Green Turtle *(Chelonia mydas)* nesting behaviour in Kigamboni District, United Republic of Tanzania.

Lindsey West

Sea Sense, 1372 Karume Road, Oyster Bay, Dar es Salaam, Tanzania

Introduction

Tanzania is located in equatorial east Africa and has a coastline of approximately 1,000 km. The coastal belt supports a rich array of natural systems including coral reefs and seagrass meadows that provide important feeding and breeding habitats for five of the world's seven sea turtle species: green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and olive ridley (*Lepidochelys olivacea*) turtle. Green turtles are the most common species and are known to nest along most of the coastline (Muir 2005). Hawksbills are also widely distributed in Tanzania although nesting activity is restricted to the islands of Mafia, Pemba and Songo Songo (Muir 2005). Olive ridley, loggerhead and leatherback turtles do not nest in Tanzania but bycatch data confirms that they are present in Tanzanian waters (West & Hoza 2014), either foraging or passing through *en route* to nesting sites elsewhere in the region.

Between 450 - 500 green turtle nests are recorded annually in Tanzania which is relatively low compared to other countries in the western Indian Ocean region (Frazier 1982). In Kigamboni District, central Tanzania (Fig. 1) there are 19 nesting beaches spanning 45km of coastline (Fig. 2). Kigamboni has the second highest green turtle nesting density in Tanzania. Twelve years of community based monitoring of nesting activity in Kigamboni District (2005 to 2016) has resulted in 1,203 nesting records and a mean annual nest count of 100 (range 68 - 147). Using nest counts and an average clutch frequency of between three (Seminoff 2004) and six (Weber *et al*. 2013) the estimated annual green turtle nesting population in Kigamboni District is 17 - 33 individuals.

While daily nest counts are relatively simple to implement, monitoring of nest counts alone does not provide accurate enough information to generate true abundance estimates or to evaluate the effectiveness of local protection measures. There are high levels of natural inter-annual variability in green turtle nesting numbers (Broderick *et al*. 2001) which may be misinterpreted without detailed information on other reproductive parameters including clutch frequency and re-migration intervals.

Fig. 1. Map of Tanzania with the Kigamboni District of central Tanzania highlighted.

Fig. 2. Nesting beaches of the Kigamboni District spanning 45km of coastline. Green turtle nesting activity is concentrated at Mbutu, Amani Gomvu and Kimbiji. Base map taken from Google Earth.

To address this issue, an intensive monitoring programme commenced in Kigamboni District in 2013. This paper reports results of nesting activity in Kigamboni District during four successive nesting seasons (2013 to 2016).

Methods

Conservation Officers conducted daily foot patrols at dawn throughout the year at six nesting sites covering 19 nesting beaches. Each nest recorded was given a unique identification number and monitored during the incubation period. Nests under threat from poaching or predation were relocated to a hatchery and nests at risk of tidal inundation were relocated above the high tide mark. After hatching, each nest was excavated and the number of empty egg shells, live and dead hatchlings remaining in the nest chamber and unhatched and undeveloped eggs were counted to determine emergence success (Miller 1999). Nests without any empty egg shells but containing undeveloped and/or unhatched eggs were categorised as unhatched nests.

Monitoring activity was intensified between April 3rd and June 3rd. Hourly night foot patrols were conducted between 19:00 and 06:00 hours for 62 nights at three sites where most nesting is concentrated (covering 13 beaches). The curved carapace length (CCL) and curved carapace width (CCW) of each turtle were measured (Bolten 1999) and the turtle was examined for the presence of existing tags. If not already tagged, individually numbered titanium tags (TZ series) were applied between the first and second scale along the posterior edges of the front flippers. To minimise disturbance tags were applied after oviposition was complete.

The mark-recapture method enabled the number of individual females nesting during the peak season to be counted and generated information on inter-nesting durations (amount of time between two nesting events), clutch frequency (number of clutches of eggs laid by each female) and re-migration intervals (the interval between successive nesting years).

Results

During the four-year survey period, 369 nests were recorded at six nesting sites (Table 1). In total, 275 nests (76%) were relocated due to the threat from poaching, predation, or tidal inundation. Mean hatchling emergence success over the four-year period was 52% (SD=38). Predation by mongoose (*Herpestidae*) had a significant effect on emergence success at three sites (Amani Gomvu, Kimbiji and Puna).

Between 2013 and 2016 intensive monitoring during the peak nesting months of April and May was carried out at 13 nesting beaches in Mbutu, Amani Gomvu and Kimbiji villages. A total of 126 emergences were recorded across the three sites, 108 of which were nesting events (Table 2). Annual mean nesting success over the four-year period was 85% (range 77% - 93%).

Table 1: *Chelonia mydas* nesting activity and fate of nests at Kigamboni District, 2013 to 2016.

Nesting site	Number of nests recorded	Emergence success (%)	Number of nests predated	Number of nests poached	Number of unhatched nests	Number of inundated nests
Mbutu	28		9	0	0	0
2013	9	38.4	3	0	0	0
2014	0	0	0	0	0	0
2015	16	53.1	6	0	0	0
2016	3	26.3	0	0	0	0
Amani Gomvu	160		19	0	15	3
2013	42	48.7	6	0	4	0
2014	31	40.2	10	0	1	2
2015	59	72.9	0	0	0	1
2016	28	30.1	3	0	10	0
Kimbiji	106		29	1	0	2
2013	32	63.2	8	0	0	0
2014	37	50.0	10	1	0	0
2015	20	42.9	5	0	0	1
2016	17	44.1	6	0	0	1
Buyuni	24		0	0	0	0
2013	0	0	0	0	0	0
2014	4	99.5	0	0	0	0
2015	12	90.8	0	0	0	0
2016	8	95.3	0	0	0	0
Puna	33		18	0	1	0
2013	4	52.5	1	0	0	0
2014	5	0.0	5	0	0	0
2015	12	19.7	6	0	1	0
2016	12	36.5	6	0	0	0
Pemba mnazi	18		0	0	0	0
2013	5	81.9	0	0	0	0
2014	7	86.9	0	0	0	0
2015	2	85.2	0	0	0	0
2016	4	84.7	0	0	0	0
GRAND TOTAL	**369**		**75**	**1**	**16**	**5**

Table 2: *Chelonia mydas* encounters during peak nesting season (April & May) at three sites, Kigamboni District, 2013 to 2016.

Year	No. emergences	No. nesting events	Nesting success (%)	No. females encountered	No. nesting females
2013	**29**	**27**	**93**	**18**	**17**
Mbutu	5	4	80	5	4
Kimbiji	7	7	100	6	6
Amani Gomvu	17	16	94	7	7
2014	**25**	**21**	**84**	**14**	**14**
Mbutu	0	0	0	0	0
Kimbiji	7	5	71	5	5
Amani Gomvu	18	16	89	9	9
2015	**46**	**40**	**87**	**22***	**21**
Mbutu	5	5	100	1	1
Kimbiji	7	6	86	7	6
Amani Gomvu	34	29	85	16	15
2016	**26**	**20**	**77**	**14***	**12**
Mbutu	0	0	0	0	0
Kimbiji	10	6	60	7	4
Amani Gomvu	16	14	88	9	9
TOTAL	**126**	**108**		**68**	**64**

* values do not sum to the total number of individuals as two individuals were observed in two locations.

A total of 16 nesting events were undetected by the survey teams. The number of individual females observed during each season ranged from 14 to 22. Mean curved carapace length was 105.5 cm (SD=3.9, range 96 - 114cm).

The mean annual nest count across the three sites with intensive monitoring was 74 (range 48 to 95, SD=20.3) (Table 3). During the peak nesting months of April and May, the mean nest count was 31 (range 19 to 44, SD=10.2), representing 42% of annual reproductive output at the three sites. A total of 66% of the turtles (n=42) encountered during the intensive monitoring period were recorded nesting only once during a season. Eight turtles nested at least twice during a season, seven turtles nested at least three times, six nested at least four times and one turtle nested at least five times. The observed clutch frequency (OCF) method (Johnson & Ehrhart 1996) was used to calculate clutch frequencies for each turtle encountered nesting at least once within each season. The observed clutch frequency was 1.7 (SD=1.1). When data for turtles that nested only once during the survey were removed from the analyses, the estimated clutch frequency was 3.0 (SD=1.1). Using

Table 3: *Chelonia mydas* nesting activity during the peak months of April and May at the three intensively monitored sites, Kigamboni District, 2013 to 2016.

Year	2013	2014	2015	2016
No. nests in peak season (Apr – May)	**30**	**31**	**44**	**19**
Mbutu	4	0	8	0
Kimbiji	9	12	8	5
Amani Gomvu	17	19	28	14
Total no. nests per year	**83**	**68**	**95**	**48**
Mbutu	9	0	16	3
Kimbiji	32	37	20	17
Amani Gomvu	42	31	59	28
% of nests laid in peak season	**36**	**46**	**46**	**40**
Mbutu	44	0	50	0
Kimbiji	28	32	40	29
Amani Gomvu	40	61	47	50

a mean annual nest count of 100 (data from 2005 to 2016), these clutch frequency values produce an annual nesting population estimate of 33 - 59 individuals.

Inter-nesting intervals were calculated according to Alvarado & Murphy (1999) and ranged from 10 to 20 days (Fig. 3). An inter-nesting interval of ≥20 days was assumed to be the result of a turtle nesting undetected, most likely on a neighbouring beach outside of the study area. In this case, the number of clutches laid was corrected (Broderick *et al.* 2003) and the corrected number was used in the analyses. The mean inter-nesting duration was 12.5 days (SD=1.8, n=46).

In total, 68 individual turtles were observed during the four-year survey period. Due to the short time scale of the study, only nine individuals were encountered in more than one nesting season (opportunistic tagging occurred in 2012 prior to the intensive programme). Remigration intervals ranged from one to four years (one year n=1; two years n=3; three years n=4; four years n=1). The mean remigration interval for the nine re-encountered turtles was three years.

Discussion

Detailed information on reproductive behaviour is needed in order to understand the underlying, complex processes that drive nesting population status and trends. A survey period of four years is too short to generate an accurate estimation of population size in green turtles, but preliminary analyses of the data have provided useful information on clutch frequency and

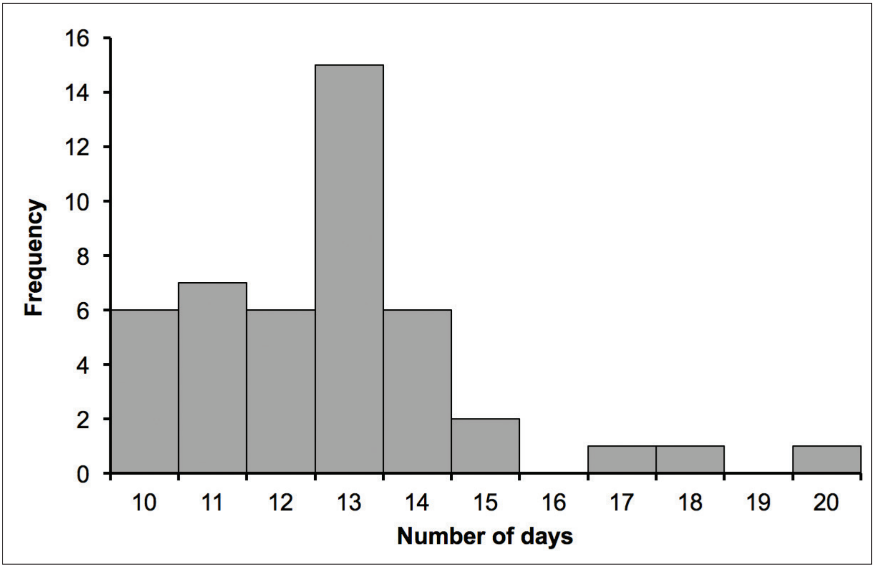

Fig. 3. Inter-nesting durations for green turtles nesting at three sites in Kigamboni District, 2012 to 2016.

remigration intervals that form the basis of population estimates. Although the estimate of 33 – 59 green turtles nesting in Kigamboni District each year should be treated with caution until data from future years are incorporated into the analyses, it is the first attempt at estimating the size of the nesting population in the area and serves as a useful starting point.

The annual number of nests at all six sites in Kigamboni District between 2005 and 2016 ranged from 68 to 147. Without information on clutch frequency, a change in the number of nests recorded may be attributed to a change in the number of females nesting but it may actually be a reflection of annual variation in reproductive output (Broderick *et al.* 2002). Mark-recapture data collected during the peak nesting season in 2015 demonstrates the inherent dangers of estimating population size without information on clutch frequency. Although the number of nesting events in 2015 (n=40) was double those recorded in 2014 and 2016, a two-fold increase in the number of nesting females was not observed. The higher number of nests recorded in 2015 was a function of higher clutch frequencies per individual turtle rather than a significant increase in the number of nesting turtles.

While changes in numbers of nests can be linked to reproductive output, inter-annual variability in numbers of nesting females can be a result of variations in re-migration intervals (Carr & Carr 1970; Carr 1975; Bjorndal *et al*. 1999). Hays (2000) tested this hypothesis using theoretical models and demonstrated that changing the remigration rate of individuals can dramatically affect the numbers of turtles nesting in different years. Although the intensive monitoring programme at Kigamboni District is in its infancy (2016 was the fourth successive season of monitoring), data have already begun to reveal some important insights into re-migratory behaviour. Nine females encountered in 2015 and 2016 had been encountered in previous nesting seasons and showed a variation in re-migration intervals of between one and four years. Changes in migratory periods are thought to reflect conditions encountered at the feeding grounds, with good feeding years leading to a reduction in the remigration interval and vice versa (Hays 2000). Satellite telemetry studies have shown that female green turtles employ multiple post-nesting migratory strategies that disperse them to varying habitat types (Seminoff *et al.* 2008; Richardson *et al.* 2013) and therefore variations in migratory periods are to be expected. In Tanzania, satellite tracking of 11 nesting green turtles showed that individual females migrated to widely separated feeding areas with some travelling more than 2,000km to northern Somalia while others settled on foraging grounds less than 120km from their nesting beach (West 2014). Hence, it is likely that the variation in re-migration intervals observed in 2015 and 2016 at Kigamboni were a result of varying feeding conditions at different foraging grounds.

The intensive monitoring programme has started to address some of the data gaps related to the nesting population in Kigamboni District and highlighted the challenges of interpreting population data based on counts of nesting females or their nests. Estimating nesting population size in Kigamboni District is particularly challenging due to the fact that nesting beaches are evenly spread over the 60km coastline. The intensive monitoring programme was conducted on 13 out of 19 nesting beaches in Kigamboni and mark-recapture data showed that individual females used more than one nesting beach per season. 66% of females nested only once at the intensively monitored sites so it is likely that they utilised nesting beaches outside of the survey area for the remainder of the season. Therefore, the OCF method may underestimate true clutch frequency for some individuals. Furthermore, in Tanzania, the main green turtle nesting season occurs between March and August with sporadic out of season nesting. There is a well-defined peak in nesting activity in April and May which is when the intensive monitoring was conducted. Therefore, individuals that commenced their nesting season towards the middle of May would only be captured on one additional nesting occasion, thereby leading to an underestimation of clutch frequency.

Despite these challenges, an improved understanding of the current size of the green turtle nesting population in Kigamboni District is of critical importance due to an emerging threat from the rapid expansion of the human population in Dar es Salaam, Tanzania’s commercial capital.

Kigamboni District is a municipality of Dar es Salaam and the least developed of five municipalities that make up Dar es Salaam city. The new Dar es Salaam City Master Plan, due to be launched in 2018, sets out a vision for the development of under populated areas, many of which have the potential to impact nesting beaches in Kigamboni District. Therefore, it is essential that there are robust, long-term annual monitoring programmes in place to monitor trends in the nesting population as development activities progress and to provide information and guidance for urban planners.

Acknowledgements

Thanks to the British Chelonia Group for contributing vital funds to the intensive monitoring programme in Kigamboni District. Thanks also to Sea Sense Conservation Officers for their efforts in monitoring the green turtle population during the peak nesting season each year.

References

Alvarado, J. & Murphy, T. (1999). Nesting periodicity and Inter-nesting Behaviour. In: *Research and Management Techniques for the Conservation of Sea Turtles* (eds. Eckert, K., K. Bjorndal, F. Abreu-Grobois & M. Donnelly). IUCN/SSC Marine Turtle Specialist Group Publication No 4, pp 115-118.

Bjorndal, K.A., Wetherall, J.A., Bolten, A.B. & Mortimer, J.A. (1999). Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. *Conservation Biology* 13: 126-134.

Bolten, A. (1999). Techniques for measuring sea turtles. In: *Research and Management Techniques for the Conservation of Sea Turtles* (eds Eckert, K., K. Bjorndal, F. Abreu-Grobois & M. Donnelly). IUCN/SSC Marine Turtle Specialist Group Publication No 4, pp 110-114.

Broderick, A.C., Godley, B.J. & Hays, G.C. (2001). Trophic status drives inter-annual variability in nesting numbers of marine turtles. *Proceedings of the Royal Society London B* 268: 1481-1487.

Broderick, A.C., Glen, F., Godley, B.J. & Hays, G.C. (2002). Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. *Oryx* 36(3): 227-235.

Broderick, A.C., Glen, F., Godley, B.J. & Hays, G.C. (2003). Variation in reproductive output of marine turtles. *Journal of Experimental Marine Biology and Ecology* 288: 95-109.

Carr, A. (1975). The Ascension Island green turtle colony. *Copeia* 1975: 547-555.

Carr, A. & Carr, M.H. (1970). Modulated reproductive periodicity. *Chelonia Ecology* 51: 335-337.

Frazier, J.G. (1982). Status of sea turtles in the central western Indian Ocean. In: *The Biology and Conservation of Sea Turtles* (ed. K.A. Bjorndal). Smithsonian Institution Press: Washington, D.C. pp 385-389.

Hays, G. (2000). The implications of variable remigration intervals for the assessment of population size in marine turtles. *Journal of Theoretical Biology* 206: 221-227.

Johnson, S.A. & Ehrhart, L.M. (1996). Reproductive ecology of the Florida green turtle: clutch frequency. *Journal of Herpetology* 30: 407-410.

Miller, J. (1999). Determining Clutch Size and Hatching Success. In: *Research and Management Techniques for the Conservation of Sea Turtles* (eds Eckert, K., K. Bjorndal, F. Abreu-Grobois & M. Donnelly). IUCN/SSC Marine Turtle Specialist Group Publication No 4, pp 124-129.

Muir, C.E. (2005). The Status of Marine Turtles in the United Republic of Tanzania, East Africa. Report commissioned by the National Tanzania Turtle Committee. 40pp.

Richardson, P.B., Broderick, A.C., Coyne, M.S., Ekanayake, L., Kapurusinghe, T., Premakumara, C., Ranger, S., Saman, M.M., Witt, M.J. & Godley, B.J. (2013). Satellite telemetry reveals behavioural plasticity in a green turtle population nesting in Sri Lanka. *Marine Biology* 160: 1415-1426.

Seminoff. J. (2004). *Green turtle Red List assessment.* <http://www.iucn-mtsg.org >. IUCN Species Survival Commission.

Seminoff, J.A., Zárate, P., Coyne, M.S., Foley, D.G., Parker, D., Lyon, B. & Dutton, P.H. (2008). Post-nesting migrations of Galapagos green turtles, *Chelonia mydas,* in relation to oceanographic conditions of the Eastern Tropical Pacific Ocean: integrating satellite telemetry with remotely sensed ocean data. *Endangered Species Research* 4: 1-16.

Weber, N, Weber, S. B., Godley, B.J., Ellick, J., Witt, M. & Broderick, A.C. (2013). Telemetry as a tool for improving estimates of marine turtle abundance. *Biological Conservation* 167: 90-96.

West, L. (2014). Sea Sense Annual Report. 27pp. http://www.seasense.org/uploads/media/Sea_Sense_2014__Annual_Report.pdf.

West, L. & Hoza, R. (2014). Recognising the regional importance of the central Tanzania coast to marine turtles. *African Sea Turtle Newsletter* 1: 45-47.

