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Beaches and the Nearshore

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Opposite page: The beach at Ulo village near Mocímboa da Praia, North Mozambique. © José Paula

The nearshore environment is generally defined as the area encompassing the transition from sub-tidal marine habitats to associated upland systems. For the purpose of this report, we define the area as that which includes habitats within the land-sea interface, extending to shallow sub-tidal waters (~2 m depth). Strong interactions occur between the marine environment and upland habitats within this interface. For example, a variety of vegetation provides bank stability, shades the upper intertidal zone and provides terrestrial input (eg woody debris as a fish refuge) to the nearshore marine ecosystem. Nearshore habitats are diverse, and include rocky shores, sandy beaches, muddy shores, mangroves, seagrass meadows and coral reefs. Their distribution is largely influenced by climate, geomorphology and coastal land use. Coral reefs, seagrass meadows and mangroves, also classified as nearshore ecosystems/habitats, are addressed in separate chapters in this report.

Coastal and estuarine shorelines are dynamic systems which undergo natural processes of erosion and accretion. Maintenance of these shoreline processes is critical for the sustainability of tidal and beach habitats and the benefits that accrue from them. Shorelines thus constantly change because of these processes, especially those caused by extreme tides and cyclones, the latter being relatively common along the coasts of Madagascar and Mozambique. While sand from the shore is often moved by wave and tidal action, human activities along the shore – including sand harvesting and coastal defence strategies – contribute to or mitigate this movement. The shores on the western boundary of the Indian Ocean have diverse littoral transport systems, with high tidal variability (up to 4 m), which plays a role in shaping the nearshore geomorphology. Natural shoreline processes and buffers maintain diverse and productive tidal fish habitats, providing the dynamic habitat complexity (eg undercut banks, shallow sand flats, snags, etc.) used by fish.

HABITATS

Rocky shores

By nature, rocky shores are relatively stable and are not subject to erosion to the extent of sandy shorelines. Rocky shores in the SWIO are relatively understudied. They consist of platforms, boulder fields, rock pools, and in some cases rocky vertical cliffs, each providing habitat opportunities for different types of plants and animals. Rocky shores are characterised by strong gradients in environmental conditions at small scales, varying within meters and hours, and so exert strong selection pressures that enhance species diversification over time (Lubchenko 1980). These features, widely distributed along the coasts of all WIO countries, constitute unique habitats shaped by a combination of waves, tides and the type of rock present. They support a diverse mix of plants and animals, which have adapted to survive the changes in exposure to water, sunlight and wind that characterize this habitat. Rocky shores are important

fish nurseries. Commercially important fish found associated with rocky shores include octopus, blackfish, yellowfin bream, tarwhine, trevally, yellowtail and samson fish. This habitat also harbours a high diversity of molluscs, including gastropods. The latter have been the subject of three comprehensive studies in the region: one on Kenyan shores (McClanahan 1989, McClanahan 2002) which revealed that the gastropod fauna was characterized by low densities but high diversity and variability in species composition. Significantly, protected reefs were found to have a higher diversity than unprotected reefs (McClanahan 1989, McClanahan 2002). More recently, Postaire and others (2014) reported high endemism in the tropical gastropod genus *Nerita* (Linnaeus) (Postaire and others, 2014).

Sandy beaches

Beaches and dunes constitute sandy habitats found along coastlines, lagoons, estuaries and sand spits. This type of shoreline is extensive in South Africa, Mozambique, Tanzania, Kenya and the island states of the WIO. A small increase in sea level recorded in Mozambique has resulted in significant regression of the high water mark. Typically, these areas were inundated in the previous high stands of sea level around 6 000 years ago. This type of coastline is most common in Mozambique with its wide continental shelf and flat, low coastal plains and river deltas. Beaches provide breeding areas for turtles throughout the region, and habitat for birds and invertebrates. They are popular destinations for human recreation.

Muddy shores, estuaries and mangroves

Estuaries, often associated with mangrove stands, are highly productive systems and comprise coastal ecosystems that are amongst the most threatened in the world (Millennium Ecosystem Assessment 2005). Their functioning is controlled by two main drivers: 1) fresh water river flow and 2) the marine processes of sedimentation and accretion. Some estuaries remain permanently open to the sea, or open and close depending on prevailing conditions, or are permanently closed with seepage being the only connection with the sea. These systems are delicately balanced, so any changes significantly affect their normal functioning, eg frequent mouth breaching which reduces their productivity, while insufficient breaching results in the accumulation of pollutants, leading to low oxygen levels and fish kills.

NEARSHORE BIODIVERSITY

Turtles

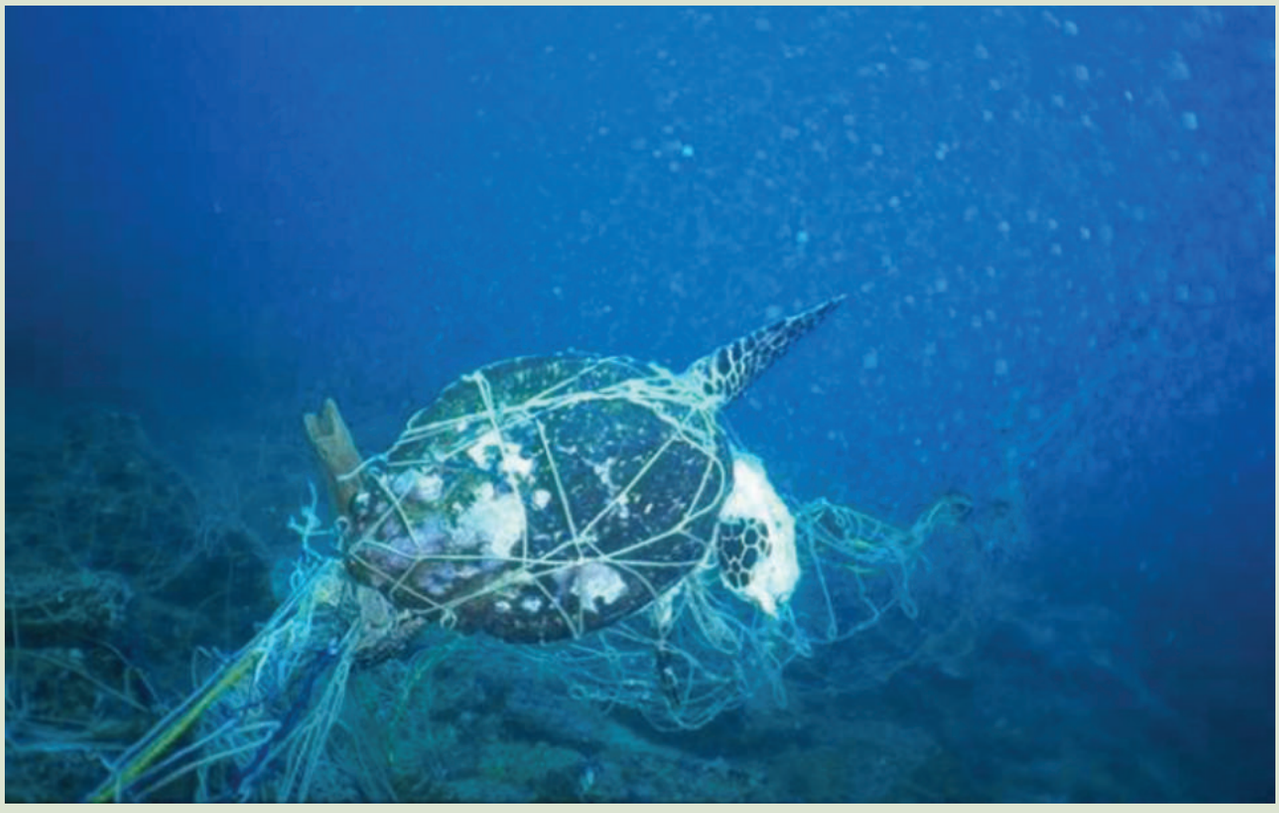
Sea turtles are vulnerable reptiles that have been subjected to direct exploitation for centuries, resulting in severe depletion in many cases. Turtles are globally threatened and are particularly vulnerable when they return to their natal beaches to lay their eggs. This they do on reaching maturity some years after hatching and the mothers, eggs and hatchlings fall easy prey to man and other predators. Growing awareness of their dilemma and threatened status has given rise to their protection in many regions, including the WIO. Despite this the threat to sea turtles remains high because of inadequate compliance with regulations and their indirect mortality in certain fisheries. The region has over the past decades seen a huge increase in fishing diversity and effort, resulting in higher turtle mortalities due to both targeted and by-catches. Although protected in most countries, they are also captured at sea by artisanal fishers. Further losses occur when they are accidentally harvested in trawl nets as by-catch or tangled in lost fishing gear (ghost fishing). Finally, sea-grass beds on which green turtles feed are also under threat, reducing their habitat.

The South West Indian Ocean is known to host five species of sea turtle which are all CITES protected (Márquez 1990, Ratsimbazafy 2003, Seminoff 2004). Of these, the green turtle (*Chelonia mydas*, endangered on the IUCN red-list) and hawksbill (*Eretmochelys imbricata*, critically endangered) are the most widely distributed and abundant, with the green turtle being by far the most numerous. These two species have also been the most severely impacted by direct exploitation (Hughes 1974, Hughes and Richards 1974). Loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*) are common in South African waters, and are little exploited (Hughes, 1974, 2010). Relatively little has been documented on the olive ridley (*Lepidochelys olivacea*) and this species is not considered to be more than a vagrant in the region.

Bivalves and gastropods

Mollusc resources are exploited in nearshore habitats, most often by foraging or snorkelling. Molluscs are often collected opportunistically as an additional catch alongside other fishing methods. The main molluscs targeted are the edible and ornamental species such as oysters, clams, whelks and mussels. Most of the shells collected for the curio trade are threatened species (ASCLME 2012a,

BOX 4 .1 TURTLES IN THE WIO by Michael H. Schleyer



A turtle snared in a 'ghost fishing' net, one of the many dangers that are threatening their survival. © Michael H. Schleyer.

Turtles are globally threatened and are particularly vulnerable when they return to their natal beaches to lay their eggs. This they do on reaching maturity some years after hatching and the mothers, eggs and hatchlings fall easy prey to man and other predators. Although protected in most countries, they are also captured at sea by artisanal fishers. Further losses occur when they are accidentally harvested in trawl nets as by-catch or tangled in lost fishing gear (ghost fishing). Finally, the seagrass beds on which green turtles feed are also under threat, reducing their habitat.

Five of the seven extant species of marine turtles occur in the WIO and all are CITES-protected. Loggerhead (IUCN Red-listed as endangered), green (endangered) and hawksbill (critically endangered) turtles are the most common and nest within the region; leatherback turtles are less common and nest only in southern Africa. The olive ridley turtle (endangered) is the rarest and nests at only a few sites in the WIO.

2012b) and their stock status ranges from fully to overexploited (FAO-SWIOFC 2011).

Crustaceans

Crustaceans make up a large proportion of the fisheries in the WIO (FAO-SWIOFC 2011). Shrimp, lobsters and crabs are very common in fished, nearshore areas, and are exploited at both the subsistence/artisanal and commercial scale. Landings for nine countries in the WIO have been estimated to be roughly 35 000 tonnes per year (van der Elst and others, 2009), with the shallow-water penaeid prawn fisheries in Mozambique and Madagascar making up a large proportion of these estimates. Several species of tropical spiny lobsters and crabs are targeted in shallow waters by artisanal and recreational fishers, and caught using simple gear operated from the shore, or from small boats. According to FAO-SWIOFC (2011), most of the crustacean stocks in the region are fully or overexploited (Table 1). However, there is lack of consensus on the status of prawns in most WIO countries, including South Africa, and deep water prawns and lobsters in Mozambique. The deep-water crustaceans in the SWIO region (ie deep-water

Table 4.1. Status of crustacean stocks in the WIO (Source FAO-SWIOFC 2012).

Comoros	Crustaceans (prawns, langoustines, crabs)	Underexploited
Kenya	Spiny and rock lobster	Overexploited
	Shallow-water prawns (commercial)	Fully exploited
	Shallow-water prawns (artisanal)	Unknown
	Crabs	Fully exploited
Madagascar	Langoustine	Fully exploited
	Prawns	Fully exploited
	Crabs	Fully exploited
Mauritius	Deep-water prawns (*Heterocarpus laevigatus*)	Under exploited
Mozambique	Spiny and rock lobster (*Palinurus delagoae*)	Depleted
	Shallow-water prawns (*P. indicus* & *M. monoceros*) (industrial)	Fully exploited
	Shallow-water prawns (semi-industrial & artisanal)	Fully exploited
	Deep-water prawns (*Haliporoides triarthus* & *Aristeomorpha foliacea*)	Moderately exploited
Seychelles	Spiny and rock lobster (*P. longipes*, *P. versicolor*, *P. penicillatus*, *P. ornatus*)	Recovering
	Spanner crab (*Ranina ranina*)	Underexploited
Somalia	Spiny and rock lobster	Overexploited
South Africa	Spiny and rock lobster (*P. gilchristi*, *P. delagoae* & *P. homarus*)	Fully exploited
	Crustaceans (deep & shallow-water prawns, langoustines, scyllarids)	Overexploited
Tanzania	Spiny and rock lobster	Fully exploited
	Shallow-water prawns Depleted	Depleted

prawns, langoustine lobsters, several deep-water spiny lobster species and deep-sea crabs) are only accessible to industrialized trap and trawl fisheries, and therefore the extent and fisheries potential of deep-water stocks are not as well-known as species living in shallower water (Groeneveld and others, 2009). Deep-water crustacean trawl fisheries in the SWIO are far less common than shallow-water prawn trawl fisheries.

Shallow-water prawns are targeted in the artisanal fisheries of Madagascar, Mozambique, Tanzania, Kenya, and Somalia using gill- and seine nets as well as fence traps ('*valakira*') in Madagascar (WIOFish 2011). Catches from the artisanal fishery in Tanzania nearly equal the landings from trawlers (ASCLME 2012a), while inshore populations of prawns are declining in Somalia (ASCLME 2012b). The artisanal fisheries also target spiny lobsters, using tangle nets, traps, spearguns or reef gleaning methods using snorkelling or SCUBA diving. This is a valuable fishery but monitoring is limited and information on stocks is insufficient; its status is currently considered as fully exploited to depleted (FAO-SWIOFC 2011). The exploitation of crabs is common in several countries in the WIO region. The main target species include the mangrove swamp crab, *Scylla serrata*, and swimming crabs; coconut crabs are exploited in Comoros and ghost crabs are caught in the artisanal and recreational fisheries of South Africa (WIOFish 2011).

According to the Scientific Committee of the FAO-SWIOFC (2011), penaeid prawns in the region are fully exploited in all of the countries on the western boundary of the Indian Ocean (South Africa, Mozambique, Tanzania, Kenya and Somalia) as well as Madagascar, mainly by industrial shallow-water trawling. The main target species are *Fenneropenaeus indicus (Penaeus indicus)* and *Metapenaeus monoceros*, which together contribute around 90 per cent of landed shallow water trawled prawn catches. Other commercial shallow-water prawn species (*Penaeus monodon*, *P. semisulcatus*, *P. latisulcatus* and *P. japonicus*) are also caught, but in much lower abundance. With the exception of South Africa, trawled catches of prawns are exported and represent a valuable source of foreign currency, particularly in Mozambique and Madagascar. Mozambique, Tanzania, Kenya, Somalia and Madagascar have substantial small-scale (traditional) fisheries which appear to be growing and are increasingly targeting prawns, leading to user-conflict with the trawl sector. In

Kenya, the trawl fishery was intermittently closed in 2000 and 2001, and again in 2006 due to clashes with artisanal fishers (Ochiewo 2004, Munga and others, 2012). After re-opening in 2007, it was closed again in 2008-2010: as of 2011, only three vessels are licensed of which two fished in 2011 and 2012 (Fennessy 2012).

While there are management measures in place for the shallow-water prawn trawl sector in each country, their objectives are not always clearly quantified, and ensuring compliance with some measures is difficult to achieve. This may have resulted in the declining CPUE observed in Tanzania and Mozambique, although in South Africa declines in prawn catches occurred as a result of the closure of the large St Lucia estuary in 2001, from which about half of the prawns recruit (Fennessy 2012). There are currently no Ecosystem Approach to Fisheries (EAF) management plans developed for the crustacean fisheries in the SWIO, although these have been proposed for the artisanal and commercial fisheries in Kenya, Tanzania and Madagascar (FAO-SWIOFC 2012). In the small-scale sector, there is currently no effort limitation, few management measures and low compliance. Consequently, artisanal catches have declined overall. For example, in Madagascar reports indicate that artisanal catches declined from 750 t in 2003 to just over 100 t in 2009. The fisheries are all managed at a national level, with no regional management strategy. There is, however, no genetic evidence at this stage to indicate that the prioritized shallow-water prawn species are shared, and it is thus appropriate that the stocks in each country continue to be managed separately (Fennessy 2012).

Cephalopods

Squid, cuttlefish and octopus are targeted in fisheries throughout the region, the most widespread being the artisanal octopus fishery. Several countries have reported declines in octopus landings (Table 2) and this is mainly attributed to over-exploitation and habitat loss. The South West Indian Ocean Fisheries Commission (SWIOFC) classified the octopus fishery as overfished in the SWIO region (FAO-SWIOFC 2011). Octopus fishing is usually undertaken by foraging on the reef flat at low tide. The most common fishing technique employed throughout the region is to use a long metal spike, or harpoon, to impale the prey. Squid-jigging in South Africa is an important commercial fishery targeting spawning aggregations of chokka squid (*Loligo vulgaris reynaudii*) in sheltered bays on the south coast (ASCLME 2012c).

Table 4.2. The status of invertebrate stocks in WIO countries (Source FAO-SWIOFC 2012).

Comoros	Cephalopods	Underexploited
	Bivalves	Underexploited
Kenya	Octopus	Fully exploited
	Sea Cucumbers	Overexploited
	Bivalves	Fully exploited
Madagascar	Octopus	Fully exploited
	Sea cucumbers	Overexploited
	Bivalves	Fully exploited
Mauritius	Octopus	Moderately exploited
	Sea cucumbers	Depleted
Seychelles	Sea cucumbers	Overexploited
South Africa	Octopus	Underexploited
	Bivalves	Overexploited
Tanzania	Octopus	Overexploited
	Cuttlefish and squid	Fully exploited
	Sea cucumbers	Overexploited
	Bivalves	Overexploited

Bêche-de-mer

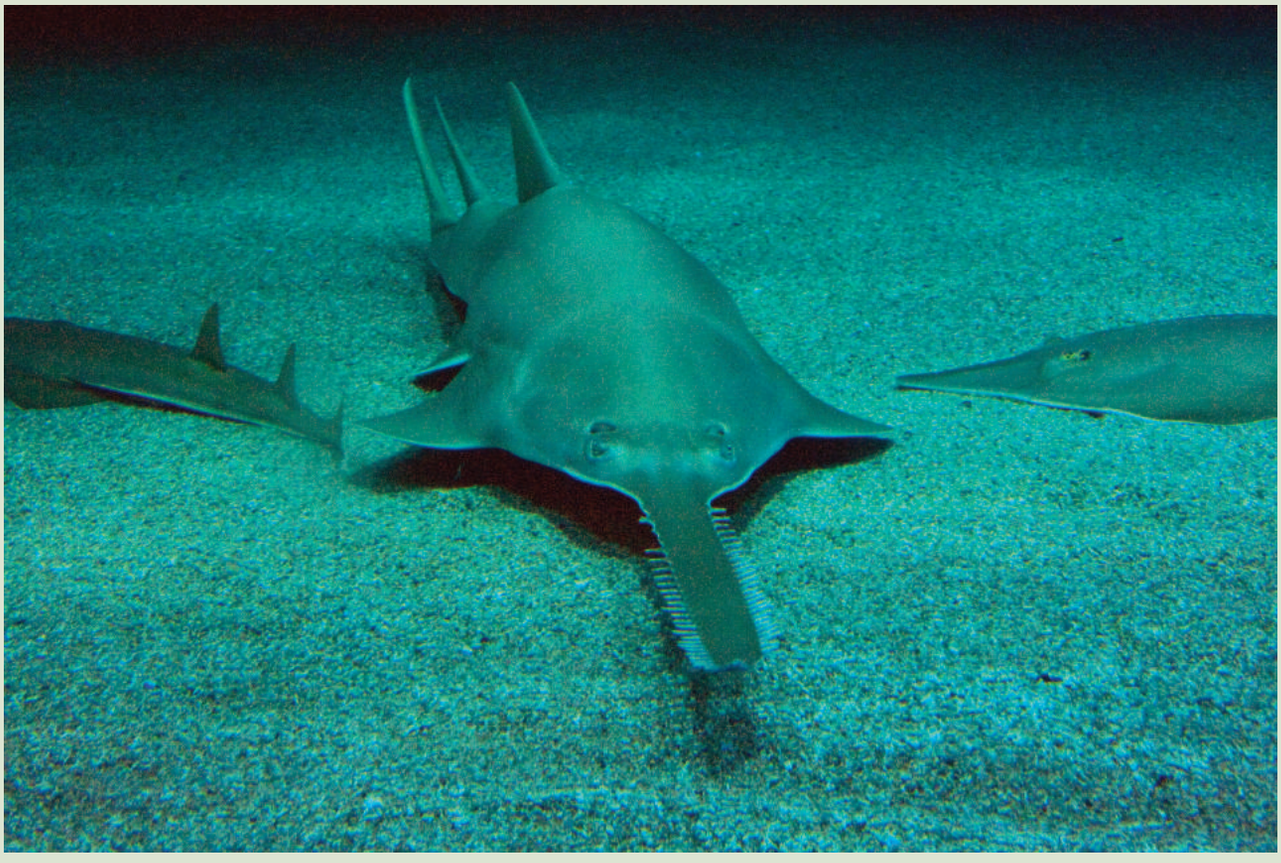
Sea cucumber (or bêche-de-mer) fishing is not a traditional fishery within the SWIO, but it has rapidly and significantly gained importance due to the high export value of the product, mainly to Asian countries. Sea cucumbers are typically targeted by fisherfolk using snorkelling or SCUBA diving, or collected as by-catch by spear fishermen and other gleaners. Fishers typically target the six highest valued species (*Holothuria nobilis*, *H. fuscogilva*, *H. scabra*, *Thelenota ananas* and *Actinopyga mauritiana*). Sea cucumber resources in all SWIO countries are largely over-exploited (FAO-SWIOFC 2011). Management regulations were introduced to control the fishery and processing industry in the Seychelles in 1999 (ASCLME 2012d). Sea cucumber fishing in Comoros has been banned since 2004 (FAO-SWIOFC 2012) and, in Mauritius, a two-year moratorium period was implemented from 1 October 2009 to 30t September 2011; this has now been extended until February 2016 (WIOFish 2011).

Seabirds

Eleven seabird families occur in the WIO as breeding species. They are penguins (Spheniscidae), albatrosses (Diomedeidae), petrels and allies (Procellariidae), storm-petrels (Hydrobatidae), diving-petrels (Pelecanoididae), trop-

icbirds (Phaethonidae), gannets and boobies (Sulidae), cormorants (Phalacrocoracidae), frigatebirds (Fregatidae), skuas (Stercorariidae), and gulls and terns (Laridae). Most of the seabirds found in the WIO fall broadly into three categories: Indo-Pacific species, pan-tropical species (highly migratory Procellariiformes from southern latitudes), and predominantly Atlantic species (with distributions marginal to the WIO). Consequently, the level of endemism is relatively low compared to other regions. There are, however, at least nine extant breeding endemics of which five are listed as globally threatened, including two critically endangered species (BirdLife International 2008). Half of these are from Sub-Antarctic islands, two from Réunion Island and two from the Arabian Sea. In

BOX 4 .2 SAWFISH IN THE WIO by Michael H. Schleyer



A sawfish between sand sharks in an aquarium; they are very seldom seen in the WIO. © J.M. Barre.

Sawfish (*Pristis* spp.) are iconic fish that were once abundant on East African shores but are now listed on the IUCN Red List as globally critically endangered. They are cartilaginous shark-like rays that live in shallow tropical and subtropical coastal waters and estuaries, and have not been seen in the WIO for some decades. The saw-like rostrum which gives them their name is used to capture prey but it has also caused their demise as they are easily ensnared in gill and trawl nets. They have thus been over-fished and habitat degradation in coastal and estuarine waters has exacerbated the situation. Two species were fairly common in WIO waters, the largetooth sawfish *Pristis pristis* and the green sawfish *P. zijsron*. Sawfish have been known to reach 7 m in size but since they are slow-growing, slow to mature and not fecund, they are prone to overfishing. Efforts to rehabilitate their stocks pose problems as the shallow waters in which they live are heavily fished. Furthermore, the live pups are dropped in rivers or estuaries where they live for some years before entering the sea. The mothers and maturing juveniles are thus prone to capture during their movement between freshwater and the marine environment and all adults are susceptible to coastal fishing activities.

addition to some endemic and very range-restricted species, the WIO region is host to globally important numbers of more widespread seabirds. The Seychelles and French islands together harbour significant proportions of tropical seabird populations, some in huge breeding numbers.

SOCIO-ECONOMIC SIGNIFICANCE

Nearshore habitats are of great socio-economic significance in the western Indian Ocean; 65 million people live within 10 km of the coast in the greater Indian Ocean region (Burke and others, 2011). For example, reports indicate that two thirds of the Mozambican population live along the coast and depend on resources in these areas to sustain their livelihoods. Preliminary results of the last Mozambican population census in 2007 indicate that it has 20.5 million people, with an annual growth rate of about 2.4 per cent. Most of the cities in the country are located on the coast. Similarly, some of the largest cities in Kenya and Tanzania are located along the coast (eg Mombasa and Dar es Salaam); these adversely affect the coastal biodiversity.

Human activities on the coast in the region focus largely on gleaning the available resources, resulting in intense exploitation of nearshore resources by recreational and subsistence fishers. It is also in this land-sea interface where trading of fisheries-related goods and services is prevalent. Seaweed farming is another important socio-economic activity in these areas. While seaweed farming, mostly undertaken by women, has been successful in supporting coastal communities on the Tanzanian coast, the same has not been true in other parts of the region.

Moreover, tourism is one of the most important economic sectors in the Western Indian Ocean and makes a substantial contribution to the GDP and total foreign exchange earnings. It is also a vital sector, which creates less resource-intensive streams of income and subsequently reduces the pressure on coastal resources.

Many coastal invertebrate stocks in the WIO are overexploited (Table 1) and significant declines have been recorded in both targeted and non-targeted species. As an example, the stock status of various fisheries in East Africa is given as: cephalopods offshore – underexploited; bivalves inshore - moderately exploited; sea cucumber – overexploited; octopus offshore – underexploited; and cephalopods inshore – underexploited.

THREATS

Climate change, changes in land-use and conversion of land (LULCC) represent the primary challenges that most ecosystems will face this century (Brook 2008) (Figure 4.1). The effects of climate change on ecosystems often involve very long time-scales (centuries), yet the trajectory of change in a specific region can be punctuated by shifts in land-use over short time-frames, even days in some cases. Shallow marine habitats are strongly affected by tectonics, eustatic sea-level changes, physical disturbances and run-off from land, impacts that continually modify habitats over various time-scales (DiBattista and others, 2013). Nearshore environments provide biophysical linkages between the coast and ocean and are therefore subject to human and climate-mediated alteration. In the WIO, sea level rise, shoreline hardening, coastal land development and nutrient enhancement are some of the pressures that are currently being experienced.

CLIMATE DRIVERS

The effects of climate change are already being experienced in nearshore habitats and estuaries in the region, with serious ecological and socio-economic consequences. Changes in sea level and coastal erosion are compromising the integrity of ecological processes in nearshore habitats. Studies that combine ground-truth data and satellite observations of the Indian Ocean sea level with simulations of factors related to climate change have identified a clear spatial pattern in sea level rise since the 1960s (eg Han and others, 2010). These studies indicate that there is a N-S latitudinal gradient of increasing sea level in some areas of the Indian Ocean, but substantial declines in southern tropical parts. More recent sea-level analysis in the region has shown that the rate of sea-level change varies in the region (Mather 2007, Mather and others, 2009). Tide gauges in the region have recorded a sea level rise (3-5 mm/year) with the exception of Zanzibar (-3.6 mm/year).

Climate change and ENSO-forced climate variability influence precipitation and hydrology in coastal watersheds and this has been profound in the WIO, evidenced by the amount of freshwater and sediment being discharged into the ocean, thereby affecting nearshore ecosystems such as estuaries and coral reefs (Maina and others, 2012). These changes, coupled with land-use

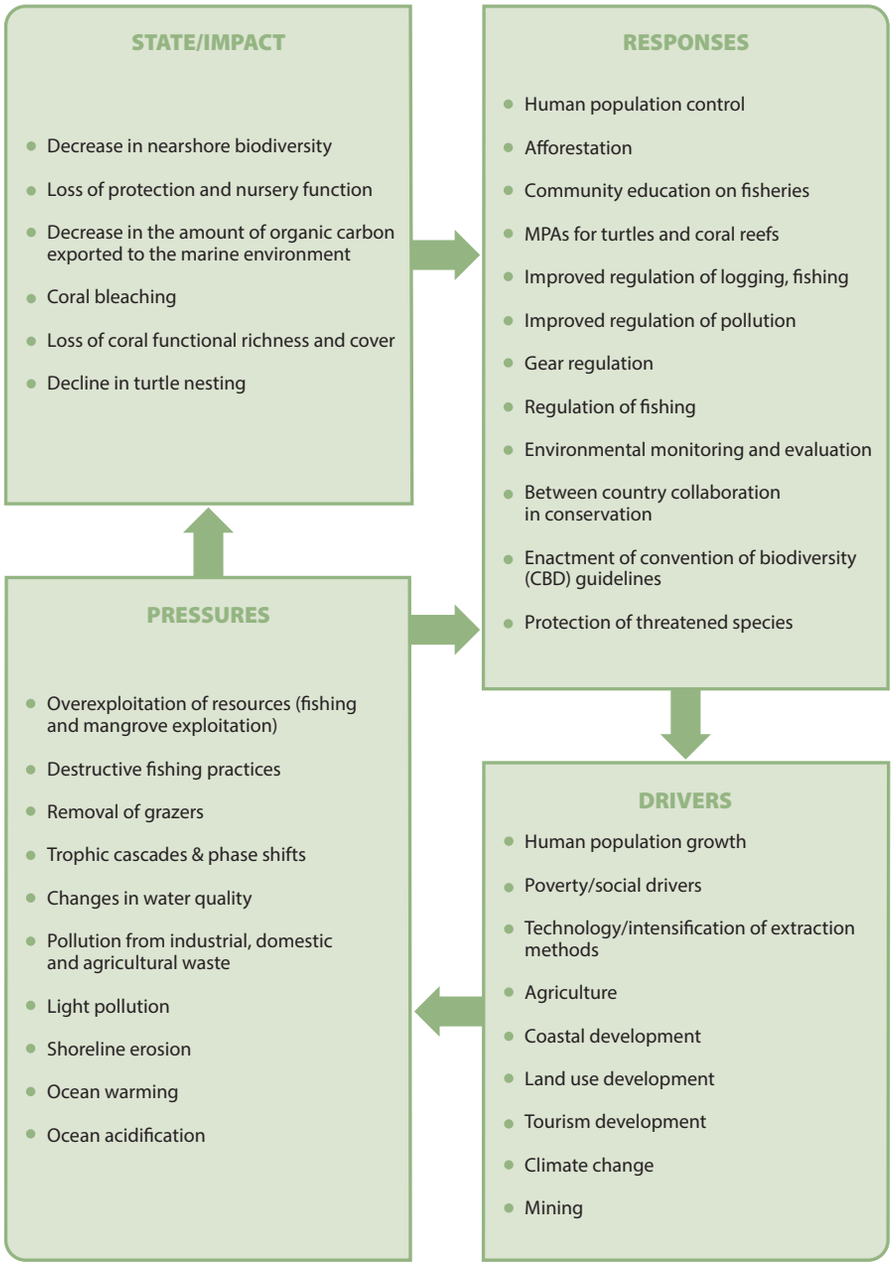


Figure 4.1. Summary of the Drivers-Pressures-Status-Impact- Response (DPSIR) for beaches and near-shore environments in the WIO.

change, continue to directly affect the hydrology of the land surface through alterations in evapotranspiration and groundwater levels, and the amount of sediment and freshwater discharged into marine coastal zones (Maina and others, 2012). A recent study on the effects of changes in temperature and precipitation on river flow and sediment discharge in Madagascar (Maina and others, 2013) revealed a general decline in river discharge. This study showed that these climate change-driven declines are outweighed by the impact of deforestation, which was shown to increase sedimentation.

HUMAN IMPACTS

An exponential increase in population, coupled with a high reliance on coastal and marine resources for sustenance and livelihood is one of the key pressures driving overexploitation and degradation of WIO nearshore ecosystems. Coastal cities and settlements are growing and developing at a rapid rate, contributing to coastal pollution from untreated sewage discharge. Industrial and agricultural activities in coastal watersheds and their residues are also contributing to eutrophication and sedimentation in the nearshore ecosystems. These human pressures reinforce

ongoing climate-mediated changes and, cumulatively, are leading to the retrogression of nearshore environments.

Mining and exploration activities are on the rise in the region, with many exploration and mining blocks located in coastal zones. Small-scale sand harvesting is currently practised in the nearshore environments of Tanzania and Mozambique (Masalu 2002), as well as in other areas. Heavy mineral sands (ie titanium, ilmenite and zircon) are currently mined in South Africa and Mozambique at an industrial scale, and such mining was recently commissioned in Kenya; exploration for these deposits still continues in Mozambique and elsewhere. In southern Kenya, the Kwale Project is located 10 km inland from the coast, and 50 km south of Mombasa, Kenya's principal port. Here, heavy mineral sand mining is being undertaken at unprecedented scales in watersheds in close proximity to the mangrove ecosystems of southern Kenya. The long-term effects of these activities possibly involve abandoned zones after mining and sedimentation of nearshore environments.

Trawl fishing is common in the region and has been found to have detrimental effects on benthic communities and non-targeted species, such as turtles. The nearshore environments of the Primeiras and Segundas Archipelago off the coast of Mozambique are heavily affected by this activity. A survey of commercial fishers, fishery observers and enforcers on the Sofala Bank and off the Primeiras and Segundas, revealed that at least 1 235-1 735 sea turtles are caught each fishing season by prawn trawlers, mainly green (*Chelonia mydas*, 48.4%) and loggerhead turtles (*Caretta caretta*, 25.8%), but catches also include olive ridley (*Lepidochelys olivacea*), hawksbill (*Eretmochelys imbricata*) and leatherback turtles (*Dermochelys coriacea*) (Brito 2012).

CONCLUDING REMARKS

Nearshore sub-tidal environments are valuable for services such as recreation and shoreline protection, and the provision of goods such as edible invertebrates and fish. Several anthropogenic pressures, including pollution, mining, overexploitation and climate change, are causing a decline in the integrity of these environments. Sub-tidal zones in the WIO are generally understudied and under-managed, with poor or no monitoring. Management of these environments should include, among others, a participatory approach in their management, awareness campaigns and education programmes. Moreover, the intertidal zone should be treated as a single organizational management entity within the larger framework of integrated coastal zone management (ICZM) (Nordlum and others, 2011).

References

Agulhas and Somali Current Large Marine Ecosystems Project (2012a). National marine ecosystem diagnostic analysis, *Tanzania*. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by the UNDP with GEF grant financing). ASCLME, 80 pp

Agulhas and Somali Current Large Marine Ecosystems Project (2012b). National marine ecosystem diagnostic analysis, *Somalia*. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by the UNDP with GEF grant financing). ASCLME, 30 pp

Agulhas and Somali Current Large Marine Ecosystems Project (2012c). *National marine ecosystem diagnostic analysis, South Africa*. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by the UNDP with GEF grant financing). ASCLME, 79 pp

Agulhas and Somali Current Large Marine Ecosystems Project (2012d). *National marine ecosystem diagnostic analysis, Seychelles*. Contribution to the Agulhas and Somali Current Large Marine Ecosystems Project (supported by the UNDP with GEF grant financing). ASCLME, 98 pp

BirdLife International (2008). *Threatened birds of the world 2008 (CD-ROM)*. BirdLife International, Cambridge, UK

Brito, A. (2012). An interview-based assessment of the incidental capture and mortality of sea turtles in Mozambique´s Sofala Bank commercial shrimp fishery

Brook, B.W. (2008). Synergies between climate change, extinctions and invasive vertebrates. *Wildlife Res*. 35, 249–252

Burke, L., Reytar, K., Spalding, M. and Perry, A. (2011).

Reefs at risk revisited. World Resources Institute, Washington, DC

DiBattista, J.D., Berumen, M.L., Gaither, M.R., Rocha, L.A., Eble, J.A., Eble, J.A., Choat, J.H., Craig, M.T., Skillings, D.J. and Bowe, B.W. (2013). After continents divide: comparative phylogeography of reef fishes from the Red Sea and Indian Ocean. *J. Biogeogr.* 40, 1170–1181

FAO-SWIOFC (2011). *South West Indian Ocean Fisheries Commission. Status of Resources*. Malé, Maldives

FAO-SWIOFC (2012). *Report of the fifth session of the Scientific Committee of the South West Indian Ocean Fisheries Commission*. Cape Town, South Africa, 27 February–1 March 2012. FAO Fisheries and Aquaculture Report/ FAO Rapport sur les pêches et l'aquaculture. Harare, FAO

Fennessy, S. (2012). *Retrospective analysis of existing data on shallow-water trawl fisheries for crustaceans in the South West Indian Ocean*. Specialist report prepared for the South West Indian Ocean Fisheries Project (SWIOFP). Oceanographic Research Institute, Durban, South Africa

Groeneveld, J.C., Cockcroft, A.C., Dias, N.M., Palha de Sousa, L., Mwakosya, C., Ulotu, E., Kimani, E., Munga, C. and Rafalimanana, T. (2009). *Regional Data Gap-Analysis for Component 2 (Crustaceans) for SWIOFP.* Proceedings of the Regional Workshop for Component 2 of SWIOFP 20th – 22nd April 2009. Oceanographic Research Institute, Durban, South Africa

Han, W., Meehl, G., Rajagopalan, B., Fasullo, J., Hu, A, Lin, J., Large, W, Wang, J-W, Quan, X.-W., Trenary, L., Wallcraft, A., Shinoda, T. and Yeager, S. (2010). Patterns of Indian Ocean sea-level change in a warming climate. *Nature Geosci.* 3, 546-550.

Hughes, G.R. (2010). Loggerheads and leatherbacks in the Western Indian Ocean. *Indian Ocean Turtle Newsletter* 11, 24-31

Hughes, G.R. (1974). *The sea turtles of southeast Africa* (Vol. 1). Oceanographic Research Institute.

Hughes, D.A., & Richard, J.D. (1974). The nesting of the Pacific ridley turtle Lepidochelys olivacea on Playa Nancite, Costa Rica. *Marine Biol*ogy, 24, 97-107.

Lubchenco, J. (1980). Algal Zonation in the New England Rocky Intertidal Community: An Experimental Analysis. *Ecology* 61, 333–344

Maina, J., de Moel, H., Vermaat, J. E., Bruggemann, J. H., Guillaume, M. M. M., Grove, C. A., Madin, J. S., Mertz-Kraus, R. and Zinke, J. (2012). Linking coral river runoff proxies with climate variability, hydrology and land-use in Madagascar catchments. *Mar. Pollut. Bull.* 64, 2047-2059

Maina, J., de Moel, H., Zinke, J., Madin, J., McClanahan, T., Vermaat, J. E. (2013). Human deforestation outweighs future climate change impacts of sedimentation on coral reefs. *Nat. Commun.* 4

Masalu, D.C. (2002). Coastal erosion and its social and environmental aspects in Tanzania: a case study in illegal sand mining. *Coast. Manag.* 30, 347-359

Márquez, M.R. (1990). Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. *FAO Fish. Synops.* 11(125), 1-81

Mather, A.A. (2007) Linear and nonlinear sea level changes at Durban, South Africa. *Afr. J. Mar. Sci.* 103, 509–512

Mather, A.A., Garland, G.G. and Stretch, D.D. (2009). Southern African sea levels: Corrections, influences and trends. *Afr. J. Mar.Sci.* 31, 145–156

McClanahan, T.R. (1989). Kenyan coral reef-associated gastropod fauna: A comparison between protected and unprotected reefs. *Mar. Ecol. Prog. Ser.* 53, 11-20

McClanahan, T.R. (2002). The effects of time, habitat, and fisheries management on Kenyan coral-reef-associated gastropods. *Ecol. Appl.* 12, 1484-1495

Millennium Ecosystem Assessment (2005). *Ecosystem and Human Well-Being: Biodiversity Synthesis*. World Resources Institute.Washington, DC, USA

Munga, C., Ndegwa, S., Fulanda, B., Manyala, J., Kimani, E., Ohtomi, J. and Vanreusel, A. (2012). Bottom shrimp trawling impacts on species distribution and fishery dynamics; Ungwana Bay fishery Kenya before and after the 2006 trawl ban. *Fish. Sci.* 78, 209 – 219

Nordlund, L.M., de la Torre-Castro, M., Erlandsson, J., Conand, C., Muthiga, N., Jiddawi, N. and Gullström, M. (2013). Intertidal Zone Management in the Western Indian Ocean: Assessing Current Status and Future Possibilities Using Expert Opinions. *Ambio* 1-14

Ochiewo, J. (2004). Changing fisheries practices and their socioeconomic implications in South Coast Kenya. *Ocean Coast. Manag.* 47,389–408

Postaire, B., Bruggemann, J.H., Magalon, H. and Faure, B. (2014). Evolutionary Dynamics in the Southwest Indian Ocean Marine Biodiversity Hotspot: A Perspective from the Rocky Shore Gastropod Genus *Nerita*. *PLoS ONE* 9, e95040

Ratsimbazafy, R. (2003). Sea Turtles. In *The Natural History*

of Madagascar (eds. S.M. Goodman and J.P. Benstead) pp. 210-213

Seminoff, J.A. (2004). Sea turtles, red listing, and the need for regional assessments. *Marine Turtle Newsletter* 106, 4-6

van der Elst, R.P., Groeneveld, J.C., Baloi, A.P., Marsac, F., Katonda, K.I., Ruwa, R.K. and Lane, W.L. (2009). Nine nations, one ocean: A benchmark appraisal of the South Western Indian Ocean Fisheries Project (2008- 2012). *Ocean Coast. Manag.* 52, 258-267

WIOFish (2011). *Western Indian Ocean Fisheries Database: A catalogue of small-scale fisheries*. http://www.wiofish.org/