Influence of the vertical beach profile on Green turtle (*Chelonia mydas*) nesting behaviour

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Influence of the vertical beach profile on Green turtle (*Chelonia mydas*) nest activity and nest site selection on Playa Norte, Tortuguero.

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This report focus on the influence of the vertical beach profile on Green turtle *(Chelonia mydas)* nest activity and nest site selection on Playa Norte, Tortuguero. This research is carried out for COTERC and is supported by HAS Hogeschool ’s-Hertogenbosch. It took place from August 20 to January 24. The author of this report is Megan Garnier.

The goal of this study is to find a correlation between the vertical beach profile of Playa Norte and the Green turtles that nest here. Furthermore, to get knowledge about the beach structure on Playa Norte and the method to use to profile the beach.

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Abstract

The vertical beach profile may influence sea turtles nest activity and nest site selection. Playa Norte, Tortuguero is known as a nest site for Green Turtles (*Chelonia mydas*). This study analysed the influence of the vertical beach profile of Playa Norte on nest site selection and nest activity of Green turtles. Playa Norte's three mile transect was divided into 94 sampling points located 50 meters apart. At each sample point, the length of the three zones (vegetation (V), border (B) and open (O)) were measured (meters) as well as total beach length (meters), and the slope (degrees) of cliffs. Female turtles nested mainly in open zones, but it was not proven with a significance difference ($t(8)= 1.47$, $p= 0,179$). The beach profile at each of Playa Norte's sample points varied during the ten weeks of the survey with respect to total length, length of the three zones and slope. Only the length of the open zone and the total length of the beach were important on Green turtle activity. The length of the open zone was negatively correlated with nesting activity of Green turtles (Wald $\chi^2= 4.13$, df= 1, p=0,042; Wald $\chi^2= 4.36$, df= 1, p= 0,037). The slope of cliffs did not influence the female turtles at all (Wald $\chi^2= 0.491$, df= 1, p> 0,05; Wald $\chi^2= 0.001$, df=1, p> 0.05). Greater nesting activity of Green turtles in open zones due to the fact that preference in zones is maybe linked to rainfall, artificial lights, but also to the presence of cliffs. Although, the presence of cliffs did not influence the turtles, it was not clear if turtles came in direct contact with the cliff. Following research is necessary to measure the beach during the hole nesting season and take GPS (global positioning system) coordinates or take a note during night patrols of the place of the cliffs, to know if a turtle nested before or after a cliff. Furthermore, influence of rainfall and artificial lights on Green turtles nesting behaviour should be investigated.

1. Introduction

Cheloniidae is one of the most distinctive groups of reptiles. Fossils of this group have been found that are over two hundred and twenty million years old (Reece *et al.*, 2011). Some turtles have adapted to desserts, ponds, or rivers while others are still living in the sea. Sea turtle numbers are in decline (Gibbon *et al.*, 2000) due to accidental capture in fishing nets, boat strikes, climate change, habitat destruction and poaching. Hatchlings and female sea turtles are threatened on the beach. a major cause of egg mortality in nesting sites around the world is predation by the red fox (*Vulpes vulpes*), golden jackal (*Canis aureus*) and dogs (*Canis lupus familiaris*) (Congdon *et al.*, 1983; Brown and Macdonald, 1995; Yerli *et al.*, 1997; Denkinger *et al.*, 2013). Nesting is very important on beaches and dune ecosystems because unhatched nests, eggs, dead hatchlings and egg shells are a source of nitrogen and other nutrients. Presence of nitrogen changes the plant abundance and diversity in these ecosystems. Furthermore, the nutrients help plants of dune ecosystems to preserve their reproductive success (Bouchard and Bjorndal, 2000).

Several sea turtle conservation organizations from around the world have the goal of protecting and saving sea turtles from extinction. In Northeast Costa Rica, Caño Palma Biological Station is an organization that helps sea turtles at the local level. It is a non- profit organization supported by the Canadian Organization for Tropical Research and Rainforest Conservation (COTERC). It is a long term Marine Turtle Monitoring and Tagging Program began in 2006.

Four marine turtle species nest on Playa Norte, Tortuquero: the Leatherback (*Dermochelys coriacea*), Hawksbill (*Eretmochelys imbricata*), Loggerhead (*Caretta caretta*) in significant lower numbers, and Green turtle (*Chelonia mydas*) (COTERC, 2015). The Green turtle is the largest of the hard- shelled marine turtles with a shell length of 80-120 cm and a weight of 65-204 kg (Spotila, 2004). Its carapace is often very colorful, including shades of black, grey, green, brown or yellow (Mast, 2014). This reptile forages in subtropical waters. Hatchlings are carnivorous and are dark brown or black with a white belly and white flipper margins (STC, 2014). As adults Green turtles eat a large amount of plants including sea grasses. Consumption of sea grasses give Green turtles their greenish- coloured fat, from which they get their name (NOAA Fisheries, 2014). Green turtles' foraging ensures that sea grasses are constantly short (Spotila, 2004; Pritchard, 2014), which helps maintain healthy sea grass beds. The decline of sea grass may be linked to the lower numbers of sea turtles (STC, 2014). Green turtles are listed by the International Union for Conservation of Nature (IUCN) as endangered (Seminoff, 2004).

The number of nesting females has decreased by 48% to 67% over the last three generations (1758 to now) (Seminoff, 2004). Abiotic and biotic conditions influence their nesting behaviour. Position of the nest on the beach is important because it has a significant effect on the reproductive success of sea turtles. The location of the nest on the beach influences the seawards orientation of hatchlings, the chance of inundation and predation of eggs and hatchlings. Abiotic characteristics like temperature affect hatchling success as it can alter their rate of emergence, the male-female ratio, embryonic development, fitness and the overall size (Antonios *et al.*, 2006).

Green turtles crawl up to the beach perpendicular to the water in search of a nesting spot. The structure of the vertical beach profile, like the position of the nest, affects their reproductive success. The vertical beach profile changes constantly as a result of human activities (Wilson and Tisdell, 2001; Schlacher *et al.*, 2014), sea level rise, strong currents and wave activity (Fish *et al.*, 2008). Some sea turtles come up to the beach and return without nesting, also known as half-moons (HLF) or a false crawl. The turtles go back to sea likely because of the not ideal nesting conditions.

The change of beach structure may affect the amount of barriers (e.g. seawalls, rocks and cliffs) present on the beach. Whiterington *et al.* (2011) concluded that barriers influence Green turtle nesting. When a barrier is present, the turtles often cannot cross it and therefore nest closer to the sea. Generally Green turtles nest above the high tide level (HTL) in border areas or at the beginning of the vegetation zone. Nests that are laid too close to the HTL may be inundated or lost when the tide rises (Whitmore and Dutton, 1985).

Based on the ecology and known nesting behaviour of Green turtles, the following question was posed: *What influence does the vertical beach profile have on the nest activity and nest site selection of Green turtles (*Chelonia mydas*) on Playa Norte, Tortuguero?* On Playa Norte barriers such as cliffs are present and are expected to influence the nesting behaviour of Green turtles. Furthermore, it was expected that most Green turtles half- mooned due to the presence of a cliff acting as a barrier and therefore nested in areas without cliffs where female turtles can access open, vegetation or border zones. It is expected that in an area with no cliffs, turtles nest in the border zones or vegetation.

The following questions were asked in order to answer the main research question:

- In which zone; vegetation (V), border (B) or open (O) did most turtle activity take place?
- In which sample point did most turtle activity take place?
- Does the amount of cliffs vary during the beach profile survey?
- Does the hypotenuse vary in length over the duration of the beach profile survey?
- Does the slope vary in degrees during the beach profile survey?
- When Playa Norte varies in slope, total length and length of zones does it influence the amount of turtle activity?
- Are the number of nests and half-moons correlated with the length of the zones?
- Is the presence of a cliff on the sample points correlated to the number of nests and half-moons?
- Do the length of the zones and the total length of the beach vary during the beach profile survey?

To answer the research questions, the three mile transect of Playa Norte, was surveyed to characterize the vertical sample points in terms of width (meters), presence of a cliff, the height (meters) and the length of vegetation (V), border (B) and open (O) zones. After collecting the beach profile data, it was compared to the activity (nests and half- moons) data of Green turtles (nests and half-moons) collected during the same time the beach profile survey took place.

2. Methods

2.1. Study area

Playa Norte is located in Northeast Costa Rica on the Caribbean coast, just north of Tortuguero National Park, within Barra del Colorado Wildlife Refuge. The study area is a three mile transect on Playa Norte (red line in figure 1). Each mile is divided in eight parts as indicated with a mile marker. To classify turtle nesting activity beaches are usually divided in three zones (figure 2); vegetation (V), border (B) and open (O). The vegetation zone is defined by being in the shade 100% of the time. This zone has the least predation but more roots and obstacles like trees and plants. The border zone is more exposed to predation but has fewer roots in comparison to the vegetation zone. Border zone gets shade and sun during the day (shade is > 50%). Therefore the temperature in this zone fluctuates more drastically. The open zone is most exposed to sun (shade is 0-50%). This zone is most vulnerable to flooding, erosion, poaching, and predation.

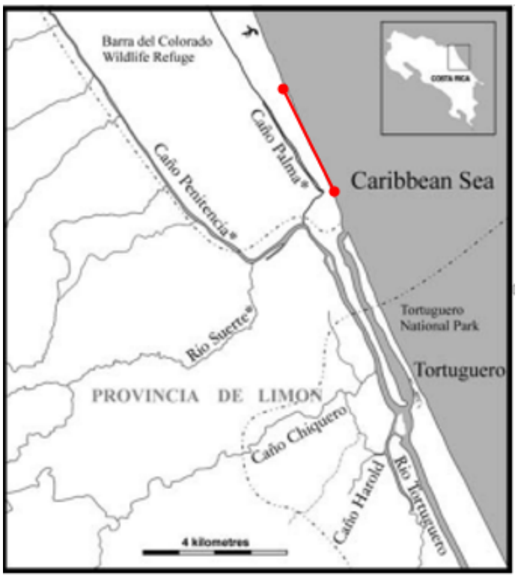

Figure 1: Map of transect Playa Norte, Tortuguero (Fernández and Pheasey, 2014)

Figure 2: Zones and place of high tide line (HTL) on Playa Norte

2.2. Data collection

2.2.1 Nesting activity and nest site selection

Every day from March until October, the whole transect of Playa Norte is surveyed by night patrols and a morning census. Night patrols collect data on nesting female turtles across the whole transect. Nests and half- moons (false crawl) are recorded by GPS (global positioning system).

During morning census additional turtle activity is recorded including turtles missed by night patrol or those that nested or half- mooned after the night patrol teams left the beach, the triangulation of nests is checked, tracks and nests are disguised if it were not encountered previously. When necessary, excavations of the nests are conducted. The nest location data collected during the night patrols and morning census are used to get an overview of the spatial and temporal distribution of Green turtle nesting behaviour.

2.3. Vertical beach profile

To profile a beach, it is measured in segments or in a fixed distance (Fish, 2014). On Playa Norte, measurements were taken every 50 metres. This scale was chosen as it provides sufficient detail whilst being within the time and personnel constraints of the project. The sample points are indicated with a numbered red flagging tape on a tree or any other type of fixed vegetation (figure 3). In total 94 flagging tapes were placed along the three mile transect. Many of The beach profile measurements started at a path which runs parallel to the entire length of Playa Norte. When it was not possible to measure from the path due to the high vegetation density, the measurement started at the farthest point away from the water that the Green turtles can advance up the beach.

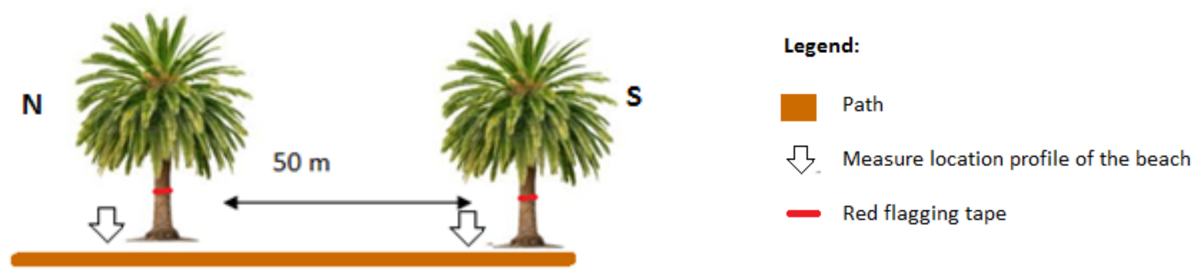

Figure 3: Position of flagging tapes on Playa Norte

At each sample point the survey team started by measuring the vegetation, border and open zones. One person of the team went to the path or dense vegetation and held the zero of the 50 meter measuring tape on the hip. The other person walked with the measuring tape and took the length in meters first of the vegetation zone, second of the border zone and at last of the open zone (till the more recent high tide line). At the same time the different sections (A,B,C,D,E, ….) were measured in length in meters (figure 4). The amount of sections depended on the amount of cliffs present. When cliffs are present, the beach is structured like a staircase (figure 5). Label B,D and F are the cliffs, it had not a 90^o angle as a staircase it is more similar to a slope.

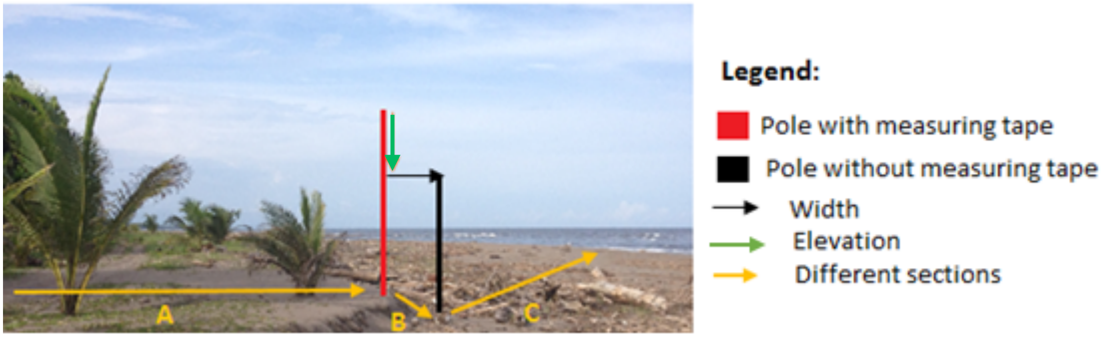

Figure 4: different sections on Playa Norte

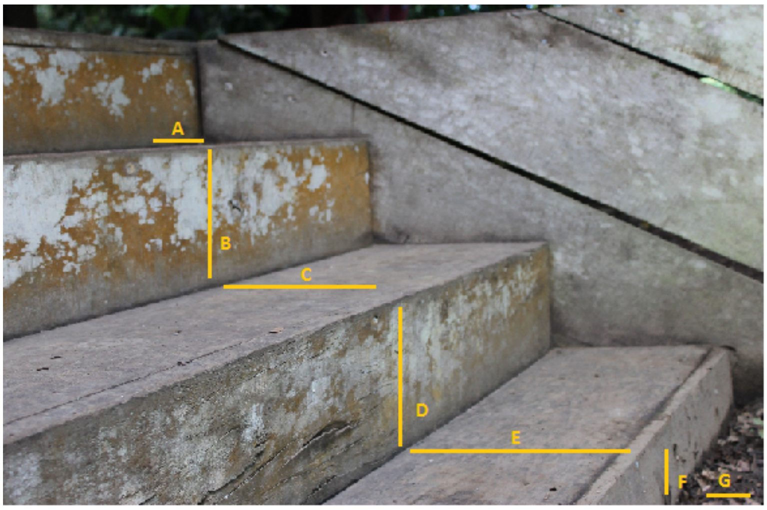

Figure 5: Example on a staircase of the sections build up on Playa Norte

When present, cliffs were measured using two poles (figure 4). One pole with a measuring tape was set on the top of the cliff, and the pole without the measuring tape was set at the bottom of the cliff. To be sure the poles and the line between them was straight, a spirit level was used. Width (W) and elevation (E) of the cliff were measured. Width is the horizontal distance between the two poles . The elevation is the difference in height between the two poles and is read from the tape measure attached to the pole on top of the cliff. With the data of elevation and width, the hypotenuse (H) (width) and angle (slope) can be calculated. The formula of hypotenuse is $\sqrt{W^2 + E^2}$ and the formula of the angle is $\sin^{-1} E/H$ (Fish, 2011).

2.3.1 Statistical analyses

The vegetation, border and open data collected on the beach were not normal. At first the data were made normal in SPSS Statistics 21 using a logarithmic transformation. To examine differences in vegetation, border, and open lengths across weeks, a RMANOVA (Repeated Measures ANOVA) was performed in SPSS Statistics 21. This analysis also examined whether or not the zones and the total length of Playa Norte varied or stayed stable in the ten weeks of the beach profile survey. The number of cliffs, the length of the hypotenuse (meters) and the slope (degrees) were tested to examine differences between the ten weeks of observation using a logistic regression in SPSS Statistics 21.

2.4 Turtle activity compares to beach profile measurements

Each nest and half- moon were associated with the closest sample point, through GPS coordinates (Appendix 2). These locations were used to examine the relationship between total length of the beach and number/location of nests and half- moons, between the length of the three distinct zones and number of nests and half- moons, and between the slope degrees and number of nests and half- moons. Due to the non-normality of the data, a Poisson and negative binomial regression was used in SPSS Statistics 21. A T-test was used to determine if the turtles nested the most in one of the three zones of the beach.

3. Results

3.1 Turtle activity

Turtle activity occurred in first five weeks of the ten week survey. During the night patrols and morning censuses most Green turtle nests were found in mile 2 1/8 which corresponded to beach profile point 67 (n= 4), and in mile 2 6/8 (point 86) (n= 4). In mile 2 1/8, three nests were in the border zone and one in the open. In mile 2 6/8, two were found in border and two in open (figure 6). Most half- moons were recorded at mile 3/8 (point 9) (n= 5). Two occurred in the border zone and three were recorded in the open zone (figure 7). In total most Green turtle activity (nests and half- moons) was at mile 3/8 (n=8 and 11 respectively). Furthermore, most Green turtles were active in open zone (n=93) than in vegetation and border (n= 43). No significance difference was found between turtles nested in open or vegetation and border zones (t(8)= 1.47, p> 0.05) (Appendix 1.1).

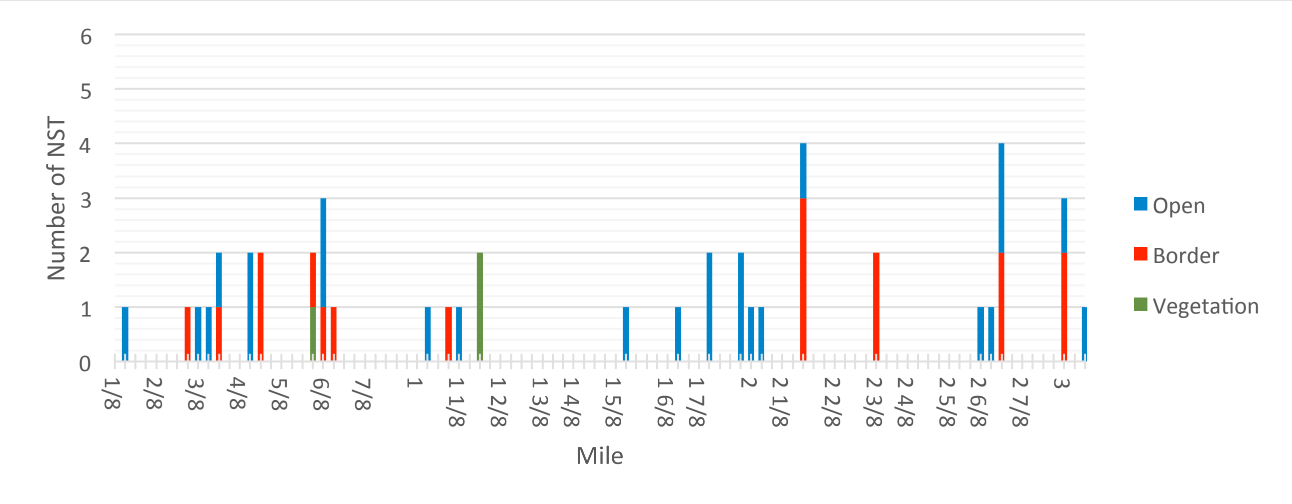

Figure 6: Number of nests (NST) in the different zones, vegetation, border and open, and in each sampling point during 23 September to 31 October.

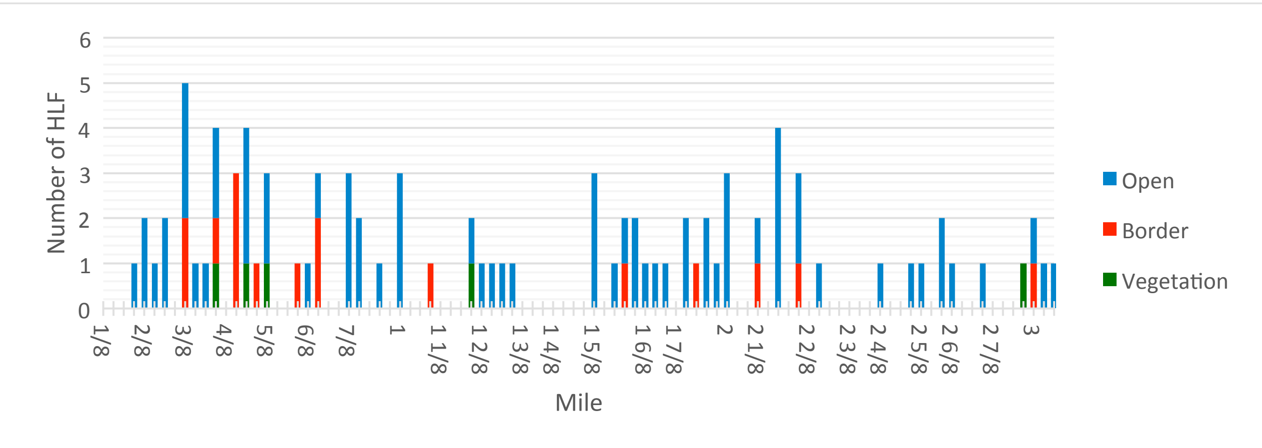

Figure 7: Number of half- moons (HLF) in different zones: vegetation, border and open, and in each sampling point during 23 September to 31 October.

3.2. Three zones of the beach

The vegetation zone's length changed significantly over the ten weeks of observation (Wald χ^2= 23.61, df=9, p< 0.05). Border and open zone also changed significantly in length over the ten week (Wald χ^2= 69.50, df=9, p< 0.001; Wald χ^2= 140,12, df=9 p< 0.001) (Appendix 1.2).

3.3.2. Sections and cliffs

The hypotenuse of the sampling points varied over weeks as did the slope (Wald χ^2= 1329.29 df= 4, p< 0.001; Wald χ^2=2570.36, df= 19, p< 0.001). The number of cliffs did not increase over the study period (Wald χ^2: 9.75, df= 9, p> 0.05) (Appendix 1.3).

3.3. Turtle activity correlated against beach profile

During the five weeks of Green turtle activity, Green turtles half mooned significantly more when the beach was shorter (Wald χ^2= 5.83, df= 1, p< 0.05). A significant difference was found between the number of nests and half-moons and the length of the open zone. Regardless of the zone the turtle nested in, nests and half- moons occurred more often when the open zone was shorter (Wald χ^2= 4.13, df= 1, p<0.05; Wald χ^2= 4.36, df= 1, p< 0,05). Most nests during the survey were encountered at sample point 67 (mile 2 1/8) (n= 3) during week one. at that time, cliffs were absent at that sample point and the length of the whole beach was 10.24 m. All of the Green turtles nested in the border zone which, at the time, covered 32.4% of the beach. The vegetation zone covered 7.1% and open 60.4%. The highest number of half- moons were found during week one at sample point 22 (6/8 of a mile) (n= 3), two in border and one in open. The Vegetation zone covered 82.4% of the beach, border 2.7% and open 14.8% When the turtles half- mooned at sample point 22 in week one the cliff had a slope of 62^{o}, and the beach length was 34.48 m. Although most nest were found in week one with absent of a cliff (n=3) and half-moons with presence of a cliff (n=3), cliffs did not influence the nesting or half-moons per week (Wald χ^2= 0.491, df= 1, p> 0,05; Wald χ^2= 0.001, df=1, p> 0.05) (Appendix 1.4).

4. Discussion and conclusion

The hypothesis of this study was that most Green turtles would nest in the border or vegetation zone. However, the results show that turtles nested the most in the open zone. This may be because the open zone is the zone nearest to the sea and therefore the zone the female sea turtles first encounter; border and vegetation are farther away. One explanation for nest site selection is the presence of cliffs, as these may serve as a barrier to forward movement toward the border and vegetation zones (Whitherington *et al.*, 2011). However, slope of cliffs did not influence the nesting of sea turtles in this research.

Due to time and man-power constraints, repeated sampling occurred only on a weekly basis and therefore it was not possible to determine if the Green turtles nested before or after the appearance of the cliff. In future research the GPS coordinates of the cliffs could be recorded and compared to the turtle activity data or take a note during night patrols of the place of the cliffs. It is also important to have more overlap of the beach profile survey and Green turtles nesting activity. In this study the Green turtles were only five weeks active during the survey. To get better results it is necessary to measure the beach during the whole nesting season.

In addition to beach structure, there are other abiotic factors that may affect nesting behaviour. Rainfall is one of the abiotic conditions that may influence the nesting behaviour of turtles. Bjorndal and Bolton (1992) found that with higher rainfall, female turtles more frequently laid their eggs in open zone. When there was less rainfall, sand collapsed into the egg chamber during digging. Under drier conditions Female turtles laid their eggs in border or vegetation zone because of the greater sand moisture. Although it was beyond the scope of this project, rainfall could be another interesting variable to include in future research.

Artificial lights alter also an abiotic condition that is known to affect nest site selection at sea turtles (Verutes *et al.*, 2014). Artificial lights can deter sea turtles from coming up to the beach and cause them to choose a less suitable location to nest (Deem *et al.*, 2007;Rich and Longcore, 2005). Data from this year found seem to show a relation between nest sites and artificial lights (Pheasey and Fernández, 2014). That is why it is essential to see if this influences the Green turtles choice to nest in a following research.

Moreover, in several studies of nest site selection a correlation between sea turtles nesting and nesting in one zone is not been found (Bjorndal and Bolten, 1992; Blamires *et al.* 2003; Serafini *et al.*, 2009). Although, A study in El Cuyo (Mexico) found that turtles do not nest randomly; it was suggested that turtles actively select their nesting site. The Green turtles in this study in El Cuyo, nested mainly in vegetation or border zones along the whole beach. The zones of the beach did not change over time and there were no barriers, such as cliffs, on this beach. Therefore female turtles were not hindered in their nest site selection (Cuevas *et al.*, 2010). Playa Norte vary in length over time and there are barriers present, a possible explanation of why the Green turtles on Playa Norte may nest more in open zone.

Variation in preference of nest sites on different beaches may be linked with population genetics. Different Green turtle populations may prefer different characteristics of the beach. This implies that Green turtles nesting on Playa Norte prefer the structure of the beach, because of their genetic background (Kamel and Mrosovsky, 2006). However, Green turtles come always back to the same beach, but not to the same nest site it hatched. Structure of beaches changes alter nest placement, not necessarily presence/absence of nesting turtles.

The nest site that female turtles choose influences hatchling success. When a female Green turtle nest closer to the high tide line, the nest has a higher chance of being inundated. When the nest get flooded and overheated by sun the eggs get boiled. The eggs could also be lost as a result of erosion. Therefore these nests have a lower hatchling and emerging success than nests placed further away from the high tide line (Serafini *et al.*, 2009; Whiterington, 1986).

From the results can be concluded that Playa Norte vary in length in zones over time. The variation of length in the vegetation and border zone does not influence the Green turtles activity. Only the open zone influences whether they nest or half- moon. When open is shorter more Green turtles are active on the beach. This is due to the fact that the crawl distance to these zones is shorter. To improve this research it is necessary to measure the beach during the whole nesting season and also to take the GPS coordinates of the cliffs, to know if a turtle nested before or after the cliff was formed. Furthermore it would be interesting to involve the variables rainfall and artificial lights when analysing Green turtles nesting behaviour. With more knowledge about the relationship between sea turtle nesting activity and their nesting beaches, better conservation strategies could be achieved to protect the sea turtles from extinction.

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Appendix 1: Output of SPSS Statistics 21

Appendix 1.1: T-test

Table 1: T-test output, between Green turtle activity in open and vegetation and border zone.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Turtle_activity	Equal variances assumed	1,043	,337	1,473	8	,179	9,00000	6,10901	-5,08740	23,08740
	Equal variances not assumed			1,473	6,705	,186	9,00000	6,10901	-5,57528	23,57528

Appendix 1.2: RMANOVA

the following tables is the output of the RMANOVA. This test give first a table of the significance difference between vegetation (table 2), border (table 4) and open (table 6) in length in the hole ten weeks of observation. After this it gives a table of the difference between vegetation (table 3), border (table 5) and open (table 7) between all the weeks separately.

Table 2: RMANOVA output, the difference between all the ten weeks in length of vegetation (meters), sample point for the hole ten weeks

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	600,573	1	,000
Week	23,609	9	,005

Dependent Variable: ln_V

Model: (Intercept), Week

Table 3: RMANOVA test output, the difference between the ten weeks in vegetation (meters) length of each sample point

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2,134	,1169	1,905	2,363	333,128	1	,000
[Week=1]	,204	,0818	,044	,364	6,213	1	,013
[Week=2]	,226	,1063	,017	,434	4,509	1	,034
[Week=3]	,044	,0773	-,108	,195	,322	1	,571
[Week=4]	,273	,1178	,042	,504	5,374	1	,020
[Week=5]	,230	,0919	,050	,410	6,275	1	,012
[Week=6]	,224	,0982	,032	,417	5,215	1	,022
[Week=7]	,009	,0661	-,121	,138	,018	1	,894
[Week=8]	,213	,0826	,051	,375	6,625	1	,010
[Week=9]	-,010	,0712	-,149	,130	,019	1	,891
[Week=10]	0[a]	.	.	.	.	.	.
(Scale)	1,069						

Dependent Variable: ln_V

Model: (Intercept), Week

a. Set to zero because this parameter is redundant.

Table 4: RMANOVA output, the difference between all the ten weeks in length of border (meters), sample point for the hole ten weeks

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	907,893	1	,000
Week	69,502	9	,000

Dependent Variable: ln_B

Model: (Intercept), Week

Table 5: RMANOVA test output, the difference between the ten weeks in border (meters) length of each sample point

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	1,680	,0866	1,510	1,850	376,405	1	,000
[Week=1]	,319	,1083	,107	,531	8,672	1	,003
[Week=2]	,079	,1103	-,137	,295	,516	1	,473
[Week=3]	,337	,0945	,151	,522	12,685	1	,000
[Week=4]	,445	,0886	,272	,619	25,255	1	,000
[Week=5]	,275	,0737	,130	,419	13,899	1	,000
[Week=6]	,186	,0683	,052	,320	7,409	1	,006
[Week=7]	,148	,0700	,010	,285	4,440	1	,035
[Week=8]	-,189	,0693	-,324	-,053	7,401	1	,007
[Week=9]	-,038	,0581	-,152	,076	,425	1	,514
[Week=10]	0[a]	.	.	.	.	.	.
(Scale)	,698						

Dependent Variable: ln_B

Model: (Intercept), Week

a. Set to zero because this parameter is redundant.

Table 6: RMANOVA output, the difference between all the ten weeks in length of open (meters), sample point for the hole ten weeks

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	1634,757	1	,000
Week	140,115	9	,000

Dependent Variable: ln_O

Model: (Intercept), Week

Table 7: RMANOVA test output, the difference between the ten weeks in open (meters) length of each sample point

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	2,494	,0658	2,365	2,623	1434,738	1	,000
[Week=1]	-,253	,0958	-,441	-,065	6,975	1	,008
[Week=2]	-,708	,1394	-,982	-,435	25,827	1	,000
[Week=3]	-,252	,0912	-,431	-,073	7,621	1	,006
[Week=4]	,225	,0762	,075	,374	8,697	1	,003
[Week=5]	,405	,0717	,264	,545	31,926	1	,000
[Week=6]	-,105	,0670	-,237	,026	2,467	1	,116
[Week=7]	-,251	,0926	-,432	-,069	7,337	1	,007
[Week=8]	-,464	,1054	-,670	-,257	19,328	1	,000
[Week=9]	,039	,0622	-,082	,161	,402	1	,526
[Week=10]	0[a]	.	.	.	.	.	.
(Scale)	,635						

Dependent Variable: ln_O

Model: (Intercept), Week

a. Set to zero because this parameter is redundant.

Appendix 1.2: Logistic regression

The following tables is the output of the logistic regression . This test gives a table of the significance difference between amount of cliffs (table 8), hypotenuse in meters (table 9), slope in degrees (table 10) between the hole ten weeks of beach profile survey.

Table 8: Logistic regression output, the difference of the amount of cliffs during the hole ten weeks of observation

Tests of Model Effects

Source	Type III		
	Generalized Score Chi-Square	df	Sig.
(Intercept)	51,958	1	,000
Week	9,745	9	,371

Dependent Variable: Cliff

Model: (Intercept), Week

Table 9: Logistic regression output, the difference of the hypotenuse (meter) during the hole ten week of observation

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	432,614	1	,000
Week * categorie	1329,289	44	,000

Dependent Variable: Hypotenus (m)

Model: (Intercept), Week * categorie

Table 10: Logistic regression output, the difference of the slope (degrees) during the hole ten weeks of observation

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	1150,845	1	,000
Week * categorie	2570,355	19	,000

Dependent Variable: slope (m)

Model: (Intercept), Week * categorie

Appendix 1.3: Poisson regression and negative binomial

The following tables is the output of the Poisson regression and negative binomial. This tests gives a table of the first five tables gives the significant difference between the number of nests (NST) per five weeks and the slope (table 11), total length of the beach (table 12) and the three zones, vegetation (table 13), border (table 14) and open (table 15) in meters. The next five tables gives the significance difference between the number of half- moons (HLF) and the slope (table 16), total length of the beach (table 17) and the three zones, vegetation (table 18), border (table 19) and open (table 20) in meters.

Table 11: Negative binomial output, difference between the number of nests (NST) and the cliffs slope (degrees)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2,610	,2480	-3,096	-2,124	110,713	1	,000
Slope	,313	,4474	-,563	1,190	,491	1	,484
(Scale)	1[a]						
(Negative binomial)	1[a]						

Dependent Variable: NST

Model: (Intercept), Slope

a. Fixed at the displayed value.

Table 12: Poisson regression output, difference between the number of nests (NST) and the total length of the beach

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2,214	,3233	-2,848	-1,581	46,924	1	,000
Totallength	-,008	,0083	-,024	,009	,865	1	,352
(Scale)	1[a]						

Dependent Variable: NST

Model: (Intercept), Totallength

a. Fixed at the displayed value.

Table 13: Poisson regression output, difference between the number of nests (NST) and the length of the vegetation zone (meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2,629	,2325	-3,085	-2,173	127,851	1	,000
V	,010	,0115	-,012	,033	,814	1	,367
(Scale)	1[a]						

Dependent Variable: NST

Model: (Intercept), V

a. Fixed at the displayed value.

Table 14: Poisson regression output, difference between the number of nests (NST) and the length of the border zone (meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2,388	,2233	-2,826	-1,951	114,404	1	,000
B	-,010	,0170	-,044	,023	,360	1	,548
(Scale)	1[a]						

Dependent Variable: NST

Model: (Intercept), B

a. Fixed at the displayed value.

Table 15: Poisson regression output, difference between the number of nests (NST) and the length of the open zone (meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-2,085	,2322	-2,540	-1,630	80,616	1	,000
O	-,034	,0169	-,067	-,001	4,126	1	,042
(Scale)	1[a]						

Dependent Variable: NST

Model: (Intercept), O

a. Fixed at the displayed value.

Table 16: Negative binomial output, difference between the number of half- moons (HLF) and the cliffs slope (degrees)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-1,592	,1593	-1,904	-1,279	99,810	1	,000
Slope	,009	,3054	-,590	,607	,001	1	,977
(Scale)	1[a]						
(Negative binomial)	1[a]						

Dependent Variable: HLF

Model: (Intercept), Slope

a. Fixed at the displayed value.

Table 17: Poisson regression output, difference between the number of half- moons (HLF) and the total length of the beach (meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-1,136	,2016	-1,532	-,741	31,758	1	,000
Total_length	-,013	,0055	-,024	-,002	5,827	1	,016
(Scale)	1[a]						

Dependent Variable: HLF

Model: (Intercept), Total_length

a. Fixed at the displayed value.

Table 18: Negative binomial output, difference between the number of half- moons (HLF) and length of vegetation(meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-1,507	,1551	-1,811	-1,204	94,510	1	,000
V	-,007	,0090	-,024	,011	,538	1	,463
(Scale)	1[a]						
(Negative binomial)	1[a]						

Dependent Variable: HLF

Model: (Intercept), V

a. Fixed at the displayed value.

Table 19: Poisson regression output, difference between the number of half- moons (HLF) and length of border (meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-1,448	,1448	-1,731	-1,164	99,958	1	,000
B	-,015	,0118	-,038	,008	1,621	1	,203
(Scale)	1[a]						

Dependent Variable: HLF

Model: (Intercept), B

a. Fixed at the displayed value.

Table 20: Poisson regression output, difference between the number of half- moons (HLF) and length of open (meters)

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-1,330	,1514	-1,627	-1,034	77,261	1	,000
O	-,021	,0099	-,040	-,001	4,357	1	,037
(Scale)	1[a]						

Dependent Variable: HLF

Model: (Intercept), O

a. Fixed at the displayed value.

Appendix 2: GPS (global positioning system) coordinates

The GPS east (E) and west (W) are given for the sample points of the beach profile survey with the nests (table 21) and half- moon (table 22).

Table 21: coordinates east (E) and west (W), of the sampling points and nests.

Sampling point		Nest					
Number	E/W	Name	coordinates	Name	E/W	Name	E/W
1	1172078	CP128	1172521				
2	1172128	CP162	1172133				
3	1172181						
4	1172227						
5	1172281						
6	1172324						
7	1172370						
8	1172416	CP154	1172447				
9	1172469						
10	1172469	NoTRI21	1172559				
11	1172560	CP153	1172592	CP158	1172604		
12	1172611						
13	1172663						
14	1172709	NoTRI12	1172715	CP160	1172722		
15	1172755	NoTRI13	1172749	NoTRI17	1172759		
16	1172795						
17	1172841						
18	1172893						
19	1172936						
20	1172984	CP139	1173019	CP147	1172988		
21	1173022	NoTRI3	1173056	NoTRI6	1173084	CP156	1173037
22	1173083	CP135	1173109				
23	1173116						
24	1171158						
25	1173313						
26	1173249						
27	1173293						
28	1173347						
29	1173390						
30	1173433						
31	1173483	NoTRI19	1173537				
32	1173520						
33	1173570	NoTRI20	1173625				
34	1173617	NoTRI25	1173643				
35	1173676						
36	1173733	CP141	1173733	CP152	1173736		
37	1173767						
38	1173815						
39	1173857						
40	1173905						
41	1173948						

42	1174041						
43	1174098						
44	1174149						
45	1174199						
46	1174238						
47	1174284						
48	1174336						
49	1174381						
50	1174425	CP151	1174435				
51	1174468						
52	1174507						
53	1174545						
54	1174601						
55	1174652	CP163	1174669				
56	1174692						
57	1174739						
58	1174787	CP140	1174816	NoTRI28	1174813		
59	1174849						
60	1174895						
61	1174942	NoTRI16	1174927	NoTRI18	1174924		
62	1174990	NoTRI22	1172559				
63	1175033	NoTRI27	1175048				
64	1175077						
65	1175123						
66	1175179						
67	1175213	NoTRi2	1175218	CP138	1172509	NoTRI5	1175215
		NoTRI15	1173648				
68	1175260						
69	1175309						
70	1175362						
71	1175410						
72	1175458						
73	1175506						
74	1175547	NoTRI4	1175555	NoTRI14	1173000		
75	1175593						
76	1175640						
77	1175667						
78	1175718						
79	1175762						
80	1175811						
81	1175908						
82	1175969						
83	1176002						
84	1176045	NoTRI1	1176086	NoTRI24	1176070		
85	1176100	CP164	1176119				
86	1176148	CP137	1176170	NoTRI7	1176171	CP155	1176201
		CP157	1176181				
87	1176199						
88	1176248						

89	1176288						
90	1176332						
91	1176373						
92	1176425	CP159	1176432	NoTRI23	1176466	NoTRI29	1176456
93	1176467						
94	1176505	NoTRI26	1176703				

Table 22: coordinates east (E) and west (W), of the sampling points and halfmoons.

Sampling point		Half- moon					
Number	E/W	Name	E/W	Name	E/W	Name	E/W
1	1172078						
2	1172128						
3	1172181						
4	1172227	HLF85	1172249				
5	1172281	HLF9	1172319	HLF53	1172297		
6	1172324	HLF3	1172365				
7	1172370	HLF50	1172465	HLF51	1172465		
8	1172416						
9	1172469	HLF8	1172492	HLF39	1172515	HLF59	1172482
		HLF78	1172481	HLF94	1172538		
10	1172469	HLF27	117252547				
11	1172560	HLF10	1172618				
12	1172611	HLF2	1172628	HLF66	1172665	HLF92	1172657
13	1172663						
14	1172709	HLF7	1172750	HLF65	1172748	HLF91	1172730
15	1172755	HLF62	1172759	HLF63	1173269	HLF81	1172778
		HLF90	1172762				
16	1172795	HLF35	1172797				
17	1172841	HLF61	1172852	HLF77	1172862	HLF87	1172878
18	1172893						
19	1172936						
20	1172984	HLF80	1172992				
21	1173022	HLF49	1173065				
22	1173083	HLF26	1173098	HLF30	1173111	HLF38	1173181
23	1173116						
24	1171158						
25	1173313	HLF31	1173267	HLF36	1173250	HLF93	1173629
26	1773249	HLF21	1173295	HLF73	1173310		
27	1173293						
28	1173347	HLF71	1174619				
29	1173390						
30	1173433	HLF5	1173505	HLF34	1173474	HLF48	1173488
31	1173483						
32	1173520						
33	1173570	HLF25	1173603				
34	1173617						
35	1173676						
36	1173733						

37	1173767	HLF37	1173685	HLF95	1173725		
38	1173815	HLF32	1173830				
39	1173857	HLF15	1173897				
40	1173905	HLF89	1173986				
41	1173948	HLF84	1174010				
42	1174041						
43	1174098						
44	1174149						
45	1174199						
46	1174238						
47	1174284						
48	1174336						
49	1174381	HLF67	1174416	HLF74	1174394	HLF79	1172450
50	1174425						
51	1174468	HLF22	1175352				
52	1174507	HLF14	1174529	HLF29	1174550		
53	1174545	HLF23	1174551	HLF68	1174567		
54	1174601	HLF28	1174652				
55	1174652	HLF76	1174715				
56	1174692	HLF72	1174741				
57	1174739						
58	1174787	HLF83	1174824	HLF96	1174959		
59	1174849	HLF82	1174862				
60	1174895	HLF12	1174936	HLF13	1174943		
61	1174942	HLF11	1174976				
62	1174990	HLF16	1175081	HLF60	1175029		
63	1175033						
64	1175077						
65	1175123	HLF64	1175173	HLF70	1175169		
66	1175179						
67	1175213	HLF17	1175222	HLF18	1175231	HLF58	1175220
		HLF97	1175258				
68	1175260						
69	1175309	HLF19	1175338	HLF20	1174656	HLF54	1175348
70	1175362						
71	1175410	HLF47	1175451				
72	1175458						
73	1175506						
74	1175547						
75	1175593						
76	1175640						
77	1175667	HLF86	1175709				
78	1175718						
79	1175762						
80	1175811	HLF4	1175893				
81	1175908	HLF33	1175924				
82	1175969						
83	1176002	HLF1	1176046	HLF55	1176011		
84	1176045						

85	1176100						
86	1176148						
87	1176199	HLF24	1176234				
88	1176248						
89	1176288						
90	1176332						
91	1176373	HLF52	1176405				
92	1176425	HLF46	1176460	HLF56	1176429		
93	1176467	HLF57	1176487				
94	1176505						