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The utility of local knowledge of olive ridley (*Lepidochelys olivacea*) nesting behaviour for turtle conservation management in Guatemala.

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Abstract

The harvest of olive ridley (*Lepidochelys olivacea*) turtle eggs by local egg collectors on the Pacific coast of Guatemala is estimated at close to 100%. Following current management, 20% of turtle eggs are required to be incubated for conservation in local hatcheries through voluntary donations by egg collectors. Beach patrols by police and volunteers increase the effectiveness of the management plan. However, regulation and hence collaboration, can be improved by a greater knowledge of nesting behaviour, specifically the hours of peak nesting.

A social survey of egg collectors was undertaken to extract ideas from their knowledge of nesting behaviour, which were consequently tested by measuring the said parameters, and by recording emerged turtles hourly over a 3km section of beach during September 2006. Parameters measured were rain, wind, wind direction, tide, moon phases, moonset and moonrise, and neap and spring tidal weeks.

The study's main findings included:

- The tendency to nest during neap tidal weeks.
- During neap tidal weeks turtles preferred to emerge during ebb tides, and during flood tides with spring tidal weeks. They could be using slacks in the tidal current as cues to emerge *after* the first high or low tide.
- Hours of greater emergence for the ebb and flood tides were during the peak strength of the tidal current.
- High and low tides witnessed significantly fewer emergences.

Other significant factors included rain, strong winds (>7m/s), and the three hours leading up to moonset.

Main recommendations for the conservation management included:

- Coordinate beach patrols by following the key findings.
- Undertake further studies to understand the effect of water levels and currents on emergence.
- Undertake an assessment of the sustainability of the current management.
- Provide adequate protection for the whole life cycle.

This study also has positive implications for other nesting beaches. As well, the utility of using local knowledge is encouraging as a sound methodology for improving scientific understanding.

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Chapter 1: Introduction

1.1 General Aims

Nesting sea turtles are offered minimal protection in Guatemala. Due to their supposed value as aphrodisiacs, nearly 100% of turtle eggs are harvested from nesting beaches. Of these, no more than 20% of turtle eggs are re-incubated in local hatcheries for conservation purposes. Local people have harvested the turtle eggs for many years and have thus acquired a certain amount of knowledge, specifically in regards to environmental parameters that influence turtle emergence from the sea to nest. Their knowledge of the link between the environment and nesting patterns could help to enhance our understanding of these marine herptiles and, consequently, improve conservation efforts.

1.2 Specific Objectives

1. Identify local knowledge through social surveys, particularly knowledge of specific environmental parameters that are likely to influence turtle emergence from the sea.
2. Coordinate a team to conduct hourly "crawl counts" during September 2006 (peak nesting month). Train surveyors in data collection and recording.
3. Collect weather and tidal/lunar data using a Mini-Met station.
4. Analyse, interpret and discuss the data through statistical analysis.

Chapter 2: Literature Review

2.1 General Ecology

Sea turtles, in general, are regarded as keystone species; the "removal of such species causes dramatic changes in the ecosystem" (Gulko & Eckert, 2003). Specialist turtles such as, sea grass-grazing green turtles (*Chelonia mydas*) and leatherbacks (*Dermochelys coriacea*), which feed entirely on jellyfish, are examples. The leatherback has a diet largely based on jellyfish (Spotila, 2004); its extinction would leave masses of jellyfish in the ocean to predate on other marine species. Therefore, the removal of such a large, numerous marine herptile from an ecosystem could have dramatic consequences.

2.2 Nesting Ecology of Olive Ridley (*Lepidochelys olivacea*) Turtles

The olive ridley is the most abundant of the sea turtles. They are small turtles, adults averaging 35 to 50kg, with an average shell length of 55-76cm (Gulko & Eckert, 2003; Spotila, 2004).

Globally, they use two types of breeding behaviour, one of which is termed an *arribada*, a nesting event whereby hundreds and even thousands nest simultaneously (Gulko & Eckert, 2003). Olive ridleys also nest individually, as is the case in Guatemala, preferring to nest on beaches separated by the mainland by estuaries or lagoons. Solitary nesting occurs in 32 different countries, whereas *arribadas* are found in only a few (Spotila, 2004).

Most females lay only two clutches of eggs with an interval of 14 days during a reproductive season, depositing about 100 eggs per clutch. They may use different beaches within the same season (Spotila, 2004). Incubation periods of olive ridley eggs range from 46-65 days, and it is thought that they reach maturity between 7-15 years (Gulko & Eckert, 2003).

In comparison with other turtles, olive ridley turtles are a lot quicker during nesting, which could be due to their smaller size. Their high activity could enable them to nest in areas of high tidal range, where the ebb and flood of the tide is fast. Other larger sea turtle species, in a high tidal range may only nest during the high tide due to high physical exertion caused by longer crawls at low tide, whereas the olive ridley may be more able to deal with with these longer crawls (Hughes, 1972).

2.2.1 Natural Threats

Naturally, the highest rates of predation during the life cycle of a sea turtle occur during the egg, hatchling and young juvenile stages (Gulko & Eckert, 2003). Ants, crabs, raccoons, foxes, coyotes and bacteria are some of the natural predators of turtle eggs, and many of those, as well as sea birds, also prey on recently emerged hatchlings. The risk of predation is reduced as sea turtles grow and gain a protective hard shell. Mature sea turtles have very few predators, only orca whales and sharks (Gulko & Eckert, 2003; Spotila, 2004). It has been estimated that only 1 in 3000 hatchlings (Sea Turtle Restoration, Olive Ridley Fact Sheet), reach maturity due to such a high rate of predation.

Gulko & Eckert (2003) explains that survivorship is the reasoning behind the necessity of laying an unusually large quantity of eggs. A high number of eggs and hatchlings are needed in order for the species to survive, due to the high rate of predation in their younger years. As well, the transfer of nutrients and energy from the ocean to the land through the transport of eggs to the beach ensures that the beach ecosystem remains healthy (Spotila, 2004).

Natural regulation of the population has not however, accounted for recent human intervention, specifically removal of eggs from the natural environment. The production of hatchlings needs to be ensured however, so that the ensuing natural predation will not affect the population.

High spring tides also threaten nest success, either through beach erosion or inundation of the nests. Whitmore & Dutton (1985) found that tidal washover to be one of the causes of increased embryonic mortality in leatherback eggs. Hatchling success of olive ridleys was also affected by humidity and distance from the high tide in Las Barracas beach, Mexico. Specifically, hatchling success was higher between 10 and 30 m above the high tide line measured on the day of oviposition (surface humidity ca. 1%), (Lopez-Castro et al, 2004). Arriving at, and identifying a suitable nesting site above the high tide line by the adults, appears to be crucial for improving hatchling success. To reach a suitable site, coming on shore during high tide appears to be a logical response to reduce time and precious energy spent in getting there (Gulko & Eckert, 2003).

2.3 Population Ecology

Figure 2.1 Map of Guatemala, and Pacific coastline. (Source: Perry-Castañeda Library Map Collection).

Nesting along the 254km of Pacific coastline (figure 2.1) is relatively uniform (Muccio, 1998). Two species of turtles nest on this coast of Guatemala: the olive ridley, and the leatherback. The olive ridley nesting season coincides with the June-October rainy season with peak months in August and September, but these turtles will also nest infrequently all-year around (Muccio, 1998). Nesting is generally nocturnal, as it reduces the amount of energy needed for nesting due to cooler conditions and a reduction in the probability of predation for both the female and her eggs. However, this can depend on the size of the turtle, larger turtles would expend more energy than smaller turtles nesting during the daytime, which could cause a potentially lethal increase in body temperature. Smaller Olive and Kemp Ridleys (*Lepidochelys kempi*) have been observed to nest during the day (Muccio, 1998; Gulko & Eckert, 2003, Spotila, 2004).

2.3.1 Population Trends

Globally the population of adult sea turtles has reduced dramatically (Gulko & Eckert, 2003). The olive ridley sea turtle is classified as endangered by the World Conservation Union Red List Data Book, and is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

In Guatemala, no accurate population estimates of adults have been made, although data has been collected sporadically since 1981 on the number of successfully nested females for particular sections of nesting habitat. Although methodologies and study areas may not have been consistent, a crude calculation showed a reduction in the mean population of nesting females between August and November of 1.86/km in 1981 (Ramboux, 1981) to 0.71/km in 2003 (ARCAS, 2005). This corroborated with the anecdotal evidence from local residents (Pers comm, 2006).

2.3.2 Human Threats

Human interference appears to be responsible for the population decline worldwide (Cliffton *et al*, 1982). Specifically, the trade of turtle eggs, due to their supposed 'aphrodisiac' qualities, is one of the most prominent causes in Guatemala (Muccio, 1998).

Conservation of sea turtles in Guatemala began in 1971 with the first law and the construction of the first hatchery (Muccio, 1998), hence a long history of egg harvesting; although local residents claim the trade of sea turtle eggs began as early as 1965 (Pers comm, 2006). Although not always so, currently it is estimated that close to 100% of sea turtle eggs are harvested in Guatemala (Muccio, 1998).

Egg harvesting is not the only threat to the Guatemalan turtle population; incidental capture in fishing boats, particularly shrimp trawlers, also causes mortality in adults (Muccio, 1998). NGO ARCAS (Asociación de Rescate y Conservación de Vida Silvestre) recorded 25 turtle carcasses stranded on an 8km stretch of beach in 2003 over 6 months (ARCAS, 2003). Necropsy results have shown drowning to be the cause of death indicating a relationship with the shrimp trawlers (ARCAS, pers comm, 2006).

2.4 Conservation and management of the Olive Ridley Turtle in Guatemala

Since the 1980s, the Guatemalan government has attempted to manage and conserve the turtle populations in a pragmatic way, ensuring that local coastal communities can continue to earn a vital income from the trade in turtle eggs. A 'Donation System' was designed, whereby local communities were permitted to harvest the eggs so long as 12 eggs (now revised to 20%) of the nest were donated to a local hatchery for incubation.

Each year there are between 16-24 hatcheries operated by a variety of NGOs, the government and private owners (Muccio, 1998). Figure 2.2 shows the location of these hatcheries. The donation system has had a variety of successes depending on the hatchery; however not all egg harvesters collaborate entirely with their local hatchery and very few of them donate the revised 20% quota (Muccio, pers comm, 2006).

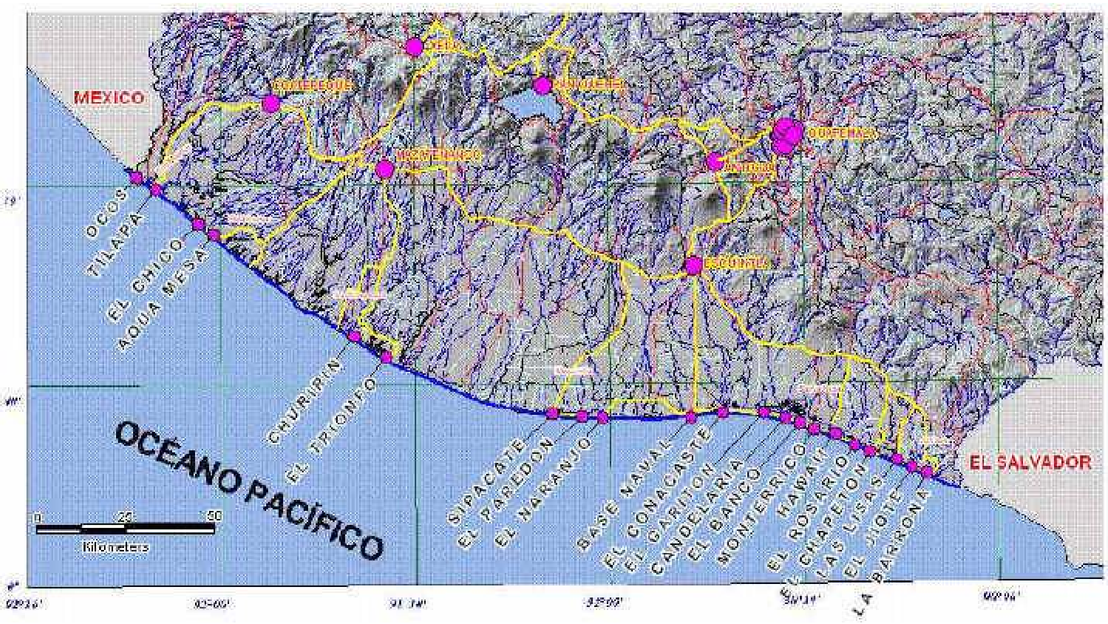


Figure 2.2 Map of location of the permanent hatcheries.
(Source: AMBIOS)

2.5 Hawaii Hatchery, Guatemala

The hatchery in Hawaii, Guatemala (operated by ARCAS), has benefited from additional resources to improve the management and conservation of the turtles in their area. This includes the regular assistance from international volunteers who patrol the beach enforcing donations and rescuing entire nests. This hatchery also benefits from an ATV quad bike, and, as with all hatcheries, is able to invite the local "green" police to make patrols. Egg incubation has increased steadily since 2003 in the Hawaii hatchery; 12,994 to 22,926 in 2005 due to these additional resources (ARCAS, 2006).

In order to increase the amount of donations and volunteer efficacy, resources (police patrols, volunteers and ATV quad bikes) need to be used more effectively, specifically at peak nesting periods. Without a complete overhaul of the management of the sea turtles of Guatemala, the donation system, as a form of community-based conservation, appears to be the most feasible approach at present, given the poverty of local coastal communities and the low priority given to conservation in general in Guatemala.

Community-based conservation does have its merits and has been shown to be successful in Brazil's TAMAR project, which boasts the participation of fishing communities through employment of former egg collectors for beach patrols, education and ecotourism (Marcovaldi & Marcovaldi, 1999). Conservation was accepted and managed by the local communities for their own benefit. In Guatemala, the donation system has been designed for the coastal communities based on their active participation. However in the future, resources will need to be used to control and ensure the better functionality of the donation system (such as complete collaboration, and more effective regulation), and, for this to occur, a greater understanding of optimal nesting times would be extremely valuable.

2.6 Previous Research

Cornelius (1986) and Plotkin *et al* (1991) have reported that before an *arribada* commences, often, olive ridley turtles wait until certain conditions are present before they emerge from the sea. This can take up to 2-3 days (Cornelius 1986). Gravid females apparently are able to wait for weeks while holding fully-shelled eggs, which may act as a cue for *arribada* synchrony (Richardson, 1997).

Carr (1968), made reference to observations by local people in Mexico; that turtle nesting was induced by strong winds. Pandav & Kar (2000) also observed that *arribada* nesting on the Orissa coast in India commences with strong southerly winds.

In Ostional, Costa Rica, another *arribada* beach, it was also found that nesting events often appear correlated with moon or tidal phases, particularly with the start of the last quarter of the moon (Gulko & Eckert, 2003; Ostional Wildlife Refuge website). Ballestero (1995) recorded numerous environmental parameters (rain, wind, ambient and water temperature, tides and moon phases) and nesting frequency for three *arribada* months in 1991 at the Ostional Wildlife Refuge. Statistical analysis indicated that all weather conditions tested could have an influence on turtle nesting, particularly that olive ridleys' massive nesting coincided with mid or high tides and with the last quarter of the moon; however in winter months, these parameters were not useful clues for predicting *arribada*.

Choudhury & Pandav (2000) also found in Orissa, India, that nesting showed a distinct temporal pattern, with most nesting occurring during neap tidal nights. Marquez *et al* (1976) also correlated Mexican *arribadas* with the waning quarter when tidal exchange is low. Dash & Kar (1990) have even recorded day nesting during neap tides. Neap tides present a relatively calm sea, providing easier access to the beach (Choudhury & Pandav, 2000).

For loggerhead (*Carreta carreta*) turtles, Brooks & Webster (1998) has shown that there is a distinct nesting pattern most frequently around the high tide on their east facing beach in Bald Head Island, North Carolina; whereas on their south facing beach, they found no significant difference in nesting in relation to tidal cycle. Frazer (1983) also showed that "loggerhead sea turtles come ashore more frequently at high tides on gently sloping beaches, but that emergences are not related to tidal activity on steep sloping beaches".

Burney *et al* (1990) studied the relationship between loggerhead nesting patterns and moon phase in Broward County in Florida. They concluded that increased frequency of nesting occurred approaching the full or new moon, and below average nesting around the time of the quarter moons.

Lux *et al* (2003) found a weak, but positive, relationship between leatherback emergence and nightly high tide at Playa Grande in Costa Rica. This relationship was also observed in French Guiana when nesting took place on beaches within the estuary. However, an additional significant relationship was found later with the full or new moon for return nesting (Fretney & Girondot, 1989, 1996).

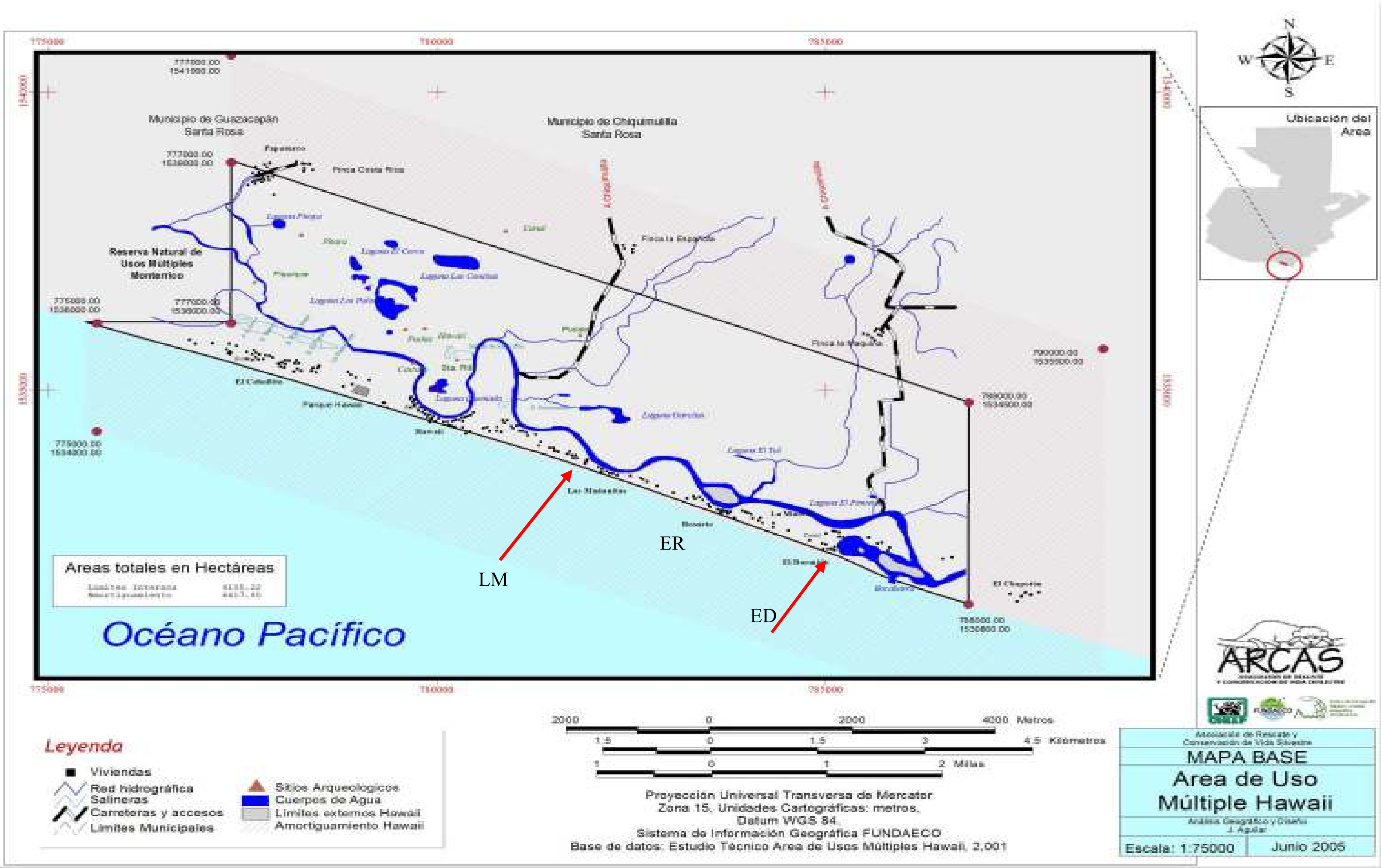
It has also been shown that other marine organisms were dictated by similar environmental parameters, particularly the horseshoe crab (*Limulus polyphemus*). Kaplan (1988) observed that when an onshore wind coincides with spring or high tides, conditions were perfect for egg laying, and the beach may be covered by horseshoe crabs.

It has become clear from the literature review that various local environmental parameters could act as cues for nesting olive ridleys, although it is important to note that the available research is nearly entirely based on *arribada* beaches. These specifically are:

- Strong winds and rain
- Mid and high tides
- Lunar phases quarter moons
- Neap tides

Through years of observing and benefiting from nesting turtles, local egg collectors have developed their own ideas of relevant cues, which they have used to harvest the eggs. So, instead of re-testing the parameters determined in the literature, an alternative methodology was designed. It was decided to examine the cues that were identified by local egg collectors, to take advantage of their experience, and scientifically test the effects of those parameters on nesting emergence.

Figure 3.1 Map of area.
(Source: ARCAS). Study Area: LM to ED. LM (Las Mañanitas), ER (El Rosario), ED (El Dormido).



Chapter 3: Methodology

3.1 *Study Area*

The study area was centred around the coastal village of El Rosario (see figure 3.1), on the Pacific coast of Guatemala. South of the village lies the beach and the Pacific Ocean. El Rosario is approximately 135km south of the capital of Guatemala, Guatemala City.

To undertake this study, two surveys were undertaken, along with the installation of a Mini-Met weather station. A social survey was designed to gather information on the local knowledge of the environmental parameters, which influence nesting behaviour. In addition, a scientific survey was undertaken to record the actual timing of turtle emergence, along with local weather and tidal/lunar data.

3.2 *Social Survey*

An informal questionnaire (see appendix 1) was designed with the purpose of extracting traditional knowledge of environmental parameters that may affect nesting behaviour. Due to time constraints, a purposive sample of interviews was undertaken. 13 Egg Collectors were interviewed separately in the coastal village of El Rosario. The small sample size was due to the small population of less than 100 adult inhabitants. Informal interviews allowed the interviewees to speak freely to six specific open-ended questions. Egg Collectors from age 18 to 80 were interviewed to confirm that the knowledge had indeed been passed on through generations through consistency of their responses. All questions and responses were given using the local language to eliminate any communication barriers.

3.2.1 Analysis and Results

The purpose of the social survey was to stimulate ideas and identify key areas that needed to be monitored in the subsequent scientific survey, so generating statistics was not considered relevant in the analysis.

The social survey identified consistent factors in the increase of nesting activities. The results and analysis are displayed in table 3.1a and 3.1b.

Table 3.1a Results of local knowledge social survey.

(For codes see table 3.1b)

Order of Importance	Respondents												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	W	W	W	M	W	MR/MS	W	R	MR/MS	W/M	W	M	MR/MS
2	D	M	MS	W	M	R	M	D	M	MS/MR	M	MR/MS	M
3	MR/MS	HT	M	E/F	R	D		AC/QA	HT	E/F	AC/QA	W	
4			R		F			M	D			R	
5					D				AC/QA			D	

Table 3.1b Description and analysis of codes for table 3.1a

		% Significant Factor	% Most Significant Factor
W	Strong onshore wind	69% (9 responses)	54% (7 responses)
D	*Descabezante*, up to an hour and a half after the tide starts to go out.	46% (6 responses)	0% (0 responses)
MR/MS	Up to an hour and a half before the moon rises or sets.	54% (7 responses)	23% (3 responses)
M	Moon Phases (full, 3Q, new, 1Q).	85% (11 responses)	15% (2 responses)
HT	High tide.	15% (2 responses)	0% (0 responses)
R	*Repunta*, up to an hour and a half after the tide starts to come in.	31% (4 responses)	8% (1 response)
F	Flood tide.	23% (3 responses)	0% (0 responses)
E	Ebb tide.	15% (2 responses)	0% (0 responses)
AC/QA	*Agua chica, quiebra de aguajon.* The week centred on the neap tide, and the first day of that week.	23% (3 responses)	0% (0 responses)

Additional responses were:

- Lightning storms do not increase nesting activity.
- The effect of rain gave inconsistent answers, ranging from an insignificant influence to a slight effect after rain ceases.
- Currents, determined by the week centred on spring (*aguajon*) and neap (*agua chica*) tides, influence nesting. Currents, and hence nesting location, follow a more westerly direction (Hawaii catchment area) during spring tides, which usually lowers nesting frequency in the El Rosario catchment area; and during neap tides, currents are more favourable for nesting in the El Rosario catchment area at the expense of Hawaii catchment area. Nesting increases due to the *quiebra de*

aguajon (the day of change from the spring to the neap tidal week). Dates of *aguajon* and *agua chica* according to the respondents are as follows in table 3.2.

Table 3.2 Dates of *aguajon* and *agua chica*.

	Dates from:	**To:**
Agua chica	27th August, 2006	3rd September, 2006
Aguajon	3rd September, 2006	10th September, 2006
Agua chica	11th September, 2006	17th September, 2006
Aguajon	18th September, 2006	25th September, 2006
Agua chica	26th September, 2006	3rd October, 2006

The results showed a general consensus of ideas, especially about the effect of moon phases (85% agreed it was significant, and 15% agreed is was the most significant factor); strong onshore winds (69% agreed significance, with 54% agreeing it was the most significant factor); 54% believed the effect of moonrise and moonset to be significant (23% agreed as the most significant factor), and the other significant factors were related to tides. Specifically these were the turn of the tide, 46% (*descabezante*) and 31% (*repunta*) agreed significance; ebb and flood tides, 15% and 23% agreed significance; and tides of lower exchanges (the week centred on neap tides), and the "*quiebra de aguajon*" the first day of the neap tidal week, with 23% agreeing significance.

Hence, the following parameters were identified to be monitored in the scientific study:

- Wind (force and direction)
- Moon Phases
- Timing of the moonrise and setting of the moon
- Tides
- Weeks of spring and neap tides
- Rain

3.3 Mini-Met Weather Station

In order to correlate hourly turtle emergence with the environmental parameters identified by the social survey, accurate local weather data was recorded on an hourly basis. A Skye Mini-Met Weather Station was borrowed from Cranfield University, and programmed to record a number of parameters described below, through minutesampling and average readings recorded every hour. The rain gauge sampled and recorded only every hour to register total rainfall in mm/hour.

3.3.1 Location of the Mini-Met Weather Station

The Mini-Met was installed in the village of El Rosario on August 10th 2006 until September 30th 2006, to record local weather. Due to security reasons, the Mini-Met was attached to a beachfront house, with the data logger hidden in the roof. The anemometer and wind vane (calibrated with a compass) were attached to wooden poles to extend beyond the roof of the house (6m from ground level). A compass identified the beach as SWS-facing, 195°, the coastline 105° to 285°, and the rain gauge was extended as far as the cable would allow. It was understood that the accuracy of the rain data may be compromised due to the proximity of the house, but the security of the data logger and Mini-Met outweighed this consideration.

3.3.2 Environmental Parameters

The Skye Mini-Met was programmed to measure:

Table 3.3 Environmental Parameters (Mini-Met)

Parameter	Units
Total Rain	mm/hour
Wind force	Metres/sec
Wind Direction	Mean direction (in degrees) /hour

A Psion computer was used to download the data and the Skye software to transfer the data to an Excel spreadsheet.

Additional Parameters to be measured:

- High tide; moon phases; "spring and neap tidal weeks" using a tide chart prepared for Port San Jose, approximately 40km west of El Rosario, provided by AMBIOS (see appendix 2).
- Moonrise and set, observed during survey.

3.4 Crawl Count Methodology

The methodology used to record the timing of nesting activity followed a modified version of ARCAS/AMBIOS', which uses track and nest pit as indicators of turtle emergence. Nesting was determined to be successful if an egg chamber could be located. This survey involved walking the 3km catchment area for El Rosario (see figure 3.1) continuously from 7pm to 5.30am (nesting is usually exclusively nocturnal). The entire area was covered by a surveyor at least every hour and a half. When a turtle nest was encountered, the surveyor recorded (see appendix 3 for Proforma) the estimated time of emergence, whether the nesting was successful, its location using a GPS position, and any other observations, such as weather.

Estimated time of emergence was based on mean timings (taken from recordings of 10 turtles) for turtle nesting:

Table 3.4 Mean timings of the nesting process.

Activity	**Average (mean) time**	**Standard Deviation**
Crawl to top of the beach	3 minutes	0.84
Dig nest	15 minutes	2.45
Lay eggs	10 minutes	2.11
Cover up nest and enter sea	12minutes	3.92
Total time:	**40 minutes**	**4.03**

In order to avoid repeat counting, the nest was marked with crosses across the track and GPS positions were compared with those already recorded for the evening.

Two teams undertook the research, which included employing a skilled local egg collector already accustomed to locating nesting turtles. Surveying was performed in two shifts, 7pm to 12am and 12am to 5.30am. All surveyors were given training in completing the proforma and operating a GPS. All data were recorded in Spanish using a code (see appendix 4) to avoid errors by local surveyors. For increased accuracy, confirmation of data with other egg collectors during the crawl count survey proved to be invaluable.

Due to time and financial restrictions the hourly survey could only be undertaken for one lunar cycle. Therefore, it was decided to survey in the peak-nesting month to take advantage of a greater sample of nesting turtles. The crawl count survey commenced on 31st August 2006 (first quarter of the lunar cycle) and concluded on 29th September 2006 (a complete lunar cycle). In addition to this, regular daily monitoring of the 3km catchment area was undertaken as part of ARCAS/AMBIOS' usual population monitoring activities from July to October 2006. The methodology was the same, except that the actual timing of turtle emergence was not recorded, nests being counted once daily at 6am, and only successful nests were recorded. A larger error rate was possible for the daily monitoring methodology, as nests that have been laid below the high tide line, or wiped out by heavy rain or wind would have been unrecorded.

3.5 Calibration of Anemometer

Anemometer readings were calibrated to a Mini-Met station at Silsoe, Cranfield University between 8th and 15th November 2006. The Mini-Met used in Guatemala was shown to be under-reading (see figure 3.2). Due to the high R- squared (0.94), all readings were corrected using the coefficient, 0.8559.

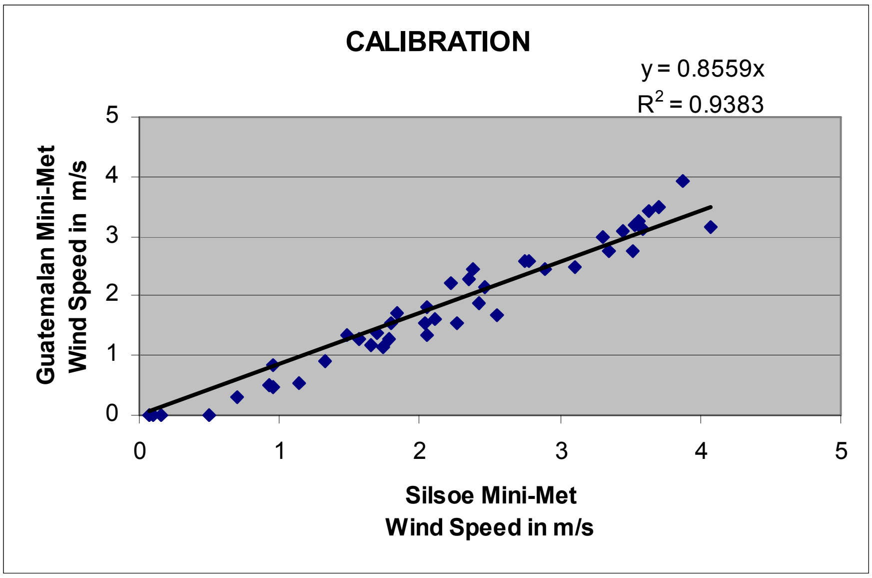


Figure 3.2 Calibration of Anemometer.

3.6 Statistical Analysis

The data collected on the individual parameters were analysed using an "unbalanced treatment structure" factorial-ANOVA and Fisher's LSD to determine distinct homogenous groups when p<0.05. The factors used for analysis were "natural" factors, so unable to be controlled in the study. As a result there were unequal replicates of the data, with particular data deficiencies of the weather data, moonrise and moonset data to analyse cross significance of factors. The rainfall and wind force data, had to be simplified into "rain" or "none", and "strong wind" or "none" respectively to improve replication. "Strong winds" as were labelled as such by using the occurrence of two such events when egg collectors began patrolling the beach for nesting turtles at midday on 27th August and at 4pm on 11th September. The anemometer recorded readings of a 'corrected' 7m/s (25.2 km/hr) up to a 'corrected' 8m/s (28.9km/hr). For analysis, all wind readings of 'corrected' 7m/s or above, were labelled as "strong wind"; all others as "none".

The effect of tides was analysed by organising all observations into "hours from high tide", high tide taking the value 0. The factor to analyse moon phase was organised into "days away from the moon phase", moon phase being full, new, quarter moons. The single day 4 that appeared in the 30-day data was altered to 3 to avoid statistical problems of under replication. Neap and spring tidal weeks were named accordingly, following the calendar provided from the social survey.

The software package, Statistica version 7.0 was used for all statistical analysis.

Chapter 4: Results

4.1 Nesting success

In total 222 turtles were surveyed, of which 21 (9.46%) did not nest.

4.2 Rain

The effect of rain was significant, p= 0.00359; F(1, 388) = 8.5871 in terms of increased turtle emergence per hour (te/hr). Figure 4.1 shows 95% confidence intervals for the predicted mean for turtle emergence, being 0.906 te/hr for rain, and 0.503 te/hr for none. Unfortunately, due to the lack of data, the effect of the intensity of rain could not be analysed, although it is interesting to note that under hours of heavy rain (two data points were greater than 20mm/hr) no turtles emerged. The inability to perform a factorial ANOVA, prevented further analysis of the relevance of this factor.

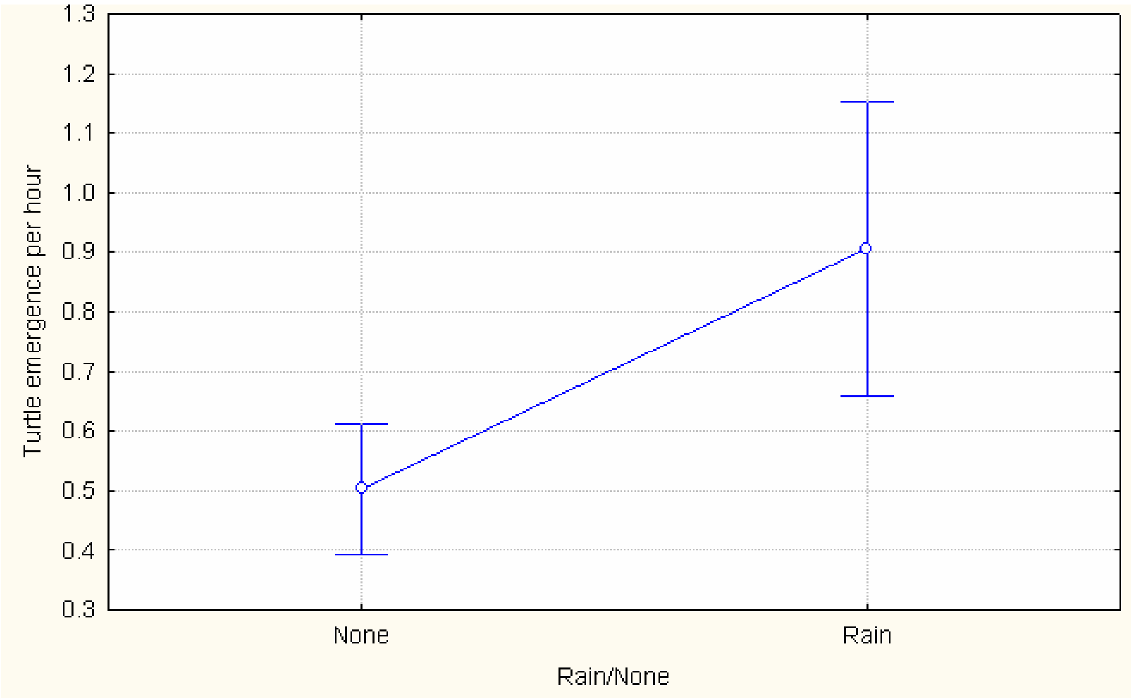


Figure 4.1 The effect of rain on turtle emergence per hour.
F(1, 388)= 8.5871, p=0.00359. Vertical bars denote 0.95 confidence intervals.

4.3 Wind

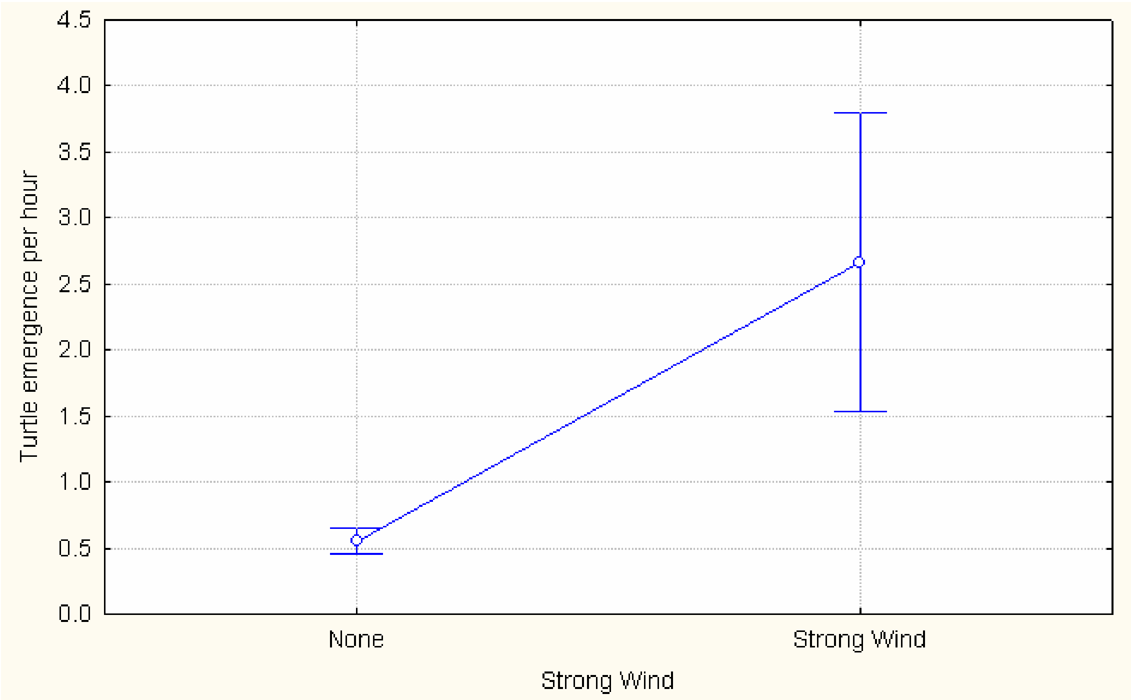


Figure 4.2 The effect of strong wind on turtle emergence.
F(1, 388)= 13.289, p= 0.00030. Vertical bars denote 0.95 confidence intervals.

Although only 3 cases (hours) were marked as "Strong wind", strong wind was significant (p=0.0003). Figure 4.2 shows the mean predicted values (strong wind 2.776 te/he and none 0.553 te/hr) and the 95% confidence intervals. These turtles that emerged during "strong winds", emerged during the day, three between 4pm and 5pm, and 2 between 5pm and 6pm, during daylight. Outside of the study period and area, on 27th August 2006, under similar conditions (corrected 7m/s winds and above), turtles were observed to nest during the daytime. These turtles nested at 1.30pm 14km from the Mini-Met. In the period when the Mini-Met was active, there has only been one other occurrence of strong winds (14th August between midday to 5pm), although no reporting of nesting turtles came forth.

The five turtles that emerged on 11th September, did not nest. This was likely to be due to the presence of many egg collectors, see figure 4.3. Four of the turtles, began to emerge from the sea, and quickly re-entered again.

Figure 4.3 Egg collectors waiting for turtles to emerge, 5pm 11th September 2006. (Source: F Barker)

4.4 Moonrise and Moonset

The effect of moonset, three hours leading up to the moonset (labelled 'moonset') has shown to be significant, see figure 4.4. Predicted means were 1.18 te/hr for moonset and 0.51 for other times. Moonrise however did not show to have a significant effect, $p=0.74$, $F(11,196)= 0.70$. Again further analysis of these factors is limited by the lack of replicates.

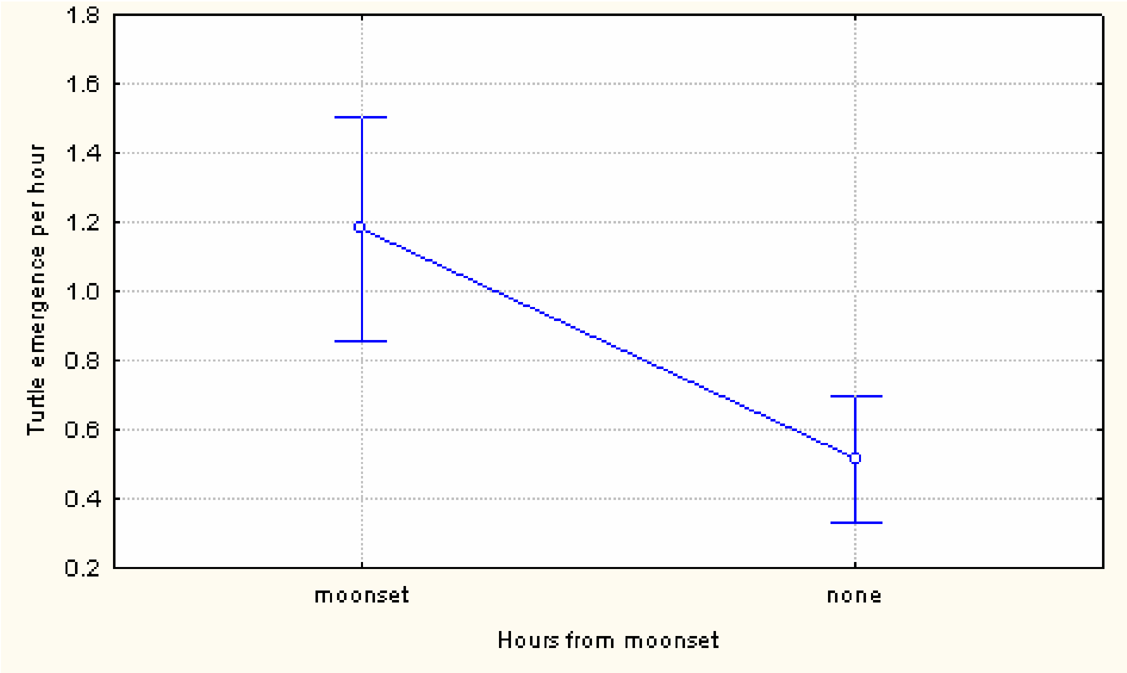


Figure 4.4 The effect of moonset on turtle emergence per hour.

F(1, 178)= 12.392, p= 0.0005. Vertical bars denote 0.95 confidence intervals.

4.5 Tide, moon phase, and the effect of neap and spring tidal weeks

A factorial ANOVA gave the following results:

Effect	SS	Degr. of Freedom	MS	F	p
Intercept	116.6027	1	116.6027	159.0634	0.000000
Hours from high tide	11.4674	11	1.0425	1.4221	0.161861
Days away from moon phase	7.0252	3	2.3417	3.1945	0.023907
Tidal Week	4.9807	1	4.9807	6.7944	0.009610
Hours from high tide*Days away from moon phase	41.1270	33	1.2463	1.7001	0.012017
Hours from high tide*Tidal Week	65.6068	11	5.9643	8.1361	0.000000
Days away from moon phase*Tidal Week	17.2595	3	5.7532	7.8482	0.000047
Hours from high tide*Days away from moon phase*Tidal Week	32.5338	33	0.9859	1.3449	0.105077
Error	215.5190	294	0.7331		

Figure 4.5 The effect of tide, moon phase and neap and spring tides on turtle emergence

Many factors have been shown to be significant (p<0.05), (see figure 4.5) in explaining the timing of turtle emergence. These factors were described below.

4.5.1 Tide

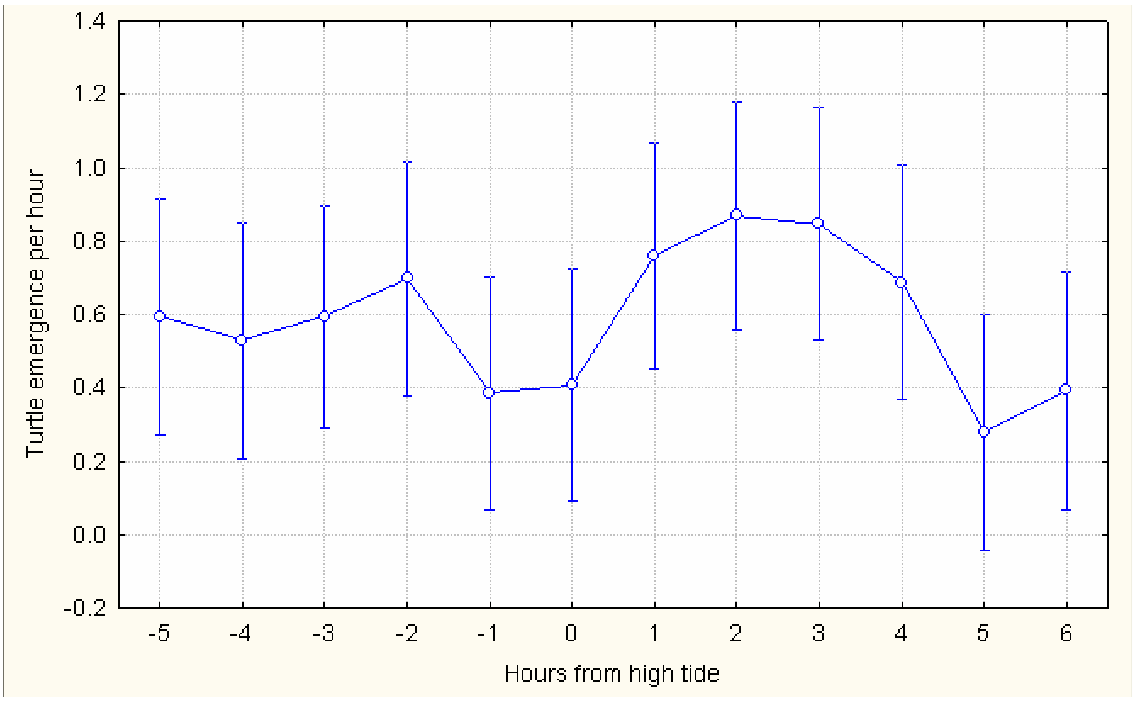


Figure 4.6 The effect of the daily tidal pattern on turtle emergence per hour. F(11, 294)= 1.4221, p=0.16186. Vertical bars denote 0.95 confidence intervals. Note insignificance.

Tidal patterns, as seen in figure 4.6, cannot explain the differences in turtle emergence, p=0.162; F(11, 294)= 1.42. There is however, an interesting pattern of dips in emergence around the time of high (-1, 0) and low tide (5, 6).

Nevertheless tides are able to explain turtle emergence when combined with neap and spring tidal weeks. There is a very high significance (p<0.000001; F(11, 294)= 8.14), and a clear pattern emerging in figure 4.7. Specifically, that during the spring tidal weeks, turtles were more likely to emerge on the flood tide; and vice versa, during neap tidal weeks, turtles were more likely to emerge on the ebb tide

.

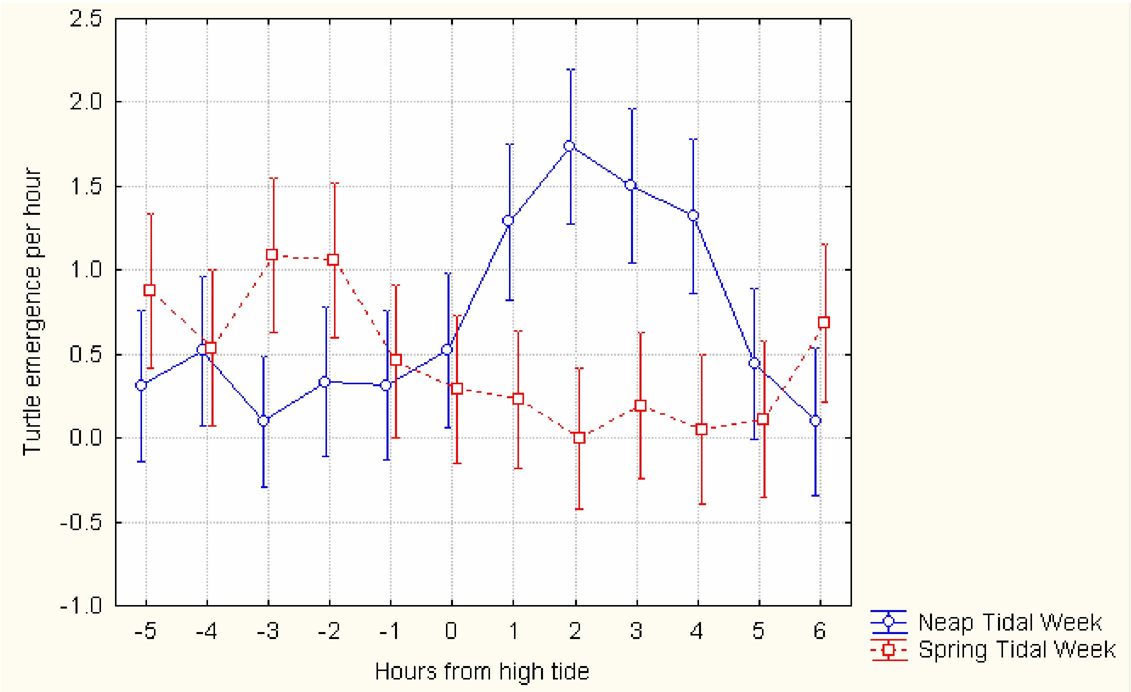


Figure 4.7 The effect of the daily tidal pattern and neap and spring tidal weeks on turtle emergence per hour.
F(11, 294)= 8.1361, p<0.00001. Vertical bars denote 0.95 confidence intervals.

Using the Fisher's LSD, comparisons between spring and neap tidal weeks and the various hours from the high tide, showed significant homogenous groups. At low (5, 6, -5, -4) and high (-1, 0) tide there are no significant differences between the tidal weeks. However, during the flood tide (-3, -2) significantly more turtles emerge during spring tidal weeks, predicted means are respectively 0.93, 1.07 te/hr for spring weeks, and 0.11 and 0.41 te/hr for neap weeks. During ebb tides (1, 2, 3, 4), significantly more turtles emerged during neap tidal weeks. Predicted means are respectively 1.2, 1.93, 1.45, 1.45 te/hr for neap tidal weeks and 0.28, 0.00, 0.22, 0.06 te/hr for spring weeks.

Using the highest predicted means, and comparing significance horizontally showed an avoidance of emerging during high (0, -1) and low tides (5, 6, -5, -4). Fisher's LSD (see appendix 5) showed the significant differences.

Further examination of high and low tides during neap and spring tidal weeks is displayed in figure 4.8.

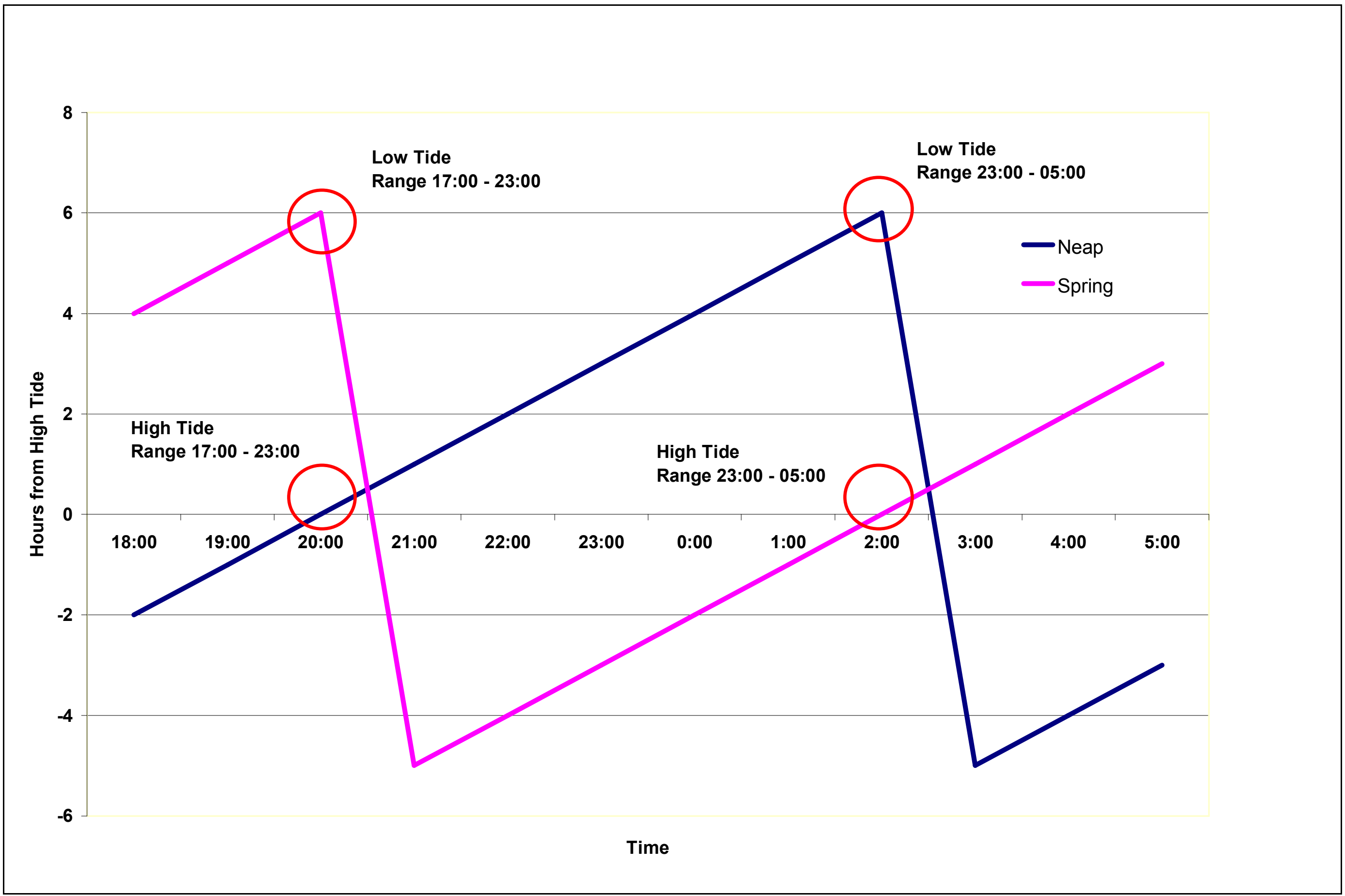


Figure 4.8 A diagrammatic representation of the relationship between daily tidal pattern and neap and spring tides.

The graph shows that for El Rosario, during a spring tidal week, high tide ranges between 5pm to 11pm, and low tide from 11pm to 5am in that week. The graph displays the tides during full and new moon. During the neap tidal week, the high tide ranges between 5pm to 11pm, and low tide from 11pm to 5am in that week. The graph displays the tides during the quarter moons.

4.5.2 Moon Phase

The effect of moon phase on turtle emergence was significant, $p=0.024$, $F(3, 294)= 3.19$. The Fisher's LSD shows that for 2 days away from the moon phase there are significantly lower turtle emergences.

Combined with tides, there was also significance, $p=0.012$; $F(33, 294)= 1.70$. Further analysis using Fisher's LSD only emphasised the above conclusion, that 2 days away from the moon experienced significantly lower turtle emergences at certain tides (-5, 2, 4).

Combined with neap and spring tidal weeks showed significance, p=0.0005; F(3, 294)= 7.85. Fisher's LSD made a distinction at 3 days away from the moon phase for spring and neap tidal weeks, see figure 4.9. Predicted means for 3 days away from the moon phase are 1.06 te/hr for neap tides and 0.22 te/hr for spring weeks.

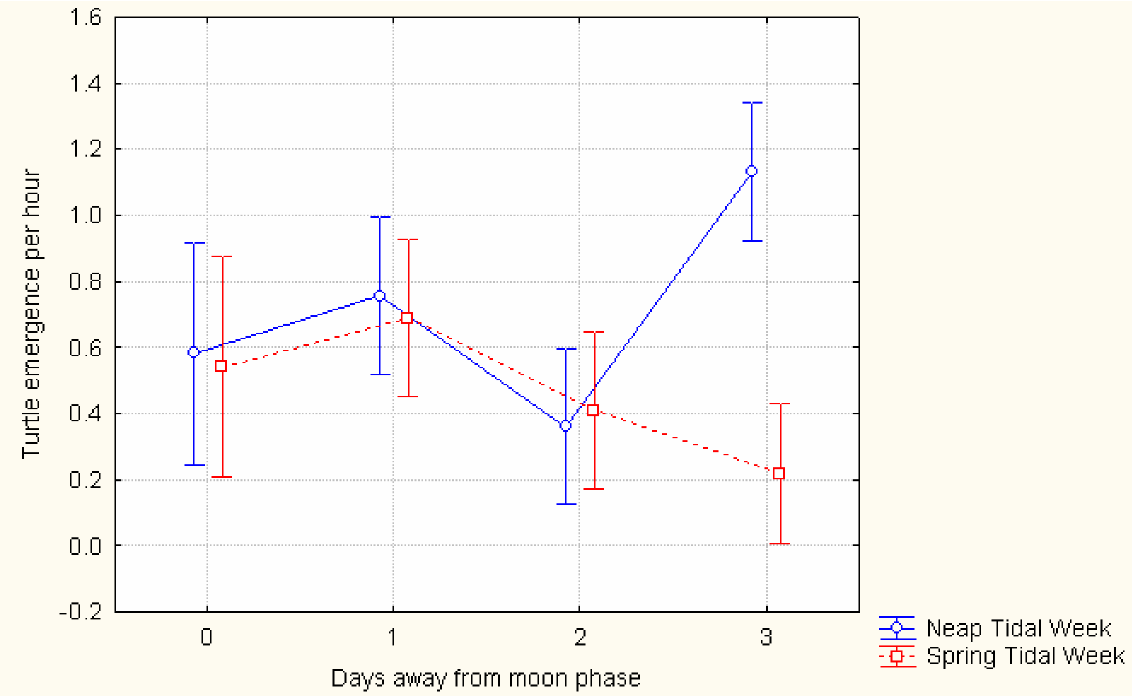


Figure 4.9 The effect of moon phase and spring and neap tidal weeks on turtle emergence per hour.
F(3, 294)= 7.8482, p= 0.00005. Vertical bars denote 0.95 confidence intervals.

4.5.3 Neap and spring tidal weeks

The effect of neap and spring tidal weeks on turtle emergence was significant (p=0.010; F(1, 294)= 6.79). Predicted means estimates neap tidal week at 0.71 te/hr and 0.42 te/hr for spring tidal weeks, see figure 4.10. Fisher's LSD shows that during neap tidal weeks, there will be significantly more turtle emergences than during spring tidal weeks.

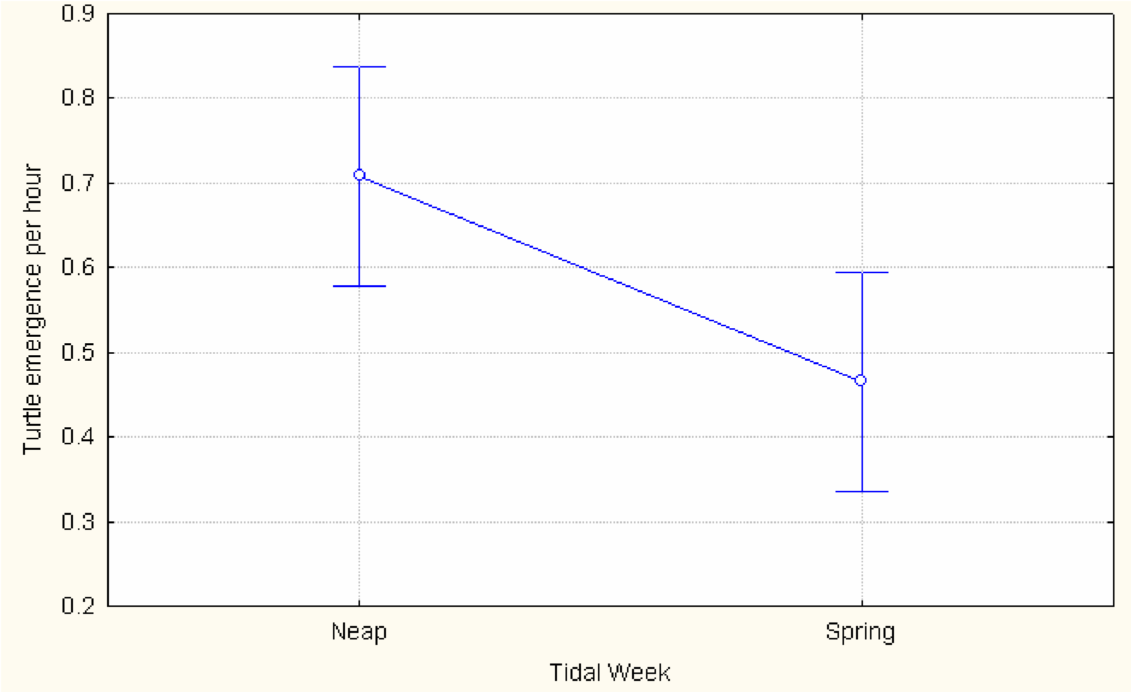


Figure 4.10 The effect of neap and spring tidal weeks on turtle emergence per hour. $F(1, 294)= 6.7944$, $p=0.00961$. Vertical bars denote 0.95 confidence intervals.

The effect of the combination of other factors with spring and neap tidal weeks has already been described above.

4.6 Additional data

Additional data were collected in the Hawaii (8km) and El Rosario (3km) catchment area from July to October 2006. Further monthly analysis was performed on the moon phase and neap and spring tidal weeks. For the Hawaii catchment area, there were no significant results, although there was a pattern for preference of neap tides during September and October. El Rosario again, is influenced by neap and spring tidal weeks and the moon phase, though for October only. Neap and spring tides are significant alone, ($p=0.002$; $F(1, 21)=12.623$); and combined with moon phase ($p= 0.0229$; $F(3, 21)= 3.919$); the effect of moon phase alone is insignificant ($p=0.27$; $F(3, 21)= 1.40$).

The predicted means for neap and spring tidal weeks are 7.71 successfully nested turtles per evening (snt/ev) for neap, and 4.47 snt/ev for spring weeks. Figure 4.11 shows the 95% confidence intervals.

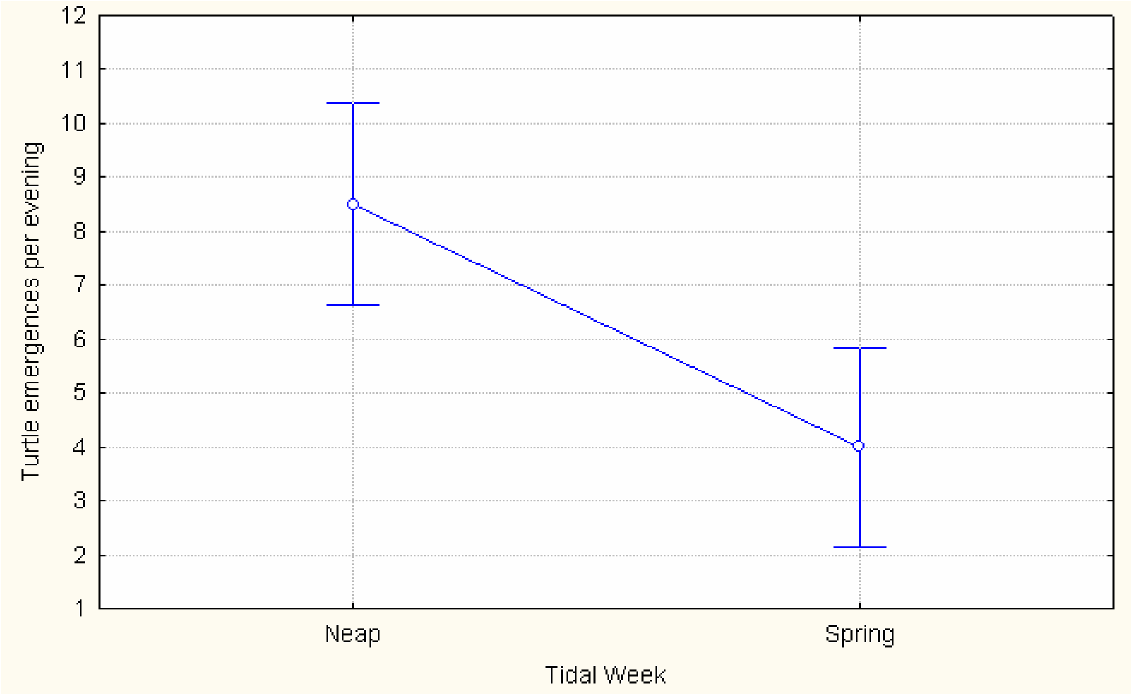


Figure 4.11 The effect of neap and spring tidal weeks, on successfully nested turtles per evening, in El Rosario October 2006.
$F(1, 21)= 12.623$, $p= 0.00188$. Vertical bars denote 0.95 confidence intervals.

The Fisher's LSD showed a significant difference between spring and neap tidal weeks on the day of the moon phase (i.e. 0). Predicted means for the quarter moons are 14 snt/ev, and 1 snt/ev for the full and new moons, figure 4.12 displays these results.

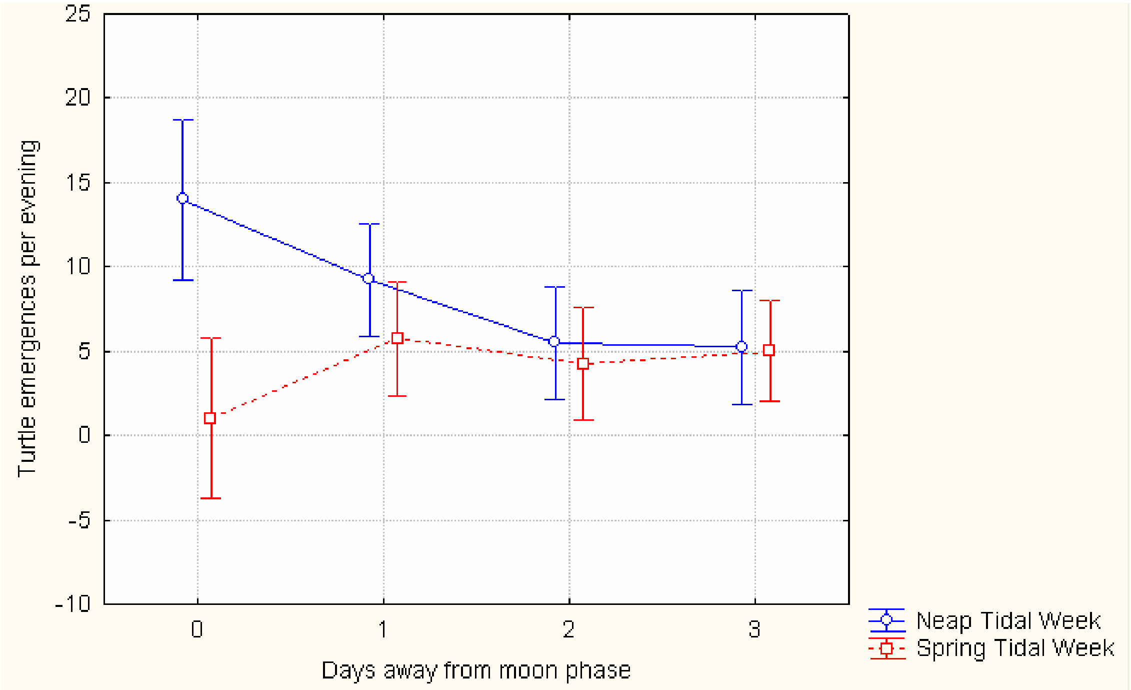


Figure 4.12 The effect of moon phase and spring and neap tidal weeks on successfully nested turtles per evening, for El Rosario October 2006.
$F(3, 21)= 3.9188$, $p= 0.02285$. Vertical bars denote 0.95 confidence intervals.

4.6.1 Location

As GPS positions were taken for both sites, an evaluation of preferred nesting sites was undertaken for 11km during September 2006. As the Hawaii monitoring programme only counted successfully nested turtles per evening, the El Rosario data was filtered to only include similar data. Both sites used a similar methodology, however, the Hawaii site undertook monitoring each morning, after nesting for the evening had finished. Assuming, the data was comparable, there are significantly higher nesting frequencies at 0km (range 0.5km either side of the centre of El Rosario), ($p=0.00005$; $F(11, 348)= 3.71$), with a predicted mean of 2.67 snt/ev. Figure 4.13 shows the predicted means with 95% confidence intervals.

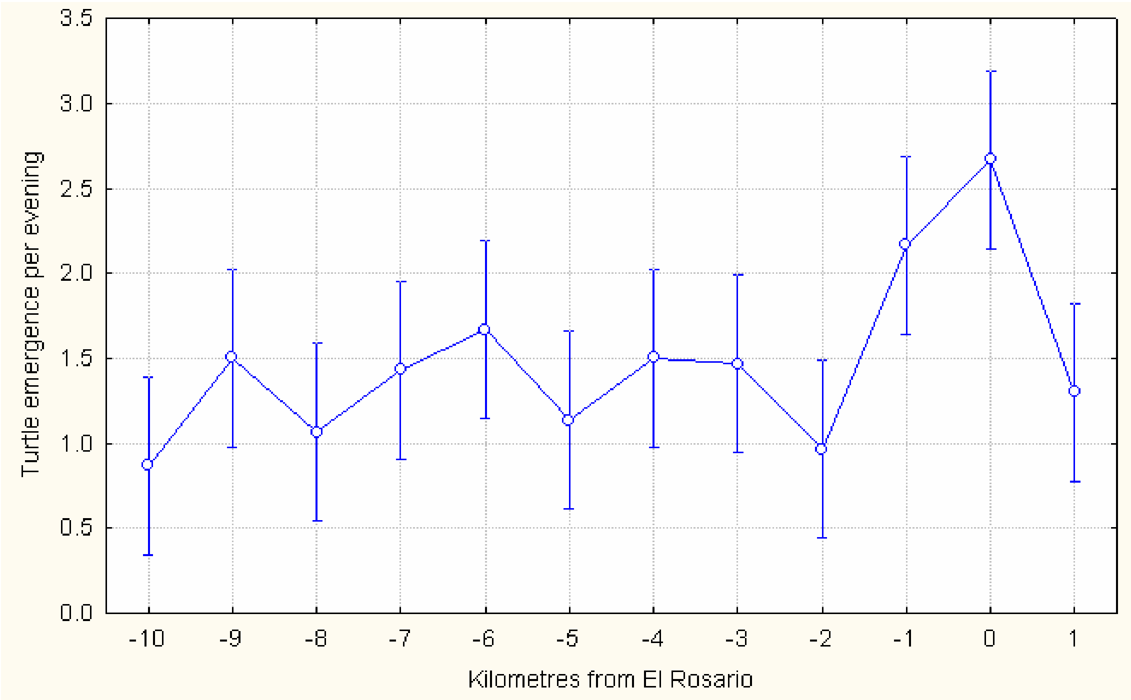


Figure 4.13 The effect of location on successfully nested turtles per evening for the El Rosario and Hawaii catchment area for September 2006.

Data rounded up or down to nearest integer 0 represents El Rosario and -1 as 1km west of El Rosario.
F(11, 348)= 3.7077, p= 0.00005. Vertical bars denote 0.95 confidence intervals.

Chapter 5: Discussion and Recommendations

There are two parts to the discussion; has local knowledge led to a clear, significant understanding of nesting behaviour, and if so, how can this research be used to improve conservation in Guatemala.

5.1 Has local knowledge led to a clear, significant understanding of nesting behaviour?

It is clear that many significant results have come out of this study, through analysing the relevant factors, which stemmed from the social survey of local knowledge. The factors of the social survey were:

- Strong onshore winds
- Moon phases
- Tidal effects: turn of tides (*descabezante, repunta*), ebb and flood, high tide
- Moonset and moonrise
- Spring and neap tidal weeks (*aguajon, agua chica*)
- First day of the neap tidal week (*quiebra de aguajon)*

The weather effects (strong wind and rain) were shown to significantly increase turtle emergence. Carr (1968), and Pandav & Kar (2000) also observed similar effects for strong wind. Emerging during strong wind and rain could be a logical response as they both deter natural predators from the nesting beach and remove the evidence of nesting (Carr, 1968). To fully understand the dynamics of these factors more data would have to be collected to be able to combine the effects of weather with other significant factors.

The moon phases have been shown to be significant in the September and October- El Rosario dataset, where three days away from the moon and the quarter moons respectively have significantly higher successful nested turtles than during the spring tide equivalent. The former corroborates the idea of the *quiebra de aguajon,* however it is not repeated for the other months. The idea behind the *quiebra de aguajon,* is, a break from high water levels. Due to the inconsistency of the results, the turtles could be reacting to a drop in the tidal exchange, which does not necessarily land on the same day between months. A lower high tide would reduce the possibility of embryonic mortality from washover (Whitmore & Dutton, 1985), and offer more viable nesting space above the high tide line (Lopez-Castro et al, 2004). September and

October are months of higher very, due to the Spring Equinox tide, which occurred around the 22nd September 2006. This may explain why significant differences were not found during August and July. To fully understand the *quiebra de aguajon,* it would be necessary to undertake a study on the exact water levels throughout the season, instead, as this study has, used the moon phase as a proxy for differing water levels over a short time period.

The effect of moonset has been shown to be significant, which follows a pattern in accordance with local theory. This could be related more to the tides than an independent factor, as the moonset generally occurs 3-5 hours after high tide. Again, more data could improve our understanding of this factor.

The effects of tide combined with spring and neap tidal weeks have led to some exciting conclusions, specifically the effect of increased turtle emergence in spring tides during the hours after low tide, and in neap tides during the hours after high tide. This analysis also illustrates the avoidance of emerging during high and low tide. The effect of the turn of the tide is significant for the ebb tide, *descabezante*, however, not for the flood tide, *repunta*.

During high and low tides, there is a slack in the current. The strength of the flood and ebb current reaches a peak halfway between high and low water (Eezway, 2006). The ebb tides are significantly better times for emerging than slack water. Peak emergences for the flood tide (-3, -2) and ebb tides (2, 3, 4) were, interestingly, during high flood and ebb tide strength, see current diagram, figure 4. Although the social survey did not specifically identify the relationship between the tidal pattern and the tidal weeks, it was however, pivotal in reaching this conclusion.

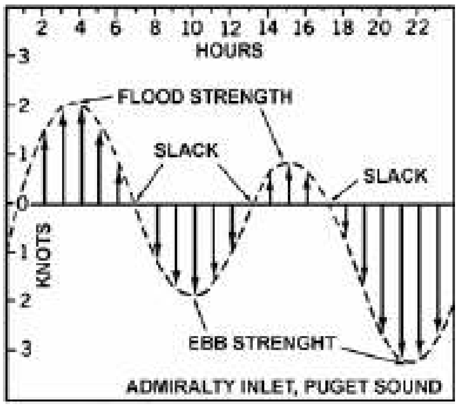


Figure 5.1 Current diagram for Admiralty Inlet, Puget Sound.
An example of water slacks and flood and ebb current strengths. (Source: Eezway)

Further thought has lead to the possible theory of the turtles using certain cues for turtle emergence. Specifically, that they generally wait until night time, and then emerge *after* the first high or low water slack, see figures 4.7 and 4.8. By following these cues, the turtles would minimise the possibility of being active in any part of the nesting process during high or low tide. This would avoid long crawls at low tide (Gulko & Eckert, 2004), and avoid the dangerous water at high tide.

Local knowledge showed the importance of the effect of ebb and flood tides. Times of higher ebb and flood tidal strength (Eezway, 2006) also coincides with times of higher emergence, see figure 4.7 and 5.1. This could also be another possible cue, the strength of the tidal currents. Emerging during the ebb tide, especially during the turn of the tide would allow for a better site selection, easily identifying the sites above the high tide line, again reducing the possibility of embryonic mortality from washover.

As mentioned above, the possible effect of lower tidal exchanges, as reflected in weeks of neap tides, *agua chica*, are apparent in both September and October for the El Rosario site, as in other olive ridley nesting beaches (Choudhury & Pandav, 2000; Marquez *et al*, 1976; Dash & Kar, 1990). If they were indeed, using lower tidal exchange cues, further studies would need to be undertaken to fully understand the interaction. It is interesting that this pattern is present only during months of higher water (September and October), and not in the other nesting months. As well, the insignificance (although a similar pattern was observed) of neap tides in the Hawaii catchment area, could mean there are other influencing factors, such as, the steeper beach profiles (Frazer, 1983) in Hawaii (pers obs, 2006); or the influence of a powerful estuary system (Fretney & Girondot, 1989, 1996) 1km east of the centre of El Rosario.

These same reasons could explain why, El Rosario site appears to be an area of higher nesting density. Again, this study cannot draw any conclusions on that; further research will be needed over a greater spatial and time period. Further research on current dynamics, especially by the estuary using drift cards could be an excellent study to understand the spatial distribution of turtle emergences.

The main limitations of this study have specifically been the short time coverage of 30 days, and the small study area. Data collected over a longer time period over a larger study area would yield more conclusive results from a greater sample of turtles, and more weather, lunar and tidal observations. This could also lead to a better understanding of temporal and spatial nesting densities. It was also understood that the tidal pattern in El Rosario could have been slightly different from the tide chart used in this study, due to variations in the shape of the coastline and sea depth. Measuring the tidal pattern in El Rosario could overcome this limitation.

5.2 How can this research be used to improve conservation in Guatemala?

As mentioned in the literature review, in the absence of radical changes to the management of nesting turtles in Guatemala, conservation will rely on the ability to use the limited resources (police patrols, volunteers, ATV) effectively. The results from this research have concluded that turtle emergence is more likely during the flood and ebb tides, depending on the occurrence of spring of neap tidal weeks. The practical conclusions from this study are that to organize patrols during “peak” nesting, it is sufficient to simply follow a tide chart with moon phases, to improve regulation.

To understand the effects of tidal heights and tidal currents more accurately, further studies will need to be undertaken.

As police patrols are limited in a season, times of neap tidal weeks will derive better results during September and October. As well, these limited resources should be focused on areas of increased nesting frequency.

I believe it is necessary for an independent assessment of the sustainability of the current management of nesting olive ridleys. Areas that need to be considered in the assessment are:

- An accurate assessment of the adult population.
- Nesting densities along the pacific coast.
- Regularity of hatcheries along the coast.
- Collaboration rates of each hatchery.
- Management of hatcheries; such as, incubation temperatures, immediate release of hatchlings, data collection.
- Use of mathematical models to demonstrate the sustainability of the current management. Predictions of likely adult populations under current and alternative management.
- Social aspects: dependency of local villages on turtle egg income; options for alternative income, such as ecotourism; and the level of ecological understanding amongst the villagers to assess the need for environmental education and awareness campaigns.
- Overall costs of current management and alternatives.

If the current conservation is not adequate, better protection needs to be offered, for example, complete protection in areas of higher nesting density. Any alternatives proposed must not be implemented without considering compensation for the poor coastal communities of their lost income.

Unfortunately, improving conservation of sea turtles in Guatemala cannot solely be based on the nesting beach. Nesting is a very small part of their life cycle; the majority of their time is spent in the sea. From 23rd to 30th August 2006, 7 turtle carcasses washed up on the El Rosario beach within a 2 km range (pers obs, 2006). This is the equivalence of 21, 000 hatchlings (Sea Turtle Restoration fact sheet)! Commercial unselective fishing trawlers have been shown to be responsible for the incidental capture of many turtles in the United States of America (Henwood & Stuntz, 1987; Epperly *et al*, 1995), and could be responsible in Guatemala. Alternative fishing gear, such as drift and gill nets and bottom longlines, also cause turtle mortalities, as found in Malaysia (Chan *et al*, 1988). Conservation, therefore, needs to incorporate all life stages of the sea turtle, especially areas of high turtle density at sea or on nesting beaches, if it is to be successful. To assess the situation and propose solutions in Guatemala, further research is needed on when and where the turtles are captured, at which depths the majority of captures occur, and how many turtles are captured and killed as recommended by Henwood & Stuntz (1987).

Currently, there has been no research on migration patterns on “Guatemalan” olive ridley turtles. Olive ridleys that nest in Costa Rica, have been observed to take distinct migratory routes up to thousands or kilometres from the beach (Spotila, 2004). Better understanding of Guatemalan turtles’ migratory path is needed if adequate protection is to be proposed. Sea turtles unfortunately cannot be the responsibility of one country, as, in their life cycle, cross many international boundaries. International cooperation is needed to offer protection across borders for this species, as recommended by Bache (2000). Sadly, the protection that is in place in Guatemala at present, specifically the obligatory use of Turtle Excluder Devices and temporal and zonal bans of fishing do not appear to be satisfactory. Realistic solutions are needed that can be implemented and easily regulated. As in every country, fisheries monitoring and regulation is not easily applied, which is something that urgently needs to be addressed.

Although sea turtle conservation management has many challenges ahead, the importance of the results of this research must be realised. If current management of nesting beaches and ocean habitat do not change, then this research allows for a more effective regulation of turtle eggs. This will have future positive implications for the adult population, and the local coastal egg harvesting communities, as they benefit from a better income from sustainable harvesting.

The results of this research could also provide explanations to nesting behaviour for other beaches and indeed other sea turtle species, possibly clarifying the uncertainty associated with nesting behaviour.

On a wider scale, the scientific community has often ignored the methodology of using local knowledge to improve understanding. This study has shown that local knowledge can be useful for the advancement of scientific thought, and should be utilised more often.

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Appendices

Appendix 1: Survey of Traditional Knowledge

Location: Village El Rosario of Chiquimulilla, Department Santa Rosa, Guatemala.

Questions:

1. Name
2. Age
3. How many years have you collected turtle eggs?
4. How long do you look for turtles each night?
5. What factors influence the emergence of turtles?
6. Can you place them in order of importance.

Answers:

1. Walter Marroquin
2. 17
3. 10 years
4. 4 years every night between August and October.
5. – For 1 hour and a half when the tide starts to go out
   – For 1 hour and a half when the tide starts to come in
   – For 1 hour and a half before the moon rises and sets
   – Strong onshore winds
6. - Strong onshore winds
   - For 1 hour and a half when the tide starts to go out
   - For 1 hour and a half before the moon rises and sets

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1. Jaime Lopez
2. 30
3. 10 years
4. 7 hours a night during August to October
5. – 4 moon phases (especially the full moon)
   - High tide
   - Strong onshore winds (because it pushes them closer to shore)
   - Rain and lightning conditions don't have an effect, although turtles emerge after heavy rain.
   - For 1 hour and a half before the moon rises and sets
6. - Strong onshore winds
   - Moon phases
   - High tide

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1. Oscar Mendez
2. 42
3. 30 years
4. 2 hours every night

5. – Moon phases (especially creciente and full moon)
   - Strong onshore winds
   - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half before the moon sets
   - They don't emerge under strong lightning storms
6. - Strong onshore winds
   - For 1 hour and a half before the moon sets
   - Moon phases
   - For 1 hour and a half when the tide starts to come in

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1. Manuel Mendez
2. 54
3. 42 years
4. 2 hours each night
5. – All moon effects
   - Strong onshore winds (especially southeasterly)
   - Mid tides
   - Rain or lightning doesn't have strong effect
6. All equal.

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1. Raimundo
2. 71
3. 40 years
4. Only during strong winds
5. – Moon phases (especially creciente and full moon)
   - Strong onshore winds
   - For 1 hour and a half before the moon rises and sets
   - They don't emerge with lightning, but they do with rain
   - Dark night
   - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half from mid tide as it's coming in
   - For 1 hour and a half when the tide starts to go out
6. - Strong onshore winds
   - Moon phases (especially creciente and full moon)
   - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half from mid tide as it's coming in
   - For 1 hour and a half when the tide starts to go out

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1. Don Jose Mendez
2. 83
3. 10 years
4. Not any more
5. – Moon phases (especially creciente and full moon)
   - Strong onshore winds
   - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half when the tide starts to go out

- For 1 hour and a half before the moon rises and sets

6. - For 1 hour and a half before the moon rises and sets
   - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half when the tide starts to go out

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1. Carlos Gomez
2. 62
3. 27 years
4. 2 – 3 hours a night
5. – Strong onshore winds (especially southeasterly)
   - Moon phases
   - For 1 hour and a half when the tide starts to go out
   - For 1 hour and a half from mid tide as it's coming in
   - For 1 hour and a half before the moon rises and sets
   - They don't emerge with strong rain or lightning
6. - Strong onshore winds (especially southeasterly)
   - Moon phases

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1. Edgar Flores
2. 45
3. 6 years
4. All night
5. - For 1 hour and a half before the moon rises and sets
   - Strong onshore winds
   - 3 days after the full moon
   - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half when the tide starts to go out
   - Moon phases
6. - For 1 hour and a half when the tide starts to come in
   - For 1 hour and a half when the tide starts to go out
   - *Agua chica,* day one of *agua chica*
   - Moon phases
   -

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1. Lionel Lucero
2. 46
3. 30 years
4. 4 hours every night
5. - For 1 hour and a half before the moon rises and sets
   - Strong onshore winds
   - High tide and for 1 hour and a half when the tide starts to go out
   - Moon phases
6. - For 1 hour and a half before the moon rises and sets
   - Moon phases
   - High tide and for 1 hour and a half when the tide starts to go out
   - *Agua chica,* day one of *agua chica*

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1. Douglas Ramos
2. 26
3. 18 years
4. 1 to 2 hours every night
5. – Moon phases (especially full moon)
   - For an half hour before the moon rises and sets
   - Mid tide to mid tide
   - Strong onshore wind
6. - Strong onshore wind combined with effect of the moon
   - For an half hour before the moon rises and sets
   - Mid tide to mid tide

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1. Jose Gonzalez
2. 46
3. 34 years
4. Doesn't look for turtles any more
5. - For 2 hours when the tide starts to come in
   - For 2 hours when the tide starts to go out
   - For 1 hour before the moon sets
   - Moon phases (especially full moon)
   - Strong onshore winds (as the winds increase the size of the waves and hits the turtles making them want to lay their eggs quickly)
   - They do emerge under rain and lightning
6. - Strong onshore winds
   - Moon phases (full moon)
   - *Agua chica,* day one of *agua chica*

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1. Alfredo Ramos
2. 37
3. 30 years
4. When the moon effects are present
5. – Moon phases
   - For 1 hour before the moon sets and rises
   - For 2 hours when the tide starts to come in
   - For 2 hours when the tide starts to go out
   - Strong onshore winds
6. - Moon phases
   - For 1 hour before the moon sets and rises
   - Strong onshore winds
   - For 2 hours when the tide starts to come in
   - For 2 hours when the tide starts to go out

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1. Alberto Jimenez
2. 22
3. 14 years
4. All night

5. - For 30 minutes when the tide starts to go out
   - Moon phases
   - Mid tide to mid tide
   - For 30 minutes when the tide starts to come in
   - Strong onshore winds (southeasterly)
   - For 30 minutes before the moon sets and rises
6. - For 30 minutes before the moon sets and rises
   - Moon phases (creciente and full moon)

Appendix 2: Predicted Tide/Moon Chart for Port San Jose

2006 AUGUST TIDE HEIGHT DATUM is CHART DATUM

date			LOW	ht(m)	HIGH	ht(m)	LOW	ht(m)	HIGH	ht(m)	LOW	ht(m)
1	Mar		0054	0.20	0717	1.66	1333	0.33	1927	1.42		
2	Mie	1C	0131	0.24	0759	1.65	1419	0.36	2011	1.35		
3	Jue		0213	0.29	0845	1.64	1511	0.38	2102	1.29		
4	Vie		0301	0.32	0937	1.64	1609	0.38	2201	1.26		
5	Sab		0357	0.35	1036	1.65	1712	0.35	2307	1.27		
6	Dom		0502	0.34	1138	1.69	1815	0.29				
7	Lun				0014	1.33	0609	0.30	1240	1.74	1913	0.20
8	Mar				0117	1.44	0714	0.22	1339	1.81	2007	0.10
9	Mie	LN			0214	1.58	0815	0.12	1434	1.87	2057	0.00
10	Jue				0306	1.72	0912	0.03	1527	1.90	2144	-0.07
11	Vie				0357	1.85	1005	-0.04	1616	1.90	2230	-0.12
12	Sab				0445	1.94	1057	-0.07	1705	1.87	2316	-0.12
13	Dom				0533	1.98	1149	-0.05	1753	1.79		
14	Lun		0001	-0.09	0622	1.98	1240	0.00	1842	1.69		
15	Mar		0047	-0.01	0711	1.93	1332	0.09	1932	1.57		
16	Mie	3C	0135	0.09	0802	1.85	1427	0.19	2025	1.45		
17	Jue		0225	0.20	0856	1.75	1526	0.28	2124	1.35		
18	Vie		0322	0.31	0955	1.66	1629	0.34	2229	1.29		
19	Sab		0424	0.39	1057	1.59	1734	0.36	2337	1.27		
20	Dom		0531	0.43	1200	1.56	1835	0.35				
21	Lun				0041	1.31	0636	0.42	1258	1.56	1928	0.31
22	Mar				0135	1.38	0733	0.38	1349	1.58	2013	0.26
23	Mie	LN			0222	1.46	0822	0.32	1434	1.61	2053	0.21
24	Jue				0303	1.55	0906	0.26	1515	1.63	2129	0.16
25	Vie				0340	1.63	0946	0.21	1553	1.64	2203	0.13
26	Sab				0416	1.68	1025	0.18	1628	1.63	2236	0.12
27	Dom				0451	1.72	1102	0.18	1703	1.60	2309	0.13
28	Lun				0526	1.74	1138	0.19	1738	1.56	2341	0.15
29	Mar				0600	1.74	1216	0.22	1813	1.50		
30	Mie		0015	0.18	0637	1.72	1256	0.26	1851	1.44		
31	Jue	1C	0051	0.23	0717	1.69	1340	0.31	1934	1.37		

2006 SEPTEMBER TIDE HEIGHT DATUM is CHART DATUM

date			LOW	ht(m)	HIGH	ht(m)	LOW	ht(m)	HIGH	ht(m)	LOW	ht(m)
1	Vie		0133	0.28	0803	1.66	1431	0.35	2025	1.32		
2	Sab		0224	0.33	0858	1.63	1530	0.37	2127	1.29		
3	Dom		0327	0.36	1002	1.61	1637	0.35	2238	1.31		

4	Lun		0439	0.35	1111	1.63	1744	0.29	2350	1.40		
5	Mar		0553	0.29	1219	1.68	1846	0.20				
6	Mie				0055	1.54	0701	0.18	1321	1.76	1941	0.09
7	Jue	LL			0152	1.70	0802	0.05	1417	1.82	2031	-0.01
8	Vie				0244	1.86	0857	-0.06	1508	1.87	2118	-0.09
9	Sab				0333	1.99	0949	-0.13	1557	1.87	2204	-0.13
10	Dom				0421	2.06	1039	-0.15	1645	1.84	2249	-0.13
11	Lun				0508	2.08	1128	-0.12	1731	1.77	2334	-0.07
12	Mar				0555	2.03	1216	-0.04	1818	1.67		
13	Mie		0020	0.02	0642	1.93	1306	0.07	1907	1.55		
14	Jue	3C	0107	0.14	0732	1.80	1358	0.20	2000	1.43		
15	Vie		0159	0.27	0825	1.67	1455	0.31	2059	1.34		
16	Sab		0258	0.39	0925	1.55	1558	0.39	2206	1.29		
17	Dom		0405	0.47	1031	1.47	1704	0.42	2315	1.29		
18	Lun		0517	0.48	1138	1.44	1805	0.41				
19	Mar				0018	1.34	0623	0.45	1237	1.45	1857	0.36
20	Mie				0110	1.43	0717	0.38	1328	1.49	1941	0.30
21	Jue				0154	1.52	0803	0.30	1411	1.53	2020	0.25
22	Vie	LN			0232	1.62	0844	0.22	1450	1.57	2055	0.19
23	Sab				0308	1.70	0922	0.16	1526	1.59	2129	0.16
24	Dom				0343	1.76	0958	0.13	1601	1.60	2202	0.14
25	Lun				0417	1.80	1034	0.12	1635	1.58	2234	0.14
26	Mar				0451	1.81	1109	0.13	1709	1.55	2307	0.16
27	Mie				0526	1.80	1146	0.16	1745	1.50	2342	0.19
28	Jue				0602	1.77	1225	0.20	1824	1.45		
29	Vie		0021	0.24	0644	1.72	1309	0.25	1908	1.40		
30	Sab	1C	0106	0.29	0731	1.66	1400	0.30	2002	1.37		

2006 OCTOBER TIDE HEIGHT DATUM is CHART DATUM

date			LOW	ht(m)	HIGH	ht(m)	LOW	ht(m)	HIGH	ht(m)	LOW	ht(m)
1	Dom		0201	0.34	0829	1.61	1459	0.33	2106	1.36		
2	Lun		0310	0.37	0936	1.57	1606	0.32	2218	1.41		
3	Mar		0427	0.34	1049	1.57	1713	0.28	2328	1.52		
4	Mie		0541	0.25	1159	1.61	1815	0.19				
5	Jue				0031	1.67	0648	0.13	1301	1.68	1911	0.09
6	Vie				0128	1.83	0747	-0.01	1356	1.74	2002	0.00
7	Sab	LN			0219	1.97	0840	-0.11	1448	1.79	2050	-0.07
8	Dom				0308	2.07	0930	-0.17	1536	1.80	2137	-0.09
9	Lun				0355	2.11	1018	-0.18	1623	1.78	2222	-0.07
10	Mar				0441	2.09	1105	-0.13	1709	1.72	2308	-0.01
11	Mie				0527	2.01	1152	-0.04	1756	1.63	2354	0.09
12	Jue				0614	1.88	1239	0.08	1844	1.54		
13	Vie		0043	0.22	0702	1.73	1329	0.20	1936	1.44		

14	Sab	3C	0136	0.34	0755	1.59	1423	0.31	2034	1.37		
15	Dom		0236	0.44	0854	1.46	1522	0.39	2139	1.33		
16	Lun		0345	0.50	1000	1.38	1624	0.43	2244	1.35		
17	Mar		0456	0.50	1106	1.35	1723	0.43	2344	1.41		
18	Mie		0559	0.45	1206	1.36	1815	0.39				
19	Jue				0034	1.49	0652	0.37	1256	1.40	1900	0.34
20	Vie				0117	1.58	0737	0.28	1340	1.45	1939	0.29
21	Sab				0156	1.67	0817	0.20	1419	1.49	2017	0.23
22	Dom	LL			0233	1.75	0855	0.14	1457	1.52	2052	0.20
23	Lun				0309	1.81	0931	0.10	1533	1.54	2127	0.17
24	Mar				0344	1.84	1007	0.08	1609	1.54	2202	0.17
25	Mie				0420	1.85	1044	0.08	1645	1.53	2239	0.18
26	Jue				0457	1.83	1122	0.10	1724	1.51	2318	0.21
27	Vie				0536	1.79	1202	0.14	1806	1.48		
28	Sab		0001	0.25	0620	1.73	1247	0.18	1853	1.46		
29	Dom	1C	0052	0.30	0711	1.66	1338	0.23	1949	1.46		
30	Lun		0152	0.33	0809	1.59	1435	0.26	2052	1.48		
31	Mar		0301	0.34	0916	1.53	1538	0.27	2159	1.54		

Appendix 3: Proforma- Crawl Counts

DATE ____________________

HIGH TIDE ____________________

LOW TIDE ____________________

MOON PHASE ____________________

MOON RISE ____________________

MOON SET ____________________

N° OF TRAWLERS ____________________

N° OF TRACKS ____________________

DESCRIPTION OF WEATHER

	DESCRIPTION OF WEATHER, RAIN, LIGHT RAIN, WIND, DIRECTION, CLOUD COVER, LIGHTNING…
7:00PM	
8:00PM	
9:00PM	
10:00PM	
11:00PM	
00:00AM	
01:00AM	
02:00AM	
03:00AM	
04:00AM	
05:00AM	

TABLE OF CRAWLS

DATE ______________________

	TIME	NESTED	GPS	WEATHER	TIDE	DARKNESS
EG	22:16	YES/NO	0784657 1532056	HEAVY/ LIGHT RAIN/ STRONG WINDS/ LIGHTNING BOLTS/ FLASHES	HIGH/ COMING IN/ LOW/ GOING OUT	STARS (MANY, FEW)/ CLOUDS (MANY/ FEW)/ MOONLIGHT
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Appendix 4: Crawl Count Data Code

RAIN	
LLF	HEAVY RAIN
LLM	MODERATE RAIN
LLZ	LIGHT RAIN

WIND	
CH	STRONG WIND
VM	MODERATE WIND
VP	LIGHT WIND

DIRECTION	
VDM	ONSHORE WIND
VT	OFFSHORE WIND

LIGHTING	
D	LIGHTNING FLASHES
R	CLOSE LIGHTNING BOLTS

TIDE	
MA	HIGH TIDE
MB	LOW TIDE
MM	MID TIDE
⇨LL	COMING IN
⇨B	GOING OUT

DARKNESS	
NE	NO STARS
PE	FEW STARS
ME	MANY STARS
NN	NO CLOUDS
PN	FEW CLOUDS
BN	MANY CLOUDS
MN	VERY CLOUDY
NLL	NO MOONLIGHT
PLL	PARTIAL MOONLIGHT
MLL	BRIGHT MOONLIGHT

Appendix 5: Fisher's LSD Homogenous Groups (Tide/Neap and Spring tidal weeks)

LSD test; variable Turtle emergence (Charles)
Homogenous Groups, alpha = .05000 (Non-Exhaustive Search)
Error: Between MS = .73306, df = 294.00

Cell No.	**Hours from high tide**	Neap/Spring	Turtle emergence Mean	1	2	3	4	5	6	7	8
16	2	Spring	0.000000	****							
20	4	Spring	0.058824	****	****						
5	-3	Neap	0.105263	****	****						
23	6	Neap	0.111111	****	****						
22	5	Spring	0.133333	****	****						
18	3	Spring	0.222222	****	****	****					
12	0	Spring	0.277778	****	****	****					
14	1	Spring	0.277778	****	****	****					
1	-5	Neap	0.312500	****	****	****					
7	-2	Neap	0.411765	****	****	****	****				
10	-1	Spring	0.437500	****	****	****	****				
9	-1	Neap	0.444444	****	****	****	****				
21	5	Neap	0.470588	****	****	****	****	****			
24	6	Spring	0.500000	****	****	****	****	****			
3	-4	Neap	0.529412	****	****	****	****	****			
11	0	Neap	0.533333	****	****	****	****	****			
4	-4	Spring	0.600000		****	****	****	****	****		
2	-5	Spring	0.800000			****	****	****	****		
6	-3	Spring	0.933333				****	****	****	****	
8	-2	Spring	1.066667					****	****	****	
13	1	Neap	1.200000						****	****	
19	4	Neap	1.466667							****	****
17	3	Neap	1.466667							****	****
15	2	Neap	1.933333								****