeklip Bay and the Orange River by diamond companies has historically restricted coastal access to the towns and recreational areas of Port Nolloth, McDougall's Bay, and Hondeklipbaai. Recreational line-fishing is confined largely to rock and surf angling in the more accessible coastal stretches in the regions. Boat angling is not common along this section of the coast due to the lack of suitable launch sites and the exposed nature of the coastline.

Port Nolloth is the only harbour offering facilities for larger commercial and fishing vessels. Currently development plans include the construction of a 1.5 megalitres per day reverse osmosis desalination plant. Hondeklip Bay provides a basic anchorage for diamond and fishing vessels whereas Alexander Bay caters only for diamond vessels.

Although the Northern Cape coast lies beyond the northernmost distribution limit of abalone on the West Coast, ranching experiments have been undertaken in the region since 1995 (Sweijd *et al*., 1998; de Waal and Cook, 2001; de Waal, 2004). As some sites have shown high survival of seeded juveniles, DAFF published criteria for allocating rights to engage in abalone ranching or stock enhancement (Government Gazette No. 33470, Schedule 2, 20 August 2010) in four areas along the Namaqualand Coast. Ranching in these areas is currently being investigated at the pilot phase.

Associated with the ranching projects are land-based abalone hatcheries located at North Point near Port Nolloth, at Kleinzee and at Hondeklipbaai. These hatcheries operate on a semi-recirculation system using seawater pumped from the shallow subtidal zone to top-up the holding tanks.

6 KEY POTENTIAL IMPACTS AND THEIR MITIGATION

There is a large and growing body of scientific literature available on the potential biodiversity and ecological impacts of mariculture. Within civil society opposition to mariculture from local and national interest groups has played a role in limiting its development (Whitmarsh and Wattage, 2006; Knapp and Rubino, 2016). In South Africa several national level assessments and feasibility studies on mariculture have highlighted some of the key impacts (e.g. DAFF 2017a; DAFF 2017b; Hutchings *et al*., 2011). Drawing from these assessments the key potential biodiversity and ecological impacts include:

- Alteration of water circulation patterns and wave regimes;
- Alteration of benthic habitat;

- Alteration of genetic structure of wild populations;
- Introduction of invasive alien species;
- Transmission of diseases and parasites to wild populations;
- Interactions with- and entanglement of marine biota;
- Destruction of terrestrial vegetation;
- Deterioration in water quality (pollution and eutrophication); and
- Socio-economic impacts (conflict of use).

These impacts are discussed in greater detail below. They are largely generic and are not universally applicable to all mariculture species and production systems. The nature and severity of these impacts varies considerably depending on the species being farmed, the nature of the production systems, the scale and duration of farming, as well as the oceanographic and biological setting in which the mariculture activity takes place.

Environmental risks from land-based production systems are typically less significant than those from sea-based cage culture which may include impacts on water quality and benthic habitats, as well as impacts on marine life and the introduction of chemicals from mariculture activity (DAFF 2017a; 2017b).

Potential impacts most relevant to the selected species and types of production system considered in this study are summarised in Table 4.

Table 4. Potential impacts most relevant to the selected species and types of production system

Potential impact	Abalone	Mediter-ranean mussel	Pacific oyster		Dusky kob			Atlantic salmon	
	Land-based flow-through	Sea-based longline/rafts	Sea-based longlines/rafts	Land-based nursery	Sea-based cage culture	Land-based RAS	Land-based pond culture	Sea-based cage culture	Land-based RAS
Alteration of circulation patterns		☐	☐		☐			☐	
Alteration of benthic habitat		☐	☐		☐			☐	
Introduction of invasive alien species		☐	☐	☐				☐	☐
Transmission of diseases and parasites to wild populations	☐	☐	☐	☐	☐	☐	☐	☐	☐

Potential impact	Abalone	Mediter-ranean mussel	Pacific oyster		Dusky kob			Atlantic salmon	
	Land-based flow-through	Sea-based longline/rafts	Sea-based longlines/rafts	Land-based nursery	Sea-based cage culture	Land-based RAS	Land-based pond culture	Sea-based cage culture	Land-based RAS
Alteration of genetics of wild populations	☐				☐	☐	☐		
Interactions with- and entanglement of marine biota		☐	☐		☐			☐	
Destruction of terrestrial coastal vegetation and habitats	☐			☐		☐	☐		☐
Deterioration in water quality	☐	☐	☐	☐	☐	☐	☐	☐	☐
Socio-economic impacts (use conflict)	☐	☐	☐	☐	☐	☐	☐	☐	☐

Each of the key potential impacts listed above is discussed in greater detail below, together with possible mitigation measures.

6.1 Alteration in water circulation patterns, wave and sediment regimes

6.1.1 Description

All structures in coastal waters alter water circulation patterns, water column structure and wave regimes to some degree. Physical impacts from mariculture production structures, such as bivalve rafts and fish cages, include localised changes in currents, associated turbulent mixing processes and water column structure. These changes may affect water residence times, settlement processes and biological processes in the immediate vicinity of the structures as well as possibly further afield (Plew, 2011). In affecting patterns in entrainment, transport and deposition of particulate matter, mariculture structures may also affect sediments. The scale of impacts vary according to the nature of these structures, the density of the installations, and their locations in coastal waters.

Key pollution impacts of cage fish and bivalve production arise from of dissolved wastes in the water column and enrichment and smothering of benthic habitat due to the deposition of particulate wastes (faeces, pseudofaeces and uneaten food pellet particulates) (see later, Sections 6.2, 6.8). Effects on ambient dissolved oxygen concentrations in both the water column and sediments are possible, with potential knock-on effects such as the possible formation of sulphides. These impacts are generally localised but can be significant depending on the location, intensity and extent of mariculture activities.

Currents are the main factor influencing the transport and dispersion of dissolved wastes in marine waters, and, with waves, are the key determinant of the deposition, re-suspension and re-distribution of particulate wastes. Both currents and waves also play a strong role in vertical mixing processes that transport dissolved oxygen from the surface to deeper waters and disrupt water column stability which is required for phytoplankton blooms to develop should there be sufficient nutrients in the surface waters. Reductions in currents and waves, brought about by mariculture structures, therefore have the propensity to exacerbate any potential pollution impacts in the vicinity of farming activities. The larger the farm and number of cages, rafts or long-lines, the greater the likely reduction in flows at larger scales. This could increase residence times in a farming area and even beyond at a bay scale (Plew, 2011) for small bays with large numbers of cages, rafts or long-lines.

Whilst flows are typically significantly reduced in fish cages and in mussel rafts, the flow diversion around these structures can also cause local acceleration of currents around and below these structures (Plew, 2011) as well as the development of downstream wakes (Helsley and Kim, 2005; Venayagamoorthy *et al*., 2011) that could upwell nutrient enriched bottom waters into the surface layers.

Changes in wave and current energies downstream of the farm structures may create changes in benthic habitats and even changes in sediment transport and shoreline changes of adjacent coastlines. Wave damping effects are typically observed only in the immediate vicinity of mariculture structures (Chan and Lee, 2001; Lader *et al*., 2007). Reduction in wave turbulence near the seabed due to such wave damping, together with an increased roughness of seabed due to the biofouling drop-off and debris accumulating below these structures, could lead to enhanced deposition of particulate matter and lower mobility of such material once deposited on the seabed' further contributing to pollution and benthic habitat impacts.

In principle, wave modification effects, if significant, could result in more remote effects on adjacent shorelines due to changes in the distribution of wave energy reaching these environments. While such wave attenuation may be considered to constitute protection for some coastlines (e.g. reducing coastal erosion), the benefits may be ambiguous due to uncertainties related to the exact nature of the changes that may occur.

Intakes and discharge infrastructure (pipelines) associated with land-based mariculture activities, depending on their design, may affect sediment movement at the shoreline crossing. However, the size and nature of such infrastructure is rarely of concern in terms of generating significant shoreline impacts.

Overall, potential hydrodynamic impacts described here can be expected to vary in magnitude seasonally due to seasonal changes in current speed and directions, waves and water column structure. In calmer periods, changes in currents, waves and mixing processes will be more significant than during periods of high winds, strong currents and high wave conditions when the water column is typically well-mixed and bottom waters well-oxygenated. In evaluating potential impacts, it is imperative that assessments are undertaken for all seasons.

6.1.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	Mitigation
Sea-based Rafts/longlines	▪ Use of modelling to help determine optimal design, size, location and number of structures (mussel rafts and long-lines) to minimise impacts within the farm as well as cumulative impacts over a larger area
Sea-based cage culture	▪ Use of modelling to help determine optimal design, size, location and number of structures (cages) to minimise impacts within the farm as well as cumulative impacts over a larger area

6.2 Alteration of benthic habitat

6.2.1 Description

Impacts to sediments and benthic habitats occur due to the deposition of particulate organic matter arising from mariculture operations. They manifest as alterations in chemical and biological processes, such as nutrient assimilation and decomposition. These sources of impact of mariculture to benthic habitats, as well as the interaction between hydrodynamic conditions and sediment dynamics, deposition of particulate matter and sediment pollution, are introduced above. Uneaten food and faeces are primary sources of particulate organic matter, but dead animals in the bio-deposits also contribute to organic loading (Wu *et al*., 1994). Disposal of fouling biomass from cages and rafts into the water may add a high pollution load (Wu, 1995) and change the nature of the substrate itself. Accumulation of organic matter may ultimately result in sediments becoming anoxic, with knock-on ecological effects, as well as impacts to other users of coastal resources.

Sediments that become enriched with organic farm waste nutrients may result in changes in the benthic invertebrate community, where high levels of enrichment can favour the proliferation of opportunistic species and a loss in species richness and diversity (Zhulay *et al*., 2015; Tomassetti *et al*., 2016). Impacts to sediments from individual farms may extend hundreds of metres beyond the farm perimeter (Lin and Bailey-Brock, 2008), but are most pronounced directly underneath the site, and are most often limited in spatial scale to less than 1 km (Wu, 1995; Zhulay *et al*., 2015; Tomassetti *et al*., 2016). Indeed, typically such effects are most evident beneath the structures and exhibit a strong gradient of decreasing impact with increasing distance. The intensity and spatial extent of benthic enrichment impacts is highly site specific (Chamberlain *et al*., 2001, Hartstein and Rowden, 2004, NIWA and Cawthron, 2013), with high flow, deeper sites producing more extensive but diffuse footprints (100 to 1000 m).

In South Africa sediment quality and benthic habitat impacts from mariculture have been reported from Saldanha Bay. Localised organic enrichment, anoxia and consequent macrobenthic impacts have been detected in Small Bay under mussel rafts (Stenton-Dozey *et al*., 1999, 2001). This is the most intensively used area for sea-based mariculture in South Africa, in large part due to its highly sheltered nature. In areas that are utilised for mariculture which fall outside of all but the most sheltered environments, long-term benthic enrichment impacts of significance beyond the immediate environs of farming activities are unlikely, because of more dynamic wave and current conditions.

6.2.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	Mitigation
Sea-based rafts/longlines	▪ Periods of fallowing[1]
Sea-based cage culture	▪ Use of feeds to maximize food conversion ratios ▪ Rotation of cages and fallowing to allow recovery of benthic communities (Holm *et al*., 2003; Zhulay *et al*. 2015)

6.3 Introduction of invasive alien species

6.3.1 Description

Globally, mariculture has been found to be a major source of alien species in marine systems (second only to shipping) and a significant threat to marine biodiversity as a result (Bax *et al*., 2003, Molnar *et al*., 2008, De Castro *et al*., 2017). While in South Africa a relatively small percentage (6%) of the reported marine alien species are likely to have been introduced through mariculture, this invasive pathway is becoming increasingly prominent and is recognised as an emerging vector (Mead *et al*., 2011).

Three mariculture species considered for the purposes of this study; Mediterranean mussel, Pacific oyster and Atlantic salmon, are alien to South African waters. Because of the production methods involved with bivalve culture it is certain that offspring from the farmed mussel and oyster species will be released into South African coastal waters. Although Atlantic salmon will be farmed in closed pens, chances of escapes into open water are highly likely. Low level escapes can occur during normal operations, or mass escapes can occur as a result of damage and collapsing of sea cages and pens. Such escapes are common all over the world where these fishes are farmed (Thorstad *et al*., 2008) and have already occurred in South Africa. Pilot-test Atlantic salmon cages near Gansbaai in the Western Cape sank in strong seas, resulting in mass escape of alien mariculture stock into the marine environment. Excessive biofouling, as a result of inadequate servicing (because a suitable service vessel was not available) was the cause for cage failure, and commercial scale ventures are likely to be much better serviced. Escapes, even from commercial operations are nevertheless still likely.

Elsewhere in the world, escaped commercially farmed Atlantic salmon have been found to comprise substantial proportions of wild populations (Thorstad *et al*., 2008). In Norway, in 1997, more than 50% of Atlantic salmon caught by fishermen were of farmed origin and in the Faroe Islands up to 60% of salmon catches have been attributed to escapes from salmon farms (Hansen *et al*., 1999; Beveridge, 2001). Interbreeding occurs with potential impacts to genetic structure of wild populations and associated fitness effects (Crozier, 1993; Gausen and Moen, 1991; McKinnell and Thomson, 1997; Ford and Myers, 2008; Glover *et al*., 2012).

In a South African context, where Atlantic salmon do not occur naturally, genetic impacts on wild populations are clearly not relevant. However, if escapees occurred in significant numbers and populations of this species were to establish they would compete with indigenous species and have ecological impacts that would be difficult to predict. The chances of this occurring are low, however.

[1] Fallowing: Rotation of cages within a site to allow recovery of benthos. "Fallowing" as a parasite and disease mitigation measure refers to leaving all cages within a farmed area, aquaculture development zone or bay, un-stocked for a period of at least two months. "Pseudo-fallowing" in this respect can be achieved by stocking all cages with a different species therefore lowering the environmental load of species-specific pathogens

Despite the mass escape of Atlantic salmon in Gansbaai noted above, none of these fishes appear to have been caught in extensive line fishing that occurs in the study area. This suggests that this event has not led to the establishment of a population of Atlantic salmon in local waters. Extensive review of mariculture of Atlantic salmon elsewhere in the world has shown that there is some evidence of spawning of escaped Atlantic salmon where the species is exotic, but that the species is actually a poor coloniser outside of its natural range (Thorstad *et al*., 2008).

The situation with bivalve species under consideration here is different. Both the Mediterranean mussel and Pacific oyster have established populations in South African coastal waters. The former is listed as one of the "World's Worst 100 Invasive Alien Species" (Lowe *et al*., 2000) and is already recognised as an aggressive invasive alien species along our coast with a distribution from the entire West coast to just west of East London on the East coast (Robinson *et al*. 2005a). Its success as an invasive species is due to its high productivity, reproductive output, growth rate, tolerance of extended periods of desiccation and tendency to grow in dense beds (van Erkom Schurink and Griffiths, 1993). It has almost completely displaced indigenous ribbed mussel *Aulacomya atra* on the West coast and, to a lesser extent, the brown mussel *Perna perna* and black mussel *Chromytilus meriodionalis* (Branch and Steffani, 2004), with significant ecological and economic impacts (Robinson *et al*., 2005a, 2007a). In addition to successful widespread colonisation of rocky intertidal areas the species also invaded sandy areas of Langebaan Lagoon in the mid-1990s, and although this population died off by mid-2001, longer term habitat impacts associated with dead shell material remained (Robinson *et al*,. 2007b). In South Africa *Mytilus galloprovincialis* is classified as a Category 2 invasive species under the National Environmental Management: Biodiversity Act Regulations (2014). As such it requires a permit to be cultured and is only permissible where populations of the species already occur. In these areas it can be argued that, given the already established naturalised populations, mariculture farms now pose little additional risk in terms of introduction in areas that they already occur.

The Pacific oyster has also established naturalised populations in South African waters, but appears to be restricted to permanently open estuaries in the Southern Cape, Eastern Cape (Robinson *et al*., 2005b) and West coast (Orange River, S. Lamberth, DAFF, pers. comm.). The species has been cultured along the South African coast for many years and the relative lack of large scale invasion suggests that it may be a poor coloniser in South African waters. That said, trigger factors facilitating establishment of Pacific oyster in selected South Africa estuaries are uncertain, and the rate of its spread is unknown (Robinson *et al*., 2005b,), and there is evidence that it is increasing its distribution (e.g., recent records from the Orange River Estuary).

In addition to these alien aquaculture species themselves posing threat in terms of biological invasions, the practise of importing them as spat presents further risk of introduction of other unwanted species, including parasitic species and diseases which could affect native species (see Section 6.4 below). In South African, Haupt *et al*. (2010) have reported four marine alien species (black sea urchin, *Tetrapygus niger*; European flat oyster, *Ostrea edulis*; Montagu's crab, *Xantho incisus*, and the brachiopod *Discinisca tenuis*) likely to have been introduced via commercially imported spat of Pacific oyster. Pacific mussel S. *algosus* may have been unintentionally introduced by oyster farms on the West Coast (De Greef *et al*., 2013).

6.3.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	Mitigation
Land-based RAS (Atlantic Salmon)	▪ Ensure a high level of management and planning is in place within nurseries to be able to respond quickly and effectively should risks be identified
Sea-based rafts/longlines (mussel/oysters)	▪ Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure for indications of non-native fouling species (other than farmed species) ▪ Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of any pests before they become established. ▪ Fouling organisms removed from infrastructure (taken onshore for maintenance) should not be discharged back into the marine environment thereby ensuring that any introduced non-native fouling species not detected previously are not released into the wild
Sea-based cage culture (Atlantic Salmon)	▪ Use of cages with solid-wall closed-containment technology ▪ Keep cages clear of biofouling to reduce risk of failure, and therefore reduce likelihood of escapes ▪ Fouling organisms removed from finfish cages (taken onshore for maintenance) should not be discharged back into the marine environment thereby ensuring that any introduced non-native fouling species not detected previously are not released into the wild

6.4 Transfer of diseases and parasites to wild populations

6.4.1 Description

Organisms known to cause diseases and/or to parasitize fish and marine invertebrates include viruses, bacteria, fungi, protozoa, crustaceans, flatworms, roundworms and segmented worms. Many of these diseases and parasites do not appear to be host specific. Disease and parasites in high density mariculture stock therefore have the propensity to impact wild populations of a variety of marine and estuarine species. This could occur via transmission of diseases and parasites in outflow waters from land-based systems or more directly across open waters in sea-based systems. Escapees also have the potential to deliver diseases and parasites to open waters, across wider spatial scales. Scavenging and predatory birds and mammals are also potential vectors or hosts of a range of disease agents, including viruses, bacteria, parasites (Beveridge, 2001).

Unsurprisingly then, the spread of parasites, viruses and bacterial infections between caged and wild fish populations (from wild to farmed, or vice versa) is a significant concern for the fish farming industry worldwide (Pearson and Black, 2001). Parasitic sea lice of the genus *Caligus* are a well-cited international example, causing losses in farmed salmon stock amounting to hundreds of millions of dollars annually, as well as impacts to natural wild stocks in temperate Northern Hemisphere waters (Heuch *et al.*, 2005). Intensive sea bass and sea bream culture in the Mediterranean has also resulted in severe disease problems in fish farms; problem diseases include *Pasteurellosis* and *Nodavirosis*, and parasitic infections include *Ichthyobodo* sp., *Ceratomyxa* sp., *Amyloodinium ocellatum, Trichodina* sp., *Myxidium leei, and Diplectanum aequans* (Agius and Tanti, 1997).

Parasites and diseases infecting the endemic South African fish species are not well studied, although Kob at least are known to be infected by *Caligus* sea lice, as well as copepod, trematode, Acanthocephalan (parasitic worm), monogean (specifically the gill fluke *Diplectanum oliverii*), dinoflagellate (*Amyloodinium ocellatum*) and myxozoan species (Grobler *et al*., 2002, Christison and Vaughan, 2009; Joubert *et al*., 2009). South Africa's indigenous marine fishes include forms that are nomadic and migratory. Should these fishes contract diseases and/or parasites from stocked (or escaped) mariculture fish, there is a risk that they could be spread regionally.

High densities of farmed shellfish also potentially pose risk in terms of transmitting pathogens or parasites to other cultured stocks, or wild populations, and even other species (Gallardi, 2014). Norcardiosis in North America, caused by the bacterium *Nocardia crassostreae*, is thought to have originated in Japan and then spread with Pacific oyster transfers (Forrest *et al*., 2009). Mediterranean mussel has been identified as a reservoir host for infections of the aquatic birnavirus in the Japanese flounder *Paralichthys olivaceou* (Kitamura *et al*., 2007), and also in King salmon *Oncorhynchus tshawytscha* in New Zealand (Diggles, 2016). Similarly, the aquabirnavirus infectious pancreatic necrosis virus detected in Blue mussel, *Mytilus edulis*, is a common virus of salmonids and is also a suspected clam pathogen in Taiwan (Webb, 2008). A recent feasibility study of oyster and mussel aquaculture in South Africa provides comprehensive summaries of additional diseases and parasites known to infect Pacific oyster and Mediterranean mussel are provided Advance Africa 2017).

6.4.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	**Mitigation**
Land-based flow-through	▪ Treatment of effluent to reduce transfer of diseases and parasites to coastal waters and wild populations ▪ Use therapeutic drugs appropriately
Land-based RAS/pond culture	▪ Treatment of effluent to reduce transfer of diseases and parasites to coastal waters and wild populations ▪ Use therapeutic drugs appropriately
Sea-based rafts/longlines	▪ Ensure a high level of biosecurity management and planning is in place to limit the introduction of pests, parasites and diseases and to be able to respond quickly and effectively should biosecurity risks be identified ▪ Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediates hosts and or pathogens ▪ Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure for indications of non-native fouling species ▪ Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of pests before they become established

Production system	Mitigation
	▪ If spat import cannot be avoided, culture facilities should only be permitted to use spat sourced from biosecure certified hatcheries ▪ Ensure that veterinarian protocols to eliminate any pests, parasites and diseases are strictly adhered to
Sea-based cage culture	▪ Use of cages with solid-wall closed-containment technology ▪ Ensure biosecurity management and planning is in place within hatcheries, holding tanks and sea cages to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified ▪ Ensure all fry undergoes a health examination prior to stocking in sea cages ▪ Regularly inspect stock for disease and parasites as part of a formalised stock health monitoring programme and take necessary action to eliminate pathogens through the use of approved therapeutic chemicals or improved farm management ▪ Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied ▪ Treat adjacent cages simultaneously even if infections have not yet been detected ▪ Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediate hosts and or pathogens

6.5 Alteration of genetics of wild populations

6.5.1 Description

Whilst the culture of species foreign to South African waters poses a threat in terms of instruction of invasive alien species, farming indigenous species can pose threats to local populations by impacting the genetic profiles of wild populations of the same species. The problem stems mainly from shifting significant numbers of individuals of a single species and establishing them elsewhere. Inbreeding from culture-based production of seed is also possible. In the context of this study, mariculture systems involving production of abalone and Dusky kob are relevant. Alterations in the genetic profile of indigenous populations, and reductions in genetic variability can clearly reduce the capacity of any species to adapt to environmental change, and compromise the long-term survival of the species in the wild (Lynch and O'hely, 2001; Landry *et al.*, 2006). This has been demonstrated in the case of Atlantic salmon (Thorstad *et al.*, 2008; Glover *et al.*, 2012).

Potential for altering genetic profiles of wild populations is largely determined by the pre-existing level of genetic structuring within that species. The risks of genetic effects are species specific and need to be managed on a case-by-case basis. In the case of Dusky kob the risk of genetic contamination is accentuated by the collapsed status of South African stocks. Ecosystem effects from escapees or significant genetic influences on relatively small wild stocks may occur, resulting in potential further loss of genetic diversity.

DAFF has developed "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries in South Africa" that recommend maintaining an effective broodstock population size of 30 to 150 individuals sourced from the area in which grow-out will take place, and also that broodstock are rotated between hatcheries and regularly replaced to ensure an effective population size of >100 (DAFF, n.d). The Marine Finfish Farmers Association of South Africa Environmental Impact Information Document includes similar recommendations, but also recommends reproductive sterility as the future key to eliminating the genetic impact of escaped fish on wild stock (MFFASA, 2010).

The potential genetic impacts of escapees to wild stocks will remain a threat until reproductively sterile fingerlings are available for fish cage farming in South Africa. Genetic effects are almost certainly species- and location specific, as they will vary according to the abundance, distribution and behaviour of wild stocks. As such, the potential for escapee endemic stock to influence local ecosystems would need to be assessed on a species- and location-specific basis, and be based on knowledge of the ecological and fishery values at specific farm locations in relation to the species in question. The issues regarding the genetic contribution from farms to wild population via gametes will also only apply if farmed fish achieve sexual maturity prior to harvest. The impact to endemic species would, however, extend across the natural range of the affected species, and as it would essentially be irreversible.

6.5.2 Potential mitigation measures

Potential mitigation measures focus on ensuring broodstock reflect the genetic variability of naturally occurring local stocks, preventing reproduction in farmed stock, and preventing the escape of farmed stock (at any life stage).

Production system	Mitigation
Land-based flow-through (abalone)	▪ Reduce likelihood of loss of gametes and larvae by treating wastewater ▪ Use of first captively bred generation males and females broodstock
Land-based RAS/pond culture (Dusky kob)	▪ Use area appropriate genetic strains of broodstock (e.g. management practices for Dusky kob) ▪ Use of first captively bred generation males and females broodstock
Sea-based cage culture (Dusky kob)	▪ Use of cages with solid-wall closed-containment technology ▪ Use robust, well-maintained containment systems ▪ Maintain cage integrity through regular maintenance and replacement, and training of staff ▪ Ensure suitable management and planning measures are in place to limit the possibility of genetic interactions ▪ Implement the "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries" developed by DAFF and ensure adequate genetic monitoring of broodstock rotation ▪ Use area appropriate genetic strains of broodstock (e.g. management practices for Dusky kob) ▪ Use of first captively bred generation males and females broodstock ▪ Use only female fish in the farms ▪ Control breeding in the stock

6.6 Interactions with- and entanglement of marine biota

6.6.1 Description

Mariculture structures serve to attract wild population of birds, fish (including sharks), seals and cetaceans. This is partly due to the nature of the structures themselves providing habitat for wild animals (e.g. roosting sites for birds, predator refugia for fishes), or for reasons of foraging, either on excess feed delivered to the farmed stock, or prey on the stock itself. Stock losses through predation (from both land- and sea-based systems) can be significant and obviously affects mariculture production and profitability. Farm operators therefore make considerable effort to deter wild predators. Problem animals, however, can become persistent and difficult to chase away, despite the use of deterrent technologies (Gilsdorf *et al*., 2003). In such cases, operators resort to lethal means to deal with predators (Wuersig and Gailey, 2002; Hutchings *et al*., 2011). This is illegal, and in many cases is ineffective (Gilsdorf *et al*., 2003). Unintentional lethal losses to wild populations also occur, as a result of predators becoming entangled in nets and cages. This affects both birds and sharks most commonly, but could also affect other species, such as turtles (Moore and Wieting, 1999). Accidental entanglement is the most likely threat in the case of various cetacean species. Incidence of whale entanglement in static fishing gear is increasing in South African waters mostly coincident with breeding migrations and in areas of habitual occurrence (Meÿer *et al*., 2011). While cetaceans swimming into mariculture gear is rare (Wuersig and Gailey, 2002) (marine mammal interactions are primarily by pinnipeds) it does occur (Kemper *et al*., 2003). In keeping with recovering populations of whales in many parts of the world the South African coast is being used by an increasing abundance of whales on migrations between feeding and breeding grounds (Best *et al*., 2001, Findlay *et al*., 2011). Mariculture in areas frequented by whales poses risk to these increasing abundances of whales on the South African coast.

6.6.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	**Mitigation**
Sea-based rafts/longlines	▪ Keep all nets and lines (including mooring lines) taught ▪ Make use of predator exclusion nets
Sea-based cage culture	▪ Keep all nets and lines (including mooring lines) taught ▪ Make use of predator exclusion nets

6.7 Destruction of terrestrial coastal vegetation and habitats

6.7.1 Description

Development of land-based infrastructure in the coastal zone has obvious implications for terrestrial coastal areas which include sensitive and threated habitats such as coastal forests and grasslands. These habitats are often influenced and supported by dynamic coastal processes. Coastal dunes are a clear example where sand supply and movement underpins natural functioning of dynamic coastal belts. Developments therefore have the potential to impact systems beyond their immediate footprints. Land-based mariculture can have significant space requirements and therefore spatial footprints. Flow-through production systems typically have larger requirements than RAS systems.

These developments clearly have consequences for terrestrial habitats as vegetation needs to be cleared to facilitate their establishment, and earth works are typically required. In South Africa, as in many maritime countries, coastal regions face greater development and growth pressures than inland regions. Terrestrial coastal habitats are threatened by this and mariculture development in coastal areas has the potential to contribute to habitat losses.

6.7.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	Mitigation
Land-based flow-through	▪ Design to reduce spatial extent ▪ In the case of land-based nurseries measures can be adopted to reduce the area needed, for example, by vertical stacking of production systems
Land-based RAS	▪ Design to reduce spatial extent

6.8 Deterioration in water quality (pollution and eutrophication)

6.8.1 Description

The mariculture industry relies on unpolluted water and has a strong self-interest in protecting water quality for its own purposes. However, to be profitable, farms stock high densities of the cultured species and generate large amounts of wastes. When released in coastal waters, these wastes can lead to impairment of water quality. Pollution is therefore one of the main environmental concerns associated with mariculture developments. Sources include organic and nutrient wastes from uneaten food and metabolic waste of the farmed animals. In the water column increased levels of nutrients can stimulate biological production and result in algal blooms. Likewise algal productivity on nearby hard substrates may be stimulated, resulting in changes to subtidal and intertidal reef communities. In cases of severe pollution, and in areas which are characterised by poor circulation and flushing, excess nutrient and organic loads cannot be assimilated or dispersed and this may result in eutrophication (Wu *et al*., 1994, La Rosa *et al*., 2001).

The magnitude of effects of the alteration of seawater nutrient chemistry by mariculture will depends on the scale of operations, stocking density and interrelated effects, such as those on the hydrodynamic regime. Typically water quality impacts from mariculture can be expected to be less marked than those the on the sea bed (Wu *et al*., 1994) but water quality might be effected over larger spatial scales. Modelling of nutrient and chemical waste dispersal from a proposed commercial-scale fish farm at Mossel Bay predicted that wastes would sink and deposit on the sea floor within 200 m of the cages. In contrast, elevated levels of dissolved nutrients were predicted to occur up to 2 km from the fish cages, with nitrate levels expected to be above background concentrations as much as 8-12 km from the site under certain oceanographic conditions (Mead *et al*. 2009).

Measured data and first-hand experience of water quality effects from South Africa are sparse, although extensive literature exists on such effects internationally. Surveys of a pilot finfish outgrowing facility Dusky and Silver kob, and Yellowtail in Algoa Bay found no marked impacts around or beneath the mariculture installation (Nel and Winter 2009, 2011). However, these results cannot simply be applied to other areas where depths, oceanographic conditions, flushing rates and carrying capacities are likely very different, and farmed species and stocking rates may not be comparable.

Water quality impacts from South African flow through land-based abalone rearing facilities can be expected to be much more limited than those that might be expected from fish cage farming (Troell *et al*., 2006), although a shift in recent years from fresh seaweed to artificial feed (with higher protein content) will have increased dissolved nitrogen release from abalone farms (Probyn *et al*., 2017). Measurement of effluent water quality from nine abalone farms in the Western Cape (between St Helena Bay and Danger Point, Gansbaai) found that environmental risks from dissolved inorganic nutrients were minimal, and that natural fluxes in nutrients and suspended solids far exceeded those associated waste flows (Probyn *et al*., 2017).

In the case of bivalves, mariculture can actually have a positive impact of water quality through removing phytoplankton and particulate organic matter (and, indirectly nutrient) inputs through filter feeding (Cloern 2001). Indeed the use of shellfish cultivation as a means of nutrient remediation to deal with land-based sources of pollution (including waste water) has been actively promoted in both the United States and Europe (Bricker *et al*., 2017). This has been countered by study of some bivalve farms which have provided evidence that ingested organic material is rapidly recycled into the water column as inorganic nutrients to stimulate further phytoplankton production. Therefore, the net effect on phytoplankton dynamics could be to increase turnover and overall production, rather than limit phytoplankton biomass (Nizzoli *et al*. 2005). Bivalve farms have been also found to lower downstream dissolved oxygen concentrations in marine waters through direct consumption by the farmed stock itself, as well as fouling organisms on the farm infrastructure (Mazouni *et al*. 1998, 2001; Nizzoli *et al*. 2006; Richard *et al*. 2006, 2007). This could be exacerbated by (or exacerbate) benthic oxygen consumption due to deposition and decomposition of particulate organic materials beneath farms.

Other potential pollution impacts that arise from chemicals used in mariculture. Inputs generally fall into two categories: intentional and unintentional inputs (NIWA and Cawthron, 2013). Intentional inputs are metals (commonly copper and zinc) and replacement compounds (tributyltin) used in antifoulants coatings, therapeutants (antibiotics and parasiticides) to treat animals from bacterial diseases or parasites, anaesthetics and detergents/disinfectants to prevent the spread of diseases. Unintentional inputs include chemicals from fish feed additives (zinc), drug formulations and plastic debris (NIWA and Cawthron, 2013). These chemicals all have the potential to impacts marine biota and ecology, or to influence water quality for other users. Potential impacts from antibiotics include increased disease resistance in fish pathogens, toxic effects on marine phytoplankton, and assimilation of antibiotics in wild fish from ingestion of feed and faecal matter (Wu, 1995). Administering therapeutic chemicals may result in direct mortality of naturally occurring biota in the vicinity of mariculture farms, increasingly resistant strains of pathogens, and accumulation of these chemicals in the sediments. Antifouling treatments that incorporate tributyltin or replacement compounds have toxic effects on both fishes and molluscs (DAFF, 2017a; 2017b).

6.8.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	Mitigation
Land-based Flow-through	▪ Treat effluent before discharge, for example by removing of

Production system	Mitigation
	solids and organic matter ▪ Use of feeds to maximize food conversion ratios ▪ Reduce dissolved inorganic nutrient loads in farm effluent by incorporating macroalgae (e.g. Ulva, Gracilaria) production systems
Land-based RAS/Pond culture	▪ Use of feeds to maximize food conversion ratios
Sea-based rafts/longlines	▪ Avoid high density culture and overcrowding of mussel droppers, oyster stacks and other structures in shellfish farms, and reduce the discard rate of over-settlement ▪ Rotation of rafts and longlines and fallowing to allow natural metabolism of organic matter in sediments ▪ Use only approved antifoulants ▪ Establish and adhere to guidelines around the use of anti-fouling products in the mariculture industry
Sea-based cage culture	▪ Use of feeds to maximize food conversion ratios ▪ Fish cages should be located at suitably deep sites that allow cages to be held at least 5 m off the seabed ▪ Appropriate spacing of cages as per specified for area (e.g. based on more detailed modelling studies) ▪ Monitor and manage feeding regimes in finfish farms to minimise feed wastage and chemical usage ▪ Use species and system-specific highly digestible, high energy and low phosphorus fish feeds to maximize food conversion ratios and minimize waste ▪ Remove any injured or dead fish from finfish cages promptly and ensure that minimal blood and offal enters the water during harvesting of finfish ▪ Rotation of cages and fallowing to allow natural metabolism of organic matter in sediments ▪ Use only approved veterinary chemicals and antifoulants ▪ Establish and adhere to guidelines for the use of anti-fouling products in the mariculture industry (there are as yet no such guidelines for the use of antifouling paints in mariculture in SA) ▪ Reduce levels of nutritional therapeutants and trace contaminants in fish feed using only the lowest effective doses ▪ Use the most efficient drug delivery mechanisms that minimise the concentrations of biologically active ingredients entering the environment.

6.9 Socio-economic impacts (user conflict)

6.9.1 Description

Coastal zones are increasingly high use areas supporting a variety of activities. Mariculture developments can have significant requirements for exclusive use of large areas, both in the sea as well as on land. In addition to ecological and biodiversity impacts, mariculture can also interfere with other socio-economic uses, either through direct competition for space or any other ecosystem service (such as assimilative capacity), or by affecting ecosystem features (e.g. clean water, fisheries stocks) of importance to the socio-economic use. This can give rise to direct conflicts with other users of coastal and marine resources. In the sea, shipping and boating activities are an important consideration, especially in the vicinity of ports. Navigation lanes and anchorage areas have to be kept clear of obstructions. Fishing grounds may also need to be considered. Indirect conflicts can also arise. Impacts to water quality, noise, odour and visual impacts can degrade the value of coastal amenities, and affect recreational and tourism use of coastal areas.

6.9.2 Potential mitigation measures

Potential mitigation measures are as follows:

Production system	**Mitigation**
Land-based flow-through	▪ Site selection and consultation with other users, as well as incorporation in marine spatial planning initiatives under various pieces of legislation, e.g. Marine Spatial Planning Bill.
Land-based RAS/pond culture	
Sea-based Rafts/longlines	
Sea-based cage culture	

7 RISK ASSESSMENT

Application of a typical Risk Assessment methodology is difficult given the nature of the ecosystems and the range of cultured species and their respective production systems considered here. Likelihoods and consequences of identified impacts are strongly dependent on scale of operation. While generic footprints of different species production systems can be assumed, the intensity of production in an area (number and density of farms, or even number of cages/rafts at a farm) cannot. Many of the likelihoods and consequences will also have a spatial dimension. Dilution and dispersion (in the case of sediments) are primary mechanisms governing the spatial scale of impact severity. While limiting the density of mariculture operations may act as a key tool in managing environmental risks associated with mariculture development, impacts can only be quantified through application of detailed hydrodynamic studies.

The approach adopted for the purposes of this study was rather to assess, through available information and expert judgement, the likely severity of the cumulative impact of the suite of identified stressors (Table 4) arising from different species production systems on important ecological and socio-economic attributes in each study area (Table 3). This allowed for an appropriate identification of areas where there is greatest potential for sustainable mariculture development (where there should be some regulatory focus on prioritising assessment of applications) and areas where mariculture development could cause significant environmental problems (where large scale mariculture should be avoided and where individual applications would need to follow rigorous impact assessment protocols). This approach also allowed for the development of risk zones around spatially explicit ecosystem features in each study area, for the different species and their respective production systems under consideration.

Confident quantitative assessment of impact likelihood was not possible within the scope of this strategic assessment, but some indication of relative likelihood across the production systems for different species was achievable. Categories of risk likelihood were adopted in line with the wider SEA approach. The generic criteria of different likelihood categories used are listed below, but as indicated should be regarded as relative measures, rather than absolute.

- Extremely unlikely = 1:10 000
- Very unlikely = 1 :100
- Not likely = 1:20
- Likely = 1:2
- Very Likely = 1:1

South African coastal waters (disregarding estuaries) are generally open, dispersive environments and widespread deterioration of water quality (including possible eutrophication) is unlikely to occur as a result of mariculture development. It bears some warning, again, that this is scale dependant. Highly localised water quality deterioration is likely in most cases, but is not likely over spatial scales exceeding further than a few hundred metres for individual farms. High densities of operations are very likely to have much wider and more severe water quality impacts.

In China, large-scale and intensive mariculture is listed as one of the major sources of coastal seawater pollution (Ottinger *et al.*, 2016). When considering risk associated with invasive alien species, alterations of genetics and transmission of diseases and parasites to wild populations sea-based systems pose the most likely risks because land-based operations have much greater control over their stock (and hence have lower escapees) and disease and parasite management. Indeed, environmental impacts of land-based farms are generally small in comparison to sea-based farms. Table 5 provides estimates (based on available information and expert judgement of the study team) of the relevant likelihood of impacts occurring for the different production systems, with, and without mitigation measures.

Table 5. Relative likelihood of relevant impacts (see Table 4) occurring with the selected production systems without and with mitigation (EU = extremely unlikely; VU = Very unlikely; NL = not likely, L= likely, VL = very likely)

LIKELIHOOD WITHOUT MITIGATION									
Potential impact	**Abalone**	**Mussel**	**Oyster**		**Dusky kob**			**Salmon**	
	Land-based flow-through	**Longline/Rafts**	**Longlines/rafts**	**Land-based nurseries**	**Cage culture**	**Land-based RAS**	**Pond culture**	**Cage culture**	**Land-based RAS**
Alteration of circulation patterns and wave regimes		L	L		L			L	
Alteration of benthic habitat		L	L		L			L	
Introduction of invasive alien species		L	L	NL				L	VU
Transmission of diseases and parasites to wild populations	NL	NL	NL	NL	VL	NL	L	VL	NL
Alteration of genetics of wild populations	VU				VL	VU	VU		
Interactions with- and entanglement of marine biota		L	L		L			L	
Destruction of terrestrial coastal vegetation and habitats	VL			VL		VL	VL		VL
Deterioration in water quality	L	NL	NL	NL	VL	NL	L	VL	NL
Socio-economic impacts (use conflict)	L	L	L	L	L	NL	VL	L	NL
LIKELIHOOD WITH MITIGATION									
Alteration of circulation patterns and wave regimes		NL	NL		NL			NL	
Alteration of benthic habitat		L	L		L			L	
Introduction of invasive alien species		L	L	NL				L	VU
Transmission of diseases and parasites to wild populations	NL	NL	NL	NL	VL	VU	L	VL	NL
Alteration of genetics of wild populations	VU				L	VU	VU		
Interactions with- and entanglement of marine biota		NL	NL		NL			NL	
Destruction of terrestrial coastal vegetation and habitats	VL			L		VL	VL		VL
Deterioration in water quality	NL	NL	NL	NL	VL	NL	L	VL	NL
Socio-economic impacts (use conflict)	L	L	L	NL	L	NL	VL	L	NL

Consequences of potential mariculture operations are a function of the impact under consideration and the area of the coast affected. Consequences were rated qualitatively as modifications to the coastal ecosystem following a similar approach as that applied in water reserve determination studies (Table 6). Cognisance was, of necessity, taken of the sensitivity of the receiving environment to a particular impact. Thus, a moderate degradation in water quality in a sensitive marine environment was regarded as having a greater consequence than a similar degradation in water quality in a non-sensitive marine area.

Table 6. Description of consequence levels used in the risk assessment

Consequence	General description
Very slight (VSl)	▪ Insignificant modification
Slight (Sl)	▪ Limited modification in all sensitivity zones in the study areas ▪ Ecosystem attributes largely unmodified and little influence on other uses ▪ Small changes in natural habitats and biota in the study area may occur, but the ecosystem functions are essentially unchanged ▪ Natural conditions and the resilience and adaptability of biota are not compromised
Moderate (M)	▪ Some modification in sensitive zones ▪ Moderate modification in non-sensitive zones ▪ A loss and change of natural habitat and biota occurs, but the basic ecosystem functions are still predominantly unchanged ▪ Moderate modification of the abiotic template and exceedance of the resource base occurs
Severe (Se)	▪ Moderate modification in sensitive zones ▪ High modification in non-sensitive zones ▪ Largely modified. A large loss of natural habitat, biota and basic ecosystem functions occurs, with risk of modifying the abiotic template and exceeding the resource base ▪ Loss of well-being and survival of intolerant biota. Associated increase in the abundance of tolerant species does not assume pest proportions
Extreme (E)	▪ High modification in sensitive zones ▪ Extreme modification in non-sensitive zones ▪ Seriously and critically modified with loss of natural habitat, biota and basic ecosystem functions

Consequences of impacts associated with mariculture are not generic across different zones (e.g. as represented by the sensitivity indicators). Consequences are rather a function of the type of impact and the zonal type. For the purposes of this study, sensitivity zones were selected based on a grouping of sensitivity indicators as listed in Table 3. These ecological and socio-ecological indicators were largely chosen based on their potential sensitivity to mariculture activities, so it is not surprising that consequences were generally high across the board. Consequences of some ecological impacts were not rated in areas highly modified by development and human activity. These areas, such as commercial ports and small harbours, were chosen as proxy zones for socio-economic and user conflict impacts. Similarly, consequence of impact in natural environmental areas were not rated in terms of socio-economic issues (space competition: other socio-economic uses).

The consequences of listed impacts (Table 7) largely depend on the sensitivity rating of various environments. However, in addition to sensitivity ratings, this assessment also distinguishes zone types in terms of their ecological (e.g. biodiversity importance), as well as socio-economic relevance. Further, ecologically relevant environments are divided into terrestrial (roughly above high water mark) or marine (i.e. roughly below the high water mark) areas.

Table 7. Relative severity of consequence of selected impacts within different sensitivity zones (defined in panel below) without and with mitigation (VSl = Very slight; Sl = Slight; M = Moderate, Se = Severe, E = Extreme)

WITHOUT MITIGATION												
Impact	Zone types and Sensitivity ratings											
	Ecological areas								Socio-economic areas		
	Terrestrial				Marine						
	Very high	High	Moderate	Low	Very high	High	Moderate	Low	High	Moderate	Low
Alteration of circulation patterns and wave regimes					E	Se	M	Sl			
Alteration of benthic habitat					E	Se	M	Sl			
Introduction of invasive alien species					E	Se	M	M			
Transmission of diseases and parasites to wild populations					E	E	Se	Se			
Alteration of genetics of wild populations					E	E	Se	Se			
Interactions with- and entanglement of marine biota					E	Se	M	M			
Destruction of terrestrial coastal vegetation and habitats	E	Se	M	Sl							
Deterioration in water quality					Se	Se	M	Sl	E	Se	M
Socio-economic impacts (use conflict)									Se	M	Sl
WITH MITIGATION											
Alteration of circulation patterns and wave regimes					E	Se	Sl	Sl			
Alteration of benthic habitat					E	Se	Sl	Sl			
Introduction of invasive alien species					E	Se	M	M			
Transmission of diseases and parasites to wild populations					E	E	Se	Se			
Alteration of genetics of wild populations					E	E	Se	Se			
Interactions with- and entanglement of marine biota					E	Se	M	M			
Destruction of terrestrial coastal vegetation and habitats	E	Se	M	Sl							
Deterioration in water quality					Se	M	Sl	Sl	Se	M	Sl

Socio-economic impacts (use conflict)									**Se**	**Sl**	**Sl**

Zones and relative sensitivity			
Ecological		**Socio-economic**	
Very High	• Formally protected areas • Critically endangered habitats • Important fish nurseries (estuaries)	High	• Important recreational areas • High density urban areas
High	• Estuaries • Fluvially-derived banks • Aggregation areas • Endangered habitats	Moderate	• Commercial ports • Small ports and fishing harbours
Moderate	• Vulnerable habitats	Low	• Cultivated lands
Low	• Least threatened habitats		

Detailed risk assessments for the various species and production systems are provided in Appendix A. Also provided is an overall risk score for each of the species/production systems, linked to different zone types and sensitivity ratings. Risks were assessed based on relationship between likelihood and consequence as illustrated in Table 8. This was applied to all the production systems for the different sensitivity indicators (see Table 3).

Table 8. Risk assessment look-up table showing relationship: Likelihood x Consequence = Risk

		Consequence				
		VSI	**SI**	**M**	**Se**	**Ex**
Likelihood	**VL**	**L**	**L**	**M**	**H**	**VH**
	L	**VL**	**L**	**M**	**H**	**VH**
	NL	**VL**	**L**	**L**	**M**	**H**
	VU	**VL**	**L**	**L**	**M**	**M**
	EU	**VL**	**VL**	**VL**	**L**	**L**

Tables 9 to 16 provide the risk assessments for different species/production systems, linked to zone types and sensitivity ratings, without and with mitigation. To relate these to specific spatial areas in the various marine study areas, the risk assessment tables need to be considered together with each of the sensitivity maps.

Table 9. Risk Assessment: Land-based abalone flow through (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Impacts	**Sensitivity rating**	**Without mitigation**			**With mitigation**		
		Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
Zone Type: Ecological Marine							
Alteration of genetics	**Very High**	E	VU	**M**	E	VU	**M**
	High	E	VU	**M**	E	VU	**M**
	Moderate	Se	VU	**M**	Se	VU	**M**
	Low	Se	VU	**M**	Se	VU	**M**
Transmission of diseases and parasites	**Very High**	E	NL	**H**	E	NL	**H**
	High	E	NL	**H**	E	NL	**H**
	Moderate	Se	NL	**M**	Se	NL	**M**
	Low	Se	NL	**M**	Se	NL	**M**
Deterioration in water quality	**Very High**	Se	L	**H**	Se	NL	**M**
	High	Se	L	**H**	Se	NL	**M**
	Moderate	M	L	**M**	M	NL	**L**
	Low	Sl	L	**L**	Sl	NL	**L**
Estimated overall risk in Zone Type[2]	**Very High**			**H**			**H**
	High			**H**			**H**
	Moderate			**M**			**M**
	Low			**M**			**M**
Zone Type: Ecological Terrestrial							
Destruction of terrestrial vegetation	**Very High**	E	VL	**VH**	E	VL	**VH**
	High	Se	VL	**H**	Se	VL	**H**
	Moderate	M	VL	**M**	M	VL	**M**
	Low	Sl	VL	**L**	Sl	VL	**L**
Estimated overall risk in Zone Type	**Very High**			**VH**			**VH**
	High			**H**			**H**
	Moderate			**M**			**M**
	Low			**L**			**L**
Zone Type: Socio-economic Important Areas							
Deterioration in water quality	**High**	E	L	**VH**	E	NL	**H**
	Moderate	Se	L	**H**	Se	NL	**M**
	Low	M	L	**M**	M	NL	**L**

[2] Overall risk refers to estimated risk of a specific species/production system (based on its suite of potential impacts) in a particular zone for a specific sensitivity rating. For this assessment the maximum risk level amongst the potential impacts constitutes estimated overall risk. Note that this does not necessarily account for synergistic or cumulative effects, but it is viewed as most appropriate at this high screening-level assessment.

Socio-economic (use area conflict)	**High**	H	L	**H**	Se	L	**H**
	Moderate	M	L	**M**	M	L	**M**
	Low	Sl	L	**L**	Sl	L	**L**
Estimated overall risk in Zone Type	**High**			**VH**			**H**
	Moderate			**H**			**M**
	Low			**M**			**L**

Table 10. Risk Assessment: Sea-based Mussel and Oyster Rafts/Longlines (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	**Sensitivity rating**	**Without mitigation**			**With mitigation**		
		Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
Ecological Marine							
Alteration of benthic habitat	**Very High**	E	L	**VH**	E	L	**VH**
	High	Se	L	**H**	Se	L	**H**
	Moderate	M	L	**M**	M	L	**M**
	Low	Sl	L	**L**	Sl	L	**L**
Alteration of waves and circulation patterns	**Very High**	E	L	**VH**	E	NL	**H**
	High	Se	L	**H**	Se	NL	**M**
	Moderate	M	L	**M**	M	NL	**L**
	Low	Sl	L	**L**	Sl	NL	**L**
Interactions with- and entanglement	**Very high**	E	L	**VH**	E	NL	**H**
	High	Se	L	**H**	Se	NL	**M**
	Moderate	M	L	**M**	M	NL	**L**
	Low	M	L	**M**	M	NL	**L**
Introduction of invasive alien species	**Very High**	E	L	**VH**	E	L	**VH**
	High	Se	L	**H**	Se	L	**H**
	Moderate	M	L	**M**	M	L	**M**
	Low	M	L	**M**	M	L	**M**
Transmission of diseases and parasites	**Very High**	E	NL	**H**	E	NL	**H**
	High	E	NL	**H**	E	NL	**H**
	Moderate	Se	NL	**M**	Se	NL	**M**
	Low	Se	NL	**M**	Se	NL	**M**
Deterioration in water quality	**Very High**	Se	NL	**M**	Se	NL	**M**
	High	Se	NL	**M**	Se	NL	**M**
	Moderate	M	NL	**L**	M	NL	**L**
	Low	Sl	NL	**L**	Sl	NL	**L**
Estimated overall risk: Ecological Marine	**Very High**			**VH**			**VH**
	High			**H**			**H**

	Moderate			M			M
	Low			M			M
Ecological Terrestrial							
No major impacts expected in terms of this production system							
Socio-economic Area							
Deterioration in water quality	High	E	NL	H	E	NL	H
	Moderate	Se	NL	M	Se	NL	M
	Low	M	NL	L	M	NL	L
Socio-economic (user area conflict)	High	Se	L	H	Se	L	H
	Moderate	M	L	M	M	L	M
	Low	Sl	L	L	Sl	L	L
Estimated overall risk: Socio-economic Areas	High			H			H
	Moderate			M			M
	Low			L			L

Table 11. Risk Assessment: Land-based oyster nurseries (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	Sensitivity rating	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Ecological Marine							
Introduction of invasive alien species	Very High	E	NL	H	E	NL	H
	High	Se	NL	M	Se	NL	M
	Moderate	M	NL	L	M	NL	L
	Low	M	NL	L	M	NL	L
Transmission of diseases and parasites	Very High	E	NL	H	E	NL	H
	High	E	NL	H	E	NL	H
	Moderate	Se	NL	M	Se	NL	M
	Low	Se	NL	M	Se	NL	M
Deterioration in water quality	Very High	Se	NL	M	Se	NL	M
	High	Se	NL	M	Se	NL	M
	Moderate	M	NL	L	M	NL	L
	Low	Sl	NL	L	Sl	NL	L
Estimated overall risk: Ecological Marine	Very High			H			H
	High			H			H
	Moderate			M			M
	Low			M			M
Ecological Terrestrial							
Destruction of terrestrial vegetation	Very High	E	L	VH	E	L	VH
	High	Se	L	H	Se	L	H

	Moderate	M	L	**M**	M	L	**M**
	Low	Sl	L	**L**	Sl	L	**L**
Estimated overall risk: Ecological Terrestrial	**Very High**			**VH**			**VH**
	High			**H**			**H**
	Moderate			**M**			**M**
	Low			**L**			**L**
Socio-economic Areas							
Deterioration in water quality	**High**	E	NL	**H**	E	NL	**H**
	Moderate	Se	NL	**M**	Se	NL	**M**
	Low	M	NL	**L**	M	NL	**L**
Socio-economic (user area conflict)	**High**	Se	NL	**M**	Se	NL	**M**
	Moderate	M	NL	**L**	M	NL	**L**
	Low	Sl	NL	**L**	Sl	NL	**L**
Estimated overall risk: Socio-economic Areas	**High**			**H**			**H**
	Moderate			**M**			**M**
	Low			**L**			**L**

Table 12. Risk Assessment: Sea-based Dusky kob cage culture (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	Sensitivity rating	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Ecological Marine							
Alteration of benthic habitat	**Very High**	E	L	**VH**	E	L	**VH**
	High	Se	L	**H**	Se	L	**H**
	Moderate	M	L	**M**	M	L	**M**
	Low	Sl	L	**L**	Sl	L	**L**
Alteration of waves and circulation patterns	**Very High**	E	L	**VH**	E	NL	**H**
	High	Se	L	**H**	Se	NL	**M**
	Moderate	M	L	**M**	M	NL	**L**
	Low	Sl	L	**L**	Sl	NL	**L**
Alteration of genetics	**Very High**	E	VL	**VH**	E	L	**VH**
	High	E	VL	**VH**	E	L	**VH**
	Moderate	Se	VL	**H**	Se	L	**H**
	Low	Se	VL	**H**	Se	L	**H**
Interactions with- and entanglement	**Very high**	E	L	**VH**	E	NL	**H**
	High	H	L	**H**	Se	NL	**M**
	Moderate	M	L	**M**	M	NL	**L**
	Low	M	L	**M**	M	NL	**L**
Transmission of diseases and parasites	**Very High**	E	VL	**VH**	E	VL	**VH**
	High	E	VL	**VH**	E	VL	**VH**
	Moderate	Se	VL	**H**	Se	VL	**H**
	Low	Se	VL	**H**	Se	VL	**H**
Deterioration in water quality	**Very High**	Se	VL	**H**	Se	VL	**H**
	High	Se	VL	**H**	Se	VL	**H**
	Moderate	M	VL	**M**	M	VL	**M**
	Low	Sl	VL	**L**	Sl	VL	**L**
Estimated overall risk: Ecological Marine	**Very High**			**VH**			**VH**
	High			**VH**			**VH**
	Moderate			**H**			**H**
	Low			**H**			**H**
Ecological Terrestrial							
No major impacts expected in terms of this production system							
Socio-economic Areas							
Deterioration in water quality	**High**	E	VL	**VH**	E	VL	**VH**
	Moderate	Se	VL	**H**	Se	VL	**H**
	Low	M	VL	**M**	M	VL	**M**

Zone Type/Impacts	Sensitivity rating	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Socio-economic (user area conflict)	High	Se	L	H	Se	L	H
	Moderate	M	L	M	M	L	M
	Low	Sl	L	L	Sl	L	L
Estimated overall risk: Socio-economic Areas	High			VH			VH
	Moderate			H			H
	Low			M			M

Table 13. Risk Assessment: Land-based Dusky kob pond culture (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	Sensitivity rating	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Ecological Marine							
Alteration of genetics	Very High	E	VU	M	E	VU	M
	High	E	VU	M	E	VU	M
	Moderate	Se	VU	M	Se	VU	M
	Low	Se	VU	M	Se	VU	M
Transmission of diseases and parasites	Very High	E	L	VH	E	L	VH
	High	E	L	VH	E	L	VH
	Moderate	Se	L	H	Se	L	H
	Low	Se	L	H	Se	L	H
Deterioration in water quality	Very High	Se	L	H	Se	L	H
	High	Se	L	H	Se	L	H
	Moderate	M	L	M	M	L	M
	Low	Sl	L	L	Sl	L	L
Estimated overall risk: Ecological Marine	Very High			VH			VH
	High			VH			VH
	Moderate			H			H
	Low			H			H
Ecological Terrestrial							
Destruction of terrestrial vegetation	Very High	E	VL	VH	E	VL	VH
	High	Se	VL	H	Se	VL	H
	Moderate	M	VL	M	M	VL	M

	Low	Sl	VL	**L**	Sl	VL	**L**
Estimated overall risk: Ecological Terrestrial	**Very High**			**VH**			**VH**
	High			**H**			**H**
	Moderate			**M**			**M**
	Low			**L**			**L**
Socio-economic Areas							
Deterioration in water quality	**High**	E	L	**VH**	E	L	**VH**
	Moderate	Se	L	**H**	H	L	**H**
	Low	M	L	**M**	M	L	**M**
Socio-economic (user area conflict)	**High**	Se	VL	**H**	Se	VL	**H**
	Moderate	M	VL	**M**	M	VL	**M**
	Low	Sl	VL	**L**	Sl	VL	**L**
Estimated overall risk: Socio-economic Areas	**High**			**VH**			**VH**
	Moderate			**H**			**H**
	Low			**M**			**M**

Table 14. Risk Assessment: Land-based Dusky kob RAS (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	Sensitivity rating	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Ecological marine							
Transmission of diseases and parasites	Very High	E	NL	H	E	VU	M
	High	E	NL	H	E	VU	M
	Moderate	Se	NL	M	Se	VU	M
	Low	Se	NL	M	Se	VU	M
Deterioration in water quality	Very High	Se	NL	M	Se	NL	M
	High	Se	NL	M	Se	NL	M
	Moderate	M	NL	L	M	NL	L
	Low	Sl	NL	L	Sl	NL	L
Estimated overall risk: Ecological Marine	Very High			H			M
	High			H			M
	Moderate			M			M
	Low			M			M
Ecological Terrestrial							
Destruction of terrestrial vegetation	Very High	E	VL	VH	E	VH	VH
	High	Se	VL	H	Se	VH	H
	Moderate	M	VL	M	M	VH	M
	Low	Sl	VL	L	Sl	VH	L
Estimated overall risk: Ecological Marine	Very High			VH			VH
	High			H			H
	Moderate			M			M
	Low			L			L
Socio-economic Areas							
Deterioration in water quality	High	E	NL	H	E	NL	H
	Moderate	Se	NL	M	Se	NL	M
	Low	M	NL	L	M	NL	L
Socio-economic (user area conflict)	High	Se	NL	M	Se	NL	M
	Moderate	M	NL	L	M	NL	L
	Low	Sl	NL	L	Sl	NL	L
Estimated overall risk: Socio-Economic Areas	High			H			H
	Moderate			M			M
	Low			L			L

Table 15. Risk Assessment: Sea-based Salmon cage culture (Risk - VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	Sensitivity rating	Without mitigation			With mitigation		
		Consequence	Likelihood	Risk	Consequence	Likelihood	Risk
Ecological marine							
Alteration of benthic habitat	Very High	E	L	VH	E	L	VH
	High	Se	L	H	Se	L	H
	Moderate	M	L	M	M	L	M
	Low	Sl	L	L	Sl	L	L
Alteration of waves and circulation patterns	Very High	E	L	VH	E	M	H
	High	Se	L	H	Se	M	M
	Moderate	M	L	M	M	M	L
	Low	Sl	L	L	Sl	M	L
Interactions with- and entanglement	Very high	E	L	VH	E	M	H
	High	Se	L	H	Se	M	M
	Moderate	M	L	M	M	M	L
	Low	M	L	M	M	M	L
Introduction of invasive alien species	Very High	E	L	VH	E	L	VH
	High	Se	L	H	Se	L	H
	Moderate	M	L	M	M	L	M
	Low	M	L	M	M	L	M
Transmission of diseases and parasites	Very High	E	VL	VH	E	VL	VH
	High	E	VL	VH	E	VL	VH
	Moderate	Se	VL	H	Se	VL	H
	Low	Se	VL	H	Se	VL	H
Deterioration in water quality	Very High	Se	VL	H	Se	VL	H
	High	Se	VL	H	Se	VL	H
	Moderate	M	VL	M	M	VL	M
	Low	Sl	VL	L	Sl	VL	L
Estimated overall risk: Ecological Marine	Very High			VH			VH
	High			VH			VH
	Moderate			H			H
	Low			H			H
Ecological Terrestrial							
No major impacts expected in terms of this production system							
Socio-economic Areas							
Deterioration in water quality	High	E	VL	VH	E	VL	VH
	Moderate	Se	VL	H	Se	VL	H
	Low	M	VL	M	M	VL	M
Socio-economic (user area conflict)	High	Se	L	H	Se	L	H

	Moderate	M	L	**M**	M	L	**M**
	Low	Sl	L	**L**	Sl	L	**L**
Estimated overall risk: Socio-economic Areas	**High**			**VH**			**VH**
	Moderate			**H**			**H**
	Low			**M**			**M**

Table 16. Risk Assessment: Land-based Salmon RAS (VL = Very low; L = low; M = Moderate; High = High; VH = Very high). Likelihood and Consequence ratings as per Tables 5 and 7 respectively)

Zone Type/Impacts	**Sensitivity rating**	**Without mitigation**			**With mitigation**		
		Consequence	**Likelihood**	**Risk**	**Consequence**	**Likelihood**	**Risk**
Ecological marine							
Introduction of invasive alien species	**Very High**	E	VU	**M**	E	VU	**M**
	High	Se	VU	**M**	Se	VU	**M**
	Moderate	M	VU	**L**	M	VU	**L**
	Low	M	VU	**L**	M	VU	**L**
Transmission of diseases and parasites	**Very High**	E	NL	**H**	E	NL	**H**
	High	E	NL	**H**	E	NL	**H**
	Moderate	Se	NL	**M**	Se	NL	**M**
	Low	Se	NL	**M**	Se	NL	**M**
Deterioration in water quality	**Very High**	Se	NL	**M**	Se	NL	**M**
	High	Se	NL	**M**	Se	NL	**M**
	Moderate	M	NL	**L**	M	NL	**L**
	Low	Sl	NL	**L**	Sl	NL	**L**
Estimated overall risk: Ecological Marine	**Very High**			**H**			**H**
	High			**H**			**H**
	Moderate			**M**			**M**
	Low			**M**			**M**
Ecological Terrestrial							
Destruction of terrestrial vegetation	**Very High**	E	VL	**VH**	VH	VL	**VH**
	High	Se	VL	**H**	Se	VL	**H**
	Moderate	M	VL	**M**	M	VL	**M**
	Low	Sl	VL	**L**	Sl	VL	**L**
Estimated overall risk: Ecological Terrestrial	**Very High**			**VH**			**VH**
	High			**H**			**H**
	Moderate			**M**			**M**
	Low			**L**			**L**
Socio-economic Areas							
Deterioration in water quality	**High**	E	NL	**H**	E	NL	**H**
	Moderate	Se	NL	**M**	Se	NL	**M**

	Low	M	NL	**L**	M	NL	**L**
Socio-economic (user area conflict)	**High**	Se	NL	**M**	Se	NL	**M**
	Moderate	M	NL	**L**	M	NL	**L**
	Low	Sl	NL	**L**	Sl	NL	**L**
Estimated overall risk: Socio-economic Areas	**High**			**H**			**H**
	Moderate			**M**			**M**
	Low			**L**			**L**

8 LIMITS OF ACCEPTABLE CHANGE

8.1 Relevant legislation, policies and guidelines

While mariculture provides some potential to provide a renewable source of seafood, and other socio-economic benefits, mariculture developments inevitably have some impact on communal coastal resources. There is therefore usually an unavoidable trade-off between environmental impact and socio-economic benefits, and this is often defined in the form of acceptable limits of effect (Telfer and Beveridge, 2001). In addition to specific legislation, policies and guidelines that pertain directly to the mariculture sector, there is other legislation and numerous policies and guidelines that set specifications (or limits of acceptable change) for any activity or development that takes place in the coastal marine environment. Those pertinent in a South African context are summarised in Table 17. It is important that mariculture developments consider these specifications as set out in relevant legislation, policies and guidelines.

Table 17. Key legislation, policies and guidelines that set specifications (or limits of acceptable change) applicable to development and activities in the coastal (marine and terrestrial) environment

Area/ Component	Specification of Targets (i.e. to be considered in setting limits of acceptable change)
Coastal zone	National Environmental Management: Integrated Coastal Management Act (No. 24 of 20 (ICM Act) (section 25). Prohibits or restricts building, erection, alteration or extension of structures that are wholly or partially seaward of coastal set-back lines.
Estuarine habitat and biota	National Water Act (No. 36 of 1998). Preliminary Reserve Determination and Classification. Set desired state ("management class") and measurable targets for water flow ("Reserve"), and water quality, habitat and biota in estuaries ("Resource Quality Objectives") (these are set specifically for each estuary).
	National Environmental Management: Biodiversity Act (No. 10 of 2004) (Biodiversity Act). Sets biodiversity targets for South Africa that need to be translated into site-specific targets for study area based on detailed quantitative assessments. These targets are articulated in the **National Protected Areas Expansion Strategy** (NPAES) updated draft available from DEA). South Africa's protected area network currently falls far short of sustaining biodiversity and ecological processes. The goal of the NPAES is to achieve cost-effective protected area expansion for ecological sustainability and increased resilience to climate change. It sets targets for protected area expansion, provides maps of the most important areas for protected area expansion, and makes recommendations on mechanisms for protected area expansion. The **National Estuarine Biodiversity Plan** (Turpie *et al.*, 2012) determined the core set of estuaries in need of formal protection to

Area/ Component	Specification of Targets (i.e. to be considered in setting limits of acceptable change)
	achieve biodiversity targets.
	Marine Living Resources Act (No. of 1998) (MLRA). The management and control of exploited living resources in estuaries fall primarily under this Act. The primary purpose of the act is to protect marine living resources (including those of estuaries) through establishing sustainable limits for the exploitation of resources; declaring fisheries management areas for the management of species; approving plans for their conservation, management and development; prohibit and control destructive fishing methods and the declaration of MPAs (a function currently delegated to DEA). The MLRA overrides all other conflicting legislation relating to marine living resources.
Marine habitat and biota	Biodiversity Act. Sets biodiversity targets for South Africa that need to be translated into site-specific targets for study area based on detailed quantitative assessments. These targets are articulated in the NPAES. South Africa's protected area network currently falls far short of sustaining biodiversity and ecological processes. The goal of the NPAES is to achieve cost-effective protected area expansion for ecological sustainability and increased resilience to climate change. It sets targets for protected area expansion, provides maps of the most important areas for protected area expansion, and makes recommendations on mechanisms for protected area expansion.
	MLRA. The management and control of exploited living resources in estuaries fall primarily under this Act. The primary purpose of the act is to protect marine living resources through establishing sustainable limits for the exploitation of resources; declaring fisheries management areas for the management of species; approving plans for their conservation, management and development; prohibit and control destructive fishing methods and the declaration of Marine Protected Areas (MPAs) (a function currently delegated to DEA). The MLRA overrides all other conflicting legislation relating to marine living resources.
Recreational waters	ICM Act. Water quality guidelines for the coastal environment: Recreational use (DEA, 2012). Set water quality targets for recreational waters to protect bathers
Water and sediment quality to protect aquatic ecosystems	ICM Act. Water quality guidelines for protection of natural coastal environment (DWAF 1995, in process of being reviewed by DEA). Sets targets for use specific chemical in marine waters and sediments to protect ecosystems
Water quality to protect mariculture use	ICM Act. Water quality guidelines coastal environment: Mariculture (DWAF 1995, in process of being reviewed by DEA). Sets targets to protect use, e.g. *E coli* limits for mussel culture area.
Water quality to protect industrial uses	ICM Act. Water quality guidelines for coastal environment: Industrial use (DWAF 1995, in process of being reviewed by DEA). Sets targets to protect use, e.g. cooling water intakes, desalination plants.
Habitat and biota targets for formally protected areas	National Environmental Management: Protected Areas Act (No. 57 of 2003). Sets specific targets for protected areas (site specific as set in regulations/government notices).
	National Protected Areas Expansion Strategy. South Africa's protected area network currently falls far short of sustaining biodiversity and ecological processes. The goal of the NPAES is to achieve cost-effective protected area expansion for ecological sustainability and increased resilience to climate change. It sets targets for protected area expansion, provides maps of the most important areas for protected area expansion, and makes recommendations on mechanisms for protected area expansion.

Area/ Component	Specification of Targets (i.e. to be considered in setting limits of acceptable change)
Estuaries	National Environmental Management Act (No. 107 of 1998) (NEMA). EIA Regulations (EIA Regulations Listing Notice 3, Government Gazette No. 33306, 18 June 2010) any development within the EFZ of an estuary is subject to an EIA. The demarcation of the EFZ for all estuaries in South Africa is available for South African National Biodiversity Institute (SANBI) (http://bgis.sanbi.org/estuaries/project.asp).
Ports	National Ports Act (No. 12 of 2005). Legal requirements as stipulated in terms of this act must be complied with in commercial ports.
Terrestrial coastal area	Spatial Planning and Land-use Management Act (No. 16 of 2013) (SPLUMA). Development in terrestrial areas will be subject to requirements and specifications as per spatial planning frameworks (SDFs) of relevant municipalities under

8.2 Recommended Management Responses for Risk Categories

The wide overview approach which was necessary for the purposes of this risk assessment should preclude its use as the sole basis for licence allocations in mariculture. The sensitivity mapping and risk categories used only provide a broad, strategic overview of the relative suitability and potential for mariculture within and across the eight selected marine study areas. Even in areas of low sensitivity it is important that some form of environmental impact assessment be undertaken to confirm and refine the outputs as presented in this strategic assessment. Table 18 provides recommended management responses that should (at a minimum) be considered when mariculture development is proposed.

Table 18. Recommended Management Procedures associated with Risk Categories

Risk Category	Recommended Management Procedures
Low (L)	Basic Assessment (as per EIA Regulations) based on requirements set out in terms of General Authorisation for Marine Aquaculture
Moderate (M)	Basic Assessment (as per EIA Regulations) based on requirements set out in terms of General Authorisation for Marine Aquaculture including limited stakeholder consultation
High (H)	Full EIA study (as per EIA Regulations) to be conducted, including stakeholder consultation
Very High (VH)	No-Go areas (i.e. avoidance of very high risk areas, mostly linked to areas with a very high and/or high sensitivity rating (buffer zones need to be agreed upon and enforced to protect highly sensitive areas at risk)

8.3 Cumulative effects and production scale

This assessment assumes risk associated with a single farming operation under each of the production systems, roughly resembling the farm footprints as provided in Table 2. It does not account for cumulative effects of multiple farms within close proximity of each another. Cumulative risk associated with multiple farms in close proximity depends on numerous factors, both environmental (e.g. circulation patterns, habitat types, etc.), as well as the scale and size of farms, a level of detail that could not be resolved within the scope of this strategic environmental assessment study. However, cumulative risks will need to be resolved (e.g. using numerical modelling) where multiple mariculture licensing in close proximity is considered.

An important critical limit of acceptable change, therefore, will be the carrying capacity of a specific area in terms of density of farms and farm sizes. Even in areas considered suitable for mariculture over-densification or inappropriate large-scale farming can ultimately have detrimental impacts. For example, in China, large-scale and intensive mariculture is listed as one of the major sources of coastal seawater pollution and negative effects to aquatic environment are increasingly recognized (Ottinger *et al.*, 2016).

Guidelines have been developed in some countries to address this issue. The capacity of marine waters to sustain mariculture without unacceptably compromising water quality depends on a number of factors, including the depth of water and current speed at the site, the size of the site, and density of operations. Guidelines can be developed for siting as well as spacing of mariculture operations based on thresholds of mixing potential and sediment mobility. In New Brunswick (Canada) the theoretical Estimated Site Potential for a site with a water depth of 20.0 - 24.99 m and a minimum area of 12.03 hectares has been calculated to be 240 000 fish (Rosenthal *et al*. 1995). Distances separating individual farms are regulated in some countries. In addition to minimising impacts on sediments and water, this reduces the risk of disease contamination between cages and farms, and allows space for other activities, such as navigation (Perez *et al.*, 2005). Distance restrictions between farms vary greatly between countries, environments, farmed species and systems used.

In New Brunswick, the minimum separation distance between salmon farms is 300 m (Rosenthal *et al.*, 1995). In Norway, Scotland, Ireland and British Columbia a minimum separation distance between farm sites of 1 km is suggested (Stewart, 1998) while in Chile 2.4 km is set as the mandatory distance between farms (Perez *et al*., 2005). The application of generic scales to deal with measures to ensure critical limits of acceptable change are not exceeded, is difficult, and can at best only be applied to certain types of environment, categorised according to waves, currents, biochemical processes, etc.

9 BEST PRACTICE PRINCIPLES AND MONITORING REQUIREMENTS

9.1 Best Practice guidelines

Key environmentally sound principles for mariculture production systems have been distilled from review of international and local literature and are discussed below.

9.1.1 Siting of farms (including key environmental considerations)

From the above it is clear that for the siting of individual mariculture farms and in considering production scales, it is important to consider a number of issues relating to the environment. Environmental best practices presented in the international literature are summarised below:

- Sites favoured for mariculture development should be well-flushed and deep, and located to avoid overlap with potentially sensitive and valuable habitats such as conservation areas, biogenic habitats and reefs.
- Buffer zones should be established around such sensitive and valuable habitats, and other ecosystem features used by other users. These could be established on a case-by-case basis using tools such as numerical modelling (see below), but as guidance buffer zones applied elsewhere are useful. A 500 m buffer zone in which no shellfish mariculture development is permitted and a 1 000 m buffer in which no finfish culture is permitted is recommended around MPAs. Furthermore, a minimum 100 m buffer is recommended around reefs and blinders. The extent of these suggested buffers is based on model results from New Zealand, which indicated that depositional footprints of >250 m were possible for shellfish farm sites in more energetic environments or greater water depth (Hartstein and Stevens, 2005; Stenton-Dozey *et al*., 2008). The results of Mead *et al*. (2009) indicated that nutrient effects in the water column could extend several kilometres from commercial-scale finfish farms.
- Predictive analytical and numerical modelling should be undertaken before authorisation for mariculture operations is granted. This is particularly important where proposed shellfish and finfish farms are proposed adjacent to MPAs. This would include for example, predicting the effects of shellfish farming on local currents, stratification and wave climates and using the results to develop alternative farm designs to minimise possible localised hydrodynamic changes. Such models could also provide an indication of the extent of waste plumes and depositional footprints of biological and feed wastes generated by farms, effects on water column nutrient parameters (dissolved carbon, nitrogen and phosphorous) and seston depletion shadows (particulate organic carbon, phytoplankton abundance and species composition) in response to the farm structures and stock. Model outputs should inform

suitability, location and design of the proposed mariculture works to ensure that these do not impact on sensitive habitats such as the shoreline, important reefs and MPAs. This is particularly important in sheltered bays such as Saldanha Bay, where hydrodynamics have been compromised by other developments and where proposed precincts are in the immediate vicinity of potentially sensitive and valuable habitats.

- Fish cages should be located at suitably deep sites and the configuration of finfish cages be such so as to limit coverage of area under cage farming, both within individual licence areas and within Aquaculture Development Zones. Unfarmed area should be used on a rotational basis for fallowing. Depth and area limitations may be derived site specifically, but work done elsewhere suggests cages be held at least 5 m off the seabed (Bryars, 2003; Beveridge, 2004) and assessment of ecological impacts of a proposed ADZ in Saldanha Bay (Pisces 2017) recommended that finfish cages should not exceed a total coverage of 30% of the total area allocated for finfish farming.
- Ensure mooring systems are well designed and placed to prevent/limit movement of anchors and chains over the sea floor.

9.1.2 Farm operations

The following are important best practices to consider during operations:

- In sea-based shellfish farming avoid high density culture and overcrowding of mussel droppers, oyster stacks and other structures, and reduce the discard rate of over-settlement.
- In sea-based farming implement recommended monitoring of biodeposition and physico-chemical changes in seabed properties, infaunal and epifaunal macrobenthic communities, at shellfish and finfish farming sites relative to undisturbed control sites. For finfish farms, adopt the MOM management system (Modelling-Ongrowing fish farms-Monitoring) or similar to monitor infaunal and epifaunal macrobenthic communities at farming sites.
- In finfish cage farming manage fish stocking densities to ensure the environmental and stock health is maintained. Optimum stocking densities and feeding rates, during each season and for different species of fish of different size classes, can only be determined after several seasons of rearing have taken place at each site (Schoonbee and Bok 2006).
- Monitor and manage feeding regimes in finfish farms to minimise feed wastage and chemical usage, and use species and system-specific highly digestible, high energy and low phosphorus fish feeds to maximize food conversion ratios and minimize waste.
- Rotate cages within suspended cage sites to allow recovery of benthos, and destock or fallow a site after a growing cycle prior to restocking.
- Install visual deterrents for birds (e.g. tori line type deterrents) on finfish cage superstructure.
- Ensure debris and waste material does not enter the water to minimise the risk of attraction and entanglement by seabirds, marine mammals and large predators.
- Monitoring by farm personnel of presence of marine mammal species in the vicinity or general region of the farm sites (and potentially also monitor the absence of important marine mammals), as well as observations of any time spent under or around the farm structures. A log of all cetaceans, as well as seabirds and predators recorded in the vicinity of farms, and

notes on behavioural observations, should be kept. These data should be periodically compiled and analysed by experts.

- Use predator exclusion nets for finfish farming as necessary; enclose nets at the bottom to minimise entanglement, keep nets taut, use mesh sizes of <6 cm (Kemper *et al*. 2003), and keep nets well maintained (e.g. repairing holes).
- Remove any injured or dead fish from finfish cages promptly and ensure that minimal blood and offal enters the water during harvesting of finfish.
- Minimise the potential for litter entering the marine environment (particularly plastic wastes).
- Use only approved antifoulants and environmentally friendly alternatives where effective. Do not apply antifoulants on site.
- Leave mooring anchors or blocks in place when undertaking maintenance of mariculture structures (cages, rafts) or fallowing sites to avoid repetitive impacts of the same activity at each site.

9.1.3 Biosecurity, genetics and disease control

The following are important best practice to consider in terms of biosecurity, genetics and disease control:

- Ensure a high level of biosecurity management and planning is in place within hatcheries, holding tanks and sea cages to limit the introduction of pests and diseases and to be able to respond quickly and effectively should biosecurity risks be identified.
- Have good house-keeping practices in place at all times i.e. in finfish cage farming keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediate hosts and or pathogens.
- Farm operators should undertake routine surveillance on and around marine farm structures and associated vessels and infrastructure for indications of non-native fouling species.
- Maintain effective antifouling coatings and regularly inspect farm structures and vessels for pests; clean structures and hulls regularly to ensure eradication of pests before they become established.
- Fouling organisms removed from oyster stacks, abalone barrels and finfish cages should not be discharged back into the marine environment thereby ensuring that any introduced non-native fouling species undetected previously, are not released into the wild.
- Develop South African bivalve hatcheries to reduce the reliance on spat import, and hence the risk of non-intentional introduction of associated alien species and diseases.
- If spat import cannot be avoided, culture facilities should only be permitted to use spat sourced from biosecure certified hatcheries.
- Ensure that veterinary protocols to eliminate any pests, parasites and diseases are strictly adhered to.
- Ensure suitable management and planning measures are in place to limit the possibility of genetic interactions between farmed stock and wild populations.

- Ensure good physical and biological containment to limit the effects of escaped stocks.
- Use sterile triploid shellfish spat to minimise the potential of reproduction in shellfish farms and releases of eggs and larvae within farmed areas allowing possible recruitment to natural shellfish habitat and competition with wild populations.
- Implement the "Genetic Best Practice Management Guidelines for Marine Finfish Hatcheries" developed by DAFF (undated) and ensure adequate genetic monitoring of broodstock rotation.
- When farming endemic species, use offspring from wild-sourced fish broodstock, as they will be genetically similar to wild fish.
- Use appropriate spawning regimes in the hatchery to maintain genetic diversity in the offspring.
- Use only female fish in farm cages.
- Control breeding in the stock and develop the technology to create sterile fry for stocking of cages.
- Use robust, well-maintained containment systems to reduce the likelihood of escape.
- Develop and implement recovery procedures should escapes from finfish farms occur.
- Ensure as far as possible that all spat and fry undergo a health examination prior to stocking in sea cages.
- Take necessary action to eliminate pathogens through the use of therapeutic chemicals or improved farm management.
- Restrict stocking densities to below 15 - 20 fish per m^3 to limit the spread of diseases and parasitic infections (DAFF, 2013).
- Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme.
- Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied.
- Locate cages stocked with different cohorts of the same species as far apart as possible; if possible stock different species in cages successively.
- Have good house-keeping practices in place at all times i.e. keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediate hosts and or pathogens.
- Treat adjacent cages simultaneously even if infections have not yet been detected.
- Use only approved veterinary chemicals.
- Reduce levels of nutritional therapeutants and trace contaminants in fish feed using only the lowest effective doses.
- Use the most efficient drug delivery mechanisms that minimise the concentrations of biologically active ingredients entering the environment.

- Consider the use of seaweeds as a co-culture species for use in Integrated Multi-Trophic Aquaculture (IMTA).

There are three components to biosecurity management, namely:

- Prevention of incursions is the most effective approach to biosecurity and should focus on the management of high-risk pathways, including from international source regions, new pathways, and regional sources known to be infected by recognised high-risk pests.
- Surveillance (detection) focussing on entry surveillance (screening at airports and ports), routine surveillance (undertaken on and around marine farm structures and associated vessels and infrastructure by farm operators) or targeted surveillance of high-risk areas.
- Control of populations and outbreaks requiring coordination with, and support from, all marine stakeholders (whose activities can spread unwanted organisms) and agencies at local, regional and national scales. Eradication measures and/or application of therapeutants are only advised if the risk of re-invasion can be managed and pests can be detected before they become widespread.

9.1.4 General best management practices

The following are important general management best practices to consider:

- Conduct monitoring as per coastal waters discharge permit (ICM Act) where effluent are being discharged to coastal waters (specified per species farmed). This should include monitoring of the immediate water column around the precincts or specific farms for nutrient parameters (dissolved carbon, nitrogen and phosphorus) and for key plankton parameters (chlorophyll a, phytoplankton abundance and species composition).(See also Section 9.2 below).
- Ensuring that minimal non-navigational lighting occurs at night and use downward-pointing and shaded lights.
- Develop and enforce strict maintenance and operational guidelines and standards in relation to potential entanglement risks on the farm including loose ropes, lines, buoys or floats.
- Ensure all mooring lines and rafts are highly visible (use thick lines and bright antifouling coatings).
- Keep all lines taught through regular inspections and maintenance.
- In sea-based farming develop disentanglement protocols in collaboration with DAFF, DEA and the South Africa Whale Disentanglement Network and establish a rapid response unit to deal with entanglements.
- Adopt appropriate maintenance and operational guidelines and standards for minimising noise in noise-generating equipment.
- Establish and adhere to guidelines around the use of anti-fouling products in the mariculture industry.

9.2 Monitoring requirements

Environmental monitoring should assist in ensuring that are mariculture farms are sustainable in the long term, taking only a proportionate share of the resource with respect to other users and without adversely affect ecosystem function and productivity, or leading to the deterioration of rare or sensitive habitat (Wilson *et al.*, 2009). Some operational monitoring requirements, which are useful in working towards environmental compliance and sustainability, are noted above and should be performed. As a generic requirement this should include monitoring of effluent quality (in the case of land-based systems with discharge flows back to sea) and monitoring of the physical, chemical and biological condition of the receiving environment (water and sediments) in the vicinity of effluent outflows, as well as around sea-based systems. The overall objective of monitoring of the receiving environment should be to assess the degree of impact that mariculture operations have on the environment, to evaluate trends in the impact, to elucidate causality and to inform appropriate management response.

Environmental monitoring requirements vary amongst different species/production systems, and site-specific conditions need to be considered in the design of monitoring programmes. As a consequence there is no single set way to monitor mariculture development, but variables commonly used in monitoring include (from Fernandes *et al.*, 2001):

Physical	**Chemical**	**Biological**
▪ Bathymetry ▪ Currents, waves, tides ▪ Wind ▪ Precipitation ▪ Substrate type ▪ Sediment movement ▪ Erosion/accretion ▪ Temperature	▪ pH, alkalinity ▪ Redox ▪ Salinity ▪ Dissolved Oxygen ▪ Nutrients ▪ Particulate/dissolved organic matter ▪ Suspended solids ▪ Specific chemicals (depending on the operation	▪ Species abundance and diversity: plankton, benthos, nekton, birds (qualitative, i.e. species list, or quantitative, i.e. full abundance) ▪ Biomass ▪ Productivity ▪ Population structure ▪ Trophic interactions ▪ Habitat mapping ▪ Rare and endangered species/habitats

Spatial (the number and location of sampling points) and temporal (the frequency of sampling) considerations in the design of marine monitoring programmes can be complex, and in most cases are influenced by site specific issues, confounding variables and high natural variability. This has been the subject of scientific consideration for several decades (e.g. Underwood, 1992). An underpinning principle is that environmental status of the potentially affected area be assessed against a `control' or `reference area' (Fernandes *et al.*, 2001; Telfer and Beveridge, 2001). This in itself can be complex and is ideally dealt with by collecting a comprehensive dataset that defines the natural variability of the area prior to mariculture development in a baseline survey. These data can be used to inform the design of future monitoring (and indeed the design of the future farm) but are primarily used as a comparison point with ongoing monitoring data collected during farm operations. In the case of older existing developments, baseline data often do not exist, and sampling of areas beyond the influence of operations can be useful in providing an indication of reference conditions for comparison. Ideally however, monitoring of impacts from mariculture should rely on comparison of both a robust set of pre-development (baseline) data, as well as contemporary data collected from unimpacted areas.

In both baseline surveys and ongoing monitoring it is important that background variability in environmental parameters being measured is assessed and accounted for (Fernandes *et al*., 2001). This generally demands high replication of sampling both temporally and spatially (Underwood, 1992), which can result in monitoring becoming a costly exercise. This can be moderated to some extent by adopting an adaptive strategy in monitoring, and reducing the scope and scale of sampling as results emerge to support this. The value and need for monitoring should not be underestimated, however. In addition to the requirement to show protection and safeguarding of the marine environment for other uses, monitoring can also have direct value for the mariculture industry. Mariculture operators have a strong self-interest in ensuring their product is grown in safe and clean conditions, and environmental monitoring data is clearly useful in this regard.

10 GAPS IN KNOWLEDGE

This assessment has highlighted an array of potential constraints of sustainable mariculture in South African coastal waters, including:

- While limiting the density of mariculture operations may act as a key tool in managing environmental risks associated with mariculture development, quantified, or even high confidence assessment of this can only be made through applying much higher spatial resolution and hydrodynamic study. This requires additional detailed and site specific studies beyond this broad-scale strategic screening process.
- South Africa's coast does offer potentially favourable environments to support mariculture. For example, the coast in general is subject to high wave energies and current flows that create a dispersive environment. However, these environmental characteristics are extremely diverse across and within the selected study areas, especially in the nearshore areas typically targeted for mariculture. This requires nearshore wave and current data at relatively high resolution which is not available for our coast at a regional or national scale.
- This assessment assumes risk associated with a single farming operation under each of the production systems, roughly resembling the farm footprints as provided in Table 2. It does not account for cumulative effects of multiple farms within close proximity to each another, largely because such information in lacking for the South African situation. Cumulative risks can be assessed using numerical modelling, for example. This type of assessment is site specific, relying on relevant environmental data (e.g. wave, current, winds etc.).
- The consequences of brood-stock harvesting of critically depleted stocks of Dusky kob, presently estimated at less than 2% of pristine spawner biomass, is lacking. With a very restricted effective population size (successful breeders) throughout its South African distribution, this species is sensitive to the harvesting of large adults and current offtake needs to be limited.

- This assessment makes use of available datasets to demarcate sensitive areas (e.g. (e.g. threat/vulnerability status from the 2011 National Biodiversity Assessment). However some of these data sets may be outdated and therefore present a potential knowledge gap to be addressed.

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- **APPENDIX A: Risk Summary Table per Production System**

Production	Zone type	Sensitivity Rating	Risk	
			Without mitigation	With mitigation
Land-based abalone flow through	Ecological Marine	Very High	H	H
		High	H	H
		Moderate	M	M
		Low	M	M
	Ecological Terrestrial	Very High	VH	VH
		High	H	H
		Moderate	M	M
		Low	L	L
	Socio-economic Areas	High	VH	H
		Moderate	H	M
		Low	M	L
Sea-based Mussel and Oyster Rafts/Longlines	Ecological Marine	Very High	VH	VH
		High	H	H
		Moderate	M	M
		Low	M	M
	Ecological Terrestrial	Not applicable to this production system		
	Socio-economic Areas	High	H	H
		Moderate	M	M
		Low	L	L
Land-based oyster nurseries	Ecological Marine	Very High	H	H
		High	H	H
		Moderate	M	M

Production	**Zone type**	**Sensitivity Rating**	**Risk**	
			Without mitigation	**With mitigation**
		Low	**M**	**M**
	Ecological Terrestrial	**Very High**	**VH**	**VH**
		High	**H**	**H**
		Moderate	**M**	**M**
		Low	**L**	**L**
	Socio-economic Areas	**High**	**H**	**H**
		Moderate	**M**	**M**
		Low	**L**	**L**
Sea-based Dusky kob cage culture	Ecological Marine	**Very High**	**VH**	**VH**
		High	**VH**	**VH**
		Moderate	**H**	**H**
		Low	**H**	**H**
	Ecological Terrestrial	**Not applicable to this production system**		
	Socio-economic Areas	**High**	**VH**	**VH**
		Moderate	**H**	**H**
		Low	**M**	**M**
Land-based Dusky kob pond culture	Ecological Marine	**Very High**	**VH**	**VH**
		High	**VH**	**VH**
		Moderate	**H**	**H**
		Low	**H**	**H**
	Ecological Terrestrial	**Very High**	**VH**	**VH**
		High	**H**	**H**
		Moderate	**M**	**M**

Production	Zone type	Sensitivity Rating	Risk	
			Without mitigation	With mitigation
		Low	L	L
	Socio-economic Areas	High	VH	VH
		Moderate	H	H
		Low	M	M
Land-based Dusky kob RAS	Ecological Marine	Very High	H	M
		High	H	M
		Moderate	M	M
		Low	M	M
	Ecological Terrestrial	Very High	VH	VH
		High	H	H
		Moderate	M	M
		Low	L	L
	Socio-economic Areas	High	H	H
		Moderate	M	M
		Low	L	L
Sea-based Salmon cage culture	Ecological Marine	Very High	VH	VH
		High	VH	VH
		Moderate	H	H
		Low	H	H
	Ecological Terrestrial	Not applicable to production system		
	Socio-economic Areas	High	VH	VH
		Moderate	H	H
		Low	M	M

Production	Zone type	Sensitivity Rating	Risk	
			Without mitigation	With mitigation
Land-based Salmon RAS	Ecological Marine	Very High	H	H
		High	H	H
		Moderate	M	M
		Low	M	M
	Ecological Terrestrial	Very High	VH	VH
		High	H	H
		Moderate	M	M
		Low	L	L
	Socio-economic Areas	High	H	H
		Moderate	M	M
		Low	L	L

Ecological		Socio-economic	
Very High	• Formally protected areas • Critically endangered habitats • Important fish nurseries (estuaries)	High	• Important recreational areas • High density urban areas • Commercial ports
High	• Estuaries • Fluvially-derived banks • Aggregation areas • Endangered habitats	Moderate	• Small ports and fishing harbours
Moderate	• Vulnerable habitats	Low	• Cultivated lands
Low	• Least threatened habitats		