21
Capture Fisheries

Johan Groeneveld

Opposite page: Prawn trawler operating in Maputo Bay, Mozambique. © José Paula.

ARTISANAL AND INDUSTRIAL FISHING SECTORS

The Southwest (SW) Indian Ocean supports a myriad of capture fisheries, along the coasts of eastern Africa and Madagascar, around small island states such as Mauritius, Seychelles and Comoros, and on shallow offshore banks such as the Mascarene Plateau. Capture fisheries in this region are typically categorized into artisanal (also called subsistence, traditional or small-scale commercial) and industrial (or semi-industrial) sectors. Artisanal fisheries comprise fishing households with small amounts of capital and access to simple gear that can be used from the shore or small boats. A mixed basket of invertebrate and fish species is captured, and the distinction between target and bycatch is vague. Fishing gear includes sticks, spears or harpoons, nets (cast, drag, mosquito, seine and gillnets), hand- and longlines with hooks, and several trap types (Jiddawi and Öhman 2002, Fulanda and others, 2011). Boats are traditional dugouts and small crafts constructed of planks and propelled by sail, with more modern boats with outboard engines and larger dhows with lateens and inboard engines for fishing further offshore (Fulanda and others, 2011, Munga and others, 2014). Artisanal fisheries dominate the SW Indian Ocean by numbers of fishers and gears, (van der Elst and others, 2005, www.wiofish.org), but because fishers are widely dispersed and some groups migrate to follow fish concentrations (Fulanda and others, 2009), records of fishing effort and catches are incomplete.

Industrial fisheries of the SW Indian Ocean comprise fleets of pelagic longliners and purse-seiners that target tuna and tuna-like species (Cochrane and Japp 2015), bottom trawlers for penaeid prawns on shallow mudbanks (Fennessy and Everett 2015a) and deep-water trawling for mixed crustaceans (Everett and others, 2015, Groeneveld and Everett 2015). Long-line trapping for spiny lobsters and crabs has been trialled, with some success (Groeneveld 2015). Semi-industrial hook-and-line (or drop line) fisheries catch demersal fishes on the banks of the Mascarene Plateau and Chagos Archipelago (Heileman and others, 2015). The artisanal and industrial fishing sectors differ in their social and economic perspectives, and to a large extent serve separate markets or economies – thus, artisanal fishers supply local or informal markets important for food security, and industrial fleets supply more affluent domestic or export markets, important to Gross Domestic Product (GDP).

The present chapter focusses on the long-term trends and status of key species groups exploited by the artisanal and industrial fishing sectors, based on information submitted by governments to the FAO and the Indian Ocean Tuna Commission (IOTC). The known environmental impacts of fishing practices in the region are outlined. Policy and management plans at local and regional (transboundary or ocean-wide) levels are synthesized, including the role of the IOTC. Recent initiatives, such as the implementation of ecosystem approaches to fisheries management in the SW Indian Ocean (eg Swaleh and others, 2015) and impact of donor-funded regional fisheries research projects on capacity development (eg SWIOFP; van der Elst and others, 2009, van der Elst and Everett 2015) are highlighted.

PRIMARY DATA AND ASSESSMENTS

For artisanal fisheries, primary data on species composition of catches, quantities landed, fishing effort and basic biology are incomplete. Landings data are unevenly collected in remote areas, where the numbers of fishers or landing points are not known with any precision (van der Elst and others, 2009, Groeneveld and others, 2014). Data are rarely reported to species level, and are mostly categorized by species groups (for instance pelagic or demersal fishes), thus precluding quantitative analyses. Frame surveys to enumerate fishing vessels, gears and fishers are conducted every few years in some countries (Kenya, Tanzania), but data on the actual numbers of fishing trips or gear-sets undertaken are virtually absent. Catch rate information (catch/fishing effort) as a measure of relative abundance trends over time is therefore unavailable for most artisanal fisheries in the SW Indian Ocean (van der Elst and others, 2005). Consequently, few well-informed decisions on fisheries development in the artisanal sector can be made by governing bodies.

Landings, fishing effort and species composition data are, however, more regularly collected in the economically important industrial prawn trawl fisheries in Mozambique and eastern South Africa (Fennessy and Everett 2015a, Groeneveld and Everett 2015). Catch and fishing effort information per trawl is reported in logbooks, and fisheries observers collect biological and species composition information at sea or at landing points. Prawn fisheries in Mozambique are assessed regularly, and recommendations are made for management purposes. Tunas and billfish (swordfish, marlins, sailfish) are considered to be highly migratory stocks, which are shared by the different countries of the region. These stocks are primarily exploited by industrial surface purse seine and long-line fisheries, and data on catches and fishing effort are reported to the IOTC (www.iotc.org). The scientific committee of the IOTC analyses catch and effort statistics and other scientific information to assess trends in stock status of tuna and tuna-like species, and in bycatch.

All governments of the SW Indian Ocean region voluntarily submit landings data from their fisheries to the FAO. These data are then summarized in standardized statistical groups (i.e. FAOStat or ICSAAP groups), and are made available on the FAO website, from where it can be accessed as summaries by country, region, time period, or species groups. It should be noted that the data submitted to the FAO are 'official' figures, which may exclude substantial unreported landings or reflect coarse estimates of actual landings. For example, catch reconstructions have added more than 200 per cent to official landing statistics from Madagascar (Le Manach and others, 2011) and 42 per cent to landings from Mauritius and its outer islands (Boistol and others, 2011) for the 1950-2008 period. Reconstructed catch for Tanzania was 77 per cent higher than reported to the FAO in 1950-2010 (Bultel and others, 2015). Therefore, trends obtained from the FAO summaries are indicative only, and should be interpreted with caution.

TRENDS IN LANDINGS AND STOCK STATUS

Official landings data were extracted from the FAO online database, by country (eastern South Africa, Mozambique, Tanzania [incl. Zanzibar], Kenya, Somalia, Madagascar, Mauritius, Seychelles, Comoros and France [Reunion and Mayotte Islands]) and by species groups (ASFIS species; all marine landings combined, cephalopods, crustaceans, pelagic fish and marine fish) for the period 1985 to 2012.

Landings from the SW Indian Ocean in 2011 was reported as 462 000 tonnes, and exports as 389 000 tonnes (FAO 2014). The difference between the two quantities (73 000 tonnes), which was presumably consumed locally, is a gross under-estimate, because much of the artisanal landings are not reported (see above). Mozambique, Madagascar and Tanzania (incl. Zanzibar) contributed the most to marine landings (all FAOStat groups combined; Figure 21.1a). Mozambique and Madagascar have the longest coastlines and substantial industrial fisheries for crustaceans (FAO 2007a, 2008). A long coastline, several densely populated islands (Zanzibar, Mafia) and many shallow and easily accessible fishing areas can also explain the high landings reported for Tanzania. In addition to its national tuna fleet, foreign tuna fleets land their catches in Seychelles, thus explaining the large contribution of this small island state to regional landings (FAO 2005, Marsac and others, 2014). Comoros, Mauritius and Kenya contributed only a small proportion to the regional marine landings (FAO 2006, 2007b). These countries have relatively short coastlines, but the former two island states have comparatively large EEZs. In Comoros, the littoral zone drops off

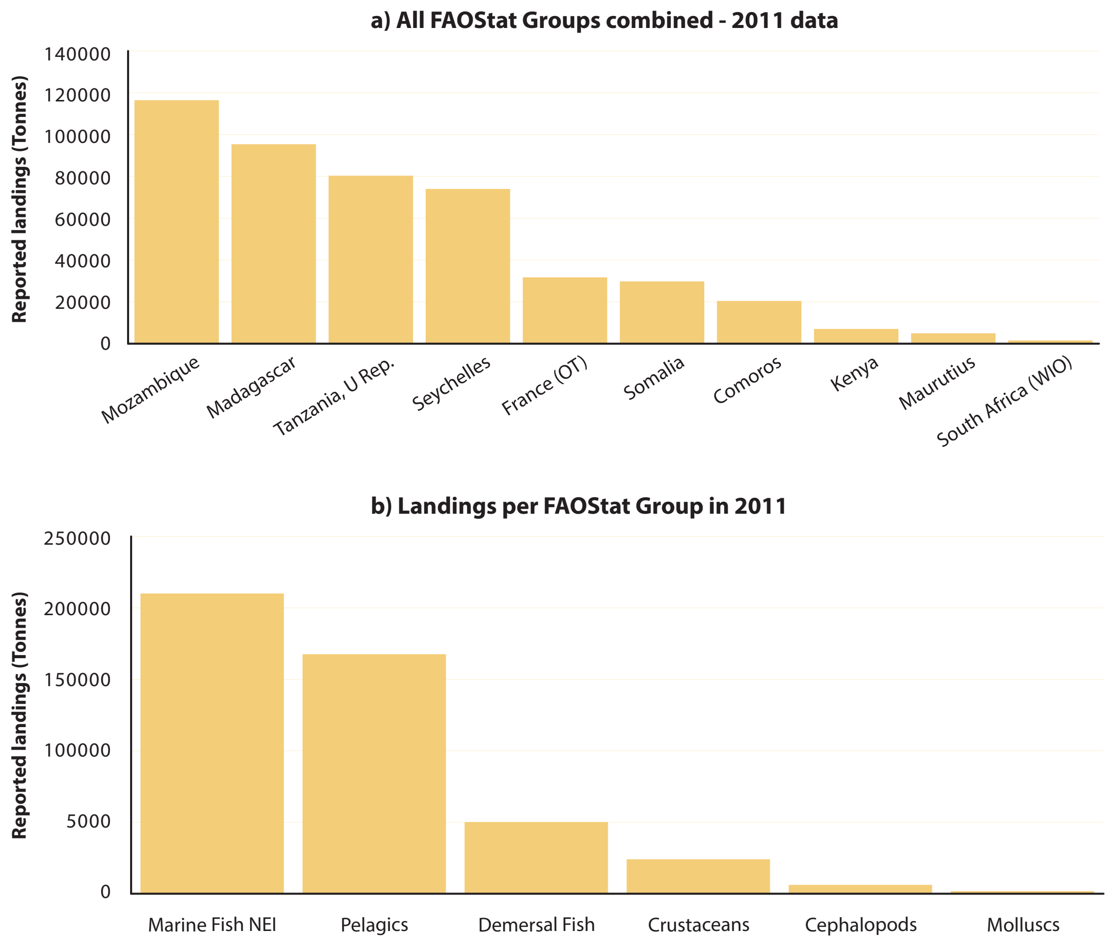

Figure 21.1. **a)** Contribution of regional countries to marine landings (FAOStat Groups combined). **b)** Landings per FAOStat Group (FAO 2014).

steeply to abyssal depths, with little or no shelf area available for artisanal fishing; large pelagic fish caught in its extensive EEZ by foreign vessels are probably reported for Seychelles (port of off-loading) or in flag countries. In Kenya, freshwater fish from lakes make up the bulk of landings reported to the FAO (not included here).

Excluding the category for marine fish NEI (meaning any species Not Elsewhere Included), pelagic fish made up 67 per cent of the reported landings in 2011 (Figure 21.1b). Presumably most pelagic fish landings are correctly categorized by industrial fisheries that report to the IOTC, thus explaining the dominance of this group. Most of the marine fish NEI category presumably comprises demersal fish landed by artisanal fishers therefore the actual contribution of demersal fish to regional landings is most likely much greater than the 20 per cent suggested in Figure 21.1b. Despite the contributions of artisanal and industrial prawn trawl fisheries to crustacean landings, this group made up only 10 per cent of total reported landings, by weight. Other invertebrates (cephalopods, molluscs) are collected in the intertidal, often by women, and their landings are grossly under-reported (except for octopus, which is a high-value export product).

A sudden increase in landings of all FAOStat groups combined in Mozambique in 2002 / 2003 (Figure 21.2a) reflects improved reporting of artisanal landings, rather than an actual quantum leap in catches over a short period. Nevertheless, it is clear that Mozambican landings have continued to increase over the past decade, illustrating growth of the fishing sector.

Octopus is extensively exploited by artisanal fishers in Tanzania, Madagascar, Mozambique and Kenya (Figure 21.2b), often for export to foreign markets (Guard and Mgaya 2002, Humber and others, 2006, Guard 2009). It is one of the main exported fishery products of Tanzania, and >95 per cent of the catch comprises *Octopus cyanea* (crepuscular or common reef octopus), a fast-growing and short-lived species that matures in 6 months and can weigh up to 11 kg. Octopus is traditionally caught in intertidal and shallow subtidal waters, by women and children using spears

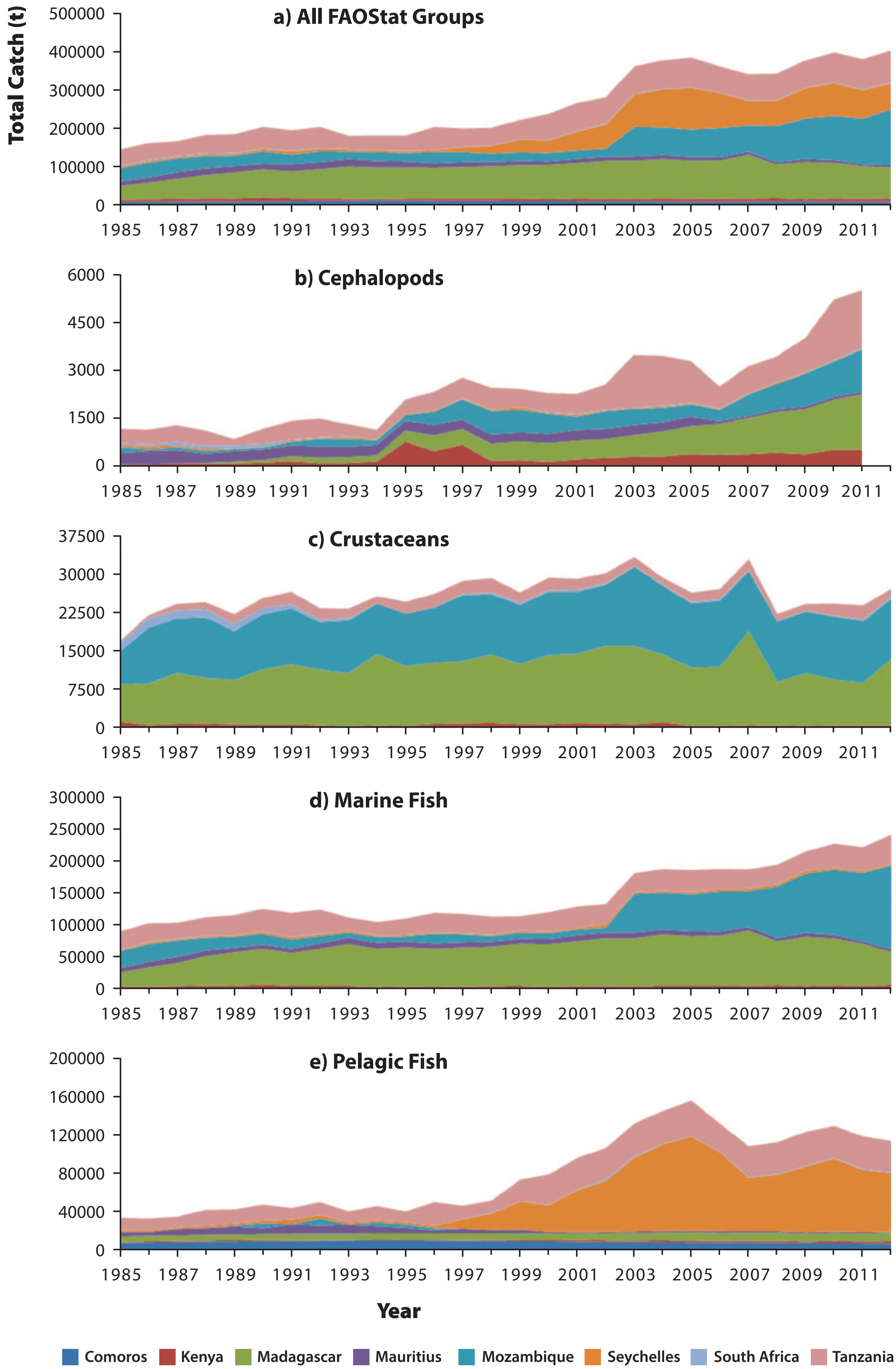

Figure 21.2. Reported landings by species group for the SW Indian Ocean region for the period 1985-2012

and sticks. Men are increasingly active in the fishery because of high demand and price. Landings in Madagascar have increased in recent years, where seasonal closures are used to recover heavily fished populations (Humber and others, 2006, Benbow and Harris 2011). In southern Kenya, octopus landings increase during the northeast monsoon, but decrease during the southeast monsoon, when sea conditions deteriorate.

Several co-occurring penaeid prawns (mainly *Penaeus indicus*, *P. monodon* and *Metapenaeus monoceros*) are targeted by industrial bottom trawl fisheries in shallow water (< 50 m deep) in Mozambique and Madagascar (Figure 21.2c), and to a lesser extent in eastern South Africa, Tanzania and Kenya (Fennessy and Everett 2015a). The trawl fisheries operate on mud and sandbanks near river outlets (Forbes and Demetriades 2005, Munga and others, 2013). Prawn abundance is susceptible to degradation of estuarine nursery habitats (see Mkare and others, 2014), and declines in landings have been observed throughout the SW Indian Ocean. A collapse of the prawn trawl fishery in South Africa was attributed to the construction of dams, which decreased river runoff, thus reducing the recruitment of juvenile prawns to offshore mudbanks. Industrial prawn trawling in Kenya and Tanzania have been discontinued, at least temporarily (Munga and others, 2012), and in Mozambique many trawlers have diverted to a deep-water trawl fishery in 2013 and 2014, because of low penaeid prawn catch rates. Deep-water trawl fisheries for mixed crustaceans (prawns, langoustines, spiny lobsters and deep-sea crabs) operate in Mozambique and eastern South Africa, and have been trialled in western Madagascar (Everett and others, 2015, Groeneveld and Everett 2015). Importantly, trends shown in Figure 21.2c exclude potentially large unreported landings of shallow water crustaceans by artisanal fishers, which are consumed or sold informally on local markets.

The marine fish category (Figure 21.2d) comprises mostly demersal and reef fish landings made by artisanal fishers, fish bycatch of industrial prawn trawlers, and shark landings (demersal and pelagic). Madagascar, Tanzania and Mozambique have consistently reported the highest landings in this category, commensurate with their long coastlines and dependence on nearshore fish resources. The 'marine fish' category apparently also includes pelagic fish landings from Mozambique after 2001, which might explain the virtual absence of pelagic fish landings reported there (see Figure 21.2e).

Small pelagic fishes (mackerels, sardines, anchovies) are caught with gill and ring nets wherever there are artisanal fisher communities along the coast and around the islands. Larger species such as skipjack, other small tunas, Spanish mackerel, dolphin fish, and some carangids are caught by artisanal fishers using gill nets further from the coast. Cochrane and Japp (2015) indicated that the catches of many pelagic species were well above 4 000 tonnes from 2004 to 2010, but these data have not been recorded in the FAO database. The increase in large pelagic fish landings in Seychelles after 1997 (Figure 21.2e) reflects the development of its fishing port as a hub for the international tuna industry. During the mid-1990s, some of the port operations were privatized, reducing trans-shipment fees and increasing efficiency. The secretariat of the IOTC was established in Seychelles in 1996. The former canning factory, Conserveries de l'Ocean Indien Ltd, created in 1987 between the Government of Seychelles and private investors, was restructured and renamed Seychelles Tuna Canning Factory. It was privatized in 1995, when 60 per cent of it was purchased by the American food company Heinz. Presently the cannery is named Indian Ocean Tuna and is owned by the Seychelles government and leased and operated by Heinz Europe. Tuna fishing is now a significant economic activity of Seychelles (28 per cent of GDP, 92 per cent of exports, Marsac and others, 2014), with earnings growing annually from licensing fees paid by foreign vessels fishing in its territorial waters (Robinson and others, 2010). Most tuna landings in Seychelles comprise yellowfin (*Thunnus albacares*), skipjack (*Katsuwonis pelamis*) and bigeye (*Thunnus obesus*).

ILLEGAL, UNREPORTED AND UNREGULATED (IUU) FISHING

In its International Plan of Action (IPOA-IUU), the FAO defines IUU fishing as any fishing activity that is illegal (in violation of the laws of a fishery), unreported (not reported to relevant national or regional authorities) and unregulated (operates without nationality, or under flag of a non-participant country in a managed area) (www.fao.org). The drivers behind IUU fishing could be as simple as food security in impoverished fishing communities, or in the case of industrial scale or systematic overharvesting, have strong economic incentives such as harvesting high value species for export markets. IUU fishing can flourish when governments fail to enforce national or international laws through weak enforcement (eg because of lack of capacity,

BOX 21.1. SWIOFP - LEGACY AND LESSONS

The South West Indian Ocean Fisheries Project (SWIOFP) formed part of the Global Environment Facility (GEF) Large Marine Ecosystems Programme in the Western Indian Ocean between 2008 and 2013. The project extended across the Exclusive Economic Zones of Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, eastern South Africa, Tanzania and the French islands of Reunion and Mayotte. SWIOFP aimed to assess offshore fisheries potential and provide scientific information and capacity for fisheries management. Many important lessons were learnt over the duration of the project (Groeneveld et al. 2013). A truly participatory process in project design and implementation ensured stakeholder buy-in and relevance of project objectives. A strong collaborative network developed, and challenges could be addressed by pooling of scarce resources across the region. An extensive Master's degree programme proved efficient in achieving two objectives simultaneously: capacity development to a masters degree level, and providing scientific manpower to analyse survey data. Linking fisheries research projects with RFMO's (such as the SWIO Fisheries Commission) enhanced post-SWIOFP continuity. On the down side, project design was over-optimistic (for instance, implementing 40 surveys at sea using research and fishing vessels, and establishing a regional observer programme) and some of it could not be fully implemented, or placed a heavy burden on project resources. SWIOFP relied largely on existing government employees and structures for its implementation – progress was therefore slower, compared to relying on consultants, but benefits included enhanced skills and networking within government agencies. The legacy of SWIOFP lies not only in its many scientific and applied outputs, but also in growing a strong, interacting network of fisheries scientists and managers in the region.

or poor levels of governance) or inadequate coverage of international agreements. Most SW Indian Ocean countries have inadequate financial, technical and manpower resources to effectively combat IUU fishing by artisanal and industrial fishing sectors (Samoilys and others, 2007, SADC 2008), and therefore the quantities of illegally caught fish are expected to be high. Social impacts of IUU fishing are numerous, but importantly, it may affect food security over short and longer terms, and cause resource-user conflicts. Apart from depleting valuable fish stocks, economic impacts of IUU fishing are a direct loss of revenue to governments (namely foregoing license fees, port and chandling income, transhipment of catches) and an indirect loss to licensed fishers confronted by diminishing catch rates of affected fish stocks, and thus higher operational costs (SADC 2008).

Individual countries in the SW Indian Ocean have taken important steps to combat illegal fishing: these include use of EU access agreement funds to improve monitoring, control and surveillance (MCS); developing fisheries monitoring centres and fitting licensed vessels with satellite monitoring devices; and chartering of additional fisheries patrol boats. International development agencies provide technical or financial support – for example the IOTC, IUCN, SADC, WWF and the World Bank. An IOTC resolution in 2010 supported the adoption of FAO port state measures to combat, prevent, deter and eliminate IUU fishing (IOTC Resolution 10/11). It also implements a regional observer programme to monitor transhipments at sea, to prevent laundering of fish through at-sea transhipments, and publishes records of authorised, active and suspected IUU fishing vessels (www.iotc.org). Although the above steps by national and regional bodies are encouraging, effective prevention of IUU fishing might require far greater political will and investment in infrastructure and expertise, probably at an integrated regional level.

ENVIRONMENTAL IMPACTS OF CAPTURE FISHERIES

Capture fisheries affect the environment in which they operate at several levels. Apart from removals of the harvested resource, bycatches of non-targeted species can be substantial when non-selective gears, such as trawl nets, are used. These bycatches may include endangered, threatened or protected (ETP) species, including marine mammals, sea turtles, seabirds and vulnerable elasmobranch or teleost species. At another level, fishing methods may be destructive to the physical environment, or to habitats required to sustain fish populations. Destructive fishing gear or methods include dragging bottom trawls or dredges that crush, smother or uproot benthic structures, or the use of poison and dynamite fishing that cause excessive incidental mortalities and reef damage (FAO 2009). At an ecosystem level, trophic balance is affected through the depletion of key species – for example, a cascading effect was observed after overfishing of triggerfish in Kenya allowed their prey (sea urchins) to multiply and overgraze seagrass beds, eventually leading to the erosion of coral reefs (Laipson and Pandya 2009).

A recent retrospective analysis of fisheries impacts in the SW Indian Ocean (van der Elst and Everett 2015) dealt with bycatch, marine mammals, sea turtles, seabirds, elasmobranchs, vulnerable teleost species and biodiversity hotspots. Defining what bycatch is can be complex, because it depends on value judgements of individual fishers, and is affected by market demand and season (Fennessy and Everett 2015b). Undesirable bycatch with low value, or which is too small to eat, non-palatable or toxic is mostly dumped at sea. It is generally assumed that small-scale fisheries have little to no bycatch, whereas industrial-type fisheries have larger amounts. Fennessy and Everett (2015b) found few bycatch issues in recreational, subsistence, artisanal and small-scale fisheries in the SW Indian Ocean, whereas more sophisticated industrial fisheries, particularly those with nets, returned high bycatches. Discard rates for industrial longline fisheries were high (~22 per cent), but varied regionally and by fleet, for example, in Seychelles the rate was around 10 per cent (Kelleher 2005). Blue sharks *Prionace glauca* and mako sharks *Isurus oxyrhinchus* comprise most of the bycatch in the industrial longline fisheries.

The bycatch of bottom trawl fisheries in the SW Indian Ocean is diverse, greatly exceeding (>70 per cent by weight) the target catch of crustaceans, and is mostly killed by trawling. Some bycatch species are retained, but most are discarded (reviewed in Fennessy and others, 2004). Notwithstanding legal requirements for the use of bycatch reduction devices in most countries in the region (mainly intended to reduce catches of turtles), high bycatch levels persist, and have led to the closure of trawl fisheries in some countries (Fennessy and others, 2008). Bottom trawling is banned in Seychelles, Comoros and Mauritius.

Kiszka (2015) reviewed existing information on the status and conservation of 37 known marine mammal species in the SW Indian Ocean. Among large cetaceans, humpback whales *Megaptera novaeangliae* are the most common and widely distributed during winter, when they breed in the region. Oceanic islands and archipelago's provide quality habitats for several toothed cetaceans. Dugongs are endangered in the region, and their numbers have progressively declined. A viable population occurs at Bazaruto Archipelago, Mozambique. While capture fisheries pose the greatest threat to marine mammal numbers, other threats include disturbance and noise pollution.

Strong legislation prohibits the direct take of sea turtles throughout the entire SW Indian Ocean, but despite this, turtle populations face significant threats from fishing (reviewed by Bourjea 2015). Gill-netting, prawn trawling and long-lining incidentally catch many sea turtles, with high mortality rates. Breeding females, eggs and hatchlings face land-based threats during nesting on sandy beaches.

Fisheries can impact seabirds through direct mortality and by reducing food availability through competition for resources. The scale and impact of fishing on seabirds in the SW Indian Ocean remains unknown, but could be significant in areas where high gill net fishing effort overlaps with the foraging ranges of diving seabird species, such as shearwaters and cormorants (Wanless 2015).

Elasmobranchs are targeted or taken as bycatch in several SW Indian Ocean fisheries, including longline, purse seine, pelagic drift net and especially shrimp trawling (Kiszka and van der Elst 2015). Some 188 shark and ray species have been recorded by 39 Indian Ocean nations, totalling a catch of >100 000 tonnes in 2012; this is considerably less than peak landings of 180 000 tonnes reported in 1996 (www.fao.org). Few mitigation measures for sharks and rays have been implemented, but the MADE project (Mitigating ADverse impacts of open ocean fisheries, www.

BOX 21.2. INDIAN OCEAN TUNA COMMISSION (IOTC)

The largest offshore fisheries in the Western Indian Ocean are those for highly migratory tunas, caught by international fleets of purse seiners and pelagic longlines. Total catches of tunas, billfishes and other species made up about 1.7 million tonnes in 2013, mostly skipjack (390 000 t) and yellowfin (380 000 t) tunas (IOTC, 2014). The fishing fleets follow the migrating tuna stocks, and fishing grounds extend over the high seas and the Exclusive Economic Zones of coastal countries in the region. The management of the fisheries for tuna and tuna-like resources, their associated environment and bycatch is coordinated by the IOTC, located in Victoria, Seychelles. The IOTC is an inter-governmental organization established under Article XIV of the FAO constitution in 1993, and as such its member countries can make binding decisions regarding tuna management in the Indian Ocean areas 51 (west) and 57 (east). The IOTC has 32 members, mostly nation states from around the world. Species under IOTC management include tuna (yellow- and bluefin, skipjack, albacore, bigeye, longtail, eastern little, frigate and bullet tuna), marlins (blue, black and striped), swordfish, Indo-pacific sailfish, and king and Spanish mackerels. In addition, the IOTC collates data on non-target species affected by tuna fishing operations, i.e. marine turtles, mammals, seabirds, sharks and fish species caught incidentally (bycatch). The key functions of the IOTC are: to review stock trends, analyse and disseminate scientific information required for fishery management; coordinate research and development, including technology transfer and training; adopt – on the basis of scientific evidence – Conservation and Management Measures; and to keep the economic and social aspects of the fisheries under review, particularly in developing coastal States.

made-project.eu) is investigating the effectiveness of "ecological FADs", better practices on board vessels, use of artificial baits, and a better vertical distribution of hooks (Dagorn 2011). Data on elasmobranch catches remain sparse, but the IOTC has greatly improved data collection protocols (www.iotc.org).

Vulnerable (or red-flagged) teleosts are captured in several fisheries as incidental or target catch (van der Elst 2015). Line fishing near reefs targets Serranidae and Labridae, including red-flagged species such as *Epinephelus tukula*, *E. lanceolatus*, *E. albomarginatus*, *E. areolatus*, *Plectropomus laevis* and *Bolbometopon muricatum*. Capture of coelecanth (*Latimeria chalumnae*) by deeper water line fisheries has been reported. In most cases, the capture of red-flagged species is not seen as a matter of concern by management agencies, except perhaps for the coelacanth. Van der Elst (2015) proposed that a list of species be drawn up which reflects a collated red-flagged species list for the SW Indian Ocean, and that countries are encouraged to managed these species accordingly.

Some 59 specific geographic sites within the SW Indian Ocean have recently been listed as biodiversity hotspots (Everett and van der Elst 2015); these sites may be vulnerable to fishing pressure, of importance to regional biodiversity, or provide control areas against which to monitor the impact of fishing at other sites. While this list is by no means complete, it begins to identify and describe critical areas in the SW Indian Ocean.

Marine Protected Areas (MPA) can conserve critical habitats and provide refuges for breeding populations of exploited species; if placed correctly, they can form a source of recruits to fishing grounds through spill-over or larval export (Planes and others, 2009, Robinson and Samoilys 2013). A WIOMSA survey listed 83 MPAs in the SW Indian

Ocean, with Seychelles having as many as 16 officially gazetted marine conservation areas (www.dlist-asclme.org). The largest MPA is the Quirimbas National Park in Mozambique, which spans over 7 500 km^2. Mozambique also has the oldest MPA, with the "Ilhas da Inhaca e dos Portugueses" Faunal Reserve gazetted as early as 1965. Three large MPAs in the Malindi-Watamu area in Kenya date from 1968. Some of the 83 MPAs are strict "no-take" areas while others are "multiple use areas" where fishing is still allowed, but restricted in terms of fishing gear, methods, and seasonal closures. Some MPAs have management plans in place, but most are only partially managed.

FISHERIES MANAGEMENT AND POLICY FRAMEWORKS

Policy and legislation

All countries bordering the SW Indian Ocean are signatories to the Law of the Sea (UNCLOS), which covers limits of maritime zones, rights of navigation, protection and preservation of the marine environment, scientific research and activities on the seabed beyond the limits of national jurisdiction (van der Elst and others, 2009). All countries also subscribe to the 1995 FAO Code of Conduct for Responsible Fisheries and the more recent Ecosystem Approach to Fisheries (EAF) (Garcia 2003), although they often do not have the capacity to implement specific management strategies.

Management of artisanal fisheries

Beach Management Units (BMUs) are the backbone of artisanal fisheries co-management in Tanzania (>170 BMUs active) and Kenya (73 BMUs) (Kanyange and others, 2014). In both countries, BMUs are supported by a legal framework (since 2006 in Kenya and 2009 in Tanzania), and are intended to bring resource user groups and governmental bodies together to share resource management and conservation responsibilities. Individual BMUs have jurisdiction over distinct geographical areas, where they manage fish-landing stations and stakeholders on behalf of fisheries departments, and are empowered to levy fees. A recent performance assessment of BMUs in Kenya and Tanzania (Kanyange and others, 2014) showed numerous factors affecting BMU performance: critical among them were leadership, representation, conflict resolution, inclusion, cost vs benefit, MCS, mutual trust and jurisdiction. Inadequate resources and infrastructure deficiencies were in the midst of this mix. Achievement of objectives was below expectations, and stakeholder livelihood had not improved. BMUs remain a promising mechanism for the decentralization of fisheries management, but as a co-management system, it needs to mature and will require considerable financial and logistic assistance (Oluoch and Obura 2008).

Van der Elst and others, (2005) evaluated artisanal fisheries in the SW Indian Ocean in terms of specific management strategies that would assist in its sustainable development. Forty-six per cent of artisanal fisheries were subject to a specific management policy, which set out, among others, management strategies, jurisdiction, access controls and licensing. Only 16 per cent of fisheries were subject to specific management plans with set objectives, whereas 84 per cent had no, or ineffective management plans in existence (van der Elst and others, 2005). A recent study in Tanzania (Groeneveld and others, 2014) showed that fishery management plans had been developed for octopus, tuna, prawn and small pelagic fisheries along the mainland coast, but that none of these had been fully implemented, because of logistical and financial constraints.

Management of industrial fisheries

Industrial fisheries for tuna and tuna-like species in the Indian Ocean are multi-national and managed by the intergovernmental Indian Ocean Tuna Commission (IOTC) located in Seychelles. The IOTC estimates stock status of key species from catch return and research data, and allocates quotas to member countries (IOTC 2014). Specific policies and conservation and management measures of the IOTC (see www.iotc.org) address target tuna species, as well as bycatches of elasmobranches and other ETP species. Longline fisheries for swordfish in the SW Indian Ocean are operated under national jurisdiction in South Africa, Seychelles and La Reunion (Kolody and others, 2010). Deep-water trawl fisheries are managed nationally, or access to resources in EEZ waters are allowed through licensing.

Regional research and management bodies

Regional Fisheries Management Organizations (RFMO) in the SW Indian Ocean region include the IOTC (described above) and the SW Indian Ocean Commission (SWIOFC), established in 2004 by the FAO council. The Indian Ocean Commission (IOC) is an intergovernmental organization created in 1982 to serve the interests of small island developing states (Comoros, Reunion, Madagascar, Mauritius and Seychelles) – these states share geographic proximity, historical and demographic relationships, natural resources and common development issues. Recent IOC cooperation has focused on marine conservation and fisheries management at regional and national levels. An example is the SmartFish project (www.smartfish-coi.org), with a focus on fisheries governance, management, monitoring control and surveillance, trade, and food security.

The SW Indian Ocean Fisheries Project (SWIOFP) from 2008 to 2013 provided a regional framework for data collection and capacity building in the offshore environment for nine countries (van der Elst and others, 2009). SWIOFP produced a detailed retrospective data analysis to show long-term fisheries and stock status trends, and environmental impacts of fishing (van der Elst and Everett 2015). The project undertook a series of resource-based knowledge gap-analyses (see Groeneveld and Oellermann 2013), facilitated regional training courses and workshops, and supported 21 Master's degree projects to analyse data collected during dedicated surveys at sea. SWIOFP left a legacy of strengthened ties among fisheries scientists and students across the region, and provided key information on abundance, biology, distribution patterns and genetic population structure of key species for fisheries management purposes (Macfadyen 2012).

The Western Indian Ocean Marine Science Association (WIOMSA) promotes educational, scientific and technological development of marine science (WIOMSA 2010). The Nairobi Convention provides resources and expertise to solve interlinked problems of coastal marine environments through regional cooperation (UNEP 2014).

Progress with World Summit on Sustainable Development (WSSD) commitments

Between 2011 and 2015, SW Indian Ocean countries made only modest progress towards WSSD commitments to implement EAF strategy (FAO 2015). The implementation of EAF is supported by the EAF-Nansen Project in African countries, and its focus areas are: understanding ecosystem impacts of fisheries; social well-being of those depending on fishing; economic well-being of the fishing industry; transparent and participatory management structures; management plans incorporating EAF; compliance with regulations; sufficient capacity, skills, equipment; good data procedures; and addressing external impacts of fisheries. The overall implementation level was computed as 49.4 per cent in 2015, compared to 46.2 per cent in 2011. Key areas of progress, challenges and possible barriers need to be evaluated.

GAPS IN CAPACITY TO ENGAGE IN CAPTURE FISHERIES AND TO ASSESS STATUS, TRENDS AND ENVIRONMENTAL IMPACTS

Several countries (Mozambique, Tanzania, Kenya, Madagascar and Comoros) have inadequate infrastructure, trained manpower and scientific skills to fully assess their marine resources (van der Elst and others, 2009). Nearly all countries bordering the SW Indian Ocean lack sufficient data and expertise to fully describe their fisheries and the anthropogenic pressures on stocks – although much pro-

Figure 21.3. Two aspects of Dar es Salaam fishmarket. © Johan Groeneveld

gress was made by the SWIOFP project after 2008. Basic information on fished species is incomplete, and more information is required to describe biological characteristics and reference points, distribution patterns, fishing pressure and stock status of key fished species. A minority of species / fisheries have effective management plans, whilst most species are at risk of overexploitation by a growing human population in the coastal areas.

The influence of environmental fluctuations on fish stocks and ecosystem functioning are weakly understood – a factor exacerbated by global climate change and predicted temperature, pH and sea level changes. A shift towards EAF management has been initiated in several countries (South Africa, Mozambique, Kenya) through donor-funded projects such as the EAF-Nansen programme. The positive spin-offs of EAF management will need to be demonstrated to stakeholders, especially in the artisanal fishing sector, to encourage its acceptance and support at community level.

Although permits are legally required by all fishers, this may not always be adhered to in remote areas, so that some artisanal fisheries are, in effect, open access in nature. The status of exploited resources is consequently often unknown. Coastal towns and communities continue to grow, thus increasing the exploitative pressure on marine resources. How to redress the scenario of dwindling fish resources versus increasing demand towards favourable socio-economic (improved food security; alternative economic and social opportunities) and environmental (sustainable fisheries and healthy ecosystems) outcomes will be a major challenge to governments in decades to come.

References

Benbow, S. and Harris, A. (2011). *Managing Madagascar's octopus fisheries. Proceedings of the workshop on Octopus cyanea fisheries*. BlueVentures. Aberdeen Centre, London

Boistol, L., Harper, S., Booth, S. and Zeller, D. (2011). Reconstruction of marine fisheries catches for Mauritius and its outer islands, 1950-2008. In *Fisheries catch reconstructions; Islands, Part II* (eds. S. Harper and D. Zeller) Fisheries Centre Research Reports 19(4), pp. 39-61. Fisheries Centre, University of British Columbia

Bourjea, J. (2015). Sea turtles: A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Bultel, E., Doherty, B., Herman, A., Le Manach, F. and Zeller, D. (2015). An update of the reconstructed marine fiheries catches of Tanzania with taxonomic breakdown. In *Fisheries catch reconstructions in the Western Indian Ocean, 1950–2010* (eds. F. Le Manach and D. Pauly) Fisheries Centre Research Reports 23(2), pp. 151–161. Fisheries Centre, University of British Columbia

Cochrane, K.L. and Japp, D. (2015). Pelagic fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Dagorn, L. (2011). An update of the EU MADE project. IOTC–2011–WPEB07–52. Victoria, Seychelles

Everett, B.I., Groeneveld, J.C., Fennessy, S.T., Dias, N., Filipe, O., Zacarias, L., Igulu, M., Kuguru, B., Kimani, E., Munga, C.N., Rabarison, G.A., Razafindrakoto, H. and Yemane, D. (2015). Composition and abundance of deep-water crustaceans in the Southwest Indian Ocean: Enough to support trawl fisheries? *Ocean Coast. Manage.* 111, 50-61

Everett, B.I. and van der Elst, R.P. (2015). Biodiversity hotspots of the Southwest Indian Ocean: Their location and primary features. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

FAO (2005). *National Fishery Sector Overview: The Republic of Seychelles*. FAO, Rome

FAO (2006). *National Fishery Sector Overview: The Republic* of *Mauritius*. FAO, Rome

FAO (2007a). *National Fishery Sector Overview: The Republic of Mozambique*. FAO, Rome

FAO (2007b). *National Fishery Sector Overview: The Republic of Kenya*. FAO, Rome

FAO (2008). *National Fishery Sector Overview: The Republic of Madagascar*. FAO, Rome

FAO (2009). *FAO/UNEP Expert meeting on impacts of destructive fishing practices, unsustainable fishing, and illegal, unreported and unregulated (IUU) fishing on marine biodiversity and habitats*. FAO, Rome

FAO (2014). *Southwest Indian Ocean Fisheries Commission (SWIOFC)*. Available at http://www.fao.org/fishery/rfb/swiofc/en [accessed 09/05/2014 2014]

FAO (2015). *Final report of the sixth session of the Scientific Committee of the South West Indian Ocean Fisheries Commission*. Dar-es-Salaam, Tanzania. FAO, Rome.

Fennessy, S.T., Mwatha, G.K. and Thiele, W. (2004). *Report of the Regional Workshop on Approaches to Reducing Shrimp Trawl Bycatch in the Western Indian Ocean: Mombasa, Kenya, 13-15 April 2003*. No. 734. FAO, Rome

Fennessy, S.T., Vincent, X., Budeba, Y., Mueni, E.M. and Gove, D. Z. (2008). Short Communication: An Update on Initiatives to Reduce Prawn Trawl Bycatch in the Western Indian Ocean. *Western Indian Ocean J. Mar. Sci.* 7(2)

Fennessy, S.T. and Everett, B.I. (2015a). Crustacean shallow-water trawl fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Fennessy, S.T. and Everett, B.I. (2015b). Fisheries bycatch: An updated assessment of the status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Forbes, A.T. and Demetriades, N.T. (2005). *A review of the commercial, shallow water penaeid prawn resource of South Africa: Status, fisheries, aquaculture and management*. Specialist report. Ezemvelo KZN Wildlife: Marine and Estuarine Research

Fulanda, B., Munga, C., Ohtomi, J., Osore, M., Mugo, R. and Hossain, M.Y. (2009). The structure and evolution of the coastal migrant fishery of Kenya. *Ocean Coast. Manage.* 52(9), 459-466

Fulanda, B., Ohtomi, J., Mueni, E. and Kimani, E. (2011). Fishery trends, resource-use and management system in the Ungwana Bay fishery Kenya. *Ocean Coast. Manage.* 54(5), 401-414

Garcia, S. M. (2003). *The ecosystem approach to fisheries: issues, terminology, principles, institutional foundations, implementation and outlook*. Report No. 443. FAO, Rome

Groeneveld, J.C., Oellermann, L.K., van der Elst, R.P., Fennessy, S.T., Everett, B.I. and Athayde, T. (2013). Harmonization of knowledge gap analyses and associated research programmes for SWIOFP components 2, 3, 4 & 5. Specialist Report. March 2013. SWIOFP RMU, KMFRI, Mombasa, Kenya (50 pp).

Groeneveld, J.C., Fennesy, S.T., Everett, B.I. and Robey, J. (2014). *Rapid Assessment of the State of Commercial Fisheries and Main Species Exploited in Tanzania*. Specialist Report. Oceanographic Research Institute. Durban

Groeneveld, J.C. (2015). Crustacean deep-water trap fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Groeneveld, J.C. and Everett, B.I. (2015). Crustacean deep-water trawl fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Guard, M. (2009). *Biology and fisheries status of octopus in the Western Indian Ocean and the suitability for marine stewardship council certification*. United Nations Environmental Programme

Guard, M. and Mgaya, Y.D. (2002). The artisanal fishery for *Octopus cyanea* Gray in Tanzania. *AMBIO* 31, 528-536

Heileman, S., Fennessy, S.T. and van der Elst, R.P. (2015). Demersal fisheries: A retrospective analysis of their status in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Humber, F., Harris, A., Raberinary, D. and Nadon, M.

(2006). *Seasonal closures of no-take zones to promote a sustainable fishery for Octopus cyanea (Gray) in Southwest Madagascar*. BlueVentures Conservation Report. , London.

IOTC. (2014). *The Commission*. Available at http://www.iotc.org/about-iotc, accessed 09 May 2014

Jiddawi, N.S. and Öhman, M.C. (2002). Marine fisheries in Tanzania. *AMBIO* 31, 518-527

Kanyange, N., Kimani, P., Onyango, P., Sweenarain, S. and Yvergniaux, Y. (2014). *Performance Assessment of Beach Management Units Along the Coastlines of Kenya and Tanzania*. IOC, Smartfish, SF/2014/47

Kelleher, K. (2005). *Discards in the world's marine fisheries: an update*. Report No. 470. FAO, Rome

Kiszka, J. (2015). Marine mammals: A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Kiszka, J. and van der Elst, R.P. (2015). Elasmobranchs (sharks and rays): A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Kolody, D., Robinson, J. and Lucas, V. (2010). *Swordfish Catch Rate Standardization for the Seychelles Semi-Industrial and Industrial Longline Fleets*. Indian Ocean Tuna Commission Working Party on Billfish Working Paper: IOTC-2010-WPB-04

Laipson, E. and Pandya, A. (2009). *The Indian Ocean-Resource and Governance Challenges*. Stimson, Washington,

Le Manach, F., Gough, C., Humber, F., Harper, S. and Zeller, D. (2011). Reconstruction of total marine fisheries catches for Madagascar (1950-2008). In *Fisheries catch reconstructions; Islands, Part II* (eds. S. Harper and D. Zeller) Fisheries Centre Research Reports 19(4), pp. 21-37. Fisheries Centre, University of British Columbia

Macfadyen, G. (2012). *Implementation completion report prepared by the participating countries (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Reunion, Tanzania, Seychelles, South Africa) for the South West Indian Ocean Fisheries Project*. Unpublished Report. http://www.swiofp.net.

Marsac, F., Fonteneau, A. and Michaud, P. (2014*). L'or bleu des Seychelles: histoire de la pêche industrielle au thon dans l'océan Indien*. Marseille

Mkare, T.K., von der Heyden, S., Groeneveld, J.C. and Matthee, C.A. (2014). Genetic population structure and recruitment patterns of three sympatric shallow-water penaeid prawns in Ungwana Bay, Kenya, with implication for fisheries management. *Mar. Freshwater Res.* 65, 255-266

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. *Fisheries Sci.* 78(2), 209-219

Munga, C.N., Mwangi, S., Ong'anda, H., Ruwa, R., Manyala, J., Groeneveld, J.C., Kimani, E. and Vanreusel, A. (2013). Species composition, distribution patterns and population structure of penaeid shrimps in Malindi-Ungwana Bay, Kenya, based on experimental bottom trawl surveys. *Fish. Res.* 147, 93-102

Munga, C.N., Omukoto, J.O., Kimani, E.N. and Vanreusel, A. (2014). Propulsion-gear-based characterisation of artisanal fisheries in the Malindi-Ungwana Bay, Kenya and its use for fisheries management. *Ocean Coast. Manage.* 98,130-139

Oluoch, S.J. and Obura, D. (2008). Assessment of fisherfolk organizations and beach management units (BMU) in the management of fishery resources in Diani-Chale, Southern Kenya. In *Ten years after bleaching-facing the consequences of climate change in the Indian Ocean*. (eds. D.O. Obura, J. Tamelander, and O. Linden) CORDIO Status Report, Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa, Kenya

Planes, S., Jones, G.P. and Thorrold, S.R. (2009). Larval dispersal connects fish populations in a network of marine protected areas. *Proc. Natl. Acad. Sci. U.S.A.* 106(14), 5693-5697

Robinson, J., Guillotreau, P., Jimenez-Toribio, R., Lantz, F., Nadzon, L., Dorizo, J., Gerry, C. and Marsac, F. (2010). Impacts of climate variability on the tuna economy of Seychelles. *Clim. Res.* 43, 149-162

Robinson, J. and Samoilys, M.A. (2013). *Reef fish spawning aggregations in the Western Indian Ocean: Research for Management*. WIOMSA/SIDA/SFA/CORDIO. WIOMSA Book Series 13

SADC (2008). *Study and analysis of the IUU fishing situation in the SADC region and an estimate of the economic, social and biological impacts*. Southern African Development Community. Cape Town: Fishing SI

Samoilys, M., Domingue, G., Kariuki, J., Payet, R., Hersi, A. and Mohammed, A. (2007). *Application of the Global List of irresponsible fishing vessels as a tool to combat Illegal Unregulated and Unreported Fishing in Eastern Africa*. IUCN. Kenya

Swaleh, K., Kaunda-Arara, B., Ruwa, R. and Raburu, P. (2015). Ecosystem-based assessment of a prawn fishery in coastal Kenya using ecological indicators. *Ecol. Indic.* 50, 233-241

UNEP (2014). *Welcome to the Nairobi Convention*. http://www.unep.org/nairobiconvention/, accessed 13 May 2014

van der Elst, R., Everett, B., Jiddawi, N., Mwatha, G., Afonso, P.S. and Boulle, D. (2005). Fish, fishers and fisheries of the Western Indian Ocean: their diversity and status. A preliminary assessment. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*. 363, 263-284

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. Manage.* 52, 258-267

van der Elst, R.P. and Everett, B.I. (2015). *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* . Special Publication No 10. Durban: South African Association for Marine Biological Research

van der Elst, R.P. (2015). Vulnerable teleost fishes: A review of fisheries impacts on threatened species in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

Wanless, R. (2015). Seabirds: A review of status, distribution and interaction with fisheries in the Southwest Indian Ocean. In *Offshore fisheries of the Southwest Indian Ocean: their status and the impact on vulnerable species* (eds. R.P. van der Elst and B.I. Everett) Special Publication No 10. Durban: South African Association for Marine Biological Research

WIOMSA (2010). *About Us*. http://www.wiomsa.org/index.php?option=com_content&view=article&id=48&Itemid=63, accessed 09 May 2014