Western Indian Ocean J. Mar. Sci. Vol. 7, No. 2, pp. 137–150, 2008

Sea Turtle Bycatch in the West Indian Ocean: Review, Recommendations and Research Priorities

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Keywords: Bycatch, sea turtle, West Indian Ocean, fishery-related mortality

Abstract— Within the framework of the FAO project GCP/INT/919/JPN and a review of published or available data, the relative importance of fishery-related sea turtle mortality in the West Indian Ocean region was assessed for Kenya, Madagascar, Mauritius, Maldives, Mozambique, Seychelles, Somalia, South Africa, Reunion, Tanzania and Yemen. Three fisheries were identified to significantly impact marine turtles: gillnetting, prawn/shrimp trawling and longlining, but it clearly appears that there is a global lack of published and reliable information regarding marine turtle population assessments and interaction with fisheries in the WIO. However, countries such as Seychelles, South Africa and La Réunion (France) already collect various and reliable data that allow an assessment of their marine turtle populations and the level of interactions related to open sea fisheries (mainly longline and purse seine). This allowed the identification of recommendations and research priorities for this region but also demonstrated that such recommendations could only by implemented through the use of appropriate policy measures, adequately designed and developed in cooperation with fishermen, stakeholders, scientists and managers in order to (a) be able to apply the measures, (b) be sure to have the capacity of implementation and (c) be able to provide follow up over time.

INTRODUCTION

Five species of marine turtles are documented from the Western Indian Ocean (Marquez 1990; Ratsimbazafy 2003; Seminoff 2004). Of these, the green turtle (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) are most widely distributed, most numerous, and have been the most severely impacted by directed exploitation (Hughes, 1974a, b; Frazier, 1980, 1982). Loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*) used to be abundant along the South African waters, but less common in the rest of the region, and have had little importance in commerce and directed exploitation (Hughes, 1974a,b). Relatively little has been documented about the olive ridley (*Lepidochelys olivacea*) and is not considered much more that a vagrant species to the region. It was recognised that sea turtles are under pressure from a number of natural and anthropogenic factors, both in the terrestrial phase of their life cycle as well as in the marine environment.

Conservation efforts will only succeed if the major threats can be managed. Little has been done in the South Western Indian Ocean to identify and

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quantify the relative importance of various human pressures. Hughes (1974b) and National Reports to the Indian Ocean South East Asian (IOSEA) Sea Turtle Memorandum of Understanding provide the best overview of impacts in this region. These national reports have highlighted the fact that fisheries interactions with sea turtles constitute a major threat (www.ioseaturtles.org). Furthermore, given the trans-boundary nature of sea turtle populations, a regional approach is essential and overdue.

Within the framework of the FAO project GCP/INT/919/JPN "Interactions between Sea Turtles and Fisheries within an Ecosystem Approach to Fisheries Management", a regional workshop was organised by the Directorate of Fisheries of Zanzibar and FAO to assess the relative importance of fishery-related sea turtle mortality in the West Indian Ocean (WIO) region. The workshop was attended by 31 participants, of which 24 were from 11 countries of the Western Indian Ocean (Kenya, Madagascar, Mauritius, Maldives, Mozambique, Seychelles, Somalia, South Africa, France /Reunion, United Republic of Tanzania and Yemen).

Completed by other regional and available information not presented in the workshop, this review is the result of the cooperation between all these countries that provided grey and reviewed literatures and data available on fishery-related sea turtle mortality in their waters. It is derived from the following main activities: (1) the collation, by country, of quantitative and qualitative information on sea turtle occurrence and general biology, as well as on natural and human-induced mortality; (2) an assessment of the main threats to sea turtles in the region; (3) the evaluation of the potential of a population model to assess the relative importance of the various sources of mortality and particularly of fishery-related mortality on turtle populations; and (4) the determination of priority follow-up activities in the region, related to sea turtle conservation, particularly in relation to fisheries issues.

It remains important to note that information and data presented in this review are composed of 37% of peer reviewed and published literature and 12% of published but no reviewed (proceedings, books, unpublished thesis), 29% of national reports for international organisations (FAO, IUCN, WWF IOSEA and IOTC) and 22% of technical national reports (mainly from reliable and recognized NGO). Therefore, the review presented here, of the available information by country, has to be considered as a rough assessment of the effective population status and interaction between sea turtle and fisheries that occurs in these countries.

PRESENTATION OF AVAILABLE INFORMATION BY COUNTRY

In order to assess the relative importance of sea turtle mortality due to fisheries in the SWIO, representatives from each country received a standard format with 18 categories of data to be compiled and used for assessing major sources of sea turtle mortality. These categories included the legislation frameworks, population census information (Table 1), and information on natural and human-induced mortality and habitat destruction. A complete synopsis of most of the information on sea turtle threats is presented in FAO (2006). As a note, information on the legislation regarding sea turtles for each country is fully presented in the national reports' online facility maintained by the Indian Ocean South-East Asian Marine Turtle Memorandum of Understanding (www.ioseaturtles.org).

Kenya

Sea turtle diversity and status

Kenya's waters host five of the seven species of sea turtles known to occur in the world, the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricate*), olive ridley (*Lepidochelys olivacea*), loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*). Of these three, the green, hawksbill and olive ridley turtles nest in Kenya (Frazier, 1975; Okemwa *et al*., 2004) while according to Frazier (1975), leatherbacks and loggerheads use Kenya's waters as foraging grounds as well as migratory routes. The marine habitats of the Kenyan coast, which include coral reefs, sea grass meadows and sandy beaches, provide diverse habitats for sea turtles. An aerial survey in 1994 indicated that sea turtles are widely distributed along the coastline within the 20m isobath mainly within sea grass beds and coral reefs (Wamukoya

Table 1. Nesting per species as recorded per country (H>1,000 individuals per annum (ipa); M=100-1,000 ipa and L<100 ipa; ?= No information available). All reports are visible in the website http://www.ioseaturtles.org

Country	*Chelonia mydas*	*Caretta caretta*	*Dermochelys coriacea*	*Eretmochelys imbricata*	*Lepidochelys olivacea*	Legislation	Presenters
Kenya	Nesting (M)	Common in-water sightings	Common in-water sightings	Nesting (M)	Rare nesting (L)	Protected	1
Madagascar	Nesting (?)	Nesting (?)	In-water sightings	Nesting (?)	Nesting (?)	Protected	2
Maldives	Nesting (M)	Very rare sightings	Very rare sightings	Nesting (?)	Rare sightings	10 year ban on adult harvesting. Egg harvesting permitted	3
Mauritius	Nesting outer islands (?)			Nesting outer islands (?)			4
Mozambique	Nesting	Nesting	Nesting				5
Reunion/Eparses Island/Mayotte	Nesting (H)	Very rare sightings	Very rare sightings	Nesting (L)	Very rare sightings	Protected	6
Somalia							
South Africa	In-water sightings (L)	Nesting (M)	Nesting (L)	In-water sightings (L)	Rare (<1 ipa)	Protected	8
Tanzania	Nesting (M)	Common in-water sightings	Common in-water sightings	Nesting (M)	Rare nesting (L)	Protected	9
Yemen							10

1. Kenya Report: Elizabeth Mueni, Mwaka Barabara, Betty Akunga
2. Madagascar report by Andriamiseza Olga, Rakotomavo Hortense, Rakotonirina Berthin.
3. Hussein Zahir; Sea turtles in the Maldives: Status, threats and management.
4. Meera Koonjul, Veemala Chelumbrun,
5. No report
6. J. Bourjea, F.Beudard, H.Grizel, S. Ciccione – Assessment of importance of sea turtle mortality in the Indian Ocean French Islands
7. No report
8. Nel, Ronel – Turtles is South Africa
9. Asha A.Khatib and Makame S. Nassor (Zanzibar) & Catharine Muir (Tanzania)
10. No report

et al., 1996). Based on a 4-year study from 1997 to 2000, 684 nests were recorded, of which green turtles made up 94% of the nesting activity, with the remainder of the nests comprising hawksbill and olive ridley nests (Okemwa, 2003).

Threats

Important sources of mortality are related to all life stages of sea turtles. Egg predation and nest inundation, together with egg poaching are believed to be the main threats on most nesting beaches. The documented mortality from incidental entanglement in fishing is 18% while pollution contributed 3% (KESKOM unpublished data). Estimated incidental catch rates of turtles in shrimp trawls seems to be as high as 2-3 turtles/day (Mueni and Mwangi, 2001; Mwatha, 2003), and 100 – 500 turtles/ year when Turtle Excluder Devices (TED) were not in use (Wamukoya *et al*., 1997). Information seems also to indicate that the relative mortality due to fisheries either as targeted or incidental is approximately 95% of all documented turtle mortalities in Kenya (Wamukoya *et al*., 1997), with approximately 58% of sea turtles killed as a result of entrapment in fishing nets (Okemwa *et al*., 2004). Other documented sources of mortality are relatively low, with the main constraint being the lack of data on foraging and developmental habitats of the turtles in Kenya and on turtles migrating out of Kenyan waters.

Madagascar

Sea turtle diversity and status

Five species of marine turtle are reported to occur in the coastal waters of Madagascar: the green, hawksbill, olive ridley, loggerhead and leatherback (Marquez, 1990; Ratsimbazafy, 2003; Seminoff, 2004). Only the first four species are known to nest along the coast of Madagascar and the distribution of the nesting sites differs according to each species (Ratsimbazafy, 2003). While marine turtles are commonly exploited by the local population little scientific data is available (Rakotonirina, 2001) and they may be by a variety of human activities including poaching, fishing and habitat disturbance (Rakotonirina and Cook, 1994, Ciccione *et al*., 2002). Several eco-tourism ventures have been established focusing primarily on marine turtles, in areas where nesting occurs, such as in Nosy Iranja Kely, in the north-western of Madagascar that hosts a stable nesting site for green and hawksbill (Bourjea *et al*., 2006).

Threats

Fishers used to take sea turtles for meat (Rakotonirina and Cook, 1994). Direct capture of juvenile and adult turtles of all five species takes place using a variety of gear types. Collection of eggs is also practiced on nesting beaches (Lilette, 2006). Direct capture of juvenile and adult turtles of all five species takes place using a variety of gear types. Mortality due to fishery bycatch takes place both in the traditional (artisanal) and in the industrial fisheries, with the former being the most important (Lilette, 2006). Even if Turtle Excluding Devices (TED) were implemented in some trawls boats to avoid sea turtle bycatches, no records of captures in shrimp trawls were available from Madagascar, but this is probably because there was no effort to document incidental capture of marine turtles (Randriamiarana *et al*., 1998).

Maldives

Sea turtle diversity and status

Five species of sea turtles occur in the Maldives. These being green, hawksbill, olive ridley, loggerhead and leatherback turtles (Frazier *et al*., 2000). However, only two, the green and hawksbill turtles, regularly nest and forage in the Maldives. Little is known regarding population status and abundance.

Threats

High level of exploitation of both eggs and tortoise shell in the past has created conservation concerns that have lead to a decree that bans catching, killing and possession of any species of sea turtles. However, according to Maldives delegates, collection of eggs was not banned and this practice has been a concern for a long time. Fishery-related mortality is largely unknown. Sea turtles reported from Maldives were either entangled in discarded fishing gear or caught incidentally in oceanic driftnets or longlines (Shanker, 2004). The costal reef fishery is not believed to pose a significant threat to sea turtles, while the emerging long-line

fisheries, mainly by foreign licensed vessels, may represent a greater threat as it was already shown elsewhere for these open sea fisheries.

Mauritius

Sea turtle diversity and status

Two species of marine turtles are commonly found in the waters of Mauritius: the hawksbill turtle and green turtle. Nesting of marine turtles is common on all the outer islands, e.g. St. Brandon, Agalega, and Chagos (Mangar and Chapman, 1996). Few nests of these two species were recorded in Mauritius and Rodrigues Islands (Thompson, 1981).

Threats

Natural disturbances such as those due to storms, cyclones and erosion are believed to represent major threats. Illegal egg collection seems to be also an important sources of mortality but no data are available. Even if foreign, open sea fisheries (longline and purse seine) used to operate around and to land enter Mauritius waters, no data are available regarding interaction with sea turtles.

Mozambique

Sea turtle diversity and status

Four species are known to nest along the coast of Mozambique. These are green turtle, hawksbill, loggerhead and leatherback turtles (Gove and Magane, 1996; Louro *et al*., 2006; Costa *et al*., 2007). According to Hughes (1971), the green turtle is widespread but nests north of the tropic of Capricorn, from Quewene Peninsula to the Quirimbas Archipelago. However, the main concentrations of nesting greens occur in the Primeiras and Segundas Islands (Costa *et al*., 2007). Small and immature animals are also concentrated around Bazaruto and Inhassoro and some found in Maputo Bay. Loggerhead and leatherback turtles are more common in the south and nesting beaches are found along the entire coast from Ponta do Ouro to the Bazaruto Archipelago (Hughes, 1971; Costa *et al*., 2007). The most important nesting areas are Ponta do Ouro region, Maputo Special Reserve, Inhaca Island, Quewene Peninsula and Bazaruto Archipelago (Gove and Magane, 1996).

Threats

While costal development presents threats to sea turtles and their habitats, the main threats to these species in this country are related to direct exploitation for eggs and shell (Costa *et al*., 2007). Fishery-related threats, such as entanglement in gillnets, seems to be dominant in Maputo Bay and Bazaruto, while beach seining (using tractors) could be the main threat in Inhassoro. These fishery practices have been estimated to kill on average 30 – 35 green turtles per month in these areas (Hughes, 1971). Sofala Bank is one of the main shallow water shrimp fishing grounds of Mozambique were shrimp trawlers may be a significant source of mortality. Gove *et al*. (2001) estimated over 1,000 deaths per year from this fishery.

La Réunion (France)

Sea turtle diversity and status

The same five species of sea turtles are found in the Indian Ocean French waters but only two species (green and hawksbill) are known to nest in the southwestern French territories (*e.g*. Europa, Juan de Nova, Glorieuses, Tromelin, Mayotte and La Reunion). The green turtle is the dominant species and it nesting population assessments shows overall large nesting populations stable or increasing in the Eparses islands (*e.g*. Europa, Juan de Nova, Glorieuses and Tromelin; Lauret-Stepler *et al*., 2007) and Mayotte (Bourjea *et al*., 2007). In La Réunion Island, nesting started again in 2005 after a 25 years absence and now there are more than 11 green turtle nests recorded in 3 years (Ciccione and Bourjea, 2006).

Threats

The small offshore longline fishery of the French islands (39 offshore longliners in 2006) seems to have a very small impact on sea turtles with very low incidental capture and mortality rates. In 1999, a 3-year study shows that less than 0,004 turtle per 1,000 hooks caught by this fishery (Poisson and Taquet, 2001; Miossec and Bourjea, 2003). Trawling and gillnets are banned in La Reunion. Rare cases of handlines bycatches were recorded the last 6 years (Ciccione, pers. comm.).

Seychelles

Sea turtle diversity and status

Loggerhead, leatherback, olive ridley, hawksbill, and green turtle were also reported to occur in Seychelles (Frazier 1973; 1974), though only the latter two nests in the Seychelles (Mortimer, 1988; 2000a; Hitchins *et al*., 2004). The green turtle nesting is gradually increasing at Aldabra Atoll (Mortimer, 1985) and some other protected areas, but the overall population seems to be decreasing due to a lack of protection on the inner granitic islands (Mortimer, 2000a). Seychelles has the largest population of nesting hawksbills in the western Indian Ocean with about 1 000 – 2 000 nesting females annually (Mortimer, 1984). The hawksbill population, which is most important around the inner islands, is declining due to poaching of nesting females, except at protected sites where there are moderate increases (Mortimer, 2000b).

Threats

According to delegates, poaching of nesting females and loss of habitat and feeding grounds are important threats for hawksbill turtles in the inner islands. Trawls, dredges, driftnets, and shark gillnets have been banned in Seychelles' waters. Fishery-related mortality of sea turtles is probably associated with longlining and purse seining. Even if data are not available for the small longline fishery; Seychelles also host an important European purse seine fleet. Sea turtle bycatch were estimated on the bases of data collected through French and Spanish observer programs representing a total of 1,958 observed fishing sets (Amande *et al*., 2008). Observations of turtles were occasional and almost exclusively made on log-associated tuna school sets (95%). Over the whole period of observations a total of 74 individuals were caught. These observations were mainly reported during the second part of the year when the fishery is actively fishing on Fish Aggregating Devices. Turtle species composition was dominated by three species: *Lepidochelis olivacea,* the olive ridley turtle; *Chelonia mydas,* the green turtle and *Eretmochelys imbricata*, the hawksbill turtle. According to the observations, *L. olivacea* seems the most impacted by the fishery and most of the bycatches occurred in the north–west Indian Ocean (up to the equator). *C. mydas* and *E. imbricata* suffered the lowest bycatch rates and were predominantly caught in the north of Mozambique Channel. Near 90 % of the turtles caught were discarded alive (Amande *et al*., 2008).

Somalia

Sea turtle diversity and status

Green and hawksbill turtles are known to nest extensively along the Somaliland coast (Frazier 1980), but there is no quantitative information on nesting numbers or the exact location of main nesting areas.

Threats

A major source of mortality seems to be related to gillnets used for shark fishing (Nurarale, pers. comm..). Illegal, Unregulated and Unreported (IUU) fishing is probably also a major threat as it seems to be a sub-regional hotspot for these activities, but no quantitative information is available. Traditionally, direct take of eggs and turtles is not practiced in Somalia (Nurarale, pers. comm.).

South Africa

Sea turtle diversity and status

Two species of sea turtles are found nesting along the 200 km north-eastern coast of South Africa, namely loggerheads and leatherbacks (Hughes, 1974a, b; 1993; 1996a,b). Nesting population assessments of these two species indicate that a small leatherback population (about 100 females/ year) also nests in Natal, South Africa (Hughes, 1996a) as well as 100 to 1,000 nesting loggerhead females annually in Tongaland. The eastern seaboard also serves as a feeding and developmental area for hawksbill and green turtles.

Threats

Threats in South Africa are relatively well managed with a virtual absence of direct take. Predation of nest and eggs occur by honey badgers, ghost crabs and water mongoose but is relatively low. Interactions with a number of fisheries do exist

in the South African EEZ. The most important interactions are with longlining operations, small prawn trawl fishery (10% of trawls; Fennesey, pers. comm.) and coastal gillnets (about 50 turtles/year; Young, 2001) with the specific purpose of bather protection against shark attacks. Turtle bycatch in the South African pelagic longline fishery operating in the South African EEZ was recently assessed by Petersen *et al*. (in press) and identified as a key threat to turtle population. A total of 181 turtles were caught on 2,256 observed sets between 1998 and 2005, at a rate of 0.02/1,000 hooks for *Caretta caretta* (60.0% of the total turtle captured), 0.01/1,000 hooks for *Dermochelys coriacea* (33.8%), 0.001/1,000 hooks for *Eretmochelys imbricate* and *Chelonia mydas* (respectively five and three individuals). Even if bycatches occurred in both Atlantic and Indian Oceans, most of them occurred on the Walvis Ridge and on the shelf edge north of the Orange River (25–31 ºS and 0–15 ºE). The catch rates of sea turtles in the swordfish and tuna fisheries differ greatly, with swordfish being far more damaging and catching 89.5% of the marine turtles.

Tanzania mainland

Sea turtle diversity and status

Five species of sea turtles occur off the 900 km long coast of Tanzania: green, hawksbill, loggerhead, leatherback and olive ridley. Of these, only the green and hawksbill nest (Howell and Mbindo, 1996). The key turtle nesting sites, and relative importance, in Tanzania are reported to be Mafia (high), Temeke / Mkuranga (medium), Mtwara (medium) and Bagamoyo / Pangani (low). Approximately 1/3 of the coastline has yet to be monitored. It is estimated that there is an average of 250 – 300 green turtle nests per year and between 5 – 10 hawksbill nests per year (Muir, 2005). However, these figures only represent data for about 1/3rd of the country's coastline. Data on foraging populations and population trends are unknown.

Threats

Main threats to sea turtles include poaching of eggs and habitat disturbance. With regard to coastal fisheries, information gathered from questionnaire interviews and catch monitoring (on Mafia Island) indicate that bottom set 'Jarife' (6-inch mesh) and 'sinia' (12-inch mesh) nets pose a major threat to sea turtles. It has been reported that every turtle captured in both artisanal and commercial shrimp fisheries in the United Republic of Tanzania is killed (Haule *et al*., 1998). The level of mortality from inshore commercial prawn trawlers, pelagic longline and purse seine nets in the Tanzania EEZ is unknown. A total ban on trawling has been implemented subsequent to the FAO meeting, due to reduced prawn stocks, high level of bycatches and commercial non-viability of the fishery.

Tanzania and Zanzibar

Sea turtle diversity and status

All five species of sea turtles occurring in the SWIO are recorded from Zanzibar waters, two of which (green and hawksbill) nest on the island's beaches (Aitchison, 1993; Khatib *et al*., 1996). Important nesting sites for green turtles are Misali (west), Vumawimbi and Kiuyu in Pemba, and Matemwe and Mnemba Islands in Unguja. Nesting population abundance is unknown.

Threats

Zanzibar used to be one of the world's major clearing houses for turtle shell and populations are believed now to be a small fraction of what they once were due to various human impacts, however no past data are available. Tourism development, leading to destruction of nesting beaches, and direct take for meat and medicine, are major concerns for sea turtles in Zanzibar. Information locally-gathered also revealed that in Zanzibar a high incidental gillnet catch rate of green and hawksbill turtles may reach 6 -10 turtles per month (Hamad, pers. comm.). There are about 878 gillnets recorded in 2003 used by fishermen in Unguja and Pemba (Jiddawi and Yahya, 2003). Gillnets were introduced in Zanzibar in the late 1960s (Tarbit, 1984) and their use has increased. Usually fishing is conducted at night during the dark phases of the moon. The drift nets usually targeting large pelagic fish such as king fish, sail fish and tuna can have a length of up to 500-900 m in length with variable mesh size of 7-20cm (Amir *et al*., 2002).

Yemen

Sea turtle diversity and status

Sea turtles are widely distributed along the coasts of Yemen, both in the Red Sea and in the Gulf of Aden. Even if no information is available for the loggerhead turtle, all the other species common in the Western Indian Ocean are found nesting or feeding in Yemen (Walczak, 1979 ; Frazier, 1980; Ross and Barwani, 1982). Large nesting grounds are located at Makulla with more than 10,000 females of green a year but several small nesting grounds are found in the region (Ross and Barwani, 1982). The beach at Ras Sharma is recognized as one of the most important nesting sites along the entire Gulf of Aden, particularly for the green turtle and, to a lesser extent, the hawksbill (Ross and Barwani, 1982).

Threats

The main threats to sea turtles (mainly hawksbill and greens) are suspected to be due to trawling but no data are available.

It clearly appears from this short regional review per country that there is a general lack of reliable information regarding marine turtle population assessments and interaction with fisheries in the WIO (see also Table 1 and 2). However, countries such as Seychelles, South Africa and La Réunion (France) already collect numerous and reliable data that allow an assessment of their marine turtle populations and the level of interactions related to open sea fisheries (mainly longline and purse seine). Even if most of local population assessments still have to be done by each country, most of this available information on the interaction with open sea fisheries from Seychelles, South Africa and La Réunion (France) could be easily extrapolated for modelling to those countries that do not currently collect such kind of data. However, of major concern is the general lack of data and knowledge on costal fisheries interaction, such as traditional gillnets that are known to impact marines turtles and whose impacts should be urgently assessed.

USING MODELS TO ASSESS THE RELATIVE IMPORTANCE OF FISHERY-RELATED SEA TURTLE MORTALITY

In order to carry out population modelling, information on relative magnitude of natality, mortality, emigration and immigration (or dispersal) should be available, and the processes should be understood. Life cycles of sea turtles are particularly complex, given their longevity, delayed maturity, wide geographic distribution, and the use of different habitats, ranging from terrestrial to pelagic, for varying amounts of time throughout their lives. Despite long-term monitoring programmes, such as for green and hawksbill turtles in Seychelles, green turtles from the French Iles Esparses (Scattered Islands), and loggerhead and leatherback turtles in South Africa, the overall conclusion was that data availability in the WIO was very limited – insufficient for thorough population modelling. It was evident that many of the region's countries do not have reliable nesting data and none have comprehensive in-water abundance estimates (Table 1). Furthermore, the data presented showed inconsistencies and lack of standardization in collection protocols.

The second outcome of this analysis was the recognition of the need to standardize current initiatives so that they take place regularly, with set monitoring protocols based on consistent effort and data standards. It was noted that often data are collected without a clear understanding of their usefulness in relation to data analysis, and often lacking a sound statistical basis. For example, many tagging and nest protection programmes are not recording nesting success per sampling effort, which makes the data inadequate for statistical analysis. However, all data and information available on sea turtles, both qualitative and quantitative, were integrated in this analysis they were collected by species, locations, and main sources of mortality.

Fisheries impacts were scored per species for each life history phase, with the lower the score the more important the threat. Table 2 shows the threats due to fisheries for each of the five turtle species. In the WIO, coastal fisheries, mainly gillnets,

Table 2. Incidental take in fisheries in the West Indian Ocean (threats ranked: 1-5) for five species of turtle. Each species was scored per life history phase, and the lower the score the more important the threat. Data collection is detailed in FAO (2006)
1 = High threat level; high importance to take action; 2 = Medium threat level; 3 Low threat level; low importance to take action; 4 = No threat level; N/A = Not applicable, ?(X)= No information available but suggested level of threat

	Leatherbacks			Hawksbill		Green		Loggerhead		Olive Ridley	
	Adult	Juvenile	Hatchling	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile	Adult	Juvenile
Incidental take in fisheries											
Longline (shallow and deep-set)	2	2	4	?(2)	?(2c)	2?	2?	1.5j	1.5j		
Demersal longline	2	2		?(2.5)	?(2.5)			4k	4k		
Purse seine	3.5?	3.5?	4	3.5	3.5	4	4	4?	4?		
Trawl	3.5	3.5	4	3.54	3.54	2.5f	2.5f	2.5	2.5	2	2
Coastal fisheries (gillnet)	2.5a	2.5a	4	2	2	1	1	2	2	2	2
Pound nets/traps/pots	4	4		3.5	3.5	3	3	4	4	3	3
FAD-based fishery	?3b	?3b		2.5?	2.5?	4?g	4?g	2.5?	2.5?	3	3
Hook and line	3.5	3.5		3.5	3.5	3.5	3.5	3	3		
Dynamite fishing	4	4	4	4d	4d	4h	4h	4l	4l	3	3
Spearing	4	4		4e	4e	4	4	4	4		
Drift-netting	4	4		4	4	?	?	4	4		
Poison	4	4		4	4	3	3	3.5	3.5		
Beach seine netting	4	4		4	4	4i	4 i	3.5	3.5		

a Specific to Tanzania, and the special case of bather-protection nets in South Africa.
b Specific to Seychelles.
c South Africa & Reunion (4)
d Tanzania (2)
e Kenya (3) & Zanzibar (2)
f Trawling more important in Kenya, Yemen and Tanzania.
g Region has a large purse seine FAD driven fishery (emerging issue)
h Rating of 2 for Tanzania/Zanzibar
i Rating of 3 for Mozambique
j South Africa good data between 2000-2004; a 43% bycatch on Cc; no other member state had data.
k South Africa not considered a problem; other member states no data.
l Zanzibar (2) & Yemen (3)

seem to have the highest impact on sea turtles, with a particular relevance to green turtle (Table 2). Trawlers appear to mainly threaten turtles that have a more coastal behaviour (namely green and hawksbill) whereas turtle species which display more pelagic behaviour during all their life stages seem to be more impacted by longlines (namely leatherback and loggerhead). Although there are limited data regarding turtle interactions with purse seine fisheries using drifting Fish Attraction Devices (FADs), a recent report shows that the level of bycatch remains low (Amande *et al*., 2008). However, the use of pieces of net, hung below the FADs, has to be banned as they are believed to be a cause of mortality of sea turtles due to entanglement and subsequent drowning. Mesh size of these net fragments used by such FADs appeared to be a key contributing factor (Amande *et al*., 2008). It is recommended that net material should be replaced with materials such as non-plastic ropes or non-plastic hoods or straps that will not entangle sea turtles.

BALANCING TREATS, MITIGATION MEASURES AND THEIR APPLICATION TO MARINE TURTLES

There are currently 141 sites of importance identified across 10 nations in the WIO that provide nesting, developmental and feeding habitats (www.ioseaturtles.org). The conservation efforts that are taking place across these sites are summarised into 10 categories ranging from monitoring programmes, to building restrictions and fishing gear modifications (Figure 1). The most commonly employed conservation measures are Marine Protected Areas (26%) accompanied by *in situ* monitoring (24%), and education and awareness programmes (23%). Hatcheries and egg relocation is reported for 10% of the sites. This is in agreement with the fact that direct take (nesting turtle poaching, egg harvesting), is the currently known to be the largest threat to sea turtles across the region. In fact, fishing gear modifications are reported to be used in only 6% of the cases, which is the lowest of all mitigation measures (Figure 1).

It is important to view the impacts of fisheries in the light of other land-based or coastal threats. It is clear that, despite strong legislation prohibiting the direct take of turtles throughout the entire WIO, it is still regarded as the most important threat. An evaluation of the level of take and impact thereof indicated it to be moderate to high in eight of the 11 countries, affecting all of the species (www.ioseaturtles.org). This impact scored higher than any of the fisheries impact ratings (see Table 3).

Appropriate conservation policies to address threat to turtles in the WIO should be require legislation but can only by implemented if they are adequately designed and developed with all stakeholders (namely fishermen, scientists and managers) in order to gain consensus. The capacity to implement such measures must exist locally (and regionally) and follow-up over the short-term and long-term is paramount to achieving success. Without such an approach, these policies are unlike to have any effects on turtle populations. This should be of major concern, especially in countries where priorities are not biodiversity conservation but more socio-economic development.

RECOMMENDATIONS AND IDENTIFICATION OF RESEARCH PRIORITIES

There are four current focus areas suggested for future research and management activities. Firstly, regarding fishery-related threats, the impacts of three fisheries were identified as significant: gillnetting, prawn/shrimp trawling and longlining, leading to a number of recommendations/priorities. These are: Ihe lack of quantitative data is the greatest weakness and therefore should be addressed at all levels, incorporating artisanal and industrial fisheries, and should involve local communities, fisheries administrations, and regional fisheries management organizations (RFMO); 2) research that will highlight turtle-fisheries interactions that could potentially lead to the reduction in bycatch, such as time-area closures, should be promoted; 3) trained-observer programmes should be initiated to collect data on both local and foreign fishing fleets; and 4) experimentation with mitigation measures, including TEDs and circle hooks should be encouraged.

The second focus area relates specifically to illegal, unreported and unregulated fisheries (IUU) as this was a frequently raised issue. While

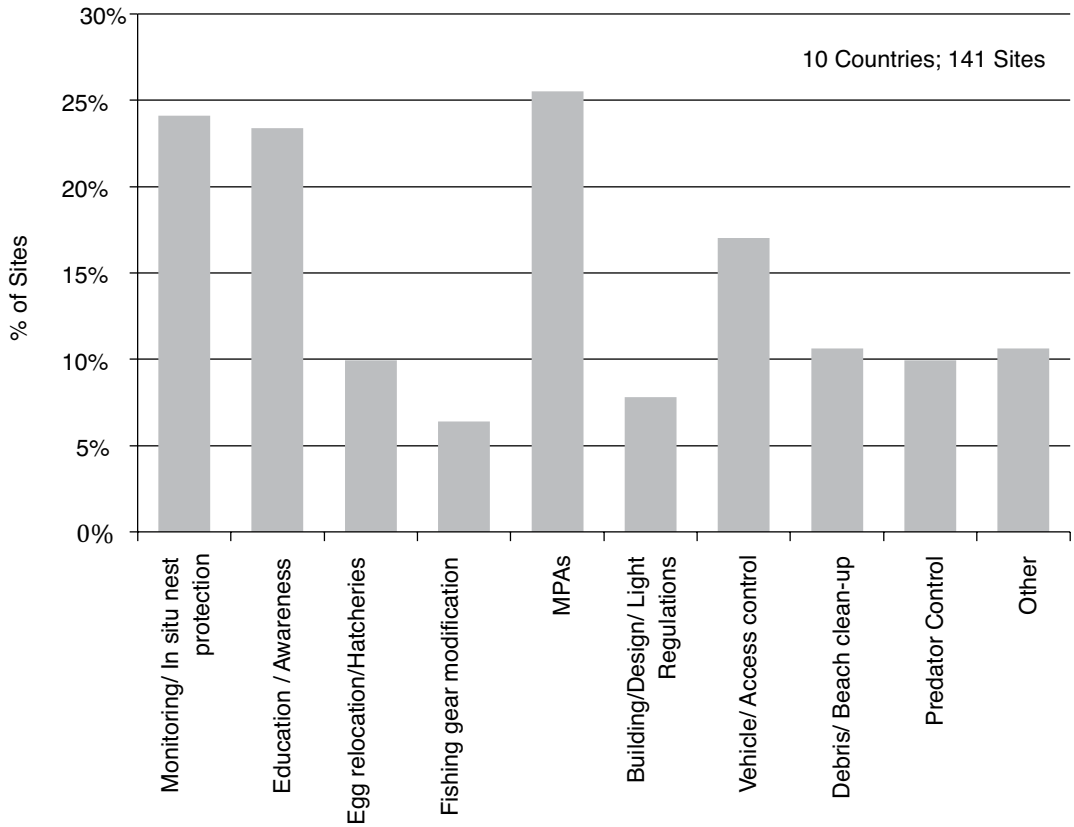

Fig. 1. Mitigation measures used to reduce impacts on sea turtles and their habitats in the Western Indian Ocean. All reports are available on the website http://www.ioseaturtles.org

Table 3. Evaluation of the level of take and impact in the dominant species nesting in the countries of West Indian Ocean (IOSEA database; All reports are available on the website http://www.ioseaturtles.org)

	Dominant Species Nesting	Level	Impact
Comoros		Moderate (2)	Moderate (2)
France (les Iles Eparses, La Réunion, Mayotte)	Cm	Moderate (2)	Moderate (2)
Kenya	Cm	Moderate (2)	Moderate (2)
Madagascar	Cm/Cc/Ei	High (1)	High (1)
Mauritius	Cm	?	?
Mozambique	Cm/Cc/Ei/Dc	High (1)	?
Seychelles	Cm/Ei	High (1)	High (1)
Somalia	Cm	?	?
South Africa	Cc/Dc	Incidental (3.5)	Incidental (3.5)
United Kingdom (Chagos)	Ei	None (4)	None (4)
Tanzania	Cm	Moderate (2)	Moderate (2)

Cm= Chelonia mydas; Cc=Caretta caretta; Ei=Eretmochelys imbricata & Dc=Dermochelys coriacea

it is recognized that the problem of IUU is being addressed in Ir fora, such as under FAO initiatives, it is important to explicitly emphasize that resolving this complex issue is intimately related to mitigating problems of sea turtle bycatch. Based on that, the national administrations were encouraged to review, improve, harmonize and enforce legislation on turtles whereas RFMOs and national administrations were encouraged to recognize the potentially significant impacts of IUU fishing on sea turtle populations in the region (especially for Somalia and Tanzania).

The third focus area relates to the biology and ecology of sea turtles. Studies are encouraged to provide information on long-term abundance and nesting trends, but these should be conducted in a structured, scientifically robust manner. Training programmes and capacity building will be the basis of this focus. More complex questions, such as genetic stock structures and population dynamics of sea turtle stocks in the region (including hatching success, sex ratios, and natural mortality), should be addressed. This will, however, require collaborative research, as suggested by FAO (2006).

The fourth and last focus area relates to the socio-economic complexities of the region. Participants from each country identified turtle catches, direct or bycaught, to be intimately dependent on social, economic, and political forces. It was thus recognised that sustainable fisheries and an ecosystem approach to fisheries management is to be obtained if socio-economic, cultural and resource use studies are included in future research plans. Without resolving root issues of livelihood, resource access and governance, even the best attempts at technological advances, such as gear modifications, will have limited success (FAO, 2006).

Acknowledgements: The authors are most grateful to FAO within the framework of the FAO project GCP/INT/919/JPN "Interactions between Sea Turtles and Fisheries within an Ecosystem Approach to Fisheries Management" for funding the Zanzibar workshop and to the attendance of most of the participants, with a special thank to the expertise of M. Chaloupka. We are also grateful to all the countries which have participated in this workshop, providing relevant data on sea turtle mortality due to fisheries and on the status of sea turtles in their country; without their contributions, no assessment could have been made. We also want to thanks the WIOMSA, Sea Sense, La Rochelle University, the Collectivité Départementale de Mayotte, the Office National de la Chasse et de la Faune Sauvage and the Naturalistes de Mayotte for organizing and funding the workshop in Mayotte. We also want to thanks 'elonia, l'observatoire des tortues marines, for funding the French contribution to this workshop. Lastly, we wish to thanks the two reviewers of this paper for their helpful comments on the manuscript.

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