ANTHROPOGENIC AND BIOPHYSICAL FACTORS INFLUENCING THE NESTING CHOICE OF THE GREEN TURTLE (*Chelonia mydas, Linnaeus, 1759*) ALONG THE KENYAN COAST

FRIDAH DERMMILLAH OBARE

(BSC. WIDLIFE MANAGEMENT, MOI UNIVERSITY)

A THESIS SUBMITTED TO THE UNIVERSITY OF NAIROBI IN PARTIAL FULFILMENT FOR THE AWARD OF MASTER OF SCIENCE IN BIOLOGY OF CONSERVATION

SCHOOL OF BIOLOGICAL SCIENCES

NOVEMBER, 2018

DECLARATION

I, Fridah Dermmillah Obare, declare that this thesis, submitted in partial fulfillment for the award of Master of Science in Biology of Conservation, University of Nairobi is wholly my original work unless otherwise referenced and has not been submitted for qualifications at any other academic institution.

Signature……………………………..Date 30th OCTOBER, 2018

Fridah Dermmillah Obare

I56/75191/2014

Declaration by the university supervisor

This thesis has been submitted for examinations with our approval as the university supervisors:

Signature……………………………..Date 21/11/18

Dr. Robert M. Chira

Signature……………………………..Date 20/11/2018

Dr. Dorcus A. O. Sigana

Signature……………………………..Date 30/10/2018

Dr. Andrew Wamukota

Department of Environmental Studies, Pwani University

DEDICATION

This thesis is dedicated to my late brothers Calvin Obare and Bobysands Obare. I will always miss them.

ACKNOWLEDGEMENT

My sincere thanks goes to my supervisors, Dr Robert Chira, Dr Dorcus Sigana and Dr Andrew Wamukota for the immense contribution on this project. I am grateful to Kenya Coastal Development Program for awarding me scholarship to pursue my Master of Science, Kenya Wildlife Service (KWS) granting me study leave so that I can study and do my research in ample time and for the University of Nairobi for accepting my studentship. I would also like to thank KWS staff from Kisite-Mpunguti Marine National Park and Reserve Sergeant Said Shee, and Customer Care Officer Mr Joseph Mutuku; from Mombasa Marine National Park Ranger Susan Mtakai and Coxswain Mr Abdalla Godana, Clerks of Work Mr Patrick Agalomba, Sergeant Mwanapili Hamisi, Corporal Samual Mureithi, Corporal Abraham Songok and Driver Mr Mukulu Hemed; from Watamu Marine National Park and Reserve Ranger Eunice Jira and Driver Mr Vincent Omondi; from Malindi Marine National Park and Reserve Assistant Warden Mr Willys Osore, Corporal Sirya Mtawali and Driver Mr Jackson Tsafwe; from Kiunga Marine National Reserve Sergeant Said Mwangira, Ranger/Coxswain Babanya Ngua and Ranger Derrick Sila for their contribution in the data collection process. I am also thankful to Assistant Director Arthur Tuda, who guided and advised me on my project. His thoughtful contribution made a great impact on my thesis. I am grateful to conservation groups that provided me with historical data they include: World Wild Fund for Nature, Funzi Turtle Conservation, Msambweni Turtle Group, Kinondoni Turtle Group, Baobab Trust, and Community Based Environmental Conservation. I will never forget this unconditional assistance. Lastly, I am thankful to my family members for their continued encouragement and support.

TABLE OF CONTENT

CONTENTS **PAGE**

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

CL	–	Confidence Limit
BMU	–	Beach Management Units
GIS	–	Geographic Information System
GPS	–	Global Positioning System
HWM	–	High Water Mark
IUCN	–	The International Union for Conservation of Nature
KMFRI	–	Kenya Marine and Fisheries Research Institute
KWS	–	Kenya Wildlife Service
LWM	–	Low Water Mark
MPA	–	Marine Protected Area
NEM	–	North-Eastern Monsoon
NGOs	–	Non Governmental Organisations
OMC	–	Organic Matter Content
SEM	–	South-Eastern Monsoon
TED	–	Turtle Excluding Device
UTM	–	Universal Transverse Mercator
WWF	–	World Wide Fund for Nature
CITES	–	The Convention on International Trade in Endangered Species of Wild Fauna and Flora

ABSTRACT

The Green turtle *Chelonia mydas* Linnaeus, 1759 accounts for highest number of sea turtles that nest along Kenya's coastline where there are varying biophysical and anthropogenic factors influencing nest sites that they select to lay their eggs. This study was conducted between February and November, 2016 and it was therefore, designed to establish the relationship between number of nests of *C. mydas* with biophysical and anthropogenic variables. A multiple regression model was employed to assess the factors that contribute to higher number of nest. The multiple regression model did not significantly predict the number of nest, $F_{(8, 22)} = 0.294$, $p > 0.05$, $R = 0.311$. All the variables: vegetation cover, organic matter content, beach width, slope of the beach, number of people, debris weight, sea defence barrier and beach font lighting did not add statistically significantly to the prediction, $p > 0.05$. However, there was decrease in number of nests with increase of organic matter content, b = -8.312, sea defence height b = -3.155 and beach front lighting b = -2.154. Anthropogenic factors thus, had the greatest negative impact on number of nests. Nonetheless, nesting of *C. mydas* was observed to occur across different spectrum of human disturbance. Some of the uninhabited beaches in Lamu County had high number of annual nests despite high amount of debris per $100m^{-2}$ brought in by waves from other regions, for example, Kitangakikuu had 7kg, KSV had 3kg and Mwanabule had 3kg. The average debris weight was 1.90kg 100 m^{-2}. It is therefore recommend that existing laws should be enforced to control beach development along the Kenyan coast to protect existing nesting areas and long term monitoring should to be put in place to evaluate the impact of human disturbance on the number of nests as a management tools in conservation efforts of *C. mydas*.

CHAPTER ONE: INTRODUCTION

1.1 Background

The sea turtles are arguably the most ancient four legged animal found on the Earth. The oldest fossils of turtles *(Proganochelys)* found in Germany date back to 215 million years during the Triassic period (Net Industries and its Licensors 2015). All the living seven species of turtles are monophyletic of Class Reptilia and Suborder Crytodira. They belong to two families: Family Choloniidae (hard-shelled turtles) consisting of six species: green turtle (*C. mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricate*), olive ridley turtle (*Lepidochelys olivacea*), kemp's ridley turtle (*Lepidochelys kempi*) and flatback turtle (*Natator depressus*) and Family Dermochelyidae consisting only of the leatherback turtle (*Dermochelys coriacea*). Among them, *L. olivacea*, *E. imbricate*, and *C. mydas* nest and forage along the Kenyan seashore. *C. caretta* and *D. coriacea* are rare visitors (Kenya Wildlife Service 2010). *C. mydas* is undoubtedly the most common sighted species making up approximately 90% of the nesting followed by the hawksbill (Okemwa and Wamukota, 2006). It is an endangered species as per IUCN conservation status and listed on Appendix I of the CITES.

In Kenya, data to determine population nesting trends of turtles is not sufficient (National Marine Fisheries Service and US Fish and Wildlife Service, 2007). Turtle nesting, mortality, hatching and incidental catch monitoring data collection is done in key sites along the Kenyan coast by government institutions, local NGOs and Beach Management Units (BMUs) which are community groups registered by Ministry of Fisheries. There is, however, inadequate information of the trends of the *C. mydas* nesting along the Kenya Coast (Okemwa and Wamukota, 2006). This is due to the fact that information of the factor affecting turtles nesting site is missing, inadequate or not harmonised hampering conservation and management efforts (The IUCN SSC, 1996). For any meaningful conservation and management ventures of *C. mydas* it is important to understand their demographic parameters. Often, these are difficult to estimate owing to the long term research and complexities of their life cycles. The growth rate of turtles is very slow and differences are observed in maturity age which ranges 15-50 years (Seminoff, 2004). Since sea turtles have wide-ranging migratory patterns and thus require international cooperation to ensure their survival.

1.2 Statement of the problem

C. mydas nesting thrive in areas that possess specific beach qualities such as gentle slope, moderate vegetation cover, absence of barriers and pollution, medium sized sand particle, darkness and minimum human disturbance (Mortimer, 1990). However, the Kenyan beaches has been affected significantly by anthropogenic activities along the coastlines impacting negatively on this critical habitat to *C. mydas* life cycle. Additionally, there is inadequate information on the nesting site ecology leaving institutions mandated to manage these animals without proper baseline for making decisions to conserve and protect them. This study serves to investigate the temporal and spatial distribution of the *C. mydas* nesting and factors which support or hinder nesting along the Kenyan coast and thereafter recommending management interventions to conserve and protect the nesting sites.

1.3 Justification

In seeking to find the ‘global research priorities’ for turtles, five important categories were identified as follows: reproductive biology, biogeography, population ecology, threats and conservation strategies. In ‘reproductive biology’, the three research question of paramount significance included finding the factors that underpin nest site selection and behaviour of nesting turtles, the primary sex ratios being produced and how they vary within or among populations and species and the factors that are important for sustained hatchling production (Hamann *et al.,* 2010). Turtle nesting sites is thus a critical habitat to the survival of turtle populations and in their life cycle. An assessment of the distribution and status of critical habitat and the protection of such habitat from both current and anticipated threats is crucial to the conservation of turtles. This is because management decisions must include precise assessment of population size, including a determination of whether populations are stable, increasing, or declining. (Eckert *et al.,* 1999). A Marine Turtle Conservation Strategy and Action Plan for the Western Indian Ocean (The IUCN SSC, 1996), in which the Sodwana Declaration emerged, tasked Kenya to identify nesting and foraging habitats so as to assess, monitor, and regulate fisheries impacts because such information was lacking. The proceedings of marine conservation workshop also identified information gaps on turtle conservation which included inadequate data and information on population status and structure of turtles and underestimation of the nest numbers due to incomplete coverage of nesting beaches (Okemwa *et al.*, 2004). Additionally, sea turtle strategy (Kenya Wildlife Service 2010), identified factors that make turtles vulnerable such as slow growth rates, resulting in high vulnerability to predation and low recruitment rates from juvenile to adult life stage. Turtle populations cannot endure current levels of egg collection by humans as well as incidental or intentional mortalities due to fisheries. They are generally nest-site specific making them vulnerable to anthropogenic threats. Turtles can also be trans-boundary making them vulnerable where international laws to protect them are not enforced. One of the objective of this strategy was to ensure sustainable management and conservation of turtle in which one of the activities tasked to KWS is to collect and collate existing information on distribution, mortalities and nesting of turtles.

1.4 Hypothesis

Anthropogenic and biophysical factors influences the number of nest of C. mydas along the Kenyan coast.

1.5 Objectives

1.5.1 Overall Objective

1. To find out the biophysical and anthropogenic factors influencing nesting of *C. mydas* in coastal Kenya.

1.5.2 Specific Objectives

1. To identify and geo-reference nesting sites of *C. mydas* in coastal Kenya.
2. To characterise biophysical factors influencing nesting sites of *C. mydas*.
3. To identify the anthropogenic threats to nesting site of *C. mydas.*
4. To compare the hatching success of *in situ* and *ex situ* incubated eggs of *C. mydas* in coastal Kenya.

CHAPTER TWO: LITERATURE REVIEW

2.1 General overview of sea turtles

Sea turtles (turtles) are easily recognised by their morphological and anatomical characteristics. Cheloniidae are characterised by the carapace, inframarginal scute patterns and numbers, scales on the head and the numbers of claws on the flippers. The prefrontal set of scales are used in species identification. Leatherbacks have five dorsal ridges running along the length of the carapace. They do not have the distinctive head scales found in other turtles as adults and keratin covering on the jaws is at minimum. The primary scutes used as key features are the marginals, laterals (costals), vertebrals, nuchal, and the inframarginal or bridge scutes. The plastron (bottom shell) also has distinct scute patterns. From posterior to anterior, they include: the anal scutes, femoral, abdominal, pectoral, humeral, gular and the intergular, as shown in Appendix I (Eckert *et al.,* 1999).

Turtles are not confined in any ocean basin and appear to exhibit migratory behaviour at different times in their lives. The olive ridley and leatherback turtles are designated as vulnerable, loggerhead and green turtles as designated as endangered, hawksbill and kemp's ridley are designated as critically endangered while flatback turtle is designated as data deficient by the IUCN. The life history of turtles is essentially the same with various deviations among the species. After the turtles eggs have hatched on the nesting beach, the hatchlings embark on the journey to the ocean (Ackerman, 1997). The green, hawksbill and loggerhead enter a pelagic phase, the flatbacks remain in coastal waters while the habitats of ridleys and leatherbacks remain unknown (Eckert *et al.,* 1999). The '*development stages of turtles*' implies the portion of the life cycle between the epipelagic stage that follows hatching and the occupation of an adult foraging range (Carr and Caldwell, 1956). It includes the benthic development habitats followed by adult resident habitat (foraging range) and afterwards nesting habitats which is between the foraging range and the nesting beach (Meylan *et al.,* 2011). Reproductive migration is the best documented during nesting as the female can be easily tagged at the beach the male turtles spends their entire life on water after the initial journey to the sea (Eckert *et al.,* 1999).

Green turtles are distributed globally and found in subtropical to tropical seas, they nests in over eighty countries globally (Marine Turtle Specialist Group, 2004). The green turtles' nesting, hatching and emergence success are affected by many threats including intentional harvest (or poaching), incidental impacts diseases (Marine Turtle Specialist Group, 2004) and habitat degradation. They are largely considered as a flagship species and are on the forefront of conservation ventures. Therefore, creating of a regional GIS database with specific habitat characteristics of key nesting sites is of high significance in managing conservation efforts (Okemwa *et al.,* 2004). The information on the trends of nesting of green turtle is crucial in helping in managing of the beaches where the turtle nest.

2.2 Ecology and behaviour of *Chelonia mydas*

C. mydas are the largest of the hard shelled turtles and the second largest of the seven species of sea turtle. An adult measures from 95 to 120 cm in carapace length and can attain weight of 150 kg while the hatchlings are about 5 cm in shell length weigh about 26 g (Eckert and Abreu-Grobois, 2001). The ventral surface is white and dorsal surface is black, they are, however, called 'green turtle' because their adipose tissue is green owing to sea-grass diet. The distinguishing characteristics of the green turtle from other sea turtle species is the four pairs of lateral (or costal) scutes on the smooth carapace and a single pair of elongated prefrontal scales between the eyes (Appendix I).

2.2.1 Distribution and life history

C. mydas was once an abundant species in tropical and subtropical region of the world but current population are remnants of what was found historically. It is currently listed as endangered by IUCN implying that they have declined by greater than 50% of its population over the last three generations (Seminoff, 2004). Globally, *C. mydas* occurs in over 140 countries and nesting occur in over 80 countries. The nesting rookeries with more than 500 nesting females per year are found at Ascension Island, Australia, Brazil (Trindade Island), Comoros Islands, Costa Rica (Tortuguero), Ecuador (Galapagos Archipelago), Guinea-Bissau (Bijagos Archipelago), Esparces Islands, Indonesia, Malaysia, Oman, Philippines, Saudi Arabia, Seychelles Islands, Suriname and United States (Hawaii), (National Marine Fisheries Service and US Fish and Wildlife Service, 2007). Kenya is estimated to have 200 – 300 females nesting annually between the periods of 1999 – 2004 but there was insufficient data to determine the trends of the population (Okemwa and Wamukota, 2006). Nesting occurs along the entire coastal region including the shores of Kwale, Mombasa, Tana River, Kilifi and Lamu counties. The green turtle makes the most sightings of turtles that come to nest and forage along the Kenyan coastal shores (Okemwa and Wamukota, 2006).

The general life history of *C. mydas* begins when the female turtle laying around 100-200 eggs which incubate for a period of 50-70 days (Hirth, 1980) at the beach. The hatchling make their initial journey to the sea, they enter into epipelagic stage which is then followed by a benthic developmental habitat further to adult resident habitat (foraging range) and thereafter to inter-nesting habitat (Carr *et al.,* 1978). However, other studies have found that life cycle models for cheloniid turtles reflect overlap between benthic developmental habitat and other stages of the life cycle (Meylan *et al.*, 2011). Due to complexities of life history of turtles, they present unique challenges in conserving and managing their population because their ecological patterns have not been adequately revealed. Figure 1 shows the generalised life-cycle of turtle.

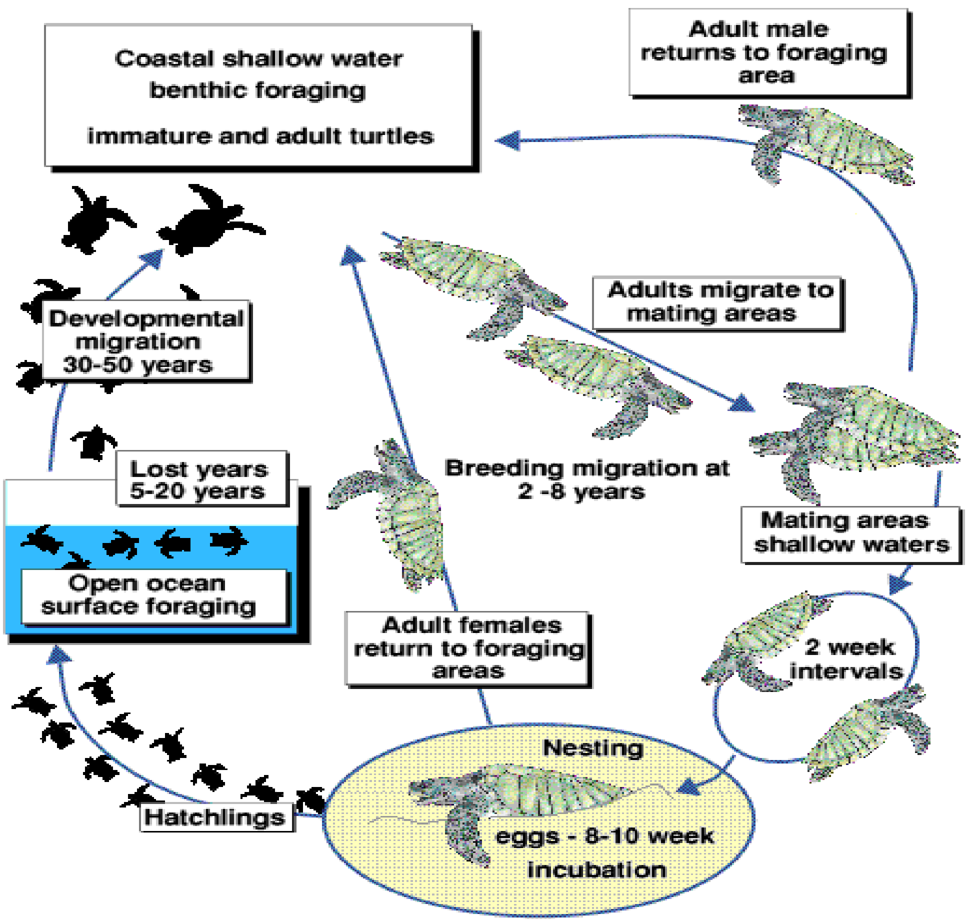


Figure 1: Generalised life cycle of the sea turtle

2.2.2 Foraging, respiration, resting, mating and courtship behaviour

Understanding the diet and foraging behaviour of sea turtle is fundamental to their conservation. Information on the diet can help identify important food resources and give guidance on decisions regarding the management of endangered green turtle populations foraging grounds. *C. mydas* primarily feed on the leaves and rhizomes of sea grasses and sometimes on algae (Ross, 1985). The breeding grounds of some populations of Chelonia is well documented since they are herbivorous and gather to forage where there is adequate cover of sea-grasses making them vulnerable to exploitation. Foraging grounds are usually far from nesting areas but they have a significant influence on population dynamics of *C. mydas* impacting on the numbers of turtle that come to nest (National Marine Fisheries Service and US Fish and Wildlife Service, 2007).

C. mydas often engage in vigorous activity like diving for extended periods. They breathe air thus implying that they have a respiratory system which should meet their energy demands. Sea turtles breathe by a distinct rush of air where the neck is arched, elevating the head and a rapid, audible expiration occurs, followed by a rapid inspiration, and finally a respiratory pause of variable duration held in the end-inspiratory position. This pattern permits a turtle in water to minimise the duration of its mandatory stay at the surface while breathing (Jackson, 1985). Turtles can sleep or rest underwater for couple of hours, however, while diving for food or to escape predators, they submerge in water for a short time. This explains the reason turtles drown in shrimp trawls and other fishing gear within a relatively short time because their breath-holding ability is affected by activity and stress (MarineBio.org, 2013).

There are few studies that indicate courtship and mating behaviour of *C. mydas* in wild. However, captive studies have shown that mating behaviour is similar to that is observed in the wild, females reared in the farm become sexually mature at a minimum of 8 to 9 year of age (Wood *et al.,* 1980) while in the wild there is considerable wide age range on the maturity of green turtle. *C. mydas* nest all year round and there significance difference relationships between the mean size of nesting females and the mean size of eggs and the (Hirth, 1980). mtDNA studies show that female green turtles have a strong propensity for nest-site fidelity, returning repeatedly to the same nesting beach to lay their eggs (Allard *et al.,* 1994).

2.3 Nesting preference of *Chelonia mydas*

Animals that do not provide parental care have to ensure that considerable number of their offspring survive to the next generation to keep their species in existence. Thus, natural selection favours individuals who choose resources that enhance fitness of their offspring. Nest-site selection can thus be defined as the placement of eggs by females at sites that differ from random sites within a delimited area (Wilson, 1998). The nesting site that a female choose will determine the successful emergence of hatchlings. Habitat features which determine successful nest site selection are important in conservation and management of a particular species.

Direct counts of *C. mydas* during foraging are not practical. The only approach to population assessment that can give good estimates since reproductive homing is very strong in Chelonia is to count tracks, nests, or female turtles on nesting beaches (Carr, 1980). The nesting beach provides a narrow but crucial temporal period of opportunity for studying reproduction and nest biology. Species-specific differences are found in variables such as nesting habitat preference, nesting strategy, size at first reproduction, average clutch size, and details of the nest size and construction (Ecker *et al.,* 1999). Even though female *C. mydas* comes to lay eggs at natal beach (Allard *et al.,* 1994; Carr, 1980) the choice of a particular nesting site is determined by various abiotic and biotic factors (Wilson, 1998). These factors mostly influence mortality of hatchlings and sex rations. The female green turtle bank on safe and health beaches with intact dune structures, native vegetation, and normal beach temperatures for nesting (Ackerman, 1997).

2.3.1 Biophysical factors affecting nesting-site selection

2.3.1.1 Intertidal Zone

Refers to the area between high and low tide as shown on Figure 2. Majority of nest sites are found 12-40 m from HWM (Venkatesan *et al.,* 2004). Water is an important factor in determining turtle egg mortality due its semi-permeability properties. Placement of nests within HWM increases the prospect of inundation and egg loss by erosion whereas placement of nests farther from HWM increases the probability of predation on nesting females, eggs, and hatchlings, desiccation of eggs and hatchling misorientation, on their initial journey to the sea (Bjorndal *et al.,* 2000). Females that place their nests a long distance from the HWM, and hatchlings emerging from these nests and moving towards the sea, incur greater energy expenditures and risks than those associated with nests located nearer to the sea. However, it was found that there was no significant difference in the distances away from sea between observed nests which were destroyed by predators and those that were not destroyed (Congdon *et al.*, 1983). The Figure 2 shows a typical beach profile (Sverdrup 1942).

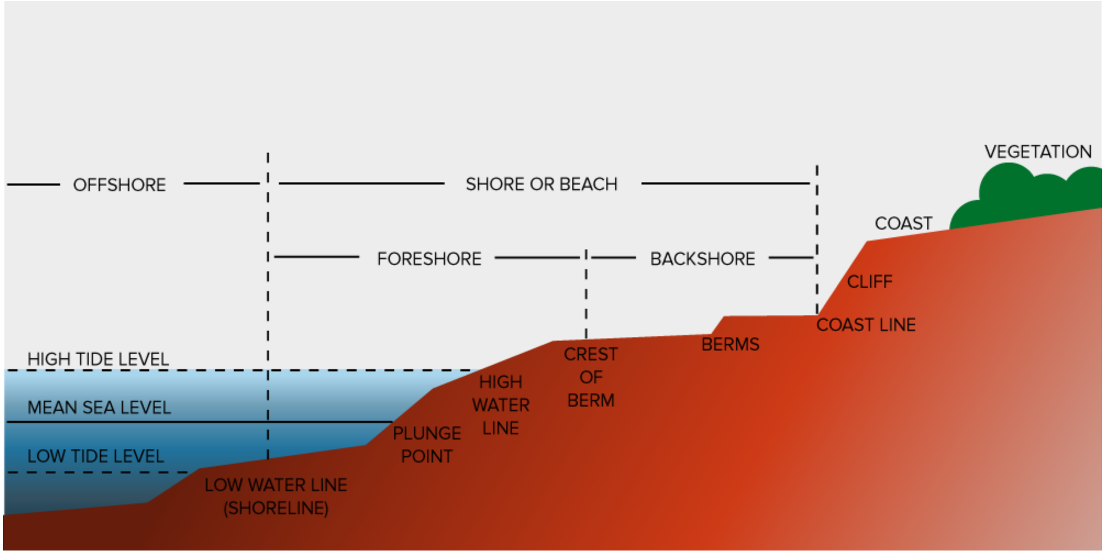


Figure 2: General profile of a sandy beach

2.3.1.2 Vegetation

Sand dunes are formed where sandy shores dry out and sand grains are blown inland and survive on continued supply of sand. They support specialised plant species and some biological communities which are confined to this habitat. Sand beaches are important in influencing nesting site choice of *C. mydas* which tend to nest in vegetated areas behind open sea (Whitmorec and Dutton, 1985). Vegetation overstory cover on sand dunes reduces the mean temperature of the microhabitat and thus influencing the sex ratios of resulting hatchling with a male bias (Janzen and Weisrock, 1999). However, it was found that low correlations between nest-site characteristics and hatchling sex ratio suggesting that a simple pattern of selection of successive nest sites would not result in a correspondingly simple response of hatchling sex ratio (Brooks and Ronald, 1987). Nest-site characteristics, weather in a given year, hatchling survival and threshold temperatures all interact to produce the hatchling sex ratio.

2.3.1.3 Soil texture

C. mydas dig in the beach sandy soils to create caves that they use to lay in eggs. Soil is made up of solid particles, organic matter, liquid (water), gas (air) and organisms which are important in embryo development and determining the survival of the hatchlings. The solid component in the soil is made up of mineral from parent material (sand, clay and silt) and organic components consisting of plant and animal residues that have decomposed (Gachene and Kimaru, 2003). Soil texture refers to the relative proportion of stone, gravel, sand, silt and clay in a specified quantity of soil. Soil texture determines soil workability, water-holding capacity, soil structure and nutrient retention. Compared to sandy soils, clay soils hold more water and retain nutrients (Gachene and Kimaru, 2003). Sand particles are 2.00-0.05 mm in diameter, silt 0.050-0.002 mm and clay <0.002 mm. *C. mydas* can tolerate a variety of soil particle size if suitable nest site is not encountered (Chen *et al.,* 2007). Studies in Ascension Island show that the median number of trial nest holes dug per nesting emergence and the mean particle diameter of the beach sands are positively correlated. Thus, turtles do not construct suitable nest in coarse and dry sand. Sand texture and mineral composition were the properties most obviously correlated with clutch survival. The relationship between the average total survival of hatchlings and the sorting coefficients and mean particle diameters shows lowest survivorship of the most poorly sorted sand (Mortimer, 1990).

2.3.1.4 Beach parameters

Beach parameters crucial to *C. mydas* nesting site preference include beach slope, beach width and beach obstacles (open access). Beach slope is the incline of the foreshore or beach face representing the natural inclination of the sand on the beach face, which is the zone of highest wave action (Zarate *et al.*, 2013). The gradient of the beach will determine the distance a turtle must crawl overland to reach a nest site. *C. mydas* avoid beaches behind mud banks that become partially exposed during low tide (Mortimer, 1981). Experiments conducted on East Coast of Florida, USA showed that in *C. mydas* hatchling slope cues may contribute weakly to orientation during sea-finding. Hatchlings showed significant orientation down slopes of 1-10° (Salmon *et al.,* 1992). Beach width determines the amount of space of the beach available for sea turtle nesting (Varela-Acevedo *et al.,* 2009; Mortimer, 1981). Open access, refer to the percentage of the length of the beach free of obstacles in the intertidal zone (Zarate *et al.,* 2013). Heaviest nesting occurs on beaches with open offshore approaches and foreshores relatively free of rock clutter (Mortimer, 1981) thus *C. mydas* prefer nesting sites without obstacles.

2.3.2 Effects of anthropogenic activities to nest-site selection

Humans directly affect the nesting sites of turtles through poaching and incidental by-catch during fishing, habitat modification, beach front lighting of the beach and pollution. Presence and behaviour of tourists on the beach during *C. mydas* nesting season resulted in disruption of nesting turtles. Days of high tourist concentration correlated with the times that a third fewer turtles came to the beach (Lopez *et al.,* 1994).

2.3.2.1 Poaching and Incidental by-catch

The Bajun Community in Kenya are seafaring and have highly developed techniques for turtle fishing because they have a turtle eating culture (Frazier, 1980). Turtles (especially green turtle) have been an important resource to this coastal communities for a long time but due to overexploitation their populations have dwindled warranting protection. Female turtles come to lay eggs at the beach. Turtles are excellent swimmers but very clumsy on land making them very vulnerable to poaching.

The Wildlife Conservation and Management (Amendment) Act, 2019 proposes high fines and long prison sentences to those found guilty poaching endangered species. The effect of the legislation to deter poaching has not yet been realised. The Act defines poaching as the illegal hunting, capturing and harvesting of any wildlife. Poaching of the female *C. mydas* at the beach and the laid eggs affects the population dynamics of the species because it interferes with recruitment of new individuals to the population.

The review of global bycatch of turtles reveal that just over 85,000 marine turtles were taken as bycatch in gillnets, longlines, and trawls globally from 1990 through 2008 (Wallace *et al.,* 2010). The study further highlight trends in magnitude of bycatch and potential population with longlines more likely to have a greater impact than gillnets on turtle populations. *C. mydas* populations have decreased throughout their range in the region. Turtles have been captured for their meat and have become bycatch in the ever increasing intensity of fishing effort. Reasons given for poaching include: high returns compared to fishing, lack of adequate law enforcement and ease of escape in the sea. Fishers' decision to catch green turtles is highly dependent on the demand from dealers and or trusted customers, as well as the presence of the turtles at their local fishing grounds (Mancini *et al.,* 2011).

In Kenya sources of mortality of turtles is related to all its life stages from egg predation, nesting inundation and poaching being the main threats on the beach (Bourjea *et al.,* 2008). The mortality as a result of fishing bycatch in Kenya is high.

Data collected by KESCOM's Turtle Conservation Groups indicates that 85% of captured turtles incidentally in artisanal and commercial fishing are either slaughtered for local consumption or traded. The national monitoring program estimates that 10% (in areas with efficient monitoring programs) to over 50% (in areas with none or inadequate monitoring programs) of nesting females and nests are poached annually (FAO, 2009).

2.3.2.2 Marine pollution and debris disposal

The global debris patches contain 200 million tons of floating debris in the oceans (Parker, 2014). Marine pollution deteriorates the habitat of turtles affecting them directly or indirectly. Some of the most dangerous ocean pollutants include fertilizers from inland farms, toxic metals and chemicals discharged by manufacturing industries, PCBs, untreated waste, and a variety of fossil fuel products. Mombasa, for example, does not have a working sewage system and all sewerage waste are deposited into the Indian Ocean. Hotels along coastal shores sometimes release waste water on beaches which has direct impact on the nesting sites of turtles. Public beaches in Mombasa are heavily visited especially during holiday season. Tourist visiting the beach discard plastic debris which is one of the sources of debris which are ingested by *C. mydas*. Bugoni *et al*, (2001) reported that anthropogenic debris ingested was as much as 60.5% of the *C. mydas* under analysis and they also had highest ingestion of oil spill among the turtles. Marine debris sources are from ships and inland via rivers and storm water. The amount of plastic debris among litter increases with distance from source areas because they transport more easily than do more dense materials such as glass or metal and because they last longer than other low-density materials such as paper (Ryan *et* *al.,* 2009). Besides being ingested, marine debris can cause entanglement of marine species impacting on their swimming abilities and sometimes killing them.

2.3.2.3 Beachfront lighting

The beaches of Kenya are dotted with hotel and residential structures especially in Diani, Mombasa, Watamu and Malindi. Lighting is one of the visual cues that turtle hatchlings use to orient towards the sea (Salmon *et al.*, 1992). Therefore, lighting from hotels and residential flats along the beach disorient the hatchlings and increase their mortality by predation, desiccation and other factors. In order to maintain stable age-structure and population size for turtles, hatchling survivorship should be a key management and conservation goal. Turtle nesting activities increases when beach is darkened (Witherington and Martin, 2003). Other experiments with turtles indicate that normal orientation of the hatchlings (sea-finding), disorientation, and mis-orientation are graded responses correlated with different degrees of co-occurring natural and artificial visual stimuli (Tuxbury and Salmon, 2005).

2.4 Management interventions on protecting nesting sites

The most significant hurdle to conservation of turtles is due to lack of adequate resources, ignorance on the ecological (or conservation) status of turtles and insufficient commitment to turtle conservation. Turtles in Kenya face myriad of threats, including poaching for consumption, predation, incidental capture in illegal fishing gears, loss of nest sites through destruction by coastal development and habitat degradation through pollution. Turtle conservation and management strategies are challenging due to their complicated life cycle and migratory nature. Turtle occupy various ecosystem in their lifetime and protection of these habitats are key to their survival. The critical habitat of turtle is nesting site where the female turtle come to lay eggs.

The Wildlife Conservation and Management (Amendment) Act, 2019 has mandated KWS to protect, manage and conserve wildlife in protected and non-protected areas. Despite the various laws that protect *C. mydas*, poaching is widespread. To reduce poaching enforcement of existing environmental laws is crucial together with raising awareness to inform fishers on the ecologically importance of sea turtles so that they can understand direct economic benefits from non-consumptive uses of turtles (Mancini *et al.,* 2011) or alternative source of livelihood. There are other laws which regulates pollution such as the Environmental Management and Co-Ordination Act, 1999 even though there is rampant pollution of marine ecosystem and the Survey Act Cap. 299 which prohibits constructing or development of the beach a distance of 60m from HWM. However, many facilities have been placed very close to the beach with various structures being constructed past the HWM.

Turtles can become entangled in fishing gear and drown or suffer serious injuries to their flippers from constriction by the lines or ropes and can also hook turtles in the jaw and oesophagus. Also, trawls that are not fitted with turtle excluder devices (TEDs results in mortality through drowning because they do not allow turtles to escape (FAO, 2009). Kenya legislated the mandatory use of TEDs in the shrimp trawl fishery in 2001. However, implementation has not been effected because of lack of surveillance and inadequate penalties (FAO, 2009).

Turtles are affected by artificial lighting at the beach. Their visual cue is impaired and thus become disoriented as they embark on their initial sea finding journey.

Experiments demonstrate that if the cues promoting normal orientation are enhanced, sea-finding will occur even in the presence of artificial lighting at the beach. Thus, restoration may not require controlling all sources of artificial lighting. This can be achieved by light management (controlling as many lights as possible) together with sand dune restoration to increase silhouette darkness and or elevation to enable the turtle hatchlings to find the sea. (Tuxbury and Salmon, 2005).

It is important to engage the public and to educate them on the dangers of inappropriate disposal of plastics and how they affect turtle in general. Legislation and regulation on pollution should be enforced to minimise debris brought in from inland. There is, however, a huge challenge in managing the debris because the garbage is spread over vast areas and it is made up mostly of micro-plastic and degraded plastic, broken down by sunlight, other elements and waves into tiny bits the size of grains of rice (Parker, 2014).

2.5 The Kenyan Coast

The monsoon winds of the Indian Ocean influences the tropical climate of Kenyan coast. Two distinct monsoon periods occur, the NEM (locally known as Kaskazi), which blows from September to February and the SEM (locally known as Kusi) which blows from March to August. The NEM usually brings calm weather, is usually hot, and wave height drops during this time. The SEM are usually windy with cool temperatures and rough seas. Long rains occurs from March to May and the short rains from October to December between the monsoon periods. The average annual rainfall ranges from 508 mm in the drier hinterland in the north to 1,150 mm in the wetter southern areas. Wind strength falls during the night and increases during the morning. Highest average wind speeds are recorded between May and September (9.3-9.8 knots). Average maximum temperature in Mombasa ranges from 28-32^{o} C, with highs between January and March and lows in July and August. Average minimum temperature in Mombasa ranges from 21^{o} C in July and August to 24^{o} C between February and April (UNEP, 1998)

2.5.1 Oceanography

Four oceanic currents majorly influence Kenyan coastal waters. They include the Somali Current, the East African Coastal Current, the Equatorial Counter Current and the South Equatorial Current. The westward moving South Equatorial Current splits into two once it reaches the African coast at Cape Delgado: the Mozambique Current which moves southwards and the East African Coastal Current which moves north-eastwards, along the coast. The East African Coastal Current moves towards north all through the year round reaching even Malindi. During the Southeast Monsoon it continues to move past Malindi northward joining with the Somali Current and continues right to the Horn of Africa. Depending on the strength of the monsoon, the northern extent of the East African Coastal Current meets and joins the southern flowing Somali Current meeting between Malindi and north of Lamu. The two watercourses then turn toward the east and flow offshore as the Equatorial counter current (Okoola, 1999). Under the influence of the monsoon, the Somali Current reverses its direction of flow towards south-westerly direction at about 1.5 to 2 knots during the Northeast Monsoon while in the Southeast Monsoon, it reverses its flow and surges its velocity to around 2-2.5 knots (UNEP, 1998). The Maximum tidal variation at Kilindini is not more than 3.8 m. During neap tide, the tidal range for Malindi is 2.0 m and 2.9 m for spring tide. There is tidal lag state and varies with distance along the northward of Kenyan coast in which Malindi is 5 minutes behind Kilindini while Lamu is approximately 40 minutes behind (UNEP, 1998).

2.5.2 Flora at the Kenyan coast

Marine beaches and dunes occurring in Kenya normally consist of plain sand dunes covering a total area of 27,000 ha. They are partially vegetated by specialised colonising plants with woody vegetation occurring in some beaches. The commonly observed plants include *Grewia* sp., *Dombeya* sp., and *Balanites* sp. which can form dense bush of herbaceous vegetation. . *Ipomea pes-caprae*, (Appendix IV) forms a dense mat towards the sea above the HWM (UNEP, 1998). Common tree species include, *Hyphaene compressa* Gaertner, 1774, *Hyphaene coriacea* Gaertner, 1774, *Garcinia livingstonei*, T. Anderson, *Afzelia quanzensis* Welw and *Euphorbia candelabrum*, Trémaux ex Kotschy.

2.5.3 Mangroves

There are nine mangrove species along the Kenya coast, none of which are endemic to Kenya. The mangrove ecosystems coverage was approximately 53,000 ha with 70% occurring in the Lamu area (second largest on the East African coast) and the Gazi Bay-Funzi coastal system near the Kenyan-Tanzanian border (ASCLME, 2012). Smaller mangrove areas occur in the mouths of seasonal coastal rivers, as well as in creeks such as Tudor, Port-Reitz, Kilifi and Mida (ASCLME, 2012). Dodori River in Lamu County and its delta, has some of the densest, most varied assemblage of mangrove forest species in Kenya. The red mangrove, *Rhizophora mucronata*, Lam, and *Avicennia marina*, (Forssk.) Vierh. are the most common found along the entire Kenyan coast. The only species found in a small patches at the Tana River estuary near

Kipini is called *Heritiera littoralis,* Dryand. *Xylocarpus moluccensis* (Lam.) M. Roem. have been found in the Kiunga and Shimoni areas (GoK, 2017). Some biotic factors and coastal geomorphology play a role in the zonation of mangroves of Kenya which exhibit the pattern of mangroves in the Western Indian Ocean, occuring at the outermost edge on the seaward side is *Sonneratia alba* Sm. and *Rhizophera mucronata*, in the intermediate levels is *Ceriops tagal (Perr.)* C.B. Robinson, followed at the higher shore levels zone by an *Avienna marina* and lastly followed with the highest landward zone by *Lumnitzera racemosa* Willd., which usually occurs as a narrow fringe behind the *Avicenna marina*. The other species, *Bruguieria gymnorrhiza* (L.) Lam. occurs above the *Rhizophora* zone, while *Xylocarpus granatum,* Koen. is mostly found well above the Avicennia levels. Kenyans have traditionally harvested mangrove trees or parts of it. Mangroves forest have been cleared for salt generation and prawn farming in Kilifi County. Loss of mangroves since pre-agricultural times has been tremendous, however, estimates of the area of mangroves coverage have remained constant over the past twenty years. Mangroves are critical habitat for a diverse of terrestrial and aquatic flora and fauna that sustain coastal livelihood. The animals includes birds, reptiles, mammals and insects (UNEP, 1998). However, threats to mangrove include overharvesting for fuel and timber; clearing and conversion to other land uses such as agriculture, aquaculture, urban development, tourism and salt production; pollution; sedimentation and changes in river flow include pest infestation, El Niño events and climate change-associated factors such as sea level rise, excessive flooding and increased sedimentation are the atural factors that contribute to mangrove decline (UNEP-Nairobi Convention and WIOMSA, 2015).

2.5.4 Seagrass beds

Seagrass beds occur along the Kenyan coastline next to or connected with coral reefs. They are an important habitat for many species of fish, octopi and holothurians. Many of these species are of commercial importance (Torre-Castro and Ronnback, 2004). Endangered species such as the *Dugong dugon, Eretmochelys imbricate* and *C. mydas* feed on seagrass beds. Seagrass bed trap sediment keeping coastal beaches pristine. In Kenya seagrass beds cover a surface area of about 3400 ha, in which the most important sites being in Diani-Chale Island, Mombasa, Malindi and Kiunga (ASCLME, 2012). Twelve species of seagrass have been documented in Kenya, none of which are endemic. The most abundant species are *Cymodocea ciliate,* (Forssk.) Hartog and *Thalassia hemprichii* (Ehrenb. ex Solms) Asch. which are rooted firmly in the hard substrate covered by sand and can tolerate high wave action. *Cymodocea. ciliata* thrive in open sea and it reaches its maximum development in areas where it is not exposed during low tide. *Thalassia hemprichii* occur in sheltered places where it may root to considerable depth. Its growth becomes affected in areas where it is uncovered during low tides (UNEP, 1998). These two species are common even though they are less conspicuous because of their smaller size. *Enhalus acoroides* (L.f.) Royle is found in Wasini Channel, Mida Creek and Lamu area. It grows in deep water away from the open ocean. Its rhizome (Mtimbi in Kiswahili) is edible. *Zostera capensis* Setch. is more common in cold or temperate regions (UNEP, 1998). The major threat to seagrass beds comes from excessive sedimentation of shallow coastal waters resulting from the erosions of coastal and hinterland agricultural lands. Artisanal fishing and commercial trawling activities often concentrated on seagrass beds negatively affecting them. Increased turbidity also reduces light penetration reducing photosynthetic activity of the seagrasses (Ochieng and Erftemeijer, 2003).

2.5.5 Fauna of the Kenyan Coast

2.5.5.1 Coral reef communities

Coral reefs are found along most of the Kenya coast. They occur as fringing reefs, reef platforms, coral lagoons, and coral flats. The total area of coral reef is estimated at 63000 ha with a total of 237 species. *Porites lutea*, *Galaxea astreata* and a broad diversity of species in the genera *Acropora*, *Pocillopera*, *Favia* and *Favites* (ASCLME, 2012) are some of dominant reef species. Other important reef building organisms include calcareous algae, coralline red algae and soft corals. The reef communities in Kenyan coast are comparable to those in other parts of the Western Indian Ocean which are also dominated by *Porites lutea* Milne Edwards & Haime, 1851, and *Galaxea astreata* (Lamarck, 1816) assemblages in calm waters and *Acropora*, *Pocillopera*, *Favia* and *Favites* assemblages in high energy environments (ASCLME 2012; UNEP 1998). Hard coral cover averages between 30-40%, however, the 1997/98 *El Nino* event caused extensive bleaching which resulted in local mortality up to 70%. The complexity of reefs topography creates habitats for various species such as 350 species of fish, 135 species of gastropods, 12 species of echinoids and at least 200 species of algae (UNEP; 1998). Green turtles, whale sharks and large groupers are commonly seen in the deeper waters off the reef edge. The Baensch's Damsel *Pomacentrus baenschi* Allen, 1991 is endemic to East Africa and within Kenya, it has been recorded in Kisite and Mombasa only (UNEP; 1998).

Coral reefs attract tourists and are also important for fisheries, with the tourism industry as one of the main markets for fish products. However, the tourism industry has also created demand for other reef resources such as corals and shells. Many of the species are being over-utilised and the fisheries methods have led to serious habitat damage. Great amounts of coral and shells are still being sold in Kenya despite law enforcement and regulations. These threats, together with sedimentation from rivers draining from mainland agricultural activities and pollution from industries, domestic sewerage systems, mining and oil discharge have affected coral growth. Majority of reef outside the marine protected areas and some in protected areas is degraded (Personal observation, 7th July, 2017).

2.5.5.2 Fishery resources

Fishers use different types of gear including, gill netting spear fishing, seining and gleaning, hook and line and trap on coral reef. The catch includes finfish of the families Lutjanidae (snappers), Scaridae (parrot fish), Siganidae (rabbit fish) and Lethrinidae. Invertebrates exploited in Kenya include: crustaceans e.g spiny lobsters, the deep water prawns and portunid crab species in mangroves. The molluscs are oyster octopus, squids, cuttlefish and snails and echinoderms e.g sea urchins and sea cucumber (ASCLME, 2012). Spiny and rock lobster and sea cucumbers are overexploited, shallow-water prawns, crabs, octopus and bivalves are fully exploited (UNEP-Nairobi Conventiona and WIOMSA 2015).

2.5.5.3 Other fauna

Marine mammals in Kenya include cetaceans and sirenian such as humpback whale (*Megaptera novaenangliae*), minke whale (*Balaenoptera acutorostrata*), bryde's whale (*Balaenoptera edeni*) and toothed whale (*Kogia Sp*) (ASCLME, 2012). Others found in Kenya territorial waters include, sperm whale (*Physeter macrocephalus*), blue whale (*Balaenoptera musculus*) and sei whale (*Balaenoptera borealis*). Dolphin species include the striped dolphin (*Stenella coeruleoalba*), spinner dolphin and spotted dolphin (*Stenella attenuate*), humpback dolphin (*Sousa chinensis*), Risso's dolphin (*Lagenodelphis hosei*), common dolphin (*Delphinus* sp), Fraser's dolphin (*Grampus griseus*) and bottlenose dolphin (*Tursiops truncatus*), (ASCLME, 2012). *Dudong dugon* (Müller, 1776) was last sighted by fisherman in 2009 at Kiunga, Lamu County. Olive ridley turtle (*Lepidochelys olivacea*), hawksbill turtle (*Eretmochelys imbricate*) and green turtle (*C. mydas*) nest and forage along the Kenyan seashore. Loggerhead and Leatherback are rare visitors (Kenya Wildlife Service, 2010). Important Bird Areas (IBAs) in Kenya include Kisite Island which hosts the largest nesting colony for roseate tern (*Sterna dougallii*) in East Africa, Chale Island, Mida Creek, Malindi-Watamu area, Kiunga Marine National Reserve, Sabaki estuary and Tana Delta (ASCLME, 2012).

2.5.6 Demographic and socio-economic characteristics

The estimated growth rate for Kenya is 2.11% with 8% of total population living in coastal region (CIA, 2015) and the 2009 National Census estimated about 3.3 million people lived in the region which covered an area of 82,892.8 km^2. The population is unevenly distributed, around 500,000 people are concentrated in the Mombasa County hosting the main East African port of Kilindini with a density of 4,414 persons/km^2. In comparison, the density of Lamu is 16 persons/km^2 and the population density for the country is 66 persons/km^2 (Kenya National Bureau of Statistics, 2010). The main economic activities in the urban areas is maritime commerce and tourism which is dependent on the rich biological diversity and the health of the environment. Outside the urban areas, the main economic activities include food production, artisanal activities and small retail and service enterprises (*Personal observation, 7th October, 2016*).

CHAPTER THREE: STUDY AREA, MATERIALS AND METHODS

3.1 Study Area

The *C. mydas* nesting site investigation occurred along the Kenya coast (Figure 3). The Kenyan coastline, approximately 600 km long, stretching from 1^0 42' S to 4^0 40' S bordering Somali in the north and Tanzania in the south (UNEP, 1998). The continental shelf covers an estimated area of about 19,120. Fringing reef systems are well developed and are present along the coastline except where Tana and Athi/Sabaki discharge into the Indian Ocean while patch reefs occur around Kiunga and Malindi in the north and Shimoni in the south. Sea grass beds grows in shallow lagoons creeks and bays and usually connected with the reef systems. Mangrove ecosystems are well largely found in the Lamu archipelago making 70% of Kenya's mangrove (UNEP, 1998). Near-shore sub-tidal environments are crucial for recreational services attracting tourist and shoreline stability and reducing acts of natural calamities. Near-shore line also provide goods such as edible invertebrates and fish. Several anthropogenic pressures such as pollution, mining, overexploitation of marine resources and climate change are causing a decline in the integrity of these ecosystems.

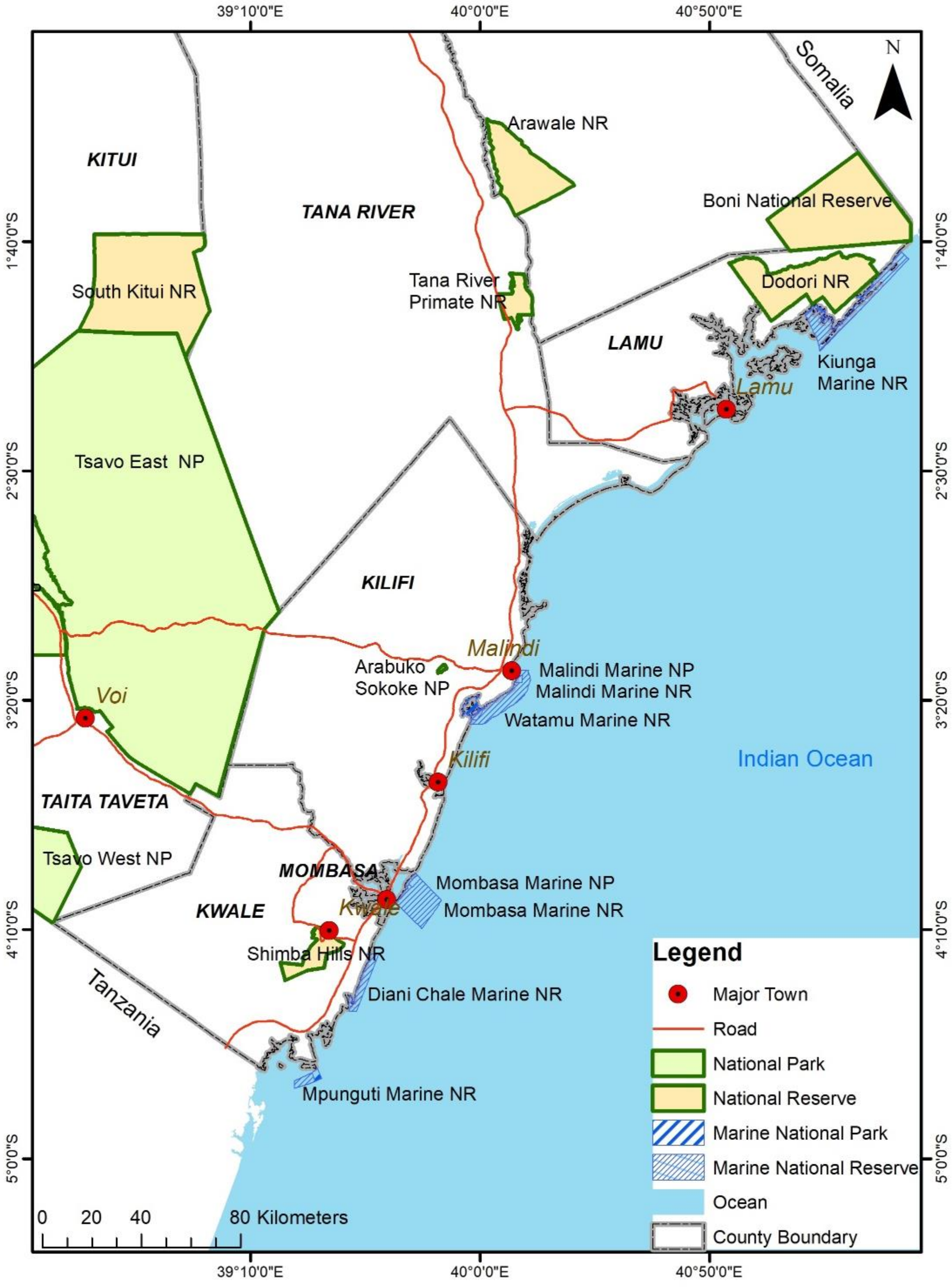


Figure 3: Kenyan coastline showing administrative boundaries and protected areas (Source: KWS)

3.2 Material and Methods

3.2.1 Sampling techniques

The study was conducted in Kwale, Mombasa, Kilifi and Lamu counties from February to November, 2016. A total of 31 turtle nesting areas were investigated using purposive sampling technique. Data for the period of 2014-2016 was used to determine the nesting trends of *C. mydas*. The nesting data was obtained from different organisations and turtle conservation groups. These organisations and community groups collect similar data during beach patrols and work in different beaches along the Kenya coast, for example, KWS (Malindi areas), Watamu Turtle Watch (Watamu area), WWF (Lamu areas), Baobab Trust (Kilifi and Mombasa area), BMU (Kwale areas). The data included number of nest, number of eggs laid and number of hatchlings per nest site. Factors investigated to determine nesting of *C. mydas* were classified as biophysical and anthropogenic. Biophysical factors were vegetation cover, soil texture, organic matter content, high water mark, width of the beach and slope of the beach. Anthropogenic factors were debris weight at the beach, height of sea defence/barriers, number of people at the beach and beachfront lighting. Some of the data collection method were adapted from Sandwatch Manual (UNESCO, 2010) and Nesting Beach Characterisation Manual (Varela-Acevedo *et al.*, 2009). The collected data for the above variables was collected during low tide to allow for proper measurements of the beach variables of the nesting areas. The beaches in which nest-site biophysical factors were investigated were classified into either occurring within protected areas and those not in protected areas. The beaches were further classified into 'vegetated beach' with over 80% vegetation cover, 'beaches with barrier' which may have structures that impede access to the high shore, 'open beaches' with no barrier and has open access and 'beaches under cliff'.

3.3 Biophysical variables

3.3.1 Vegetation cover

This was obtained by use of 1m by 1m quadrat. Three quadrats were randomly established at each sampling location fringing herbaceous foreshore at a nest site. The percentage vegetation cover was determined by what was covered by a perpendicularly projected outline of herbaceous vegetation in the quadrat. For ease in estimation the quadrat was divided in four equal quarters and the percentage vegetation cover was determined by addition of the estimated percentage vegetation cover in all the four quarters of the quadrat. Plant encountered in each quadrat were identified to species level (Abuodha *et al.*, 2003).

3.3.2 Organic matter content

Weight Loss on Ignition method (Agvise Laboratories, 2017) was used to determine the OMC. The beach soil did not require grinding because the sandy soil did not clump. The soil was placed in the oven within the aluminium foil to dry each of the sample at 70°C for 72 hours. The sample was thereafter homogenised and three replicates of 5 g sub-sample were put in a furnace of 450°C for 6 hours. The difference between the initial weight of the sample and final weight of the burnt sample represented the OMC. At 450°C the OMC was converted to carbon dioxide. The three replicates gave a mean for the OMC.

3.3.3 Soil texture

Sieve method was used to determine the soil texture (Gee and Bauder, 1986). Three set of soil samples was collected randomly from the nest site surface and at a depth of 50 cm. The surface soil sample and the soil sample taken from 50 cm depth gave the soil texture analysis of the nest site. The three pairs of collected samples were sealed in a polythene bag and taken to the KMFRI laboratory. Soil texture was determined by first drying each of the sample at 70°C for 72 hours. A sample of 100g was placed on shaker for 10 minutes with sieve of 1.60mm, 1.00mm, 0.710mm, 0.500mm, 0.250mm, 0.125mm, 0.063mm and 0.038mm. The retained sample at particular sieves was placed in a petri dish of known weight and weighed. The weight passing through each sieves was converted into percentages of the total weight.

Table 1: Soil particle size and the respective categories

Soil particle size (mm)	**Category**
1.000 – 1.600	Very Course Sand
0.500 – 0.710	Course Sand
0.250	Medium Sand
0.125	Fine Sand
0.068	Very Fine Sand
0.038	Silt

3.3.4 Width of the beach

This distance was measured from the area fringing vegetation on the shoreline to the LWM (Varela-Acevedo *et al.*, 2009), sampled nesting site being reference point. Second and third replicates of the beach width was measured to get an average estimate of the width. The beach width was measured in metres.

3.3.5 High Water Mark on the beach

High Water Mark (HWM) was the highest point reached by waves on sampling days. It was identified at a beach during low tide, by a line of debris such as seaweed, shells or pieces of wood, or by differences in the colour of the sand between the part of the beach recently wetted by the water and the part that remains dry (Varela-Acevedo *et al.,* 2009). The measurement was not conducted in spring or neap tide. In the neap tide, the beaches are not exposed because the difference between HWM and LWM is least while in spring tide the difference between HWM and LWM is greatest which can led to overestimation of HWM. The HWM beach width was measured in metres. The distance of sampled nest site from the mean HWM was measured. Three replicates were taken to get an average estimate

3.3.6 Slope of the beach

The slope of the beach was measured from the sampled nesting site point to the LWM. The method used is called Emery which was developed by Kenneth Orris Emery (Emery, 1961) as shown in Figure 4 and 5. The equipment consists of two wooden rods of 1.5m connected by a 5m rope or measuring tape. This length sets the measurement interval for individual data points along the profile. Each rod has a measurement scale which runs from 0 to top (negated to indicate the drop in slope) and 0 to the bottom (positive to indicate increase in elevation) of the rod.

The Kenyan coastal beaches slope downward toward the sea, thus the observer sighted on the sight-hole at the zero point to the level of the horizon, and determined the distance (a) from the top of the landward board to the sightline. The measured distance (a) is equal to the distance (b) that the beach has either dropped or risen within the horizontal distance between the boards (Figure 4). This approach was advantageous because the equipment was inexpensive and light hence easily carried across various beaches. Using the data of the beach profiles recorded from the field, cumulative vertical elevations (y- axis) as a function of cumulative horizontal position (x-axis) was plotted. This revealed the actual beach profile. Slope was calculated by dividing the difference in elevation between any two adjacent points by the difference in horizontal distance between those two points. The elevation in degrees was calculated as from cumulated distance against cumulated elevation from the Emery Survey Method. Appendix III illustrates the calculations in Microsoft Excel 2010.

$$\tan \emptyset = \text{cumulated elevation/cumulated distance}$$

$$\textit{thus} \quad \emptyset = \tan^{-1} (\text{cumulated elevation/cumulated distance})$$

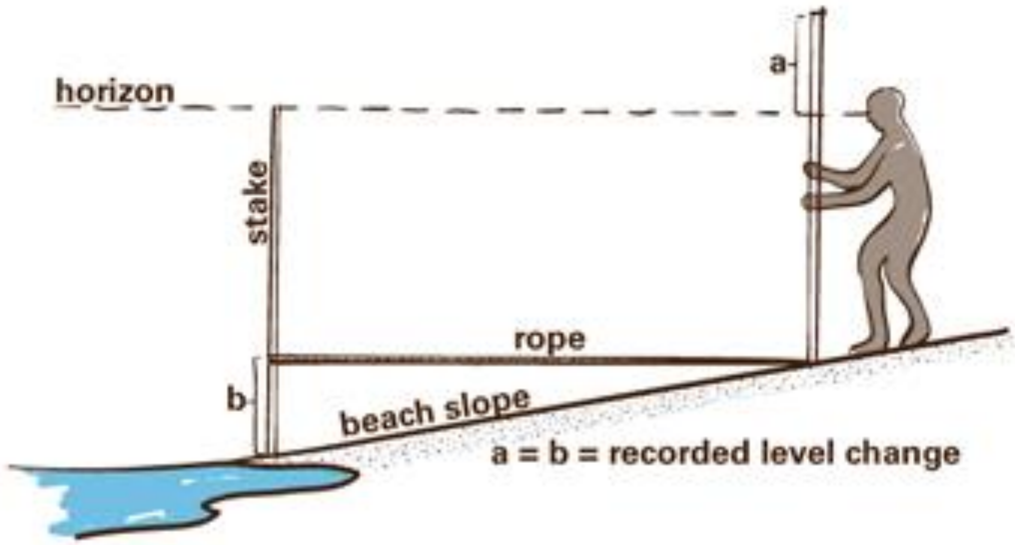


Figure 4: Emery Survey Method (Florida Centre for Instructional Technology, 2005)

Figure 5: Survey wooden rod used for Emery Survey Method (Obare, 2016)

3.4 Anthropogenic variables

3.4.1 Number of people at the beach

It was the first variable that was measured at the nest site. This was done by observing and recording the number of people from either side of the nest site within 100m.

3.4.2 Debris weight

The weight of the debris was determined using a 10m by 10m quadrat at the nesting area. This was done by careful removal of visible foreign debris (such as bottles, polythene bags, clothes) on the beach weighing them on a weight scale. Sea weed debris or any marine biodegradable substance were not considered because they provide food and habitat for various marine species, they also do not harm *C. mydas.*

Debris weight was measured in kilograms (Kgs) using a portable weighing scale.

3.4.3 Sea defence barrier

The presence, location and type of any sea defences was noted on the sampled nesting site. The mean height of the sea defence or barrier was measured and an average of three measurements was taken. Sea defence structures prevent turtle from nest or they make them lay eggs in sub-optimal conditions such as between tides where they could be washed away. The mean height measured in metres of sea wall was estimated by average of three replicates.

3.4.4 Beachfront lighting

The study area with establishments known to have evening and night time operational hours were assessed and the amount and type of lights that shine onto the nesting beach was measured using lux meter. Three measurements were taken per site. Lux (lx) is the SI unit of illuminance and luminance emittance measuring luminous flux per unit area. Light pollution poses a significant threat for sea turtle reproduction. Strong lights with high illuminance deter turtles from coming ashore on suitable nest areas. This measurement determined the ideal illuminance for *C. mydas* nesting areas. This was measurement using Digital Light Meter Luxmeter Lux/FC. The average lux measurement in a nest site was calculated from the replicates.

3.5 Data analyses

Spatial data analysis was conducted using Arc-GIS 10 to map the distribution of *C. mydas* nest sites. GPS Garmin GPS 64s was used to take the UTM coordinates of the nest sites from the field survey while the foraging grounds data was taken by use of aerial survey. The nest site coordinates was taken along the Kenyan coastline from

Funzi Island in South Coast (Kwale County) to Mwongo Sherrif in North Coast (Lam County). *In situ* and hatchery *ex situ* (translocated) incubated eggs were compared using hatching success rate. Hatching success rate was calculated from number eggs hatchling divided by number of eggs as a percentage. The number of eggs laid is normally recorded from counting number of eggs shells after hatchings *in situ* nesting. A t-test was performed to find out the difference in mean of *in situ* and *ex situ* hatched eggs. Correlation was used to find the relationship of number of observed nesting with the biophysical and anthropogenic factors. Pearson Chi-Square was performed to find the association between conservation status of nesting areas and classification of nesting areas, beach type. Multiple Regression Analysis was performed to find the factors which influence the number of nest in 2016. The data was analysed at a confidence level of 95% or $\alpha = 0.05$ using SPSS 23.0.

CHAPTER FOUR: RESULTS

4.1 Identification and geo-reference of *Chelonia mydas* nest areas

Coordinates collected by GPS shows the nesting sites and the foraging areas of *C. mydas* along the Kenyan coast (Figure 6). The 2016 aerial census showed that Lamu coastal line had high foraging populations of *C. mydas* and the highest nesting per annum sightings while those in Mombasa had the lowest foraging population and per annum nesting sightings.

4.1.1 Comparison of conservation status of sampled nesting areas

Most of turtle nesting occurred in areas which were not protected. Areas within MPAs had less nest sightings than those outside protected areas. All the nesting areas in Kwale County were outside protected areas. Kisite-Mpunguti MPA, within Kwale County has rocky beaches which was not suitable for *C. mydas* nesting. In Mombasa, English Point and Nyali South were within the Mombasa MPA and nesting was previously reported to occur but have decreased in recent past due to human activities. In Kilifi County, a large proportion of nesting areas are outside MPAs and those within MPA were found in tourist zones. Watamu Turtle Bay and Watamu Garoda Resort were within Watamu MPA. Malindi nesting area was found to be within Malindi MPA. In Lamu, a large number of nest areas were found within Kiunga Marine Reserve. In 2016 the total number of *C. mydas* nests were 133 (57.83%) in unprotected areas and those in protected areas were 97 (42.17%) along the Kenyan Coast (Figure 7).

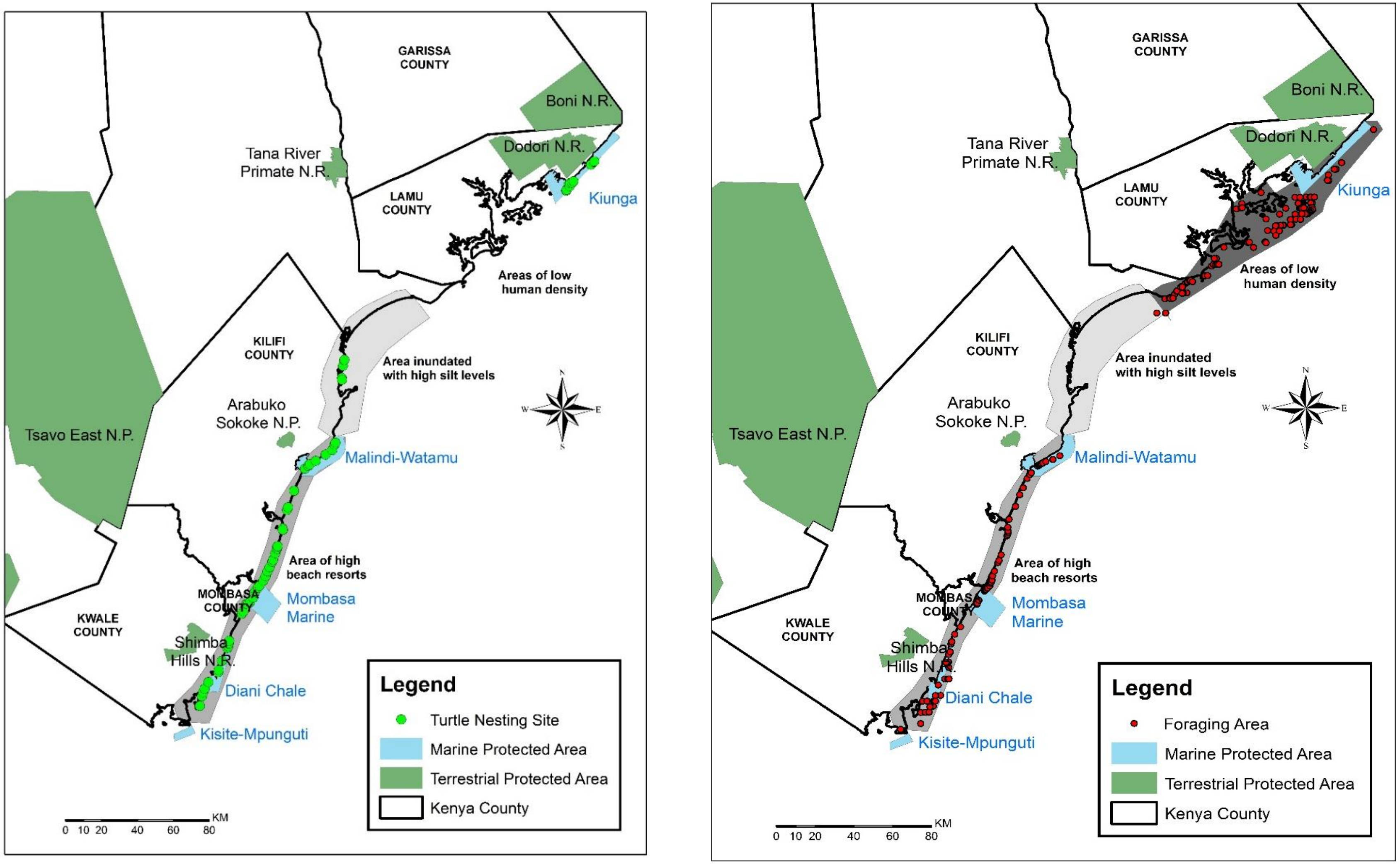


Figure 6: Nesting sites (right) and foraging areas (left) of *Chelonia mydas* along the Kenyan Coast

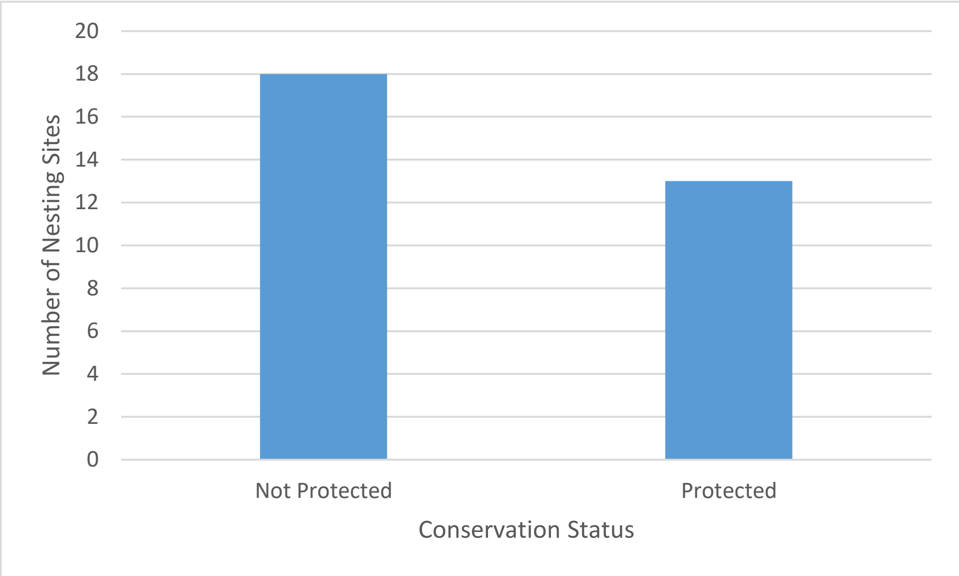


Figure 7: Conservation status of areas in which *Chelonia mydas* nesting occurred in 2016

4.1.2 Types of beaches sampled

Nesting areas sampled were classified as those with barriers, open beaches, those under cliff and those vegetated as shown on Figure 8. Beaches with barriers constituted 12.90% (4 counts), open beaches 58.06% (18 counts), beaches under cliff 3.23% (1 count) and those with vegetated beaches 25.81% (8 counts) where *C. mydas* were found to lay eggs. Figure 9 show that open beaches had most of the sightings of *C. mydas* nests in 2016 at 85% (196 nests), followed by vegetated areas at 12% (28 nests), those with barrier at 2% (4 nests). The beach with the least nest sightings was under cliff beaches at 1% (2 nests). Figure 10 show that most of the open beaches and vegetated nest occurred in areas which are not protected. There was same number of nest sites (2) with barriers in areas which were protected and those which were not protected, there was no beach under cliff in areas which were not protected. Despite these observed differences, results from Pearson Chi-Square performed to find the association between conservation status of nesting areas and classification of the beaches indicate that there was no statistically significant association; both protected and unprotected areas have similar beach types $\chi^2(3) = 1.625$, $p = 0.654$ ($p > 0.05$). Cramer's V tests show that the association between the variables was acceptable at a value of 0.229.

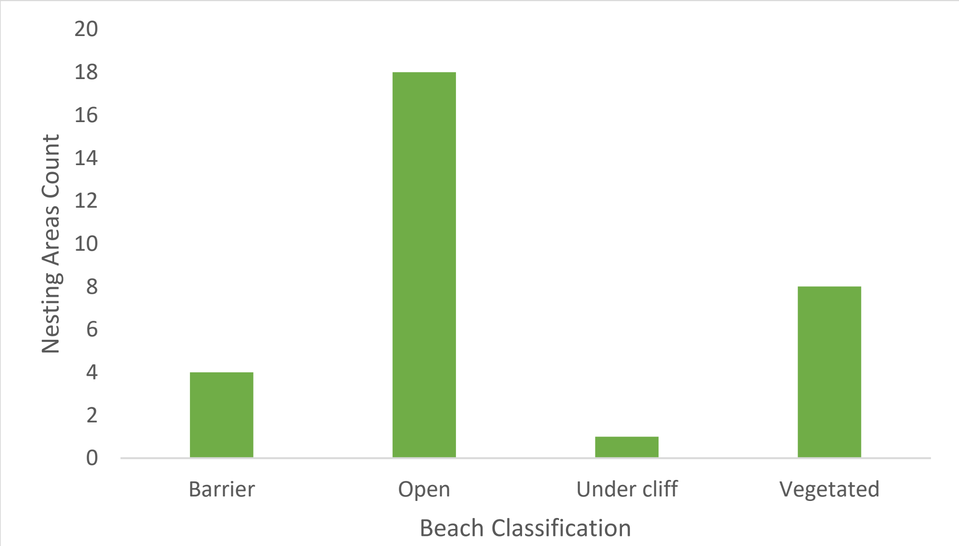


Figure 8: Classification of sampled nesting beaches along Kenyan Coast in 2016

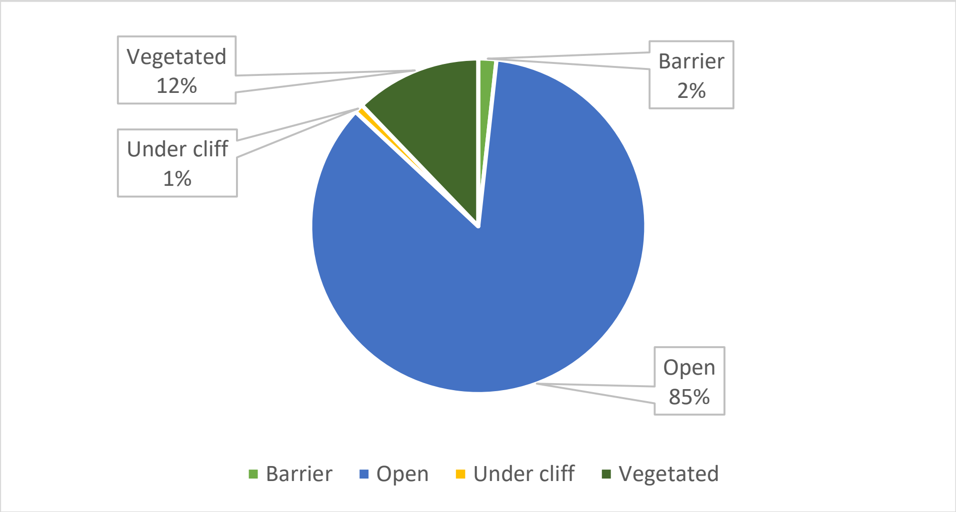


Figure 9: Percentage of number of nest found as per nest classification in 2016

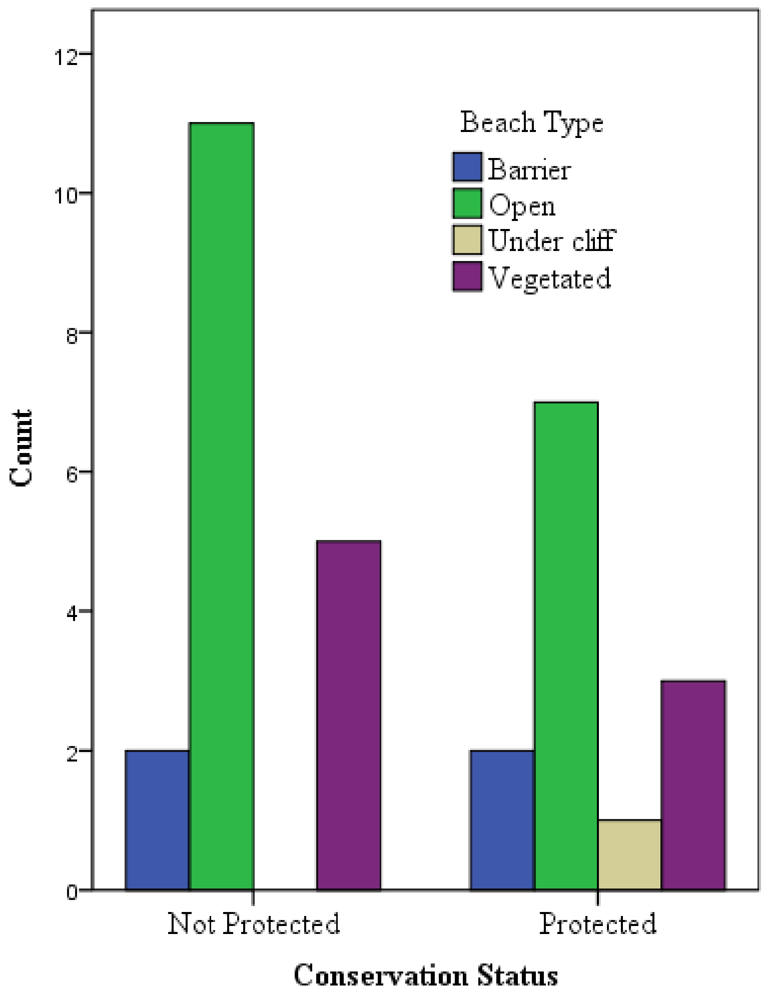


Figure 10: Comparison of conservation status and types of beaches in 2016

4.1.3 Nesting trends of important nesting areas in the period of 2014-2016

The nesting areas were drawn from each county where sampling occurred. Historical data show that these areas had consistent nest sightings. These were Shemu Shemu, English Point, Jumba Ruins and Mongo Sherriff.

4.1.3.1 Shemu Shemu nest site, Funzi Island, Kwale County

In Shemu Shemu nesting area, high number of nesting occurred in the first quarter of the year and in the month of May as shown in Figure 11 in 2014 and 2015. There was no nest observation in April and from June to December. Nests were not sighted in 2016. The total number of nests sighted in 2014 and 2015 was 4 and 8 respectively.

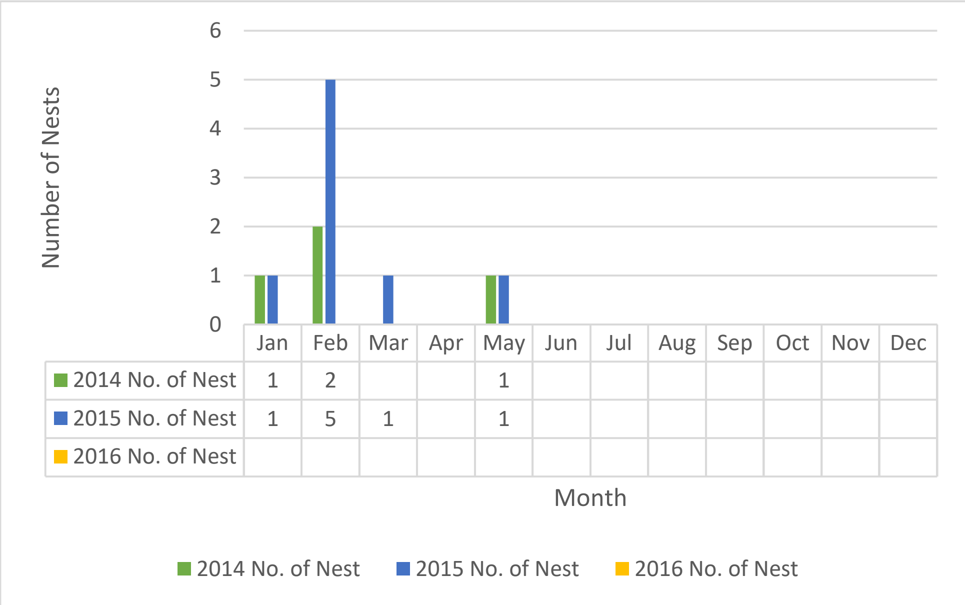


Figure 11: Nest sightings at Shemu Shemu during the period of 2014 - 2016

4.1.3.2 Aga Khan English Point nest site, Mombasa County

Figure 12 show that nesting occurred in March and June of 2016. There were 2 nests observed in March and 3 nests in June, 2016 totalling to 5 nests. There was no observed nesting in 2014 and 2015.

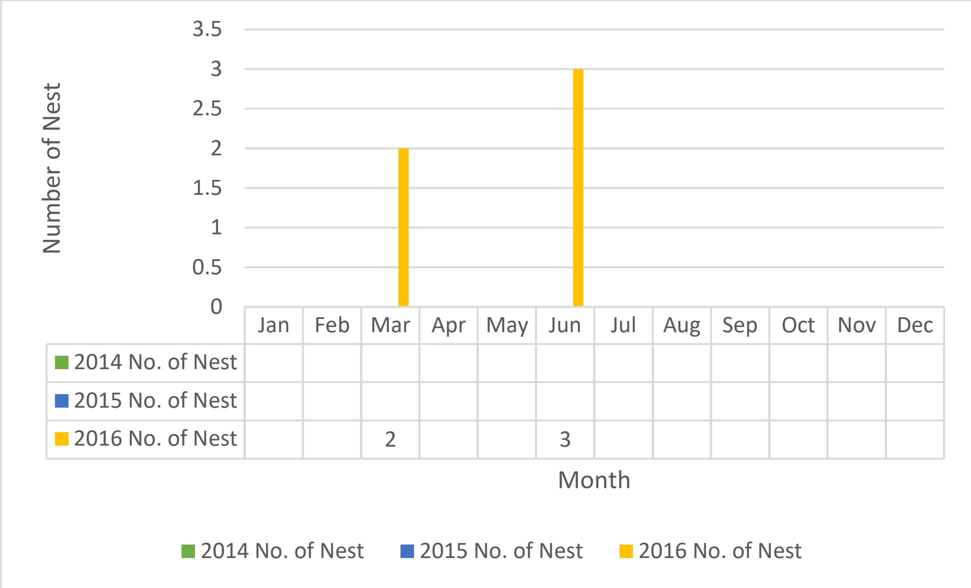


Figure 12: Nest sightings at English Point during the period of 2014 -2016

4.1.3.3 Jumba Ruins, Kilifi County

Figure 13 shows this is a heavy nesting area where nesting was observed to occur throughout the year in 2015 and 2016. In 2014, nesting was observed to occur in the months of February to August. Nesting was generally observed to peak between the months of March and June with highest recording of 23 nests observed in April, 2015. The least number of nest (1 nest) was observed in August of 2014, January of 2015 and January, February and March of 2016. Low number of nests of not more than 7 were observed from July to December. The total number of nest sighted in 2014, 2015 and 2016 was 58, 95 and 64 respectively. High nesting in the three year period therefore occurred in 2015.

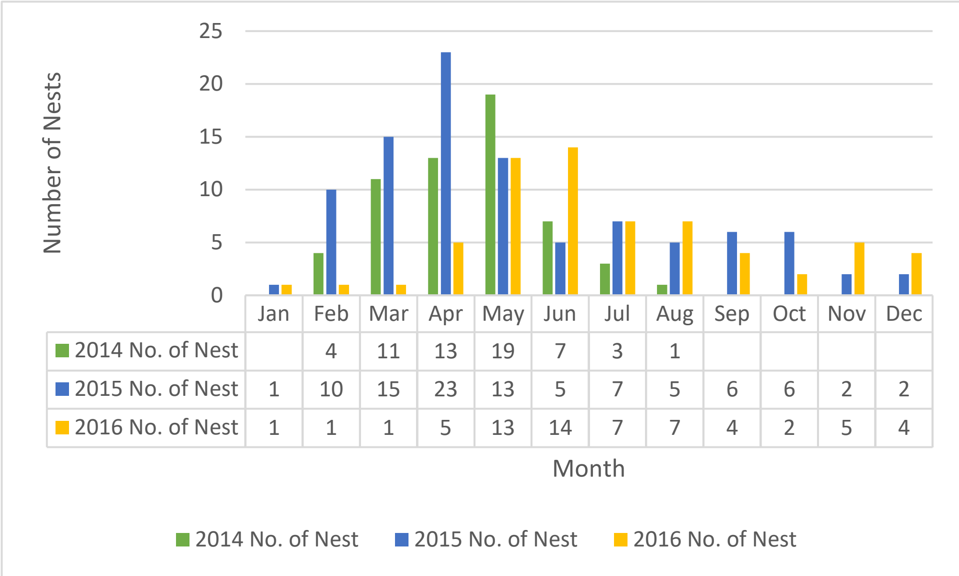


Figure 13: Nest sightings at Jumba Ruins during the period of 2014 - 2016

4.1.3.4 Mongo Sheriff, Lamu County

This island was an important nesting area in Lamu County, as shown in Figure 14 nesting peaks in the period of March to June. Nesting occurred in the month of February and March in 2014. In 2015, nesting occurred in month of January to June. In 2016, nesting occurred from March to December. The highest number of nesting (11 nests) was observed in April in 2015. The least number of nest (1 nest) was observed in June of 2015 and September, October and November of 2016. There was increase in number of nest sighted over the three year period. In 2014 there was 12 observed nests, 2015 there was 24 observed nest and 2016 there was 49 observed nests.

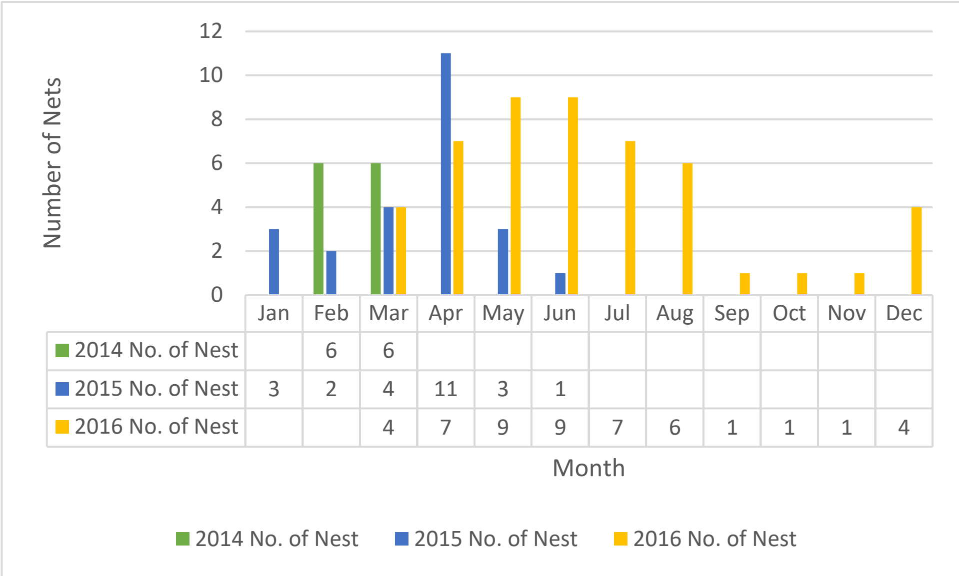


Figure 14: Nest sightings at Mongo Sheriff during the period of 2014 - 2016

4.2 Characterising biophysical factors influencing nesting sites of *Chelonia mydas*

4.2.1 Vegetation cover at the nest site

The important herbaceous vegetation observed along the Kenyan beaches was *Halopyrum mucronatum, Ipomoea pes-caprae* and *Scaevola plumieri* as shown in Appendix VI. These plants grow beyond HWM, they are however inundated with water during spring tides. The average vegetation cover was 46.86% for all the sampled nest sites. The nest sites with vegetation cover of less than 11% included Malindi MPA in Kilifi County, Leopard Beach in Kwale County and Kongowale in Lamu County. The observed number of nest in those nest sites was 0, 5 and 1 respectively in 2016. The nest areas with high vegetation cover of over 85% included Aga Khan English Point in Mombasa County, Msambweni House and Seascape in Kwale County. The observed number of nest was 5, 3 and 1 respectively. Table 2 show the number of nest in 2016 at various percentage vegetation cover along Kenyan coast. Approximately 58% of nesting occurred within vegetation cover of 0-50%. Only 9% of nesting was observed to occur in percentage vegetation cover of 76-100%. However, results of Pearson product-moment correlation, run to determine the relationship between vegetation cover and number of nest show that there was a weak, negative correlation which was not statistically significant r = -0.055, n = 31, p=0.767 ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

Table 2: Number of nests laid within ranges of vegetation cover

Vegetation cover (%)	Number of observed nest	Percentage
0-25	90	39%
26-50	44	19%
51-75	75	33%
76-100	21	9%

4.2.2 Organic matter content of nest site soils

Sampled collected in 2016 showed that areas of high OMC included Watamu Garoda Resort in Kilifi County, Mwanabule in Lamu County and Msambweni House and Seascape areas in Kwale County with over 0.2g of OMC. Nesting sites with less than 0.01g of OMC was Kongo Mosque in Kwale County, Nyali South in Mombasa County and KSV in Lamu County. The average OMC for the sampled nest sites was 0.11 g. Table 3 shows the number the amount of organic matter content in the soil at the nesting areas against number of nest observed along the Kenyan coast. 61.73% of nesting occurred in soils with 0.0500-0.0999g of OMC. There was no observed nesting with soils having 0.1500-0.1999g of OMC while soils with 0.2000-0.2499g of OMC had a nesting of 7.39%. To determine the relationship between OMC in the soils and number of nest Pearson product-moment correlation was used. There was a weak, negative correlation which was not statistically significant r = -0.109, n = 31, $p = 0.561$ ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

Table 3: Number of nests laid within ranges of organic matter content

Organic Matter Content (g)	Number of observed nest	Percentage of nest
0.0000-0.0499	57	24.78%
0.0500-0.0999	142	61.73%
0.1000-0.1499	14	6.09%
0.1500-0.1999	0	0.00%
0.2000-0.2499	17	7.39%

4.2.3 Soil classification at nesting beaches

Laboratory soil analysis showed that all the soil were found to be sandy soil without loam or clay content. Table 4 show the average percentage of sand classification in the nesting areas sampled. Majority of the nesting areas had medium sized grain.

Table 4: Percentage soil classification at the nesting areas

Very Course sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt
1.48%	22.00%	41.36%	28.45%	3.42%	0.13%

Most of nest occurred in medium and fine sand totalling 69.81% as shown in Table 4. Soil with very course sand was 1.48%, course sand 22.00%, very fine sand 3.42% and silt content 0.13%. Kinondo nest site in Kwale County had the highest amount of very course sand at 5.28% with one observed nest in 2016, Bureni nest site in Kilifi County had the highest amount of coarse sand at 75.63% with 12 observed nests in 2016, KSV nest site in Lamu County had 81.28% of medium grained sand with 12 observed nests, Nyali South nest site in Mombasa had highest amount of fine sand at 85.96% with no observed nest in 2016 while Mwaepe in Kwale County had the highest amount of very fine sand at 31.37% with two nests in 2016.

4.2.4 Width of the beach at the nest site

The widest beach sampled in 2016 included beaches such as Kiwayuu and Chandani in Lamu County, Nyali South in Mombasa County and Mwaepe in Kwale County with 61-85 m width. As shown in Table 5 these beaches had the least number of observed nests in 2016 with 6.09% of the nesting. The beaches with shortest width included Bureni in Kilifi County, Massage Area and Kinondo in Kwale County. Highest nesting (79.13%) was observed to occur within beach width of 31-60 m. The average beach width was 44.40 m for the sampled nest sites. From Pearson product-moment correlation, was run to determine the relationship between width of the beach and number of nest. There was a weak, negative correlation which was not statistically significant was observed $r = -0.025$, $n = 31$, $p = 0.895$ ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

.

Table 5: Number of nest within ranges of width of the beach

Width of the Beach (m)	Number of observed nest	Percentage
15-30	34	14.78%
31-45	116	50.43%
46-60	66	28.70%
61-85	14	6.09%

4.2.5 Slope of the beach at the nest site

Most of the observed nest in 2016 such as Kitangakikuu, Mwanabule and Mongo Sherrif in Lamu County and Mwanamia and Musumarini in Kilifi County had gentle slopes. Table 6 shows most of nest were placed within ranges of gentle slope (8.0^{o}-12.9^{o}). The average slope for beach was 9.44^{o} for the sampled nest sites. High number of nest (85.66%) occurred in near flat to gentle slope, 3.0-12.9^{o}. Least nesting (14.34%) occurred in steep beaches of 13.0-17.9^{o}. Pearson product-moment correlation, was run to determine the relationship between slope of the beach and number of nest at the beach. There was a weak, negative correlation which was not statistically significant $r = -0.008$, $n = 31$, $p = 0.968$ ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

Table 6: Number of nest within ranges of slope of the beach

Slope of the Beach (º)	Number of observed nest	Percentage
3.0-7.9	85	36.96%
8.0-12.9	112	48.70%
13.0-17.9	33	14.34%

4.3 Identification of anthropogenic threats to nesting of *Chelonia mydas*

4.3.1 Number of people at the nest site

Table 7 shows the number of people observed in beach against the number of total nest in 2016. The beaches which had 21-30 number of people within 10 m from nesting site included Kongo mosque and Massage area in Kwale County in 2016. There was no observed nesting in 2016 in beaches with more than 40 people within 10 m from nesting site. These nesting site include Malindi MPA and Watamu Turtle Bay in Kilifi County. The average number of people at the beach was 20 for the sampled nest sites. Nest sites from Lamu County had the least number of people and had the highest number (84.47%) of *C. mydas* nests. To determine the relationship between number of people at the beach and number of nest at the beach Pearson product-moment correlation was performed. There was a weak, negative correlation which was not statistically significant r = -0151, n = 31, p = 0.416 ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

Table 7: Number of nest within ranges of number of people observed in nesting area

Number of People	Number of observed nest	Percentage
0-10	195	84.47%
11-20	6	2.61%
21-30	24	10.43%
30-40	5	2.18%
40>	0	0.00%

4.3.2 Debris weight at the nest site

The beaches with highest amount of debris per square metre included Kitangakikuu, KSV and Mwanabule in Lamu County. These areas are within, Kiunga Marine Reserve and are not inhabited hence minimal human activities. The debris were brought by intense action wave action from other regions. Areas with human activities with least amount of debris weight included Leopard Beach and Massage Area in Kwale County and Aga Khan Bamburi in Mombasa County. These beaches were tourist attraction areas and were cleared of debris regularly. The average weight of debris at the beach was 1.90kg for the sampled nest sites. Table 8 shows nests with different classes of debris weight in 2016. The least observed nesting (17.83%) occurred in debris weight of >3.0 Kgs 100 m^{-2}. Nesting was observed to occur in the different classes and thus Pearson product-moment correlation, run to determine the relationship between debris weight at the beach and number of nest at the beach showed that there was no relationship, $r = 0.000$, $n = 31$.

Table 8: Number of nest within ranges of debris weight at the beach

Debris Weight Kgs 100 m^{-2}	Number of observed nest	Percentage
0.0-0.9	52	22.61%
1.0-1.9	71	30.87%
2.0-2.9	66	28.70%
3.0>	41	17.83%

4.3.3 Sea defence barrier at the nest site

Over 98% of the nest occurred in beaches without sea defence barriers as shown in Table 9. Nest areas with sea defence barriers of 0.76-3.00 m height had a combined nest of 1.73%. The average height of sea defence barrier at beach was 0.27 m for the sampled nest sites. The beaches without barriers were found in remote areas such in Lamu and in Kwale County. Beaches which were reinforced with barriers to prevent erosion occurred in tourist attraction areas such as Watamu Turtle Bay and Billionaire Resort in Kilifi County. There was no observed nest in Malindi MPA nest where Billionaire Resort was based in the period of 2014-2016. These barriers sometimes forced *C. mydas* to lay nest in sub-optimal conditions such as within HWM. However, when Pearson product-moment correlation, was run to determine the relationship between height of the barrier at the beach and number of nest at the beach. There was a weak, negative correlation which was not statistically significant r = -0.195, n = 31, $p = 0.292$ ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

Table 9: Number of nest within ranges of sea defence barrier

Sea Defence Barrier (m)	Number of observed nest	Percentage
0.00-0.75	226	98.26%
0.76-1.50	1	0.43%
1.60-3.00	3	1.30%

4.3.4 Beachfront lightening at the nest site

Natural beaches with no human settlement or activities had a Lux measurement of 1 lx in clear sky. They included all the nest sites sampled in Lamu County and in Kwale County such as Shemushemu. Leopard beach in Kwale County had a Lux measurement of 5.67 lx and was in front of a hotel resort. In Kilifi County a Lux measurement of 3.33 lx was observed in Watamu Turtle Bay and Watamu Plot 16. Table 10 show lux measurements against the number of nest in 2016, 96.09% of nesting occurred within ranges 1.0 -1.9 lx while 3.91% of nest occurred in 2.0<4.0 lx. Nesting observed in areas of high lux measurements occurred in front or near beach resort with high lux. The managers of these facility make concerted efforts to protect these nest sites as a tourist attraction. The average lux measurement at the beach front lighting was 1.5 lx for the sampled nest sites. Pearson product-moment correlation, was run to determine the relationship between lux measurement at the beach and number of nest at the beach. There was a weak, negative correlation which was not statistically significant $r = -0.155$, $n = 31$, $p = 0.405$ ($p > 0.05$) there was thus inconclusive evidence about the significance of the association between the variables.

Table 10: **N**umber of nest within ranges of lux measurements

Lux	Number of observed nest	Percentage
1.0-1.9	221	96.09%
2.0-2.9	2	0.87%
3.0-3.9	0	0.00%
4.0>	7	3.04%

4.4 Comparison of hatching success of in situ and ex situ conditions incubated eggs

Number of eggs laid and left to hatch *in situ* with those translocated and incubated *ex situ* were compared in Table 11 and 12. The eggs were transferred to Bamburi and Jumba Ruins hatcheries for the *ex situ* incubation. In Mombasa and Kilifi areas the hatch success rate was 66.00% for *ex situ* incubated eggs and 77.00% hatch success for *in situ* in 2016 while 2015 hatch success rate was 56.00% for *ex situ* incubated and 71.00% hatch success for *in situ* incubated eggs and in 2014 the hatch success rate was 71.68% for *ex situ* and 92.81% hatch success for *in situ* incubated nests. There was an observed decline of number of nest from 156 nests in 2014, to 129 nests in 2015 and 79 nests in 2016 in Kilifi and Mombasa areas. Number of predated eggs also peaked in 2015 at 671 eggs with more occurring in *ex situ* incubated conditions. Animals that feed on *C. mydas* eggs were mostly mongoose, crabs and red ants. Dead hatchlings were observed to mostly in 2014 at 280 compared to 60 and 96 in 2015 and 2016 respectively. Rotten eggs were abundant in *ex situ* incubated eggs compared to *in situ* incubated eggs. In 2014, there were 1290 rotten eggs in *ex situ* compared to 90 in *in situ*. In 2015 there were 1273 rotten eggs in *ex situ* and 225 in *in situ* and in 2016 there were 703 and 63 rotten eggs in *ex situ* and *in situ* respectively. Damaged eggs were also higher in *ex situ* incubated eggs, at 90 in 2014, 6 in 2015 and 111 in 2016. The same trend was observed with unfertilised eggs, there was 1240 in *ex situ* and 132 in *in situ* 2014, 1418 in *ex situ* and 331 in *in situ* in 2015 and 481 in *ex situ* and 144 in *in situ* in 2016. In Lamu hatch success for *in situ* incubation was 89.74% while *ex situ* incubation was 82.88% in 2016. In 2015 hatch success *in situ* incubation was 88.78% while *ex situ* incubation was 82.18%. In 2014 hatch success *in situ* incubation was 91.05% while *ex situ* incubation was 86.35%. In Lamu the eggs were translocated to nearby beaches or above HWM within the beaches where nesting occurred. The translocated eggs are placed in areas with same biophysical conditions as with the original nests. In Lamu areas there was an observed increase in human interventions over the years; there was increase in number of *ex situ* incubated eggs from 52 in 2014, 81 in 2015 and 121 in 2016. An independent sample *t*-test revealed that there was a difference in mean of hatching success in *in situ* and *ex situ* incubated eggs. The *in situ* (n=6) hatch success $\bar{X}$ = 4404.17 (SD = 643.31) was lower compared to *ex situ* hatch success $\bar{X}$ = 5451.00 (SD = 3858.96). The *t*-test was associated with not a statistically significant difference $t(10) = -0.655$, $p = 0.527$ ($p > 0.05$) between the sites.

Table 11: Comparison of hatching success rate of in situ and ex situ incubated eggs in areas of Kilifi and Mombasa, 2014 – 2016 (Source: Baobab Trust)

Incubation	**Nests**	**Eggs**	**Hatchlings**	**Percentage Hatch Success**	**Unfertilised**	**Rotten in Shell**	**Dead in Shell**	**Predated**	**Damaged Eggs**	**Dead Hatch**
2014										
Ex situ	122	12942	9277	71.68	1240	1290	733	73	90	239
In situ	34	4546	4219	92.81	132	90	61	3	-	41
Total	**156**	**17488**	**13496**	**77.17**	**1372**	**1380**	**794**	**76**	**90**	**280**
2015										
Ex situ	80	9183	5,118	56.00	1,418	1273	897	449	6	22
In situ	49	4319	3,079	71.00	331	225	420	222	4	38
Total	**129**	**13502**	**8197**	**61.00**	**1749**	**1498**	**1317**	**671**	**10**	**60**
2016										
Ex situ	61	6871	4549	66.00	481	703	415	151	111	81
In situ	18	1664	1281	77.00	144	63	61	-	-	15
Total	**79**	**8535**	**5830**	**68.00**	**625**	**766**	**476**	**151**	**111**	**96**

Table 12: Comparison of hatching success rate of in situ and ex situ incubated eggs in areas of Lamu, 2014 – 2016

Incubation	Number of Nests	Number of eggs	Successful Hatch	Unsuccessful Hatch	Total Hatch	Percentage Hatch Success
2014						
In situ	43	-	4984	504	5474	91.05
Ex situ	52	-	5493	879	6361	86.35
Total	**95**		**10477**	**1383**	**11835**	**88.53**
2015						
In situ	67	Unknown	3340	418	3762	88.78
Ex situ	81	8502	2712	584	3300	82.18
Total	**148**	**8502**	**6052**	**1002**	**7062**	**85.70**
2016						
In situ	36	-	4215	487	4697	89.74
Ex situ	121	-	10864	2244	13108	82.88
Total	**157**	**-**	**15079**	**2731**	**17805**	**84.69**

4.5 Important factors influencing nesting of *Chelonia mydas* along the Kenyan Coast

A multiple regression was undertaken to find out the relationship between the number of nest at the beach with vegetation cover, organic matter content, beach width, slope of the beach, number of people, debris weight, sea defence barrier and beach front lighting. The multiple regression model did not statistically significantly predicted number of nest, F (8, 22) = 0.294, $p > 0.05$, R = 0.311. All the variables: vegetation cover, organic matter content, beach width, slope of the beach, number of people, debris weight, sea defence barrier and beach font lighting did not add statistically significantly to the prediction, p > 0.05.

The Unstandardised coefficient (b) showed how the variables varied with number of nesting if other independent variables were held constant; for each percentage increase in vegetation cover there is decreased number of nesting by 0.076 (b = -0.076). An increase in one gram of organic matter content was associated with a decrease in number of nesting by 8.312 (b = -8.312). A metre increase in beach width was associated with a decrease in number of nesting by 0.075 (b = -0.075). An increase in one degree of slope was associated with decrease in number of nesting by 0.190 (b = -0.190). One person increase at the beach was associated with a decrease in number of nest by 0.046 (b = -0.046). A kilogram increase in debris weight was associated with decrease in number of nesting by 0.635 (b = -0.635). A metre increase in sea defence height was associated with a decrease in number of nesting by 3.155 (b = -3.155). An increase of one lux in beach front lighting was associated with a decrease in number of nesting by 2.154 (b = -2.154).

CHAPTER FIVE: DISCUSSION

5.1 Identification and geo-referencing of *Chelonia mydas* in coastal Kenya

Sea turtles have been known to be nesting along the Kenyan coast with over 90% population consisting of *C. mydas* species (Okemwa *et al.,* 2004). Studies using m-DNA analysis have shown that *C. mydas* in a particular foraging grounds have high haplophyte diversity. This indicated that foraging areas have population that was fed from the hatchling of nearby nesting areas and from other areas. This is the case if the foraging areas are affected by different current systems which brings in larger *C. mydas* from other areas (Bass *et al.,* 2006). *C. mydas* were observed to forage and nest along the Kenya coast, however, the observed foraging turtles should not be presumed as the ones coming ashore to nest. *C. mydas* have been documented migrating over 2000 km between their feeding and nesting grounds (Read *et al.,* 2014). Lamu had high numbers of nesting and foraging grounds and unlike other parts of coastal Kenya, Lamu coastal waters is affected by Somali Current and Monsoon winds. Turtle nesting studies in inhabited conditions has shown an increase in nesting trends over time (Antworth *et al.,* 2006) however, human activities such as construction of sea wall barriers, emission of luminous light and high beach population as those observed in the public beaches in Mombasa impact on nest sites making them unsuitable areas.

5.1.1 Comparison of conservation status of sampled nesting areas

Long term studies from South Africa showed that MPAs are effective management tools in conservation of *Caretta caretta* and *Dermochelys coriacea*. The study however indicated that since future factors affecting nesting of the sea turtle are stochastic, MPAs cannot effectively help to predict status of future populations (Nel *et al.,* 2013). Sea turtle nesting population were observed to recover on protected areas globally, these population recovery successes were attributed to conservation efforts aimed at managing nesting areas and reduction of bycatch (Mazaris *et al.,* 2017). Geological survey of Tortugas National Park, Florida, USA showed that *C. mydas* benefitted from the MPAs. By tracking the sea turtles with satellite tags, it was observed that they spend a lot of time in the protected areas (Hart *et al.*, 2016). In Kenya, the MPAs are proportionally smaller in comparison to the whole coastal Kenya, explaining the reason *C. mydas* mostly lay nest in unprotected areas, 58.06%. However, high nesting in observed to occur in Lamu under Kiunga Marine Reserve. The legal notices that established MPAs in Kenya are also not clear on conservation status of the nearby beaches in which the MPAs are based. This thus brings complication in terms of enforcing laws to protect nest sites in protected areas.

5.2 Biophysical factors influencing nesting sites of *Chelonia mydas*

5.2.1 Vegetation cover at the beach

Xavier *et al* (2006) showed that *C. mydas* had preference of 76% in nesting on sand dunes or vegetation zone. Nesting sites with very low vegetation cover (<10%) causes nesting caves to collapse while very high vegetation cover (>40%) affected *C. mydas* digging success because it enhances compactness of the surface layer by numerous rooting system increasing workload of the turtle. Moderate vegetation (10%-30%) assist in sand accumulation and nest site stabilisation (Chen *et al.,* 2007). Madden, *et al*, (2008), study showed that there was decreased egg mortality in the upper beach due to increased proximity to vegetation. Clutches laid under large bushes and trees had higher hatching and emergence success than those in other habitats (Zarate *et al.,* 2013). These was shown with positive correlation between of the percentage vegetation cover and hatching success rate. Beaches without vegetation can have an effect on thermal regimes on beach and thus influence on incubation and resulting sex ratios (National Marine Fisheries Service and US Fish and Wildlife Service 2007). Most of the observed nesting areas in coastal Kenya were on sandy beaches that had vegetation cover or in beaches with vegetation. The mean percentage vegetation cover was 46.86% ± 25.95 SD.

5.2.2 Organic matter content at the beach

Organic matter content in the soil enhances it in many ways. The organic matter builds and improves soil structure improving its soil drainage and thus infiltration of water and air into the soil. It also increases the ions exchange capacity of a soil and provides a buffering effect on soil pH (Gachene and Kimaru, 2003). Organic matter content is an important factor in nest selection because soils that are high in it have water-stable aggregates that bind soil particles together and are resistant to being broken down by the impact of water (Gachene and Kimaru, 2003). High organic content also support vegetation cover that is sometimes crucial in nest placement. High vegetation however makes it harder for the sea turtle to dig and lay eggs (Chen *et al.*, 2007). Beaches with high OMC were found next to human settlements and activities (Stancyk and Ross, 1978). High OMC were also observed in Watamu Garoda Resort in Kilifi County, Mwanabule in Lamu County and Msambweni House and Seascape areas in Kwale County which had human activities. Weslawski, *et al*. (2000) observed the one of the main threats to sandy beaches is pollution which might lead to eutrophication which can lead to growth of invasive vegetation at the beach affecting the ecology of it.

5.2.3 Soil Texture

C. mydas dig in beach sandy soils to create caves that they use to lay in eggs. Soil is made up of solid particles, water and air which are important in embryo development and determining the survival of the hatchlings. Soil texture determines soil workability, water-holding capacity, soil structure and nutrient retention (Gachene and Kimaru, 2003). *C. mydas* can tolerate a variety of soil particle size if suitable nest site is not encountered (Chen, *et al.,* 2007). Studies in Ascension Island show that the median number of trial nest holes dug per nesting emergence and the mean particle diameter of the beach sands were positively correlated. Thus, turtles find it difficult in constructing suitable nest in coarse and dry sand explaining the few observed nests. The relationship between the average total survival of hatchlings and the sorting coefficients and mean particle diameters shows lowest survivorship of the most poorly sorted sand (Mortimer, 1990).

5.2.4 Width of the beach

Narrow beaches are more vulnerable to effects of climate change as the sea level rise will wipe out possible nesting grounds for the sea turtle (Fish *et al.,* 2005). Since sea defence barriers affect general morphology of beaches, it was observed that beaches which had minimal human interventions such as sea defence barriers were wider for example, Kongowale and Ashuwei in Lamu County, Nyali beach in Mombasa County and Msambweni beach in Kwale County. Short beaches had high rates of erosion especially if there was overlying cliff. Even if the short beaches were secluded with minimal human activities, the hatching success rate was low because of effect of the wave energy on the cliff. As a result of action of wave energy and reaction of the wave energy on the cliff, nest were easily washed (Tsoukala *et al.*, 2015). Magogo nest site in Lamu County had 2 nests laid in 2016 despite it being secluded with minimal human activities ideal for turtle nesting.

5.2.5 Slope of the beach

Studies in Mexico indicated that 65% of nesting occurred in two zones one with gradual slope and beach mean width of 38m and other moderate beach slope with beach width of 30m (Zavaleta-Lizárraga and Morales-Mávil, 2013). In Florida, USA Rizkalla and Savage (2011) showed that sea turtles prefer to nest in intermediate inclines. This was confirmed by this study as *C. mydas* showed a slight preference to gentle slopes with a mean preference of 9.44^0 ±3.24 SD and a mean beach width of 44.40 m ±16.93 SD. Wood and Bjorndal (2000), reported that the mean average slope of the beach for loggerheard turtle was 9^0 however as also from the findings of this study, there was weak negative correlation between slope and number of nest. The slope of the beaches in coastal Kenya are affected by SEM (December to March) and NEM (April to September) winds. Historical data collected showed that nesting of sea turtle in Kenya was high during the months of March to July.

5.3 Identification of anthropogenic threats to nesting of *Chelonia mydas*

5.3.1 Number of people at the beach

Human disturbance can have a '*scarecrow'* effect on the beach and thus increase the survival rate of hatchlings and secure eggs by scaring predators especially in vegetated areas which provide cover for the predators (Leighton *et al.*, 2010). Nesting areas in Jumba Ruins in Mtwapa, Kilifi County are guarded to prevent nest destruction, poaching and help dis-oriented hatchling on their initial journey towards the sea explaining high number of nestings. The nearby property owner engages in turtle conservation employing people at night to guard nest against possible poachers. However, high human traffic can disturb existing nest with trampling and pollution. Poaching is a major issue in turtle conservation in Kenya. Eggs and the female turtle ashore are normally poached for food and medicinal purpose (Caldwell, 1962). Urban areas with public beaches such as Malindi, Mombasa and Watamu had the most number of people at the beach. Beach users in Kenya coast include tourists, beach traders, sun bathers, visitors and fishers. Areas like the Jomo Kenyatta public beach in Mombasa have not recorded any nest in recent past yet historically the area used to be a nesting ground. It is the busiest beach with high human traffic. The number of people negatively correlated with the number of nests at the beach.

5.3.2 Debris at the beach

Marine plastic debris affect sea turtles at all levels hence entanglement and ingestion occur at the sea and on the nesting beaches. Large debris at the beach can be an obstacles and may cause sea turtles to false nest and return to the sea without depositing eggs at the stage of selecting nest sites (Nelms *et al.*, 2016). Plastic debris can lead to invasion of alien species as they attach to the floating debris and get deposited in foreign areas (Derraik, 2002). Macro-plastic within the sand column can trap hatchling below the surface by prevent them from leaving the egg chamber (Nelms *et al.*, 2016). Despite these reasons the Islands in Lamu had the high debris weight per $100m^2$ yet there were recorded with high number of nest per annum. The islands were ideal for nesting because they were uninhabited and it was found within Kiunga MPA. The Somali Currents and northern monsoon wind brings in debris from all over the world and depositing them in the small islands. This seemingly did not deter the turtles as they normally nest in the area because of the minimal human disturbance. Lamu County have one of the most significant nesting grounds of *C. mydas* in coastal Kenya. As suggested by (Nelms *et al.*, 2016) the establishment of a globally accessible database of marine debris surveys on nesting beaches would help facilitate an improved understanding of the impacts of plastics on sea turtles that use sandy beaches. Management tool can be devised through oceanographic modelling that could be used to forecast how and when key coastal areas are likely to be impacted by debris in the future. Derraik (2002) suggests '*thinking globally and acting locally'* as a fundamental attitude to reduce the environmental threat and in combination with education awareness make people change aware of their consumerism habits and impacts on status of sea turtle populations.

5.3.3 Sea defence barrier

Sea barriers affected nesting of loggerheads turtles by reducing nesting success and increasing erosion during storms (Rizkalla and Savage, 2011). Witherington *et al.*, 2011) reported that nest next to barriers have high mortality affecting the hatching success rate and thus hampering conservation efforts of sea turtle. There was negative correlation of height of the sea defence barrier with number of nests. These barrier which were constructed to mitigate the effect of sea wave's action results causes the beaches to erode and thus undulating the nest sites. The wave energy could be gradually be absorbed in a natural beach without any barrier. These action also results in removal of vegetation exacerbating the problem (Witherington *et al.*, 2011). Sea defence barriers emerged one the most important factor against the number of nest in a particular beach. The negative relationship with sea defence barriers is exemplified in Malindi Marine Park beach by Time series Google Earth satellite images shown in Appendix II. A nesting area that could be seen by satellite images was wiped out after construction of sea defence barrier at Billionaire Resort in 2012. The eroded beach used to be a *C. mydas* nest site at shown by historical data. Explaining the reason of 0 number of nests recorded in the period of 2014-2016.

5.3.4 Beachfront lighting

Light of on the beach is known to cause disorientation of hatchlings towards the initial journey to the sea (Tuxbury and Salmon, 2005). However, it can also not be an impediment to nesting (Kamrowski, *et al*, 2012) because *C. mydas* have been documented to nest in full moon (Ekanayake, *et al*, 2002). Human influence on beaches surveyed was varied, beaches which were lit had record of *C. mydas* regularly come to nest. In the public beach in Mombasa which had highest lux measurement, no nest site was recorded in recent past even though there were documentation that the area used to be a nest site. Number of nest was however high rate was highest in places where there was no lighting such, as Jumba Ruins in Mtwapa, Mongo Sheriff in Lamu and Funzi Island.

5.4 Comparison of hatching success of *in situ* and *ex situ* incubated eggs

Eggs laid by *C. mydas* in coastal Kenya were translocated if there was human threat or if they were laid in sub-optimal biophysical conditions as considered by turtle conservation groups. These include conditions such as eggs laid within HWM, under cliff with intense wave action or heavily eroded beaches. Human threats include high density of people at the beach which may lead to trampling on the eggs and poaching. Conservation groups in Kenya considered translocating eggs if there was an imminent threats of nest predation by crabs, mongoose or red ants. In a study of leatherback turtles (*D. coriacea*), it was reported that *in situ* incubated eggs had a higher hatch success rate compared to *ex situ* translocated eggs at 64.10% compared to 53.70% respectively (Eckert and Eckert, 1990). However, in unpublished study, in Gandoca Beach, Costa Rica the hatch success of *D. coriacea in situ* incubation was lower than in translocated eggs at 57% and 45% respectively (Furler 2005). Data collected by

Baobab Trust and WWF Kenya show that hatch success is higher *in situ* than in translocated eggs. In 2016 the hatch success was 77.00% *in situ* while 66.00% in translocated in areas of Kilifi and Mombasa while in Lamu it was 82.88% and 89.74% respectively. Hatching success of tranlsocated nests is thus dependent on handling which can negatively influence embryonic development (Abella *et al.*, 2007) and thus cannot give accurate natural survival rates (Fowler, 1979).

5.5 Important factors influencing nesting of *Chelonia mydas* along Kenyan Coast

Sea turtles are wide-ranging species and single populations often utilize habitats under several different geopolitical boundaries, making conservation efforts complex (Antworth *et al.,* 2006). *C. mydas* nest along the Kenyan coast with varying biophysical and anthropogenic factors thus a single variable cannot be considered as an overriding factor in influencing the number of nest per nest-site. In the Multiple Regression Analysis, organic matter content, sea defence height, debris weight and beach front lighting were found to have most negative impact on the number of nest. These factors are directly associated with human activities. In this study, organic matter content was considered as a biophysical factor, however, beaches with high organic matter content were found to be those nearby human settlement and activities. Sea defence barriers directly impedes access to nesting grounds and those laid could easily be washed away if they are within the HWM. Debris at the beach also affect mobility and the digging ability of the turtle at the beaches. Light disorient the hatchlings in their initial movement towards the sea, thus female *C. mydas* may shy away from nesting in these beaches with a lot of lighting. High nesting records was observed to occur in places with minimum human disturbance. This study showed that *C. mydas* preferred nesting in areas with no sea barriers, minimal lighting and people at the beach since such areas had the highest annual sightings of nests.

5.6 Limitation of the study

Sea turtles are difficult reptiles to study due to their complex life cycle; they live long and their maturity age in the wild is highly variable and cannot be compared to those held in captivity (Pritchard, 1980) thus the age and other aspects of nesting females cannot be predicted. One of the feasible way of monitoring the population status is by studying nesting habits of the green turtle. This however has its own challenges because of the variation in clutch frequency and nest site fixity (Johnson and Ehrhart, 1996). The Kenyan coastline is also long and field study conducted in different time frames can have an impact on the results. Additionally, few studies of sea turtles have been conducted in Kenya making this study without a basis of meaningful comparison.

5.7 Conclusion

Most of the green turtle nest and foraging areas were sighted in the coastline of Lamu County. Nest were especially observed to occur in the Island of Mwongo Sherriff. There was dwindling population of nests sighted in Mombasa and Kilifi Counties due to development and human traffic at the beach areas. Kwale County had intermediate observations as some areas had a stable populations of nests. Green turtles preferred to nest in areas with vegetation cover of less than 50%; 61.73% of nest occurred in areas of 0.0500-0.0999 g of OMC; highest number of nest were observed to occur in beaches with width of 31-60 m and the least amount of observed nests were observed to occur in steep beaches with an inclination of 13.0-17.9^{o}. Most of nest occurred in medium and fine sand totalling 69.81%. Green turtles showed high preference of 84.47% to nest in areas with less than 10 people; it nest site selection did not however show any preference with amount of debris at the beach; 98.26% of nests occurred in beaches with less than 0.75 m height of sea defence barriers and 96.09% of nest occurred in beaches with less than 2 lux of lighting those with more than 4 lux had an observed nests of 3.04%. Comparison of nest incubated in situ and ex situ in Lamu and Kilifi counties showed that higher success rate of nest hatchlings (over 80%) occurred in natural areas where the eggs were laid.

5.8 Recommendations

1. Human activities need to be regulated if not completely stopped at important nesting areas by enforcing existing laws controlling beach developments particularly in the areas of Mombasa and Kilifi counties.
2. There are invasive plants on some of the beaches, particularly cactus (*Opuntia sp.*) which act as barriers because the leaves are thorny and the plant can grow to even 3 m in height. The invasive species need to be continually managed (removed) to allow other suitable beach vegetation to grow.
3. Due to dynamics of the beach, there should be long term monitoring of nesting sites of turtle so that the impact of human activities can be assessed.
4. Eggs laid by green turtles should be left on site, to be incubated and hatched under natural conditions. Only in situations where nests are prone to destruction and poaching, should human intervention be sort.
5. There is need to harmonise data collecting methods of different groups and organisations engaged in turtle conservation efforts.

REFERENCES

Abuodha, JOZ., WM Musila and H van der Hagen. 2003. "Floristic Composition and Vegetation Ecology of the Malindi Bay Coastal Dune Field, Kenya." *Journal of Coastal Development* 9: 97-112.

Abella, E., A. Marco, and L. F. Lopez-Jurado. 2007. "Success of Delayed Translocation of Loggerhead Turtle Nests." *The Journal of Wildlife Management* 71 (7): 2290-2296.

Abreu-Grobois, A., and P. Plotkin. 2008. *Lepidochelys olivacea.* Vers. Version 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

Ackerman, Ralph A. 1997. "The Nest Environment and the Embryonic Development of Sea Turtle." *The Biology of Sea Turtles* 1: 83-106.

Agvise Laboratories. 2017. *Soil Organic Matter (A choice of methods).* Accessed December 20, 2017. https://www.agvise.com/educational-articles/soil-organic-matter-a-choice-of-methods/.

Allard, Marc W., Michael M. Miyamoto, Karen A. Bjorndal, Alan B. Bolten, and Brian W. Bowen. 1994. "Support for Natal Homing in Green Turtles from Mitochondrial DNA Sequences." *Copeia* 1994 (1): 34-41.

Antworth, Rebecca L., David A. Pike, and John C. Stiner. 2006. "Nesting Ecology, Current Status, and Conservation of Sea Turtles on an Uninhabited Beach in Florida, USA." *Biological Conservation* 130: 10-15.

ASCLME. 2012. *National Marine Ecosystem Diagnostic Analysis. Kenya.* Unpublished Report.

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1987. “Method of Sampling the Plant Community.” In *Terrestrial Plant Ecology*, Chapter 9. Menlo Park, CA: Benjamin/Cummings Publishing Co.

Bass, Anna L., Sheryan P. Epperly, and Joanne Braun-McNeill. 2006. “Green Turtle (Chelonia mydas) Foraging and Nesting Aggregations in the Caribbean and Atlantic: Impact of Currents and Behavior on Dispersal.” *Journal of Heredity* 97 (4): 346-354.

Bjorndal, Daniel, W. Wood, and A. Karen. 2000. “Relation of Temperature, Moisture, Salinity, and Slope to Nest Site Selection in Loggerhead Sea.” *Copeia* Vol. 2000 (No. 1): 119-128.

Bourjea, J., R. Nel, N. S. Jiddawi, M. S. Koonjul, and G. Bianchi. 2008. “Sea Turtle Bycatch in the West Indian Ocean: Review, Recommendations and Research Priorities.” *Western Indian Ocean Journal Marine Science* Vol. 7 (No. 2): 137-150.

Brooks, Lin Schwarzkopf, and J. Ronald. 1987. “Nest-Site Selection and Offspring Sex Ratio in Painted Turtles, Chrysemys picta.” *Copeia* Vol. 1987 (No. 1): 53-61.

Bugoni, Leandro, Ligia Krause, and Maria Virginia Petry. 2001. “Marine Debris and Human Impacts on Sea Turtles in Southern Brazil.” *Marine Pollution Bulletin* 42 (12): 1330-1334.

Caldwell, D. K. 1962. “The Sea Turtle Fishery of Baja California, Mexico.” *California Fish and Game* 48 (3): 140-151.

Carr, A. F., M. H. Carr, and A. B. Meylan. 1978. “The Ecology and Migrations of Sea Turtle.” *Bulletin American Museum Natural History* 162 (No. 7): 1-46.

Carr, Archie. 1980. “Some Problems of Sea Turtle Ecology.” *American Zoologist* (Oxford University Press) Vol. 20 (No. 3): 489-498. http://www.jstor.org/stable/3882479.

Carr, Archie, and David K. Caldwell. 1956. “The Ecology and Migrations of Sea Turtles.” *American Museum Novitates* (American Museum Novitates) 4 (1793): 23.

Chen, Ho-Chang, L-Jiunn Cheng, and Eason Hong. 2007. “The Influence of the Beach Environment on the Digging Success and Nest Site Distribution of the Green Turtle, Chelonia mydas, on Wan-an Island, Penghu Archipelago, Taiwan.” *Coastal Education and Research Foundation, Inc.* Vol. 23 (No. 5): 1277-1286.

CIA. 2015. *The World Factbook.* 26 June. Accessed July 3, 2015. https://www.cia.gov/library/publications/the-world-factbook/geos/ke.html.

Cohen, Jacob. 1988. *Statistical Power Analysis for the Behavioral Sciences.* Hillsdale, NJ: Lawrence Earlbaum Associates.

Congdon, Justin D., Donald W. Tinkle, Gary L. Breitenbach, and Richard C. VanLoben Sels. 1983. “Nesting Ecology and Hatching Success in the Turtle Emydoidea blandingi.” *Herpetologists' League* Vol. 39 (No. 4): 417-429.

Derraik, Jose G. B. 2002. “The Pollution of the Marine Environment by Plastic Debris: A Review.” *Marine Pollution Bulletin* 44: 842-852.

Eckert, K. L., and F. A. Abreu-Grobois. 2001. “Proceedings of the Regional Meeting: "Marine Turtle Conservation in the Wider Caribbean Region: A Dialogue for Effective Regional Management".” Santo Domingo: WIDECAST, IUCN-MTSG, WWF and UNEP-CEP.

Eckert, K. L., K. A. Bjorndal, F. A. Abreu-Grobois, and M. Donnelly. 1999. *Research and Management Techniques for the conservation of Sea Turtles.* IUCN/SSC Marine Turtle Specialist Group Publication No. 4., Washington DC: SSC/IUCNMarineTurtleSpecialistGroup.

Eckert, Karen L., Karen A. Bjorndal, F. Alberto Abreu-Grobois, and M. Donnelly. 1999. *Research and Management Techniques for the Conservation of Sea Turtles.* Pennsylavia, USA: IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Eckert, Karen Lind, and Scott Alan Eckert. 1990. “Embryo Mortality and Hatch Success in In Situ and Translocated Leatherbak Sea Turtle Dermochelys coriacea Eggs.” *Biological Conservation* 53 (1): 37-46.

Emery, Kenneth Orris. 1961. “A Simple Method of Measuring Beach Profiles.” *Limnology and Oceanography* 6: 90-93.

FAO Fisheries and Aquaculture Department. 2009. *Guidelines to reduce sea turtle mortality in fishing operations.* Rome: FAO.

FAO South West Indian Ocean Fisheries Commission. 2009. “Report of the Workshop on Bycatch, Particularly in Prawn Fisheries, and on the Implementation of an Ecosystem Approach to Fisheries Management. Maputo, Mozambique, 15–24 November 2005.” Rome: FAO Fisheries and Aquaculture Report. No. 873. Rome, FAO. 2009. 47p.

Fish, Marianner R., Isabelle M. Cote, Jennifer A. Gill, Andrew P. Jones, Saskia Renshoff, and Andrew R. Watkinson. 2005. “Predicting the Impact of Sea-Level Rise on Caribbean Sea Turtle Nesting Habitat.” *Conservation Biology* 19 (2): 482-491.

Fowler, Lynn E. 1979. “Hatching Success and Nest Predation in the Green Sea Turtle, Chelonia mydas , at Tortuguero, Costa Rica.” *Wiley on Ecological Society of America* 60 (5): 946-955.

Frazier, J. 1980. “Exploitation of Marine Turtles in the Indian Ocean .” *Human Ecology* Vol 8 (No. 4): 329-370.

Furler, Sue. 2005. “Hatching success of the Leatherback Sea Turtle, Dermochelys coriacea, in Natural and Relocated Nests on Gandoca Beach, Costa Rica.” Basel.

Gachene, Charles K.K., and Gathiru Kimaru. 2003. *Soil Fertility and Land Productivity: A guide for Extension Workers in the Eastern Africa Region.* Technical Handbook No. 30. Nairobi,Kenya: Regional Land Management Unit (RELMA), Swedish International Development Cooperation Agency (Sida).

Gee, G. W., and J. W. Bauder. 1986. “Particle-Size Analysis.” In *Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods*, edited by A. Klute and Agronomy Monograph No. 9, 383-411. Madison, WI: American Society of Agronomy/Soil Science Society of America.

GoK. 2017. *National Mangrove Ecosystem Management Plan.* Nairobi: Kenya Forest Service.

Hamann, M., M. H. Godfrey, J. A. Seminoff, K. Arthur, P. C. R. Barata, K. A. Bjorndal, A. B. Bolten, et al. 2010. “Global Research Priorities for Sea Turtles: Informing Management and Conservation in the 21st Century.” *Endangered Species Research* Vol. 11 (doi: 10.3354/esr00279): 245-269.

Hart, Kristen, David Zawada, and Rachel Pawlitz. 2016. *USGS Science for a Changing World.* Accessed October 17, 2018. http://soundwaves.usgs.gov/2013/06/research2.html.

Hirth, Harold F. 1980. “Some Aspects of the Nesting Behavior and Reproductive Biology of Sea Turtles.” *American Zoologist* Vol. 20 (No. 3): 507-523.

Jackson, Donald C. 1985. “Respiration and RespiratoryControl in the Green Turtle, Chelonia mydas.” *Copeia* Vol. 1985 (No. 3): 664-671.

Janzen, D. W., and F. J. Weisrock. 1999. “Thermal and fitness-related consequences of nest location in Painted Turtles (Chrysemys picta).” *British Ecological Society* Vol. 13 (No. 1): 94-101.

Johnson, Steve A., and Llewellyn M. Ehrhart. 1996. “Reproductive Ecology of the Florida Green Turtle: Clutch Frequency.” *Journal of Herpetology* 30 (3): 407-410.

Kenya National Bureau of Statistics. 2010. *The 2009 Kenya Population and Housing Census "Counting Our People for the Implementation of Vision 2030".* Volume 1 A. Nairobi: GoK.

Kenya Wildlife Service. 2010. *Conservation and Management Strategy for Sea Turtle in Kenya 2011-2015.* Mombasa: Kenya Wildlife Service.

Leandro Bugoni, Ligia Krause and Maria Virginia Petry. 2001. “Marine Debris and Human Impacts on Sea Turtle in Southern Brazil.” *Marine Pollution Bulletin* Vol. 42 (No. 12): 1330-1334.

Leighton, Patrick A., Julia A. Horrocks, and Donald L. Kramer. 2010. "Conservation and the Scarecrow Effect: Can Human Activity Benefit Threatened Species by Displacing Predators?" *Biological Conseravtion* (Biological Conservation) (143): 2156-2163.

Lopez, Susan, K. Jacobson, and Alfredo Figueroa. 1994. "Biological Impacts of Ecotourism: Tourists and Nesting Turtles in Tortuguero National Park, Costa Rica." *Wiley* Vol. 22 (No. 3): 414-419.

Madden, Derek, Jorge Ballestero, Carlos Calvo, Robert Carlson, and Elaine Christians. 2008. "Sea Turtle Nesting as a Process Influencing a Sandy Beach Ecosystem." *Biotropica* Vol. 40 (No. 6): 758-765.

Mancini, Agnese, Jesse Senko, Ricardo Borquez-Reyes, Juan Guzman Poo, Jeffrey A. Seminoff, and Volker Koch. 2011. "To Poach or Not to Poach an Endangered Species: Elucidating the Economic and Social Drivers Behind Illegal Sea Turtle Hunting in Baja California Sur, Mexico." *Human Ecology* Vol. 39 (No. 6): 743-756.

Marine Turtle Specialist Group . 1996. *Caretta caretta.* Vers. Version 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

Marine Turtle Specialist Group. 1996. *Lepidochelys kempii.* Vers. Version 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

Marine Turtle Specialist Group. 2004. *The World Conservation Union Species Survival Commission Red List Programme.* IUCN.

MarineBio.org. 2013. *MarineBio Conservation Society.* Accessed May 05, 2014. http://marinebio.org/species.asp?id=51.

Mazaris, Antonios D., Gail Schofield, Chrysoula Gkazinou, Vasiliki Almpanidou, and Graeme C. Hays. 2017. “Global Sea Turtle Conservation Successes.” *Science Advances* (3): e1600730.

McClanahan, Timothy R. 1988. “Seasonality in East Africa's Coastal Water.” *Marine Ecology - Progress Series* 44: 191-199.

Meylan, Peter A., Ann B. Meylan, and Jennifer A. Gray. 2011. “The Ecology and Migrations of Sea Turtles 8. Tests of Developmental Habitat Hypothesis.” *Bulletin of the American Museum of Natural History*, 10 August: 70.

Meylan, Peter A., Anne B. Meylan, and Jennifer A. Gray. 2011. “The Ecology and Migrations of Sea Turtles '8. Test of the Developmental Habitat Hypothesis'.” *Bulletin of the American Museum of Natural History* 357 (August 10, 2011): 1-70.

Mortimer, J. A. 1981. *Reproductive Ecology of the Green Turtle, Chelonia myda, at Ascension Island.* Gainesville, Florida: Unpublished Ph.D Dissertation, University of Florida.

Mortimer, J. A., and M. Donnelly. 2008. *Eretmochelys imbricata.* Vers. Version 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

Mortimer, Jeanne A. 1990. “The Influence of Beach Sand Characteristics on the Nesting Behavior and Clutch Survival of Green Turtles (Chelonia mydas).” *Copeia* Vol. 1990 (No. 3): 802-817.

National Marine Fisheries Service and US Fish and Wildlife Service. 2007. *Green Turtle (Chelonia mydas) 5-Year Review: Summary and Evaluation.* Maryland, Florida: National Marine Fisheries Service and US Fish and Wildlife Service.

Nel, Ronel, E. Andre Punt, and George R. Hughes. 2013. "Are Coastal Protected Areas Always Effective in Achieving Population Recovery for Nesting Sea Turtle." *PLoS ONE* 8 (5): e63525.

Nelms, Sarah E., Emily M. Duncan, Annette C. Broderick, Tamara S. Galloway, Mathew H. Godfrey, Mark Hamann, Penelope K. Lindeque, and Brendan J. Godley. 2016. "Plastic and Marine Turtle: A Review and Call for Research." *ICES Journal of Marine Science* 73 (2): 165-181.

Net Industries and its Licensors. 2015. *Turtles-Histroy and Fossil Record.* Accessed May 12, 2015. Turtles - History And Fossil Record.

Ochieng, C. A., and P. L. A. Erftemeijer. 2003. "The Seagrasses of Kenya and Tanzania." In *World Atlas of Seagrasses*, edited by Edmund Peter Green, 82-92. California: University of California.

Okemwa, G. M., and A. Wamukota. 2006. "An Overview of the Status of Green Turtle (Chelonia mydas) in Kenya." *Book of Abstract. Twenty-Sixth Annual Symposium on Sea Turtle Biology and Conservation*, 311.

Okemwa, G. M., N. A. Muthiga, and E. M. Mueni. 2004. "Proceedings of the Western Indian Ocean Region Marine Turtle Conservation Workshop." Mombasa: NEPAD.

Okemwa, Gladys M., Simmons Nzuki, and Elizabeth M. Mueni. 2004. *The Status and Conservation of Sea Turtles in Kenya.* Accessed January 23, 2015. www.seaturtle.org/mtn/archives/mtn105/mtn105p1.shtml.

Okoola, Raphael E. 1999. “A Diagnostic Study of the Eastern Africa Monsoon Circulation During the Northern Hemisphere Spring Season.” *International Journal of Climatology* (19): 143-168.

Owens, Diana K., Crowell Comuzzie, and Wm. David. 1990. “A Quantitative Analysis of Courtship Behaviour in Captive Green Sea Turtles (Chelonia mydas).” *Herpetologists' League* Vol. 46 (No. 2): 195-202.

Parker, Laura. 2014. *The Best Way to Deal With Ocean Trash.* Accessed August 17, 2015. http://news.nationalgeographic.com/news/2014/04/140414-ocean-garbage-patch-plastic-pacific-debris/.

Pritchard, P.C.H., and J.A. Mortimer. 1999. “Taxonomy, External Morphology, and Species Identification.” In *Research and Management Techniques for the Conservation of Sea Turtles*, edited by K.L. Eckert, K.A Bjorndal, F.A Abreu-Grobois and M. Donnelly, 21-38. Gland: IUSC/SSC Marine Turtle Specialist Group Publication No. 4.

Pritchard, Peter Charles Howard. 1980. “The Conservation of Sea Turtles: Practices and Problems.” *American Society of Zoologists* 20: 609-617.

Read, Tyffen C., Laurent Wantiez, Jonathan M. Werry, Richard Farman, George Petro, and Colin J. Limpus. 2014. “Migrations of Green Turtles (Chelonia mydas) between Nesting and Foraging Grounds across the Coral Sea.” *PLoS ONE* 9 (6): e100083.

Red List Standards & Petitions Subcommitee. 1996. *Natator depressus.* Vers. Version 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

Rizkalla, Carol E., and Anne Savage. 2011. "Impact of Seawall on Loggerhead Sea Turtle (Caretta caretta) Nesting and Hatching Success." *Journal of Coastal Research* 27 (1): 166-173.

Ross, James Perran. 1985. "Biology of the Green Turtle, Chelonia mydas, on an Arabian Feeding Ground." *Society for the Study of Amphibians and Reptiles* Vol. 19 (No. 4): 459-468.

Ryan, G. Peter, J. Charles Moore, Jan A. van Franeker, and Coleen L. Moloney. 2009. "Monitoring the Abundance of Plastic Debris in the Marine Environment." *Royal Society Publishing* Vol. 364 (No. 1526): 1999-2012.

Salmon, Michael, Jeanette Wyneken, Elizabeth Fritz, and Mark Lucas. 1992. "Seafinding by Hatchling Sea Turtles: Role of Brightness, Silhouette and Beach Slope as Orientation Cues." *Behaviour* Vol. 122 (No. 1/2): 56-77.

Seminoff, J. A. 2004. *Chelonia mydas.* Vers. 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

SPNL. 2015. *Sea Turtles.* Accessed May 26, 2015. http://www.spnl.org/sea-turtles/.

Stancyk, S. E., and J. P. Ross. 1978. "An Analysis of Sand from Green Turtle Nesting Beaches on Ascension Island." *Copeia* 1978 (1): 93-99.

Sverdrup, Harald Ulrik. 1942. *The Oceans, Their Physics, Chemistry and General Biology.* New York: Prentice-Hall.

The IUCN SSC. 1996. *A Marine Turtle Conservation Strategy and Action Plan for the Western Indian Ocean.* Arlington, VA USA: IUCN.

Torre-Castro, M. de la, and P. Ronnback. 2004. “Links between Humans and Seagrasses - an example from Tropical East Africa.” *Ocean & Coastal Management* 47 (7-8): 361-387.

Tsoukala, V. K., V. Katsardi, and K. Hadjibiros. 2015. “Causes of Beach Erosion.” *Environ. Process.* 55 (Suppl 1): 2.

Tuxbury, Susan M., and Michael Salmon. 2005. “Competitive Interactions Between Artificial Lighting and Natural Cues During Seafinding by Hatchling Marine Turtles.” *Bilogical Conservation* Vol 121: 311-316.

UNEP. 1998. *Eastern Africa Atlas of Coastal Resources.* Nairobi: UNEP Regional Reports and Studies, No. 1.

UNEP-Nairobi Convention & WIOMSA. 2015. *The Regional State of the Coast Report: Western Indian Ocean.* Nairobi: UNEP and WIOMSA.

UNESCO. 2010. *Sandwatch: Adapting To Climate Change and Educating for Sustainable Development.* Paris: UNESCO.

University of Nairobi - Department of Soil Science. n.d. *The Determination of Organice Carbon in the Soil by the Walkey-Black Method.* Nairobi: Unpublished.

Univesity of Nairobi-Department of Soil Science. n.d. *Hydrometer Method of Soil Mechanical (Texture) Analysis.* Nairobi: Unpublished.

Varela-Acevedo, Elda, Karen L. Eckert, Scott A. Eckert, Gillian Cambers, and Julia A. Horrocks. 2009. “Sea Tutle Nesting Beach Characterisation Manual.” *Examining the*

Effects of Changing Coastline Processes on Hawksbill Sea Turtle (Eretmochelys imbricata) Nesting Habitat, 46-97.

Venkatesan, S., P. Kannan, M. Rajagopalan, and E. Vivekanandan. 2004. "Nesting ecology of the Green Sea Turtle Chelonia mydas Along the Saurashtra Coast." *Marine Biology Association India* Vol. 46 (2): 169-177.

Wallace, B. P., M. Tiwari, and M. Girondot. 2013. *Dermochelys coriacea.* Vers. Version 2014.3. Accessed February 24, 2015. www.iucnredlist.org.

Wallace, Brayan P., Rebecca L. Lewison, Sara L. McDonald, Richard K. McDonald, Connie Y. Kot, Shaleyla Kelez, Rhema K. Bjorkland, Elena M. Finkbeiner, S'rai Helmbrecht, and Larry B. Crowder. 2010. "Global Patterns of Marine Turtle Bycatch." *Wiley-Blackwell.*

Weslawski, Jan Marcin, Barbara Urban-Malinga, Lech Kotwicki, Krzysztof Opalinski, Maria Szymelfenig, and Marek Dutkowski. 2000. "Sandy Coastlines - Are there Conflicts between Recreation and Natural Values?" *Oceanological Studies* XXIX (2): 5-18.

Whitmorec, P., and P. H. Dutton. 1985. "Infertility, Embryonic Mortality and Nest-Site Selection in Leatherback and Green Sea Turtles in Suriname." *Biology Conservation* 34: 251-272.

Wikipedia The Free Encyclopedia. 2014. *Littoral Zone.* Accessed May 26, 2015. http://en.wikipedia.org/wiki/Littoral_zone.

Wilson, Dawn S. 1998. “Nest-Site Selection: Microhabitat Variation and Its Effects on the Survival of Turtle Embryos.” *Ecological Society of America* Vol. 79 (No. 6): 1884-1892.

Witherington, B. E., and R. E. Martin. 2003. *Understanding, Assessing and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches.* Florida: Florida Marine Research Institute Technical Report TR-2.73 p.

Witherington, Blair, Shigetomo Hirama, and Andrea Mosier. 2011. “Sea Turtle Responses to Barriers on their Nesting Beach.” *Journal of Experimental Marine Biology and Ecology* 401: 1-6.

Wood, Daniel W., and Karen A. Bjorndal. 2000. “Relation of Temperature, Moisture, Salinity, and Slope to Nest Site Selection in Loggerhead Sea Turtles.” *Copeia* 1: 119-128.

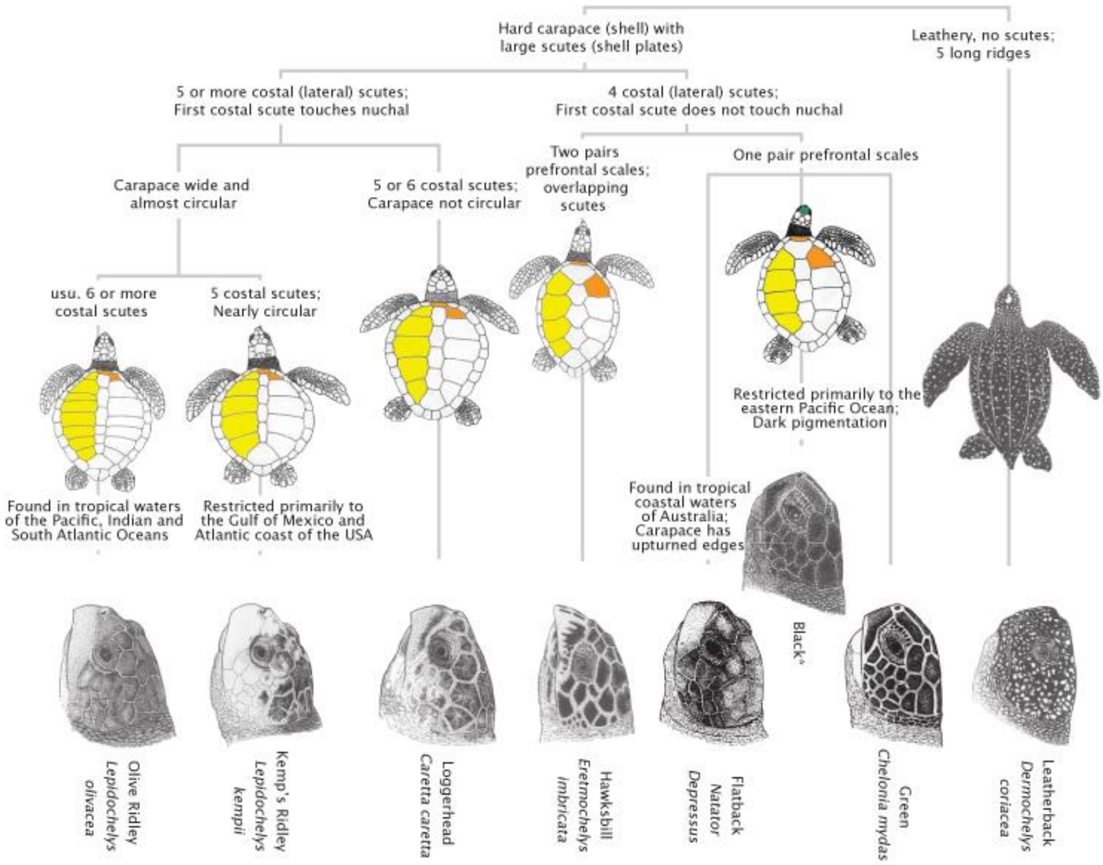
Wood, James, R. Wood, and E. Fern. 1980. “Reproductive Biology of Captive Green Sea Turtles Chelonia mydas.” *American Zoologist* Vol. 20 (No. 3): 499-505.

Zarate, Patricia, Karen A. Bjorndal, Macarena Parra, Peter H. Dutton, Jeffrey A. Seminoff, and Alan B. Bolten. 2013. “Hatching and emergence success in green turtle Chelonia mydas nests in the Galápagos Islands.” *Aquatic Biology* Vol. 19: 217-229.

Zavaleta-Lizárraga, Leonel, and Jorge E. Morales-Mávil. 2013. “Nest site selection by the green turtle (Chelonia mydas) in a beach of the north of Veracruz, Mexico.” *Revista mexicana de biodiversidad* 84 (3).

APPENDIX I

Taxonomy, External Morphology, and Species Identification of Sea Turtle



Taxonomy, External Morphology, and Species Identification of Sea Turtle (Pritchard and Mortimer 1999)

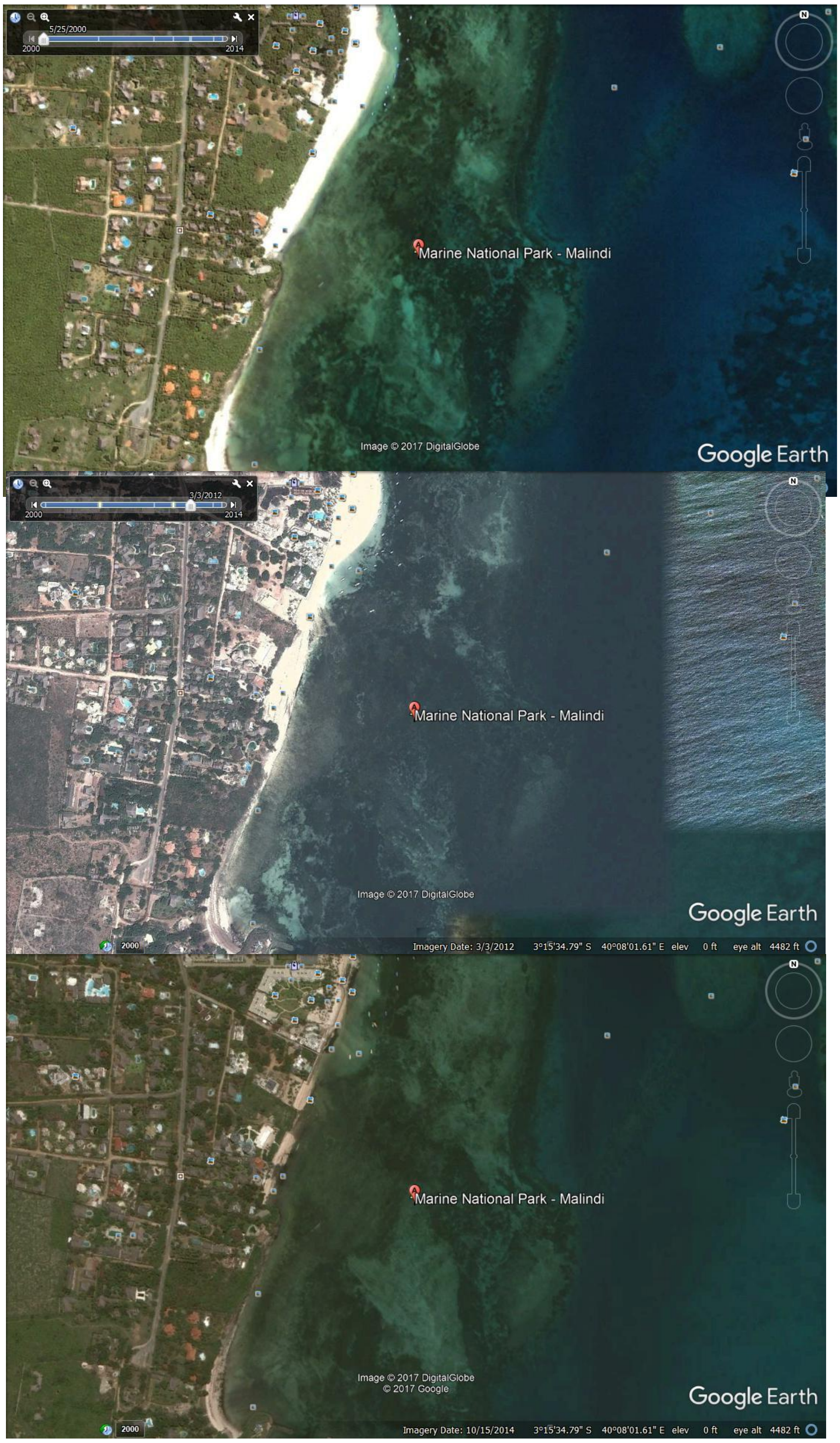
Figure 15: *C. mydas* from laying a nest at Pride Inn

Figure 16: Excavated nest of *C. mydas* near Serena beach in Mombasa County

Figure 17: *C. mydas* at Mombasa Marine National Park and Reserve

APPENDIX II

Google satellite images of the changes to the beach of Malindi Marine National Park and Reserve from the year 2000, 2012 when sea wall was constructed and 2017.

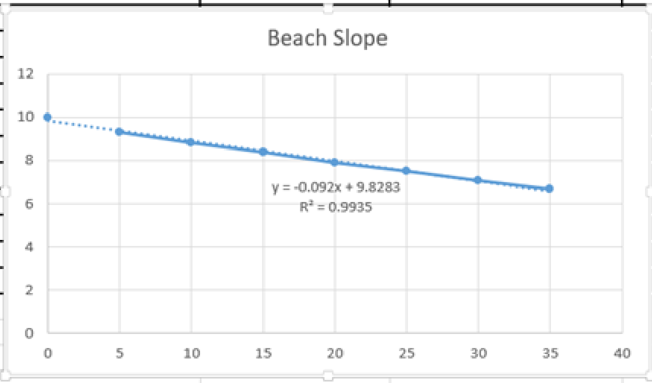


APPENDIX III

Data Analysis

REF: 055

CHANGE IN DISTANCE (METRES)	CUMULATIVE DISTANCE (METRES)	CHANGE IN ELEVATION (METRES)	CUMULATIVE ELEVATION (METRES)	NOTE
--	0	--	10	*Start o*
5	5	-0.68	9.32	
5	10	-0.51	8.81	
5	15	-0.41	8.4	
5	20	-0.49	7.91	
5	25	-0.39	7.52	
5	30	-0.44	7.08	
5	35	-0.38	6.7	



Graph plotted of cumulative elevation against cumulative distance of Mwongo Sheriff beach, Lamu County

APPENDIX IV

Photos of organic matter and soil texture laboratory analysis

Sieves for soil texture analysis

Shaker used together with the sieve

Kiln to determine organic content

APPENDIX V

Field data collection photos

The only bridge to a nest site in Marereni

Emery survey rod

APPENDIX IV

Important vegetation along the Kenyan coastal beaches

Ipomoea pes-caprae

Halopyrum mucronatum

Scaevola plumeri

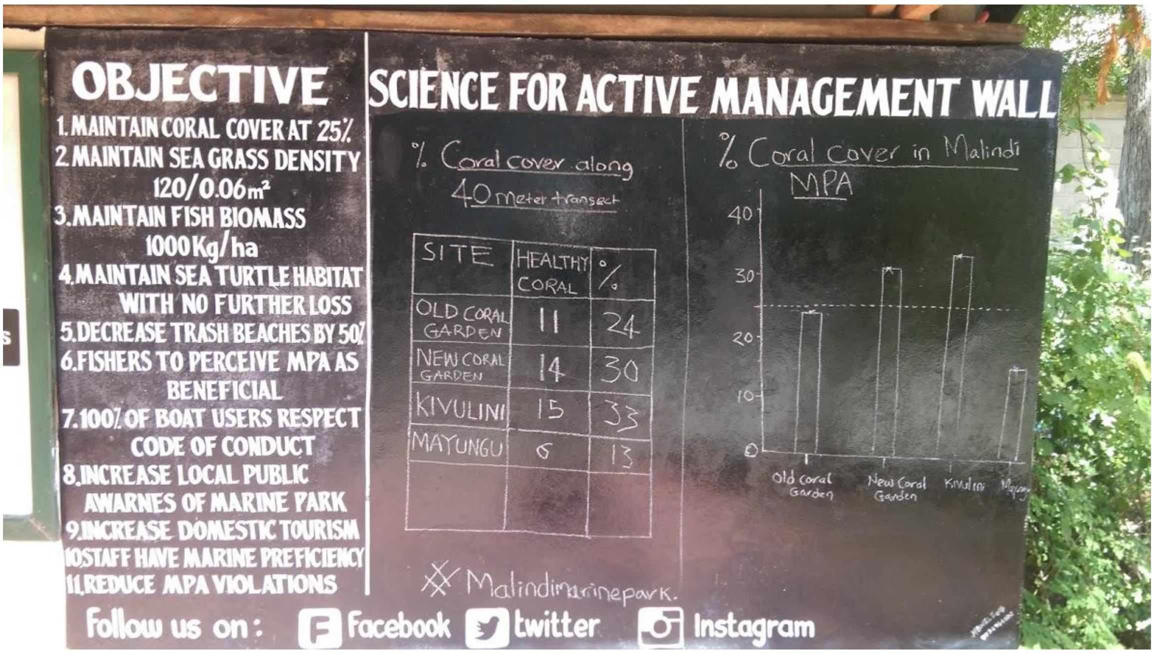
Calotropis procera

Fishers catch of the day at Maungu beach (landing site)

Data collection at Giriama Village Island, the beach has dark soil particles because of the effect of River Sabaki

Data collection in Ashuwei, Mkokoni

Erosion as result of wave action



Management objectives of Malindi MPA the turtle nest sites have been affected greatly be construction of sea wall at Billionaire Resort