Appendix 1.

South African marine bioregions

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1. Introduction

Biogeography is defined as the study of biological life in a spatial and temporal context and is concerned with the analysis and explanation of patterns of distribution (Cox and Moore 1998). An important application of biogeographic studies is the generation of knowledge necessary to achieve adequate and representative conservation of all elements of biodiversity. Conservation of biodiversity pattern requires that a viable proportion of any habitat or species in each biogeographically distinct area is protected, either within a protected area or by management measures that mitigate threats. It is therefore important to realise that any habitat or species in each biogeographic region is seen as distinct and deserving of protection. It is thus recommended that representative marine protected areas need to be established within each principal biogeographic region in South Africa (Hockey and Buxton 1989; Hockey and Branch 1994, 1997; Turpie *et al.* 2000; Roberts *et al*. 2003a; Roberts *et al*. 2003b).

A prerequisite to achieving this goal is, however, a knowledge of where biogeographic regions begin and end. For this project, distinct biogeographic areas with clear boundaries were needed for the South African marine environment. The area of interest was from Lüderitz in Namibia to Inhaca Island in Mozambique.

2. Marine biogeographic patterns in South Africa

Many studies have investigated marine biogeographic patterns around the coast of South Africa (e.g. Stephenson and Stephenson 1972; Brown and Jarman 1978; Emanuel *et al.* 1992; Engledow *et al.* 1992; Stegenga and Bolton 1992; Bustamante and Branch 1996; Bolton and Anderson 1997; Turpie *et al.* 2000; Sink 2001; Bolton *et al.* 2004), but there has been little consensus regarding the names of biologically distinct areas, levels of dissimilarity between regions, region boundaries and the existence of overlap zones.

This lack of consensus is hardly surprising given the nature of the studies to date. Firstly, separate analyses of the distribution of different taxonomic groups and of species from different habitats have yielded contrasting patterns, reflecting different species responses to environmental determinants. Secondly, there have been strong biases in sampling effort (where some taxa have been sampled more intensively and some areas have received much more attention), and this can provide a skewed view of the underlying patterns. Thirdly, patterns are strongly influenced by the ocean depth to which the analysis extends, with different species turnover rates at different depths. Fourthly, there is a lack of single studies that have achieved sampling coverage of the entire South African coastline (Brown and Jarman 1978; Turpie *et al.* 2000). Lastly, different authors have divergent opinions about how to define overlap regions or pinpoint biogeographic breaks, related to a lack of agreed criteria to define and delimit biogeographic units.

What is needed is an integration of all the spatial pattern and process information (biotic and abiotic) currently available in order to arrive at a more definitive, comprehensive and

integrated single description of the biogeography of South Africa's Exclusive Economic Zone (EEZ – 200 nautical miles offshore). In this study, we used two complementary approaches to define marine bioregions for the South African EEZ. The first approach was to summarize and synthesize information available from all existing studies related to biogeographic pattern for South Africa's marine environment. The second approach was to hold expert workshops at which the existing published information could be reviewed and debated, and unpublished data and knowledge of experts could be used to fill gaps, resolve conflicting definitions, interpret and integrate disparate patterns for different taxa and habitats, and define boundaries.

3. Synthesis of existing studies

Provinces and sub-provinces

For all place names please refer to Figure 1.

Stephenson (1939, 1944, 1948) pioneered biogeographic research in South Africa. He recognised three primary biogeographic regions based on the distributions of intertidal species: (i) the cool-temperate west coast; (ii) the warm-temperate south coast, and (iii) the subtropical east coast (Stephenson and Stephenson 1972). His work has provided a broad template that has endured the march of time and the challenge of subsequent efforts. Intertidal work by Brown and Jarman (1978), Emanuel *et al.* (1992) and Bustamante and Branch (1996) also identified three broad biogeographic regions. An analysis of seaweed distributions (Bolton 1986) suggested only two provinces, a warm temperate (with west and south coast components) and a subtropical east coast province. Recent analyses, however, have consistently defined the south coast as an independent province (Emanuel *et al.* 1992; Stegenga and Bolton 1992; Bustamante and Branch 1996). Marine and estuarine fish distributions also reflect three provinces (Turpie *et al.* 2000; Harrison 2002). Shorebird communities in South Africa reflect two major zoogeographical zones, a west coast zone from the Namibian border to Cape Agulhas and a south and east coast zone from Cape Agulhas to the Mozambique border (Hockey *et al.* 1983). However, there were two sectors identified within the latter zone, with a division near the Kei River, and greater bird diversity in the south. A similar pattern is suggested for marine mammals, in that there are several small odontocetes confined to the west coast (including dusky, heavyside's and southern right whale dolphins) and some other species are confined to the east coast (e.g. Indo-Pacific humpback dolphin).

Emanuel *et al.* (1992) further divided the west coast of southern Africa into two separate cool-temperate provinces, the Namaqua and Namib Provinces, with a division near Lüderitz. On the basis of seaweed flora, a third subdivision is recognized on the southern portion of the Cape west coast (Engledow *et al.* 1992; Bolton and Anderson 1997). This is termed the Southwestern Cape sub-province and is more species-rich in terms of seaweeds than the Namib Province or the northern part of the Namaqua Province (Engledow *et al.* 1992; Bolton and Anderson 1997). These authors also identified northern and southern sub-provinces within the Namaqua province with a break near Cape Columbine. This division is also reflected in the zoogeographic analysis of Emanuel *et al.* (1992).

Boundaries and overlaps

Many authors recognise overlap regions between provinces, because biogeographic boundaries are difficult to pinpoint. This is because available species data may indicate large sections of coast (>500 km) with few endemics, and many species may have affinities with more than one province. Stephenson and Stephenson (1972) defined an area of overlap between the cool temperate west coast and the warm temperate south coast. This western overlap extends from Cape Point to Cape Agulhas with a rapid reduction of west coast species between Hermanus and Arniston (Stephenson 1948). This overlap region has been supported by recent studies, particularly those looking at marine benthic flora (Jackelman *et al.* 1991; Stegenga and Bolton 1992).

The east coast has received less attention and there is no consensus regarding the eastern limit of the Agulhas Province, the existence or the position of an overlap region, or the existence and northern limit of the subtropical "Natal" region. Stephenson (1948) identified an eastern overlap area between East London and Durban on the KwaZulu-Natal (KZN) coast, with an important break near Port St Johns. Stephenson and Stephenson (1972) considered the subtropical east coast province to extend all the way from Port St Johns to Mozambique. Jackson (1976) proposed a subtropical province extending from a southern boundary between Port St Johns and Qolora in the Transkei to a northern boundary somewhere between Cape Vidal and Mabibi on the northern KZN coast. Emanuel *et al.* (1992) proposed that the division between the east coast and south coast was south of Port St Johns and recognised an additional break at Durban. Bolton and Anderson (1997) argued against the existence of a subtropical province in KZN because the marine flora reflects an eastwardly decreasing number of temperate south coast Agulhas Province species, replaced largely by Indo-West Pacific species. On these grounds, they suggested that there is an extended overlap region from East London to Mozambique including the entire KZN coast. Turpie *et al.* (2000) reported that coastal fishes do not reflect a clear biogeographic break between the east and south coast provinces, but show a gradual species turnover east of Cape Point.

The northern limit of the subtropical Natal province is also disputed with several scientists placing it in Mozambique. Jackson (1976) showed two areas of change in intertidal communities in northern KZN. The first was in the vicinity of Port Durnford and the second and more prominent change occurred between Cape Vidal and Mabibi. Emanuel *et al.* (1992) found no further breaks north of Durban to at least as far as Ponta da Barra Falsa in Mozambique. One of the problems in defining the northern limit of the subtropical region was inadequate sampling in northern KZN. Stephenson (1972) had only one site in northern KZN near Cape Vidal, Emanuel *et al.*'s analysis was based on data that barely sampled this region and Bustamante and Branch (1996) had only 3 sites east of Dwesa, with only two in KZN. Sink (2001) had 42 rocky shore sites in KZN, 13 between St Lucia and Mozambique, and identified a clear biogeographic break in intertidal community structure (invertebrates and macroalgae) at Cape Vidal. Bolton *et al.* (2004) sampled shallow water seaweeds at two sites north of Cape Vidal and found that these were distinct from those further south. There is also some evidence of a change in echinoderm fauna in the vicinity of St Lucia (Bolton *et al.* 2001). Bolton *et al.* (2004) consider the St Lucia area as a region of major change in the seaweed flora and the area north of this is considered as the southernmost section of the tropical Indo-Pacific floristic region. The subtropical Natal region is not regarded by these authors as a distinct biogeographic province but rather as an extended overlap region with low endemicity and relatively equal

numbers of seaweeds with affinities to the temperate Agulhas and tropical Indo-west Pacific floras.

4. Incorporating current expert knowledge

Expert workshops

Three workshops were held to obtain expert input for identifying appropriate biogeographic boundaries based on the assessment of existing published information and knowledge of specialists in the fields of marine biosystematics, conservation biology, ecology, geology, oceanography and fisheries management (see list of workshop participants at the beginning of the main report). At these workshops the specialists provided up-to-date information on species distribution studies, they mapped geophysical and oceanographic features, they debated the validity of existing published biogeographic boundaries, and identified key ecological processes underlying biotic patterns. These workshops were augmented by interviews with a number of key specialists who added further detail and perspectives (see list of other participants at the beginning of the main report).

Bioregions as biogeographic units

A key problem encountered was the loose and confusing usage of terminology for biogeographic pattern descriptions and units. This is largely because the criteria for defining the difference between provinces and the sub-provinces within these are not explicit and vary amongst the studies, and because of gaps in data that prevent the "strength" of the boundaries to be determined and compared. For the purpose of this systematic conservation planning exercise it was decided that independent new units needed to be used (separate of province or sub-province), which acknowledged the smallest spatial scale at which significant differences in biodiversity pattern could be detected given the information at hand and the expert views available. We decided to use the term bioregions for these independent units, and, along the coastline, these bioregions are relatively discrete stretches of coast within which species composition or community structure is fairly uniform. Disjuncture in either distribution of key species, abrupt changes in the abundance of dominant species or spikes in the turnover of species provided the primary basis for defining boundaries between bioregions. We recognise that some breaks (boundaries) between these bioregions are far more distinct than others and our bioregions represent either biogeographic provinces, sub-provinces or large stretches of coast within which experts argued that biodiversity was sufficiently different to justify defining the area as a bioregion. Thus bioregions represent stretches of coast that in terms of biodiversity pattern can be considered as different from one another, by measurable but differing degrees. The bioregion breaks are likely to be related to oceanographic and geological features but our intention was to derive them principally from biotic patterns.

After preparation of a number of draft versions that were circulated to all participants for comment, nine marine bioregions were identified (Figure 6.3, main report). They spanned the area from the Orange River (Namibian border) to Ponta do Oura (the Mozambican border), between the shoreline to the EEZ. These bioregions include five inshore and four offshore bioregions (see discussion below). The boundaries of these bioregions correspond closely with oceanographic conditions. The west coast is influenced by the cold, relatively slow Benguela current that drifts northwards, and large-scale upwelling is

characteristic along this coast (Brown and Jarman 1978; Branch and Griffiths 1988). On the east coast, the warm Agulhas current is a well-defined intense jet approximately 100 km wide and more than a kilometre deep that moves rapidly down the southeast coast (Shannon 1985; Schumann 1998). Upwelling on the west coast and its virtual absence on the east coast has resulted in a productivity gradient around southern Africa (Shannon 1985; Brown and Cochrane 1991; Brown *et al*. 1991). Large-scale variations in biomass and community composition along the South African coast have been linked to these gradients of primary production and nutrient concentrations (Bustamante *et al.* 1995). Furthermore, depth is a key factor defining biodiversity pattern and it was decided that separate inshore and offshore bioregions were required. Offshore there was less justification for dividing areas into five bioregions, because we assume that habitats are more uniform over larger areas and there is a greater degree of community structure convergence. It should be noted, however, that there is a corresponding paucity of biodiversity information as we move offshore. This is supported by the presence of globally cosmopolitan species in the off-shelf (deeper) habitats and similar fauna offshore on the south coast as occur in the north and south Atlantic (E. Anderson pers. comm.).

5. Nine South African bioregions

Chapters 5 and 6 in the main report provide a summary of the nine bioregions, and figures outlining the positions of the bioregions.

Five inshore marine bioregions that extend from the shoreline to the continental shelf break are recognized (Figure 5.1, pp. 17 main report). The Namaqua bioregion is a cool temperate region that extends from Sylvia Hill in Namibia to Cape Columbine. The South-western Cape bioregion extends from Cape Columbine to Cape Point. The warm temperate Agulhas bioregion incorporates the area from Cape Point to the Mbashe River. The subtropical Natal bioregion extends from the Mbashe River to Cape Vidal, and the tropical Delagoa bioregion extends from Cape Vidal northwards into Mozambique.

Four offshore bioregions extend from the shelf break out to the EEZ (Figures 6.2 and 6.3, pp. 20 main report). The Atlantic offshore bioregion extends from a line southeast of Cape Agulhas up into Namibia and includes both slopes and abyss. The West Indian offshore bioregion includes the slopes from the Atlantic offshore bioregion western boundary to Cape Vidal. The South-west Indian offshore bioregion includes the area north of Cape Vidal, and the Indo-Pacific offshore bioregion includes the abyss of the entire east coast (there is no abyss north of Cape Vidal in the South African EEZ, because we defined abyss as the area deeper than 3500 m, see Figure 6.1, pp. 19 main report). Another bioregion incorporates the Prince Edward Islands, but this bioregion is not dealt with further in this report.

On the west coast, north of South Africa, we recognize the Namib bioregion that extends from just north of Lüderitz at Sylvia Hill to southern Angola. North of this, a subtropical west coast province is recognised (Penrith and Kensley 1970). The Namib, Namaqua and South-western Cape bioregions are components of the cold temperate Benguela system. There is debate as to whether these constitute components of a single large biogeographic province or whether each bioregion represents a discrete biogeographic province. On the east coast, the Agulhas bioregion is the only bioregion identified in the cool temperate Agulhas biogeographic province. The Natal bioregion is subtropical, with a

mix of temperate and tropical species. The Delagoa bioregion is generally considered a component of the large tropical Indo Pacific and it was agreed that further surveys extending throughout the western Indian Ocean are needed to assess properly whether there are several bioregions within this area. Kensley and Penrith (1973) recognised a true tropical east coast province north of central Mozambique. The East African Marine Ecoregion Programme (WWF) currently (2003) recognises four ecoregions along the east coast. The area from Cape Vidal to Bazaruto (encompassing the Delagoa bioregion) is termed the parabolic dune coast. North of this, the inshore waters are turbid and the area from Bazaruto to Angoche is known as the swamp coast. Still further north, the area from Angoche to Lamu in Kenya (including Tanzania) is characterised by extensive true tropical coral reefs and has been named the coral coast. From Lamu to Somalia, coral diversity declines and upwelling causes colder water temperatures. This area is referred to as the monsoon coast.

6. Description of inshore bioregions

6.1. Namaqua Bioregion: Sylvia Hill to Cape Columbine

The Namaqua bioregion is a cool temperate region that extends from Sylvia Hill in Namibia to Cape Columbine. The rationale for the break at Sylvia Hill just north of Lüderitz is that the area constitutes the northern edge of a large upwelling cell. This break is supported by seaweed and invertebrate data and for intertidal and subtidal habitats (Bustamante and Branch 1996; Bolton and Anderson 1997; Emanuel *et al.* 1992; Engledow *et al.* 1992). The Namaqua bioregion is dominated by the cold Benguela Current and is characterized by large-scale intensive upwelling and nutrient rich water. Low oxygen events are a feature of this region. Extensive mud banks are an important characteristic of the Namaqua bioregion. This productive bioregion supports major commercial fisheries including hake trawl and longline fisheries. A significant proportion of the commercial linefish effort occurs within this bioregion.

6.2. South-western Cape Bioregion: Cape Columbine to Cape Point

The shelf in this area is relatively narrow. There is a change in geology at Cape Columbine (granite) and true offshore mud habitat only occurs to the north of this bioregion. Two canyons, the Cape Point Valley and Cape Canyon occur in this bioregion and there is extensive inshore reef development. Eekhout *et al.* (1997, in Harrison 2002) recognized a change in river communities at Cape Columbine. The biological break at Cape Columbine is reflected most strongly in seaweed communities (Engeldow *et al.* 1992; Bolton and Anderson 1997) although intertidal communities also reflect some change in this area (Emanuel *et al.* 1992). It should, however, be noted that in most biogeographic studies that include the cape west coast, the sampling intensity in the vicinity of this Cape Columbine boundary is not as high as that further north.

Further support for the break at Cape Columbine is provided by important environmental differences in this area, between the northern and southern components of the west coast rock lobster fishery (see Griffiths *et al.* in press). The area south of Cape Columbine is less prone to oxygen deficient bottom water that extends close inshore at times causing hypoxic conditions and lobster walkouts. Important commercial fisheries in the South-western Cape bioregion include trawl and longline fisheries for deep water and inshore

hake, as well as the pelagic fishery for pilchard, anchovy and roundherring. This bioregion has the most commercial linefish vessels in the country (Mather *et al.* 2003; Sauer *et al.* 2003). It also supports a shark directed longline fishery.

At the eastern end of the bioregion, the break at Cape Point is very distinct in the inshore and intertidal habitats, but in deeper habitats it cuts obliquely southeastwards so that at a depth of 150m, the boundary is approximately south of Cape Agulhas. This angled line is more consistent with the mixing zone of the Benguela and Agulhas currents, and their associated fish communities. It groups the eastern Agulhas shelf as part of the Agulhas bioregion, and the western area as part of the South-western Cape bioregion. The coastal break at Cape Point is widely accepted in the marine science community and in the literature (Stephenson and Stephenson 1972; Brown and Jarman 1978; Bolton 1986; Emanuel *et al.* 1992; Bustamante and Branch 1996; Turpie *et al.* 2000; Harrison 2002). Cetacean distributions also support the Cape Point boundary with heaviside's and dusky dolphins occurring west of Cape Point, and the Indo-Pacific humpback dolphin occurring in the Indian Ocean, to the east of Cape Point.

6.3. Agulhas Bioregion: Cape Point to the Mbashe River

The Agulhas bioregion incorporates the area from Cape Point to the Mbashe River (in the centre of the former Transkei). During the marine workshops held for this project, the locality chosen for this break was much debated, but the Mbashe River was chosen as the most appropriate boundary between the subtropical Natal province to the north, and the warm temperate Agulhas region to the south.

The warm temperate south coast is widely recognised as an independent province and bioregion (Emanuel *et al.* 1992; Stegenga and Bolton 1992; Bustamante and Branch 1996). The area from Cape Point to Cape Agulhas constitutes an overlap zone with a mixing area of the two currents. The continental shelf is at its widest in the Agulhas bioregion, extending up to 240 km on the Agulhas Bank. There is extensive slumping on the shelf edge. There is a series of reef complexes on the Agulhas Bank including the Alphard Banks, an important fishing ground. The Agulhas bioregion hosts the greatest number of South African endemics including sparid reef fish, octocorals and algae and is a spawning and nursery ground for many species. This bioregion supports numerous important commercial fisheries including the pelagic fishery, trawl fisheries for hake and sole, a trap fishery for the endemic deep-water rock lobster (*Palinurus gilchristi*) and an abalone fishery. Pilchard and anchovy spawn on the Agulhas bank and eggs and larvae are transported up the west coast via the Benguela jet. This is also the only known squid spawning area in South Africa and supports a commercial squid fishery. The horse mackerel stock of the Agulhas Bank is the mainstay of the midwater fishery in South Africa. A shark directed longline fishery also occurs in this bioregion.

The Mbashe boundary was the subject of extensive debate. It was agreed that additional comparative quantitative sampling of invertebrates and algae between Port Edward and the Kei mouth is needed to pinpoint this boundary more accurately. The Mbashe boundary is supported by the work of Beckley and van Ballegooyen (1992) who found a strong inshore subsurface temperature front that maintains a fixed location in the vicinity of the Mbashe system. Upwelling cells are reported to still have a major impact south of the Mbashe and this river marks the distribution limit for abalone (confined to the area south of the Mbashe) and east coast rock lobster (occurs to the north). There is also a clear break

in estuarine fish communities at the Mbashe (Harrison 2002; A. Whitfield pers. comm.). Fennessy *et al.* (2003) found a clear difference in the species composition of linefish catches between the northern and southern Transkei with fish in the north being predominantly subtropical and those in the south comprising mainly warm temperate species.

Other localities put forward as potential boundaries for this bioregion were Waterfall Bluff, Port St Johns, Mbotyi and Woody Cape. Researchers studying the sardine run emphasise that oceanographic conditions change in the area between Lupatana and Waterfall Bluff. Reef scientists detect a change in reef communities at Mbotyi with water visibility declining south of Mbotyi, and this is reflected by the absence of the coral genus *Stylophora*. Cetacean researchers place the break near Woody Cape to correspond with the distribution of Bryde whales and long beak common dolphins. Bolton *et al.* (2004) place the change in seaweed communities south of the Mbashe as their data show that Hluleka belongs in the Agulhas province.

6.4. Natal Bioregion: Mbashe River to Cape Vidal

The Natal bioregion is characterised by shelf widths ranging from less than five to a maximum of 50 km off the Tugela Bank. This area has high riverine input and includes the Thukela River, the largest river system in KZN. The Agulhas Current is the major driving force of the oceanography of the Natal bioregion. The region north of Cape St Lucia and south of Port Shepstone where the shelf is narrowest is strongly influenced by the southward flow of the Agulhas Current with speeds typically > $1 m.s^{-1}$. South of Cape St Lucia where the coastline separates from the shelf edge (the Natal Bight), a dynamically driven upwelling cell exists. This is an important source of nutrients for the Tugela Bank. A cyclonic eddy exists near Durban that causes a northward current to flow at times between Aliwal Shoal and Ballito.

There are many submarine canyons in the Natal Bioregion, for example the Tugela and Goodlad canyons in the north and many more canyons between Port Shepstone and Port St Johns. Reefs occur mainly in the southern and central areas within this bioregion and there is an important deep reef complex along most of this coastline. The commercial linefishery is one of the most important fisheries in this bioregion as there are few alternative resources that can support commercial exploitation. Effort is spread along the entire area as it is largely based on surf-launched vessels whereas west of this region the linefish effort is concentrated around harbours and launch sites. There is an increasing dependence on deep-water species and migratory species (Mather *et al.* 2003; Sauer *et al.* 2003). Reef habitat is limited and major reef complexes include Aliwal Shoal and Protea Banks. The biological communities on the rocky reefs of the Natal bioregion are distinct from the coral communities further north as corals decline with increased turbidity (found further south). The Natal bioregion supports endemic soft corals. The annual sardine run is a feature of the southern portion of the Natal bioregion. KZN has important major estuarine systems including Durban Bay, Richards Bay and the St Lucia system. The Tugela mud banks constitute the only mud belt on the east coast and support unique biotic assemblages. The estuarine and mud habitats also support prawn fisheries offshore and are nursery areas for elasmobranchs and fish.

Several subregions defined by physical characteristics, principally shelf width and fluvial input, were recognised at expert workshops but due to the absence of corresponding

biological pattern differences, these were not delineated as separate bioregions. Suggested additional breaks within this biozone were at Waterfall Bluff (see discussion around Mbashe break), Port Edward, Durban and Port Durnford.

Most biogeographic studies in South Africa have not sampled extensively in northern KZN and the earlier works failed to detect a biogeographic break at Cape Vidal. A clear change in marine community structure at Cape Vidal is however reflected in the intertidal habitat (Sink 2001; Bolton *et al.* 2004). Seagrass and mangrove distribution patterns also support this break. Tropical seabird and cetacean species (such as tropical spinner and Risso's dolphins) occur only south of Cape Vidal.

6.5. Delagoa Bioregion: Inhaca to Cape Vidal

The Delagoa bioregion is characterised by a narrow continental margin, a shallow steep shelf break and the highest density of submarine canyons. The warm Agulhas current is the dominant oceanographic feature and this current flows strongly southward along the narrow shelf. The water is clear as there is little riverine input and inshore reefs are colonized by scleractinian corals. Unconsolidated sediments are primarily medium to fine grained sands and calcium carbonate rich gravel and rubble. Sub aqueous dunes occur on the shelf. The coastline is exposed with zeta (heart-shaped) bays. Leatherback and loggerhead turtle nesting beaches are found only in this bioregion. Rocky shore habitats show a clear break in community structure at Cape Vidal (Sink 2001) and subtidal reef communities change in the vicinity of Leven Point (M. Schleyer pers. comm). There are no commercial fisheries in the South African component of the Delagoa bioregion but southern Mozambique supports commercial fisheries for line fish, pelagic species, sharks and shallow and deepwater crustaceans.

Available information suggests that the Delagoa bioregion includes Inhaca Island and that environmental differences north of Inhaca distinguish this area from the Delagoa bioregion. The WWF East African Marine Ecoregion Programme (2003) refers to this area as the parabolic dune coast and places the northern limit at Bazaruto.

7. Description of Offshore Bioregions

The offshore bioregions are described in Chapter 6 of the main report (pp. 18-20).

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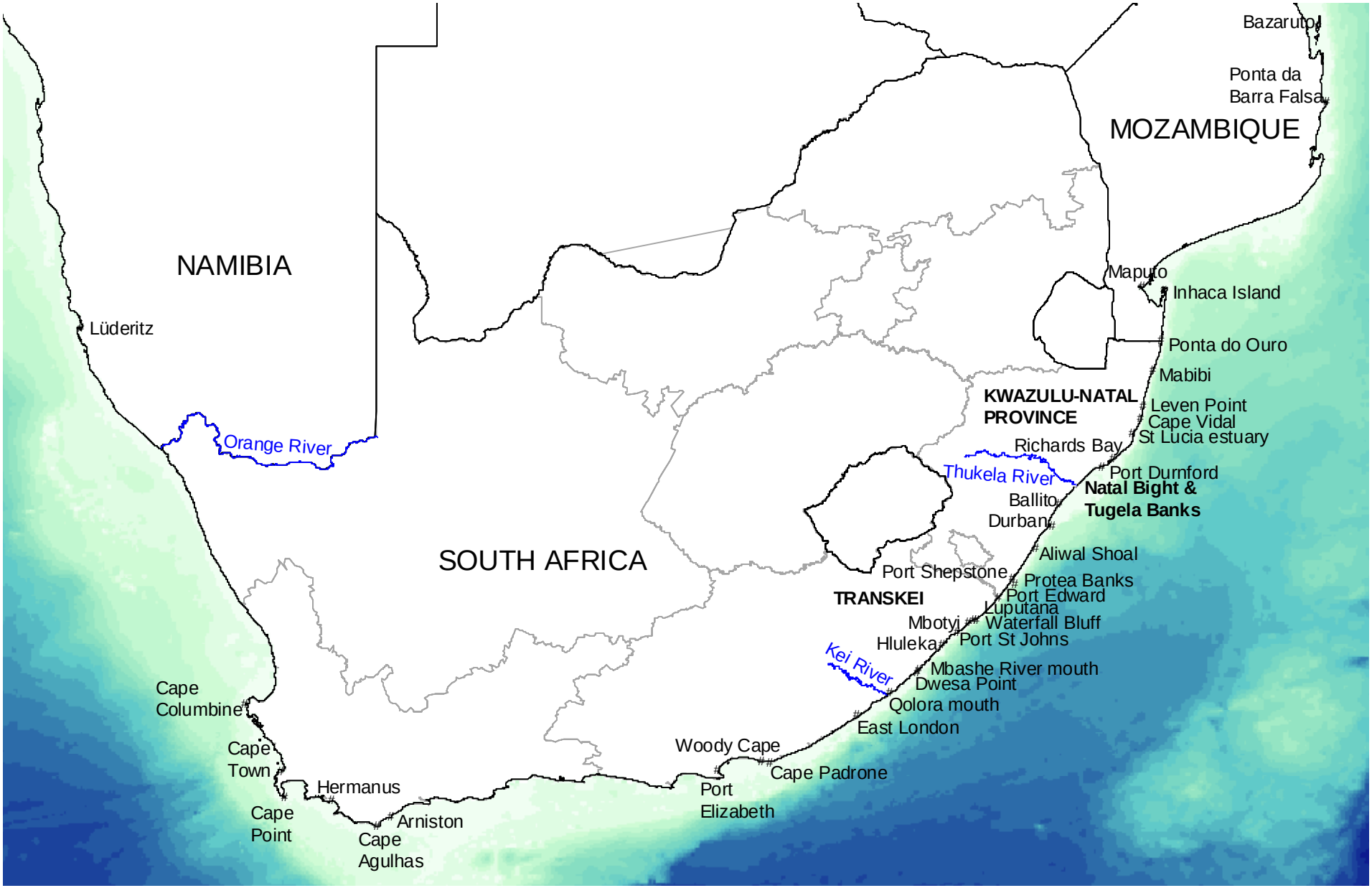

Figure 1. Geographic locations referred to in this Appendix. Offshore bathymetry is shaded in blues.

Appendix 2.

Threats affecting marine biodiversity in South Africa

K. Sink

A list of threats to marine biodiversity in South Africa was compiled on the basis of outcomes from expert workshops, follow-up correspondence and a literature review. These threats were grouped into the nine categories listed in Table 1. Table 2 subdivides these categories into a comprehensive list. Each threat is then discussed further in the rest of the Appendix. B. Mann from the Oceanographic Research Institute (ORI) provided many examples of the species discussed here, and ORI is acknowledged for all photographs, unless otherwise specified.

Table 1. The nine threat categories addressed in this Appendix.

1. Extractive marine living resource use (EMLRU)
2. Pollution
3. Mining
4. Coastal development
5. Climate change
6. Catchment issues (catchment degradation)
7. Non-extractive recreational activities (NERA)
8. Alien invasive species
9. Mariculture

Table 2. A provisional list of threats to marine biodiversity in South Africa.

No.	Category	No.	Subdivision 1	No.	Subdivision 2
1	**Extractive marine living resource use**	1	Commercial exploitation	1	Commercial offshore demersal trawl
				2	Commercial inshore demersal trawl
				3	Commercial slope /seamount trawls (orange roughy)
				4	Commercial shallow water crustacean trawl
				5	Commercial deep water crustacean trawl
				6	Commercial mid water trawl
				7	Commercial pelagic fishery
				8	Commercial pelagic longline (tuna, swordfish)
				9	Commercial shark longline (both pelagic and demersal)
				10	Commercial demersal longline – hake, kingklip
				11	Commercial demersal longline – toothfish
				12	Commercial tuna baitboat
				13	Commercial linefish
				14	Commercial hake handline
				15	Commercial west coast rocklobster
				16	Commercial south coast rocklobster
				17	Commercial Natal rocklobster (and experimental deep water traps)
				18	Commercial squid fishery
				19	Commercial abalone
				20	Commercial rock oyster harvesting
				21	Commercial *Donax* harvesting
				22	Commercial seaweed harvesting - reds
				23	Commercial drift kelp harvesting
				24	Commercial harvest of fresh kelp

No.	Category	No.	Subdivision 1	No.	Subdivision 2
		2	Shark Control Programme		
		3	Recreational fishing	1	Recreational linefish - rock and surf fish
				2	Recreational linefish - skiboat
				3	Recreational estuarine linefish - shore based
				4	Recreational estuarine linefish - boat based
				5	Recreational charter boat industry
				6	Recreational fishing competitions
				7	Recreational west coast rock lobster
				8	Recreational east coast rock lobster
				9	Recreational rock & sand mussels
				10	Recreational oysters
				11	Recreational octopus
				12	Recreational swimming crabs
				13	Recreational alikreukel (*Turbo sarmaticus*)
				14	Recreational bait fishery - fish
				15	Recreational bait fishery - marine worms
				16	Recreational bait fishery - estuarine worms
				17	Recreational baitfisheries - rock crabs (*Plagusia chabrus*)
				18	Recreational bait fishery - redbait
				19	Recreational bait fishery - rocky shore
				20	Recreational bait fishery - sandy beach
				21	Recreational bait fishery - estuarine sand and mudprawn
				22	Recreational spearfishing
		4	Subsistence and small scale commercial use	1	Small scale motorized boats linefish
				2	Small scale non-motorized boats linefish

No.	Category	No.	Subdivision 1	No.	Subdivision 2
				3	Small scale gillnet and seine-net fishery
				4	Small scale shore-based rod and handline fishery
				5	Small scale rocky-shore intertidal benthic invertebrates
				6	Small scale sandy-beach invertebrates
				7	Small scale subtidal invertebrates
				8	Small scale kelps and seaweeds
				9	Small scale estuarine benthic invertebrates
				10	Small scale estuarine seine- and cast-nets
				11	Small scale estuarine gillnets
				12	Small scale estuarine trap-fishery
				13	Small scale estuarine shore-based rod and handline
				14	Small scale swimming crabs
		5	Illegal fishing/poaching	1	Illegal demersal longlining - hake and kingklip
				2	Illegal toothfish fishing
				3	Illegal pelagic longlining
				4	Illegal - linefish (boat & shore based angling)
				5	Illegal - FADS (fish aggregating devices)
				6	Illegal - west coast and deep sea rock lobsters
				7	Illegal - abalone
				8	Illegal - east coast rock lobster
				9	Illegal - intertidal shellfish/rockstripping
				10	Illegal - estuarine gillnets
		6	Aquarium trade		
		7	Ornamental shell trade		
		8	Magico-medicinal trade		
		9	Mangrove harvesting		

No.	Category	No.	Subdivision 1
2	**Pollution**	1	Shipping
		2	Catastrophic oil pollution
		3	Chronic oil spills (persistent)
		4	Pipelines
		5	Outfalls (storm water and sewerage etc.) - bacteria
		6	Outfalls - eutrophication
		7	River/stream/estuarine discharge - pollution/eutrophication
		8	Nuclear waste disposal
		9	Plastic pollution
		10	Entanglement
		11	Persistent organochlorine pollutants in dolphins (the levels in East Coast dolphins approach some of those in the Northern Hemisphere)
3	**Mining**	1	Sand winning
		2	Fossil fuel mining
		3	Titanium (RBM) mining
		4	Diamond mining
		5	Phosphate mining
4	**Coastal development**	1	Coastal infrastructure - cities, towns, housing, roads
		2	Infrastructure - tourism
		3	Dredging activities and disposal of sediments
		4	Harbours and launch sites
5	**Climate change**		
6	**Catchment issues (catchment degradation)**	1	Freshwater abstraction
		2	Siltation

No.	Category	No.	Subdivision 1
7	**Non-extractive recreational activities**	1	Coastal trails
		2	Off road vehicles
		3	Land based marine ecotourism - e.g. turtles, bird colonies
		4	Boat based ecotourism - e.g. whales, dolphins
		5	Diver based - e.g. scuba divers, cage diving
8	**Alien invasive species**	1	Alien species - *Mytilus galloprovincialis*
		2	Alien species - *Carcinus maenas*
		3	Alien species - *Littorina saxatilis* (Langebaan Lagoon)
		4	Alien species - *Sagartia ornata* (Langebaan Lagoon)
		5	Alien species - new marine
		6	Alien species - vegetation
9	**Mariculture**	1	Mariculture - European mussel *Mytilus galloprovincialis*
		2	Mariculture - oysters
		3	Mariculture - abalone *Haliotis midae*
		4	Mariculture - algae (Rob)
		5	Mariculture - prawns Amatikulu
		6	Mariculture - finfish - Turbot and salmon
		7	New mariculture operations

1. Extractive marine living resource use

Direct exploitation and its associated impacts constitute one of the most serious threats to marine biodiversity in South Africa. This includes commercial exploitation, control programmes, small scale commercial and subsistence fisheries, recreational exploitation, illegal harvesting and trade in marine species for ornamental, medicinal or construction purposes.

Direct impacts

The effects of extractive marine living resource use include both direct and indirect impacts. In South Africa, the direct effects of exploitation have included dramatic declines in the populations of some targeted species. Southern Right Whales were estimated to have been reduced from 20 000 individuals to as few as 35-68 mature females in the 1930s, but have now recovered to over 3 000 individuals. Many important linefish species have been reduced to a point where population size and catch per unit effort are less than 10% of pristine value. Amongst invertebrates, populations of rock lobster and abalone are greatly reduced from historical values, as are those of mussels in some areas. Despite this, no marine species has been recorded as having been driven to extinction in the region. Global marine extinctions include the Stellar seacow, the west Indian monk seal and the Atlantic eelgrass limpet. Seamount fishing is of particular concern, as many seamounts support endemic species that can easily be eliminated by fishing activities. The biodiversity of South Africa's seamounts is relatively unknown.

Indirect impacts

Four major indirect effects of fishing threaten marine biodiversity: (i) alteration to the benthic environment; (ii) incidental mortality on non-target species; (iii) changes in community structure and ecosystem functioning; and (iv) changes to gene pools. These indirect fishing impacts have received little attention in South Africa and there are often no baseline data to assess these effects locally.

(i) Alteration to the benthic environment

Some fisheries are known to alter the benthic environment physically. Bottom (or demersal) trawling has been shown to transform habitats elsewhere, but has not been examined in South Africa. One of the key problems in assessing trawl impacts worldwide is the lack of adequate control areas – for example, pristine soft-bottom habitat in which to measure the normal abundance of biogenic habitat in soft sediments. Trawling on the shelf slope is a concern as it could result in landslides or slope collapse, which could have a significant impact on the diversity of this poorly known habitat. In South Africa, there is concern that all trawlable grounds on the west and south coast have already been damaged. On the east coast, there are only three main areas that provide significant habitat for prawns in South Africa: the Tugela Bank, and specific areas off Richards Bay and St Lucia. All of these have been trawled.

(ii) Bycatch and incidental mortality of non-target species

The direct impact of most fisheries is not confined to the target species but also includes a bycatch. Non-target species can be retained and sold in which case they would contribute to the commercial viability of the fishery. The less selective the fishery, the greater the bycatch – trawl fishing has the greatest bycatch. Some non-target species may have no commercial value and may be discarded. Changing markets have caused some bycatch species to become valuable. In South Africa this has occurred with kingklip, swordfish and sharks. Bycatch should be considered as a component of the catch and differs from incidental mortalities. Incidental mortalities result from other components of the fishery such as sea bird or marine mammal mortality, sometimes referred to as "bykill". South African fisheries with bykill include longlining. Fisheries that are prone to gear loss can pose a threat to marine biodiversity. This is termed "ghost fishing" and occurs when traps (rock lobster and fish traps) and nets (especially gill nets) are lost at sea and continue to trap animals.

(iii) Changes in community structure and ecosystem functioning

Another indirect impact of fisheries is the ripple effect that can occur through food chains. The fishery with the greatest perceived ecosystem impact is the pelagic fishery, because small pelagic fishes are an ecologically important link in marine food webs. They are abundant and occupy an intermediate trophic level position, exerting bottom-up control of predators and top-down control of zooplankton. As a food source for larger fish, seabirds and marine mammals, their collapse has led to sharp declines in marine bird and mammal populations elsewhere. In South Africa, over-fishing of species like sardine and the subsequent "sardine collapse" led to declines in African penguin populations. Fishing of top predators such as sharks is also likely to result in ecosystem impacts. Modelling studies have indicated that reef ecosystems in KwaZulu-Natal are also markedly different from their pristine states due to the ecosystem effects of reef fishing. Management has only just begun to take ecosystem impacts into account.

(iv) Genetic effects

Because many fisheries are highly selective, fishing can influence the genetic complement of a stock. For example in the Southern African pelagic fishery, selective fishing in the primary reproductive habitat of sardines and the removal of individuals with strong affinities for that habitat has been linked to a spatial change in the primary breeding areas of this species.

South African Fisheries

Three fishing sectors need to be considered

(i) The commercial sector

Commercial fishers have permits to catch fish to sell. The sector includes large-scale trawl and longlining fisheries, pelagic purse seining, rock lobster fisheries and the commercial component of the line-fishery.

(ii) The recreational sector

Recreational fishers fish for fun, sport or personal consumption. They are not allowed to sell, earn money from, or exchange their fish for a consideration. They require a permit to fish. This sector includes the recreational component of the linefishery, the harvesting of intertidal species such as mussels and octopus, and recreational crayfish harvesting.

(iii) The subsistence and small-scale commercial sector

These fishers are now a formally recognised sector, with management procedures including permit systems, allocation procedures and monitoring. The sector is in its development phase in South Africa.

Fishing methods and conservation issues

(i) Linefishing

Linefishing is boat-based fishing using handlines, rods or poles. This is a very selective method with little bycatch. However, when fish are caught that cannot be sold (protected or recreational species, or fish below size limits), they cannot be retained and are just discarded. The South African linefishery was declared in a state of emergency in 2000 and urgently requires attention.

(ii) Longlining

Longlining is offshore fishing using a main line with several branch lines set with baited hooks. Longlines can be up to 100km long with as many as 20 000 baited hooks. Target species in South Africa include tuna, swordfish and hake. There is a problem with incidental mortality of seabirds with many longline fisheries. Some fisheries do employ methods to reduce bird mortality.

(iii) Trawling

Trawling is a non-selective method that involves dragging a funnel-shaped net through the water or along the seabed. Trawled species in South Africa include hake, kingklip and sole on the west and south coasts, and prawns and crab on the east coast. Demersal trawling can alter the seabed and may have a substantial bycatch. Prawn trawling is one of the fishing sectors with the highest discarded catch, accounting for one third of global discarded catch. Midwater trawling is more selective and does not affect the seabed.

(iv) Purse seining

Purse seining involves the use of a large net to encircle shoaling fish. The net is drawn closed around the shoal. South African fish caught using this method include sardines, anchovy and mackerel. Tuna purse seining is not practiced in South Africa but in some countries it results in the incidental mortality of dolphins.

(v) Gill nets

Gillnetting is illegal in South Africa with the exception of the Natal Sharks Board's shark control fishery and the small-scale commercial fisheries on the west coast. Gillnetting is unselective and usually has a substantial bycatch. Smaller mesh sizes incur greater bycatch. Ghost fishing is a problem when gill nets are lost.

(vi)Traps and pots

Traps and pots are cages or baskets set with bait that then serve to trap rock lobster or crabs. Ghost fishing is an issue for some trap fisheries, particularly deepwater rock lobster fisheries.

Fisheries management

Most South African fisheries are managed with catch or effort limits. A TAC (Total Allowable Catch) is used to limit the catch of several commercial fisheries. The TAC is the absolute amount of a resource that may be harvested in a given period. This is usually recalculated each year using mathematical models based on many years of data to assess stocks. Seven South African fisheries are managed with TACs: deep sea hake; inshore hake; longline hake; pelagic purse seine; west and south coast rock lobster; and abalone. Effort limitations restrict the number of people participating in a fishery. South Africa's commercial linefishery and squid fishery are examples of effort-limited fisheries.

1.1. Commercial exploitation

There is no comprehensive list of all marine species used commercially in South Africa and this needs to be compiled. We listed a total of 26 commercial operations that are based on extractive marine living resource use (Table 3). For additional information on these fisheries, see Table 4.

Figure 1: A prawn trawler operating off the Tugela Banks in KwaZulu-Natal.

Figure 2: Woman harvest intertidal oysters along the KwaZulu-Natal coast as part of a small commercial fishery.

Table 3. Commercial fisheries or marine living resource harvesting operations in South Africa. Fisheries managed using a TAC (Total allowable catch) are indicated (+). Fisheries with known impacts on the benthic environment (a), significant bycatch or incidental mortalities (b) and potential significant ecosystem impacts (c) are also identified (+).

	Fishery	**TAC**	**(a) Habitat Change**	**(b) Bycatch/ incidental mortality**	**(c) Ecosystem impacts**
1	Commercial offshore demersal trawl	+	+	+	
2	Commercial inshore demersal trawl	+	+	+	
3	Commercial slope /seamount trawl	+	+	+	
4	Commercial shallow-water crustacean trawl		+	+	
5	Commercial deepwater crustacean trawl		+	+	+
6	Commercial midwater trawl	+		+	
7	Commercial pelagic purse-seine fishery	+			+
8	Commercial pelagic longline	+		+	+
9	Commercial shark longline	+		+	+
10	Commercial demersal longline – hake, kingklip	+		+	
11	Commercial demersal longline – toothfish	+		+	
12	Commercial tuna poling				
13	Commercial linefish				+
14	Commercial hake handline				
15	Commercial trap fishery (experimental)				
16	Commercial West coast rock lobster	+			
17	Commercial South coast rock lobster	+			
18	Commercial Natal rock lobster (experimental)	+			
19	Commercial squid fishery				
20	Commercial abalone fishery	+			
21	Commercial octopus fishery				
22	Commercial rock oyster harvesting		+		
23	Commercial *Donax* harvesting				
24	Commercial seaweed harvesting – reds				
25	Commercial drift kelp harvesting				
26	Commercial harvest of fresh kelp				

Table 4. Target species, bycatch species and threats posed by commercial fisheries.

	Fishery	Target species
1	Commercial offshore demersal trawl	Target species include deep and shallow water hake. There are a large number of associated bycatch species, some of which are retained e.g. horse mackerel, chub mackerel, snoek, monkfish and kingklip, and others are dumped as "trash fish" e.g. various elasmobranchs and rattails. All demersal trawls have an associated impact on the seabed.
2	Commercial inshore demersal trawl	Target species include primarily soles, panga and squid, but there is a high associated bycatch of various elasmobranchs. Bycatch of silver kob overlaps with the linefishery.
3	Commercial slope /seamount trawl	Target species include orange roughy and oreos. Slow growth rate in these species leads to rapid extermination of stocks.
4	Commercial shallow-water crustacean trawl	Target species include penaeid prawns, but a very high associated bycatch exists, consisting mainly of sciaenids and elasmobranchs and sometimes turtles. Squaretail kob bycatch overlaps with the linefishery.
5	Commercial deepwater crustacean trawl	Target species include pink prawns, langoustines, deepwater rock lobster, deepwater crabs and a high associated bycatch exists of species such as rattails, splitfins, greeneyes and various elasmobranchs.
6	Commercial midwater trawl	Target species include horse mackerel, chub mackerel, snoek and sauries.
7	Commercial pelagic purse-seine fishery	Main target species include pilchards and anchovies but chub mackerel, sardinellas and round herring are also targeted.
8	Commercial pelagic longline	Target species include longfin tuna, yellowfin tuna, bigeye tuna, skipjack tuna, southern bluefin tuna, swordfish, other billfish and pelagic sharks. There is also much concern regarding the incidental mortality of seabirds especially albatrosses and petrels in this fishery.
9	Commercial shark longline	Primary targets are soupfin sharks and bronze whalers but other shark species are also taken and the international market is increasing. Stocks of soupfin sharks have been substantially depleted.
10	Commercial demersal longline	Target species are kingklip and hake but there is a high associated bycatch, particularly of elasmobranch species. Seabird mortalities associated with this form of longlining are also a major concern.
11	Southern Ocean commercial demersal longline	This type of fishery targets Patagonian toothfish off the Prince Edward and Marion Islands. Slow growth rates lead to rapid extermination of stocks.
12	Commercial tuna poling	Main target species include longfin and yellowfin tuna but snoek and Cape yellowtail are also targeted.

	Fishery	Target species
13	Commercial linefish	A large number of species are targeted but snoek, silver kob, hottentot, yellowtail, carpenter, geelbek and slinger comprise the bulk of the catch. Substantial declines in the abundance of certain species of linefish, particularly endemic reef fish species, resulted in the Minister declaring a state of emergency in the linefishery in 2000.
14	Commercial hake handline	The target here is shallow water hake but large catches of silver kob and carpenter also occur at certain times of the year.
16	Commercial west coast rock lobster	*Jasus lalandii* is caught using traps and hoop nets. Stocks have been greatly reduced from pristine levels.
17	Commercial south coast rock lobster	This entails deep water trap fishing of *Palinurus gilchristi*. There is also the problem of ghost fishing with traps that are lost.
18	Commercial east coast deepwater rock lobster	There is an experimental deepwater trap fishery of *Palinurus delagoae*. Some associated bycatch includes the deepwater crabs and various fish species.
19	Commercial squid fishery	The main target species is *Loligo vulgaris reynaudii*. Squid are targeted at night on spawning aggregations using chokka jigs. Squid also form part of the catch of the inshore demersal trawl fishery. *Loligo duvaucelii* is taken as a retained bycatch in the shallow water trawl fishery on the east coast.
20	Commercial abalone fishery	*Haliotis midae* – South Africa's most threatened exploited species due to extensive illegal harvesting.
22	Commercial rock oyster harvesting	*Striostrea margaritacea* is harvested intertidally along the KwaZulu-Natal coast. Some incidental mortality and habitat alteration occurs through harvesting with crowbars.
23	Commercial white mussel harvesting	The target species is *Donax serra.*
26	Commercial seaweed harvesting	The main genus harvested is *Gelidium sp.*, primarily along the Eastern Cape coast.

The commercial linefishery - in a state of emergency

There are serious problems within the South African linefishery and urgent management action is needed.

Figure 3: A typical day's catch of small reef fish taken on a commercial ski-boat on the lower KwaZulu-Natal south coast.

Reef associated fish targeted by this fishery include species from the seabream (Sparidae), rockcod (Serranidae), emperor (Lethrinidae) and snapper (Lutjanidae) families. Unlike more pelagic species, most reef-associated fish have a limited geographic range, have far less habitat available to them and many are highly resident. They are easily fished out from any reefs where bottom fishing is permitted. Many such fish have complicated life histories, mature at a late stage, grow slowly and often change sex. They also suffer from barotrauma – when they are caught in deepwater and brought to the surface, their swimbladders expand and the fish is "blown". These characteristics make these reef-associated species highly vulnerable to over-fishing. Many of our reef-associated fish are endemic to the South African coast, which leaves us with the sole responsibility of ensuring the future of these fish.

The Minister of Environmental Affairs and Tourism declared a state of emergency in South Africa's linefishery in December 2000. New management plans are currently being developed – these are aimed at rebuilding fish stocks and reducing fishing effort where necessary. The poor state of linefish is attributed to 3 factors:

1. the vulnerable life-history of many species
2. unrestricted fishing effort
3. poor compliance with existing legislation

1.2. Shark Control Programme

The Natal Sharks Board's gillnetting operation aimed at reducing shark populations in KwaZulu-Natal to diminish the risk of shark attack constitutes the only control program for a marine species in South Africa. A large variety of elasmobranch species are captured by the Natal Sharks Board in large-mesh gillnets set along some of KwaZulu-Natal's popular bathing beaches. Incidental by-catch of rays, large teleosts, turtles and dolphins and other marine mammals also occurs. There is specific concern about the impact of the shark nets on the Indo-Pacific Humpback Dolphin *Sousa chinensis*, population estimates of which are below 200 in KwaZulu-Natal. The Natal Sharks Board is currently assessing the use of drum-lines (baited hooks) which are more selective than gillnets as an option for shark control. Net numbers have been reduced in recent years and nets are removed during the annual sardine run. Nevertheless the removal of large numbers of top predators by this inshore fishery may have resulted in significant ecosystem impacts. It also adds to the already severe pressure on elasmobranchs from other fisheries, particularly longlining and trawl fisheries.

1.3. Recreational fishing

Recreational use of marine resources in South Africa is extensive and targets many species, with at least 14 different recreational fisheries currently operating along our shores (Table 5). There is no comprehensive list of species targeted by these fisheries. During this assessment, particular concern was expressed for linefisheries including shore angling, boat-based angling, the charter boat industry and fishing competitions. There is no comprehensive list of fishing competitions and critical linefish species are being targeted for large rewards in some angling events. The practice of allowing competitions within MPAs is controversial. Other fisheries raising special concern include some baitfisheries, particularly those targeting worms and involving habitat destruction (by removing other biota, disrupting sediment, or using chemicals). For more detail on these fisheries see Table 5.

Table 5. Recreational fishing and collecting in South Africa.
(Note: all forms of recreational use of marine resources is subject to annual permitting).

	Fishery	**Target species**
1	Recreational linefish – shore (rock and surf fish)	A large number of different species are captured and they vary regionally. However, main species harvested by shore anglers include shad/elf, strepie, blacktail, galjoen, piggy, southern mullet, silver kob, white steenbras, white stumpnose, hottentot, dusky kob, stonebream, bronze bream, white musselcracker, dusky sharks and copper sharks. Some species have been overexploited and are strictly managed.
2	Recreational linefish – offshore (skiboat)	Recreational boat anglers catch an even greater variety of linefish including pelagic gamefish (e.g. scombrids, carangids), demersal migrants (e.g. silver and dusky kob, geelbek) and reef fish (e.g. sparids, serranids, lutjanids, lethrinids). A number of species have been critically overexploited and severe restrictions are required to rebuild stocks.
3	Recreational estuarine linefish – shore based	Again species vary regionally but the main target species include spotted grunter, dusky kob, white stumpnose, Natal stumpnose, riverbream, southern mullet, garrick/leervis. There has been considerable habitat degradation in most of South Africa's estuaries and some estuarine-dependent species are overexploited.
4	Recreational estuarine linefish – boat-based	Same as above.
5	Recreational charter-boat fishing	This sector targets both gamefish and reef fish species as described for the recreational skiboat fishery.
6	Recreational fishing competitions	Competitions are held in all sectors of the recreational linefishery and all the species described above are targeted.
7	Recreational west coast rock lobster *(Jasus lalandii)*	Recreational collection by free-diving and hoop nets is allowed subject to strict regulations.
8	Recreational east coast rock lobster (*Panulirus homarus)*	Recreational collection by free-diving and use of certain traps is allowed subject to strict regulation. No sale or commercial harvesting of this species is allowed and the stock is still believed to be in a relatively good condition.
9	Recreational mussels	Brown mussels, black mussels and Mediterranean mussels are harvested intertidally by recreational collectors.
10	Recreational oysters	Rock oysters such as the Cape and Natal rock oysters are harvested intertidally by recreational collectors.
11	Recreational octopus	Common octopus are harvested intertidally by recreational collectors.
12	Recreational swimming crabs	Estuarine mud crabs may be harvested by recreational collectors in estuaries, subject to strict regulations.
13	Recreational bait fishery	Recreational anglers harvest a number of different

	Fishery	Target species
		kinds of bait from various habitats. Along the seashore baitfish such as mullet, strepies and sardines are caught using a cast net. In estuaries these include mullet and swimming prawns caught by cast-net, and blood worms and burrowing prawns (i.e. sand and mud prawn) caught using a prawn pump. On rocky shores molluscs, ascidians, polychaete worms, crustaceans, mussels, siffies, octopus, red bait, mussel worm and rock crabs are collected for bait. Along sandy beaches white mussels, ghost crabs and mole crabs are also collected for bait.
14	Recreational spearfishing	A variety of reef fish (e.g. rockcod, bronze bream, knifejaws, baardman, roman) and gamefish (e.g. garrick, yellowtail, queen mackerel, king mackerel, kingfish) are targeted. Again some species, especially those that overlap with other sectors of the linefishery, have been overexploited.

Figure 4: Recreational anglers fishing off Nyoni Rocks near Amanzimtoti in KwaZulu-Natal.

1.4. Subsistence and small-scale commercial use

We list 14 types of small scale commercial or subsistence fisheries in South Africa (Table 6). It was not possible to separate these two sectors at present, although several scientists and managers requested that they should be treated separately.

Table 6. Subsistence and small-scale commercial (artisanal) use in South Africa.

	Fishery	Target species
1	Small-scale motorized boats – linefish	This form of fishing takes place predominantly on the West Cape coast and target species are snoek and hottentot.
2	Small-scale non-motorized boats – linefish	As above.
3	Small-scale gillnet and seine-net fishery	These net fisheries are primarily situated along the West Cape coast and in False Bay. Gillnet fisheries mainly target southern mullet (haarders) and larger mesh nets are used to target St Joseph sharks. Seine or trek-nets are used to target mullet, yellowtail, horse mackerel (maasbanker), elf/shad, white steenbras and silver kob.
4	Small-scale shore-based rod and handline fishery	Catch is similar to the recreational shore fishery but small, easily caught species are heavily targeted such as strepies, mullet, blacktail, piggy, banded galjoen and Cape stumpnose.
5	Small-scale rocky-shore intertidal benthic invertebrates	The species harvested vary regionally but most common species include mussels, oysters, red bait, limpets, octopus, and chitons.
6	Small-scale sandy-beach invertebrates	Mainly ghost crabs and mole crabs harvested in northern KwaZulu-Natal.
7	Small-scale subtidal invertebrates	Mainly east coast rock lobster harvested in the former Transkei and illegally in KwaZulu-Natal.
8	Small-scale kelps and seaweeds	Same as for commercial seaweed harvesting
9	Small-scale estuarine benthic invertebrates	These primarily include bait species harvested for sale such as sand and mud prawns. Mangrove crabs are harvested for subsistence in Kosi estuary.
10	Small-scale estuarine seine- and cast-nets	Mullet and swimming prawns are the main target species.
11	Small-scale estuarine gillnets	Mullet are the most important species targeted, especially along the West Coast. In KZN other species such as pouters, tilapia, spotted grunter, dusky kob and sharptooth catfish are also collected in this way.
12	Small-scale estuarine trap-fishery	Traditional fish traps (fish kraals) are used by local people to harvest fish in Kosi Bay. The main target species include mullet, spotted grunter and pouter.
13	Small-scale estuarine shore-based rod and handline	Species targeted are similar to the recreational estuarine fishery but are generally smaller, more abundant species such as pouter and Cape stumpnose.
14	Small-scale swimming crabs	This is mainly a small fishery for estuarine mud crabs in Richards Bay (currently not operating).

Figure 5: An artisanal fisherman collects his catch from a fish kraal in Kosi Bay, northern KwaZulu-Natal.

Figure 6: Sardines caught in a beach seine net during the sardine run along the KwaZulu-Natal coast.

1.5. Illegal fishing/poaching

Although most potential resource species are harvested illegally to some extent we identified ten specific illegal fishing operations (Table 7). Although it is difficult to assess the extent, frequency and impact of these illegal activities, it is clear that these activities threaten marine biodiversity in South Africa.

Large scale organised operations such as illegal toothfish or pelagic longlining operations pose a serious threat to marine biodiversity. FADS (fish aggregating devices) and artificial reefs pose a pollution threat (and can also incur significant costs to the maritime industry) and may increase access to otherwise inaccessible resources. FADS target species such as dorado, the status of which is unknown. Sharks emerged as a group that is threatened by illegal fishing. Recreational species are being targeted and sold. Small sharks are also being targeted for sale to shark ecotourism operators who use them for baiting large sharks.

Table 7. Illegal fishing / poaching in South Africa.
(Note that species targeted by illegal fishing are generally the same as those described in other types of fishing, as far as specific gear type and habitat are concerned).

	Fishery	**Target species**
1	Illegal demersal longlining - hake and kingklip	
2	Illegal toothfish fishing	
3	Illegal pelagic longlining	
4	Illegal linefishing	
5	Illegal FADS (fish aggregating devices)	These structures are used primarily by recreational skiboat anglers to attract species such as dorado and cobia.
6	Illegal – west coast and deep sea rock lobsters	
7	Illegal abalone poaching	
8	Illegal east coast rock lobster poaching	
9	Illegal intertidal shellfish / rockstripping	
10	Illegal gill and seine-netting	A large amount of illegal gillnetting for galjoen occurs along the Cape west coast. Much illegal gillnetting occurs in St Lucia and Kosi Bay, targeting fish species such as spotted grunter. Illegal seine-netting in St Lucia targets swimming prawns.

1.6. Aquarium trade

The trade in marine aquarium species is growing. The marine biodiversity working group at MCM has flagged this trade for assessment in South Africa. The Oceanographic Research Institute is currently investigating some aspects of this trade in KZN. Main fish species harvested for the aquarium trade include Pomacentrids (e.g. clown fish), Serranids (e.g. sea goldies), Labrids (wrasses), Chaetodontids (butterfly fishes), Pomacanthids (angel fishes) and Gobiids (gobies). Aquarium fish collecting is focused mainly on the east coast and comprises primarily Indo-Pacific species at the southernmost limits of their distribution. Imports of aquarium fish exceed numbers harvested locally. Some popular aquarium species such as the endemic Knysna seahorse are locally threatened due to habitat degradation.

Figure 7. The Knysna seahorse, *Hippocampus capensis*.

1.7. Ornamental shell trade

Most of the ornamental shell trade in South Africa comprises imported shells, but little information is available about the extent and impact of this trade on local species. Several specimens have high market value and may be under threat. There have been problems with commercial shell traders dredging for shells using research permits. High value specimens also disappeared from the South African museum mollusc collection. Several scientists expressed concern about localised species for sale in curio shops in coastal towns.

1.8. Magico-medicinal trade

At least 60 marine species are used by traditional medicine men, herbalists, sangomas, animal product traders and their customers in the magico-medicinal trade in South Africa. These were recorded from markets in KwaZulu-Natal and the former Transkei. One species of concern is the endemic chiton (*Chiton salihafui*) known only from three rocky shores in the Greater St Lucia Wetland Park.

1.9. Mangrove harvesting

In South Africa mangroves are harvested at Kosi Bay in the Greater St Lucia Wetland Park and there is some harvesting in Richards Bay. White, red and black mangrove trees are harvested for their wood, which is very durable. At Kosi Bay mangroves are harvested for building materials and for construction of fish traps. This threat is increasing in this area due to the phasing out of gillnetting. Extensive mangrove cutting is considered a problem in many of the former Transkei estuaries, particularly the Mngazana, Mtata, Xora and Mntafufu.

2. Pollution

Pollution information was limited and there was little expertise in this field at our workshops. Pollution reports were also not available at MCM. Nine pollution threats were however identified during the NSBA project (Table 8). Overall, pollution was considered the second most serious threat to marine biodiversity.

Table 8. Nine categories of pollution identified as threats to marine biodiversity in South Africa.

1	Catastrophic oil pollution
2	Chronic oil pollution
3	Shipping
4	Pipelines
5	Outfalls (including eutrophication effects)
6	Dredge disposal
7	Nuclear waste disposal
8	Plastic pollution
9	Ghost fishing

The threat of oil pollution was considered as one of the most severe and extensive pollution threats to marine biodiversity. Catastrophic oil pollution is an ongoing threat as this region includes important shipping routes and maritime traffic is extensive. Oil spills impact on shorelines and foul the fur and feathers of seals and seabirds respectively. The African penguin (*Spheniscus demersus*) is particularly threatened by oil spills. South African coral reefs have not been damaged by oil pollution and are less vulnerable than other reefs owing to their depth. Catastrophic oil pollution has intermittently impacted marine biodiversity in the past 50 years although improved legislation and clean-up procedures have reduced incidents in recent times.

Shipping and its associated impacts were identified as a significant threat to marine biodiversity. Noise pollution is a concern for marine mammals. SAMSA (the South African Marine Shipping Association) has developed PSSAs - Particularly Sensitive Sea Areas, which are being proclaimed with their legislation.

The South African marine science community has some concern over the pollution threat posed by the disposal of materials at sea including pipelines, outfalls and dredge disposal. At least 61 pipelines occur along the South African coast. Storm water and sewerage outfalls pose a threat to biodiversity in terms of the introduction of bacteria and pollutants, as well as causing eutrophication. By international standards, there are relatively few marine outfalls along the South African coastline and the impact of these is thought to be relatively localized.

Toxic compounds in the South African marine environment include a diversity of industrial waste products such as heavy metals, petroleum products and halogenated hydrocarbons. These can lead to infections and disease in marine biota. Heavy metals accumulate in food chains and top predators

are most vulnerable. Organochlorines are having an effect on bottlenose and humpback dolphins on the east coast. DDT has been used in malaria control programs for many years in northern KZN and its continued use threatens biodiversity.

Increased organic loading (e.g. from sewerage effluent or food processing plants) can lead to unhealthy levels of bacteria (causing infections in marine life), eutrophication and anoxia. Increased frequencies and intensities of noxious red tides have been linked to anthropogenic eutrophication. Sheltered bays are more susceptible to organic overloading. Nutrient loading and eutrophication have been cited as a serious threat to coral reef ecosystems and have been linked to increased cover of macro-algae and declining coral cover in some countries. There have been no documented impacts related to changes in runoff or sedimentation in South African reefs to date.

The dumping of dredge spoil threatens subtidal habitats and biodiversity. Suspension of fine sediments can be toxic and increased turbidity can depress phytoplankton production and impact on photosynthetic communities including algal beds and coral reefs.

In South Africa, plastic constitutes approximately 90% of marine litter and this threatens marine biota, particularly seabirds, turtles and marine mammals which are at risk from plastic ingestion and entanglement. Other types of pollution that result in entanglement includes lost or disposed fishing gear. A problem was reported that discarded fishing tackle was having a significant negative impact on coral communities in the areas where game fishing is permitted in the Greater St Lucia Wetland Park. Fishing line discarded at sea becomes entangled in branching and digitate corals resulting in fouling and overgrowth by algae. Lost gear from net and trap fisheries continue to fish (ghost fishing).

3. Mining

Mining impacts include large-scale removal of biota (e.g. strip mining), sediment removal and disruption, siltation, noise, pollution and their associated effects on biological communities. As with fishing, constant advances in mining technology increase access to resources. Five types of mining are currently considered to threaten marine biodiversity in South Africa: sand winning; mining for titanium (RBM); diamonds; fossil fuels; and phosphate. Sand winning, particularly in estuarine habitats can have a large knock-on effect disrupting downstream or nearshore sediment processes. Strip mining for titanium or other heavy minerals transforms dune communities in KwaZulu-Natal, but this impact is offset to some extent by rehabilitation programs. Diamond mining in South Africa is confined to the west coast from the Orange to the Olifants Rivers and involves an offshore (<150 m) and inshore component. Studies of diamond mining impacts have shown that sediment disruption alters sediment patterns but may not interfere with the sediment distribution processes. Disturbance of the benthic macrofauna by mining was examined in Namibia and researchers found clear changes in community composition. However, these communities may recover, albeit very slowly, after mining ceases. Sediment plumes caused by mining activities can be problematic by suffocating marine organisms and may even reach toxic concentrations. These plumes can also change fish communities. Sediment disruption and removal of gravel can alter the beach habitat. There is concern that diamonds could be confined to a particular habitat type with a unique fauna and that this habitat is threatened wherever it is found. Fossil fuel mining has a comparatively localised impact (compared to strip mining for diamonds or titanium) and the greatest threat of this activity is the potential oil pollution risk. Oil exploration involves high-power, low-frequency sound blasts, the impact of which has not been established. The mining of phosphate involves strip mining

over very large areas owing to low concentrations in the marine environment. At this stage, phosphate mining in South Africa is limited to exploration on the west and south coasts.

4. Coastal development

Coastal development includes development activities such as infrastructure (harbours and launch sites, cities, towns, housing, roads and tourism), as well as dredging activities and the disposal of sediments. Coastal developments and their associated impacts need to be very strictly controlled. These developments pose a major threat to many components of the marine environment, owing to their cumulative effects, which are often not taken into account by impact assessments. These effects include organic pollution of runoff and sewerage, transformation of the supratidal environment, alteration of dune movement, increased access to the coast and sea, and the negative impacts on estuaries.

5. Climate change

Increasing ultraviolet radiation, global warming, shifting weather and ocean circulation patterns, and sea level changes could threaten biodiversity by altering the distribution patterns, production rates and reproductive success of marine species. Increasing UV radiation may impact on the health of many marine species particularly nearshore organisms such as algal communities and coral reefs. Coral bleaching (the loss of symbiotic zooxanthellae from the tissue of host corals) and disease are now considered to be the most severe threats to coral reef health. Bleaching episodes have increased in magnitude, severity and frequency over the last decade.

South Africa's coral reefs were among the few reefs not to have suffered serious bleaching as a result of the elevated sea surface temperatures in 1998. In 2000 and 2001, monitoring studies at Sodwana Bay showed that bleaching in the Greater St Lucia Wetland Park was less than that experienced by reefs elsewhere in the Indian Ocean. However, bleaching has increased significantly from <1% in 1998 to 5-10% in 2002. Changes in current volumes and patterns and changes in the frequency and intensity of upwelling could alter nutrient supply and affect larval recruitment. In South Africa, small pelagic fish and associated ecosystems are particularly likely to be influenced by climate change.

6. Catchment management issues

Freshwater inputs have important roles in estuarine and marine environments. Freshwater, nutrient and sediment input represent important processes and marine biodiversity is threatened by activities that affect these inputs. Over-abstraction of fresh water, construction of water supply reservoirs and inter-basin water transfer schemes result in reduced river flow, desiccation, increased salinities and changes in estuarine mouth dynamics. This has serious consequences for coastal processes and fisheries and threatens biodiversity in both estuarine and marine habitats. Changing flow regimes and severe flooding can also dramatically impact near-shore marine communities. Poor catchment management and siltation effects threaten marine biota over large areas. Siltation can impact negatively on phytoplankton, benthic algal communities and coral reefs.

7. Non-extractive recreational activities

Five categories of non-extractive recreational activities were considered as potential threats to South African marine biodiversity. Marine eco-tours in search of marine mammals, seabirds and other marine fauna are increasing in popularity.

Coastal trails including walking trails and beach-based activities such as fossicking (exploring of intertidal shores and pools) can impact on marine biodiversity. Shore organisms can be negatively impacted by the disturbance associated with fossicking. Trails increase access to resources in the intertidal and shallow sub photic zones. Offroad vehicles including 4x4s and scrambler bikes can have an impact on dune and beach communities. Beach driving in South Africa was recently banned and the potential impact of off-road vehicles on marine biodiversity is currently under investigation. Potential impacts include destruction of sandy beach fauna and dune habitats, disturbance of bird communities (including nesting species) and the impacts associated with the increased access to living marine resources such as linefish and intertidal resources.

Three other categories of ecotourism were recognised as impacting on marine biodiversity: (i) Land-based activities, such as visits to bird colonies and tours to view nesting turtles; (ii) boat-based activities, such as whale viewing operations; and (iii) diver-based activities.

(i) Tourism to seabird colonies in the Namib and Namaqua regions has developed to the extent that it may threaten seabird populations. Island habitats are particularly sensitive. In northern KwaZulu-Natal, ecotourism is being developed around the nesting activities of two species of sea turtles, the leatherback (*Dermochelys coriacea*) and loggerhead (*Caretta caretta*) turtle. It is important to have representative breeding areas for turtles, birds and marine mammals that are not subject to disturbance.

(ii) Boat-based ecotourism in South Africa includes operations focussed on marine mammals, birds and sharks. The whale watching industry has been formalised in South Africa and there are 20 licensed areas around the coast. There are dolphin-viewing operations in KwaZulu-Natal. A code of conduct that is legally enforceable has been drawn up on the basis of studies looking at impacts of whale watching operations on Southern Right Whales. The available literature on the effects of boat-based whale watching on cetacean behaviour and distribution indicates varying responses for different species, areas and research techniques. For humpback whales, much of this research was conducted in calving and nursing grounds and may not be relevant to KZN, where humpbacks are passing through an area for a limited time during their migration (K. Findlay pers. comm.). There have been proposals to assess impacts of swim-with-dolphin programmes and the effects of boat-based whale watching on migrating humpback whales (*Megaptera novaeangliae*) but these were not funded. Elsewhere, bottlenose and common dolphins have been known to alter socialising behaviour in response to boats, but feeding behaviour is mostly unaffected.

(iii) Diver-based ecotourism includes snorkelling, scuba diving and cage diving to view sharks. It has been established that scuba diving and associated activities can cause significant damage to coral communities by destructive contact (anchoring and diver damage), resuspension of sediments and by hand-to-coral contact. Coral reefs in South Africa are confined to the Greater St Lucia Wetland Park where anchoring or mooring is prohibited. Generally, most divers cause very little damage to coral reefs although underwater photographers have been identified as a group that

causes more damage to reefs than other users. The prevalence of predominant soft corals on South African reefs makes them fairly resilient to diver damage and within the Greater St Lucia Wetland Park, current research has indicated that the coral reefs have not experienced serious diver damage. However, diver impacts should be considered in developing zonation patterns in existing and new MPAs, particularly in the light of the suite of other factors that can impact on reef ecosystems, many of which are not manageable.

Species-directed diver-based ecotourism initiatives include shark diving activities and there is potential for coelacanth-based diving. Shark diving is a growing industry, the impacts of which have not been adequately assessed. We can anticipate a growth in this sector. Ragged tooth shark (*Carcharias taurus*) diving is concentrated at Aliwal Shoal and quarter-mile reef in the Greater St Lucia Wetland Park where these sharks congregate during their gestation period. This activity does not involve feeding but research has shown that diver impact on ragged tooth shark distribution and behaviour is significant (V. Peddemors pers. comm.). For this reason it is important to have some refuge areas where ragged tooth sharks can remain undisturbed by divers (e.g. the existing Leadsman sanctuary). Great white shark and Tiger shark diving involve baiting, and the impacts of this on the energy budget and behaviour of sharks warrants further consideration. There is no management plan for great white sharks in South Africa.

Whale sharks (*Rhincodon typus)* are migratory and are usually encountered on the east coast in summer. Since 1995, dive operators in southern Mozambique were running dedicated whale shark diving operations using microlights to spot whale sharks and direct divers to them. In South Africa there has yet to be a whaleshark-directed tourism operation but the presence of these animals constitute an important draw card for dive tourism at Sodwana Bay. The impact of divers on the behaviour and distribution of whale sharks has not been adequately assessed but there is evidence that divers can disturb and agitate whale sharks. Whale sharks are found from southern Mozambique along a 410 km stretch of coast, but are currently known to have refuge from divers along 360 km of this area.

At present, divers are not permitted to dive deeper than 60m in the Greater St Lucia Wetland Park and coelacanths are known to occur from 54 m to 144 m. The trimix diving fraternity is small and trimix divers are restricted by very short bottom times although their impact on deep reef environments or biota has never been examined. The Sodwana Bay coelacanths are the only coelacanths that have interacted with divers and currently there is no evidence to suggest that a limited number of divers can disturb coelacanths to the extent that they will leave an area. It would be prudent to ensure that at least one canyon with resident coelacanths is maintained as a sanctuary area where coelacanths are not disturbed. A coelacanth management plan is in place.

8. Alien invasive species

A total of 22 alien marine species are known or suspected to have been introduced to South African waters. Five of these, all commercially cultured molluscs, were deliberately introduced, but only one (the oyster *Crassostrea gigas*) has become naturalized and is found in several estuaries along the south coast. Two marine species have become truly invasive - the European shore crab (*Carcinus maenas*) and the Mediterranean mussel (*Mytilus galloprovincialis*). In addition, the algae (*Schimmelmannia elegans*) (from Tristan da Cunha) has been discovered in Table Bay.

Carcinus maenas was first recorded from Table Bay Docks in 1983 and by 1990 had spread from Camps Bay to Saldanha Bay, a distance of some 100 km. This species has the potential to devastate

mollusc populations and there is concern that it could cause widespread damage if it establishes large populations in the sheltered waters of Saldanha Bay. *Mytilus galloprovincialis* was first recorded in South Africa in 1984, by which stage it had already established extensive populations along the west coast between Cape Point and Lüderitz, in Namibia. By the early 1990s it had spread as far east as Port Alfred, and was the dominant rocky shore species along the entire west coast. The main ecological effect of the invasion has been the increase in standing stock and vertical extent of mussel beds in the region. This has led to the displacement of other primary space occupying species, particularly the limpet, *Scutellastra angenvillei*. The invasion has also increased habitat availability for infaunal species and has increased the amount and availability of food for predatory species, notably oystercatchers.

9. Mariculture

The culture of profitable species in or near the coastal zone has had negative impacts on the marine biodiversity of many countries through habitat loss, eutrophication, introduction of invasive species and the spread of disease. The South African coastline is generally considered unsuitable for mariculture but there have been several operations developing in sheltered bays, and advances in mariculture technology are increasing the potential of local mariculture operations. Below is a list of seven mariculture operations that are considered as potential threats to South African marine biodiversity:

1. The highly invasive European mussel (*Mytilus galloprovincialis*) is farmed by raft farming in Saldanha Bay.
2. The exotic fast-growing Pacific oyster (*Crassostrea gigas*) is farmed using racks and or oyster baskets in Saldanha Bay, Knysna and Port Elizabeth. This species was originally deemed non-invasive, but there are recent reports of populations appearing in southern Cape estuaries.
3. Saldanha Bay also supports seaweed farming with tank and raft cultivation of the indigenous red alga (*Gracilaria verrucosa*).
4. Abalone (*Haliotis midae*) is farmed on the west and south coasts.
5. Some abalone farms harvest kelp for feed and this activity can pose a threat to the kelp forest habitat if it is not undertaken responsibly.
6. Prawns are cultured in brackish water ponds at Amatikulu on the northern KwaZulu-Natal coast and this operation includes an associated harvest of mudprawns to feed broodstock.
7. Techniques for farming of marine finfish are developing rapidly with farming of the exotic turbot (*Psetta maxima*) just starting in South Africa. Turbot and salmon (introduced aquaculture species) are significant species. In addition, research is focusing on local species such as dusky kob, silver kob and spotted grunter.

The ranching of indigenous species can also pose a significant risk to marine biodiversity, with genetically manipulated animals impacting on local stocks when they escape and breed with wild populations. Mariculture is considered a growth industry and we can anticipate significant growth in fish mariculture in South Africa in the near future. It is very important that applications for new mariculture activities are adequately assessed, and that environmental monitoring of existing and new mariculture activities is undertaken.

Appendix 3. Marine species targeted by South African fisheries. *C. Attwood.*

	Species name	Common name
Plants		
Division Phaephyta	*Ecklonia maxima*	see bamboo
	Laminaria pallida	split-fan kelp
Division Rhodophyta	*Gracilaria gracilis*	agar weed
	Gracilariopsis longissima	gracilaria
	Porphyra capensis	purple laver
	Gelidium pteridifolium	fern-leafed jelly weed
	Gelidium abbotiorum	Abbot's jelly weed
	Gelidium capense	Cape jelly weed
	Gelidium pristoides	saw-edged jelly weed
	Gelidium vitatum	red-ribbons
	Carpoblepharis flaccida	flacid kelp weed
Division Chorophyta	*Ulva spp*	sea lettuce
Animals		
Phylum Nemertea	*Polybrachiorhynchus dayi*	ribbon worm
Phylumn Annelida		
Class Polychaeta		
Subclass Errantia		
	Pseudonereis variagata	musselworm
	Marphysa sp	wonderworm
	Arabella iricolor	iridescent worm
	Eunice spp.	wonderworm
Subclass Sedentaria		
	Arenicola loveni	bloodworm
	Sabellastarte spp	fanworms
Phylumn Arthropoda		
Class Crustacea		
Order Macrura		
	Aristaeomorpha loliacea	red prawn
	Haliporoides triarthrus	pink prawn
	Jasus lalandii	west coast rock lobster
	Metapenaeus monoceros	brown prawn
	Palinurus delagoae	Natal deep-sea lobster

	Species name	Common name
	Palinurus gilchristi	south coast rock lobster
	Panulirus homarus	east coast rock lobster
	Penaeus indicus	white prawn
	Penaeus japonicus	bamboo prawn
	Penaeus monodon	tiger prawn
	Penaeus semisulcatus	zebra prawn
	Scyllarides elizabethae	slipper lobster
	Metanephrops mozambicus	langoustine
	Nephropsis stewartii	langoustine
	Callianassa kraussi	sand prawn
	Emerita austroafricana	mole crab
	Upogebia africana	estuarine mudprawn
	Chaceon maritae	red crab
	Ocypode ceratophthalmus	horn-eyed ghost crab
	Ocypode madagasacrensis	green ghost crab
	Ocypode ryderi	pink ghost crab
	Ovalipes trimaculatus	three-spot swimming crab
	Plagusia chabrus	Cape rock crab
	Portunus sanguinolenta	Tugela crab
	Scylla serrata	mud crab
	Sesarma meinerti	red-clawed mangrove crab
Phylum Mollusca		
Class Polyplacophora	*Dinoplax gigas*	giant chiton
Class Bivalvia	*Choromytilus meridionalis*	black mussel
	Donax serra	white mussel
	Mactra glabrata	smooth trough shell
	Mytilus galloprovincialis	Mediterranean mussel
	Perna perna	brown mussel
	Pinctada capensis	Cape pearl oyster
	Saccostrea cucculata	Natal rock oyster
	Solen capensis	pencil bait
	Stiostrea margaritacea	Cape rock oyster
Class Gastropoda	*Bullia laevissima*	fat plough shell

		Species name	Common name
		Cellana capensis	
		Cymbula granatina	granite limpet
		Cymbula oculus	goat's eye limpet
		Cymbula sanguinanas	
		Haliotus midae	South African abalone
		Haliotus spadicea	venus ear
		Helcion concolor	variable limpet
		Nerita spp.	nerites
		Oxystele sinensis	pink-lipped topshell
		Scutellastra argenvilliei	Argenville's limpet
		Scutellastra barbara	bearded limpet
		Scutellastra cochlear	pear limpet
		Scutellastra granularis	granular limpet
		Scutellastra longicosta	long-spined limpet
		Scutellastra pica	
		Scutellastra tabularis	giant limpet
		Turbo cidaris	smooth turban shell
		Turbo coronatus	crowned turban shell
		Turbo sarmaticus	giant periwinkel
	Class Cephalopoda	*Loligo duvaucelii*	Indian Ocean squid
		Loligo vulgaris	chokka squid
		Octopus magnificus	giant octopus
		Octopus valgaris	common octopus
		Sepia vermiculata	common cuttlefish
		Todarodes angolensis	red squid
		Todaropsis eblanae	red squid
Phylum Echinodermata			
	Class Holothuroidea	*Holothuria spp.*	sea cucumber
	Class Echinoidea	*Echinometra mathaei*	oval urchin
		Tripneustes gratilla	short-spined urchin
Phylum Chordata			
	Class Ascidiacea	*Pyura stolonifera*	red bait
	Class Chondrichthyes		
		Superorder Squalomorpha (sharks)	
		Alopias superciliosus	bigeye thresher

	Species name	Common name
	Carcharhinus brachyurus	bronze whaler
	Carcharhinus leucas	Zambesi shark
	Carcharhinus limbatus	blacktip shark
	Carcharhinus melanopterus	blackfin reef shark
	Carcharhinus obscurus	dusky shark
	Carcharhinus sealei	blackspot shark
	Charcharius taurus	ragged tooth shark
	Galeocerdo cuvier	tiger shark
	Galeorhinus galeus	soupfin shark
	Isurus oxyrinchus	shortfin mako
	Mustellus mustellus	smoothhound shark
	Notorynchus capedianus	broadnose sevengill shark
	Poroderma africanum	pajama shark
	Prionace glauca	blue shark
	Rhizoprionodon acutus	milkshark
	Sphyrna zygaena	smooth hammerhead shark
	Squalus megalops	spiny dogfish
	Triakis megalopterus	spotted gulley shark
Superorder Batoidea (rays)		
	Aetobatus narnari	spotted eagleray
	Dasyatis chrysonota	blue stingray
	Gymnura natalensis	diamond ray
	Himantura gerrardi	sharpnose stingray
	Himantura uarnak	honeycomb stinray
	Myliobatis aquila	duckbill ray
	Pteromylaeus bovinus	bull ray
	Raja alba	spearnose skate
	Raja miraleutus	twineye skate
	Raja straeleni	biscuit skate
	Rhinobatos annulatus	lesser guitarfish
	Rhinobatos blochii	bluntnose guitarfish
	Rhinobatos djiddensis	giant sandshark
Subclass Cheimereas		
	Callorhincus capensis	St Joseph shark
Class Osteichthyes		
Family Albulidae		
	Albula vulpes	bonefish

Species name	Common name
Family Ambassidae	
Ambassis gymnocaphalus	bald glassy
Ambassis natalensis	slender glassy
Ambassis productus	longspine glassy
Family Anguilidae	
Anguilla bengalensis	African mottled eel
Anguilla bicolor	giant mottled eel
Anguilla mossambica	longfin eel
Family Ariidae	
Galeichthyes feliceps	white seacatfish
Galeichthyes ater	black seacatfish
Family Berycidae	
Beryx splendens	alfonsino
Family Bramidae	
Brama brama	pomfret
Family Carangidae	
Carangoides armatus	longfin kingfish
Carangoides ferdau	blue kingfish
Carangoides fulvoguttatus	yellowspotted kingfish
Caranx ignobilis	giant kingfish
Caranx lugubris	black kingfish
Caranx melampygus	bluefisn kingfish
Caranx papuensis	brassy kingfish
Caranx sem	blacktail/blacktip kingfish
Caranx sexfasciatus	bigeye kingfish
Decapterus macarellus	mackerel scad
Decapterus russelli	Indian scad
Elagatis bipinnulatus	rainbow runner
Gnatahnodon speciosus	golden kingfish
Lichia amia	leervis
Scomberoides commersonnianus	Talang queenfish
Scomberoides lysan	doublespotted queenfish
Scomberoides tol	needlescale queenfish
Seriola lalandii	yellowtail
Seriola rivoliana	longfin yellowtail
Trachinotus africanus	southern pompano
Trachinotus botla	largespot pompano
Trachurus trachurus	horse mackerel
Family Chanidae	
Chanos chanos	milkfish

Species name	Common name
Family Cheilodactylidae	
Chirodactylus brachydactylus	twotone fingerfin
Chirodactylus grandis	bank steenbras
Chirodactylus jessicalenorum	natal fingerfin
Family Chirocentridae	
Chirocentrus dorab	wolfherring
Family Cichlidae	
Oreochromis mossambicus	Mozambique tilapia
Family Clupeidae	
Etrumeus teres	east coast red eye
Sardinops sagax	pilchard
Etrumeus whiteheadi	redeye roundherring
Hilsa kelee	razorbelly
Family Congidae	
Conger wilsoni	Cape conger
Family Coracinidae	
Coracinus capensis	galjoen
Coracinus multifasciatus	banded galjoen
Family Coryphaenidae	
Coryphaena aquiselis	dolphinfish
Family Cynoglossidae	
Cynoglossus zanzibarensis	redspotted tonguefish
Family Dinopercidae	
Dinoperca petersi	cavebass
Family Elopidae	
Elops machnata	springer
Family Emmelichthydae	
Emmelichthyes nitidus	red seaharder
Family Engraulidae	
Engraulis japonicus	anchovy
Thryssa vitrirostris	glassnose
Family Ephippidae	
Tripterodon orbis	spadefish
Family Gempylidae	
Lepidocybium flavobrunneum	escolar
Lepidopus caudatus	buttersnoek
Ruvettus pretiosus	oilfish
Thyrsites atun	snoek
Family Gerreidae	
Gerres acinaces	small-scale pursemouth
Gerres metheuni	evenfin pursemouth

	Species name	Common name
Family Haemulidae		
	Diagramme pictum	sailfin rubberlip
	Plectorhinchus chubbi	dusky rubberlip
	Plectorhinchus flavomaculatus	lemonfish
	Plectorhinchus playfairi	whitebarred rubberlip
	Plectorhinchus schotaf	grey sweetlips
	Pomadasys commersonni	spotted grunter
	Pomadasys furcatum	grey grunter
	Pomadasys kaakan	javelin grunter
	Pomadasys multimaculatum	cock grunter
	Pomadasys olivaceum	olive grunt
Family Istiophoridae		
	Istiophorus platypterus	sailfish
	Makaira indica	black marlin
	Makaira nigricans	blue marlin
	Tetrapturus albidus	white marlin
	Tetrapturus angustirostris	shortbill spearfish
	Tetrapturus audax	striped marlin
Family Kyphosidae		
	Kyphosis bigibbus	grey chub
Family Labridae		
	Anchichoerops natalensis	Natal wrasse
	Halichoeres iridis	rainbow wrasse
	Thalassoma purpureum	surge wrasse
	Thalassoma trilobatum	ladder wrasse
Family Lethrinidae		
	Lethrinus crocineus	yellowfin emperor
Family Lobotidae		
	Lobotes surinamensis	tripletail
Family Lophidae		
	Lophus upsicaphalus	monk
	Lophus vomerinus	monk
Family Lutjanidae		
	Aprion virescens	green jobfish
	Lutjanus argentimaculaatus	river snapper
	Lutjanus bohar	twinspot snapper
	Lutjanus rivulatus	speckled snapper
	Lutjanus russellii	Russels snapper
	Lutjanus sanguineus	bloodsnapper
	Paracaesio xanthura	yellowtail fusilier
	Pristipomoides filamentosus	rosy jobfish

Species name	Common name
Family Megalopidae	
Megalops cyprinoides	oxeye tarpon
Family Merlucciidae	
Merluccius capensis	shallow-water hake
Merluccius paradoxus	deep-water hake
Family Monodactylidae	
Mondactylis falciformis	Cape moony
Family Mugilidae	
Liza alata	diamond mullet
Liza dumerilii	groovy mullet
Liza macrolepis	large-scale mullet
Liza melinoptera	giantscale mullet
Liza richardsonii	southern mullet
Mugil cephalus	flathead mullet
Valamugil buchanani	bluetail mullet
Valamugil robustus	robust mullet
Valamugil seheli	bluespot mullet
Family Mullidae	
Parupeneus indicus	Indian goatfish
Parupeneus rubescens	blacksaddle goatfish
Family Muraenesocidae	
Muraenesox bagio	pike conger
Family Muraenidae	
Gymnothorax undulatus	leopard moray
Uropterygius tigrinus	tiger reef-eel
Family Myctophidae	
Lampanyctodes hectoris	lanternfish
Family Ophidiidae	
Genypterus capensis	kingklip
Family Oplegnathidae	
Oplegnathus conwayi	Cape knifejaw
Oplegnathus robinsoni	Natal knifejaw
Family Oreosomatidae	
Allocyttus verrucosus	warty dory
Neocyttes rhomboidalis	oreo dory
Oreosoma atlanticum	oxeyedory
Pseudocyttus maculatus	smooth dory
Family Parascorpidae	
Parascorpis typus	jutjaw
Family Pentacerotidae	
Pentaceros capensis	Cape armourhead

Species name	Common name
	(boarfish)
Family Platycephalidae	
Platycephalus indicus	bartail flathead
Family Plotosidae	
Plotosus nkunga	eeltail barbel
Family Polynemidae	
Polydactylus plebeius	striped threadfin
Family Polyprionidae	
Polyprion americanus	wreckfish
Family Pomatomidae	
Pomatomus saltatrix	elf/shad
Family Rachycentridae	
Rachycentron canadum	prodigal son
Family Sciaenidae	
Argyrosomus inodorus	silver kob
Argyrosomus japonicus	dusky kob
Argyrosomus thorpei	squaretail kob
Atractoscion aequidens	geelbek
Atrobucca nibe	longfin kob
Johnius dussumieri	mini-kob
Otolothes ruber	snapper kob
Umbrina canariensis	deepwater belman
Umbrina ronchus	belman
Family Scomberesocidae	
Scomberesox scomberoides	saury
Family Scombridae	
Acanthocybium solandri	wahoo
Euthynnus affinis	eastern little tuna
Gymnosarda unicolor	dogtooth tuna
Katsuwonus pelamis	skipjack tuna
Rastrelliger kanagurta	Indian makerel
Sarda orientalis	striped bonito
Sarda sarda	katonkel
Scomber japonicus	chub mackerel
Scomberomorus commerson	king mackerel
Scomberomorus plurilineatus	queen mackerel
Thunnus alalunga	albacore
Thunnus albacares	yellowfin tuna
Thunnus maccoyi	southern bluefin tuna
Thunnus obesis	bigeye tuna
Family Scorpididae	

	Species name	Common name
	Neoscorpis lithophilus	stonebream
Family Sebastinae		
	Helicolenus dactylopterus	jacopever
Family Serranidae		
	Acanthistius sebastoides	koester
	Cephalopholis sonnerati	tomato rock-cod
	Epinephelus albomarginatus	white-edged rock-cod
	Epinephelus andersoni	catfaced rock-cod
	Epinephelus chabaudi	moustache rock-cod
	Epinephelus flavocaeruleus	yellowtail rock-cod
	Epinephelus gauza	yellowbelly rock-cod
	Epinephelus malabaricus	malabar rock-cod
	Epinephelus rivulatus	halfmoon rock-cod
	Epinephelus tauvina	greasy rock-cod
	Variola louti	swallowtail rock-cod
Family Sillaginidae		
	Sillago sihama	silver silago
Family Soleidae		
	Austroglossus microlepis	west coast sole
	Austroglossus pectoralis	east coast sole
	Synaptura marginata	shallow-water sole
Family Sparidae		
	Acanthopagrus berda	river bream
	Argyrops filamentosus	soldierbream
	Argyrops spinifer	king soldier bream
	Argyrozona argyrozona	carpenter
	Boopsoidea inornata	karel grootoog
	Cheimerius nufar	santer
	Chrsyroblephus lophus	false englishman
	Chrysoblephus anglicus	englishman
	Chrysoblephus cristiceps	dageraad
	Chrysoblephus gibbiceps	red stumpnose
	Chrysoblephus laticeps	roman
	Chrysoblephus puniceus	slinger
	Crenidens crenidens	white caraanteen
	Cymatoceps nufar	poenskop
	Diplodus curvinus	wildeperd
	Diplodus sargus	blacktail
	Gymnocrotaphus curvidens	johnbrown
	Lithognathus aureti	west coast steenbras
	Lithognathus lithognathus	white steenbras

	Species name	Common name
	Lithognathus mormyrus	sand steenbras
	Pachymetopon aeneum	blue hottentot
	Pachymetopon blochii	hottentot
	Pachymetopon grande	bronze bream
	Pagellus natalensis	red tjor-tjor
	Petrus rupestris	red steenbras
	Polyamblyodon german	german
	Polyamblyodon gibbosum	cristie
	Polysteganus coeruleopunctatus	blueskin
	Polysteganus preorbitalis	scotsman
	Polysteganus undulosus	seventy four
	Porcostoma dentata	dane
	Pterogymnus laniarus	panga
	Rhabdosargus globiceps	white stumpnose
	Rhabdosargus holubi	Cape stumpnose
	Rhabdosargus sarba	natal stumpnose
	Rhabdosargus thorpei	bigeye stumpnose
	Sarpa salpa	strepie
	Sparadon durbanensis	musselcracker
	Spondyliosoma emarginatum	steentjie
Family Sphyraenidae		
	Sphyraena barracuda	great barracuda
	Sphyraena jello	pickhandle barracuda
Family Sternoptychidae		
	Maurolicus muelleri	light fish
Family Stromateidae		
	Centrolophus niger	black ruff
	Hyperoglyphe antarctica	Antarctic butterfish
Family Teraponidae		
	Terapon jarbua	tigerfish
Family Trichiuridae		
	Trichiurus lepturus	cutlassfish
Family Triglidae		
	Chelidonichthys capensis	Cape gurnard
	Chelidonichthys kumu	bluefin gurnard
	Chelidonichthys queketti	lesser gurnard
Family Xiphidae		
	Xiphius gladius	swordfish
Family Zeidae		
	Zeus faber	john dory

	Species name	Common name
	Zeus capensis	Cape dory

Appendix 4. Threatened marine species. *C. Attwood.*

Species name	Common name	*Also targeted
Haliotus midae	abalone	Yes
Pristis pectinata	sawfish	
Chrysoblephus cristiceps	dageraad	Yes
Chrysoblephus gibbiceps	red stumpnose	Yes
Chrysoblephus puniceus	slinger	Yes
Cymatoceps nasutus	black steenbras	
Petrus rupestris	red steenbras	Yes
Lithognathus lithognathus	white steenbras	Yes
Polysteganus undulosus	seventy four	Yes
Polysteganus praeorbitalis	scotsman	Yes
Hippocampus capensis	Knysna seahorse	
Syngnathus watermeyerii	estuarine pipefish	
Xiphias gladius	swordfish	Yes
Argyrosoma japonicus	dusky kob	Yes
Argyrosoma inodorus	silver kob	Yes
Epinephelus tukula	potato bass	
Epinephelus lanceolatus	brindle bass	
Dermochelys coriacea	leatherback turtle	
Spheniscus demersus	African penguin	
Haematopus moquini	African black oystercatcher	
Phalacrocorax coronatus	crowned cormorant	
Phalacrocorax neglectus	bank comorant	

*From Appendix 3.

Note: This list does not include all collapsed fish (e.g. geelbek), and some unassessed species are included (e.g. red stump). Naturally rare but unthreatened species are excluded (e.g. coelacanth).

Appendix 5. The three most threatened marine habitats, in the most urgent need of conservation. *L. Hutchings and C. Attwood.*

1. High profile reefs and pinnacles
2. Soft-bottom trawling grounds
3. The areas being mined (the shallow areas are totally turned over, but as you move deeper, the activity is more point based).

Appendix 6. Priority spatial marine projects for future research.

1. A fish atlas is required, where all available fish distribution data are compiled and mapped accurately.
2. The spatial distribution and intensity of bottom trawling requires mapping (at the finest scale possible).
3. A Red Data listing is required for certain marine species (especially within the fish fauna). In addition, species of special concern must be identified, and their distributions mapped.
4. The distribution and profile of reefs requires mapping (at the finest scale possible).
5. Important biodiversity processes must be identified and mapped, where possible. Within these, we need to identify which processes can benefit from spatial interventions, e.g. fish aggregation areas, which could be protected with appropriate spatial and other management interventions. Other process-related questions include: is upwelling on the west coast sufficiently different between sites to make a difference to habitats on the shore?
6. Sandy beaches need to be classified into habitat categories (e.g. reflective versus dissipative beaches).
7. A systematic study of deep benthic biodiversity is required (especially deeper than 30m)
8. The supratidal zone (those components that influence, or are influenced by, the marine environment), needs to be analysed together with estuaries and intertidal habitats, as well as all appropriate species data, in an integrated coastal conservation assessment. The earlier supratidal dune work of Tinley (1985) provides a good starting point for the supratidal zone, and the estuarine report (Turpie 2004) and this report, both prepared for the National Conservation Assessment, can provide other points of departure. A host of other published data and reports exist, and these should be incorporated into an integrated assessment.
9. Coastal access points require mapping and categorization (e.g. boat access, fishing access, pollution access, etc.).
10. Finer scale regional conservation assessments are required all along the South African coastline, for incorporation into regional and local land-use planning initiatives.

Appendix 7. GIS map projection information.

All the spatial analyses in this report were produced with Geographic Information System (GIS) software (ArcInfo 7.2.1 and ArcView 3.2, Environmental Systems Research Institute). We worked with the WGS84 datum, and an Albers equal area projection. The ArcInfo projection file (which shows the parameters used) for all GIS maps was as follows:

input
projection geographic
units dd
datum wgs84
parameters 6378137.0 6356752.314245179500
output
projection albers
units meters
datum wgs84
parameters 6378137.0 6356752.314245179500
-31 39 00
-25 18 00
24 45 00
00 00 00
0.0
0.0
end