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Marine environmental threats in Namibia

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Executive summary

This report provides a summary and an assessment of environmental threats facing the marine environment and its living resources off Namibia. In **Section 1**, a broad overview of the marine biophysical environment off the coast is given which briefly describes features of the northern Benguela Current, the biological resources and habitat types of the region. A review of the commercial fisheries is also outlined which includes descriptions of the status of stocks. The regional importance of the Benguela Current as a large marine ecosystem is emphasised and an account of some of the fisheries and oceanographic research undertaken in parts of the system is also presented. Marine industries such as diamond mining, offshore oil and gas exploration and exploitation and commercial development at the coast are important activities relating to the marine environment and a short summary of the status of these operations is also discussed and described.

Section 2 provides an account of the trends taking place in the marine environment ranging from the natural variability within the Benguela Current system to major perturbations and changes such as the anomalous conditions that occurred off the Namibian coast during period 1993 to 1995. These include increased eutrophication leading to low oxygen conditions in shelf waters to major phytoplankton blooms, localised sulphur eruptions and the occurrence of Benguela Niño events. Trends taking place within the fisheries as a result of past over-exploitation and environmental effects such as regime shifts, changes in trophic levels and species flips are also described and briefly discussed. Environmental threats from developments taking place in population centres along the coast are identified. These are associated with harbour activities, fish processing and tourism (recreational fishing) and include degradation of water quality, oil spills, red-tide blooms and over-exploitation of recreational fish by numerous anglers. Marine diamond mining activities, the effects on the environment and in particular on rock lobster stocks are also outlined and discussed along with some assessments of possible impact.

The direct and indirect causes of real and perceived marine environmental problems are summarised in **Section 3**. These vary from fluctuations in environmental conditions and impacts on fisheries to pollution and dumping of waste, uncontrolled coastal developments and marine diamond mining. Gaps are identified in **Section 4** where additional information and participatory involvement is required and where further research and monitoring needs to be addressed.

Section 5 lists some strategic options and interventions which would assist in mitigating current and perceived threats facing Namibia's marine environment. It is recommended that one of the best means of tackling future threats would be the initiation and implementation of an integrated regional management plan for the Benguela Current as a large marine ecosystem.

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List of acronyms and abbreviations

| | |
|----------|---|
| BCLME | Benguela Current large marine ecosystem |
| BENEFIT | Benguela Environment Fisheries Interaction and Training |
| CDM | Consolidated Diamond Mines |
| CSIR | Council for Scientific and Industrial Research |
| DANCED | Danish Cooperation for Environment and Development |
| DEA | Directorate of Environmental Affairs, Ministry of Environment and Tourism |
| EIA | Environmental impact assessment |
| EPZ | Economic processing zone |
| GEF | Global Environmental Facility |
| GDP | Gross domestic product |
| GTZ | Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation Agency) |
| ICEIDA | Icelandic International Development Agency |
| ICZM | Integrated coastal zone management |
| INCO | Cooperation with Third Countries and International Organisations (European Union) |
| IEM | Integrated environmental management |
| I & AP's | Interested and affected parties |
| IMO | International Maritime Organisation |
| LFA | Logical framework analysis |
| MAWRD | Ministry of Agriculture, Water and Rural Development |
| MET | Ministry of Environment and Tourism |
| MFMR | Ministry of Fisheries and Marine Resources |
| MHSS | Ministry of Health and Social Services |
| MME | Ministry of Mines and Energy |
| MSY | Maximum sustainable yield |
| mt | Metric tonnes |
| MWTC | Ministry of Works, Transport and Communication |
| MRLGH | Ministry of Regional and Local Government and Housing |
| NAMCOR | National Petroleum Corporation of Namibia |
| NAMDEB | Namibia-De Beers Diamond Mining Group |
| NAMPORT | Namibian Port Authority |
| NAMSAR | Namibian Search and Rescue |
| NATMIRC | National Marine Information and Research Centre |
| NORAD | Norwegian Agency for International Development |
| SAP | Strategic action plan |
| TBT | Tributyl tin |
| UNCED | United Nations Conference on Environment and Development |

1 The marine biophysical environment off Namibia

The waters off the Namibian coast are unusually cold for their latitude (17°20'-28°40'S), but they support some of the highest concentrations of marine life found anywhere in the world. This high biological productivity results from seasonal south to southeast winds which induce upwelling at the coast and make available an abundant supply of nutrients in the upper layers. These nutrients, together with sunlight, promote extensive blooms of phytoplankton, rich resources of zooplankton, and an abundance of pelagic fish such as pilchard, anchovy and juvenile horse mackerel. These fish shoals in turn provide food for large populations of higher predators such as seals, dolphins and seabirds. Further offshore over the continental shelf, large stocks of hake inhabit the deeper waters near the seabed, and adult horse mackerel form large shoals in the midwater layers.

1.1 The Benguela Current

The Benguela Current forms the eastern boundary of the south Atlantic intercontinental gyre. It sweeps northwards within 150 km off the west coast between latitudes 15° and 34°S, bringing cold Antarctic water into warmer subtropical regions. It flows in a north to north-westerly direction along the west coast of southern Africa, roughly following the isobaths or contours of the seabed. North of Walvis Bay (23°S), the current flow moves offshore away from the coast. A southward undercurrent reportedly flows at deeper levels on the continental slope, and also nearer the coast at depths greater than 30 m. The speed of the current varies between 10 and 30 cm/sec depending on the location off the coast, wind direction and speed, and season.

During the upwelling process, surface water is transported in an offshore direction by the effects of the prevailing equatorward winds, in combination with the rotation of the earth (Coriolis Force). This is compensated for by the movement of deeper cooler bottom water into the upper layers at the coast. The rate and intensity of upwelling fluctuates with seasonal variations in wind patterns. Bottom topography and the continental shelf also influence the upwelling processes, with high energy areas being found where the shelf is narrowest and the wind strongest. The most intense and most important upwelling region off the Namibian coast is located in the south near Lüderitz (27°-28°S). There are smaller less intense upwelling cells at Cape Fria (18°S), Palgrave Point (20°30'S) and Conception Bay (24°S). Typical surface temperatures and salinity in coastal upwelling areas such as Lüderitz range from 11°-14°C and 34.8 - 35.2 parts per thousand (ppt) respectively.

The marine environment off Namibia and the dynamics of the Benguela Current are controlled by seasonal changes in the south Atlantic high-pressure system. Southerly winds which blow off Namibia throughout the year are strongest in winter and spring. In the Lüderitz area, these winds are strongest in spring and summer, whereas at Cape Fria they tend to be most intense in spring and autumn. Hot dry "berg" winds (mountain winds from the east or north in autumn and winter) also influence the coastal marine environment by suppressing local upwelling and occasionally transporting large quantities of dust and sand far out to sea.

In summer and autumn, the southerly winds relax off central and northern Namibia and upwelling becomes weak. The warm and more saline Angolan Current moves south and mixes with the cooler water of the Benguela Current, leading to stable stratified conditions in the ocean. The surface water temperatures can rise to 17°-22°C and salinities are usually within the range of 35.5 to 35.9 ppt. These frontal areas where the two currents mix have high plankton production, and are important spawning and nursery grounds for pelagic fish.

1.2 Living marine resources

The living marine resources of Namibia are rich and varied, encompassing microscopic phytoplankton and zooplanktonic organisms, soft-bodied invertebrates, marine worms, bivalves, crustaceans, fish, and marine mammals. Marine animals and plants extend from shallow intertidal areas to the deep ocean on the edge of the continental shelf, and occupy a wide spectrum of surface, pelagic, demersal and benthic habitats.

A comprehensive list of the living marine resources of Namibia with detailed description of crustaceans, squids, fish, seabirds, seals, whales and dolphins is given by Bianchi *et al.* (1993).

1.2.1 Phytoplankton

Phytoplankton production in the northern Benguela system is dominated mainly by diatoms, which outnumber dinoflagellates by one or two orders of magnitude. Species belonging to the genera *Chaetoceros*, *Rhizosolenia* and *Coscinodiscus* are most common.

However, dinoflagellates can undergo large blooms during quiescent conditions when thermoclines become well developed in summer months. These blooms or "red tides" can reach densities of more than 3 million cells per litre and can cause localised fish and shellfish mortalities. Some of the most commonly occurring dinoflagellates recorded in the Walvis Bay area are the species *Gymnodinium galatheanum* and *Gonyaulax tamarensis*.

Upwelling takes place during most of the year off Namibia, with a maximum in late winter and spring, and a minimum during late summer. Phytoplankton distribution depends on the supply of nutrients and the subsequent stabilisation and seeding of upwelled water. Typical densities of phytoplankton recorded from coastal waters off central Namibia are > 10 million cells/l with the range of surface chlorophyll "a" values for coastal and shelf regions being 3-10 mg/m². Very high primary production rates of approximately 71 mg/m²/h have been recorded. The amount of phytoplankton carbon in the neritic zone of the northern Benguela region has been estimated at between 4 and 12 g/m².

The seasonal distribution of phytoplankton suggests that in late autumn, moderate to high levels of chlorophyll "a" occur along the coast. During active upwelling months of spring, chlorophyll "a" maxima occur further offshore whereas in the quiescent phase in summer, highest chlorophyll "a" concentrations occur in a narrow coastal band. With the approach of autumn, phytoplankton production in the Walvis Bay area and further south often shows a dramatic increase in abundance, leading to local algal blooms (Shannon and Pillar 1986).

1.2.2 Zooplankton

Zooplankton abundance off Namibia is characterised by two peaks, one in the late spring and early summer (November - December) and the other mainly during autumn (March - May). Abundance is highest during the upwelling season when phytoplankton blooms along the coast. Both zooplankton and phytoplankton generally occur in bands parallel to the coast, with the phytoplankton maxima occurring inshore and the zooplankton appearing further offshore.

Copepods are the most numerically dominant and diverse group in the zooplankton, with neritic species such as *Centropages brachiatus* and *Calanoides carinatus* inhabiting the cool upwelled waters (Timonin *et al.* 1992). Species such as *Nannocalanus minor* are numerically dominant warm water species. A high biomass of copepods is found on the wide shelf region to the west and south of Walvis Bay.

The euphausiids are also an ecologically important component of the zooplankton community. They are dominated by the species *Nyctiphanes capensis* and *Euphausia hanseni*. Studies have shown that the former can reach very high densities in the shallow coastal waters between Cape Cross and Conception Bay, with biomass estimates of > 5000 mg dry weight/m². Both euphausiids are important in the diet of many fish species off Namibia, particularly hake, and their ecology and interaction may have far reaching consequences for fish stock dynamics.

Zooplankton migrate up and down in the water column by day and night, especially the euphausiids which, along with pelagic gobies, form a significant proportion of the 'scattering layer' at night.

Other groups present in the zooplankton include the coelentrates (jellyfish), chaetognaths (arrow worms), tunicates (doliolids, salps), amphipods and decapod larvae. Ichthyoplankton, consisting of the eggs and larval stages of fish, also form an important component of the zooplankton, and their seasonal distribution and abundance off the Namibian coast are critical to spawning success and recruitment for the major fisheries. Zooplankton production off the central Namibian shelf is thought to be between 34 and 46 g C/m²/yr, with a population doubling time of about 35 days.

Shannon and Pillar (1986) and Crawford et al. (1987) have reviewed the occurrence, seasonal distribution and abundance of zooplankton off the Namibian coast.

1.2.3 Benthic communities

There is very little information on the occurrence, distribution and biomass of the animals living within the seabed sediments (benthic infauna) along the coastal and continental shelf regions of Namibia. Although much of the sea bed has been broadly categorised according to sediment type (Rogers and Bremner 1991), the assemblages and ecological interactions of benthic animals are poorly understood.

It is likely that polychaetes (segmented marine worms) and small bivalves dominate the system, particularly in shelf waters < 200 m deep, while echinoderms (starfish, sea urchins, etc.), burrowing and swimming crabs and shrimps are probably more common in deeper waters. In the sediments of inshore waters off southern Namibia coast, Rogers (1977) found the shells of the bivalves *Lucinoma capensis*, *Dosinia lupinus* and *Carditella similis* to be common along with the gastropods *Turitella declivis* and *Nassarius analogica*. Berrisford (1963) published a species list of near-shore benthic macrofauna in the Lüderitz area, and more recently Bickerton and Carter (1995) described some benthic macrofauna distributions on the continental shelf off Lüderitz. The benthic fauna are dominated by polychaetes (*Pectinaria capensis*), bivalves (*Dosinia* sp., *Macoma ordinaria*, *Phaxus pellucidus*) and the gastropod *Nassarius plicatellus*.

The occurrence of poorly oxygenated water and sulphurous anoxic sediments in coastal waters of the central Namibian shelf is well documented. Marchand (1930) reported that the seabed between Cape Cross and Conception Bay from about 3 to 25 miles offshore was devoid of life, with much evidence of dead shells and fish bones. Bottom samples from the area were of a green muddy or clay-like consistency, with an unbearable smell of hydrogen sulphide and other odours of putrefaction. The sediment consisted almost entirely of diatomaceous ooze.

By contrast, on the outer edge of the azoic zone, bottom samples had no smell and the benthic fauna was rich in segmented marine worms, crustaceans, echinoderms and fish. Live specimens of the bivalve *Crassatella africana* were also taken in the trawls.

Mass mortalities of fish due to low oxygen and sulphurous eruptions frequently take place along this part of the coast. Such losses can sometimes run into thousands of tonnes (Copenhagen 1953). Evidence to support the existence of this large azoic or anoxic bottom zone is supported by bottom trawl data collected during numerous surveys by the R.V. Dr Fridtjof Nansen across the shelf since 1990. These data indicated virtually no benthic fauna or bottom living fish present in the trawl catches inshore of the 150 m isobath, whereas hauls taken in deeper water contained crustaceans such as portunid crabs and squillid shrimps, as well as bottom dwelling fish such as monkfish, dogfish and ray.

1.2.4 Intertidal and sub-littoral macrofauna

The Namibian coastline consists predominantly of medium to coarse grained sandy beach, with occasional rocky outcrops and reefs extending offshore into sub-littoral waters. The two bays in the central region, Walvis Bay and Sandwich Harbour, are bound by extensive sandy spits.

The coastal zone of the west coast of southern Africa, and the ecology of intertidal and sub-littoral organisms, have been comprehensively reviewed by Branch and Griffith (1988), with additional interpretation of the intertidal region by Field and Griffith (1988). The geomorphology, beach fauna and flora of Namibia have also been recently reviewed by Campbell (1993).

The intertidal regions have a rich population of algae, with a lower species diversity of littoral animals. The upper littoral zone of shore is dominated by high concentrations of small winkles *Littorina africana* in association with the alga, *Porphora capensis*. The mid-shore region is characterised by grazers such as the winkle *Oxystele variegata* and the limpet *Patella granularis*. The lowest intertidal region is exposed to heavy wave action, and may be dominated by mussels *Perna perna* or *Chloromytilus meridionalis* and limpet species. Below the lower shore, kelp beds comprising of *Ecklonia maxima* and *Laminaria schinzii* provide food and shelter for a variety of marine life including the commercially important rock lobster *Jasus lalandii*. Fish inhabiting the rocky pools of the intertidal zone belong mainly to the families Clingiidae, Gobiesocidae and Blennidae, and have a low species diversity along the Namib coast.

Sandy shores dominate the coastline along the central Namibian region, and can be described as a high energy environment. The intertidal macrofauna have been investigated by McLachan (1985, 1988) and Donn and Cockfort (1989) near Walvis Bay. The upper to mid-shore parts of the beaches are usually characterised by small crustacean species such as the amphipod *Talorchestia* and the giant isopod *Tylos* sp. Various other isopods, the marine worm *Scolepis squamata*, and the white mussel *Donax serra* are also found. The lower part is often dominated by mysid crustaceans (*Gastrosaccus* sp.) and the scavenging whelk, *Bullia* sp.

There are very few data available on the sublittoral fauna off the Namib coast. Cockfort (1986) found that polychaetes were the major contributors to biomass in shallow waters, whereas gastropods dominated deeper waters. Species belonging to the taxa Polychaeta, Amphipoda, Isopoda, Mysidacea, Decapoda and Gastropoda were represented in samples.

The sublittoral fauna along parts of the Namaqualand coast, regarded as similar to that of southern Namibia, are generally sparse (Barkai and Bergh 1992). This is thought to be due to a combination of harsh sea conditions, narrow subtidal rocky outcrops, mobile sandy sediments and low oxygen. Lower diversity of benthic animals was found in deeper water, as well as a marked drop in the number of rock lobster away from the shallow reefs.

1.2.5 Crustaceans

Two species of crab occur off the Namibian coast, the deep sea red crab *Chaceon maritae*, and the stone crab *Lithodes tropicalis*.

The deep sea red crab is relatively common and occurs mainly in northern Namibian waters. It forms the basis of a small but valuable trap fishery between the 400 and 900 m isobath. Female crabs tend to dominate the shallower water whereas males tend to prefer the deeper water. There is little known about spawning behaviour, egg and larval distribution, or occurrence of juveniles off the Namib coast.

Red crabs are found on sand to sandy-mud bottoms at temperatures of 4.5-9.5°C and in areas where oxygen levels frequently fall below 1.0 ml/l. These benthic predators scavenge a wide variety of prey such as small molluscs and polychaete worms. In 1992, the density estimates from bottom photography varied from 214 crabs/ha in the north to 34 crabs/ha in the central Namibian shelf region.

In contrast to the deep sea crab, less is known about the stone crab which is presently relatively uncommon and found mainly from Cape Cross to Lüderitz.

The rock lobster is widely distributed on kelp covered reefs in the shallow subtidal areas, especially along the southern Namib coast. It forms the basis of a small but important fishery in Lüderitz. The species is most abundant from Hottentot Bay, north of Lüderitz, to the Orange River at the border with South Africa. It generally occurs in waters of less than 30 m deep but is known to be also found in deeper water.

Rock lobsters feed mainly on ribbed mussels *Aulacomya ater*, black mussels *Choromytilus meridionalis*, and epifauna such as polychaetes and bryozoa attached to rocky substrates. They are long lived but slow growing, and are particularly sensitive to fluctuations in environmental conditions such as oxygen levels and temperature which can markedly influence their distribution, behaviour and availability (Pollock and Beyers 1981).

Female rock lobsters moult and mate during May and June, and incubate up to 200 000 eggs on the underside of the tail. The larvae have a planktonic stage of up to 18 months, during which the larvae may travel hundreds or thousands of kilometres. The developing larvae are carried back to the home territories by currents and settle out amongst the rocks and kelp of the inshore reefs. Most of the settlement of young rock lobster takes place along the south coast from Kerbe Huk (28°S) to Sylvania Hill (25°S). Some settlement also occurs between Cape Cross and Conception Bay.

1.2.6 Fish

The main commercial species of demersal and pelagic fish exploited off the Namibian coast are the hakes (Cape hake *Merluccius capensis* and deep water hake *M. paradoxus*), monkfish *Lophius vomerinus*, kingklip *Genypterus capensis*, pilchard or sardine *Sardinops sagax*, anchovy *Engraulis capensis*, round herring *Etrumeus whiteheadii*, horse mackerel *Trachurus capensis*, albacore *Thunnus alalunga*, big-eye tuna *T. obesus*, yellow-fin tuna *T. albacares*, and more recently the deep sea orange roughy *Hoplostethus atlanticus*. Other species which are numerically important in the ecosystem, both as food for other fish and as grazers of zooplankton, are pelagic gobies *Sufflogobius bibarbatus* and myctophid lanternfish, *Lampanyctodes hectoris* and *Diaphus* spp.

Recreational angling is a popular activity along parts of the Namibian coastline. The most common species caught by anglers include cob *Argyrosomus hololepidotus*, steenbras *Lithognathus aureti*, dassie or black-tail *Diplodus sargus*, galjoen *Coracinus capensis*, and barbel *Galeichthys feliceps*. Other species such as snoek *Thysites atun* and various sharks, skates and rays are also caught by anglers. Most are caught within 5 km of the coast.

Hake are distributed widely over the shelf, and occur as a thick horizontal band close to the bottom at depths of 200-600 m. Cape hake are found in shallower water (200-400 m) than the deep water hake (300-600 m). The juvenile stages frequent shallower inshore water. Hake are opportunistic feeders and live close to the seabed, especially by day. At night, fish move off the bottom and into the midwater layers to feed. The diet consists mainly of gobies, small horse mackerel, euphausiids and lantern fish. Cannibalism is thought to be widespread and may strongly influence recruitment. Fish become sexually mature at about 2 years and spawn during late winter and spring.

Monkfish live on the soft muddy sand and have the same geographic distribution as hake. These fish feed intermittently, preying on fish that live near the bottom. They grow rapidly during the first year but slow down thereafter. Sexual maturity is attained after about four years at 40- 50 cm in length. In contrast to monkfish, kingklip occur mostly on rough ground in deep water (300-500 m) to the west of the Orange River and northwest of Lüderitz. The main food of kingklip are hake and other fish such as pelagic gobies, squid and myctophid lantern fish. Kingklip reach sexual maturity at 4-6 years, and there is an inshore spawning migration and an offshore movement of juveniles to the feeding grounds.

Pilchard and anchovy are free swimming pelagic fish occurring usually in the upper layers. Horse mackerel, in contrast, have a pelagic phase for the first two to three years, and then migrate offshore to deeper waters where the mature adults become more demersal and mesopelagic. Both pilchard and anchovy are mixed particulate and filter feeders, with juveniles often feeding on zooplankton and adults on phytoplankton. Horse mackerel are opportunistic feeders and prey on zooplankton (copepods and euphausiids) and juvenile fish at all stages of their lives.

Pelagic fish are typically short-lived but highly productive, often with large population fluctuations. All three species are serial batch spawners, with spawning taking place over extended periods with well defined peaks in spring and summer/ autumn. Acoustic surveys and fish sampling indicate that these pelagic species can form huge shoals which can be particularly dense during the day. These shoals tend to remain deep and move inshore during daytime, but rise to the surface and disperse during the night. Pilchard can reach an age of up to 10 yr, but the most of the Namibian population is currently only 1-2 yr old. Anchovy is a shorter lived species with a maximum age of 3 yr. The structure of its population is typically narrow, with most commercial catches being taken from young stock. The age of the horse mackerel population indicates that juvenile fish up to 3 yr old occur in the pelagic zone. Once migration to deeper water takes place, the fish grow more slowly, with mature adult horse mackerel reaching ages in excess of 10 to 15 yr.

Pelagic gobies and lanternfish form an important part of the ecosystem and food stocks for larger fish. It is likely that their combined biomass in the northern Benguela system is in the order of a few million tonnes. Pelagic gobies occur widely over the shelf in waters of < 200 m depth and are semi-pelagic. They are short-lived (1-3 yr) and feed mainly on plankton. The myctophid lanternfish are found in large numbers along the edge of the continental shelf at depths of 300-600 m. Occasionally these fish can be found closer to the coast during certain conditions. There is little known of their biology in these waters.

1.2.7 Marine mammals

A variety of marine mammals including seals, whales and dolphins is widely distributed in Namibian waters.

The occurrence of whales and dolphins off the coast has been documented by Findlay (1989) and Findlay and Best (1993). Twenty-four species of resident, seasonal resident and migratory cetaceans are known to occur in Namibian waters. All species are given the status of Absolutely Protected (AP) in the Sea Fisheries Act of 1992. Information on the distribution of whales and dolphins within Namibian waters is scarce, but the majority of species that have been recorded are widely distributed throughout the southern ocean.

Species that undergo seasonal migration through the continental shelf waters of Namibia include the blue whale *Balaenoptera musculus*, humpback whale *Megaptera novaeangliae*, fin whale *Balaenoptera physalus*, sei whale *Balaenoptera borealis*, minke whale *Balaenoptera acutorostrata*, Bryde's whale *Balaenoptera edeni*, sperm whale *Physeter catodon* and pygmy right whale *Caperea marginata*. Those known to pass closer to the coast include the humpback and the southern right whale *Eubalaena australis*.

Four species of small whales, Cuvier's beaked whale *Ziphius cavirostris*, Gray's beaked whale *Mesoplodon grayii*, Layard's beaked whale *Mesoplodon layardii* and Blainville's beaked whale *Mesoplodon densirostris* (Ziphiidae) are known to occur off the coast of southern Namibia and are thought to be pelagic.

Ten species of dolphins (Delphinidae) have also been recorded from strandings and sightings along the west coast of southern Africa. These include cosmopolitan and pelagic shelf edge species such as killer whales *Orcinus orca*, false killer whales *Pseudorca crassidens* and pigmy killer whales *Feresa attenuata*. The common dolphin *Delphinus delphis* and the Risso's dolphin *Grampus griseus* have been recorded along the shelf and in coastal waters, whereas the Heaviside's or Benguela dolphin *Cephalorhynchus heavisidii*, endemic to the west coast of southern Africa, is resident year-round in near-shore Namibian waters of <100 m deep. This species is quite common in the Lüderitz area where up to 60 animals have been observed in the sheltered bay (Roux 1993). The dusky dolphin *Lagenorhynchus obscurus* and the bottlenose dolphin *Tursiops truncatus* also live in the coastal waters, with the latter frequently occurring close inshore in the vicinity of Walvis Bay (Praetsch 1995). The southern right-whale dolphin is found in both pelagic and coastal habitats. It has a localised distribution off the coast of Namibia, possibly associated with the Lüderitz upwelling cell.

Three species of seals occur in Namibian waters, the Cape fur seal *Arctocephalus pusillus pusillus*, the subantarctic fur seal *Arctocephalus tropicalis*, and the southern elephant seal *Mirounga leonina* (Roux 1993). Both of the latter species are vagrants (Tarr 1987).

The Cape fur seal occurs in large numbers along the coast of Namibia, with about 75% of the African population present in Namibian territorial waters. Since the 18th century, the seals have been heavily exploited for their pelts, which resulted in widescale destruction of populations. At the beginning of this century, the number of seals was very small, but populations have recovered in recent years to a level where controlled exploitation at a sustainable level is allowed.

One of the largest breeding colonies in the country is at Cape Cross, where the population exceeds 250 000 animals (Wickens *et al.* 1992). Other important breeding colonies are found along the southern Namibian coast near Lüderitz, where up to 16 breeding sites are known to occur ranging from a few tens of hundreds of animals to over 100 000 animals. The main breeding areas in this region are at Atlas and Wolf Bays and Long Island near Lüderitz, which make up over 38% of the total pup production. There are also a number of non-breeding colonies in this area.

The seals feed over an extensive area of the continental shelf, but tend to remain close to shore within 150 to 200 km of the breeding colonies. Prey items consist mainly of pelagic gobies, juvenile hake, myctophid lantern fish, horse mackerel and pilchard, but also include invertebrates such as squid and euphausiid shrimps (David 1987; Roux 1994).

Adult male seals arrive at breeding colonies from mid-October to mid-November to establish territories, and remain on the colonies until the end of the mating season (late December-early January). Adult females come ashore to mate and give birth between mid-November and late December. They remain on or close to the colony for several months while weaning the pups. Pups are born in early December and usually remain in the vicinity of the breeding colony until the onset of the following breeding season, when they are displaced by territorial adults. At weaning, the pups weigh 16-22 kg. Young non-breeding adults usually remain at sea and around non-breeding colonies until sexual maturity.

Estimates of seal numbers, including pups and yearlings, along the southern Namibian coast have been given at over 1 million individuals (Roux 1994; Wickens *et al.* 1992). However, numbers have been considerably reduced over the period 1993-1995 due to large scale starvation associated with displacement of fish within the northern Benguela Current system. Since 1983, with the exception of Cape Cross, the population has shown no significant increase as a whole despite a reduction in harvest rate.

The seal colony at Cape Cross is an important tourist attraction, with over 10 000 visitors to the region annually. There is also considerable potential for the development of ecotourism at the seal colonies at Atlas Bay and Wolf Bay, south of Lüderitz.

1.3 Harvesting of living marine resources

At one time, Namibia had one of the richest pelagic fish resources in the world, but heavy exploitation by the South African inshore pelagic fleet in the late 1960s and early 1970s led to overfishing and a decline in the pilchard resource. At the same time, the abundant deep sea resources of hake were depleted by intense fishing activities by foreign trawler fleets including those from Spain, the former Soviet Union, the eastern bloc countries and Japan (Stuttaford 1994). Responsibility for fisheries management and regulation at the time was divided between the International Commission for the South East Atlantic (ICSEAF) for offshore deep water catches and the South African administration in Windhoek for inshore pelagic fisheries. Although resource monitoring and conservation of stocks improved in the 1980s, catches by foreign fleets continued to rise.

In 1990, after Namibian independence, a 200 mile exclusive economic zone (EEZ) was declared, within which fishing by foreign trawlers was prohibited except under licence to Namibian companies. A new Ministry of Fisheries and Marine Resources (MFMR) was created in 1991 to take over resource management and regulatory responsibilities. The

initial work by the Ministry was the formulation of the Government White Paper on fisheries policy entitled "Towards Responsible Development of the Fisheries Sector". This White Paper outlines policies to rebuild the depleted living marine resources, encourage the efficient exploitation of these resources and ensure that the maximum benefits from these resources accrue to Namibians (Amutenya 1995). The government currently maintains strict limits on catches so that fish stocks can recover fully from the decades of overexploitation. It is also pursuing a policy of increasing onshore processing capacity and enlarging the Namibian fishing fleet.

In 1994, the recorded fish landed in Namibian waters was 640,000 metric tonnes (mt), which was about 18% less than the volume landed in 1993 and about the same as in 1992. The total value of these fish and fishery products was N\$1380 million, and much was exported. In 1994, the fishing industry's share of the total Namibian exports was about 28%, which has increased threefold since 1990.

The fishing industry employs about 7,000 seagoing crew members and about 5,000 shore based employees working in processing factories and fishing companies mainly at Walvis Bay and Lüderitz. It is estimated that about 4,000 of those working at sea are foreign nationals who work on board the foreign-flagged midwater trawlers and tuna fishing boats.

In 1994, Namibia's fishing industry contributed about 7.5% of the Gross Domestic Product (GDP). The fisheries sector also made a significant contribution to the food security in the continent, with the export of over 500 000 mt to other African countries, much consisting of low priced horse mackerel and canned pilchard.

At present, fishing is one of the cornerstones of the Namibian economy, and the industry is expected to earn nearly N\$1500 million/yr. Furthermore, with the development of indigenous companies and the processing of more fish onshore, some optimists predict that the fishing industry could contribute N\$2 billion to the economy by the year 2000 and provide up to 15 000 jobs. A summary of recent efforts towards building up a modern fishing industry was given by Kankondi (1994). Landing statistics by fishery and species, as well as export volume and value of processed and unprocessed fish products from the period 1990 to 1994, are given in MFMR (1995).

1.3.1 Pelagic fishing industry

The pelagic fishery, mainly pilchard, anchovy and juvenile horse mackerel, is exploited by a fleet of about 40 purse-seine vessels varying in length from 23 to 48 m. Most of these boats work for canning and fish meal factories in Walvis Bay. All anchovy, round herring and juvenile horse mackerel are processed into fish meal, whereas about 90% of the pilchard caught are canned. There are three canneries and five fish meal plants at Walvis Bay employing 1000 permanent staff and about 3000 seasonal staff. There are approximately 480 fishermen employed on pelagic vessels.

In good years, most of the fish occur in dense shoals close inshore within 30 km of the coast with stocks widely distributed from Cape Frio in the far north to Conception Bay in the southern central region. However, the availability and abundance of these pelagic fish to purse-seine vessels varies greatly between years, depending on recruitment and environmental conditions. In the early 1990s, fish shoals were relatively close to Walvis Bay whereas during the last two years (1994-1996) pilchard and anchovy have been very scarce in Namibian waters and concentrated instead in southern Angolan waters.

Quotas are strictly allocated for pilchard. In 1994, the quota was set at 125 000 tonnes. However, this has been sharply reduced to 40 000 tonnes in 1996 following the disappearance of pilchard shoals from Namibian waters (Boyer *et al.* in prep.). Other pelagic species such as anchovy and round herring are non-quota species. Traditionally, the pelagic fishing season runs from 1 January to 31 August each year.

It is difficult to estimate the value of the pelagic catches landed at Walvis Bay, as prices vary with species and condition of fish, and whether the catch goes to fish meal or canning. However, the export value of canned pilchard for 1994 was estimated at N\$429 million.

1.3.1.1 Pilchard

Pilchard stocks were at their highest in the 1960s, and were estimated at over 2 000 000 tonnes with annual catches of 300 000 to 800 000 tonnes.

The stock later collapsed during the 1970s through a combination of overfishing and unfavourable environment, and in 1994 were only at a quarter of the former population levels at 400 000 tonnes (Stuttaford 1994). Since independence in 1990, over 14 acoustic biomass surveys have been carried out by the MFMR using the Norwegian vessel R.V. Dr Fridtjof Nansen and the Namibian vessel R.V. Welwitschia. These surveys indicated that adult pilchard stocks showed good signs of recovery from 1990 to 1992, rising to 650 000 tonnes, although this is still low compared with historical levels.

Since 1992, estimates have steadily declined. Pilchard biomass in Namibian waters in 1993 was put at 450 000 tonnes, and in 1995 had fallen even further to about 125 000 tonnes.

1.3.1.2 Anchovy

Anchovy stocks, although generally not as plentiful as pilchard, have shown similar fluctuations in abundance, with catches between 1970 and 1980 varying between 150 000 and 350 000 tonnes. Apart from some very large catches in 1987, when approximately 376 000 tonnes were landed, anchovy stocks have also shown a steady decline. In 1992, only about 60 000 tonnes were landed during the fishing season. Biomass estimates from 1993 resource surveys for both anchovy and round herring put the combined estimate at 220 000 - 335 000 tonnes, with most shoals occurring between the Kunene River and Dune point in the north, and south of Conception Bay to the Orange River in the south.

Since 1994, anchovy and round herring biomass have dramatically declined with landings of these species contributing only a few thousand tonnes to the total pelagic fish catches.

1.3.1.3 Juvenile horse mackerel

Besides pilchard and anchovy stocks, inshore pelagic shoals of juvenile horse mackerel are also exploited by the local purse seine fleet for reduction to fish meal at Walvis Bay. These small fish are abundant and widely distributed in the coastal waters north of Walvis Bay, with an estimate of 420 000 tonnes of juvenile stock in 1993.

Purse seine vessels usually land between 65% and 75% of the tonnage allocated to them. In 1994, about 34 000 tonnes of juvenile horse mackerel were landed and converted to fish

meal. The export value of this product was worth N\$20 million. This species is currently the most abundant pelagic fish in the northern Benguela, and high TAC levels (e.g. 200 000 tonnes for 1995) have been consistently set.

1.3.2 Midwater horse mackerel fishery

The deep water adult Cape horse mackerel stocks forms the basis of a large midwater trawling industry, located mainly in the rich fishing grounds off northern Namibia. This horse mackerel fishery has been particularly resilient over the last twenty years, with annual catches of 200 000 - 500 000 tonnes by foreign fleets (Klingelhoeffer 1994).

In 1993, there were between 30 and 40 catcher vessels consisting predominantly of Russian and Ukrainian stern trawlers fishing the region between Cape Cross and Cape Frio throughout most of the year. Some of the catches are converted to fish meal, but more recently large horse mackerel are frozen whole and used for human consumption in regional African markets. During the last two years, many of the large Russian vessels have become uneconomical to run, and the fishery has become more streamlined with the addition of new more efficient vessels and joint venture companies.

Resource surveys carried out by the MFMR between 1990 and 1995 have indicated a biomass of between 1.2 and 2.1 million tonnes of offshore horse mackerel present in the northern fishing grounds. Biomass peaked in 1992 but declined somewhat in 1995 to about 1.5 million tonnes. The fishery is regarded as being very healthy and in a steady state.

The horse mackerel fishery is regulated by quotas and operates the whole year round. The total allowable catch for 1996 has been set at 450 000 tonnes, of which 150 000 is reserved for the local inshore pelagic purse seiners. In 1994, over 330 000 tonnes of adult horse mackerel were landed, worth an estimated N\$300 million.

1.3.3 Demersal fisheries

The main commercially exploited demersal or bottom living fish are Cape hake, deep-water hake and monkfish. Kingklip (below) is a valuable by-catch of the hake fishery. Hake and monkfish form the main component of the Namibian whitefish trawling industry, and are the most valuable fishery resource being used directly for human consumption.

1.3.3.1 Hakes

Hake stocks have been slowly recovering since 1990, with an estimated 120 000 tonnes caught by Namibian demersal trawlers in 1993, compared with only about 20 000 tonnes in 1986.

Resource surveys of both species of hake have been undertaken by the MFMR over the Namibian continental shelf since 1990, mainly with the assistance of the Norwegian vessel R.V. Dr Fridtjof Nansen. Results have indicated a total hake biomass fluctuating between about 500 000 and one million tonnes. Cape hake predominate in the central Namibian shelf region, and can make up about 50% of the total hake biomass (Hamukuaya 1994).

The estimated total biomass of hake has dropped from about 790 000 tonnes in 1994 to about 575 000 tonnes in 1995. Hake TACs for 1993 and 1994 were set at 120 000 and 150 000 tonnes respectively.

Over 60% of all hake are caught in the central and northern fishing grounds and landed in Walvis Bay. The remainder are caught in the southern region and landed in Lüderitz.

The annual current market value of hake species caught in Namibian waters is estimated at between N\$400 million and N\$500 million, with over 40% of the catch processed on land. Most of the hake is headed, gutted and filleted before being exported to overseas markets mostly as frozen block fillets or catering packs. An increasing percentage of the catch is also being airfreighted fresh on ice to markets in Spain and other European countries.

1.3.3.2 Monkfish, kingklip and west coast sole

Monkfish, kingklip and west coast sole form the remainder of the commercial demersal fish caught in Namibian waters, and are keenly sought after with high market demand. These species are not subject to quotas and are caught mainly as a by-catch by trawlers fishing for hake.

Monkfish is the most commercially valuable species taken by bottom trawlers. In 1994, it was estimated that the biomass of monkfish off the coasts was between 25 000 and 30 000 tonnes, and of this, over 8800 tonnes with a value of about N\$60 million was landed. Catches of kingklip can comprise up to 16% of the by-catch from hake long-line vessels. However, most fish are caught by bottom trawlers, and annual landings for 1994 exceeded 1500 tonnes. West coast sole are caught in localised patches inshore of the 200 m isobath, and are taken as a by-catch during hake trawling operations. Total catches by Namibian trawlers have fluctuated from 69 to 1940 tonnes during the 1980s, and now comprise about 600 tonnes per annum, at a value of about N\$2.3 million.

1.3.4 Commercial line fisheries

Line fishing has been carried out in Namibian waters since the early 1960s. It reached its height in the early 1980s, but since then catches have declined and in 1993 there were only 17 line fishing vessels from eight companies registered and operating out of Walvis Bay (Botes 1994). The main species targeted by linefish vessels are snoek, cob, albacore and big eye tuna.

1.3.4.1 The albacore fishery

The Namibian albacore tuna fishery operates from November to May each year, with catches taken predominantly by pole and line fishing vessels. These boats are usually 20-30 m long and have freezer capacity, or chill the fish using ice wells.

The main area of fishing activity is located around the Tripp Seamount, about 200 km WNW of the Orange River mouth. Occasionally, in the southern Namibian region, well developed seasonal frontal systems can move close inshore, bringing albacore tuna within 20 km of the coast.

In 1990, after Namibian independence, there were only three vessels exploiting albacore stocks. However, the effort has greatly increased during the last few years, with 26 vessels registered in 1994. Subsequent catches have reflected this increased effort, with 2900 tonnes landed in 1994 compared with 215 tonnes in 1991. The export value of tuna in 1994 was valued at N\$18.5 million. The south Atlantic albacore resource has been heavily exploited over the last decade, with the maximum sustainable yield (MSY) currently estimated at about 24 000 tonnes. Albacore catches taken in Namibian waters make up about 10% of the total south Atlantic catches. The commercial tuna fishery and monitoring of catches in Namibian waters has been recently reviewed by Lehmensiek (1995).

1.3.4.2 The big-eye tuna fishery

Big-eye tuna are found throughout the Atlantic Ocean between 45°N and 45°S (ICCAT 1993). During migratory journeys, the fish feed along the boundaries of the Benguela Current before moving into other parts of the Atlantic. Fishing takes place over a broad area from Walvis Bay to the Orange River. The seasonal locations depend on where shoals of fish concentrate or the location of the oceanic fronts. Satellite imagery of sea surface temperature is being increasingly used by fishermen to locate likely feeding areas for tuna. Since independence, a tuna longline fishery for big-eye has developed off the northern Namibian coast, with stocks exploited by Japanese vessels. The fish are gutted at sea, frozen and later shipped to Japan to the high value sashimi market.

In 1994, a total of 979 tonnes of tuna were caught by longliners fishing off northern Namibia, of which over 80% were big-eye. Export values were roughly N\$17 million. Catches of big-eye off Namibia make up about 1% of the total Atlantic big-eye catches, which are now approaching the MSY of 69 000 tonnes (ICCAT 1993).

1.3.4.3 Ski-boat fishery

Several ski-boats operate out of Swakopmund, catching linefish on a regular basis with up to 25 boats fishing from time to time. Most fishing takes place within a few hours distance of the town. Boat owners have a commercial licence to catch and sell fish, and are subject to monitoring by fisheries inspectors. The main species caught by ski-boat fishermen are snoek, cob, west coast steenbras and barbel. Annual catches can exceed 100 tonnes, with cob and barbel making up the bulk of the landings. Much of the catch is sold locally to restaurants and hotels.

1.3.4.4 Recreational angling

Shore angling is an important tourist attraction along the coast of Namibia. Several thousand fishermen flock to the coast each year especially during summer months, making a significant contribution towards the local economy (Holtzhausen 1996). Most of the shore based recreational angling along the Namibian coast takes place in the area from Swakopmund north to the Ugab River at well known locations such as Mile 14, Jakkalsputz, Torra Bay and Terrace Bay. The area between Walvis Bay and Sandwich Harbour is also a popular fishing area especially in summer. The most popular angling fish are cob, steenbras, dassie, barbel and galjoen, with annual landings of cob alone exceeding 500 tonnes. Daily catch statistics indicate heavy fishing pressure on some species, and there are regulations to limit fishermen to 30 kg of processed fish per day.

1.3.5 Deep sea fish stocks

In 1994 and 1995, stocks of new unexploited deep sea fish species were located in deep water off the coast of Namibia during exploratory fishing operations. These were orange roughy *Hoplostethus atlanticus*, alfonsino *Beryx splendens*, and various species of oreo dory, i.e. *Pseudocyttus maculatus* and *Allocyttus niger*. These fish inhabit waters of 800-1500 m deep and frequent the continental slopes and submarine pinnacles bordering the eastern part of the Walvis Ridge. Significant stocks are also thought to exist in the high seas region outside the 200 mile EEZ.

Orange roughy are particularly long-lived, reaching a maximum age of 120 years. Maturity is attained only at age of 25-30 years. This makes the species highly vulnerable to fishing pressure, especially since it forms dense aggregations which can be readily exploited. As has been found out in other parts of the world, such as New Zealand, orange roughy stocks can easily be "mined out" over a short period, with stocks extremely slow to recover. The catching of orange roughy, alfonsinos and oreo dory is a specialised deep sea operation that commands a high degree of skill and the use of precision underwater sensors for monitoring trawl behaviour and fish aggregations.

At present, there is one major fishing company based in Walvis Bay carrying out exploratory fishing and research on these deep sea fish stocks. Priorities for 1996 are to obtain further scientific data on these species and to carry out explorations for new fishing grounds. So far, about 4000 tonnes of orange roughy and alfonsino have been landed and processed into fillets for the export market. These fish have firm white flesh and are highly valued internationally, especially in the USA. Prices can reach over US\$20/kg for quality products.

The status of the orange roughy, alfonsino and oreo dory stocks in Namibian waters is presently unknown. Given the distribution of the likely habits in which these fish occur, adult stock biomass could exceed 150 000 tonnes.

1.3.6 Deep sea crab fishery

The deep sea red crab forms the basis of a small but valuable fishery in the relatively deep waters off southern Angola and northern Namibia. It is fished along the edge of the continental shelf at depths of between 295 and 850 metres. Continuing good growth rates of individual deep sea red crabs were recorded in 1993, leading to a slight increase in biomass and catch rates. Since then, however, stocks have stabilised. Biomass, catch rates and total landings are still at historically low levels, and the species is considered over-exploited.

The crabs are semi-processed at sea during which the legs and shoulders are removed, cooked and blastfrozen. Further processing is sometimes carried out ashore where the meat is extracted from the legs.

Yields of deep sea red crab were estimated at over 5000 tonnes in the mid-1980s, when several Japanese fishing boats were exploiting the stocks. Catches have since declined with increased fishing intensity, and have fluctuated between 2676 mt in 1991 and 3598 mt in 1994. The landed value of unprocessed deep sea red crab in 1994 was estimated at about N\$66 million, and over 1790 mt was exported to Japan. The deep sea crab fishery is regulated by a quota which was set at 4500 tonnes for 1994. The stocks are presently exploited by a small number of Japanese vessels in joint ventures with Namibian companies.

1.3.7 Rock lobster fishery

The rock lobster presently forms a small but valuable fishery in the inshore waters of southern Namibia. In contrast to catches in the 1960s when several thousand tonnes were taken annually, stock have steadily declined through overfishing and unfavourable environmental conditions to their present low levels. Recent research indicates that the stocks may be slowly recovering, but it is still too early to make any projections. The catching of rock lobster is strictly regulated by quotas, which for 1994 were set at 130 tonnes. These allocations are usually filled within several days after fishing commences. A closed season operates between May and October.

Depth distribution and availability of rock lobsters appears to be strongly influenced by the presence of poorly oxygenated water, which frequently moves inshore. Such conditions can cause mass mortalities, including "walkouts" onto the shore. Rock lobsters are also vulnerable to red tide occurrences which can lead to localised mortalities from gill clogging, low oxygen and toxins.

The rock lobster industry is important economically to the town of Lüderitz. Two of the main companies employ over 500 full-time and 650 part-time seasonal staff. The value of 130 tonnes of landed live rock lobster for 1994 was estimated at N\$10 million. Most of the catch is exported to Japan. A review of the Namibian rock lobster fishery is given by Grobler (1993,1994).

1.3.8 Seals

Two sealing concessions exist in Namibia, and commercial exploitation takes place only at Atlas Bay and Wolf Bay to the south of Lüderitz and at the main breeding colony at Cape Cross. Products from seal harvesting consist mainly of pelts and meat which were valued at about N\$600,000 in 1994. Harvesting quotas vary from year to year, depending on the success of breeding and variation in natural mortalities. In 1993, 21 500 pups and 1200 bulls were harvested at Cape Cross, and 26 000 pups and 1650 bulls at Lüderitz. The 1994 quota was for 43 000 pups and 12 000 bulls from the three main seal colonies (MFMR 1995). Sustainable utilisation of Namibia's seal population as a resource is part of government policy. It is estimated that existing harvesting levels can only be sustained if the population of 500 000 individuals is maintained. In the wake of recent catastrophic losses of adult and pups in 1994 as a result of environmental perturbations and decline in pelagic fish stocks, current seal harvesting strategies may be approaching or exceeding sustainable levels.

1.3.9 Mariculture

The development of mariculture is at an early stage in Namibia. The only species currently farmed in commercial quantities are shellfish such as Pacific oysters *Crassostrea gigas*, European oysters *Ostrea edulis* and black mussels *Choromytilus meridionalis* (Zoutendyk 1993). These operations are still relatively small by European standards. Some experimental work is also being done with abalone, clams, shrimps, microalgae and seaweeds. Certain seaweeds such as *Gracilaria verrucosa*, which grows in abundance in Lüderitz Lagoon, could also be extensively cultivated and the wild stocks propagated and harvested (Molloy 1992; Critchley 1993).

The main producers of oysters in Namibia are located at Swakopmund, Walvis Bay and Lüderitz. The Swakopmund operation is based 10 km north of the town in the salt pans of a commercial salt producer. Both Pacific and European oysters are grown here in trays submerged in raceways and ponds. Water is pumped directly from the sea and then flows via a narrow channel into the pans. A similar operation in the saltworks of Walvis Bay lagoon also produces about the same quantities of Pacific oysters. Further south in Lüderitz Bay, Pacific oysters and black mussels are being cultivated using both long-lines and bag culture techniques. These operations up to recently have been producing about 100 tonnes of shellfish.

Total annual production of this operation would be about 100 tonnes of Pacific oysters and 10 tonnes of European oysters. Much of the production is marketed locally and in South Africa. The export value in 1994 was estimated at about N\$15 million.

1.4 Marine resource management

The Directorate of Resource Management in the MFMR undertakes research to provide advice on the optimal use of fish resources and ensure that stocks are managed at a sustainable level. Advice is provided to the Minister and the Sea Fisheries Advisory Council on the status of stocks and recommendations are made on yields. If necessary, recommendations are also made for protecting the resources such as limiting fish size, closed seasons and areas, and limitations on the type and effectiveness of fishing gear.

1.4.1 Stock assessment

In order to make these recommendations, a number of routine stock assessment surveys are carried out off the Namibian coast each year. These resource surveys quantify populations of demersal and pelagic species such as hake, pilchard and horse mackerel using both swept area trawling and hydroacoustic techniques. In addition, sampling programmes from the commercial and survey vessels provide information on the biological parameters of fish. Deep sea crab stocks are monitored by trap fishing and tagging and through sampling of commercial catches. Rock lobster populations are monitored for size and age structure through sampling of commercial catches, diving surveys and tagging. Seal populations at major colonies are also monitored each year, and recommendations to ensure sustainable harvesting levels are also made. An outline of Namibia's fisheries research responsibility has been given by Jürgens (1994). In making recommendations for harvesting of stocks, the state of the environment and the likely effects of oceanographic conditions on the living marine resources are also taken into account.

1.4.2 Total allowable catch (TAC)

On a yearly basis, the Minister of Fisheries and Marine Resources announces the TACs for regulated marine species. This is usually done in December, prior to which the Minister is advised by a Sea Fisheries Advisory Council established in terms of the Sea Fisheries Act of 1992. The Advisory Council consists of fifteen members, appointed by the Minister with the Permanent Secretary as chairperson and is constituted as follows: three officers of the MFMR, one officer of the Ministry of Trade and Industry, one officer of the Ministry of Finance, one officer of the Ministry of Environment and Tourism, two marine biology or sea fishery economics experts not employed by the State, two persons representing employees

in the fishing industry, five persons with experience or demonstrated capacity in any branch of the fishing industry.

To advise the Minister on TACs, the advisory council meets in September to consider rock lobster and in October to consider hake, pilchard, red crab and horse mackerel. Two weeks prior to the Sea Fisheries Advisory Council meeting, MFMR fisheries biologists submit a report detailing research methodology, results and recommendations on TACs and other management options to advisory council members. This report is based only on natural resource data and does not take into account socio-economic aspects. The function of the advisory council is to take social and economic aspects into account before making a motivated recommendation to the Minister.

1.4.3 Fisheries management policy

The 1991 White Paper, "Towards Responsible Development of the Fisheries Sector," clearly defines major fisheries policies set out by Government. The Sea Fisheries Act of 1992 was later enacted based on these policies. Following the exclusion of a large number of foreign vessels from Namibian waters at independence, the main challenges of the Directorate of Resource Management have been the rebuilding of devastated fish stocks and the regulation of fishing capacity at a sustainable level. Achieving these aims involves a complex series of control measures relating to fishing effort, gear, season, area, and the setting of TACs.

Besides fishing mortality, research scientists also have to estimate natural mortality in order to calculate TACs. Natural mortality in fish populations is highly variable, depending on changes in environmental conditions and subsequent biological interactions within the ecosystem. Such uncertainties surrounding natural mortality estimates can make it difficult to predict the accuracy of the TAC levels.

Relative to management strategies elsewhere in the world, fisheries management in Namibia has been one of the more successful to date. This is evident from the gradual increase in TACs since 1990, when low TACs were initially set in order to rebuild depleted stocks. However, recent perturbations in the marine environment off Namibia in 1994-1995 have had a major impact on some fish stocks, particularly pilchards, and have led to TAC declines. As a result, this has created pressure from the fishing industry to maintain catch levels to protect investment.

A detailed review of the fisheries sector for 1993 and 1994 including landing statistics has been published by the Ministry of Fisheries and Marine Resources (MFMR 1995).

1.4.4 Monitoring the marine environment

The marine environment off Namibia is routinely monitored by research vessels of the MFMR and the Norwegian R.V. Dr Fridtjof Nansen (Rist *et al.* 1996). These vessels are equipped with modern oceanographic instruments and recording devices for measuring temperature, salinity, oxygen and nutrients such as phosphates, nitrates and silicates. The seasonal movements and interactions of cold and warm water masses, as well as the speed and direction of currents, are also measured. These studies have important applications in oil spill contingency planning, establishing the migration patterns of fish, and mapping the dispersal of fish eggs and larvae from spawning to nursery grounds.

Satellite remote sensing has important implications for fisheries management and knowledge of the marine environment. Since the upwelling processes taking place off the Namibian coast are among the most intense in the world, the information collected by satellites is of great interest both to Namibian and international scientists. A satellite receiving station located in the National Marine Information and Research Centre (NATMIRC) at Swakopmund monitors changes taking place in the marine environment and aids in the understanding of the interactions between oceanographic processes and fisheries.

The German Technical Cooperation Agency (GTZ) through the Marenpro Programme is currently assisting the MFMR on various aspects of environmental monitoring, particularly with regard to the potential impacts of diamond mining on rock lobster stocks in the Lüderitz area. The results of such studies will enable future changes in the coastal marine environment to be monitored and models to be tested as commercial developments of these resources proceed.

1.5 The Benguela Current ecosystem

The Benguela Current is a very productive ecosystem, with a mean annual productivity of 1254 g C/m²/yr. This is exceeded only by the Humboldt Current off the west coast of South America, with a productivity of 1256 g C/m²/yr, and can be compared with the North Sea ecosystem at 200 g C/m²/yr or the northeast shelf ecosystem of the United States at 350 g C/m²/yr. It is characterised by upwelling which is often intense and subject to large interannual and interdecadal variability. Pelagic fish such as pilchard (sardines) and anchovy frequently exhibit marked fluctuations in abundance associated with these changes, which range from episodes of collapse to rebound and rapid switches in dominance. This is particularly evident off Namibia in the northern Benguela system, where the ability to estimate and predict fish stock abundance and recruitment is important for sustainable management.

1.5.1 Regional importance of the Benguela Current

The fish stocks of the Benguela ecosystem support major artisanal and industrial fisheries that make important contributions to food security in Africa and to the economies of Angola, Namibia and South Africa. Shared marine resources including migratory fish stocks are a feature of the ecosystem, with the movement of some species between countries requiring an increasing integrated and co-operative strategy for management and harvesting.

The near-shore sediments also hold rich deposits of diamonds, diatomite and phosphorite, as well as natural gas and possibly oil reserves. The natural beauty of the coastal regions has enabled a significant coastal tourism industry to develop in certain areas.

The Benguela Current ecosystem is considered unique because it is the only global upwelling current region that has warm water frontal systems along its northern and southern borders, i.e. the Angolan and Agulhas Currents. Situated between the Atlantic and Indo-Pacific and Southern Oceans, it is also influenced by both natural and anthropogenic processes in these oceans. It therefore attracts wide interest from both the regional and international marine scientific community.

1.5.2 Benguela Current as a large marine ecosystem

The Benguela Current can be regarded as a large marine ecosystem (LME). Such regions consist of ocean space (typically 200 000 km² or larger) encompassing coastal areas from river basins and estuaries out to the seaward boundaries of continental shelves and coastal current systems. They are characterised by distinct bathymetry, hydrography, productivity and trophically dependent populations (Sherman 1994). LMEs are being subjected to increasing stress from exploitation of renewable resources and human-induced habitat damage or loss, such as from coastal developments and various forms of pollution. They are subject to natural variability on time-scales ranging from seasonal to decadal, and there is increasing evidence that a number of LMEs respond to interannual and decadal variability of climate.

Approximately 95% of the annual world fish catches are taken within LMEs. Sherman (1994) identified 49 LMEs, four of which are associated with eastern boundary current upwelling systems. Primary productivity is generally higher at the margins of the oceans, and it is these regions that are subject to the greatest impact by man through fishing, physical disturbance and pollution. Degradation of coastal environments by eutrophication and harmful algal blooms, overexploitation and, in some LMEs, the collapse of major fish stocks compounded by the impacts of natural variability, has resulted in growing international concern about the health of the oceans.

1.5.3 Marine scientific research

During the last fifteen years, a major co-ordinated research effort between government and university institutions was undertaken by South Africa to study various aspects of the Benguela Current ecosystem. Much of this work was concerned with pelagic fish and rock lobster and carried out in the southern Benguela region off South Africa. Some significant research was also undertaken off the Namibian coast in the northern Benguela Current. Extensive reviews of scientific research into the Benguela ecosystem include those on evolution, physical features and processes (Shannon 1985), chemistry and related processes (Chapman and Shannon 1985), plankton (Shannon and Pillar 1986), fish and invertebrate resources (Crawford et al. 1987) and the coastal zone (Branch and Griffith 1988).

The South African research programme, known as the "Benguela Ecology Programme" (BEP), was run in three 5-year phases. The first phase was concerned with anchovy and sardine life cycles in the southern Benguela system, drogue studies and algal bloom development after upwelling and sediment nutrient regeneration. Systems of estimating pelagic fish recruitment success were also studied. The second phase of BEP concentrated mainly on physical processes such as new and regenerated production, food web models and carbon budgets. The third phase, to end in late 1996, was more focused on sardine, anchovy and squid spawning, growth and recruitment, and the development of models of plankton dynamics and current/ advection processes.

The results of the BEP so far have been presented at two international symposia and published in two comprehensive volumes of scientific papers (Payne *et al.* 1987, 1992). This successful venture has resulted in the rapid development of capacity in marine and fisheries science in South Africa and to some extent in Namibia. Approximately 200 scientists have been associated with the BEP since its inception, and approximately R25 million (US\$ 8 million) spent to date.

1.6 Coastal and offshore marine industries

There are numerous activities taking place along the coast which impact on the marine environment. These chiefly relate to fish processing factories and port authorities operating in Walvis Bay and Lüderitz, marine diamond mining in the shallow coastal waters off the southern part of Namibia, and oil exploration activities in offshore waters.

1.6.1 Coastal zone developments

The main centres for industrial development at the coast in Namibia are centred in the two main ports, Walvis Bay and Lüderitz. In contrast, Swakopmund and to a lesser extent Henties Bay are focused on tourism and are sensitive to any industrial development which would affect the tourist potential. Along the rest of the coast, outside the immediate confines of the main coastal towns, there is little development and the coastal environment can be regarded as in pristine condition.

In Walvis Bay, the fish factories, harbour and port activities and the operation of the synchrolift port equipment are the main industrial activities affecting the marine environment. In the past, such developments were largely undertaken independently of each other, and were not planned in a co-ordinated and environmentally sensible manner. Consequently, the increased industrialisation of Walvis Bay has led to more pollution of water from organic and inorganic sources. Conservation and protection of the Walvis Bay Lagoon, a coastal bird sanctuary of international importance, is of major concern. A similar situation, although on a smaller scale, can be found in Lüderitz Harbour.

Developments associated with increased harbour and shipping activities have also resulted in local oil spills in Walvis Bay, whereas anchorage by foreign fishing vessels outside the harbour zone contributes to beach contamination by oil and pollution with rubbish.

Future planned coastal development includes the exploitation of dune sands between Swakopmund and Walvis Bay, which are rich in heavy minerals. A desalination plant is proposed for construction at the coast near Walvis Bay, and plans are going ahead for a feasibility study to build a new fishing harbour at Möwe Point in northern Namibia. A new export processing zone (EPZ) is also planned for Walvis Bay which is expected to stimulate the local economy and lead to increased development in the area.

Danish Co-operation for Environmental and Development (DANCED) have recently provided assistance to MFMR and the Ministry of Environment and Tourism (MET) to introduce clean water technology for the fish processing industry in Walvis Bay and to develop an integrated coastal zone management programme for the region (DANCED 1995a,b,c). Integrated coastal zone management (ICZM) offers an alternative to conventional planning approaches by formulating holistic coastal area developments which more actively involve inhabitants of the area as well as relevant national and local authorities.

1.6.2 Marine diamond mining

The mining industry in Namibia comprises about 51% of all exports and 43% of the GDP. Diamonds are one of the cornerstones of the Namibian economy, accounting for about 47% of total export earnings in 1995. In recent years, marine diamond mining activities have

intensified along the coast of Namibia, with the main thrust of operations moving from land into the shallow coastal and even deeper waters. This has been brought about by the depletion of land based reserves and new developments in seabed surveying and mining technology which have located new rich deposits of gem quality diamonds in submarine gullies and ancient shorelines beneath the sea. Currently, marine deposits make up about 40% of the country's diamond production.

1.6.2.1 Coastal open cast mining

One of the largest open cast diamond mines at the coast is situated at Elizabeth Bay, south of Lüderitz. This mine was recommissioned in 1991 and has a life expectancy of about ten years. Tailings from the ore deposits (< 2.0 mm in diameter) are discharged through pipes from the mine into the sea at various points along the beach at Elizabeth Bay. It is expected that during the lifespan of the mine, up to 1.5 million tonnes will be discharged into the bay as tailings, thereby extending the shoreline some 300 m seaward from the original boundary.

1.6.2.2 Subtidal mining

In the Lüderitz area and south to the Orange River, Namibia-De Beers Diamond Mining Group (NAMDEB) have sub-leased some of their shallow water concessions (up to three miles from the coast) to smaller contractors. These operators use small boats equipped with airlifting pumps or diver operated suction pumps. Some miners use pumps from the shore to exploit diamondiferous gravels that have collected in gullies in the surf zone and beyond. Sites where the gravel is exposed or lightly covered with overburden are usually selected because of the demands of diving operations. There are other independent companies that also hold concessions in this nearshore environment and operate in the same way.

1.6.2.3 Deep sea mining

The mining of diamonds from seabed deposits in relatively deep water off the west coast of Namibia and South Africa was pioneered by De Beers Marine in 1990. Whereas conventional dredging techniques are generally limited to 50 m, ore bodies mined by new technology are at depths of over 100 m.

Specialised recovery techniques are used in which diamondiferous gravels are pumped directly from deposits to the vessel. Alternatively, automated tracked mining vehicles are used and controlled on the seabed using an umbilical connection to the surface vessel. Deposits are screened onboard to retain the size fractions likely to contain diamonds. The gems are retrieved using an x-ray extraction machine. The unwanted fractions of sediment and gravel (< 1.5 mm and > 16.0 mm), which usually make up over 75%, are discharged overboard.

Concessions may cover an area of between 30 000 and 50 000 ha, and before production commences, extensive geophysical and hydrographic surveys must be undertaken to locate diamond ore-bearing gravels. This process is usually followed up by an intensive exploration phase involving test coring, grab sampling and trial mining of deposits.

During the commercial mining operations, large quantities of sediments are continuously sucked from the seabed to the mining vessel and the finer and coarser gravels discharged into the sea, generating extensive sediment plumes. Extractions can vary from 25 tonnes/hr during the pilot mining phase to as high as 100 tonnes/hr in commercial operations. Annual extraction rates during the first three years of operation can range from between 70 000 to 300 000 m³/yr.

Since the commencement of the De Beers Marine operations, new companies have entered into the field and have carried out extensive surveys of the seabed deposits closer to the coast off Lüderitz at depths of 20 to 50 m. Applications for both trial sampling and commercial production have been sought, with at least one company already exploiting diamonds commercially. In the next few years, it is expected that several specially equipped diamond mining vessels will be operating in the coastal waters in the Lüderitz area and off the Orange River.

1.6.3 Offshore oil and gas exploration

In the late 1960s and early 1970s, several offshore concessions for oil and gas exploration were awarded by the South West African Administration to companies which covered the whole continental shelf from the Angolan border in the north to the South African border in the south. Some 50 000 kilometres of seismic surveys using the recently developed air guns were carried out; 23 000 km of magnetic data and 10 000 km of gravity data were obtained. Only one well was drilled in this period, the Kudu 9A-1 well, which struck a large reservoir of dry gas off the Orange River.

In 1985, the petroleum corporation Swakor, which since Namibian independence has become NAMCOR, carried out a fairly detailed seismic survey of the Kudu area. In order to prove further gas reserves, as suggested by the seismic data, two further wells were drilled. The flow from the Kudu 9A-3 well was 38 million ft³/day. An *in situ* reserve of 5 trillion ft³ had been calculated, of which 2 trillion ft³ could be recovered.

Namibia's first formal oil exploration licensing round was first opened in May 1991. The areas licensed in the first round were blocks 1911, 2012, 2213, 2815 and the Kudu area 2814A respectively, operated by Norsk Hydro, Sasol, Ranger Oil, Chevron and Shell.

Since 1992, six oil exploration wells have been drilled over wide regions of the Namibian continental shelf, in water depths ranging from 300 to 600 m and at distances of up to 80 km offshore. To date, no indications of oil apparently have been found. However, further drilling is to take place off the Orange River both to assess the gas reserves and commercial development of the Kudu field and to explore for oil.

A review of the history of oil and gas exploration in Namibia is given by Hangala (1994).

2 Marine ecosystem and environment: trends and threats

The marine environment off Namibia undergoes constant change through regional and local variations in wind patterns, upwelling intensity and water circulation. These changes directly affect temperatures, nutrient availability and plankton production, which in turn markedly influence fish distribution, spawning and growth. The position and seasonal migration of the south Atlantic high pressure system over southern Africa determines regional wind patterns, and subsequently has a major effect on the marine environment.

2.1 Variability in the marine environment

The northern Benguela Current can exhibit extreme temperatures, characterised by intrusions of unusually warm water and periods of prolonged intense upwelling which give rise to extensive cold water distribution. Of particular environmental significance has been the "Benguela Niños" of 1984 and 1995 and the eutrophication of the northern Benguela in 1993 - 1994, which resulted in an abnormal intensification and widespread distribution of low oxygen water on the Namibian continental shelf and a poleward expansion of oxygen-depleted water from Angola. These conditions had major impacts on marine species, causing sharp reductions of the Namibian seal population and marked population declines in pilchards and pelagic gobies (an important food resource for hake). These changes in turn can severely impact on the local fishing industry, through altering distribution and migration patterns and affecting the success of spawning.

Other unusual features include the periodic occurrence of local sulphur eruptions along the coast and occasional sudden increases in phytoplankton biomass leading to algal blooms or "red tides." Such occurrences can have also have significant local effects on marine resources.

2.1.1 Benguela Niños

The effects of the warm water events known as the Pacific El Niño on the anchovy fishery off Peru and Chile during 1972-73 and 1983-84 have been well documented. These warm water intrusions led to the depletion of nutrients and phytoplankton in upper layers and a collapse of the anchovy stocks. Similar but less intense occurrences, known as Benguela Niños, have been recorded in the northern Benguela off Namibia during 1934, 1963, 1973-74, 1984 and 1995, when warm tropical water from Angola pushed further south than usual to reach Walvis Bay (Shannon *et al.* 1986). During the summer of 1995 a strong Benguela Niño was recorded in southern Angola and the northern Benguela (O'Toole and Bartholomae 1995; Gammelsrod *et al.* 1995). These regional climatic and oceanographic events exhibit decade-scale trends, characterised by the relaxation of equator wind stress, higher sea level rises, suppression of effects of upwelling, and strong thermal gradients in the water column.

Studies have suggested strong links between the Pacific El Niño and regional climatology, oceanography, rainfall and crop yields around southern Africa, with an apparent time lag of one year between the occurrence of the Pacific event and effects around southern Africa. Such connections, although poorly understood, may provide a useful mechanism for future forecasting of such environmental anomalies and predicting fish spawning success and recruitment.

Benguela-Niño type events have considerable impact on Namibian marine biota, especially in the northern and central region, and usually result in marked reductions in plankton production, decreased spawning intensity of pelagic fish, and lowered food availability for developing larvae. In 1963, biological parameters including plankton biomass, pilchard oil yields, gonadal development and spawning activity, and survival of larvae were affected. Changes in the distribution and abundance of plankton faunal assemblages were also noted, and fish species of tropical origin were found close to Walvis Bay.

The impact of the 1984 Benguela Niño on the northern Benguela ecosystem was also significant, with reports of a major southward shift of pilchard shoals. During the pelagic fishing season of that year, the biomass of recruited anchovy was the lowest on record, and only 13 000 tonnes of a quota of 20 000 tonnes were landed. Phytoplankton and zooplankton biomass were four times lower on average in the summer and autumn of 1984 than during the same period in 1982-83 or in the two previous summers. In March 1984, phytoplankton abundance was ten times less than in previous years with the plankton dominated by warm water species. Pilchard egg production for the 1984-84 spawning season declined by 25% from that of the previous two years, and anchovy spawning was poor with egg production only 10% of that in the 1982-83 season.

The 1995 Benguela-Niño off northern Namibia caused widespread local mortalities of fish such as pilchard, horse mackerel, cob and steenbras along parts of the coast. This was followed by a poor fishing season for pilchard and very low levels of recruitment. By contrast, the warm water event favoured horse mackerel, resulting in a wider distribution and successful spawning season.

2.1.2 Sulphur eruptions

During the summer and winter months, sulphur eruptions frequently occur along the coast between Cape Cross (22°S) and Conception Bay (24°S). These eruptions are caused by the build-up of high levels of organic matter, mainly from the decay of phytoplankton. This breakdown of organic matter consumes oxygen, leading to temporary oxygen depletion in seabed sediment and in the near-bottom water. Here, muds accumulate which have little or no marine life but are rich in decaying organic matter and sulphur. Local sulphur eruptions are triggered by seasonal changes, water temperature and unknown factors, and give the sea a lime green colour accompanied by a characteristic pungent smell. Such eruptions can cause localised environmental degradation and heavy mortalities of near-shore marine life, especially when accompanied by low oxygen levels.

2.1.3 Phytoplankton blooms and eutrophication

Phytoplankton blooms ("red tides") are formed when algal cells rapidly multiply, a phenomenon caused by complex chemical and biological processes that take place under specific meteorological and hydrological conditions. Such events often cause large scale mortalities to fish and crustaceans, either due to neurotoxins produced by the bloom or to physical clogging of the gills. Decay of blooms can also lead to localised oxygen deficiency, as well as promoting conditions for the formation of hydrogen sulphide. The occurrence of red tides and fish mortalities has been widely reported and documented off the coast of Namibia for many years, especially in the vicinity of Walvis Bay.

These blooms generally occur during summer and autumn, when upwelling is suppressed and calm, warm conditions prevail. Mass mortalities of fish (juvenile pilchard, horse mackerel and steenbras) caused by algal blooms have been reported by Brongersma-Sanders (1957) and Copenhagen (1953) in the inshore waters around Walvis Bay. The causative agents were identified as the dinoflagellates *Peridinium triquetrum*, *Gymnodinium galatheanum*, *Goniaulax tamarensis* and *Noctiluca milaris*. The majority of organisms that cause red tides are non-toxic, although they may have an adverse effect on the marine fauna and the environment through secondary complications such as gill clogging, hypoxia, anoxia and oxygen embolism. Although toxic effects caused by red tides off Namibia are relatively rare, some poisonings have been reported associated with eating mussels of the genus *Chloromytilus* and the white mussel *Donax serra*. The organism responsible is thought to have been a *Gymnodinium* or *Goniaulax* sp.

In recent years, phytoplankton blooms in the northern Benguela Current have become more frequent and widespread. This was especially noticeable in 1993 and 1994, when regional climatic changes produced major shifts in wind direction, resulting in reduced upwelling, calmer conditions and an increase in phytoplankton blooms along much of the coast. The effect of these climate changes was an increase in eutrophication in coastal waters, leading to a buildup of low oxygen water. These conditions subsequently had a negative impact on water quality, resulting in the degradation of some traditional fish spawning and feeding grounds.

The introduction of alien species and strains of microscopic algae into Namibian waters from the discharge of ballast water from international tanker traffic could pose a threat to the environment and health of the system. The introduction and subsequent establishment of alien species in other geographical areas by these means have sometimes had negative environmental consequences in other regions.

2.2 Fluctuations in fish stock abundance and species flips

Past overexploitation of fish stocks in the Benguela Current, together with the inherent variability of the system, has resulted in major changes in fish abundance in the region. This has been particularly noticeable since 1982. There have been major environmental perturbations and changes in the distribution and abundance of principal harvested species, such as pilchard and anchovy.

Since 1982, the anchovy stock in the northern Benguela has all but disappeared, whereas that in the southern Benguela has boomed and declined. The relatively small population of pilchard inhabiting Namibian waters has recently vanished after a few years of recovery in the early 1990s. In contrast, the pilchard population in the southern Benguela has suddenly increased following years of low availability and decline.

The principal changes taking place in the resource stocks and environment of the Benguela Current system during the last decade have been documented by Shannon *et al.* (1992). Species "flips" between dominant species in the Benguela, and their likely anthropogenic and physical causes, are discussed by Crawford *et al.* (1991). These "regime shifts" in the Benguela which correspond to similar shifts in other eastern boundary current systems and in the western Pacific have been described by Crawford *et al.* (1991).

International research on fish population variability worldwide now suggests that global synchrony may exist between periods of dominance and collapse of fish species, and that these flips could also be triggered by El Niño events and climate change (Bakun 1995), rather than totally to local overfishing *per se*.

2.3 The Benguela Current ecosystem

During the last two decades, Namibian waters of the northern Benguela Current were intensively overexploited during a "free-for-all" on pilchard, anchovy and hake by South African purse seine pelagic vessels and international trawling fleets. It is well known from other parts of the world that the impacts of intense fishing pressure such as this can contribute to changes in species dominance and composition within the ecosystem. This influences the primary production requirements of fish stocks, thereby affecting sustainable yields, trophic level functioning and predator prey interactions. These factors, coupled with variability in the marine environment, have a marked effect on fish population distribution, spawning success and recruitment.

Changes in ecosystem balance occurred off Namibia during the 1970s and 1980s when there were major shifts in dominance from commercially valuable pelagic species such as pilchard and anchovy to less economically important species such as horse mackerel and pelagic gobies. The distribution and abundance of jellyfish have also increased in the coastal ecosystem in the past decade.

Current threats to the sustainable harvesting of marine resources in the northern Benguela Current ecosystem stem mainly from our inability to track accurately the increased environmental variability associated with regional and global climate change. These factors, together with the existing low levels of commercially important small pelagics such as pilchard and anchovy, indicate that future recovery of these stocks to economically sustainable levels will be very slow.

2.4 Coastal zone developments

With the re-incorporation of Walvis Bay into Namibia in February 1994, coastal zone management has become an area to which importance is attached. At present the harbour in Walvis Bay accounts for much of Namibia's fishing industries, and it is expected that the human population will double within the next ten years. Lüderitz, located further south along the coast, is also an important fishing port.

2.4.1 Threats to the coastal environment

With the trends towards increased industrial development, the need for coastal zone management in Namibia is apparent both in Walvis Bay and in Lüderitz. Both these areas combine fishery activities with industrial production, but are situated in highly fragile environments incorporating important wetlands, coastal deserts and rock lobster fishing grounds. Future growth is likely in terms of fishing industries, offshore mining for diamonds, phosphorite and diatomite, and oil drilling activities.

2.4.1.1 Oil spills

A major environmental threat to the whole Walvis Bay area, but especially the sensitive nearby wetlands, is the risk of an oil spill occurring in the harbour or drifting into the bay from an outside anchorage. In 1994 and 1995, some minor spills occurred from shipping accidents and during the transfer of bunker oil both in the bay and at the harbour. These spills fortunately did not cause major damage to marine life or the ecology of the wetlands.

One of the main difficulties encountered with any oil spill is the one of disposal after clean-up operations. The disposal of recovered oil from a major spill in the Walvis Bay area is likely to be a problem, as there is no designated "Class A" site for the dumping of oil or toxic waste in the region. The disposal of used oil from commercial business operations, fishing vessels and garages in Walvis Bay is also problematic. Much of the existing oily waste from commercial operations is stored in drums or containers on land, and there is no exact information on the quantity stored, the conditions of the containers, or the future plans for disposal. Direct disposal such as dumping at land fills or quarries is a possibility, but health implications, impacts on the environment and possible contamination of groundwater would have to be carefully considered.

In the event of a significant maritime incident involving a major oil spill in the Walvis Bay area, large parts of the surrounding coastline and the sensitive wetlands and lagoon are likely to be threatened and ultimately impacted by oil. Such pollution would also affect seabirds, aquaculture operations, marine mammals, shallow subtidal regions, amenity beaches, marinas, water extraction, exposed shorelines, sheltered shorelines and shorebirds.

The main threat of oil pollution in the Walvis Bay area comes from the bunkering facilities at the harbour. Here, coastal tankers and fishing vessels transfer and load on fuel. The fishing fleet itself poses some threat to pollution, since the boats carry substantial amounts of fuel along the coast during the fishing season. Foreign trawlers moored outside harbour limits also pose a pollution threat to the nearby beaches by transshipping fuel.

The priority area for environmental protection is the Kuiseb estuary, including the Walvis Bay lagoon which supports the greatest number of wetland birds in southern Africa (over 60 000 seabirds and migrant waders). It is also an important feeding area for these protected migrant and resident bird species, including the greater and lesser flamingo. Localised oil spills within the harbour or bay could also threaten the nearby saltworks and oyster farm, and taint water in the harbour used by the fish factories during processing.

2.4.1.2 Seawater quality

Water quality in both Walvis Bay and Lüderitz is generally poor due to fish factory effluents, minor oil spills, local phytoplankton blooms, high organic levels, and in some cases heavy metals in the bottom sediments (O'Toole 1995; Botha 1995). This seawater is routinely used by some fish factories in washing and ancillary processing activities, and does not meet standards required by the European Community. Thus new sources of clean water are required, and the feasibility of constructing a desalination plant on the coast near the saltworks is presently being considered. Some fish factories have already solved this problem by installing expensive water purification units to treat the seawater pumped from the harbour into their factories.

2.4.1.3 Recreational fish stocks

There is some concern about overexploitation of recreational fish, especially cob and steenbras, by shore fishermen, and that catches may be approaching unsustainable levels. Research indicates that some stocks are declining, while at the same time it is increasingly difficult to control fishing activities and enforce bag limits. In the case of cob stocks, exploitation also takes place at sea by the commercial line-fish and recreational ski-boat fisheries, putting additional pressure on the stock. Occasionally, high by-catches of cob are made by trawlers and purse-seiners operating in shallow coastal water.

The trend towards increasing industrialisation, threats to the local marine environment and the problems of effluent and water quality in relation to the fish processing industry have resulted in DANCED instigating a priority programme to look into the issues of coastal zone management, particularly in relation to Walvis Bay (DANCED 1995a,b,c). This programme is to be carried out with the Directorate of Environmental Affairs (DEA) of the MET and supported by the MFMR and the Ministry of Agriculture, Water and Rural Development (MAWRD). Its primary focus will be on the coastal area between Walvis Bay and Henties Bay. This is an important tourist region which has rich local marine resources, a fragile coastal ecosystem of beach and dunes, and an inland desert ecosystem and riverbeds.

The DANCED integrated coastal zone development plan is broad based and aimed at increasing the co-ordination and planning between stakeholders and government officials to ensure sustainable economic, environmental and social development. Problems to be addressed by the project include town planning, erosion, competing land uses, resource depletion and environmental degradation, legislation, sewage and waste disposal, pollution, clean technologies, desalination, uncontrolled mining and coastal sensitivities.

DANCED have already adopted a participatory approach to the ICZM project, and have had workshops at the coast with all of the interested and affected parties and stakeholders, including municipalities and relevant government ministries. The logical framework approach (LFA) was used in the project proposal formulation workshop, which was later followed up by a feedback workshop.

2.5 Diamond mining

The mining of diamonds from coastal gravel deposits along the southern part of Namibia is developing into a major industry attracting international attention and investment. Already, marine diamonds make a sizeable contribution to the national GDP and a very valuable export commodity.

The trend in current activities and future plans by mining companies suggest an intensification of marine diamond mining, especially in the use of a greater number of large surface vessels with on-site processing plants.

2.5.1 Threats to marine biota and the environment

The threats posed by diamond mining operations to the local biota, particularly rock lobster, as well as to the quality of the marine environment in general, are very real. At present, however, they are not readily quantifiable (Pallet 1995; below).

2.5.1.1 Impacts on marine biota

The continuous discharge of large volumes of fine particles during diamond dredging could increase turbidity levels to such an extent that the pelagic ecosystem within the mining area could be negatively affected. Localised effects on marine organisms of increases in turbidity and suspended solids are varied, but these increases can harm fish, shellfish and crustaceans. For example, heavy sediment loads in the water are known to cause physical harm by clogging of gills and filtering mechanisms of fish, crustaceans and benthic organisms, especially filter feeders. The reproduction, growth and survival of benthic infauna will also be seriously affected by heavy sedimentation. In the plankton, the development of eggs and larval stages of marine organisms can be adversely affected by excessively high silt concentrations.

The potential threats of diamond mining activities on marine organisms will ultimately depend on the type of equipment used, the methods of operation, and the prevailing physical oceanographic conditions at the site, such as winds, currents and thermal stratification. Possible impacts will also be influenced by the frequency and seasonality of dredging, the particle size of the sediment, and the amount of turbidity generated in the water column by the dredging operation itself.

2.5.1.2 Water quality

When fine bottom sediments are disturbed by dredging activity, the amount of suspended material in the water increases, causing turbidity clouds. These sediments can then be transported both vertically and horizontally over long distances by bottom currents, and can produce a variety of deleterious effects. Sediment loading can reduce light penetration in the water column and affect plankton productivity and subsequent food availability for pelagic fish. Marine sediments often contain large quantities of organic material which are reintroduced into the water column during dredging. These organic particles usually come from an anoxic environment and have a high oxygen demand, which can reduce the levels of dissolved oxygen in the seawater to a lethal range for marine organisms. The main source of turbidity is the resuspension of fine organic material in the water column when sediments are pumped to the surface for screening during dredging. These tailings are discharged over the side of the vessel into the sea. Depending on the commercial scale of the operation, such discharges could exceed hundreds of tonnes per day, resulting in an increase in sedimentation and perhaps causing local smothering of benthic organisms.

2.5.1.3 Mining and rock lobster stocks

One of the main concerns in the Lüderitz area has been the likely impact of marine diamond mining on the local rock lobster population, which forms a small but valuable fishery in this community (Oelofsen 1994). Rock lobsters mainly inhabit the subtidal reefs from the low tide mark out to depths of about 20 m. Some mining concessions are located in the main rock lobster fishing areas, and potential conflict exists between the mining companies and this fishing industry. Concern has been expressed by fishermen that shallow water diamond dredging and disturbances on the sea bottom put stress on the rock lobster populations and in some cases cause direct damage and mortalities to juveniles and adults.

Rock lobster stocks are currently at a low level. A quota of only 200 tonnes was allocated for the 1995 fishing season. By contrast, during the 1960s and early 1970s, lobster stocks were estimated at 9000 tonnes but declined rapidly to present levels due to overexploitation and adverse environmental conditions. It is doubtful if the lobster population will ever recover to former levels given the current low level, slow growth, complex life history, and sensitivity to low oxygen, temperature changes, and the impacts of coastal diamond mining.

Concern has also been expressed by lobster fishermen about the effects of the Elizabeth Bay open cast mine on the marine environment. The threat of this operation on local lobster stocks is also being closely monitored by the CSIR and NAMDEB in consultation with MFMR. Results show that much of the sediment from the discharge pipes is being retained within the bay and blown back inland by strong southwesterly winds. Transportation of fine sediments out of the bay northwards towards Lüderitz can occur periodically, but the amounts potentially affecting rock lobsters on nearby reefs are regarded as insignificant.

As a precautionary measure, the MFMR and the German GTZ group through the Marenpro project have initiated a study of the environmental effects of diamond mining on rock lobster stocks in the Lüderitz area, in which assistance will be given to monitor the effects of sedimentation and habitat disturbance on lobster grounds over the next few years.

2.5.2 Assessments of environmental impacts

Detailed environmental impact assessments of the marine diamond mining concession areas off Lüderitz have recently been carried out (CSIR 1995b,c; UCT 1994b; Pallett 1995). These were undertaken using an Integrated Environmental Management (IEM) participatory approach, in which interested and affected parties were identified and consulted at various stages. The EIAs made an assessment of likely impacts of the mining project on marine species and the local environment, compared to the current situation. Specialist studies were also commissioned to examine and model the effects of sediment plumes resulting from mining operations, giving particular attention to the potential impacts on the rock lobster population and fishery. Recommendations were then made to mitigate potential negative effects and to address any threats posed by the operations on the ecosystem.

The EIA studies, especially along the near-shore concession off Lüderitz, concluded that there would be a small short-term negative impact on local marine resources and industries (mainly the rock lobster fishery and mariculture). Localised, temporary degradation of the marine environment could result from inshore operations, but would be less damaging than offshore mining concession areas in deeper water. Less is known about possible threats to rock lobster populations posed by the long-term or cumulative effects of intensified mining taking place from large surface vessels near Lüderitz. Tomalin (1995) points out that compared to the environmental variability in the Lüderitz region and the recent reduction in lobster growth rates, impacts on rock lobster stocks and fishery are likely to be very small.

In relation to diamond mining activities by small diver operations along the shore, recent studies south of the Orange River have shown that direct threats on rock lobster populations, sub-littoral fauna and flora in the subtidal regions by these smaller operators were regarded as minimal (Barkai and Bergh 1992). However, two potential impacts that could have indirect effects on rock lobsters were identified. These were kelp-cutting to clear paths for pipes when operating from the shore and the occurrence of unstable piles of boulders which may crush sheltering juvenile rock lobsters during storms.

2.6 Offshore oil and gas exploration

The marine ecosystem, like any other, is sensitive to change. Industrial activities can detrimentally affect the environment through oil pollution, dumping of waste, release of toxic substances, or disruption of water chemistry. As the search for offshore diamonds, oil, gas and other deposits increases, so does the risk of environmental degradation. Trends in offshore oil exploration in Namibia indicate that further licensing will take place and that exploratory drilling activities on the continental shelf will continue into the foreseeable future. It is also likely that commercial development of, and production from, the Kudu gas field will take place within the next few years.

2.6.1 Threats to the marine biota and environment

The main environmental issues and potential effects from exploratory work are the deposition of drill cuttings and water-based drilling muds on the seabed around the rig. Local direct effects such as smothering of benthic (seabed-dwelling) organisms are likely to occur, as well as some indirect effects from potentially toxic components of drill cuttings and muds. The impacts of these activities on the benthos are expected to be localised and limited, as a result of rapid dispersal and dilution of these substances as well as bioturbation and recolonisation by benthic organisms. Accidental spills of diesel fuel from operations onboard the rigs into the marine environment are also possible, but such localised spills would pose minor risks because of rapid dispersal and evaporation.

One of the main threats to the marine environment associated with offshore oil exploration would be the occurrence of a well "blow-out." Such a happening, although fairly rare (1 in 2000 wells drilled) could release over 3000 barrels of crude oil per day into the marine environment. This could have a devastating impact on the living marine resources. Commercially important fish, spawning grounds, marine birds and mammals could be affected, and slicks could affect pristine terrestrial habitats, wetlands and amenities in important tourist areas.

Concerns on the threats posed by the offshore oil exploration industry on fisheries and the marine environment were addressed in detail during a recent international workshop held in Swakopmund (O'Toole 1994). With the exception of a blow-out, the likelihood of any significant impacts on the marine environment as a result of exploratory drilling for hydrocarbons on the Namibian shelf are regarded as minimal.

In the event of a blow-out, the Namibian government has already in place a national emergency plan under the management of a Government Action Control Group (GACG). This group was established prior to drilling of the first offshore well in 1993, and consists of small group of senior officials and experts representing the Ministry of Works, Transport and Communication (MWTC), the MFMR, MET, Ministry of Regional and Local Government and Housing (MRLGH), Civil Defence, Namibian Police, Namibian Port Authorities (NAMPORT), National Petroleum Corporation of Namibia (NAMCOR) and Namibian Search and Rescue (NAMSAR). Its main function is to co-ordinate responses to national emergencies, such as a major oil spill at sea or a blow-out, through implementing a national emergency contingency plan and by collecting information, providing advice and assistance, acting as a main contact point, and liaising with the media. The group has received advance training in oil spill and emergency responses, including simulated and live exercises.

2.6.2 Assessment of environmental impacts

Namibia has made provision in the Petroleum Exploration and Production Act of 1991 that registered license holders conduct environmental impact assessments and prepare detailed oil spill contingency plans before commencing drilling activities. These regulations also require strict control in the selection and use of materials and the disposal of solid waste by using a waste management plan and a materials balance system.

Baseline environmental assessments are required prior to seismic surveying, and a detailed impact assessment must be produced before the exploration drilling phase can commence. The detailed assessments contain an outline of the proposed drilling programme, a brief description of the existing environment, a summary of possible threats and proposed mitigation measures, together with a summary of environmental issues remaining following mitigation. However, before drilling starts, three action plans are finalised by each operator: the health, environment and safety plan for work and waste management practices on the rig, the contingency plan to cover any type of emergency, and the oil spill contingency plan. Before the development of an oil well, a third environmental assessment study must be completed to cover all aspects of production.

The national environmental assessment policy drawn up by MET also regulates aspects of environmental protection and planning. Although the companies fund the assessments, the Ministry can at the cost of the licensee appoint an independent reviewer to test or monitor the assessment.

In the production of baseline studies and impact assessments carried out to date, there has been regular and close consultation throughout the preparation of each EIA between the operators and the Ministry of Mines and Energy (MME), MET, MFMR and Ministry of Health and Social Services (MHSS), as well as NAMCOR and the maritime divisions of the MWTC. Recent EIAs completed for offshore Namibia include those by Norsk Hydro (1993a), Sasol (1994), Ranger Oil (1994), and Chevron (1995a,b,c).

Final baseline and EIA reports are evaluated by all the above ministries and NAMCOR, and where necessary external consultants are brought in. Thus, the EIAs are not only evaluated and approved by the MME and NAMCOR but by Namibia's environmental ministries as well.

The EIAs conclude that the main impacts from exploratory drilling activities on the local marine environment would be the discharge of water-based drilling muds, sediment plumes in the water column, accumulation of discharged drilling muds and cuttings on the seabed, accumulation of heavy metals in bottom sediments, and possible toxic effects of mud additives on marine organisms and communities. The threats to the local biota and marine environment are regarded as insignificant, given the depth of water at drill sites, the short duration of drilling activity (a few weeks), and the small number of wells in relation to the expanse of the continental shelf.

Environmental threats arising from blow-outs are also assessed in detail, and response and contingency plans prepared which include drift and dispersal trajectories, containment and recovery as well as cleanup operations. Detailed coastal sensitivity maps and contingency plans should oil pollution occur have also been prepared.

3 Root causes of marine environmental problems

The direct causative factors influencing the variability of Namibia's marine environment and fisheries resources seem primarily related to regional, and possibly global, climate changes. In some cases, overexploitation of certain fish species has taken place, which in the case of pilchard suggests that present harvesting practices are unsustainable.

Apart from widespread environmental degradation caused by naturally occurring events, such as deoxygenation of coastal and shelf waters, phytoplankton blooms and sulphur eruptions, the northern Benguela Current system in terms of industrial pollution and water quality can be regarded as relatively pristine. On a more local level, however, the direct root causes of environmental degradation along the coastal zone originate mainly from harbour activities, fish factory effluent, ship pollution, accidental oil spills, marine diamond mining activities, and uncontrolled industrial development. At present, the effects of offshore oil exploration activities on the marine environment are regarded as insignificant because of the low level of activity and the wide distribution of drill sites over the continental shelf.

Indirectly, some of the causes contributing to marine environmental problems can also be traced to lack of coordination in policies, planning and management strategies, and to poor communication between ministries that share responsibilities for different aspects of the marine environment.

3.1 Climate change, environmental variability and fisheries

The root causes of recent problems experienced in the marine environment of the northern Benguela Current relate more directly to marked changes in oceanographic conditions than to unsustainable fishing pressures. These perturbations were associated with a slackening of upwelling, eutrophication, and low oxygen conditions in 1993 and 1994, followed by a major warm event (Benguela Niño) in 1995. Such unusual oceanographic conditions seem associated with patterns of regional climate change, perhaps correlated with Pacific El Niño effects and "global teleconnections," or links between marine anomalies around the world.

The impact of such variability on the ecosystem and marine resources such as fish and seals has been dramatic. Following a period of steady increase in the biomass of marine resources for the first few years after independence, stocks of certain species such as pilchard and anchovy began to decline with the onset of unfavourable environmental conditions. This was also reflected in mass mortalities of juvenile hake in early 1993, changes in availability and migration of both pelagic and demersal fish species, and poor recruitment, starvation and death of marine predators, including over 300 000 seals.

Given that fish stocks and investment in the fishing industry were expanding during the early 1990s, there were strong pressures on the vessels and companies to catch the quotas of allocated to them. However, during 1993 and 1994 with the changes in environmental conditions, stocks were increasingly difficult to catch and most of the pilchard shoals apparently moved out of Namibian waters into southern Angola. The fact that vessels intensively fished this adult spawning stock in Angola may also add to difficulties concerning the future recovery of this stock. Latest surveys by the MFMR now indicate that pilchard and anchovy have all but disappeared from Namibian waters, with only a few thousand tonnes being reported.

Present uncertainties about natural mortality and the effects of environmental changes on fish behaviour, as well as about some aspects of survey design and biomass assessment, make it difficult for fisheries scientists to make confident recommendations. Added to these uncertainties are the general lack of understanding of the interrelationship between climatic factors and oceanographic processes operating off southern Angola, Namibia, and the west coast of South Africa, and their relation to regional climate changes, Pacific El Niños and global warming. However, the quality of the scientific advice and the confidence of MFMR fisheries biologists have recently improved through continued training and assistance by international experts. An internal review system recently adopted within the research institute (NATMIRC) ensures that the final report presented to the advisory council is of a high standard.

Other factors which contribute indirectly to constraints are the lack of trained and experienced fisheries, oceanographic and environmental research manpower at NATMIRC. The absence of such personnel restricts capacity to monitor and predict environmental change and subsequent impacts on fisheries resources. Strategic planning and management for monitoring and researching of the marine environment also needs to be addressed. The MFMR has improved its capacity to do stock assessment work, assess status of commercial fish species, and produce TACs. In contrast, marine environmental and plankton research and ecosystem analyses have received less attention, and the capacity to undertake this important work has been severely restricted due to lack of training and experienced manpower as well as the absence of a clear research strategy. Because of this situation, the Ministry's ability to monitor and predict the impact of environmental change on its fish resources has been severely limited. This weak environmental research capacity was highlighted recently during a major environmental anomaly in the northern Benguela Current system during 1993 and 1994. The subsequent effects of this perturbation on fish stocks are not clearly understood, except that there was a decline in availability of some pelagic stocks and high mortality in other living marine resources such as seals.

In the past, information exchange and reporting between the fisheries scientists, management and the fishing industry was weak. This has improved considerably with more frequent meetings between the MFMR's fisheries scientists, international experts, consultants and industry now taking place. There is still a need for clearer management guidelines and realistic objectives in order to address critical issues, such as sudden declines in stocks and recruitment levels due to adverse environmental conditions.

With regard to understanding the Benguela Current system as a whole, there is at present only limited co-ordinated research, information exchange and co-operation in fisheries and oceanographic research between countries in the region. Collaboration in research and planning is essential to manage and exploit the living marine resources sustainably, and to address such issues as straddling stocks, high seas fisheries, and contingency planning for and response to major oil spills or pollution threats.

3.2 Pollution and dumping of waste

One of the direct root causes of local environmental degradation of water quality in Walvis Bay harbour, and to a lesser extent in Lüderitz harbour, is the amount of effluent being discharged by fish processing factories. This results in high organic loading, high suspended solids and discolouration. The discharge also contributes to deoxygenation of the water and is compounded by phytoplankton blooms, sulphur eruptions and stratification, especially

during summer and autumn months. Conditions are further complicated by reduced dilution because of poor circulation and water exchange. Harbour activities, accidental oil spills during transshipment of fuel, ship maintenance and dredging also contribute to local marine pollution. These activities lead to the presence of hydrocarbons, heavy metals and trybutyl tin (TBT) in harbour sediments, and the periodic resuspension into the water column of potentially toxic compounds bound in the sediments. Recent oil spills occurring in Walvis Bay were caused by the accidental discharge of fuel oil into the harbour during discharging of vessels at the tanker terminal. A sizeable spill also resulted from bunker oil leaked from a sub-standard freighter anchored in the bay. None of these spills caused major damage, but would have posed a serious threat to the Walvis Bay lagoon had the spills been larger or the weather conditions different. Pollution of seawater in ports is regulated by NAMPORT under the Ports Authority Act 2 of 1994, which prohibits dumping of oil and waste.

The causes of other local environmental problems in the Walvis Bay harbour and surrounding region are the dumping of waste, oil and raw sewage from foreign fishing fleets at anchor outside harbour limits. These activities result in contamination of local beaches at Dolfynstrand. Such practices contravene the Sea Fisheries Act (1992), which clearly details penalties and offences in relation to the dumping or discharging into Namibian waters of "any substances that may be injurious to fish or which may disturb or change the ecological balance in any area of the sea or which may detrimentally affect the marketability of fish or aquatic plants or which may hinder the catching of fish." The Prevention and Combatting of Pollution of the Sea by Oil Amendment Act 24 of 1991 regulates pollution of seawater by oil from ships.

Factors indirectly contributing to localised pollution of the marine environment have been:

- Poor control over procedures for unloading of oil at tanker terminals in harbours
- Lack of a functional and well tested oil spill contingency and response plan
- Lack of equipment, training and exercise scenarios to combat local spills rapidly in the harbour or other sensitive coastal areas; poor co-ordination between the various agencies and government ministries responsible for dealing with environmental pollution
- No designated disposal site for oil or toxic waste
- Lack of a co-ordinated integrated coastal zone management strategy involving all responsible agencies and ministries to deal effectively with environmental degradation
- Lack of waste management plan
- Absence of legislation controlling the use of TBT paints
- No effective service for collection of rubbish from foreign mid-water fleets anchored outside harbour limits; poor control over transfer of oil between anchored vessels
- Insufficient and irregular monitoring of effluent by authorities.

As this report was being written, it was learnt that the Norwegian Government has donated to the Walvis Bay harbour authorities a sizeable amount of oil spill combatting, containment and recovery equipment, and has hosted an intensive course in combatting oil spills.

3.3 Coastal zone management

The MFMR's Directorate of Resource Management is responsible for ensuring that coastal development activities are undertaken in a way that leads to the environmentally sustainable use and harvesting of marine resources.

Increased industrial development and expansion of fish factories and processing capacity in and around Walvis Bay harbour has led to a deterioration in water quality and pollution from effluents. Local nutrient enrichment has led to frequent occurrences of algal blooms, and accidental oil spills in the harbour have threatened bird populations in the Walvis Bay lagoon. This Walvis Bay coastal wetland supports the greatest number of wetland birds in southern Africa. It is the tenth richest wetland bird area in the whole of Africa and is designated a "Ramsar" wetland of international importance. It is also the main feeding grounds south of West Africa for a number of protected migrants and resident bird species, including the greater and lesser flamingo. The Damara tern is a threatened species breeding mostly in Namibia, with about 90% of the world's population occurring along the coast. There are also a number of other actual or potential Ramsar sites at Sandwich Harbour, the Orange River mouth, Cape Cross, and the saltworks at Swakopmund which are of critical biodiversity conservation concern. There are important breeding grounds close to the Walvis Bay wetlands, for which the wetlands provide necessary feeding grounds.

The future construction of a desalination plant near Walvis Bay, and the likely effects of the discharge of large quantities of warm, highly saline water on marine organisms and the immediate environment, also need to be investigated and mitigation measures proposed.

3.4 Diamond mining

The direct cause of environmental problems associated with marine diamond mining is the local physical disturbance of large amounts of bottom sediments and resuspension into the water column, potentially contributing to deoxygenation and damage to rock lobster stocks.

The effects of a few mining operations on the marine environment and biota may not be initially detectable, and indeed may not cause any visible detrimental effect. However, the cumulative effects of several operations working in the same region may be significant. The precise extent of these effects will only be quantified by a long-term monitoring programme.

Other factors potentially contributing to the problems of marine diamond mining are:

- * Insufficient co-ordination and planning of research by agencies into the effects of diamond mining on rock lobster and other resources
- * Absence of agreed guidelines between the diamond mining industry, MME, MFMR, and rock lobster fishermen on parameters to be measured and monitored, frequency of sampling and reporting, and defined actions to be taken to mitigate negative impacts.

4 Gaps

The main gaps which need to be addressed to reduce the threats to marine resources and environment include gaps in information, communication, research, monitoring, institutional capacity, and policy.

4.1 Benguela Current ecosystem

Although projects related to the development and management of natural resources and to environmental conservation have been carried out in the Benguela Current region (e.g. South Africa's Benguela Ecology Programme) and through bilateral agreements with donor states (e.g. Norway and Iceland in the case of Namibia, and Sweden in the case of Angola), there has been little success in co-ordinating research and management of the marine resources and the Benguela environment as a whole. This is partly due to war (e.g. Angola), political considerations (Namibia only gained independence in 1990; South Africa only emerged as a free and fair society in 1994), lack of adequate institutional capacity and infrastructure (in Angola there is a severe shortage of trained staff and facilities), language- and infrastructure-related communication problems, and inadequate funding. In all three countries, funding for monitoring, assessment and other ecosystem studies is insufficient to service national needs, let alone those of the region as a whole. Except in the extreme southern Benguela, there is inadequate understanding of ecosystem functioning, and throughout the region ongoing work lacks a proper socio-economic framework.

The main problems and issues necessary for the sustainable management and utilisation of the marine resources of the Benguela Current LME can be identified as follows:

1. There is a lack of institutional capacity and infrastructure to address a wide spectrum of activities, particularly in Angola but to a lesser extent in Namibia and South Africa.
2. There has been an apparent increase in the variability of the Benguela Current LME, which has national, regional and global implications for sustainable use and biodiversity conservation. The reasons for this are not clearly known or understood.
3. Current ecosystem monitoring is wholly inadequate and in some cases inappropriate. Marine mining and tourism industries are expanding in a fragile pristine environment, with inadequate prior impact assessments and follow-up monitoring strategies.
4. There is an increasing incidence of blooms of algal species derived from ballast water and other ship discharges. Introduced fauna have unknown but perhaps devastating consequences for the ecosystem. Degradation of the coastal environment, shrinking of habitats, and pollution are also on the increase.
5. Finally, there is a lack of structure to cater for the co-ordination and management of the BCLME as a whole, and an absence of any form of integrated ecosystem management. Some of the main constraints and information gaps are as follows:
 - a lack of research and poor understanding of the functioning of Benguela Current Large Marine Ecosystem as a whole, the effects of the environment on fish population dynamics, and linkages between these and climate change

- insufficient information on the long-term fish stock fluctuations in the Benguela Current and the effects of other marine anomalies on variability
- no infrastructure for regional co-operation in resource and environmental monitoring, research and resource management within the BCLME
- lack of standardisation in survey design, resource assessment methodology and calibration of equipment between countries of the Benguela Current region
- little retrospective analysis of historical environmental data sets including remote sensing, comparative analyses with other upwelling systems, and assessments of "regime shifts" and past climate scenarios including El Niños
- urgent technical and scientific training required in marine and oceanographic sciences to meet future Namibian demands and regional needs
- lack of a strategic plan to enhance national and regional efforts to address critical ecosystems and environmental problems
- ineffective mechanisms and capacity for consultation, co-ordination and decision making at local, regional and international levels in the management of and research on the Benguela Current ecosystem
- insufficient data to assess problems, issues and threats facing the Benguela Current LME

4.2 Coastal zone management

Tourism is a growing industry in Namibia with many visitors arriving at the coast during summer, when the population of the coastal towns can double. Seafood is popular with local and foreign visitors, and the consumption of shellfish such as oysters and mussels is increasing. Phytoplankton blooms are widespread along the coast of Namibia and seem to be increasingly associated with local eutrophication. In populated areas like Walvis Bay and Swakopmund, which are also important tourism areas, toxic forms of algae occur, potentially posing a public health hazard through consumption of contaminated shellfish. There is thus a need to identify, monitor and predict red tides and have contingency plans prepared on toxic algal blooms and on public safety relating to shellfish consumption.

Government provisions for the operation of mariculture activities, and issues such as property rights and environmental protection, have not been adequately addressed. Existing mariculture ventures operate under the provisions of the Sea Fisheries Act, where approval is being granted under the rights of exploitation and licensing.

In Lüderitz, integrated coastal zone management is needed to address the interactions of the fishing, diamond mining, rock lobster, mariculture and tourism industries.

4.3 Diamond mining

The cumulative longterm effects on the rock lobster and mariculture industries of many large vessels mining in the shallow coastal waters around Lüderitz is of some concern. Some seasonal increase in turbidity levels can be expected, depending on the intensity of

mining and the number of vessels involved. Routine, effective monitoring of the marine environment should be carried out near diamond mining operations to ensure that sediment plumes do not significantly change local nutrient and oxygen levels in the area. Further data on currents and wind in the region are needed, plus models of the dispersal and distribution of sediments resulting from mining operations under different scenarios.

Agreement between relevant government ministries (e.g. MFMR, MET, MME) and the marine diamond mining industry is needed to identify sites and parameters to be monitored and the frequency of measurements needed to assess the impacts on the local ecosystem. Procedures are being put in place through the GTZ Marenpro programme to co-ordinate efforts in monitoring while continuing to facilitate participatory workshops between ministries, the industry and the public. Public participation at these meetings is encouraged, and more effort should be extended by government in advance advertising and invitations.

4.4 Oil pollution and contingency planning

A number of national plans exist for oil spill response in Namibia, but none are up to date. Two of these were produced by South Africa prior to the reintegration of Walvis Bay into Namibia (DEA 1988, 1989) and give accounts of preparatory activities, responsibilities of various departments, job description of departmental and local authority officers, facilities, coastal protection and cleanup as well as site-specific responses. The coastal plan includes telephone numbers of priority personnel, responsible authorities and scientific advisors.

The most recent contingency plan outlines biological considerations, coastal sensitivity, and protective action to be taken in relation to major oil pollution occurring off the coast (O'Toole 1993b). It briefly lists infrastructure that may be available by relevant government ministries and municipalities and various ways to deal with protection and coastal cleanup. This plan mainly concerns major emergencies, such as large oil spills occurring off the coast from tanker accidents or blowouts from oil production activities offshore.

There are numerous gaps in oil spill contingency planning in Namibia. These are especially evident in the overall co-ordination and management structure for oil spills, responsibilities of government agencies, and planning for tiered responses, especially in the case of less severe spills that could occur in Walvis Bay and Lüderitz harbours.

NAMPORT up to very recently have been underequipped to deal with the threat of localised spills in the harbour. The port authority has now received significant oil spill containment and recovery equipment, and an intensive training course has been given to representatives of NAMPORT, various ministries and municipalities. Such regular training exercises in the use of this equipment are required to ensure that the sensitive environment is protected.

There is at present no oil spill contingency plan for Lüderitz harbour, and designated dump sites at the coast or elsewhere have not yet been made available for the disposal of oily waste or hazardous material. This calls for a joint effort between the MAWRD, MFMR and MET as well as municipalities. The report of O'Toole (1993) needs updating and revision to include more information and incorporate a more detailed Walvis Bay and Lüderitz plan into the overall national context.

5 Strategic options and interventions

Some strategic options and recommendations follow for addressing current and future threats to the marine environment. The suggestions are broad based, and focus on improved understanding of fisheries dynamics and the Benguela Current system as a whole. Mechanisms for improving coastal zone management issues and mitigating the impacts of water pollution, red tides, oil spills, marine diamond mining and coastal development projects are also considered.

5.1 Benguela Current ecosystem

It is recommended that an integrated management plan for the Benguela Current large marine ecosystem (BCLME) be drawn up and implemented. Such a plan, to include southern Angola, Namibia and the west coast of South Africa, would have the strategic objectives of enhancing national and regional efforts to protect the health of the ecosystem and manage the living resources of the BCLME on a sustainable basis, by:

- developing a framework for regional co-operation on all management aspects of the BCLME, and establishing effective mechanisms and capacity for consultation, co-ordination and decisionmaking at national, regional and global levels
- undertaking a comprehensive assessment of the current state of the ecosystem and our understanding of it
- developing a detailed understanding of and general consensus on the problems, issues and threats facing the BCLME
- developing a Strategic Action Plan for the BCLME through stakeholder participation, and co-ordinating donor support for the implementation of priority projects
- developing institutional capacities and an ecosystem approach to management
- establishing effective ecosystem monitoring programmes
- promoting sustainable development of the coastal zone, especially in the areas of mining, tourism and resource utilisation
- improving resource management strategies and measures to protect biodiversity
- investigating the BCLME as a CO² source and early warning site for global climate change.

Integrated management of the BCLME would enable the mitigation of imminent threats to a major international ecosystem. These threats encompass ecological degradation from overexploitation of marine species, offshore petrochemical exploration and exploitation, coastal and offshore diamond mining, increased incidence of algal blooms (red tides), inappropriate development in certain coastal areas, and significant temperature increases, possibly as a result of global warming.

5.2 Fisheries management and research

Strategic options and interventions in this sector would include the following:

- Formulating an agreed longterm strategy and response mechanisms to avoid stock depletion, involving the fishing industry, resource managers and biologists. This may mean adopting a more conservative approach toward stock management, including considering a moratorium on pilchard should this species remain at low levels.
- Introducing mechanisms for better and more frequent communication between fisheries scientists, international experts and the fishing industry on improved surveying and stock assessment techniques and discussion of survey results. This will help ensure a degree of ownership and acceptance of scientific TAC recommendations by the fishing industry.

A more comprehensive regional research plan is also needed to study the fisheries resource dynamics and environmental interactions that will ultimately lead to the optimal use and management of the living marine resources of the Benguela ecosystem. The outline for such a programme, the BENEFIT framework document (Benguela Environment Fisheries Interaction Training), has already been drawn up (Anon 1995) and initiated. Implementation of BENEFIT would contribute greatly to:

- improved understanding of fish stock fluctuations and predator/ prey interactions
- improved understanding of environmental and harvesting effects on fish stock dynamics
- improved understanding of longterm stock fluctuations and marine anomalies through comparisons among upwelling systems
- improved infrastructure for regional co-operation in research and resource management.

5.3 Diamond mining

The environmental threats posed by marine diamond mining off the Namibian coast cannot yet be quantified. However, future activities are likely to increase, raising concerns about cumulative effects on the environment and on rock lobster stocks especially in the shallow waters off Lüderitz. To ensure that these concerns are addressed, it is necessary to:

- establish an independent research management committee involving representatives of relevant ministries (i.e. MFMR, MME and MET), rock lobster fishermen, and the diamond mining industry to oversee research on and monitoring of environmental impacts
- initiate an agreed monitoring programme to assess the longterm effects of diamond mining on the biota, especially in the near-shore environment. Such monitoring should assess sites both inside and outside mining concession areas
- strengthen participatory mechanisms already in place, and encourage dialogue and exchange of information between I & APs.
- ensure mitigation measures are developed that can be put into effect should adverse impacts on the biota result from future cumulative mining effects.

5.4 Coastal zone management

An integrated approach to coastal zone management must be taken to address the various threats to the marine environment that result from harbour development activities, the fishing industry, coastal development projects (e.g. desalination plants), marine diamond mining, the oil exploration industry, and tourism. This approach should focus on potential resource conflicts and other interactions between activities and users in the coastal zone and neighbouring regions. Planning should actively involve residents and national or local authorities, and the process should be both proactive and reactive by considering the needs and interests of all major groups. Such a process would meld environmental protection goals with economic and technical decisionmaking to achieve sustainable development.

Aspects of such a plan could include:

- coordinating pollution control and monitoring by local and national authorities
- enhancing local expertise and assisting with development of methods for implementing a coastal zone management plan efficiently
- strengthening capacity of government ministries to collaboratively implement such a plan
- developing mechanisms for collaborative action between ministries, universities, NGOs, private sector and local communities
- establishing effective operational plans to combat oil pollution and protect marine reserves, sensitive coastal habitats and especially Walvis Bay lagoon.

Some of these problems are currently being addressed by DANCED, which is in the process of formulating an integrated coastal zone development plan for the Erongo Region, including the main population and tourist area between Henties Bay and Swakopmund.

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