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Monitoring Nesting Trends and Hatchling Success of the Green Turtle (Chelonia mydas) Population on Mnemba Island, Zanzibar

Taylor Dunbar
SIT Study Abroad

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By: Taylor Dunbar
Advisor: Lindsey West
Academic Director: Helen Peeks
Coastal Ecology and Natural Resource Management
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Abstract

The nesting trends and hatching success of Green sea turtles (*Chelonia mydas*) were studied on Mnemba Island. This study involved a continuation of data collection for the ongoing monitoring program of sea turtles on Mnemba Island. Data was collected from nesting females as well as from post hatching nest excavations. The data that has been collected over the course of ten years was then analyzed to examine trends over time as well as to assess the current status of the turtle population on Mnemba Island. Hatch success as a function of different seasons was analyzed. It has been concluded that there is a significant difference between hatching success in wet and dry seasons, but not in the different monsoon seasons. Hatch success as a function of location on the island was also explored, and trends in frequencies of nest sites in various locations were examined. Trends in nest location selection were investigated in relation to coastal erosion occurrences. The only significant preferences for nest location found was that the majority of nest sites were concentrated on the western and southwestern sides of the island. This is also related to trends in nest site selection in relation to coastal erosion, as there are no occurrences of nests on eastern side of the island, which experiences the most erosion. Furthermore, it has also been concluded that there is no difference in hatching success between years, and that hatching success has not significantly changed over time. This implies that Mnemba Island provides a stable environment for nesting green turtles, and is therefore an important area to continue to conserve. Recommendations for future studies are made.

Introduction

There are seven extant species of marine turtles worldwide, five of which can be found in the Western Indian Ocean. These species include Green (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*), Loggerhead *(Caretta caretta*), Leatherback (*Dermochelys coriacea*) and Olive Ridley (*Lepidochelys olivacea)* (Frazier 1975). Tanzania's mainland coastline, along with Zanzibar and other nearby islands, provide feeding habitats for these five species. Green and hawksbill turtles are known to also have nesting grounds in Tanzania. The conservation of sea turtles on the coast of Tanzania, specifically on nesting beaches, has been an ongoing effort. Several management and conservation initiatives have been implemented; however, monitored areas only include about a third of the coast of Tanzania (Muir 2005).

The present study involved the monitoring of the green turtle population on Mnemba Island. The green turtle is the most common nesting species in Tanzania, and is currently the only species nesting on Mnemba Island. The nesting population on Mnemba Island has been monitored for approximately ten years. The purpose of this study was to analyze nesting and hatching success trends in an attempt to gain an understanding of the effects of certain environmental and geographical conditions on these trends and the status of the population over time.

Taxonomic Identification

Green turtles are the largest of the family Cheloniidae. While hatchlings are only approximately 5 cm in length, adults average a carapace length of up to 140 cm and

weigh between 90 kg and 200 kg (Muir 2005). They have a smooth carapace that can be shades of black, gray, green, or brown, while their plastron has a yellow-white coloring. Hatchlings have a black carapace and white plastron. They are unique from other sea turtles in that they are herbivorous as adults. Their diet consists mainly of sea grass and algae. This diet is believed to give their fat a green coloring, from which they inherit their name. It is estimated that green sea turtles reach sexual maturity between 20 and 50 years of age. Once they have reached sexual maturity, females return to their natal beaches every two to four years to lay eggs. Females nest at approximately two-week intervals, and lay an average of three clutches in a season (NOAA). On average, one clutch contains about 110 eggs, which are about 4 to 5 cm in diameter. The nests hatch after an incubation period of 50 to 75 days, depending on the temperature of the nest. The warmer the nest is, the faster the embryos will develop. Nest temperature is also critical in determining the sex of the hatchlings (Ripple 33). According to antecedent studies on green turtles, temperatures below 28°C are found to produce 90 to 100 percent males, while nest temperatures of 30.5°C or higher produce 94 to 100 percent females (Morreal 1982).

Green turtles utilize three distinct habitats throughout each stage of growth. The first is oceanic beaches for nesting. Once the hatchlings emerge from the nest and leave their natal beach, they swim to the sargassum weed lines in convergence zones. It is thought they live in these convergence zones for several years. During this stage of

growth, green turtles are omnivorous, feeding on a variety of pelagic plants and animals. However, once the juveniles reach a certain age and size range, they then travel to near-shore areas and estuaries. Once they reach adulthood they move into benthic feeding grounds, where they shift to a mainly herbivorous diet (Ripple 16). Green turtles are highly migratory, moving hundreds or thousands of kilometers between foraging and nesting grounds.

The green turtle is globally distributed, and is typically found in tropical and subtropical waters along continental coasts and islands. Green turtles are believed to inhabit coastal areas of more than 140 countries. In east Africa, green turtles are the most abundant sea turtle species and are most widely distributed in Kenya, Tanzania, Mozambique, South Africa, Madagascar, Comoros, Seychelles and Mayotte. The Seychelles and Comoros have the largest green nesting colonies in the region. In Tanzania, the green turtle is the most common nesting species. Green turtles are recorded to have concentrated nesting activity occurring on Misali Island, Mnemba Island, Mafia Island, and on beaches in Temeke and Pangani Districts ((Sea Sense, pers.comm) The main threats that face marine turtles include both natural and human influenced causes. Human threats to marine turtles include activities such as the subsistence harvesting of eggs on nesting beaches as well as the harvesting of adult individuals for meat, oil and medicine. Furthermore, incidental capture in fishing gears is a serious ongoing source of mortality that adversely effects the population of marine turtles worldwide. Incidental capture in nets, especially gillnets and commercial prawn trawlers is a problem that faces

marine turtle populations in Tanzania. Furthermore, the use of destructive fishing gears and illegal fishing practices, such as the use of dynamite and seine nets, continues to be a threat to marine turtles (Frazier 1980).

The destruction or disturbance of important feeding habitats, as well as the disruption of nesting beaches due to human development is another major threat to marine turtles in Tanzania. The development of coastal areas has taken away important nesting areas, and light pollution on nesting beaches has various adverse effects to both adult females and hatchlings. Adult females are easily disturbed by lights and will avoid nesting in areas of light pollution. Therefore, many coastal areas, when developed by humans, often render these beaches unsuitable for adult females to nest. Hatchlings are also potentially impacted by light pollution caused by human development. Hatchlings emerge from their nests at night and instinctively move towards the brightest horizon, which in nature would be the ocean due to the reflection of the moon and stars on the water. However, with lights, human development and urbanization, hatchlings potentially become disoriented and are unable to locate the ocean.

Pollution also greatly impacts marine turtle survival. As Tanzania continues to expand human development in the coastal region, this human development leads to an increase in pollution levels and a decline in water quality. The discharge of untreated or semi-treated sewage, heavy metals, chemicals and more can lead to serious damage to sea grass habitats and cause coral reef mortality. These areas are crucial foraging habitats for marine turtles (Gibson & Smith 1999). In addition, pollution in the form of debris such as

discarded fishing nets and traps and plastic waste in the water are another threat to marine turtles, as the turtle often become entangled and drown. Also, marine debris, especially plastic, can often be mistaken for food by foraging turtles. When swallowedit causes blockages in the gastro-intestinal system and eventual death.. Furthermore, debris on nesting beaches has the potential to disturb nesting activities of the population. On Mafia Island, it was found that large quantities of refuse, such as plastic, glass and driftwood accumulates on beaches located on the eastern side of the island. This collection of debris creates a blockade on the beach that nesting turtles are unable to negotiate. As a result, many turtles nest below the high tide line. The nest becomes inundated on the next high tide and the eggs will usually rot Natural threats to marine turtle populations include non-human predation and beach erosion. Non-human predators on nesting beaches include ghost crabs (*Ocypode quadrata)*, birds such as the Indian House crow *(Corvus splendens)*, dogs and more. Once hatchlings have reached the ocean, they then face predators such as large fish like barracuda, sharks and groupers (Muir 2005). Coastal erosion is another natural threat to marine turtles. Natural beach erosion and accretion can lead to the turtles experiencing difficulties nesting on natal beaches as they change or disappear. Furthermore, nests located on eroding beaches are more vulnerable to the threats of being uncovered, deluged or swept away by the tides (Witherington 1999).

Study Area

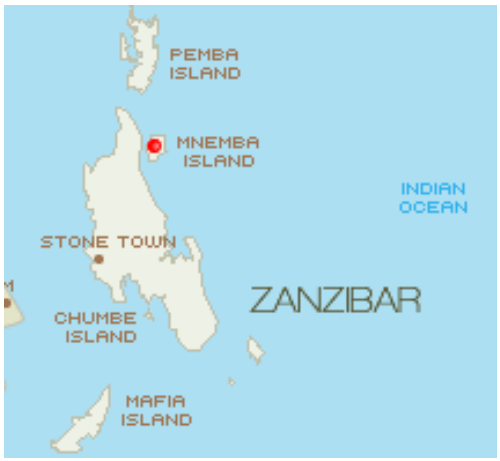

Figure 1. Mnemba Island

The Zanzibar archipelago, made up of the two islands of Unguja and Pemba, is located off the coast of mainland Tanzania. The present study was conducted on Mnemba Island. Mnemba Island is located 4.5 km off of the northeastern coast of Unguja Island in the West Indian Ocean (S 05° 49.219'E 039° 22.959'). The island has a circumference of 1.5km and an approximate area of 1 km^2 (Mnemba Island Website). The island houses Mnemba Island Lodge, a private high-end luxury resort. The island is a Marine Protected Area, the Mnemba Island Conservation Area, where a sea turtle conservation program has been ongoing since 1996. Activities of this initiative include turtle nest protection and monitoring, tagging, eco-tourism and awareness and education. The Mnemba Lodge Sea Turtle Monitoring Program is one of the longest running monitoring programs and is also one of the most consistent tagging programs in Tanzania (Sea Sense). The specific study area utilized consists of the shoreline of the island. Figure 2 shows the site

locations of each of the green turtle nests on Mnemba Island that were monitored during the course of this study.

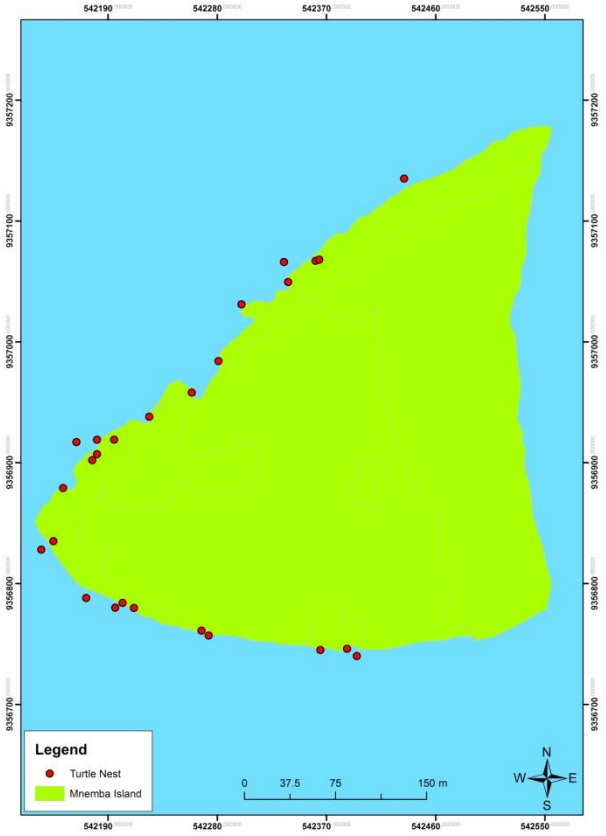

Figure 2. Mnemba Island and the Distribution of Green Turtle Nests on Mnemba Island. A total of 26 green turtle nests existed on the island during the course of this study. Of the 26 nests existing on the island, 8 nests hatched and 5 were laid during the time of this study. Map courtesy of Abbas Juma Mzee of Wildlife Conservation Society, Tanzania.

The current study was conducted from April 4 to April 23, 2011. This period of time falls within both the southeast monsoon and the main rainy season. The western Indian Ocean has sea level air temperatures that typically do not fall below 20°C and seawater temperatures between 20 and 30°C. The climate of the region is subject to two alternating, discrete seasons. These include the southern and the northern monsoon wind seasons, known respectively as Kusi and Kaskazi. The southeast (Kusi) monsoon wind

occurs from April to September and the northeast (Kaskazi) monsoon wind occurs from November to March. Kusi is characterized by stronger winds and the true rainy season occurs during the Kusi monsoon season. The long rainy season occurs from March to June. Kaskazi is typically associated with short rainy periods that occur mainly in November and December (Richmond 2002).

The coastline in Zanzibar is being eroded at a rate of 1 to 3 meters a year, as estimated by a study commissioned by the Department of Environment. The areas most threatened in Unguja include Nungwi, Bwejuu, Jambiani and Mnemba Island (Khatib 1998). Mnemba Island is currently experiencing coastal erosion that has caused changes in the geography of the island over the past ten years. The western side of the island has been accreting while the eastern side of the island has been eroding. The southern side of the island has remained relatively stable over the past ten years. As a result of this erosion, there have been various building structures associated with the Mnemba Island Lodge that have since been washed away, trees have been uprooted and general area of beach reduced (Glen 2011).

Methodology

This study involved the monitoring of turtle nests and nesting females. The work that was conducted in this study includes post hatching excavation of turtle nests, as well as the observation of nesting turtles.

Excavation

Nests were excavated one to two days after the date the nest is estimated to hatch in an attempt to check for live hatchlings that may have gotten stuck, as well as to count the number of eggs laid (clutch size). Specifically, the number of eggs successfully hatched, rotten, and dead hatchlings were counted. To check the status of the hatchlings, the sand from the top of the nest was gently removed. In the event that this disturbance of the nest caused hatchlings to emerge from the nest, excavations were done in the evenings when there are cooler temperatures and fewer natural predators for the hatchlings, such as crabs, birds and fish. After hatching events were concluded, the nest was dug up and all eggs shells and rotten eggs were removed from the nest. The number of empty eggshells (successful hatchlings), rotten eggs (unsuccessful hatchlings), and dead hatchlings (unsuccessful) were then counted and recorded.

Observation of Nesting Turtles

When females came up the beach to nest, her progress was monitored throughout the nesting process. After she finished laying and completed covering the nest, her tag number was checked and recorded. Curved carapace length and curved carapace width was also measured and recorded for each nesting female using a tape measure. If a

nesting event was not observed during the night, the width of the turtle tracks in the sand was measured to determine the relative size of the nesting female.

Data Analysis

Over the past ten years, the sea turtle monitoring program on Mnemba Island has made an effort to compile data relating to the nesting green turtle population. This data includes data of a nesting event, time of the event, location of the nest, length and width measurements of the female, and the tag number of the female (if present). Data collection has also included post hatching nest excavation data, which is comprised of hatching date and the details of the hatching: number of hatchlings, number of dead hatchlings, and number of rotten or undeveloped eggs. In this study, an attempt was made to utilize this data compiled over the past ten years to analyze certain trends occurring in the population and assesses the status of the population on Mnemba.

Data was analyzed to determine hatching success in relation to different environmental factors, such as the different rain and monsoon seasons. Hatch success was also analyzed as a function of time to determine if the success rates of nests on Mnemba Island under the supervision of the marine turtle monitoring program has changed over the past ten years. Furthermore, hatch success in relation to location on the island was examined as well as how nest location and population trends have changed over time in relation to the beach erosion patterns occurring on Mnemba Island.

Results

Environmental Effects of Rain and Monsoon Seasons on Hatching Success

This study observed the effects of different environmental conditions on hatchling success. The number of hatched (successful hatchlings), dead hatchlings and undeveloped eggs (unsuccessful hatchlings) were observed in relation to the environmental effects of both rain and monsoon seasons.

I tested the null hypotheses that the number hatched, the number dead, and the number undeveloped does not differ between wet and dry seasons. I used an independent samples t-test. The data provide evidence that at alpha = 0.05, the null hypothesis that there is no difference between the wet and dry seasons for hatched (successful hatchlings) can be rejected (P = 0.007). The data also provide evidence that the null hypothesis that wet and dry seasons have no effect on number of dead hatchlings can be rejected (P = 0.007). The data provide evidence that the null hypothesis that rain seasons have no effect on number of undeveloped eggs cannot be rejected (P = 0.102).

The null hypotheses that the number hatched, the number dead, and the number undeveloped does not differ between Kusi and Kaskazi monsoon wind seasons were also tested. I used an independent samples t-test. The data provide evidence that at alpha = 0.05, the null hypothesis that there is no difference between Kusi and Kaskazi monsoons for hatched (successful hatchlings) cannot be rejected (P = 0.294). The data also provide evidence that the null hypothesis that monsoon seasons have no effect on number of dead hatchlings cannot be rejected (P = 0.694). The data provide evidence that the null

hypothesis that monsoon seasons have no effect on number of undeveloped eggs can be rejected (P = 0.003).

This study also observed the effects of different environmental conditions on percent hatchling success. The percent hatched (successful hatchlings in a nest) were observed in relation to the environmental effects of rain and monsoon seasons.

I tested the null hypotheses that the percent hatched does not differ between wet and dry seasons. I used an independent samples t-test. The data provide evidence that at alpha = 0.05, the null hypothesis can be rejected (P = 0.008).

The null hypothesis that there is no difference between Kusi and Kaskazi monsoon wind seasons in percent hatched was also tested. I used an independent samples t-test. The data provide evidence that at an alpha of 0.05, the null hypothesis cannot be rejected (P = 0.092).

Hatching Success Trends Over Time

The hatching success of a nest was measured through proportions between number of individuals hatched (successful) and the number of dead hatchlings and number of rotten or undeveloped eggs (unsuccessful). Figure 3 represents the average number of individual turtles hatched from a nest for each year over the span of ten years. Figure 4 represents the average percent successful (hatched individuals) in comparison to the average percent unsuccessful (dead hatchlings or undeveloped eggs) over the span of ten years. There is no overall trend over time that is suggested by either Figures 3 or 4.

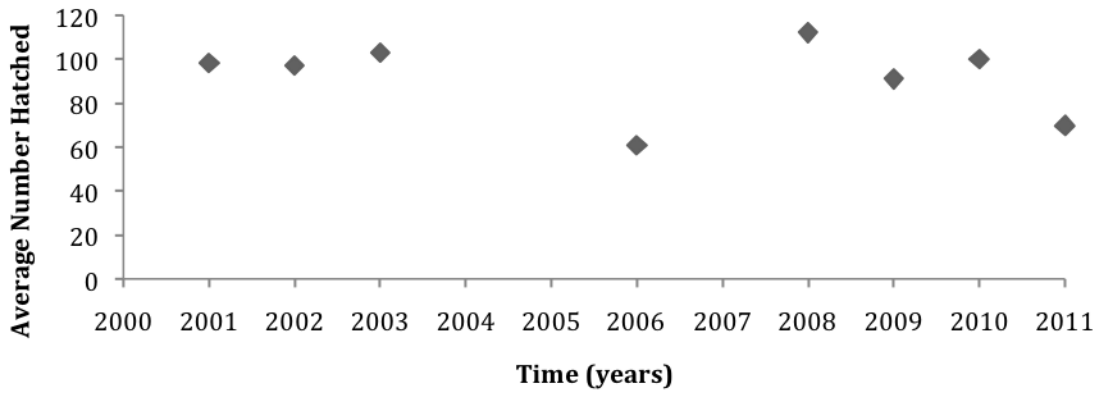

Figure 3. Average Number Hatched as a Function of Time (years). The average number of hatched (successful) individuals was calculated for each year from 2001-2010. The data for the years 2004 and 2007 are not available. It is also important to note that the data for the year 2011 includes average number hatched for the months January-April only.

The null hypothesis that the distribution of average number of hatched individuals in a nest does not differ across the span of ten years was tested. It was determined that there was no statistical significance with a p-value of 0.429. Therefore, the null hypothesis cannot be rejected.

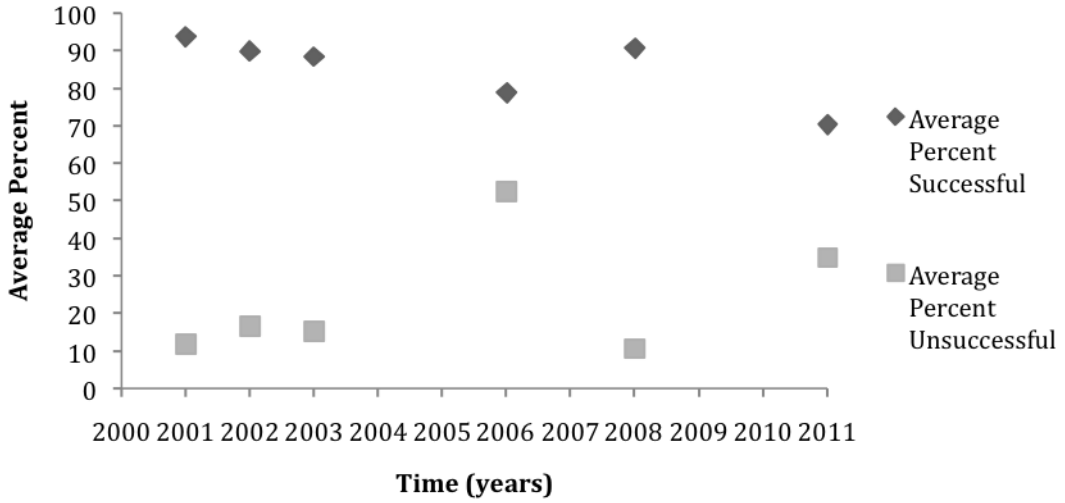

Figure 4. Average Percent Success Rates for Green Turtle Nests on Mnemba Island as a Function of Time (years). The average percent successful (hatched) and the average number unsuccessful (dead and undeveloped hatchlings) were calculated for each year from 2001-2011. Note that the data from years 2004, 2005, 2007 and 2009 are incomplete, and that the data includes averages for the months January-April only for the year 2011.

The null hypotheses that the distribution of the average percent of successful hatchlings in a nest over the course of ten years does not differ, and that the average percent of unsuccessful hatchlings is not different between years, were tested. It was found that the null hypothesis could not be rejected as no statistical significance was found ($P = 0.416$).

Hatching Success of Green Turtles as a Function of Location on Mnemba Island

The coastline of Mnemba Island was divided into six different zones, as shown in Figure 5. The average percent success of green turtle nests located in each of these areas were then calculated for the years 2001, 2003 and 2008 to look at trends over time in relation to geographic location. The average percent success as a function of location was also calculated for months January-April for the year 2011 to examine the current state of the population on Mnemba. As illustrated in Figures 6 through 9, it appears that in general, the average percent hatch success is not dependent on location. Furthermore, the data showed that there is no correlation between average percent hatch success and location in the different monsoon seasons.

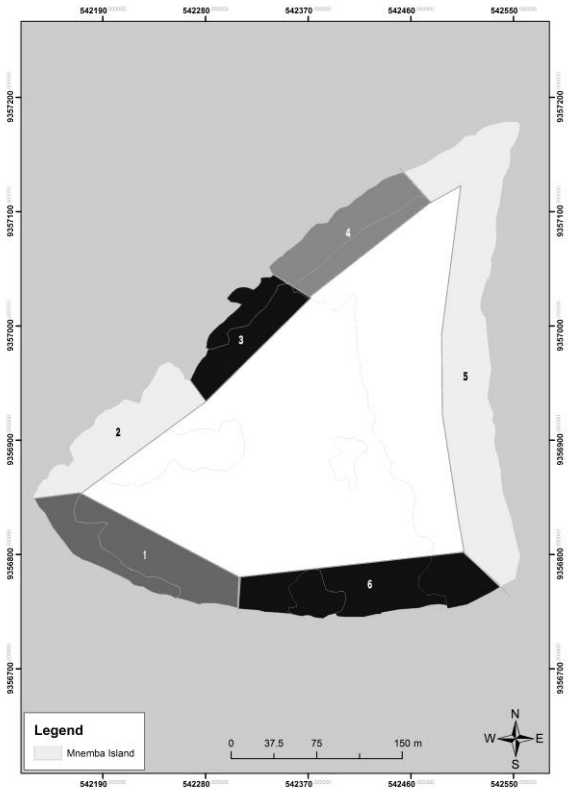

Figure 5. Six Distinct Areas of Mnemba Island Coastline.

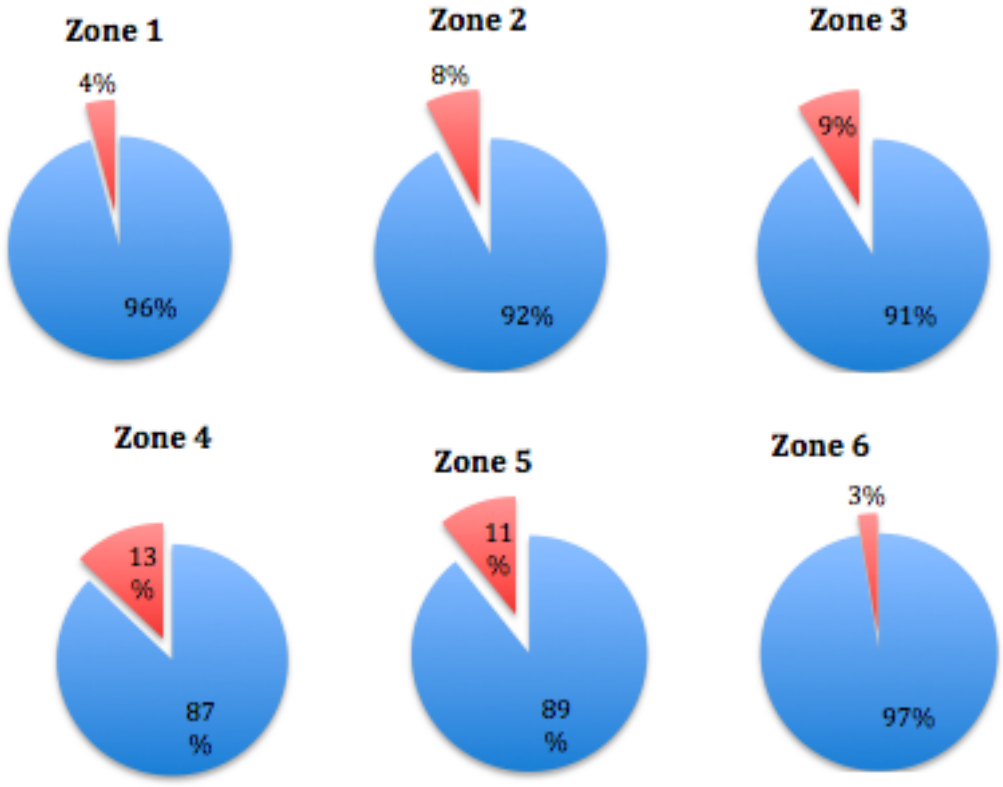

Figure 6. Average Percent Hatching Success for Each Zone for 2001.

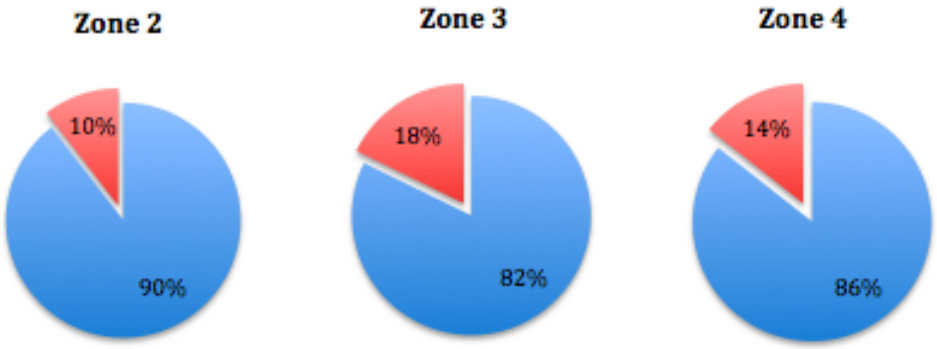

Figure 7. Average Percent Hatching Success for Each Zone for 2003.

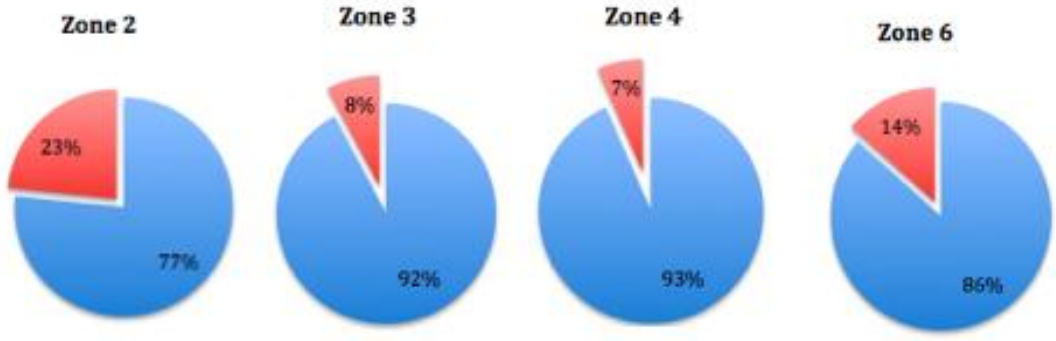

Figure 8. Average Percent Hatching Success for Each Zone for the year 2008.

Figure 9. Average Percent Hatching Success for Each Zone for months January-April in the year 2011

Nest Location in Relation to Coastal Erosion on Mnemba Island

The effects of coastal erosion on nest site location on Mnemba Island were investigated. The northern tip and eastern side of the island experiences beach erosion. As seen in Figure 5, the section on the map denoted as area 5 encompasses the areas that are subject to coastal erosion. It was found that while ten years ago there were green turtles recorded nesting on the eastern side of the island, there are no longer any turtles in the population nesting on that side of the island, as shown in Table I. Nesting sites currently occur exclusively on the western and southern portions of Mnemba's coastline. Nests are mainly concentrated on the western side of the island.

Table I. Total Number of Green Turtle Nests Located in Zone 5.

Year	Number of Nests
2001	9
2002	4
2003	3
2004	2
2005-2011	0

Nest Location Preference in Relation to Season

The total number of nests laid during the different monsoon seasons in the years 2001-2003 and 2008-2011 was reviewed and the areas of the coastline of Mnemba Island in which these nests were located during the Kusi and Kaskazi monsoons was analyzed. Overall, there was no meaningful difference found between seasons in location preferences over time. The western side of the island was found to have the largest

concentration of nest sites over both monsoon seasons. Other trends noticed include that over the course of 2001-2003, the south coast of the island supported zero nests during the Kaskazi monsoon and very few nests in the Kusi monsoon seasons. However, over the course of 2008-2011, there were a much larger number of nests found on the southern coast of the island.

Table I. Total Number of Nests Laid During Different Monsoon Seasons for Years 2001-2003.

Season	Zone	Total Number of Nests
Kaskazi	1	0
	2	10
	3	11
	4	21
	5	4
	6	0
Kusi	1	2
	2	8
	3	10
	4	31
	5	7
	6	1

The total number of nests laid between the years 2001 and 2003 is 105. On average, 35 nests were laid per year between the years 2001 and 2003. As shown in Table I, no nests were laid in Zones 1 and 6, or on the southern coast of the island during the Kaskazi monsoon. The main concentration of nests during Kaskazi is found in zones 2-4, or the western side of the island. In contrast, during the Kusi monsoon, nests were laid in zones 1 and 6 on the southern coast. The main concentration during the Kusi monsoon remained on the western side of the island.

Table II. Total Number of Nests Laid During Different Monsoon Seasons For Years 2008-2011.

Season	Zone	Total Number of Nests
Kaskazi	1	11
	2	21
	3	15
	4	24
	5	0
	6	6
Kusi	1	15
	2	8
	3	4
	4	26
	5	0
	6	1

The total number of nests laid between the years 2008 and the beginning of 2011 is 131. Approximately 37 nests on average are laid per year. It was found that during the Kaskazi monsoon season, zones 1 and 3 and zones 2 and 4 experience similar number of nests in total. While in the Kusi monsoon season, the majority of nests are laid in zones 1 and 4. It was found that no nests are laid in Zone 5, which includes the side of the island that had experienced significant coastal erosion by this time.

Green Turtle Population Estimate on Mnemba Island

Based on the data, a general estimation of the nesting green turtle population on Mnemba Island can be made. Annual nest data since 2001 indicates that on average, 36 nests are laid in a year. It is estimated that 12 to 15 individual turtles nest on Mnemba Island a year based on these figures.

Discussion

Statistically significant differences were found between the number of hatched and dead hatchlings in dry and wet seasons. Furthermore, the difference between percent hatched in wet and dry seasons was also found to be statistically significant. However, there was no evidence that the different rain seasons have an effect on the number of undeveloped or rotten eggs in a nest. This suggests that there is an environmental effect of wet and dry seasons on the survival of hatched turtles, but not necessarily on the development of the eggs. It was found that in general, greater mortality of hatchlings occurs during the wet season. Antecedent studies have suggested that all developmental stages of marine turtles are vulnerable to rain-induced suffocation. It was noted that green turtle nests on the coast of Sarawak, Borneo experienced a lower percentage of hatchery success during the monsoon season (Hendrickson 1958). Similarly, in a green turtle hatchery on Heron Island, Australia, a lower hatching success was found during a season that experienced prolonged wet weather (Bustard 1972). The results from the present study are consistent with these trends, as they show statistically significant data that hatching success is reduced in the main wet season on Mnemba Island. However, statistically significant data found included effects of increased amounts of rainfall on the survival of developed embryos, not of incubating eggs in general. This contrasts previous research that has suggested that increased mortality of incubating sea turtle eggs due to increased rainfall is a widespread phenomenon (Kraemer 1980).

Environmental effects on hatching success rates do not extend to the monsoon seasons. It was found that there were no statistically significant differences between number hatched, as well as number dead, in the different monsoon seasons Kusi and Kaskazi. It was also found that percent hatched does not differ in the different monsoon seasons. This suggests that although there is a correlation between hatching success rates and the main rainy season, which occurs during the southeast monsoon, the Kusi monsoon season overall does not have any significant effect on turtle hatchling success. Green turtles in Tanzania are known to have their main nesting season occur between February and July, which falls predominately during the southeast monsoon (Muir 2005). While it was determined in this study that the rainy season negatively impacts hatch success rates, it would appear that concentrating the majority of nesting events for a population in the wet season would be maladaptive. However, the results also suggest that the timing of the main nesting season does not in fact negatively impact hatching success overall. Furthermore, concentrating the nesting events in the rainy season has the benefits of reducing risk of overheating in the nest. Many nests are lost to excessive heat in the months of February and March when Tanzania is hottest. However, during the rainy season the sand temperature is lower and is not at risk of overheating (West 2011).

Hatching success was also measured in relation to relative location on the coastline of Mnemba Island. It appears that there is no meaningful correlation between location and nest success in general. Overall, the various locations of nest sites on Mnemba Island yield similar hatch success rates over time. However, general trends in

location of nest sites have changed slightly over the past ten years. The total number of nests in a year located in area 5, which is located on the eastern coastline of the island, has diminished gradually over the course of five years. Since 2005, there have been zero nests recorded on the eastern side of the island. This shift in nest location selection away from area 5 is suspected to be caused by the beach erosion that Mnemba Island experiences on this area of its coast. Coastal erosion subjects turtle nests to threats of being uncovered, submerged and flooded, or being washed away entirely. It has been suggested that nesting turtles are able to combat this natural threat through the ability to identify and avoid eroding beach sites. Antecedent studies on leatherback turtles have found that leatherbacks actively select nest sites that are not undergoing erosive processes. The findings suggest that leatherback turtles use slope of the beach as a cue for site selection (Spanier 2010). The findings of the present study suggest that the nesting population on Mnemba Island has exhibited this trend of avoiding eroding beach sites as well.

Furthermore, there were no significant overall trends over time found in hatching success. This indicates that over the past ten years, the turtle population has maintained a relatively consistent success rate, on average. This denotes that Mnemba Island provides a reliably stable environment for its green turtle population. One of the largest threats to marine turtle populations in Zanzibar is coastal development impacts on nesting populations. There has been dramatic development in Zanzibar over recent years that has caused disruptions to important nesting areas for marine turtles. Due to the fact that the

conservation of these important nesting sites has often not been considered during the development of coastal areas, many current conservation efforts are falling short of the damage already inflicted. For example, the Kiwenga Controlled Area on Unguja was established because of its nesting turtle population. However, no recent nests have been recorded. It has been asserted that this is due to the extensive hotel development in the area. In contrast, the development of Mnemba Island and the establishment of the Mnemba Island Marine Conservation Area has been done in a carefully planned and sustainable manner. The Mnemba Island Marine Conservation Area was created in 2003 and integrates a cooperative partnership between local communities, tourism operators and the government (Muir 2005). The present study shows that as a result of these efforts and planning, Mnemba remains a reliable nesting environment for the green turtle population. Mnemba is also known to be one of the few areas on Unguja where green turtles currently maintain nesting grounds. It is therefore crucial to protect the Mnemba Island green turtle population, as it is one of the few remaining suitable nesting grounds in the area and is essential to the conservation of this marine turtle.

Conclusion

The findings of this study suggest that Mnemba Island is an important resource, as it is one of the few remaining green turtle nesting sites in Unguja. Also, Mnemba Island has been carefully developed in a manner so as to sustain favorable conditions for its nesting green turtle population. As a result, the island provides a stable environment for its nesting green turtle population, unlike many of the other nesting sites in Zanzibr. It was found that one side of the island is unsuitable for nesting due to the natural causes of beach erosion. However, hatch success was found to not differ between the locations of the Mnemba coastline that do support green turtle nest sites. Furthermore, it has also been concluded that there is no difference in hatching success between years, and that hatching success has not significantly changed over time. This implies that Mnemba Island has provided a stable environment for nesting green turtles over time, and is therefore an important area to protect to ensure that it continues to provide a suitable nesting environment for green turtles in Tanzania.

Overall, the results from this study reflect the success and consequence of the ongoing sea turtle monitoring and conservation efforts on Mnemba Island. Moreover, this study shows the overall importance of Mnemba Island as a resource and the necessity of continuing to conserve the island in general, as it provides vital nesting grounds for green turtles in Tanzania that has proven to be a reliably stable environment.

Recommendations

A continuation of this study is necessary to obtain a more complete understanding of the trends occurring in the green turtle population on Mnemba Island, and in Tanzania as a whole. While the present study focused on analyzing data to investigate natural weather and geographical effects on hatching success rates, there is a meaningful amount of data available to analyze, and many other things could be examined. It is suggested that return rates of nesting females to compare performance of individual nesting females, annual mortality and more be analyzed and studied in the future to create a more complete portrait of the Mnemba Island population. Furthermore, expanding this study to investigate some of the threats that face the turtle populations of Tanzania would be useful. For example, studying human impacts on nesting populations and hatchling success rates, such as the effects of poaching, incidental catch in fishing gears, or the impacts of coastal development on nesting populations in Zanzibar. Specifically evaluating the larger implications of human influence impacts on turtle populations in Zanzibar is important to be able to assess the effectiveness of many of the conservation efforts currently in place. Further study is fundamental to ensuring that the conservation and management efforts of sea turtles continues to be successful by identifying the most pressing threats and issues.

Furthermore, there is an overall lack of data harmonization, completeness and accuracy existing within the marine turtle monitoring programs. A standardized manner in which data is collected and recorded is needed to ensure a thorough account to create a more consistent record that can then be easily analyzed and the information assessed.

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Marine Turtle Conservation in Tanzania

The Importance of Conservation Education: Tools to Raise Awareness

Many people worldwide are unaware of the threats that face marine turtles. Education and awareness campaigns revolving around the value of marine and coastal resources and the survival of endangered species are vital to the conservation of these important resources. Conservation efforts can take place at many different levels, from government policy to school children, everyone can play a role in conservation efforts surrounding marine turtles. Common strategies to raise education and public awareness include communicating relevant information through various avenues of media, in school curriculums and more. It is especially important to educate children on issues that face their environment and introduce them to ways in which they can make a difference. Raising interest and awareness of these subjects early on in their education is critical, as children will be responsible for these resources in the future and will be the ones accountable for continuing conservation efforts. Turtle education campaigns have already proven to be highly valuable conservation tools in Zanzibar, Mafia and Mtwara (Muir 2005).

This study involved expanding and contributing to these ideas surrounding marine turtle conservation efforts. A children's book was written about sea turtles that can be utilized in schools and in the home as a way in which to educate children and their families about sea turtles and to create a personal connection and investment of interest in these charismatic marine creatures. The book incorporates a variety of details that relate to education about sea turtle biology in general, as well as threats that face marine turtles and the importance of protecting and conserving marine turtles. For example, information

about marine turtle life cycles is integrated in the beginning of the story, including information about nesting behavior, hatchling biology, behavior, and habitat. Furthermore, threats that face hatchlings are discussed, such as the impacts of human development and light pollution on nesting beaches and non-human predation threats. Other human based threats are assimilated into the story, as threats of fishing practices and incidental catch of turtles in fishing nets are depicted. General life lessons for children are also integrated into the story, including the importance of being an individual and making your own decisions, as well as being brave. At the end of the book, fun facts about sea turtles are listed in an attempt to provide a more forthright way in which to educate and raise awareness.

An activity booklet was also created. This booklet includes coloring pages, maze, word search, connect the dots and color by number exercises for children to enjoy. Each activity is directly connected with information on marine turtles in Tanzania. Pairing fun activities with educational information will work to engage children in active learning about marine turtles and the status of marine turtles in Tanzania.

Combining Culture and Conservation: Marine Resources Conservation Khanga

The khanga has held an important place in the history and culture of Tanzania for generations. Khangas have been used in many forms; they are used to tell stories, send messages, advertise points of view, and more. They are widely distributed throughout the region, easily accessible to the public and highly conspicuous; therefore making them an ideal platform to be utilized in propaganda strategies. Political parties have utilized khangas to promote themselves and to express their views, and the government has been

known to employ as a means of raising awareness and alerting the public to various public health issues. Therefore, it is proposed that the cultural power and eminence of the khanga be utilized in conservation initiatives.

Specifically on the subject of the conservation of marine resources, such as coral reefs or marine turtles, khangas could be a potential implement in raising awareness and education of the public. Furthermore, the use of khangas in conservation education campaigns integrates ideas of community-based initiatives. Khangas and their phraseology are already established as an integrated social and cultural aspect of the community. They are exchanged as gifts, and are often used by people to send messages to each other. Due to this practice of community members distributing khangas and circulating their messages, using them to circulate conservation messages will work as a self-perpetuating process promoting interest, awareness and dialogue amongst the community by the community itself.

Furthermore, there are many traditional uses and myths surrounding the use of turtle products that has lead to the poaching and endangerment of the marine turtle population in Tanzania. It would be an interesting stratagem to use a historical and cultural symbol such as the khanga and the traditions of khanga use to combat these other traditional practices.