ASSESSMENT OF MARINE MEGA-FAUNA BY-CATCH IN THE ARTISANAL FISHERY ALONG NORTH COAST KENYA

MOHAMED ATHMAN MOHAMED

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DECLARATION

By the candidate

This is my original work and has not been presented for a degree in any other university or any other award.

Mr. Mohamed Athman Mohamed ____________ Date 19/10/2017

Registration number: I56/PU/2184/13

By Supervisors

This thesis is submitted for examination with our approval as supervisors.

Prof Mlewa C. Mwatete ____________ Date 19/10/2017.

Pwani University, Kenya

Dr Nina Wambiji ____________ Date 19/10/2017

Kenya Marine and Fisheries Research Institute, Mombasa Kenya

DEDICATION

This thesis is dedicated to my father Athman Khatib, my mother Shekha Omar and my wife Khalila Khalid for their support throughout my study.

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ABSTRACT

The populations of long-lived marine mega-fauna including elasmobranchs, marine mammals and sea turtles is declining around the world because of their high vulnerability to fishing activities and mortality. Most mega-fauna have been reported as by-catch globally. However, specific information on the magnitude of by-catch is largely lacking in the artisanal, commercial and semi-industrial fisheries. Therefore, by-catch mitigation measures are non-existent in most of these fisheries. The aim of this study was to assess by-catch of elasmobranchs, marine mammals and sea turtles in artisanal bottom-set and drift gillnet fisheries along north-coast Kenya. The study was conducted during May through November 2016 in the small scale fisheries of Old Town and Nyali in Mombasa, Malindi beach and Ngomeni in Malindi and Kiwayuu and Kizingitini in Lamu. Data was collected using structured questionnaires and species guide books were used for identification of species. A total of 92 questionnaires were administered in Old town (n = 4), Nyali (n = 2), Malindi (n = 17), Ngomeni (n = 37), Kiwayuu (n = 20) and Kizingitini (n = 12) landing sites. By-catch incidences were calculated by dividing the number of individual species caught by the number of fishing vessels at the landing sites. Forty seven (47) by-catch species were identified including thirty five (35) species of elasmobranchs, seven (7) species of marine mammals and five (5) species of sea turtles. The most common and most frequently caught species of sea turtles were the green turtle *Chelonia mydas* (50%), hawksbill turtle *Eretmochelys coriacea* (18%), olive ridley turtle *Lepidochlys olivacea* (18%) and leatherback turtle *Dermochelys imbricata* (9%). Among marine mammals, the most common species were the Indian Ocean bottlenose dolphin *Tursiops aduncus* (42%), common bottlenose dolphin *Tursiops truncatus* (20%), Risso's dolphin *Grampus griseus* (13%) and Indo-pacific humpback dolphin *Sousa chinensis* (11%). Spotted eagle rays *Aetobatus narinari* (11.9%), honeycomb sting rays *Himantura uarnak* (10.7%) and cow-tail sting rays *Pastinachus sephen* (10.2%) were the most frequently caught ray species while hammerhead sharks *Sphyrna spp* (6.7%), whale sharks *Rhincodon typus* (5.4%) and black-tip reef sharks *Carcharhinus melanopterus* (3.3%) comprised the bulk of the frequent by-catch of sharks. By-catch incidences (BI = 42) were significantly (df = 11; f = 3.21; $p < 0.05$) higher during north-east monsoon than during south-east monsoon (BI = 29). Drift gillnet fisheries reported higher by-catch incidences of sharks (BI = 4) and marine mammals (BI = 1) and are considered as the biggest threat to these marine mega-fauna along the Kenya coast. Therefore, there is a need to develop defined management strategies for the gillnet fisheries in order to mitigate the by-catch of these mega-fauna. There is also need to promote awareness among artisanal fishers on the importance of protecting these vulnerable marine mega-fauna. The study further suggests that rapid by-catch assessments need be extended to other artisanal fisheries including long-lines, bottom trawls, beach seines, cast nets and other types of nets which present potential threats to marine mega-fauna in Kenya.

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ABBREVIATIONS AND ACRONYMS

BYCAM	By-catch Assessment and Mitigation in Western Indian Ocean Fisheries
CCRF	Code of Conduct for Responsible Fisheries
EAME	East African Marine Eco-region
ERA	Ecosystem Risk Assessment
FAO	Food and Agricultural Organization of the United Nations
GoK	Government of Kenya
IUCN	International Union for Conservation of Nature
KCDP	Kenya Coastal Development Project
KMFRI	Kenya Marine and Fisheries Research Institute
KNBS	Kenya National Bureau of Statistics
MASMA	Marine Science for Management grants of WIOMSA
MEA	Millennium Ecosystem Assessment
MPAs	Marine Protected Areas
NEM	Northeast Monsoon
RBAs	Rapid By-catch Assessments
SEM	Southeast Monsoon
SWIOFP	South West Indian Ocean Fisheries Project
UNCLOS	United Nations Convention on the Laws of the Sea, 1982
WIO	Western Indian Ocean

WIOMSA	Western Indian Ocean Marine Science Association
WWF	World Wildlife Fund for Nature Conservation

CHAPTER 1: INTRODUCTION

1.1 Background Information

The Food and Agricultural Organization (FAO) of the United Nations defines by-catch as "part of a fishing unit taken incidentally, in addition to the targeted species towards which fishing effort is directed" (Kiszka *et. al*., 2009a). The FAO Code of Conduct for Responsible Fisheries (CCRF, 1995) calls for the reduction of catch of non-targeted species and promotion of conservation of biodiversity by mitigating fisheries impacts on non-targeted species and ecosystems in general. According to Kiszka (2012a), marine mega-fauna may be defined as large marine species such as elasmobranchs (sharks and rays), marine mammals and sea turtles. These species are characterized by low fecundity and productivity, slow growth, late maturity, large size at birth, high natural survivorship and a long life in the marine ecosystem. These biological characteristics have serious implications for the sustainability in fisheries, such as by-catch. Such species depend on a stable environment and generally have limited capacity to sustain and recover from fishing pressure (Kiszka, 2012a).

The marine environment is facing unprecedented threats from deleterious fishing practices worldwide. Degradation of inshore marine fisheries and coastal ecosystems is escalating due to increase in unplanned development activities, fueled by industrialization, the tourism industry and the need for land among other factors (WWF EAME, 2004). These factors increase the risk of extinction of marine species especially the marine mega-fauna which are highly vulnerable to impacts of such activities. The rapid decline of marine mega-fauna due to the increase in the fishing pressure has been evident in various studies conducted worldwide with the Western

Indian Ocean (WIO) showing high vulnerability to these impacts (e.g. WWF EAME, 2004; Ransom *et. al*., 2007; Kiszka *et. al*., 2008; Kiszka *et. al*., 2009a; Kiszka *et. al.*, 2009b; Moore *et. al*., 2010; Kiszka, 2012a; Kiszka & van der Elst, 2015).

In Kenya, population increase also poses a threat to marine mega-fauna due to increased anthropogenic impacts on the marine ecosystem (Government of Kenya, 2014). Projections based on the Kenya Population 2009 census indicated that there was a rapid increase in the country's population (Government of Kenya, 2010). Along the Kenya coast it has been noted that human population explosion can also be attributed to migration of people to coastal cities and towns in search of employment, thus intensifying the fishing pressure in these coastal areas. Coastal fisheries play a central role in the economies and livelihoods of people along the Coast by providing food and source of incomes to coastal communities (Government of Kenya, 2014). As dependence upon marine resources for food and income increases, fishing effort also increases which in turn leads to increase in the rate of by-catch including that of the marine mega-fauna (Cosandey-Godin *et. al*., 2013). Hoorweg *et. al.* (2009) estimated that 7.5% of the population along the Kenya coast was wholly or partly dependent on fisheries. A survey by the Government of Kenya indicates that coastal and marine fisheries offered direct employment to over 13,000 fishers in the country (Government of Kenya, 2014).

Several species of marine mammals have been recorded in a number of coastal areas by various studies (e.g Pérez-Jorge *et al.*, 2015; Pérez-Jorge *et al.*, 2016). The Indo-pacific humpback (*Sousa chinensis*) and bottlenose dolphins (*Tursiops aduncus* and *T. truncatus*), as well as the dugong (*Dugong dugon*) have been reported by previous studies as the most affected marine mammal species through by-catch in gillnet fishery (Kiszka *et al.*, 2009a). Historically, the dugong occurred in large numbers off the Kenyan coast before the 1970's with large groups of about 500 reported along the south coast in 1967 (Husar, 1975; WWF EAME, 2004). A study by Kiszka *et al*. (2009a) attributed the incidental capture of dugong in the Indian Ocean to gillnets and poaching which has reduced their population. The study also indicated that dugongs still occur, though in small numbers, off the Tana Delta area, in the Lamu Archipelago and in the Kiunga Marine reserve in the extreme north.

Worldwide, sharks face an exceptional threat because they are also commonly fished for their fins, liver oil, for cartilage and for food in addition to being caught as by-catch in various fisheries. By-catch of sharks has caused serious declines in shark populations in many parts of the world (Baum *et. al*., 2003; Cosandey-Godin & Morgan, 2011) including the Western Indian Ocean (WIO) countries, such as Kenya. Sharks are top apex predators with low fecundity, slow growth rate and late maturity, and are therefore more vulnerable to overfishing. If shark populations decline or even disappear, the species associated with top predators' removals i.e. species which are lower in the food chain will also be negatively affected. The loss of these top predators also affects trophic interactions associated with resultant increases in lower-level predators, such as rays, skates and smaller sharks. The prevailing view is that it is important to control shark by-catch for effective management and conservation of marine resources (Kiilu & Ndegwa, 2013).

On the other hand, sea turtles are facing unmatched threats worldwide and are listed as endangered species under the International Union for Conservation of Nature (IUCN)

Red list with varied vulnerability. Kenya is home to five species: loggerhead turtle (*Caretta caretta*), leatherback turtle (*Dermochelys coriacea*), olive ridley turtle (*Lepidochlys olivacea*), hawksbill turtle (*Eretmochelys imbricata*) and green turtle (*Chelonia mydas*) out of the seven species recorded globally. The hawksbill turtle is considered to be the most critically endangered species among the five species recorded along the Kenyan coast (Kiszka, 2012a). High sea turtle mortalities have so far been reported in the country in various studies, with majority of kills linked to by-catch (Wamukoya *et. al.,* 1995; Wamukoya *et. al.,* 1998; Mueni & Mwangi, 2001; Okemwa *et. al.,* 2004; Bourjea *et. al*., 2008; Kiszka, 2012a; Olendo & Mwasi, 2017).

Kenya marine fisheries comprise both artisanal and semi-industrial sectors and are of major socio-economic importance especially to the coastal communities. Artisanal fisheries are confined to shallow coastal waters but account for 90% of the annual total marine fish landed (Kiszka & van der Elst, 2015). Some studies have also been conducted on by-catch of marine mega-fauna, but very few of them focused on the Kenyan coast artisanal fisheries (Kiszka *et. al.*, 2008; Kiszka *et. al*., 2009a; Kiszka *et. al.*, 2009b; Kiilu & Ndegwa, 2013; Kiszka & van der Elst, 2015). Therefore, the data and information on the impacts of by-catch on marine mega-fauna populations in the small-scale artisanal fisheries is still scanty. Consequently, this study was aimed at assessing the by-catch of the large marine megafauna; elasmobranchs, marine mammals and sea turtles in the small-scale artisanal fisheries along the Kenyan coast off Lamu, Malindi and Mombasa in order to generate data and information necessary for the effective management and conservation of these marine resources.

This study was part of a larger project on mega-fauna; By-catch Assessment and Mitigation in the Western Indian Ocean Fisheries (BYCAM) funded by the Marine Science for Management (MASMA) grant of the Western Indian Ocean Marine Science Association (WIOMSA). The overarching goal of the project was to assess the levels of mega-fauna catches in the Western Indian Ocean (WIO). The MASMA project was implemented in Kenya, Zanzibar Mozambique and Madagascar. The implementing institutions were Kenya Marine and Fisheries Research Institute (KMFRI, Kenya), Institute of Marine Science (IMS, Tanzania), Instituto Nacional de InvestigaçãoPesqueira (IIP, Mozambique), Oceanographic Research Institute (ORI, South Africa), Watamu Marine Association (WMA, Kenya), Newcastle University in UK, Florida International University (FIU) and Community Centered Conservation (C3, Madagascar).

1.2 Problem Statement and Justification of the Study

According to Article 61 of the United Nations Convention on the Law of the Sea (UNCLOS, 1982) the exploitation of marine living resources should take into account the impact of fisheries on “species associated with, or dependent upon, harvested species with a view towards maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened”. Marine mega-fauna such as sharks are apex predators which are very important in the top-down control of marine ecosystems that balance population of middle and lower level predators and thus enhance productivity of the marine ecosystems. Therefore, their depletion can significantly affect other predators as well as herbivorous fish, hence interfering with the whole marine ecosystem (Kiszka *et al.*, 2009a). Many elasmobranchs serve as important links between other compartments of the food web. This shows the importance of top-down control in the structuring of marine trophic webs (Bornatowski *et al*., 2014).

Further, under article 65 of UNCLOS (1982), the United Nations urges all the nations in the world to walk the extra mile to conserve marine mammals, especially cetaceans, and work hand in hand with international organizations in order to conserve, manage and even conduct more studies on these cetacean species. Marine mammals are also make very important contribution to energy flow in the marine ecosystem. Cetaceans as a group and sperm whales alone, can consume a greater quantity of prey than all teleost fish combined. Some marine mammals such as cetaceans have an important ecological role in the recycling of nutrients by feeding at depth and then defecating in the euphotic zone. Large cetaceans also continue to play an important ecological role even after death through the downward transfer of nutrients to benthic communities (Bowen, 1997). In Kenya, marine mammals are facing extraordinary threats due to fisheries and fishing activities, and many species have been listed as endangered or vulnerable and data deficient, while others such as dugongs have been reported to have almost completely disappeared from the Kenyan waters (Kiszka *et. al*., 2009b).

Sea turtles spend most of their lives in coastal or pelagic waters, making uninterrupted coastal waters critical to their population stability. They play a significant role in the marine ecosystem and can transfer substantial quantities of nutrients and energy from nutrient-rich foraging grounds to nutrient-poor nesting beaches for other marine organisms to benefit. The loggerhead turtle (*C. caretta*) can modify the physical structure of their habitat in a number of ways, including digging trenches through soft substrates in search of in-faunal prey (Bjorndal & Jackson, 2003). Sea turtles have been negatively impacted by a number of anthropogenic factors including oil spills, chemical contaminants and other types of marine pollution. Direct offtake and habitat modification have also been shown to affect sea turtles. In spite of this, the human activity that has the greatest impact on sea turtles is fisheries' by-catch. Because fishing is an important source of protein and the livelihood for millions of people worldwide, by-catch of sea turtles continues to be the most pressing human impact on sea turtle populations globally (Lewison *et. al.*, 2013).

Evidently, the by-catch of marine mega-fauna remains one of the main threats to these species at the global scale, including in Kenya. However, information on the magnitude of by-catch is still lacking for small-scale artisanal fisheries. Kiszka (2012a) noted that by-catch levels are suspected to be significantly under reported and specifically identified the need for better understanding of the problem with regard to the artisanal fisheries. Therefore, more studies were needed to identify the species which were more vulnerable to by-catch in the small-scale artisanal fisheries, for design of effective conservation strategies. The present study focused on the gillnet artisanal fisheries because despite the widespread use of this gear along the Kenya coast, no study has specifically aimed to determine the by-catch species and levels associated with the gear. Consequently, this fishery and the issue of associated by-catch has remained generally poorly monitored and reported.

1.3 Aims and Objectives

The overall objective of this study was to assess by-catch of marine mega-fauna including elasmobranchs, marine mammals and sea turtles in the artisanal fishery along north coast Kenya.

1.3.1 Specific Objectives

The specific objectives of this study were:

i. To determine the species of elasmobranchs, marine mammals and sea turtles caught as by-catch in the artisanal fisheries along the north coast Kenya.

ii. To compare the by-catch levels of elasmobranchs, marine mammals and sea turtles between bottom-set and drift gillnet fisheries along the north coast Kenya.

iii. To determine temporal composition of by-catch of elasmobranchs, marine mammals and sea turtles in bottom-set and drift gillnet fisheries along north coast Kenya.

1.4 Research Questions

i. What are the species of elasmobranchs, marine mammals and sea turtles caught as by-catch in the artisanal fishery along north coast Kenya?

ii. What are the imperative impacts of drift gillnets and bottom-set gillnet fisheries on mega-fauna by-catch along north coast Kenya?

iii. What is the temporal species composition of by-catch of elasmobranchs, marine mammals and sea turtles caught along north coast Kenya?

CHAPTER 2: LITERATURE REVIEW

2.1 Problem of Marine Mega-fauna By-catch in Fisheries

By-catch of marine mega-fauna remains a huge threat to populations of marine mammals, sea turtles, sharks and rays. However, fishery impacts on by-catch populations are often difficult to evaluate due to factors such as lack of data, poorly defined management objectives and lack of quantitative by-catch reduction targets (Moore *et. al*., 2013). By-catch is the most widespread and direct driver of change and loss of marine biodiversity (Cosandey-Godin & Morgan, 2011).

There is growing evidence of relatively high sea turtle mortality in coastal set-gillnet fisheries (Gilman *et. al*., 2010). A number of case studies have suggested that greater attention is needed for assessment of the impacts of artisanal fisheries on sea turtles, dugongs and other marine mega-fauna (Moore *et. al*., 2010; Moore *et. al*., 2013; Pusineri *et. al*., 2013).

In 2011-2012, a regional by-catch assessment project in the artisanal fisheries was implemented in the South West Indian Ocean Fisheries Project (SWIOFP), based on interview surveys conducted in the WIO region, including Kenya, Tanzania, Zanzibar and Mozambique (Kiszka, 2012a). This study, which only provided baseline data, revealed very high extent of by-catch in artisanal fisheries, especially in drift and bottom-set gillnets. At least 59 species were identified as by-catch and by-product species, including five (5) species of sea turtles, eight (8) species of marine mammals and forty-six (46) species of elasmobranchs. This study aimed at building on the baseline data provided by previous studies as well as to provide data and information on the fisheries identified as having by-catch of mega-fauna species.

Identification, documentation and by-catch assessment of elasmobranch species is not sufficient in the Western Indian Ocean region, with only a few descriptive and often non-comprehensive studies published to date (Wamukoya *et. al*., 1996; Schaeffer, 2004; Fennessy & Isaksen, 2007; Kiszka, 2012a; Kiilu & Ndegwa, 2013). The by-catch in fisheries has led to serious decline in many long-lived elasmobranchs (Baum *et. al*., 2003).

There is limited information on the status of marine mammals off Kenya, but several species have been recorded by previous studies, including the sperm whale (*Physeta macrosephalus*), humpback whale, Bryde's whale (*Balaenoptera edeni*), common minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), melon-headed whale (*Peponocephala electra*), Indian Ocean humpback dolphin (*Sousa chinensis)*, spinner dolphin (*Stenella longirostris*), Indian Ocean bottlenose dolphin (*Tursiops aduncus*), spinner dolphin (*Stenella longirostris*), Fraser's dolphin (*Lagenodelphis hosei*), Risso's dolphin (*Grampus griseus*), striped dolphin (*Stenella coeruleoalba*), pan-tropical spotted dolphin (*Stenella attenuate*), short-beaked common dolphin (*Delphinus delphis*) and dugong (*Dugong dugon*) (Wamukoya *et. al*.,1996; Kiszka, 2012a). According to DeMaster *et. al*. (2001), the interaction of the marine mammals and the commercial fisheries has increased in intensity and frequency. This situation might continue into the foreseen future. According to Read & Rosenberg (2002), mega-fauna species population will be extinct in some few decades if no action is taken on by-catch. It is, therefore, critical to assess the extent of by-catch threat, both spatially and quantitatively, to ensure the effective management of marine mammals and other marine mega-fauna (Kiszka *et. al*., 2009a).

The study of by-catch is one of the most significant conservation issues in the world due to the serious threats posed to fish stocks (Kiszka *et. al.*, 2009a). However, a consistent understanding of by-catch is lacking due to several unresolved issues such as definition of by-catch, its measurement and quantification, among others. To date, by-catch has largely been determined by establishing the element of the catch which is not targeted. Davies *et. al*. (2009) noted that the fundamental problem is that differing value judgments lead to varied perceptions of what is considered as non-target catch, especially with the emergence of fisheries where no specific species appear to be targeted. Further, in most cases there is little or no effective regulation on the use of indiscriminate fishing gear, thus creating an incentive to use such gear to maximize catch (Davies *et. al*., 2009).

2.2 Gillnet Fisheries

A gillnet is a type of fishing gear designed to entangle fish by either keeping the net near or at the surface with floats (Government of Kenya, 2014). Some gillnets freely drift with the currents (drift gillnets), or may be anchored and kept at the bottom or mid-water (bottom-set gillnets). Gillnets catch a wide range of species based on the mesh sizes. The primary threat of gillnets to marine mega-fauna is entanglement in the net mesh, which can result in injury or death from drowning (Lewison *et al*., 2013). Despite the 1999 United Nations ban on high-seas drift gillnets, studies show that gillnets are still extensively used, and reports high mortality rates of marine mega-fauna are still evident (Kiszka *et. al*., 2009a; Cosandey-Godin & Morgan, 2011).

In an Ecological Risk Assessment (ERA) conducted by Kiszka (2012b), it was emphasized that at least 17 species were particularly vulnerable to artisanal fishery gillnet by-catch in the WIO, including 5 species of sea turtles (loggerhead, green, hawksbill, olive Ridley and leatherback turtles), four (4) species of marine mammals (the dugong, Indo-Pacific bottlenose, humpback and spinner dolphins) and eight (8) species of elasmobranchs (Kiszka, 2012b). However, detailed analysis of the by-catch in gillnet fisheries was still lacking. According to Government of Kenya (2014) survey of the coastal and marine fisheries, gillnets make up the second most commonly used fishing gear (n = 3,325) after long-line fishery. The dominant mesh sizes are mostly the <6 inch category.

Marine mammal by-catch in artisanal fisheries has been documented in several countries in the WIO: Comoros and Mayotte (Poonian *et. al*., 2008), Zanzibar and Tanzania mainland (Amir *et. al*., 2002; Pusineri & Quillard, 2008) and the west coast of Madagascar (Razafindrakoto *et. al*., 2009). Although the extent of marine mammal by-catch in Kenya is little unknown, it could potentially be considerable due to the extensive local use of gillnets which are principally the main threat for marine mammals (Lewison *et. al*., 2004; Kiszka *et. al*., 2009a; Reeves *et. al*., 2013).

CHAPTER 3: MATERIALS AND METHODS

3.1Study Area

The study was conducted along the Kenya coast focusing on landing sites in Lamu, Malindi and Mombasa towns (Figure 1), with two landing sites selected for each of the three towns: Kiwayuu and Kizingitini fish landing sites in Lamu; Mbuyuni and Ngomeni landing sites in Malindi; and Nyali and Old-town landing sites in Mombasa. The landing sites were selected for sampling because they are easily accessible and have high numbers of gillnet fishers based on data from the state department of fisheries (Government of Kenya, 2014).

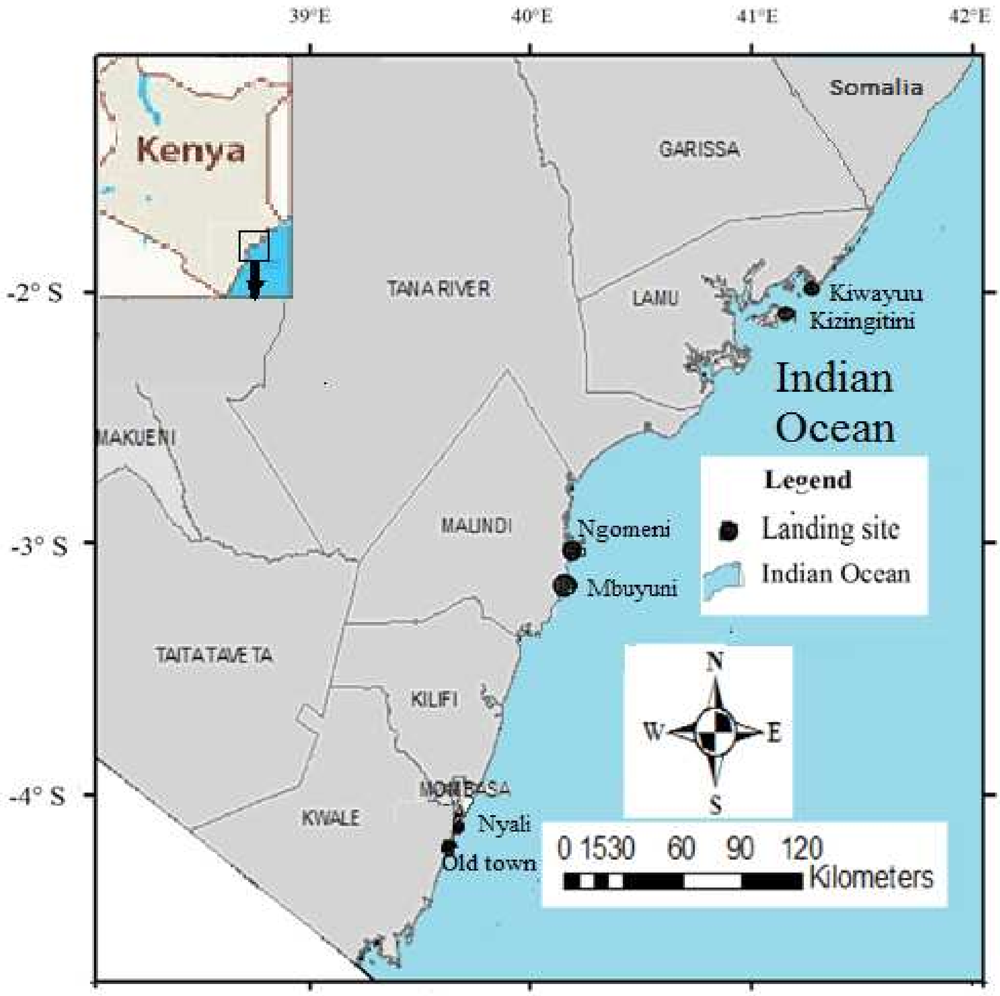

Figure 1: A map of Kenya (inset) showing the location of the sampled landing sites along north coast Kenya.

The Kenya coast is about 640 km, extending from Vanga in the South to Kiunga in the north. It forms part of the western border of the Indian Ocean marine eco–region. It is characterized by the presence of a continuous fringing coral reef commonly distributed at 16-40mwater depths (Anam & Mostarda, 2012). Mangrove forests occur in many tropical estuaries and deltas, while sea grass beds are distributed between the mangrove and reef zones. The coastal and marine habitats along the coast support a wide variety of species, most of which are harvested by artisanal fishers operating between the reef and the shoreline (Anam & Mostarda, 2012).

The major fish landing sites along the Kenya coast are found along the Kiunga coastline and Lamu islands in the North, Tana River mouth, Malindi-Ungwana Bay including the offshore North Kenya Bank; and Shimoni, Vanga, Funzi Island and the coral reef areas bordering the southern border. The key areas of high fisher density along this coast include the Vanga-Majoreni stretch in Kwale county, Ngomeni and Kiunga areas of Kilifi and Lamu counties, respectively. There are 197 fish landing sites along the entire coastline distributed by counties; Kilifi (72), Kwale (54), Mombasa (38), Lamu (28) and Tana River (5) (Government of Kenya, 2014).

Different types of vessels are used by the artisanal fishermen adapted to the different fisheries and weather conditions. The fishing vessels range from dugout canoes (*mtumbwi*), Plank boats (*hori, dau, mtori*), dhows (*mashua*), outrigger canoes (*ngalawa),* surf and rafts, and fibre reinforced plastic (FRP) boats (Government of Kenya, 2014).. The *dau* is a flat-bottom vessel build from plank wood and propelled by small sails while *Mtori* is a keeled dhow pointed at both ends (Fulanda *et. al.* 2011). Dhows and canoes are locally made, and designed to tackle rough weather and open offshore fishing expeditions. They are mainly equipped with shark nets, drift nets, and other types of set gillnets as well as longline gears. Canoes are mainly deployed in the operation of active gears such as beach seine and cast nets, drift long-lines and inshore passive gears such as set gillnets, fishing pots and traps, and barricade trap. In many of the coastal villages, many fishers access the shallow fishing grounds on foot (foot-fishers), swimming and by gleaning (women and children collecting mollusks and crabs during the low tides) (Fondo, 2004).

The climate on the Kenyan coast is dominated by two seasons: Northeast monsoon (Kaskazi): November – February and Southeast monsoon (Kusi) with two inter-monsoon seasons (Matlai) during March-April and September-October (Fondo, 2004). The southeast monsoon season is characterized by high cloud cover, heavy rainfall averaging 900mm/year, low air temperatures averaging 25°C, river discharge, terrestrial runoffs, cool waters and a deep thermocline. Fish catches are lowest during this season partly due to fish migrations, decreased fish density and fish activity, and reduced fishing effort. The reduced fishing effort results from the inability to venture beyond the reefs and fear of braving the rougher waters. The northeast monsoon is characterized by weak wind speeds and low air temperatures (Government of Kenya, 2014). This period offers more favourable conditions for fishing along the Kenya coast.

3.2 Research Design

This study was part of a bigger project investigating marine mega-fauna by-catch along the Kenya coast focusing on Lamu, Malindi and Mombasa. Structured interviews with questionnaires have been used in the similar studies in the past (Moore *et. al*., 2010; Kiszka, 2012a; 2012b). The original questionnaire for the BYCAM project was developed by Kenya Marine and Fisheries Research Institute as the implementing agency of the wider project, which covered several gear types and fisheries within the artisanal fisheries along the Kenya Coast. The questionnaire were modified and adapted to fit the aims and objectives of the present study focusing only on the gillnet fishery along the Kenya coast as shown in Appendix 1. The questionnaires were administered to fishers in the selected landing sites; Kiwayuu and Kizingitini landing sites in Lamu; Mbuyuni and Ngomeni landing sites in Malindi; and old town and Nyali landing sites in Mombasa. Only fishers using gillnets were interviewed at the study site.

3.3 Sampling Procedures

The study was conducted from late May through early November 2016. Data was collected once in every month using structured interviews (questionnaires). Questionnaires were administered to the fishers available at the landing sites during the field visits. Interviews were conducted at the landing sites and at the fisher camps during different activities; when fishers were repairing their fishing gears/boats, when fishers were landing catch, or when the fishers were going to or returning from the fishing activities (Plate 1 & 2). Depending on the availability of fishers on the landing site, about 3-5 fishers from different fishing vessels were interviewed each day. Although the questionnaire was originally prepared in English, they were translated to Kiswahili (the national language) for the respondents during the interviews. Each participant in the study was issued with a consent form (Appendix 2) that aimed to ensure that participation in the study was voluntary. The forms were then taken back after being signed by the fishers. By-catch data was recorded by the researcher with the help of field assistants. Species identification was done using species identification keys (Plate 1) adopted from the FAO species catalogues and a field guide (Anam & Mostrada, 2012).

Plate 1: Training of the fishermen on the use of species identification keys at Kiwayuu landing site, Lamu, during the survey.

Plate 2: Researcher interviewing a fisherman who was repairing his fishing gear at Old town landing site, Mombasa.

3.5 Data Analysis

Data on the species of sea turtles, marine mammals and elasmobranchs identified, number of times (frequency) a species was recorded over the study period were transferred from the questionnaires to Microsoft® Excel for analysis. By-catch composition was analyzed descriptively and presented in graphs or tables for drift and bottom set gill nets. Differences in numbers of sea turtles, marine mammals and elasmobranchs were compared between landing sites and seasons. Since the count data was not normally distributed, square-root data transformation was performed (McDonald, 2014). The transformed data was later tested for homoscedacity using the Levene's test (Levene, 1960) prior to statistical analysis. Two-way Analysis of Variance (ANOVA) was performed on the data that conformed to the assumption of homoscedacity while Kruskal-Wallis test was performed on the data which did not meet the requirements for ANOVA test.

By-catch incidences were calculated for each species group using the following equation adapted from Kiszka (2012a):

$$BI = (N_{\text{species/study period}} / N_{\text{fishers}}).$$

Where BI is by-catch incidence, $N_{\text{species/study period}}$ is the number of individual species during the whole study period and N_{fishers} is the total number of fishermen interviewed during the entire study period.

Differences in the by-catch incidences between bottom-set and drift gillnet fishery during NEM and SEM seasons and at different landing sites were compared using two-Way ANOVA.

CHAPTER 4: RESULTS

4.1 Fishermen Characteristics and Fishing Gears Used

A total of 92 interviews were conducted. All respondents were males. At least 26% of respondents had already been involved in questionnaire surveys in the past. The age of interviewed fishermen had a Mean ± SD of 46.3±13.01. Their mean fishing experience was 23.8±11.5 years (mean ± SD). For all interviewees, fishing was their primary activity as opposed to fish trading, gear repair etc.

Ngomeni had the highest number of fishing vessels using gillnets (40%, n=37), while Nyali had the lowest (2%, n=2) (Figure 2). About 61% of fishing vessels (n=56) were using bottom-set gillnets, 15% (n=14) of them were using drift gillnets, while 24% (n=22) were using both gillnet types.

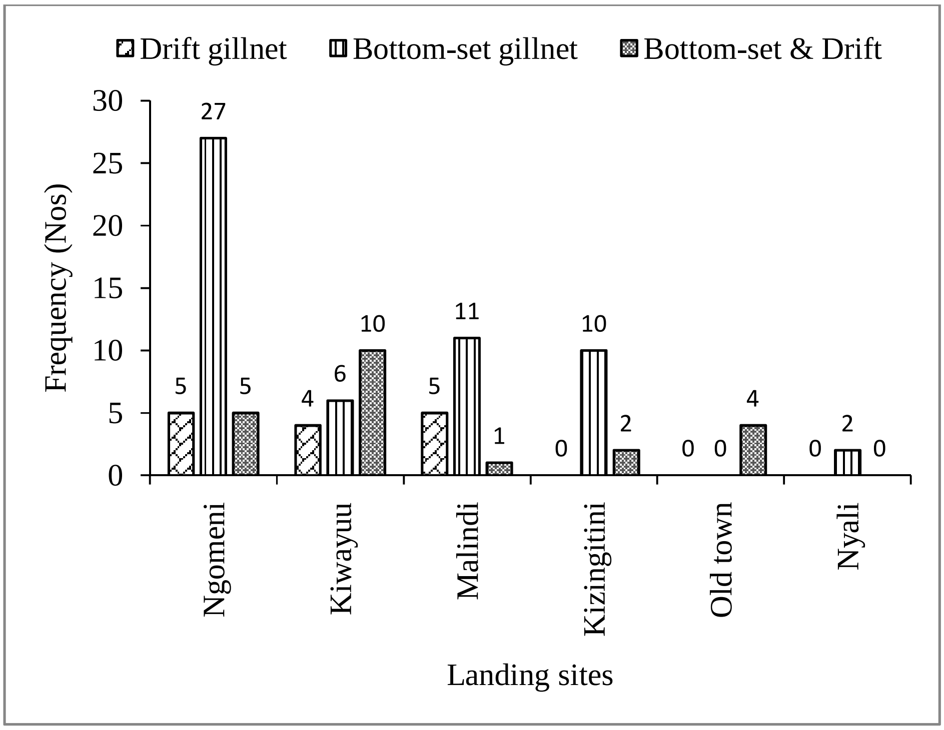

Figure 2: Distribution of the fisheries at the studied landing sites along north coast Kenya.

4.2 Fishing Effort

The number of days the fishers go fishing per week ranged between 5 and 7, with most fishermen (90%) reporting fishing durations of 6 to 7 days. This applied to those fishermen who go fishing and returned to the landing site on a daily basis. Night fishers (kwenda ago) declared that they spend 23-24 days at sea (depending on appearance of the moon from 17^{th} to 10^{th} of every month of lunar calendar) and spend 6 days travelling back to the home villages. Based on fishermen declarations, the lowest effort (4%) was observed during the Southeast monsoon (Kusi, May to August) while highest effort (59%) was observed during Northeast monsoon (Kaskazi, November to February). Some respondents (37%) declared that they fished throughout the year. Five vessel types were commonly used along the coast of Kenya; dhow (91.3%), fiber re-enforced plastic (FRP) (5.4%), *dau* (1.1%), *motaboti* (modern boats with outboard engines) (1.1%) and *mtori* (1.1%).

4.3 By-catch Composition of Sea Turtles

The five species of sea turtles were recorded as by-catch in all landing sites (*E. imbricata*, *C. mydas*, *L. olivacea*, *C. caretta* and *Dermochelys coriacea*). The green turtle *C. mydas* was the most recorded by-catch species (n = 63) with Ngomeni reporting the highest by-catch rate (19.6%; n = 32) followed by *E. imbricata* with 17.2% in Ngomeni (n = 28) and 7.4% in Kiwayuu landing site (n = 12). *Caretta caretta* reported the lowest by-catch (n = 13) (Figure 3). There was no significant difference in the by-catch of sea turtles between different landing sites (Kruskal-Wallis test: H = 8.886 p =0.064).However, there was a significant difference in the by-catch of sea turtles between the seasons (Figure 4) (Kruskal-Wallis test: H =60.461; $p<0.05$).

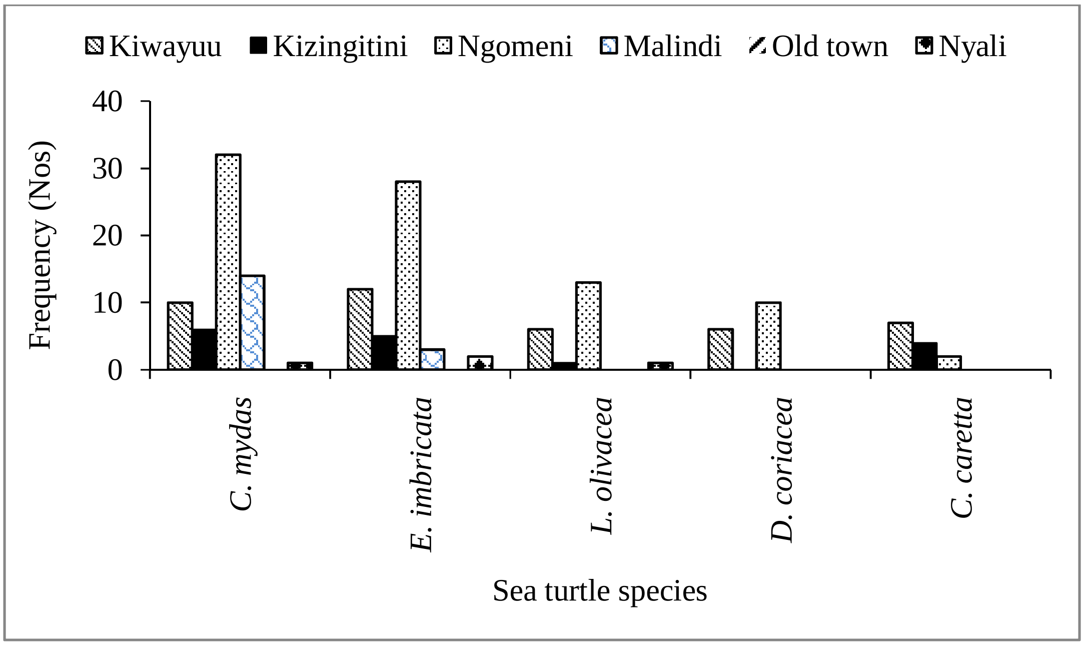

Figure 3: Spatial occurrence of by-catch of sea turtles at the sampling sites along north coast Kenya.

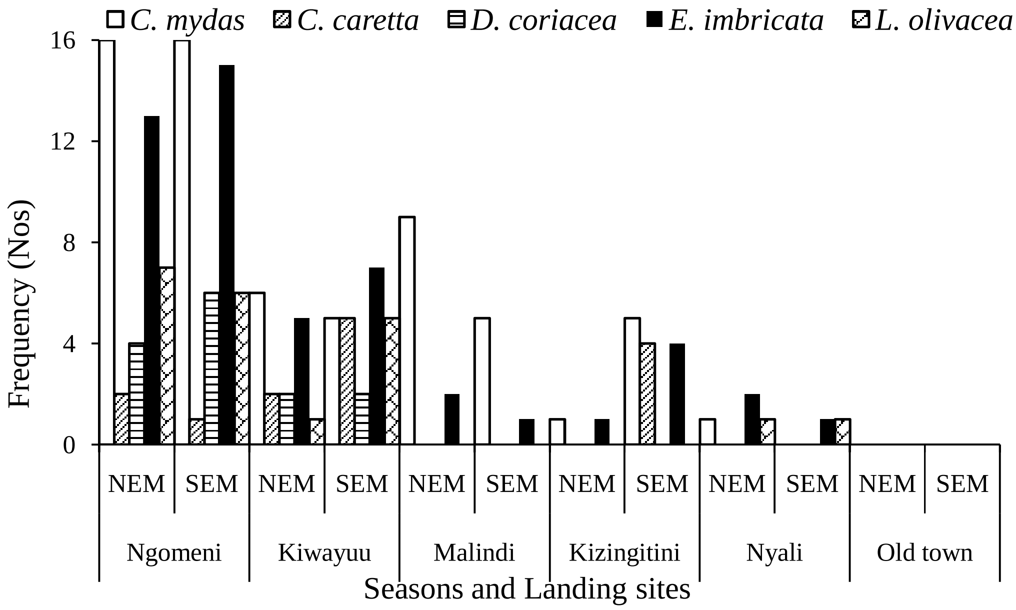

Figure 4: Temporal occurrence of sea turtles by-catch by season (NEM and SEM) at the sampling sites along north coast Kenya.

4.4 By-catch Composition of Marine Mammals

A total of seven species of marine mammals (Figure 5) were recorded as by-catch in all landing sites; Common minke whale *Balaenoptera acutorostrata,* Spinner dolphin *Stenella longirostris,* Fraser's dolphin *Lagenodelphis hosei,* Indo-pacific humpback dolphin *Sousa chinensis*, Rissor's dolphin *Grampus griseus*, Indian Ocean bottlenose dolphin *Tursiops aduncus* and Common bottlenose dolphin *Tursiops truncatus*. Overall by-catch of these species was low in all landing sites with the highest by-catch reported in Kiwayuu (n = 9) with *T. aduncus* having the highest by-catch (37.5%; n = 9) followed by *G. griseus* and *S. chinensis* both at 20.8% (n = 5). A significant difference in by-catch of marine mammals across the landing sites was evident; Ngomeni reported significantly higher by-catch (46.7%, n = 21) while Nyali had the lowest (2.2%, n=1) (Kruskal-Wallis test: H = 60.081; p <0.05).

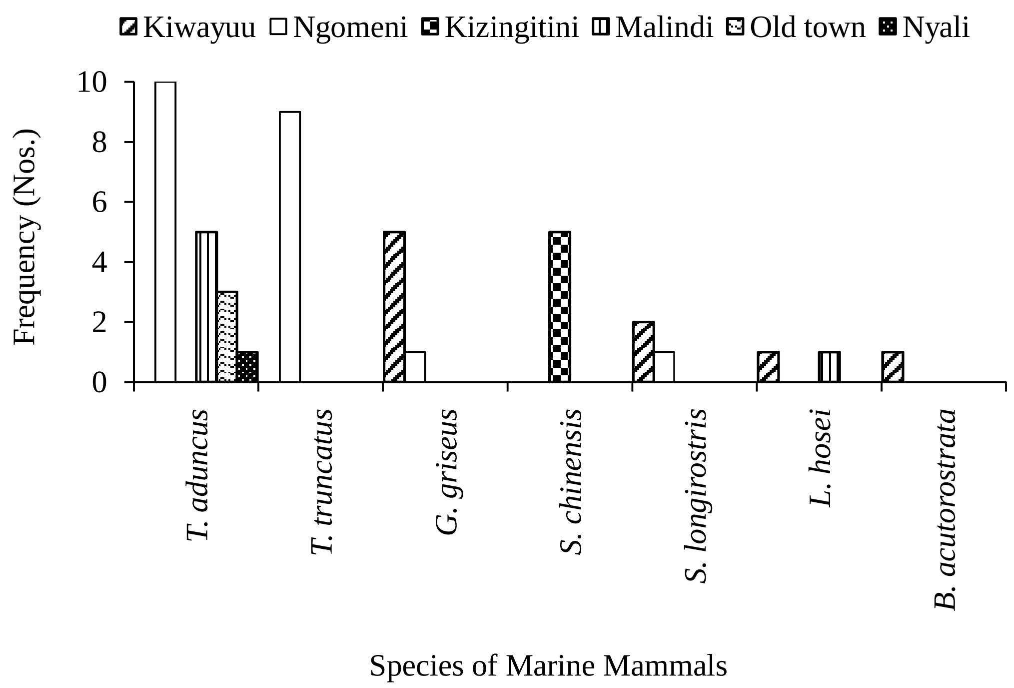

Figure 5: Occurrence of by-catch of marine mammals at the sampling sites along north coast Kenya.

There was significant differences in the by-catch of marine mammals between seasons (Kruskal-Wallis test: H = 9.388, $p<0.05$) (Figure 6)

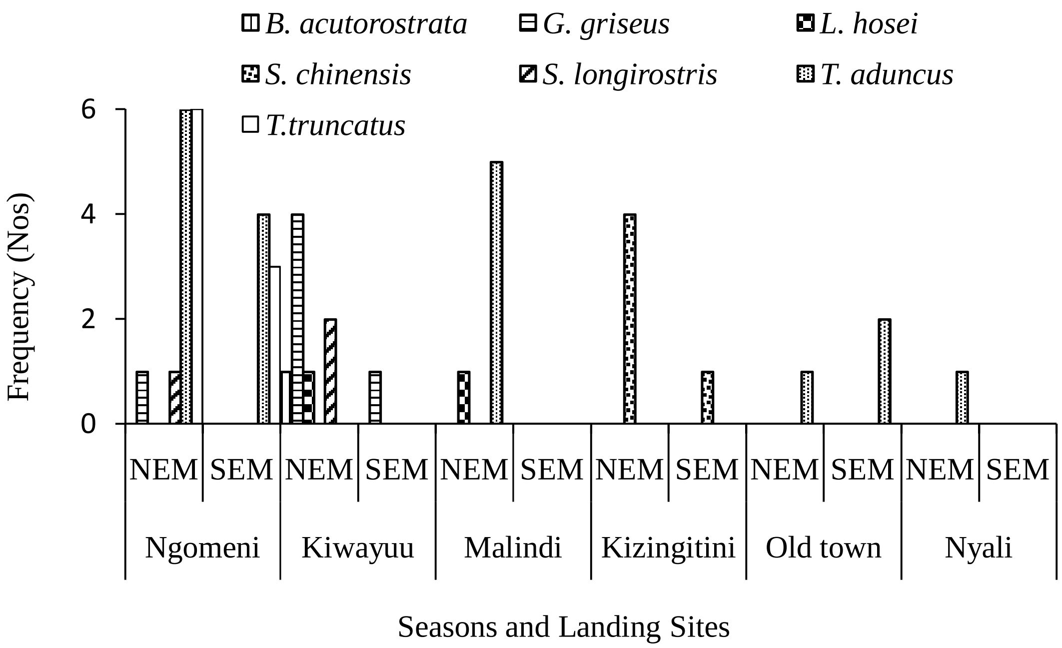

Figure 6: Temporal occurrence of marine mammals' by-catch by season at the sampling sites along north coast Kenya.

4.5 By-catch Composition of Elasmobranchs (Sharks and Rays)

Thirty-five species of elasmobranchs were reported as by-catch at the six (6) landing sites. These included 14 species of rays and 21 species of sharks (Figure 7 and 8). A total of 10 species could not be identified to species level (scientific/English names) including; five (5) species of rays (Swahili; *Hamam*, *Shepwa mthangi*, *Shepwa kipanga pangai*, *Yama kuu* and *Yama mweupe*) and five (5) shark species (Swahili; *Guguye*, *Sheswa*, *Gereniye*, *Jori jori* and *Firfir mwamba*).

Results showed significant difference in the by-catch of elasmobranchs across the six (6) landing sites with Ngomeni reporting the highest by-catch (39.6%, n=301) while Nyali landing site reporting the lowest (2.4%, n=18). Sharks and rays were analyzed separately (Kruskal-Wallis test: H = 279.68; p <0.05 and H =23.342; p< 0.05 respectively).

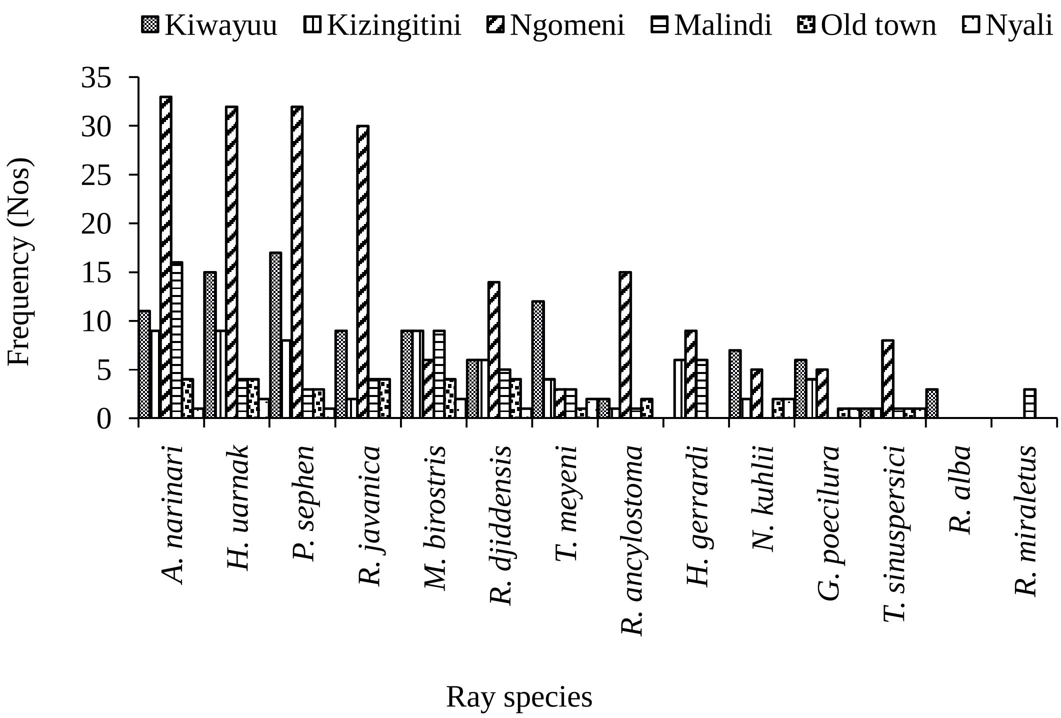

Figure 7: Spatial occurrence of by-catch of rays at the sampling sites along north coast Kenya.

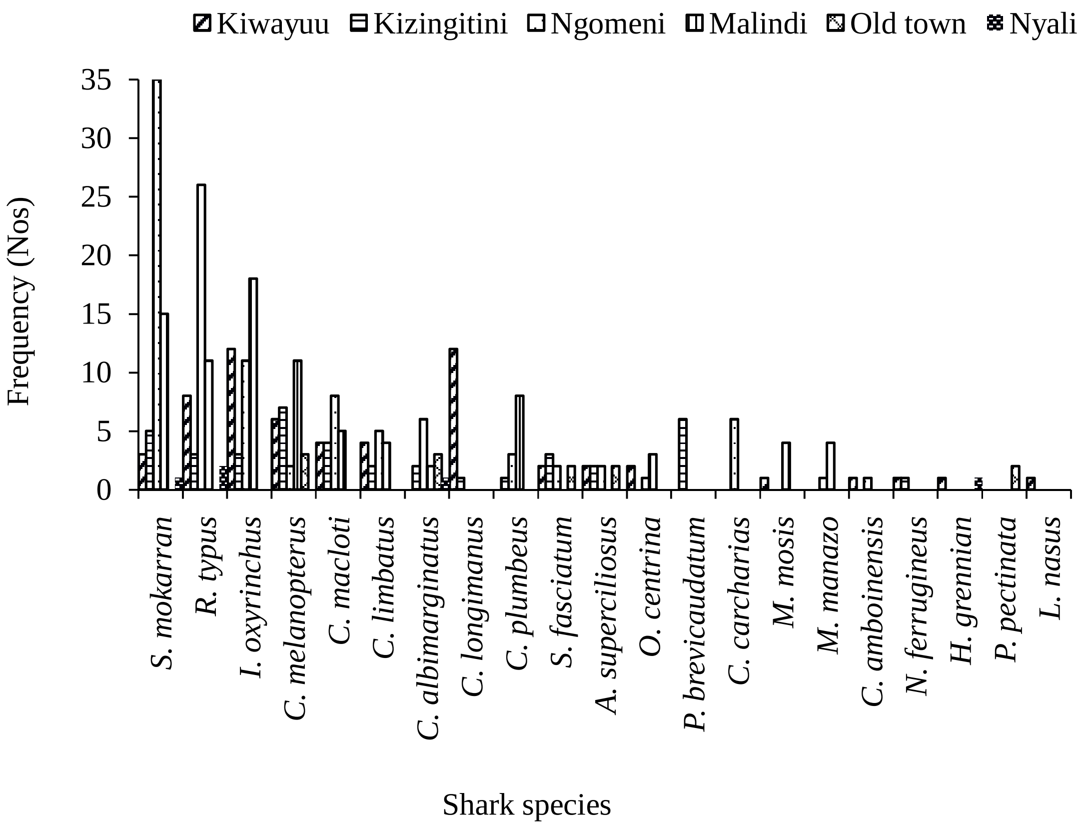

Figure 8: Spatial occurrence of by-catch of sharks at the sampling sites along north coast Kenya.

The by-catch of rays (Dasyatidae, Gymnuridae, Maliobatidae, Pristidae, Rajidae, Rhynchobatidae and Torpedinidae) was significantly higher during NEM than during SEM season especially in Ngomeni; NEM by-catch was reported as 23.8% (n = 110) while SEM period reported lowest ray by-catch in Nyali at 1.95% (n = 9) (Kruskal-Wallis test: H = 30.008; $p<0.05$). By-catch of sharks (Carcharhinidae, Proscyliidae, Scyliorhinidae, Sphyrnidae, Triakidae, Ginglymostomatidae, Alopiidae, Lamnidae, Rhincodontidae, Stegostomatidae, Echinorhinidae and Oxynotidae) was significantly higher during NEM with 72% (n = 212) where respondents reported catching different species of sharks during the season. However, only 28% (n = 84) of respondents declared catching sharks during the SEM season (Kruskal-Wallis test: H = 34.668,

$p<0.05$). The by-catch of rays and sharks between NEM and SEM seasons is presented in Table 6 (Appendices).

4.6 Gillnet Fishery

About 74% of respondents reported by-catch of sea turtles in the bottom-set gillnet fishery while 19% of them declared by-catch of sea turtles in the drift gillnet fishery. In bottom-set gillnets, *C. mydas* had the highest by-catch (38.4%, n=26) while *C. caretta* (7.4%, n=5) had the lowest. Over 16% of fishermen declared that they caught 1-10 sea turtles in the year prior to the interview while only 3.2% of the respondents declared by-catch of between 21-50 sea turtles on the same period. In the drift gillnet fishery, *C. mydas* reported the highest sea turtle by-catch (50%, n=17) while the lowest was *C. caretta* (6%, n=2; Figure 9).

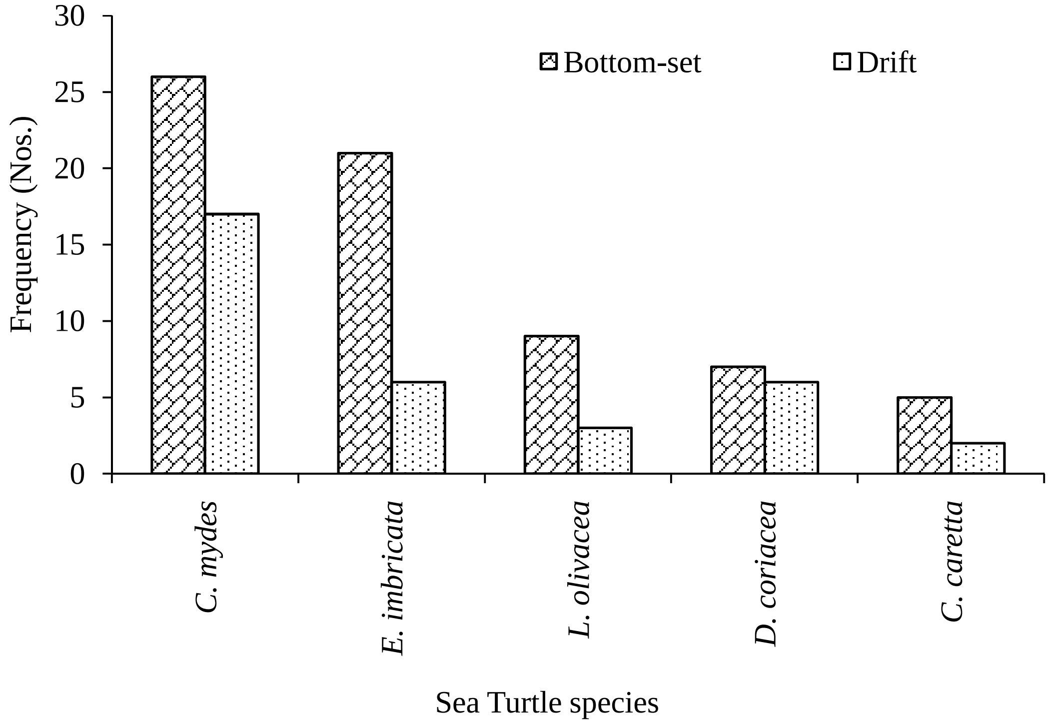

Figure 9: Occurrence of by-catch of sea turtles (Counts) in both bottom-set and drift gillnet fisheries along north coast Kenya.

The result of two-Way ANOVA show significant difference in the by-catch of different species of sea turtles in the bottom-set and drift gillnet fisheries (df = 1; f = 29.8; $p < 0.05$). By-catch of marine mammals in bottom-set gillnet fishery was not reported in the present study while drift gillnets reported by-catch by 51% of fishermen using these fishing gears. The most commonly reported species were *T. aduncus* (42%, n = 19) *and T. truncatus* (20%, n = 9), while the least cases were reported for *S. longirostris* (4%, n = 2), *L. hosei* (4%, n = 2), *B. acutorostrata* (2%, n = 1), and *D. dugon* (2%, n = 1) (Table 2). The size of marine mammal by-catch in the previous year (2015) varied from 0 to 10 individuals. About 6% (n = 17) of the respondents declared that they did not catch or land any marine mammals in the year prior (2015) to the present interview.

By-catch of elasmobranchs in bottom-set gillnet fishery was declared by all respondents with 99% reporting by-catch of rays and 100% of the fishers reporting by-catch of sharks. Fifteen (15) species of rays were identified as by-catch by fishermen; *A. narinari* (11.9%, n = 73), *H. uarnak* (10.7%, n = 66) and *P. sephen* (10.2%, n = 63) reported the higher by-catch levels while *R. alba* was the lowest (0.5%, n = 3). At least eighteen (18) species of sharks were identified as by-catch in bottom-set gillnets including *Sphyrna* spp. which recorded the highest by-catch (6.7%, n = 41) followed by *R. typus* (5.4%, n = 33). Two species; *C. Longimanus* and *E. radcliffei* reported the lowest by-catch at 0.2% (n = 1 each. When fishermen were asked about how many species of the marine mega-fauna they caught during the previous year (2015) before the present study, the response was highly varied by species group, as shown in Table 1.

Table 1: Summary of total by-catch by species group reported from questionnaires for the previous year (2015) before the present study.

Group	0	Range 1–10	Range 11–20	Range 21–50	Range >50	Sub-total
Elasmobranchs	0	15	16	36	117	184
Sea turtles	6	47	7	9	0	69
Marine mammals	17	14	0	0	0	31

Elasmobranch by-catch was common in drift gillnets for both rays and sharks. By-catch of Rays was reported by 93% of fishermen. The ray species with highest by-catch was *A. narinari* (39%, n = 62) followed by *Manta* spp. (19%, n = 30) and *R. javanica* (15%, n = 24). The ray species with the lowest by-catch in this study was *R. ancylostoma* at1% (n = 2). Shark by-catch in drift gillnet was reported by 98% of the interviewed fishermen. Nineteen (19) species of sharks were recorded as by-catch in drift gillnets. The most regularly caught species were *Sphyrna* spp. (18%, n = 64), *R.*

typus (16%, n =58), *I. oxyrinchus* (12%, n = 43) and *C. Melanopterus* (10%, n = 34), while the least caught species were *P. pectinata* (1%, n = 3), *N. ferrugineus* (1%, n = 2), and *C. longimanus* (0.3%, n = 1). The comparison of by-catch of rays and sharks in both bottom-set and drift gillnets is shown in Figure 10 and 11, respectively. The result of two-Way ANOVA shows significant difference in the by-catch of the different species of rays between bottom-set and drift gillnetswith73% (n = 421) respondents declaring by-catch of rays in bottom-set gillnets (df = 1; f = 37.8; $p < 0.05$). The results further show significantly higher by-catch of sharks in drift gillnets (63%, n = 339) than in bottom-set gillnets (37%, n = 195; df = 1; f = 10.5; $p < 0.05$).

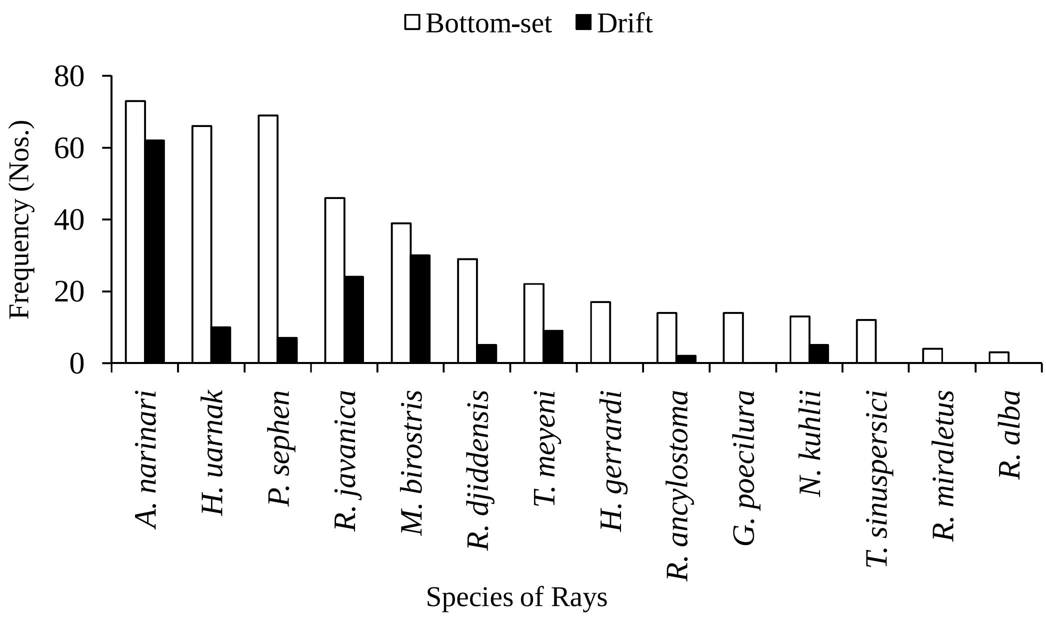

Figure 10: Occurrence of by-catch of rays (Nos.) in both bottom-set and drift gillnet fisheries along north coast Kenya.

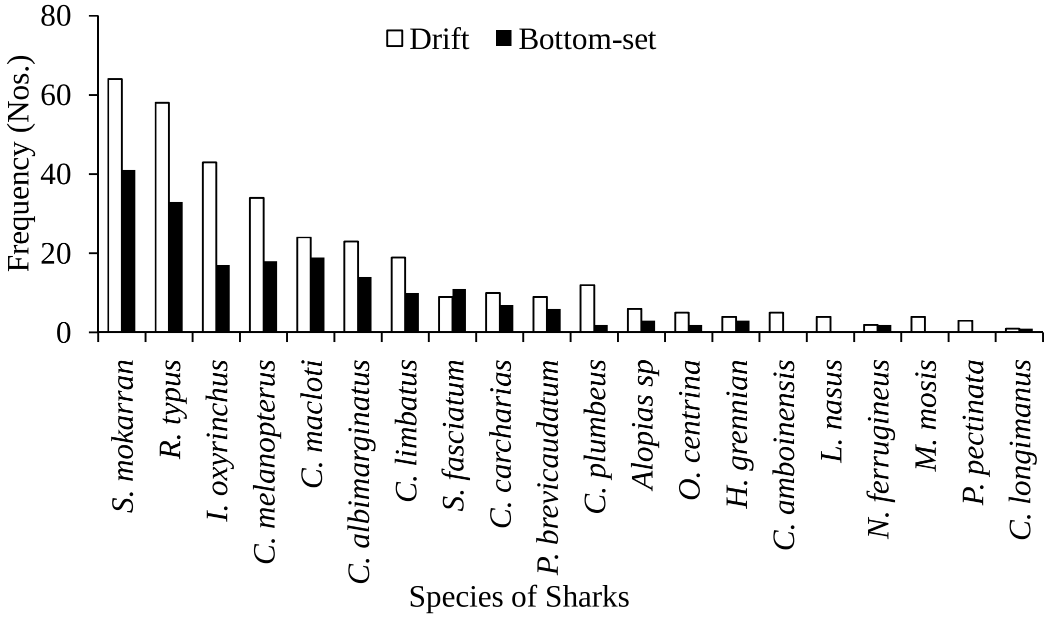

Figure 11: Occurrence of by-catch of sharks (Nos.) in both bottom-set and drift gillnet fisheries in north coast Kenya

Bottom-set and drift gillnets were variably used (Figure 12) during the different seasons (NEM and SEM) and the difference was statistically significant (df = 1; f = 26.3; $p < 0.05$). The difference in the use of bottom-set and drift gillnets along different landing sites was also statistically significant (df = 5; f = 5.6; $p < 0.05$).

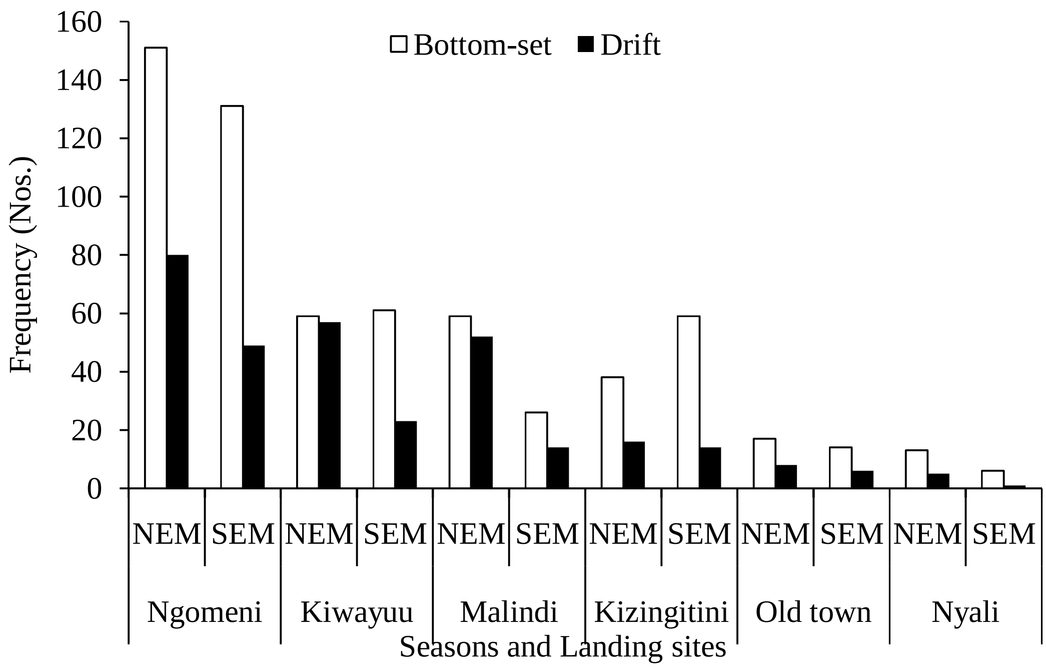

Figure 12: Temporal occurrence of bottom-set and drift gillnet fisheries by season (NEM and SEM) and sampling sites along north coast Kenya.

The result of two-Way ANOVA indicated no significant difference in the by-catch of sea turtles, marine mammals and elasmobranchs between bottom-set and drift gillnet fisheries (df = 2; f = 8.8; p = 0.102).

4.8 By-catch Incidence

By-catch incidence (number of individual species reported as by-catch per boat) was calculated for each fishery and each taxonomic group (elasmobranchs, marine mammals and sea turtles) between different seasons and landing sites. The results are presented in Table 2, 3 and 4.

There was a significant difference in the by-catch incidences of marine mega-fauna between NEM and SEM seasons at the six landing sites (df = 11; f = 3.2; p< 0.05) as shown in Table 2. The results of two-Way ANOVA further showed a significant difference in the by-catch incidences between the use of bottom-set and drift gillnet fishery across different seasons at the six landing sites (df = 1; f = 21.66; $p < 0.05$). By-catch incidences of bottom-set and drift gillnets across different seasons and landing sites are presented in Table 3.

Table 2: By-catch incidences (BI: rate of by-catch per one fishing vessel) of marine megafauna by species group (mammals, sea turtles, sharks and rays), landing site and season in artisanal fisheries of north coast Kenya.

BI = ($N_{species/study\ period}$ / $N_{fishers}$).

Marine megafauna	Kiwayuu		Kizingitini		Ngomeni		Malindi		Old town		Nyali	
	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM
Marine mammals	0	0	0	0	0	0	0	0	0	1	1	0
Sea turtles	1	1	0	1	1	1	1	0	0	0	2	1
Rays	2	3	2	3	3	2	2	1	4	5	6	5
Sharks	2	0	2	2	2	1	4	1	2	1	3	0

Table 3: Overall by-catch incidences (BI: rate of by-catch per fishing vessel) by fishery type (bottom-set and drift gillnets), landing site and season in artisanal fisheries of north coast Kenya.

BI = ($N_{species/study\ period}$ / $N_{fishers}$).

Fishery Type	Kiwayuu		Kizingitini		Ngomeni		Malindi		Old town		Nyali	
	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM
Bottom-set gillnets	3	3	3	5	4	4	3	2	4	4	7	3
Drift-gillnets	3	1	1	1	2	1	3	1	2	2	3	1

Based on the by-catch incidences, sea turtles appear to have higher by-catch incidences in bottom-set gillnets than in the drift gillnet fisheries. On the contrary, marine mammal by-catch was higher in drift gillnets than bottom-set gillnets. In sharks, by-catch was also higher in drift gillnets than in bottom-set gillnet fishery. Generally, overall by-catch incidences were relatively higher in bottom-set gillnets than in drift gillnets. However, these differences were not statistically significant (Kruskal-Wallis test: $H = 4.5$, $p=0.212$).

Table 4: Overall by-catch incidences (BI) of marine megafauna by species group (sea turtles, marine mammals, rays and sharks) and fishery type (bottom-set and drift gillnet) in the in artisanal fisheries of north coast Kenya.

$BI = (N_{species/study\ period} / N_{fishers})$.

Fishery type	Sea turtles	Marine mammals	Rays	Sharks
Bottom-set gillnet	2	0	5	2
Drift gillnet	0	1	2	4

4.9 Use of By-catch Species

All interviewed fishers declared that they released all sea turtles incidentally caught in the fishing gears. The fishers explained that the marine mammals were systematically discarded or released alive, except in some cases e.g. where by-catch species such as dugong were consumed secretly. Rays were, even for large species (e.g *Manta* spp.), all consumed or sold on local markets as fresh or dried fish products (Plate 3 & 4). Similarly, all shark species caught were sold whole on local markets (fresh or as dried fish products).

Plate 3: Salted ray meat awaiting to be sun-dried at Kiwayuu landing site, Lamu County.

Plate 4: Sun-drying ray meat at Kiwayuu landing site, Lamu County.

4.10 Perceptions on Status of Populations of Marine Megafauna

Perceptions on the status of populations of the marine megafauna; elasmobranchs, marine mammals and sea turtles, were recorded from key informant interviews.

According to the fishers, there was a high decline in the populations of elasmobranchs in Kenyan waters (54%, n = 50). On the contrary, marine mammals and sea turtles were reported on the increase over the recent years as perceived by the artisanal fishers. However, *D. dugon* was considered to have completely disappeared from the coastal waters of Kenya (41%, n = 38). On the other hand, 4% of the respondents (n = 4) claimed that the status of marine mega-fauna remains the same and is only affected by seasonality.

CHAPTER 5: DISCUSSION

This study investigated the by-catch of elasmobranchs, marine mammals and sea turtles along the Kenya coast. It was based on 92 interviews conducted on the artisanal fishers in four fishing villages; Lamu, Ngomeni, Malindi and Mombasa, where little was reported about the mega-fauna by-catch problem in the artisanal fisheries. This is one of the very few studies on elasmobranchs, marine mammals and sea turtle by-catch in the Kenyan coast. The study reveals a deep extent of marine mega-fauna by-catch in artisanal fisheries in both bottom-set and drift gillnets. A total of 47 species were identified as by-catch, including five (5) species of sea turtles, seven (7) species of marine mammals and 35 species of elasmobranchs.

The most common and most frequently caught species of sea turtles were *C. mydas*, *E. imbricata*, *L. olivacea* and *D. coriacea* while the marine mammal species were represented by *T. aduncus*, *T. truncatus*, *G. griseus*, and *S.chinensis*. For elasmobranchs, the most common by-catch species were seven (7) ray species: *A. narinari*, *H. uarnak*, *P. sephen*, *R. javanica*, *M. birostris*, *T. meyeni*, *R. djiddensis*, and eight (8) shark species: *Sphyrna* spp., *R. typus*, *C. melanopterus*, *I. oxyrinchus*, *C. macloti*, *C. carcharias*, *C. plumbeus* and *C. albimarginatus*. The results of this study are consistent with the earlier studies by Wamukoya *et. al*. (1996) and Kiszka (2012a) in the area, both in terms of species involved and by-catch incidences. However, this study reported more by-catch species of marine mega-fauna (45 species) compared to the study by Kiszka (2012a) which reported only 31 species. Additionally, this study reported by-catch of 33 species of elasmobranchs compared to 19 species in the previous study by Kiszka (2012a) along the same coast. Among the species which were not recorded by Kiszka (2012a) but were recorded in this study include *G. griseus, B. acutorostrata, L. hosei* and *T. truncatus*. On the contrary, Kiszka (2012a) also recorded by-catch of three (3) more species; Pantropical Spotted Dolphin *Stenella attenuate,* Humpback whale *Megaptera novaeangliae* and Common dolphin *Delphinus delphis* which were not recorded in this present study.

One of the most threatened and vulnerable species in the region, *D. dugong*, was reported to have declined by majority of fishers. They reported that they used to capture dugongs a lot in the past but presently the species is not reported in by-catch anymore. This is in contrast to previous studies that reported higher by-catch and mortality rates of this species in the late 1970s (Husar, 1975) as well as more recently in the early 2000's (WWF EAME, 2004) and its presence in reasonably small numbers in Kiunga, Lamu archipelago in the late 2000's (Kiszka *et. al*., 2009a). Fishermen in Kizingitini village reported that there used to be many dugongs in their fishing grounds, especially in a fishing area called "dugong hill" ("Mlima wa nguva" in Swahili). This area had rich grass meadows and dugongs used to graze there. The present study did not record any dugong by-catch in the areas around dugong hill. This is also linked to the generally low populations of this species, currently, along the East African coast and its rapid decline since the early 2000s due to incidental capture in gillnets (Kiszka *et. al.*, 2009a).

As indicated by this present study, there is a difference in the extent and effect of by-catch of vulnerable mega-fauna among gears. By-catch levels of demersal species such as rays, reef sharks and sea turtles were higher in bottom-set gillnets than in drift gillnet fisheries. On the contrary, by-catch levels of pelagic species, such as marine mammals and pelagic sharks, were higher in drift gillnets than in bottom-set gillnet fishery. However, the difference in the by-catch incidences between the two gear types was not statistically significant ($p = 0.102$). The difference in the use of bottom-set and drift gillnets between different seasons was significant because fishers preferred using bottom-set gillnets during SEM season (due to rough weather) and drift gillnets during NEM as they can venture offshore during this calm season. The adverse effects of gillnets, including bottom-set and drift gillnets, have been highlighted in previous studies along the Kenya coast (Kiszka *et. al*., 2009a; Kiszka, 2012a) and in the region for particularly vulnerable species, such as the dugong (WWF EAME, 2004; Kiszka, 2012b; Pusineri *et. al*., 2013).

By-catch incidences (or by-catch rate per fishing vessel) for marine mammals and sharks were higher in drift gillnets than in bottom-set gillnets in both studies. This could be attributed to the fact that marine mammals (specifically dolphins) escape from the bottom-set gillnet due to the duration the net is left at sea. However, the marine mammals don't get time or opportunity to escape in cases where the gillnet is drifting. Sharks are pelagic species (apart from few benthic feeders) and can be more impacted by drift gillnets than bottom-set gillnets. On the other hand, by-catch incidences for rays and sea turtles were higher in bottom-set gillnet- than in drift gillnet fisheries in both studies. This could be attributed to the fact that rays (apart from few pelagic feeders) and sea turtles are demersal species and are more susceptible to bottom-set gillnets which is set at the bottom of the sea.

This study reported higher by-catch of sea turtles especially at Ngomeni landing site. The difference in the by-catch of sea turtles across the six landing sites was statistically significant ($p < 0.05$). This study also highlighted new results on sea turtle by-catch in gillnets with high by-catch levels observed for leatherback turtles (*D. coriacea*) in the Kenyan coastal waters compared to the previous study by Kiszka (2012a) where no records of this species were reported. Loggerhead turtles were reported previously by the same study as frequently caught in the Kenya coast, but the present study reported very low by-catch of this species (only by 1.5% of the artisanal fishers) along the north coast Kenya. Therefore, the by-catch issue should be given a more serious redress since the species is severely declining in the region (Kiszka, 2012a).

The seasonal variations in by-catch were directly related to fishing effort. The highest fishing effort was recorded during the Northeast monsoon season i.e. from October/November to February/March while lowest effort was observed during the Southeast monsoon season i.e. from May to August. This phenomenon is linked to calmer sea conditions, especially between October and March when most fishers are able to venture out to deeper waters to fish. However, this was not the case for all gears; bottom-set gillnets were more preferred during the Southeast monsoon season when the seas were rougher and venturing offshore was quite difficult. This could be attributed to the fact that bottom-set gillnet can also be set near shore and could therefore be deployed in the inshore and sheltered fishing grounds.

The artisanal fishers interviewed declared that sharks and rays were declining in the artisanal fishery catches. However, they indicated that sea turtle and marine mammal by-catch was on the increase. While it is difficult to take these perceptions as indicators of actual population trends, it is interesting to note that observations correlate well with earlier previous studies, which also highlighted a decline in the dugong and elasmobranch populations at the regional level (WWF EAME, 2004; Kiszka, 2012a; Kiszka & van der Elst, 2015). In all the study sites, marine mammals and sea turtles were considered as illegal and non-food by-catch and were therefore not commonly consumed in the region. However, majority of the fishers did not consider sharks and rays as by-catch but as legal food by-product species of the fishery activities, and therefore, suitable for consumption or sale in the market as dried or fresh fishery products. When hauled still alive, the marine mammal and sea turtle by-catch were therefore, generally released back to the waters. Overall, marine mammals and sea turtle consumption may be underestimated since fishers often fear being reprimanded for killing and consumption of these species which are prohibited in the country by law.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study clearly highlighted that an important diversity of marine mega-fauna were exposed to artisanal fisheries by-catch in Kenya. Dugongs, mostly the highly vulnerable species according to IUCN conservation status, are still in decline and were also reported in this study to have almost completely disappeared from the Kenyan waters. With regards to by-catch of sea turtles, high rates are reported by this study especially at the Ngomeni landing site, north of Malindi. The fishers also perceived the tough penalties against fishing of sea turtles as oppression against them while the species (in their perception) increases abundantly when sustainably utilized.

Further, the results of this study clearly highlighted that many coastal populations of dolphins, especially Indian Ocean bottlenose dolphin, the common bottlenose dolphin, risso's dolphin and the Indo-Pacific humpback dolphin, and pelagic elasmobranchs are facing detrimental interaction with the drift gillnet fishery. It can also be concluded that demersal species such as sea turtles and benthic elasmobranchs (rays and reef sharks) are facing an exceptional threat by bottom-set gillnet fishery.

Based on the results and conclusions, some recommendations for future research and management initiatives are highlighted below:

- Extend and enhance routine by-catch assessments to other artisanal fisheries such as artisanal long-lines, trawl nets, beach seines, cast nets and other types of nets which pose a threat to the marine mega-fauna along the Kenya coast.

However, a special focus should be directed to the drift gillnet fishery which was reported in this study to have a great impact.

- Create awareness, through training, to fishermen in the coastal counties on the importance of protecting the coastal and marine resources especially the marine mega-fauna, and empower the fishers to seek alternative livelihoods to reduce fishing effort on the fisheries. Alternative fishing gears, other than drift gillnets, should also be developed to ensure the impacts on the marine megafauna and associated by-catch are reduced.
- Conduct further studies including collection of biological samples for laboratory identification of un-identified species in this present study, including the ten (10) species whose Swahili/local names are however known.

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APPENDICES

APPENDIX 1: Fishery Questionnaire

Gillnet fishery questions
Vessels use gillnets in the BMU

Table 5: Data entry form

Fisher's Name	Vessel type	Propulsion	Sets of Drift GN	No. of Crew	Gear length (m)	Mesh size	Fishing months	Fishing days/ week

Background questions:
Have you previously participated in research related to:
Sharks ______? Marinemammals ________? Sea turtles _________? None of these___?

If you have participated in any of the above, describe:_______________________________________

____

How old are you? ________________

For how many years has fishing been your occupation?______________________________

Is fishing your primary occupation? ___________________________
Is fishing your only occupation?_________ If no, what are your other occupations?_______________

During which months did you fish out of the last 12 months? __________________

Do you own your own fishing boat? _________________

Do you lead the fishing trips or are you a crew member on trips that someone else leads _________

Boat description:
What type of boat do you fish on? __________________

How long (in meters) is your boat or the boat you fish on? __________________

Is the boat motorized? _______________________

What is the horsepower of the motor? _______________

Fishing and catch questions:
What type of gear do you use <u>most often</u> over the course of one year?

Bottom-set gillnet_______ Length______________ Mesh size_________

Drift gillnets_____ Length_________ Mesh size________

How many fishermen, including your-self, are on the boat to fish with this gear? ________

During which months of the year do you use this gear? _____________

How many days per week do you fish with this gear, during these months?______________

What are you trying to catch when you fish with this gear?__________________

Have you ever caught sea turtles using this fishing gear? Yes ____ No____Can't recall___

If yes, which sea turtle species have you caught with this gear and how certain are you of this? List species in order from most commonly to least commonly caught

1st species____________ very sure__________fairly sure_________not sure _____

2nd species___________verysure___________fairly sure_________not sure ____

3rd species___________very sure___________fairly sure_________not sure ____

During which months of the year have you caught sea turtles with this gear?

1st species____________

2nd species____________

3rd species____________

How many sea turtles did you catch in the last year, with this gear?

0___1-3__________4-10__________11-20_________>20_________don't know

In what depth or how far from the shore were you fishing when you caught them?____________

Have you ever caught marine mammals when you use this fishing gear?

Yes ________________________ No__________________ Can't recall_________________

If yes, which species have you caught with this gear and how certain are you of this? List species in order from most commonly to least commonly caught

1st species ________________very sure ______ fairly sure________not sure________

2nd species ________________very sure ______ fairly sure________not sure________

3rd species ________________ very sure ______ fairly sure________not sure________

4th species _________________very sure _____ fairly sure______not sure________

5th species _________________ very sure _____ fairly sure______not sure________

During which months of the year have you caught marine mammals with this gear?

1st species_____________

2nd species____________

3rd species_____________

How many marine mammals did you catch in the last year, with this gear?

0_____1-2_______3-5________6-10__________>10_________don't know

In what water depth or how far from shore were you fishing when you caught them? __________

Have you ever caught rays when you use this fishing gear?

Yes________________________No ___________________Can't recall___________________

If yes, which species have you caught with this gear and how certain are you of this? List species in order from most commonly to least commonly caught

1st species ________________very sure______fairly sure______not sure________

2nd species ________________very sure______fairly sure______not sure________

3rd species _________________very sure______fairly sure______not sure________

4th species _________________very sure______fairly sure______not sure________

5th species _________________very sure______fairly sure______not sure________

During which months of the year have you caught rays with this gear?

1stspecies____________

2ndspecies___________

3rdspecies____________

How many total rays did you catch <u>in the last year</u>, with this gear?

0__________1-10________11-20_________21-50__________>50_________don't know

In what water depth or how far from shore were you fishing when you caught them?____________

Have you ever caught sharks when you use this fishing gear?
Yes________________No_________________can't recall____________________

If yes, which species have you caught with this gear and how certain are you of this? List species in order from most commonly to least commonly caught

1stspecies _________________very sure______fairly sure______not sure________

2nd species _________________very sure______fairly sure______not sure________

3rdspecies _________________very sure______fairly sure______not sure________

4thspecies ________________very sure______fairly sure______not sure________

5thspecies ________________very sure______fairly sure______not sure________

During which months of the year have you caught sharks with this gear?

1stspecies____________

2nd species____________

3rd species_____________

How many total sharks did you catch in the last year, with this gear?

0___________1-10_________11-20__________21-50___________>50__________don't know

In what water depth or how far from shore were you fishing when you caught them?_____________

Historical questions

Compared to when you started fishing, are there more, fewer, or the same amount of turtles in the areas you fish or do you not know? ____________________

Are accidental sea turtle captures in fishing gear higher, lower, the same, or do you not know?____

Is intentional sea turtle capture more or less common, or the same, or do you not know?_________________________________

Compared to when you started fishing, are there more, fewer, or the same amount of sharks/rays in the areas you fish or do you not know?

Are accidental rays/sharks captures in fishing gear higher, lower, the same, or do you not know?_____________________________________

Is intentional rays/sharks capture more or less common, or the same, or do you not know?____

Compared to when you started fishing, are there more / fewer / the same number of cetaceans or dugongs in the areas you fish?___________________________________

Are accidental cetacean/dugong captures in fishing gear higher, lower, or the same?____

Is intentional cetacean capture more common, less common, the same, or do you not know?____

APPENDIX 11: Consent Form
RESEARCH ETHICS CONSENT FORM

Assessment of Marine Mega-fauna By-catch along the Kenyan coast

PART 1: GENERAL INFORMATION ABOUT THE STUDY

You are invited to participate in research about the assessment of elasmobranchs, marine mammals and sea turtles by-catch along the north coast Kenyan with case studies in Mombasa, Malindi and Lamu. Mohamed Athman Mohamed a master's student in the school of Pure and Applied Sciences, Pwani University, will conduct the study.

Participation in this study is voluntary. If you agree to participate in this study, you will be required to fill out questionnaires, soliciting for relevant information on the subject.

Participating in this study may not benefit you directly, but the information that you provide will help us learn more about persistent challenges related to by-catch of these marine mega-fauna and specifically the elasmobranchs, marine mammals and sea turtles and how they could possibly be addressed. You may skip any questions that you do not want to answer.

We assure you that all the information that you share with us through your participation in the study will be kept completely confidential. When the study is completed and data analyzed, any information that could link you to study will be destroyed. Study findings will be presented in summary and your name will not be used in any report.

If you have any question about this study contact:

Mohamed Athman Mohamed, Mobile Number 0721500621/0763500621 Email mohammadathman@yahoo.com. Kindly note that this proposal has been reviewed and approved by Ethics Review Committee (ERC) of Pwani University, committee whose task is to make sure that research participants are protected from harm. If you wish to find more about the ERC, please contact the ERC secretariat Pwani University.

PART 11: CERTIFICATE OF CONCENT

I have read the foregoing information, I have had the opportunity to ask questions about it, and all my questions been answered to my satisfaction. I therefore give my consent to voluntarily participate as a respondent in this research.

Print Name of Participant

Signature of Participant

Date

Day/Month/Year

Statement by the Researcher/Person taking consent

Table 6: Elasmobranch species composition and incidence during the study period by landing site and season

		Ngomeni		Kiwayuu		Kizingitini		Malindi		Old town		Nyali	
	Species	NEM[1]	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM
Rays	*A. narinari*	**19**	**14**	5	6	5	4	**15**	1	3	1	1	1
	G. poecilura	3	2	2	4	1	3	–	–	1	1	1	1
	H. gerrardi	5	5	–	–	5	1	3	2	–	–	–	–
	H. uarnak	**20**	**15**	6	**11**	3	6	3	2	1	3	2	1
	M. birostris	5	1	5	4	4	6	9	–	1	4	2	1
	N. kuhlii	2	3	3	4	1	1	–	–	1	1	2	1
	P. sephen	**17**	**13**	7	**12**	2	6	2	1	1	2	1	1
	R. alba	–	–	2	1	–	–	–	–	–	–	–	–
	R.ancylostoma	8	6	2	3	1	2	–	1	1	1	–	–
	R. djiddensis	8	4	2	4	2	6	2	5	2	2	–	1
	R. javanica	**17**	**13**	5	4	–	2	4	–	3	1	–	–

[1](NEM = Northeast Monsoon; SEM = Southeast Monsoon; **bold** numbers being most abundant; and dash meaning not found).

		Ngomeni		Kiwayuu		Kizingitini		Malindi		Old town		Nyali	
	Species	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM	NEM	SEM
	R. miraletus	–	–	–	–	–	–	–	3	–	–	–	–
	T. meyeni	1	2	3	5	3	1	1	2	–	1	2	1
	T. sinuspersici	5	3	–	1	1	1	1	1	1	1	1	1
Sharks	*I. oxyrinchus*	**10**[2]	1	**16**	3	**11**	1	2	1	–	–	–	–
	S. mokarran	9	**25**	4	**11**	3	–	1	4	–	–	1	–
	S. fasciatum	1	–	–	–	2	–	2	2	2	–	–	–
	L. nasus	–	–	–	–	1	–	–	–	–	–	–	–
	C.melanopterus	1	–	9	3	5	–	6	2	2	1	–	–
	C. limbatus	3	1	4	–	4	–	2	1	–	–	–	–
	C. amboinensis	1	–	–	–	1	–	–	–	–	–	–	–
	R. typus	**19**	4	**11**	1	8	–	2	2	–	–	2	–
	C. macloti	2	4	5	–	4	–	3	2	–	–	–	–

[1](NEM = Northeast Monsoon; SEM = Southeast Monsoon; **bold** numbers being most abundant; and dash meaning not found).

N. ferrugineus	–	–	–	–	1	–	1	1	–	–	–	–
P.brevicaudatum	–	–	–	–	–	–	3	3	–	–	–	–
C. plumbeus	2	1	7	2	–	–	1	–	–	–	–	–
C. carcharias	3	1	–	–	–	–	–	–	–	–	–	–
C.albimarginatus	5	–	2	–	–	–	2	–	2	1	1	–
M. mosis	–	–	4	–	1	–	–	–	–	–	–	–
Alopias sp	1[3]	–	–	–	2	–	1	1	1	1	–	–
O. centrina	1	1	1	2	2	–	–	–	–	–	–	–
H.grennian	–	–	–	–	2	–	–	–	–	–	1	–
P. pectinata	–	–	–	–	–	–	–	–	2	–	–	–
C. longimanus	–	–	–	–	1	–	–	–	–	–	–	–
M. manazo	–	–	3	1	–	–	–	–	–	–	–	–

[1](NEM = Northeast Monsoon; SEM = Southeast Monsoon; **bold** numbers being most abundant; and dash meaning not found).

APPENDIX 1V: Marine Mega-fauna Species Recorded in this Study

Table 7: Species of sharks recorded as by-catch in the present survey along the north coast of Kenya.

Class	Order	Family	Scientific Name	FAO/English Name	Local Name
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus melanopterus*	Blacktip Reef Shark	Jehera
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus limbatus*	Blacktip Shark	Saidue
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus leucas*	Bull Shark	Zimawi/Dhimawi
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus macloti*	Hardnose Shark	Subili
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus albimarginatus*	Silvertip Shark	Kipii/Kipai
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus amboinensis*	Pigeye/Java shark	Mayasa
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus plumbeus*	Sandbar Shark	Bakesh/ Humi/Abrasi
Elasmobranchii	Carcharhiniformes	Carcharhinidae	*Carcharhinus amblyrhynchos*	Backtail Reef Shark	Karage
Elasmobranchii	Carcharhiniformes	Proscyliidae	*Eridacnis radcliffei*	Pigmy Ribbontail Catshark	Kiongwe
Elasmobranchii	Carcharhiniformes	Scyliorhinidae	*Holohalaelurus grennian*	Grinning Izak Catshark	Vame/Madoamadoa
Elasmobranchii	Carcharhiniformes	Sphyrnidae	*Sphyrna mokarran*	Great Hammerhead Shark	Mbingusi

Elasmobranchii	Carcharhiniformes	Sphyrnidae	*Sphyrna lewini*	Scalloped Hammerhead Shark	Mbingusi
Elasmobranchii	Carcharhiniformes	Triakidae	*Mustelus manazo*	*Starspotted smooth hound*	Papa miba
Elasmobranchii	Carcharhiniformes	Triakidae	*Mustelus mosis*	Arabian Smooth-hound	Klabi
Elasmobranchii	Orectolobiformes	Ginglymostomatidae	*Pseudoginglymostoma brevicaudatum*	Short-tail nurse sharks	Guigui/Shisa
Elasmobranchii	Lamniformes	Alopiidae	*Alopias pelagicus*	Pelagic thresher	Papa pepo/Papa mkia mrefu
Elasmobranchii	Lamniformes	Alopiidae	*Alopias vulpinus*	Thresher Shark	Sulungwi/Papa mkia mrefu
Elasmobranchii	Lamniformes	Lamnidae	*Charcharodon carcharias*	Great white shark	Sumbwi
Elasmobranchii	Lamniformes	Laminidae	*Isurus oxyrinchus*	Shortfin Mako Shark	Mako/Meu
Elasmobranchii	Lamniformes	Laminidae	*Lamna nasus*	Porbeagle	Dhimawi
Elasmobranchii	Orectolobiformes	Ginglymo-stomatidae	*Nebrius ferrugineus*	Tawny Nurse Shark	Ove
Elasmobranchii	Orectolobiformes	Rhincodontidae	*Rhincodon typus*	Whale Shark	Zambarani
Elasmobranchii	Orectolobiformes	Stegostomatidae	*Stegostoma fasciatum*	Zebra Shark	Kiharehare
Elasmobranchii	Squaliformes	Echinorhinidae	*Echinorhinus brucus*	Bramble shark	Papa
Elasmobranchii	Squaliformes	Oxynotidae	*Oxynotus centrina*	Angular rough-shark	Mbiu

Table 8: Species of skates and rays recorded as by-catch in the present survey along the north coast of Kenya.

Class	**Order**	**Family**	**Scientific Name**	**FAO/English Name**	**Local Name**
Elasmobranchii	Myliobatiformes	Dasyatidae	*Himantura uarnak*	Honeycomb Stingray	Yama Tuvii/Chui
Elasmobranchii	Myliobatiformes	Dasyatidae	*Neotrygon kuhlii*	Blue Spotted Stingray	Nyenga/Yeda
Elasmobranchii	Myliobatiformes	Dasyatidae	*Pastinachus sephen*	Cowtail Stingray	Yama/Shepwa Kuchi/kuti
Elasmobranchii	Myliobatiformes	Dasyatidae	*Taeniura meyeni*	Round Ribbontail ray	Yama Nundwi/ Taa Maji
Elasmobranchii	Myliobatiformes	Gymnuridae	*Gymnura poecilura*	Longtail Butterfly ray	Yama/Shepwa Ngozi/ Taa Shuari/Muungwana
Elasmobranchii	Myliobatiformes	Myliobatidae	*Aetobatus narinari*	Spotted Eagleray	Kipungu
Elasmobranchii	Myliobatiformes	Myliobatidae	*Manta birostris*	Giant manta	Chenga/Tenga
Elasmobranchii	Myliobatiformes	Myliobatidae	*Mobula eregoodootenkee*	Longhorned mobula	Chenga/Tenga
Elasmobranchii	Myliobatiformes	Myliobatidae	*Mobula kuhlii*	Lesser devilray	Chenga/Tenga
Elasmobranchii	Myliobatiformes	Myliobatidae	*Rhinoptera javanica*	Flapnose ray	Kedu
Elasmobranchii	Pristiformes	Pristidae	*Pristis pectinata*	Smalltooth Sawfish	Busefu/Papa Msumeno
Elasmobranchii	Rajiformes	Rajidae	*Raja miraletus*	Brown skate	Shepwa
Elasmobranchii	Rajiformes	Rajidae	*Rostroraja alba*	Bottlenose skate	Yama Idhuka
Elasmobranchii	Rajiformes	Rhinidae	*Rhina ancylostoma*	Bowmouth Guiterfish	Simbe Mawe
Elasmobranchii	Rajiformes	Rhynchobatidae	*Rhynchobatus djiddensis*	Giant Guiterfish	Simbe Safi/Fuamba
Elasmobranchii	Torpediniformes	Torpedinidae	*Torpedo sinuspersici*	Electric ray	Smaku/Shoti

Table 9: Species of marine mammals recorded as by-catch in the present survey along the north coast of Kenya.

Class	**Order**	**Family**	**Scientific Name**	**FAO/English Name**	**Local Name**
Mammalia	Artiodactyla	Balaenopteridae	*Balaenoptera acutorostrata*	Common minke whale	Pomboo
Mammalia	Cetacea	Delphinidae	*Grampus griseus*	Rissor's/Gray dolphin	Pomboo
Mammalia	Cetacea	Delphinidae	*Lagenodelphis hosei*	Fraser's/Sarawak Dolphin	Pomboo
Mammalia	Cetacea	Delphinidae	*Sousa chinensis*	Indo-pacific humpback dolphin	Pomboo
Mammalia	Cetacea	Delphinidae	*Stenella longirostris*	Spinner dolphin	Pomboo
Mammalia	Cetacea	Delphinidae	*Tursiops aduncus*	Indo-pacific bottlenose dolphin	Pomboo
Mammalia	Cetacea	Delphinidae	*Tursiops truncates*	Common bottlenose dolphin	Pomboo
Mammalia	Sirenia	Dugongidae	*Dugong dugon*	Dugong	Nguva

Table 10: Species of sea turtles recorded as by-catch in the present survey along the north coast of Kenya.

Class	**Order**	**Family**	**Scientific Name**	**FAO/English Name**	**Local Name**
Reptilia	Testudines	Cheloniidae	*Caretta caretta*	Loggerhead	Iladhi
Reptilia	Testudines	Cheloniidae	*Chelonia mydas*	Green turtle	Kasa
Reptilia	Testudines	Cheloniidae	*Dermochelys coriacea*	Leatherback	Chasa
Reptilia	Testudines	Cheloniidae	*Eretmochelys imbricata*	Hawksbill	Ng'amba
Reptilia	Testudines	Cheloniidae	*Lepidochlys olivacea*	Olive ridley	Kigange