Western Indian Ocean JOURNAL OF Marine Science

Volume 15 | Issue 1 | Jan – Jun 2016 | ISSN: 0856-860X

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Western Indian Ocean JOURNAL OF Marine Science

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ISSN 0856-860X

Cover image: Fisherman pushes his boat along the channels around Inhaca Island, Mozambique (© José Paula)

Current status of sea turtle protection in Lamu Seascape, Kenya: Trends in nesting, nest predation and stranding levels

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Abstract

Globally sea turtles are threatened including in Kenya where they are legally protected. Results of sea turtle protection in Kenya are presented in this paper in reference to the WWF Lamu seascape conservation efforts. Temporal and spatial trends in sea turtle nest protection, predation and strandings based on beach monitoring efforts in five locations totaling 20.7 km of beach were investigated. A total of 2021 nests in 6,205 days (between 1997 and 2013) were recorded where 64.4% (n = 1299) were translocated to higher safer sites for successful hatching. An increasing trend in nest density was observed with highly significant difference among locations (1-way ANOVA; p = 0.001). A slight decreasing trend in monitoring effort of sea turtle strandings was observed, however, decreasing trends in predation levels were observed and this was higher in the warmer NEM season with no significant difference among locations (Kruskal-Wallis test; p = 0.085). A total of 227 sea turtle strandings were recorded in 188 days (between 2001 and 2014) and this generally showed a decreasing trend. The causes of sea turtle strandings were mostly fishery-related (53%). This was followed by unknown causes (20%), shark attacks (13%), with the tumor-causing viral disease fibropapillomatosis recorded in 11% of the strandings. Overall, the highest number of strandings was recorded for Mkokoni (35%) while the lowest was recorded for Mvundeni (4%). Green turtles with a mean size of 68.9 ± 1.9 cm CCL, comprised the bulk (79%) of the strandings recorded. Stranding incidences were observed year-round; however, this was higher during the dry NEM season (January to March) when fishing effort is highest as compared to the SEM season (April to September) when fishing effort is low. To continue the observed improving trends over time, it is vital that sea turtle conservation efforts, including a comprehensive monitoring programme, are supported.

Keywords: Predation, Protection, Sea turtles, Conservation, Lamu seascape, Kenya

Introduction

Of the seven species of sea turtles, three species are documented to nest in Lamu, Kenya; these are the green, *Chelonia mydas,* hawksbill, *Eretmochelys imbricata*, and olive ridley turtle, *Lepidochelys olivacea*. Even though loggerhead, *Caretta caretta,* and leatherback turtles, *Dermochelys coriacea,* forage along the coast or migrate through Kenyan waters, they do not nest along the Kenyan coast (Frazier, 1980; Church and Palin, 2003). Sea turtles have a global distribution ranging from temperate, sub-tropical to tropical regions (Hirth, 1997; Bjorndal, 1997), however, they have very specific nesting and foraging preferences influenced by their natal homing behavior (Rees *et al*., 2012; Lohmann *et al*., 2013). For example, green turtles in the southwestern Atlantic prefer to nest in island rookeries (Domingo *et al*., 2006).

Sea turtles occupy various habitats (nesting beaches, coastal, neritic and oceanic areas) throughout their lifetime, transcending various Exclusive Economic Zones and international waters while conducting feeding and reproductive migrations (Domingo *et al*., 2006; Rees *et al*., 2012; Jensen *et al*., 2016). The migration to, and residence time of sea turtles in foraging grounds also depends on the prevailing physico-chemical water parameters such as sea temperature, upwelling as well as water depth (Rees *et al*., 2012). Further, preference of foraging grounds and migration routes also depend on the age of individuals (Jensen *et al*., 2016), which has been revealed through spatial and temporal genetic variation studies on the green turtle (Jensen *et al*., 2016). Their complex life cycle exposes turtles to high risk of mortality from myriad natural and anthropogenic threats. According to the World Conservation Union Red List category, the green turtle, loggerhead and olive ridley are "Endangered" and the leatherback and hawksbill are "Critically Endangered" (Hilton-Taylor, 2000; IUCN, 2004).

Commonly reported fisheries-related sea turtle mortalities are due to entanglement in long lines, or as bycatch in trawling and gill net operations (Domingo *et al*., 2006; FAO, 2004; Bourjea *et al*., 2008). Other anthropogenic threats include direct hunting for meat, shell and eggs; habitat degradation from coastal developments, and pollution (Wamukoya *et al*., 1997; Frazier, 1982; McLellan *et al*., 2012). Sea turtles are also threatened by nest predation and pollution causing diseases such as fibropapillomatosis (Domingo *et al*., 2006; McLellan *et al*., 2012).

Protection of nesting beaches is one of the components of sea turtle conservation (Antworth *et al*., 2006); however, this is considered part of a broader suit of conservation strategies that also take into consideration in-water mortality factors during other stages of a sea turtle's life cycle (Frazier, 1992). Nesting beach protection includes translocation of nests (*ex-situ*) to more suitable locations commonly employed to reduce the threats from poaching, predation, erosion or inundation due to poor placement (Beggs *et al*., 2007). On the other hand, *In-situ* protection of nests from natural predation is also carried out (Garcia *et al*., 2003; Antworth *et al*., 2006) where turtle nests on safe sites are left to hatch without moving them. In Kenya, the main conservation strategies for sea turtles include a complete ban on exploitation or trade of sea turtles and sea turtle products, monitoring of nesting activities, and nest protection. Monitoring of nesting beaches occurs on the entire Kenyan coastline, well supported by community-based sea turtle conservation groups (Okemwa *et al*., 2004). A total of 34 sea turtle nesting beaches (20.7 km of beach), covering 5 locations within the Lamu seascape have been monitored since 1997. The Lamu seascape hosts the most important nesting sites for sea turtles in Kenya with higher concentrations of nesting green turtles having been documented than elsewhere (Frazier, 1982; Church and Palin, 2003). This paper presents the spatio-temporal status of sea turtle conservation efforts in Lamu seascape through trends in nest densities, predation levels as well as trends in sea turtle strandings.

Materials and methods

Study area

Lamu County stretches from the Kenya-Somalia border in the north to the Tana River Delta to the south, incorporating the Dodori forest channels. The northern most part hosts the Kiunga Marine National Reserve (KMNR), a marine protected area (MPA) rich in biodiversity. The seascape comprises a series of linear islands and islets including Rubu Island, Kiwayu Island, and Kiunga which provide important sea turtle foraging habitat and nesting beaches. An estimated 20.7 km of beach has been monitored in the study and this includes five monitoring locations at Kiunga, Rubu Island, Mvundeni, Mkokoni and Kiwayu (Fig. 1). The beach stretch at these locations range from relatively long open beaches backed by vegetated dunes to small pocket beaches surrounded by cliff edge or scrub vegetation (Church and Palin, 2003), measuring between 1.1 and 7.6 km long.

The biodiversity in the MPA includes rare coral species such as *Horastrea indica* and *Siderastrea savignyana* (Obura *et al*., 2007), extensive sea grass beds composed of eight different species (Gullstrom *et al*., 2002), mangrove forests of about 20,000 hectares comprising 30% - 40% of the total mangrove cover in Kenya composed of the dominant *Rhizophora mucronata* and *Ceriops tagal* (Kairo *et al*., 2002). The landscape adjacent to the MPA contains indigenous forests protected in the Dodori and Boni National Reserves covering an area of over 1,000 km^2 (Church and Palin, 2003). The Kiunga MPA allows for multiple subsistence uses, unlike other MPAs in Kenya which do not permit extractive resource use (McClanahan and Kaunda-Arara, 1996).

The coastal climate of Kenya, including Lamu, is influenced by an interplay of monsoon winds and ocean currents; the north flowing East Africa Coastal Current (EACC) and the southwest flowing Somali Current (SC). This interplay creates two distinct seasons, characterized by very strong winds and rough seas between April and September (southeast monsoon, SEM season) and calm seas with moderate currents between October and March (northeast

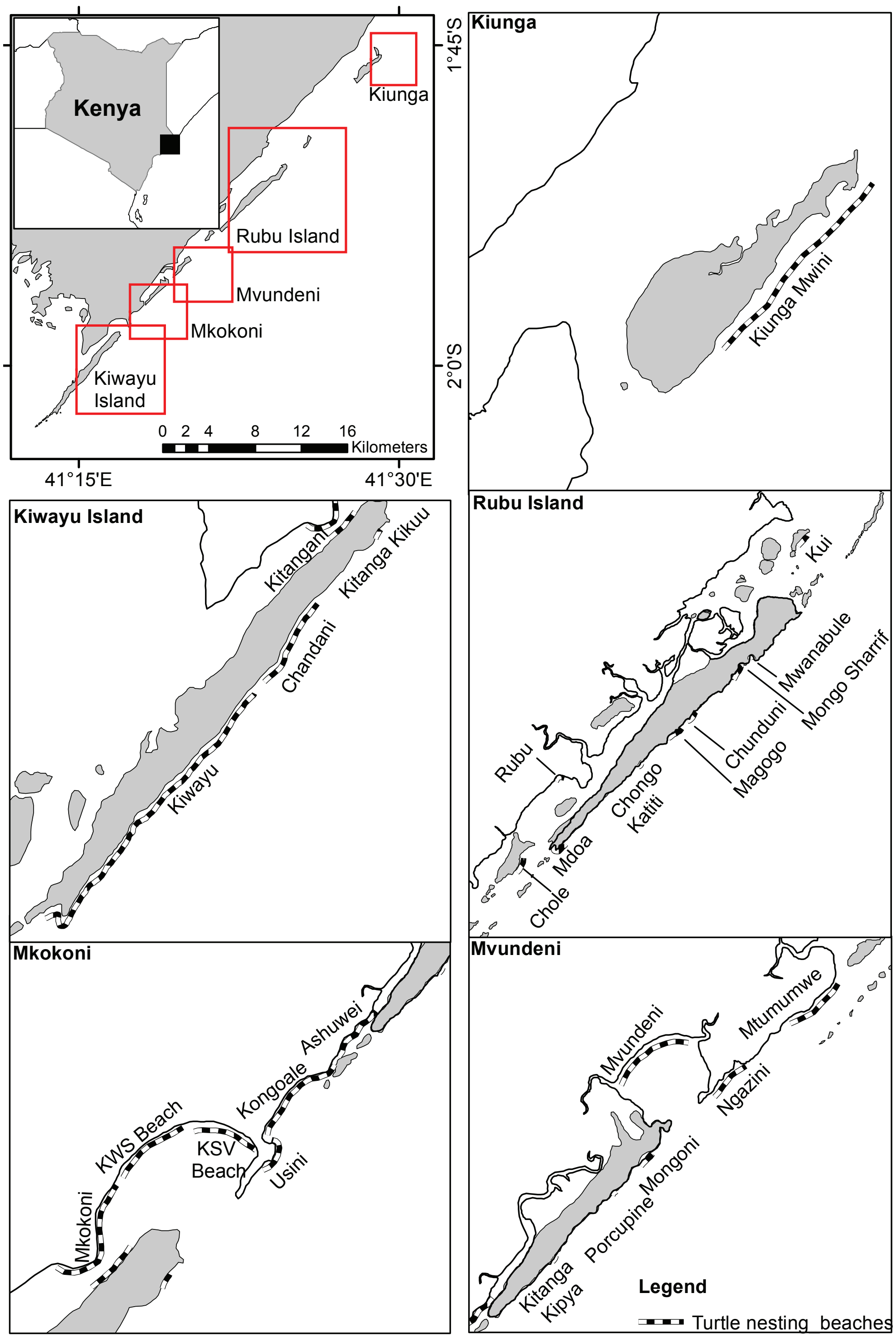

Figure 1. Map of the Lamu seascape, Kenya showing the different monitoring locations and beach stretches.

monsoon, NEM season; McClanahan, 1988; Benny, 2002; Spencer *et al.*, 2005). In particular, the northern area of the seascape is characterized by mild upwelling events and eutrophic conditions (Gert, 1989; Schott, 2001; Benny, 2002; Spencer *et al.*, 2005) resulting in increased algae and high fisheries productivity during the NEM season.

Data collection

Sea turtle nesting data were collected following the WWF Lamu sea turtle nesting protocol developed for sea turtle conservation groups (TCGs) in the area (WWF Lamu, 2012). This protocol requires nesting data to be collected at night by trained data collectors. Data collectors used minimum light and observed the nesting and egg laying process in silence. After laying, the turtle was restrained to read tag information, attach a new flipper tag and record carapace length and width. Beach surveys were regularly conducted at dawn and late at night, and nesting data collected using WWF standardized beach monitoring data sheets.

Observed sea turtle tracks were examined and potential nests verified to confirm existence of an egg clutch. Once verified, nests were left in the same position (*in situ*) above the drift line of the high water mark, or translocated (*ex situ*) when below the drift line of the high water mark, to suitable sites to avoid inundation, then covered and marked, numbered and location recorded with a hand-held GPS (Taiwanese GARMIN). Turtle tracks were then smoothed over to avoid attracting attention of potential predators. Regular surveillance of both GPS marked and translocated nests were conducted and progress of incubation monitored for signs of hatchling emergence.

Hatchlings emerging during the day were released at night, and hatchlings that emerged at night were released at dawn. The released hatchlings were guided to the sea to minimize the chances of predation from land-based predators. Predation data were collected from the number of affected clutches, and from turtle strandings through beach surveys conducted during

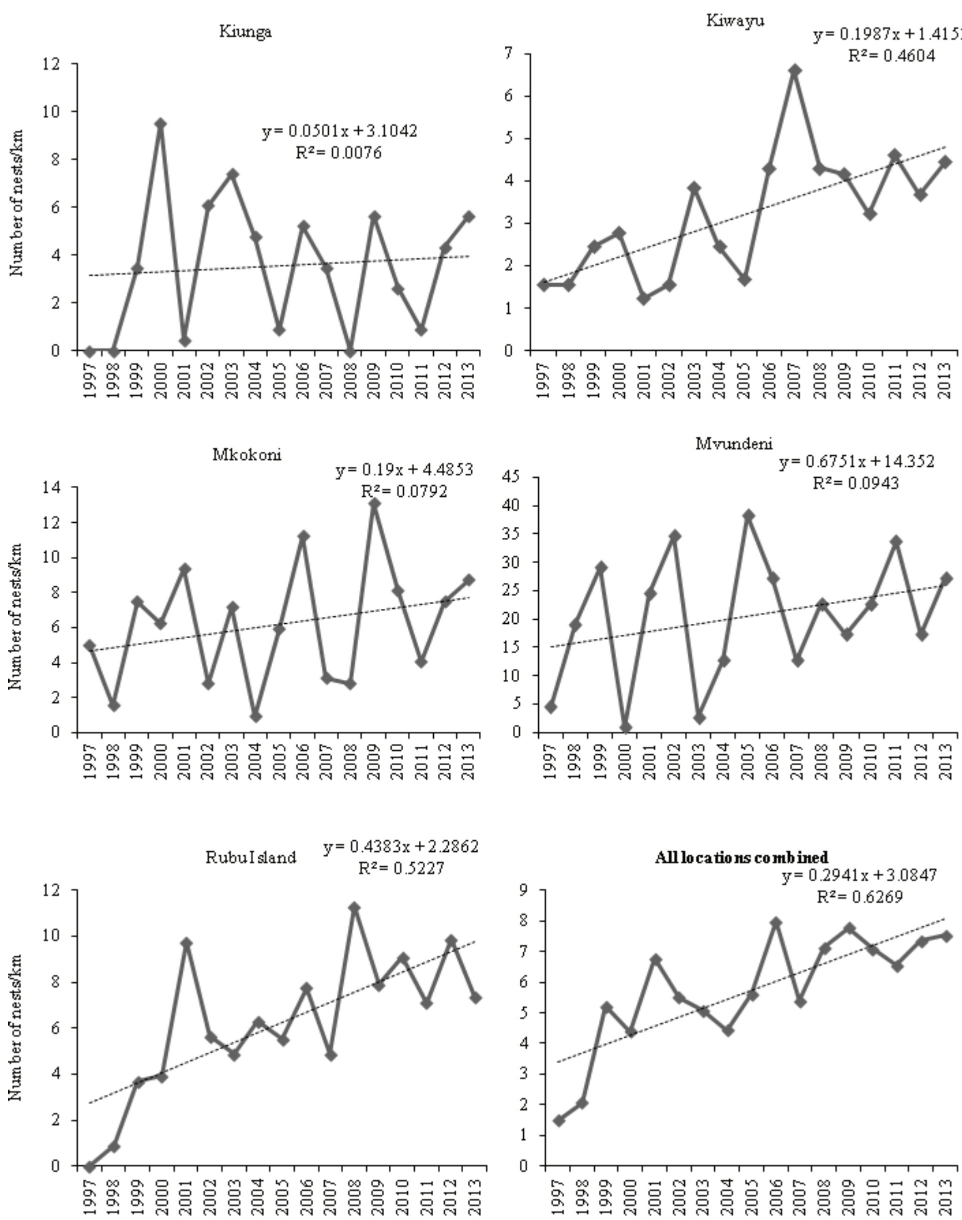

Figure 2. Spatial and temporal trends in sea turtle nest density in Lamu seascape, Kenya during the study period.

the day. Details recorded for turtle strandings were: species and sex, cause of mortality (by observing the injury category or possible viral infection), and size determination by measuring the curved carapace length (CCL, cm) using a flexible tape measure.

Data analyses

Sea turtle nesting data collected over 6,205 days between 1997 and 2013 were analyzed in the five locations with a total beach length of 20.7 km for spatial and temporal trends in nest protection (nest density per km) and predation levels (%). Predation levels were assessed for seasonal patterns between months, location, and between *in situ* and translocated nests. Predation level was calculated as a percentage of the number of nests predated out of the total number of nests recorded. Data on sea turtle strandings for a total of 188 days between 2001 and 2014 over a total distance of 20.7 km were also analyzed for spatial and temporal trends in the rate of sea turtle strandings (number per km), and by identified causes of strandings. The parametric 1-way ANOVA was used to test for significant differences in nest densities among locations and the Tukey HSD test was used for post-hoc pair wise comparison analysis. Spatial differences in predation levels were tested by the non-parametric Kruskal-Wallis test. STATISTICA version 7.0 was used for all statistical analyses.

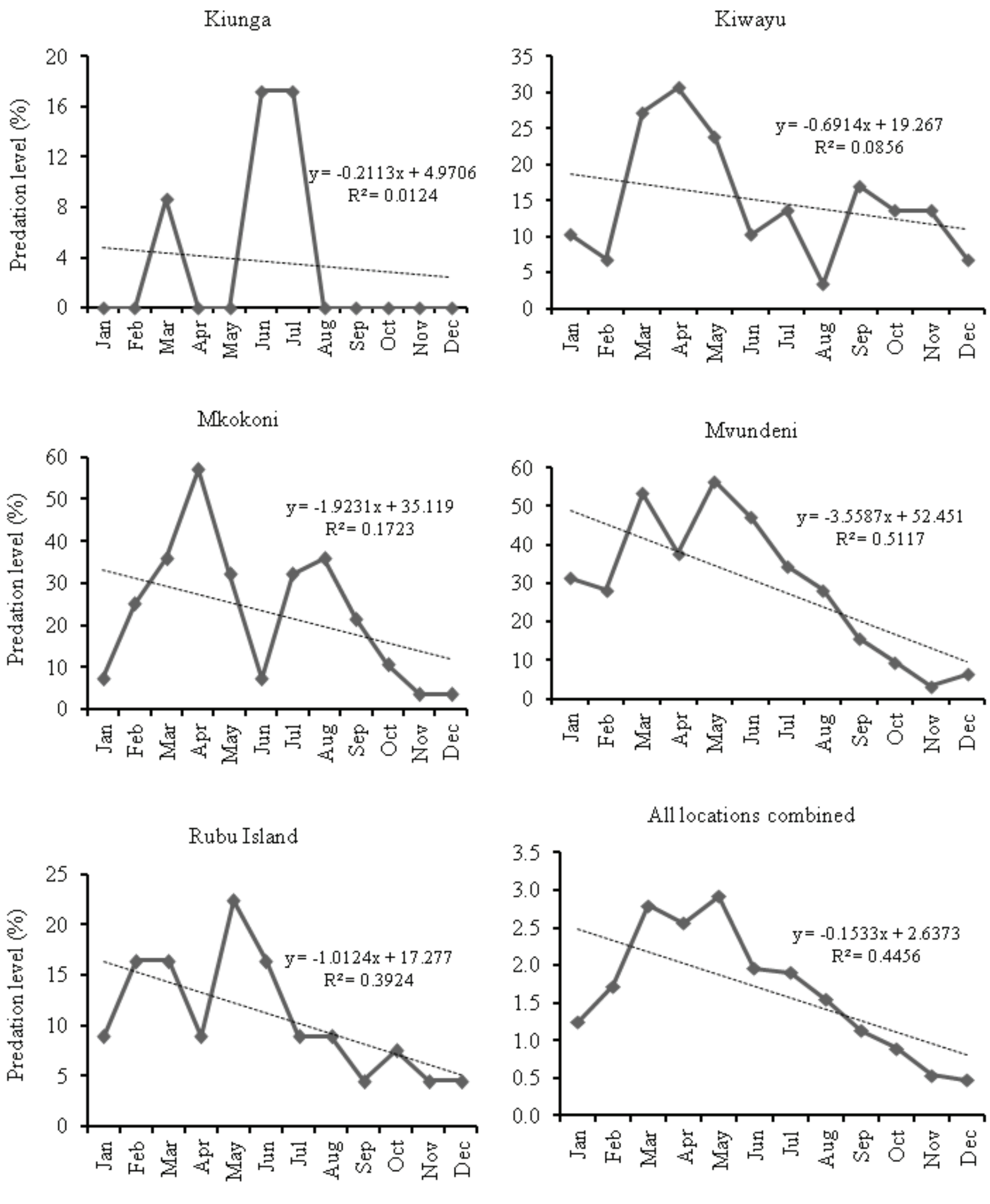

Figure 3. Trends in monthly predation levels (%) of sea turtle nests by location over the monitoring period in Lamu Seascape, Kenya.

Results

Spatial and temporal trends in sea turtle nesting

A total of 2021 sea turtle nests were recorded in 6,205 days between 1997 and 2013. In general, an increasing trend in annual sea turtle nest density was observed (Fig. 2; R^2 = 0.627). However, spatial differences in increasing trends were observed among the different locations, where higher trends were observed for Rubu Island (R^2 = 0.523) and Kiwayu (R^2 = 0.460). Overall, the annual mean number of translocated nests was significantly higher (76 ± 8 nests) than *in situ* nests (42 ± 5 nests) (1-way ANOVA: df = 1; f = 12.459; p = 0.001). The overall monthly mean number (± SE) of sea turtle nests was 168 ± 31. Higher numbers were recorded for translocated nests (108 ± 22) and much lower for *in situ* nests (60 ± 9). Higher numbers of sea turtle nests were observed between April and July, and lower numbers were observed between August and March.

Spatially, the mean (± SE) nest density over the study period was highest for Mvundeni (20 ± 3 nests/km) followed by Mkokoni and Rubu Island with 6 ± 1 nests/km. Kiunga and Kiwayu recorded the lowest nest densities of 4 ± 1 and 3 ± 1 nests/km respectively. There was a highly significant spatial difference in nest density among locations (1-Way ANOVA: df = 4; f = 15.614, p = 0.001). Post-hoc pair wise comparison confirmed that Rubu Island significantly differed from the rest of the locations (Tukey HSD: $p < 0.05$).

Spatial and temporal trends in predation of sea turtle nests

From a total of 2,012 nests recorded between 1997 and 2013, 16.5% (n = 331) were predated. Decreasing trends in predation levels were observed in all locations and this was more pronounced in Mvundeni and Rubu Island (Fig. 3). Higher predation levels were observed mostly within the first six months of the year especially during the warmer months of January, February, March coinciding with the NEM season, and to some extent April and May at the beginning of the SEM season. Spatially, the mean monthly predation level was highest for Mvundeni followed by Mkokoni. The locations of Kiwayu, Rubu Island and Kiunga followed in that order (Fig. 4). Results of the Kruskal-Wallis test however, indicated no significant difference in predation levels among these locations (p = 0.085).

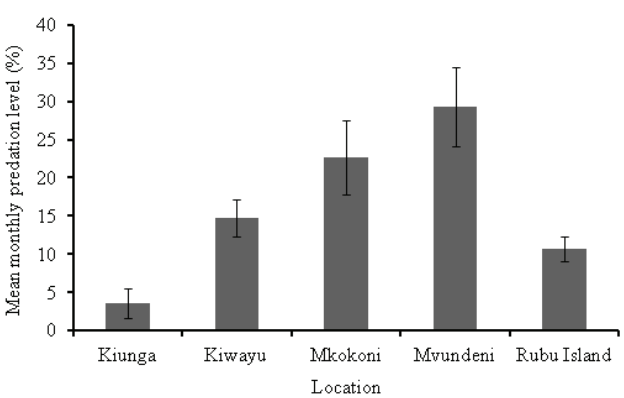

Figure 4. Mean (±SE) monthly predation levels of sea turtle nests by location over the monitoring period in Lamu seascape, Kenya.

Spatial and temporal trends in sea turtle strandings

In general, a slight decreasing trend in shore-based monitoring effort for sea turtle strandings was apparent at all locations with higher effort between 2002 and 2005, and a peak in 2013 (Fig. 5). Shore-based monitoring for strandings occurred over a total of 188 days between 2001 and 2014, and a total of 227 sea turtle strandings were recorded. The sampling effort was an average of 14.5 ± 4 days annually with a general decreasing trend over time (Fig. 5). Sampling effort peaked between 2001 and 2005 with a drop between 2006 and 2011, another peak in 2013, and a drop again in 2014. The rate of sea turtle strandings ranged between 0.3 and 1.4 strandings/km at an annual average of 0.8 ± 0.1 strandings/km. There was an observed decreasing trend in sea turtle strandings with peaks in 2003, 2005 and 2013 (Fig. 6, all locations combined). On the other hand, each location was sampled at an average of 37.6 ± 10 days per year. Sampling by location was highest for Mkokoni (total of 67 days) followed by Kiwayu and Rubu Island with a total of 51 and 37 days respectively. Sampling was lowest for Kiunga (24 total days) and Mvundeni (9 total days). The rate of sea turtle strandings was highest for Mkokoni (24 strandings/km) followed by Kiunga (16 strandings/km). On the other hand Kiwayu, Mvundeni and Rubu Island recorded the lowest rates at 9, 8 and 6 strandings/km respectively.

The causes of sea turtle strandings differed by location (Fig. 7). The highest number of sea turtle strandings was attributed to fishery interactions (n = 121) in all the locations monitored, followed by unknown causes (n = 46), shark attacks (n = 30) and the viral disease fibropapillomatosis (n = 26). Hyena attacks and poaching incidents were reported at Mkokoni only, with 3 and 1 incidences respectively. Higher numbers of sea turtle strandings were observed in the months of January, February and March during the dry NEM season attributed mostly to fishing interaction causes (Fig. 8). Higher numbers of sea turtle strandings were also recorded between July and September. Lower numbers of strandings were recorded between October and December and the lowest in May and June, during the wet SEM season.

The curved carapace length (CCL), of stranded green turtles ranged between 10 and 130 cm CCL at an average size (± SE) of 68.9 ± 1.9 cm (n = 180; Fig. 9). The majority of these stranded turtles (94 %) measured between 30 and 110 cm CCL at an average size of 69.3 ± 1.8 cm CCL (n = 169). The fewest strandings were recorded for both the smallest and largest individuals of <30 cm at an average size of 23.9 ± 2.3 cm CCL (n = 6), and of >110 cm at an average size of 118.8 ± 3.8 cm CCL (n = 4) respectively. Sizes of stranded hawksbill turtles ranged between 20 – 80 cm at an average of 50.9 ± 2.1 cm CCL (n = 40) and the majority (87.5%) of these ranged between 30 – 70 cm at an average size of 50.6 ± 1.8 cm CCL (n = 35). Sizes of the stranded loggerhead turtles measured between 80 – 90 cm, at an average of 84.5 ± 0.5 cm CCL (n = 2), and the sizes of stranded olive ridley turtles ranged from 20 – 90 cm at an average of 51.4 ± 7.7 cm CCL (n = 5).

Discussion

The long-term conservation of sea turtles in Kenya is highly dependent on protection of nesting sites, and continuous creation of awareness of sea turtle conservation among local communities (Okemwa *et al.*,

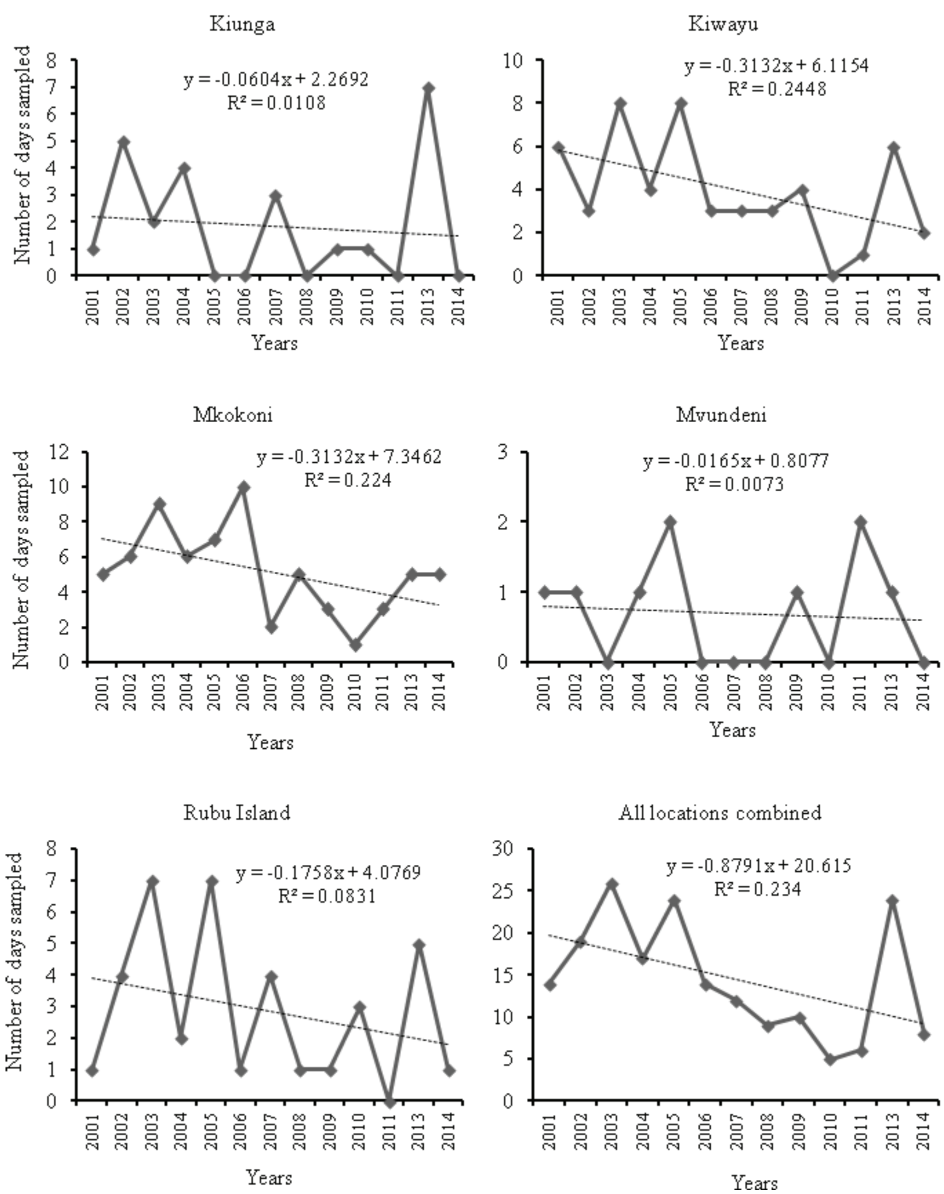

Figure 5. Spatial and temporal trends in sea turtle monitoring effort in Lamu seascape, Kenya during the study period.

2004). Fisheries related measures to protect sea turtle bycatch have also been tried especially in the bottom trawl shrimp fishery in the Malindi-Ungwana Bay area using Turtle Excluder Devices (Fennessy *et al.*, 2008). Perhaps as a result of these initiatives, results of this study indicate an increasing trend in sea turtle nest densities over the study period in the Lamu seascape, notwithstanding the spatial differences observed. These spatial differences in nest densities might be attributed to a number of factors including accessibility of the monitoring locations by the monitoring team, beach nesting preference by sea turtles (Domingo *et al.*, 2006), as well as differences in the intensity of human impact such as poaching for sea turtle eggs.

This increased trend in sea turtle nesting, as well as a slight decreasing trend in nest predation can be attributed to the increased sea turtle conservation efforts in the area. Lower nest predation levels were observed during the rainy southeast monsoon (SEM) season when nesting activity peaked, while higher nest predation levels coincided with the dry northeast monsoon (NEM) season. This seasonal difference could be attributed to the different weather conditions experienced, where during the dry NEM season risk exposure of turtle nests to predators could be higher than during the rainy SEM season. Turtle track marks are clearer and more exposed during the sunny NEM season and therefore, predators such as hyenas and porcupines can easily identify and locate these nests.

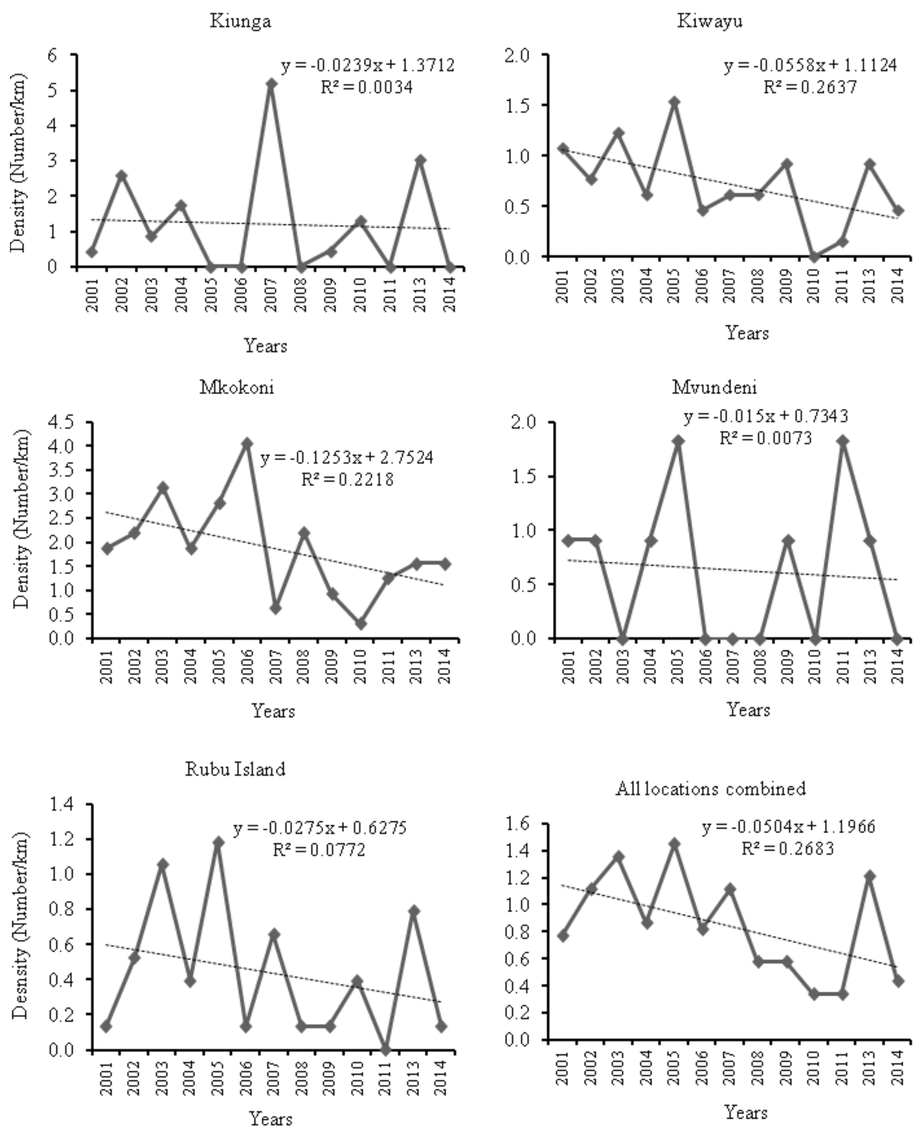

Figure 5. Spatial and temporal trends in sea turtle monitoring effort in Lamu seascape, Kenya during the study period.

Spatially, higher levels of nest predation levels were observed in Mvundeni and Mkokoni locations attributed mostly to the higher presence of wild animals especially hyenas and porcupines that were reported.

A slight decreasing trend in monitoring effort for sea turtle strandings was apparenrt for all the locations in the study area. This also coincided with a decreasing trend in the density of sea turtle strandings. This decreasing trend in stranding density despite reduced monitoring effort could be as a result of increased awareness of sea turtle conservation by the communities, especially the fishermen, whose activities contributed to the majorly of sea turtle strandings in the area. More pronounced stranding density was observed in two peaks of the year; between January and March (part of the NEM season), as well as between July and September; part of the SEM season. This is attributed mostly to increased fishing activity at offshore fishing grounds during the NEM season, as well as increased fishing effort in the sheltered inshore fishing grounds during the SEM season.

The highest number of sea turtle strandings, especially in Mkokoni and Kiwayu, were linked to interactions with fishing activities. Cases of sea turtles missing some of their flippers or their head were documented, similar to what has been found in other areas. This can be attributed to mutilation by fishermen while removing entangled sea turtles from gillnets (Domingo *et al.*,

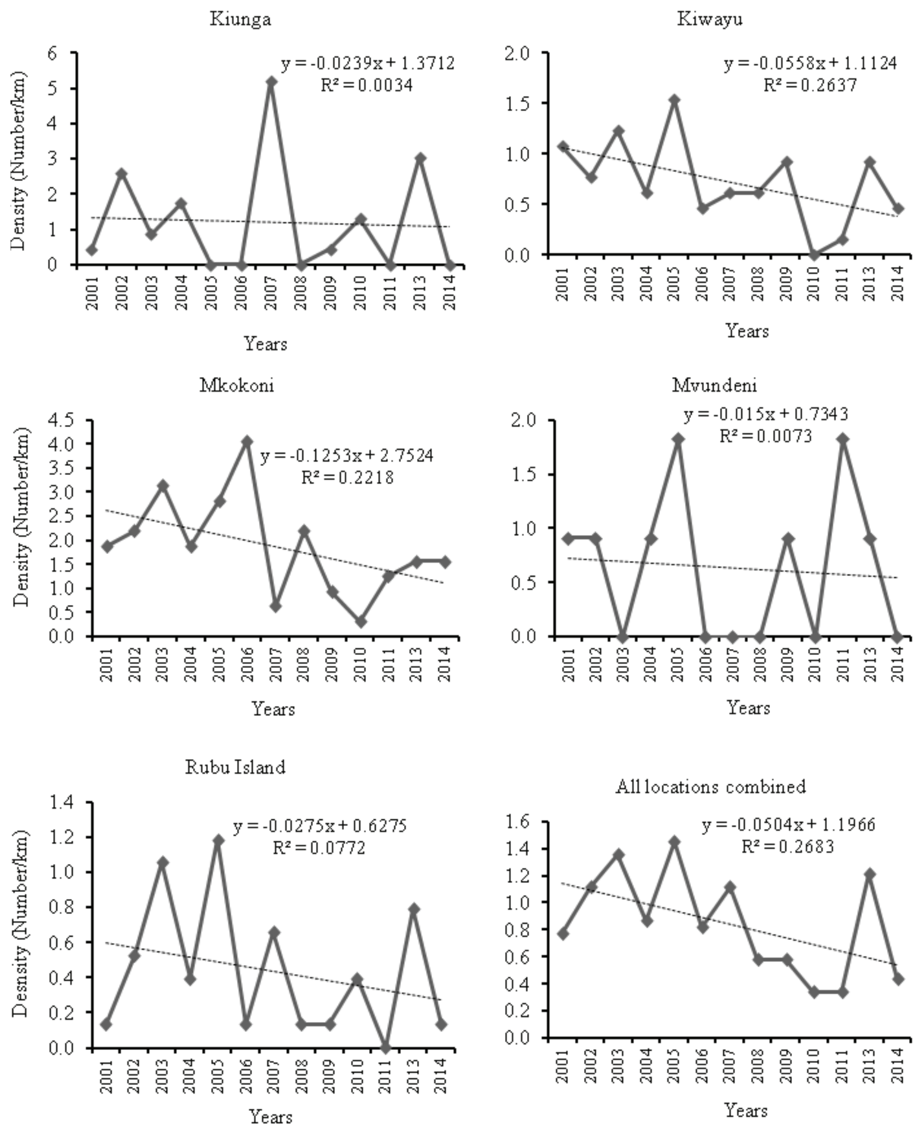

Figure 6. Spatial and temporal trends in the rate of sea turtle strandings in Lamu seascape, Kenya, during the study period.

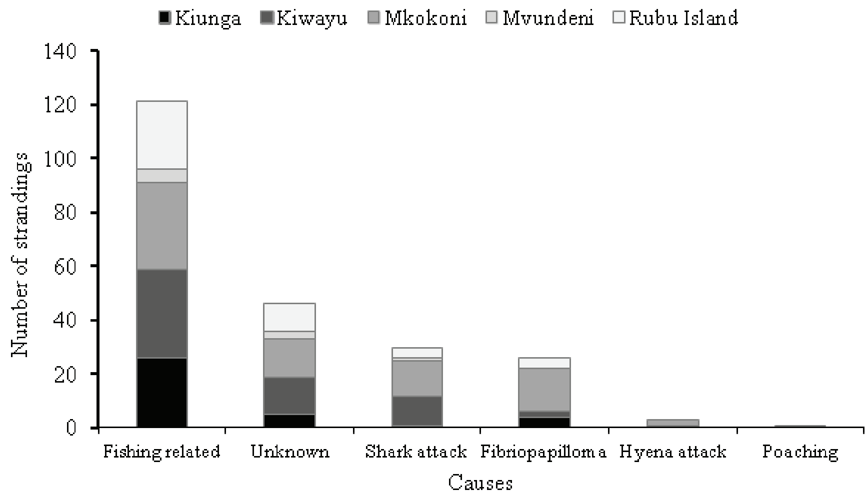

Figure 7. Sea turtle strandings by causes and locations in the Lamu seascape, Kenya during the study period.

2006), or decay. The viral fibropapillomatosis tumors and shark attacks were also common causes of sea turtle strandings or death in this present study. Sea turtles infected with fibropapillomatosis tumors are more likely to be weak and emaciated, and are more vulnerable to entanglement (Witherington *et al.*, 2006). The increasing prevalence of fibropapillomatosis infection in green turtle populations of the Western Indian Ocean (WIO) is a concern. In Madagascar it has been observed that only immature green turtles of between 40 and 80 cm CCL were affected by this desease, with prevalence in individuals between 50 and 59 cm (Leroux *et al.*, 2010). Similarly in Florida, tumors have been documented to be rare in the smallest and largest juveniles, indicating that the disease is acquired by juveniles after recruiting to coastal waters, with older juveniles either dying or recovering from the disease (Witherington *et al.*, 2006). There are indications that environmental factors are associated with the prevalence of the disease; however, more research is needed to determine these factors with certainty (Hamann *et al.*, 2010).

In this study, sea turtle strandings due to fishing related causes (incidental fisheries capture) seem to show a decreasing trend from the month of August onwards to the month of December, even though there is generally higher turtle strandings during this part of the year. Fishing related stranding cases appear to slightly increase from the month of January onwards to March, even with a generally lower

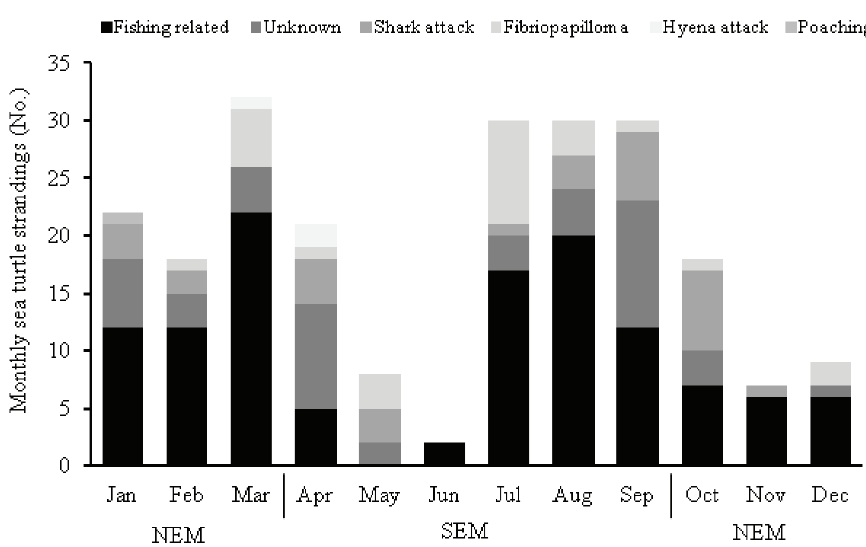

Figure 8. Monthly and seasonal distribution of sea turtle strandings by causes in Lamu seascape, Kenya during the study period.

number of strandings in this period. The months of April, May and June show the lowest fishing related sea turtle stranding level coinciding partly with the SEM season when fishing activity is lowest. In other areas of the Kenya coast, sea turtle strandings due to incidental fisheries capture has been reported to be generally similar to the pattern observed in the Lamu seascape. In the Watamu area, for example, during the second half of the year from June onwards, sea turtle strandings from gillnets contribute 80% (Zanre, 2005). This author also noted that the amount of sea turtle bycatch does not always correspond to the good fishing NEM season when fishing effort is highest, suggesting that there may be behavioral changes amongst local sea turtle populations at certain times of the year that affect their bycatch rates.

Findings of this study have shown that seasonality in fishing activity plays a key role in contributing to the seasonal patterns in sea turtle strandings. In the artisanal fishery along the Kenyan coast, fishing effort begins to increase in late September as the winds and sea start to calm with the onset of the NEM season. This enables fishing boats to venture beyond the fringing reef. By late October through until the end of March, fishing effort is at its highest. In the Lamu seascape, turtle strandings from fishing related causes is observed to be highest in the month of March (NEM season) followed by August and July (SEM season). Results of marine fisheries frame surveys conducted between 2004 and 2014 indicate relatively higher numbers of large fishing boats (*mashua* and *hori*) in Lamu as compared to other parts of the coast (Government of Kenya, 2014). These fishing boats are associated with large fishing nets (beach seines, gill nets and monofilament nets), and use long lines. Currently, the number of gill nets in Lamu stands at 1,138 with the most common mesh size being 6 inches. Also there are a total of 2,165 long line hooks, and 746 monofilament nets (Government of Kenya, 2014). The area has the highest concentration of beach seines, especially in the Amu and Faza fishing grounds. The fishing effort in Lamu, therefore, can be described as being relatively high. This ultimately contributes to the higher fishing related stranding of sea turtles within the Lamu seascape.

The highest number of sea turtle strandings was observed for green turtles followed by hawksbills. The lowest number of strandings occurred for olive ridley and the loggerhead turtle. The highest number of green turtle strandings coincided with the highest level of nesting in the area. Overall, most of the sea turtles that were stranded measured more than 40 cm CCL. In comparison, smaller green turtle individuals ranging

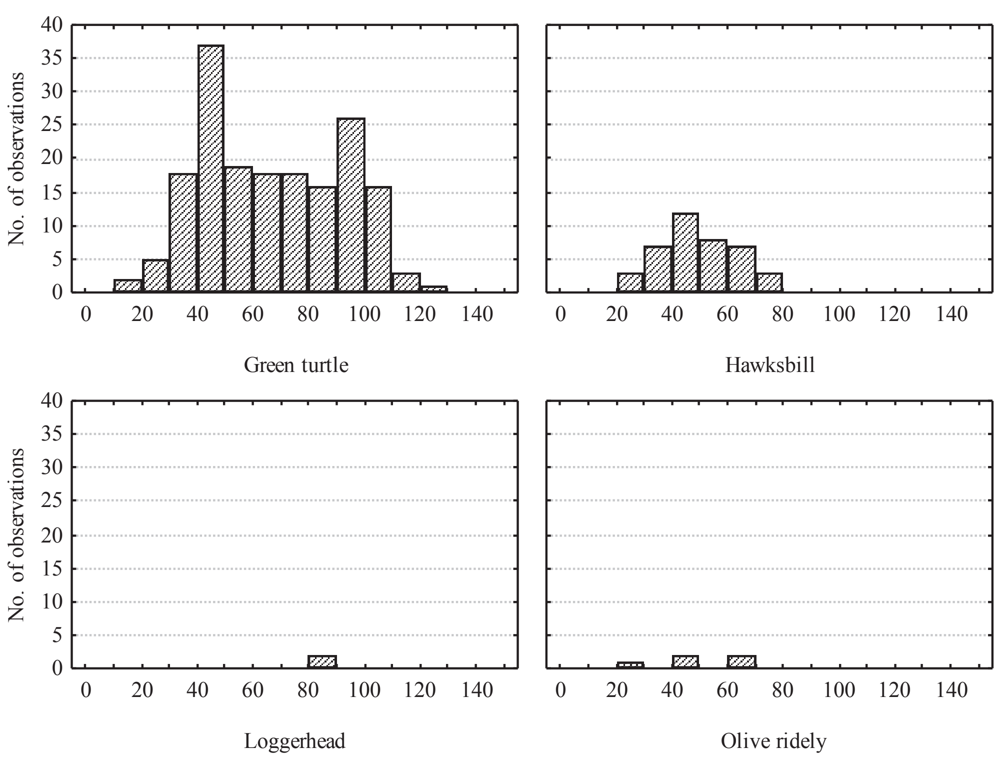

Figure 9. Curved carapace length (CCL) distribution of sea turtle strandings (sexes combined) by species in Lamu seascape, Kenya during the study period.

from 4.5 – 111.5 cm CCL (mean of 45.7 cm), and hawksbills ranging from 3.9 – 85.4 cm CCL (mean of 36.1 cm) were recorded in Watamu (Zanre, 2005), situated further south of the Lamu seascape. In Brazil, female green turtles have been documented to range between 101 and 143 cm CCL with a mean CCL of 116.8 cm (Moreira *et al*., 1995).

In conclusion, the success of sea turtle conservation efforts in the Lamu seascape, Kenya is clearly demonstrated by increased nesting density over time, as well as the reduced trends in sea turtle nest predation, and strandings. This is attributed to increased awareness among communities about sea turtle conservation. This study has confirmed that fishery related interaction is the major cause of turtle stranding in the area. We therefore recommend that in addition to shore-based monitoring of sea turtle nesting, predation, and strandings, there is need to enhance offshore monitoring to better quantify the interactions between fishers and sea turtles so as to better understand the in-water impacts and status of sea turtle populations in the Lamu seascape.

Acknowledgements

We would like to extend our utmost gratitude to WWF Netherlands, WWF US and the Keane Family Foundation Trust for funding sea turtle conservation and data collection activities in the Lamu seascape. We would also like to thank WWF UK and the people postcode lottery (PPL) for supporting the analysis and conversion of this raw data into a publication. We also recognize the pivotal role of the local community in Lamu for their collaborative spirit and goodwill. They are the true custodians of sea turtles and indeed the champions of sea turtle conservation not only in Lamu but also the entire Kenya. Finally, we appreciate the partnership of the government agencies namely: Kenya Wildlife Service (KWS), State Department of Fisheries, Lamu County Government, and the Kenya Marine and Fisheries Research Institute (KMFRI).

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