July 13, 2013

"Size, clutch size and nesting distribution in leatherbacks on Playa Norte, Costa Rica"

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ABSTRACT: During 8 years (2006-2013) data was collected from leatherbacks nesting on Playa Norte, Costa Rica. In this study relationships between Curved Carapace Length (CCL)/Width (CCW) and clutch size were examined as well as the difference in CCL and clutch size between newly recorded turtles and previously recorded turtles. Clutch size increased significantly with larger CCL/CCW and newly recorded turtles (assumed to likely be younger) were significantly smaller and laid fewer eggs than previously recorded turtles. Out of 181 recorded individuals only 5,5% were recorded more than once on Playa Norte in different breeding seasons and the number of newly recorded turtles was relatively high compared to other studies. A more frequent consistency of surveys and an extension of the beach length could contribute to more representative results.

KEY WORDS: Leatherback · Carapace · Clutch size · Remigration · Costa Rica

INTRODUCTION

Leatherback sea turtles *Dermochelys coriacea*, once the most abundant of the world's marine turtles (Pritchard 1982), are now listed as critically endangered (IUCN 2009, Saba et al. 2012, Sarti-Martínez 2000). For conservation the need of biological knowledge of the turtles is highly necessary. To understand the life history aspects of marine turtles the most crucial and important aspects to investigate are probably size growth (Jones et al. 2011, Price et al. 2006), reproductive output (Price et al. 2006), remigration (Shillinger et al. 2008) and age (Broderick et al. 2003), although these aspects are poorly understood (Hirth 1980, Pritchard & Trebbau 1984). On the other hand, fecundity and biometrics, are well studied as females periodically migrate to their nesting beaches for egg deposition which makes it possible to mark, recapture and collect data consistently.

Data of nesting leatherbacks has been collected since 2006 by Caño Palma Biological Station (CPBS) on Playa Norte, but aspects like growth, remigration and relationships between clutch size and carapace length have never been analyzed. The research period spanned from 2006 to 2013 and data was collected from March to June in each year. The main focus of this study was on relationships between carapace size and clutch size of leatherbacks. Based on findings of other studies, clutch size was hypothesized to increase with carapace size. In this study also growth in remigrating leatherbacks was expected to be found and based on this remigration intervals and spatial distribution along the beach were examined. Additionally, new recorded turtles were hypothesized (without tag history) to have a

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smaller Curved Carapace Length (CCL) and to have a smaller clutch size than remigrating turtles.

Remigration and spatial distribution

Leatherbacks are known as the most widely distributed of all marine turtles (Eckert et al. 2006, Reina et al. 2002), as foraging of adult leatherbacks occurs in regions from the tropics to the Arctic Circle (from 71° N to 47° S latitude in all oceans) (Pritchard and Trebbau 1984, Goff & Lien 1988). Nesting however, only occurs on tropical and subtropical beaches (James et al. 2005a). This may be the reason for their long-distance migrations from feeding habitats to tropical nesting beaches, located between 30° N and 20° S (Starbird et al. 1993). As the period between remigrations may have a variable interval of 2 to 7 years (Price et al. 2006, Reina et al. 2002), adult turtles could invest energy in growth instead of reproduction in any given year and delay their migration (Bull & Shine 1979, Price et al. 2006). Since breeding migration can be a costly energetic investment for sea turtles (Eckert & Sarti 1997, Hughes et al. 1998, Morreale et al. 1996), storing of energy resources by remigrating less often, and as a result of that producing more eggs during the reproductive season, might be beneficial (Price et al. 2006). However, the available data that Hirth & Ogren (1987) used indicated that 2- or 3- year nesting cycles are most common. Boulon et al. (1996) showed that Caribbean leatherbacks nesting at St. Croix return every 2 to 5 years. Though, variable migration and remigration intervals may be affected by influences of food abundance (Hays 2000), predation, ambient temperature (Solow et al. 2002) and length of breeding migrations.

Size, growth and clutch size

The size of leatherbacks can run up to 257 cm in Curved Carapace Length (CCL) (Eckert & Luginbuhl 1988), which makes them the largest (Buskirk & Crowder 1994) and, besides, probably the fastest growing (Rhodin 1985, Rhodin et al. 1996) of all marine turtles. However, variation in size occurs between and within the world's nesting populations (Van Buskirk & Crowder 1994, Zug & Parham 1996). Several studies suggest that on average nesting leatherbacks from the Pacific population are smaller and lay fewer eggs than leatherbacks from the Atlantic population (Benabib-Nisenbaum 1983, Brown & Brown 1982, Eckert & Eckert 1983, Hirth 1980, Tucker & Hall 1984). Based on the data used in the study of Hirth & Ogren (1987) even eggs and hatchlings were suggested to be smaller in eastern Pacific leatherbacks. Even though the number of eggs may vary (Hirth 1980, Hirth & Ogren 1987, Price et al. 2004), leatherbacks lay the largest clutches (~5-10 kg), the largest eggs (~80 g each) and lay the highest number of clutches in a breeding season (mean of 7 clutches, with 8-10 days between nesting events) of all sea turtle species (Boulon et al. 1996, Miller 1997, Reina et al. 2002) and moreover, by mass the greatest reproductive output of all reptiles (Price et al. 2006). Besides a larger reproductive output the advantage for large-sized turtles may also be a greater annual survival (Congdon & Gibbons 1990, Congdon et al. 2001). This is not confirmed in leatherbacks, although in many organisms, including several turtle species, a greater body size is positively correlated with characteristics that are presumably related to fitness (Congdon et al. 1999). Due to the capability of carrying more eggs (Price et al. 2006) a larger clutch size is shown to be found in larger individuals of marine turtle species (Broderick et al. 2003, Van Buskirk & Crowder 1994) and several other turtle species (Congdon et al. 2001, Hays & Speakman 1991, Hirth & Ogren 1987, Shine et al. 1980). This is confirmed by the study of Hirth & Ogren (1987) as they showed strong positive relationships between the size of nesting leatherbacks of the Atlantic population and their clutch and egg size. However, this relation has not been confirmed in Pacific Leatherbacks (Reina et al. 2002).

Materials & Methods

Data collection

During the leatherback nesting season (March-June) nightly surveys were conducted on Playa Norte, Limón Province, Costa Rica from 2006 to 2013 following guidelines of IUCN/SSC Marine Turtle Specialist Group. Records in the month June in the 2013 leatherback season were not included in the analysis (n=4).

Depending on available personnel teams patrolled the beach for a minimum of four hours in order to cover the beach for most of the night. Although the beach was patrolled every night in the 2013 season, in other years this was not the case due to lack of personnel or severe weather conditions. Therefore, survey effort was not consistent over the years. Moreover, nights could not always be completely covered as the last teams usually got back before sunrise (around 3:30–4:00 AM). In early mornings a team patrolled the beach to record any activity missed by the previous night's patrols.

Study area

The ca. 5 km long study area Playa Norte is located within the Barra Colorado Wildlife Refuge (BCWR) and extends from the Tortuguero river mouth (10º35'34.4"N - 83º31'28.6"W) to the north end of Laguna Cuatro (10º38'06.9"N - 83º32'31.7"W) (Fig. 1). The area is managed by the Tortuguero Conservation Area (ACTo), under the SINAC (Sistema Nacional de Areas de Conservacion). To help determining spatial distribution of nest activity beach markers have been put up along the study transect at every $^1/_8$ of a mile (ca. 200 meters) from mile 0 to mile 3 $^1/_8$. A path used by pedestrians and drivers runs parallel to the beach and connects two hotels, several houses and at the southern end the village of San Francisco (approximately 300 residents).

Tagging, egg counting, and biometrics

Leatherback individuals can be identified by externally attached metal tags, which is essential in determining growth rates and remigration patterns. The unique numbered tags are placed in the membrane between the rear flippers and the tail using National Band & Tag Co., Newport, USA Monel #49 tags (in each flipper). Tags were applied with appropriate applicators. Evidence from previous tagging was recorded as Old Tag Notches (OTNs) or Old Tag Holes (OTHs). Clutch size was physically determined during oviposition (using a Maria counter) (Miller 1999) and yolkless eggs were counted and reported separately (Miller 1999). CCL and CCW were measured three times, to the nearest millimetre (with a maximum accepted error of 10 mm between measurements) with a flexible measuring tape and means were calculated to use in the analysis. CCL was measured from where the skin meets the carapace behind the head to the end of the caudal projection on the right side of the central ridge (Bolten 1999). CCW was measured from the last ridges on both sides of the carapace's widest points (Bolten 1999). After recording biometrics, an assessment of the turtle's external condition was conducted. This includes classification of the completeness of the caudal projection (as this can affect the measurements), injuries, damaged tissue, tumors or any other abnormalities. Even though Geleán Gordon & Harrison (2011) showed no significant difference in CCL between leatherbacks with complete or incomplete projections, in this study leatherbacks with incomplete caudal projections were excluded from the data analysis (n = 53) as it is a subjective assessment. Remigration refers to previously tagged individuals migrating back to their breeding waters (REM). Turtles without tag history are called newly recorded (REC). The term renesting is used for leatherbacks laying multiple clutches within the same nesting season, and thus, of which individual information has previously been recorded earlier in the season.

Fig. 1. Map of the study area Playa Norte. The most southernly and northernly red dots respectively represent mile markers 0 and 3 1/8, Tortuguero, Costa Rica, Google Earth, 2013.

Data Analysis

Variables used for relationships between clutch size and CCL/CCW were tested for normality with the Shapiro-Wilk test. Three outliers in the number of yolked eggs (3,5, and 7) were excluded from the analysis as well as one female (CCL: 125 cm; clutch size: 23 yolked eggs) as the clutch size deviated over 30% from the average clutch size found. These records affected the normal distribution and are probably unusual for clutches, as Carr and Ogren (1959), Hughes (1974), Price et al. (2004) and Pritchard (1971) found clutch size ranges from respectively (45-121 in Matina, Costa Rica), (65-130 on Trinidad Island), (55-121 in Tongaland, South-Africa) and (30-120 in Las Baulas, Costa Rica). Hirth (1980) stated that leatherbacks lay an average number of fertile eggs varying from 66 to 104. The remaining data for CCL, CCW and their corresponding clutch size were analyzed using one-way ANOVA. Analysis on the difference in CCL between RECs and REMs was performed with the Mann-Whitney U test and differences in clutch sizes

between RECs and REMs with the independent samples t-test. All tests were performed with SPSS statistics 17.0. As clutch size may change when laying several clutches within a season (Broderick et al. 2003, Kaufman 1975), data from renesting turtles was excluded from the analysis. Several studies suggest that leatherbacks eat less during their breeding season and rely on energy stores (Hays et al. 2004, James et al. 2005b, Miller 1979, Reina et al. 2005) and lose weight over the breeding season (Eckert et al. 1989).

RESULTS

Encountered turtles

During nightly surveys 264 times a leatherback female was encountered in the period 2006-2013 on Playa Norte. Some individuals were encountered on the beach more than once as they renested and/or remigrated. A total of 181 different individuals could be identified by tag information (including RECs and REMs). The total number of nests for all years was 474, out of which 226 nests were recorded while the female was present. All leatherbacks were encountered between the 5th of March and the 30th of June (Fig. 2).

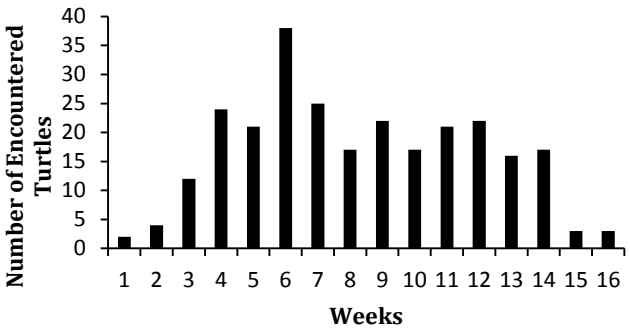

Fig. 2. Leatherback encounters between March and June for the years 2006 and 2013. Each month is represented by four weeks: March (1-4), April (5-8), May (9-12) and June (13-16).

Carapace length/width versus clutch size

During the eight years of data collection the carapace length of 214 leatherback females was measured. After the exclusion of misrepresentative records previously discussed in the methods, 100 data points of average CCL with corresponding clutch sizes remained for the analysis. For CCW, however, 127 data points remained as no correction for incompleteness of caudal projections had to be applied. CCL and CCW respectively ranged from 122,3 to 171,2 cm (mean ± S.D.; 150,6 ± 7,9 cm) and 88,5 to 131,1 cm (mean ± S.D.; 110,1 ± 6,6 cm). The corresponding clutch size (yolked eggs) ranged from 33 to 130 for CCL (mean ± S.D.; 78 ± 17,2, n=100) and for CCW (mean ± S.D.; 78 ± 17,4, n=127). Clutch size increased with increasing CCL (ANOVA: R^2 = 0,102, $F_{1,98}$ = 11,160, P < 0,01) (Fig. 3). Clutch size also increased significantly with larger CCW (ANOVA: R^2 = 0,182, $F_{1,126}$ = 27,949, P < 0,01) (Fig. 4).

CCL and clutch size of RECs and REMs were compared. The length in the RECs and REMs differed significantly (Mann-Whitney, *U*=1140.5, n_{rec} = 57, n_{rem} = 62, P = 0,001 two tailed, $mean_{rec}$ ± S.D.; 148,7 ± 8,3 and $mean_{rem}$ ± S.D.; 152,6 ± 8,6). RECs were found to be smaller than REMs in CCL. A test has also been done for RECs, REMs and their clutch size with the independent samples t-test. RECs were found to lay fewer eggs ($t_{(-2,1)}$ = 38, P < 0,05, $mean_{rec}$ ± S.D.; 68,3 ± 5,7 and $mean_{rem}$ ± S.D.; 81,6 ± 3,2).

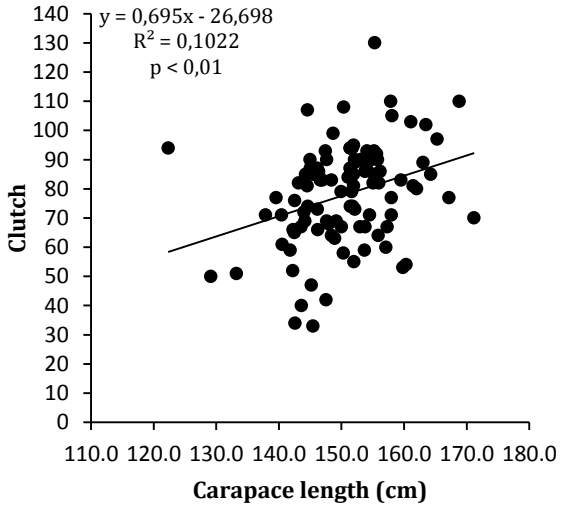

Fig. 3. Relation between Curved Carapace Length (CCL) and reproductive output of adult female leatherback turtles nesting at Playa Norte, Costa Rica.

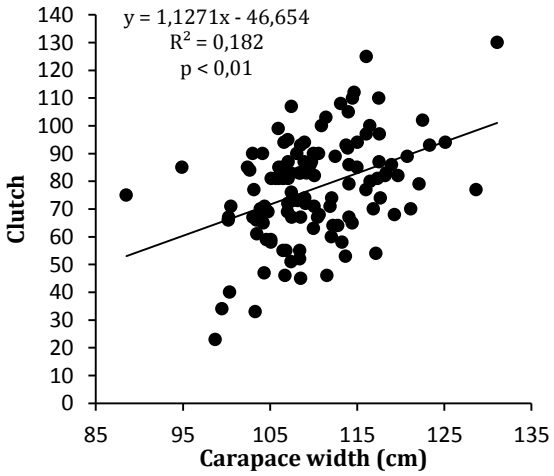

Fig. 4. Relationship between Curved Carapace Width (CCW) and reproductive output of adult female leatherback turtles nesting at Playa Norte, Costa Rica.

Spatial distribution along the beach

For all 264 leatherback encounters on Playa Norte (including turtles encountered without nesting) GPS coordinates and mile markers were recorded. Figure 5 shows the spatial distribution of

leatherback nesting activity between 2006-2013. Most turtles were encountered at mile 1, $1^1/_8$ and $1^2/_8$.

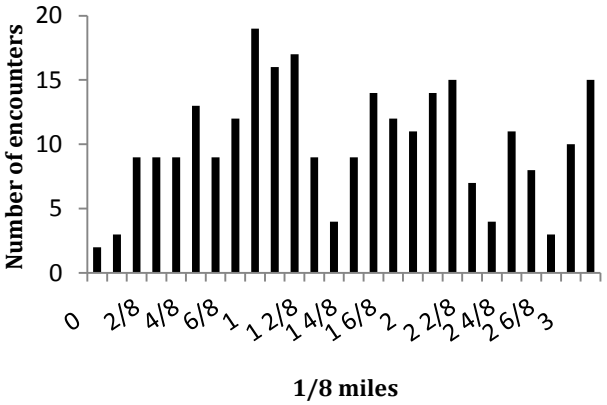

Fig. 5. Leatherback encounters (n = 264) in the period 2006-2013 along the 3,125 mile (5 km) patrolled beach. The study transect is divided into 1/8 of a mile (~200 meter) sections from 0 -3 $^1/_8$.

Remigration of leatherbacks

Out of the total 181 individuals, 87 (48%) individuals were newly recorded and tagged by CPBS, although in 7 of them old tag evidence was found. 96 individuals were tagged either by CPBS, STC (Sea Turtle Conservancy) and organisations ordering the same tag types, which makes the original tagging beach of the individuals uncertain.

Besides this, several other organisations along the Caribbean coast have leatherback tagging programs. For a better understanding of nesting habitat use, the original tagging beaches are shown in table 1. As turtles may have two tags, the tag with the most distant origin from Playa Norte is shown. For the only female tagged with BC tag codes the origin is unknown.

Between 2006-2013 only 10 (5,5%) out of 181 individuals were recorded once or twice before on Playa Norte and seasonal renesting occurred in 42 individuals (23%). For seasonal renesting 64% came back once, 19% twice, 14% three times and 2% four times. On average renesting occurred 1,55 times per season.

Growth in nesting leatherbacks

As previously discussed 10 of the 181 individual leatherback females remigrated to the study area Playa Norte. 4 out of these 10 were recorded three times at Playa Norte and 6 of them twice. There is thus, a lack in successive measurements of their carapaces and a test on growth could not be carried out.

Tab. 1. Table of nesting distribution of original nesting beaches for leatherback turtles recorded on Playa Norte.

Original tag beach	Leatherback individuals	~Distance to Playa Norte (km)
Playa Norte	87	0
Tortuguero Beach/Playa Norte	68	6
Parismina Beach	15	37
Pacuare Beach	9	47
Chiriqui Beach (Panama)	2	280

DISCUSSION

Carapace length/width versus clutch size

The expectation that sea turtles increase their clutch size with body size (Hays & Speakman, 1991) is supported by this research as a strong positive relation was found between both CCL and CCW and clutch size. Although, the range especially in CCL was found to be wide as this ranged from 122,3 to 171,2 cm. Hirth & Ogren (1987) also found a larger variation in CCL compared to CCW. As a comparison, studies in Trinidad Island, Sri Lanka, Playa Naranjo, Costa Rica and Tortuguero, Costa Rica show a range in CCL of 125-185 (Pritchard, 1971), 125-165 (Deraniyagala, 1939), 133-155 (Cornelius, 1976) and 133,2-166,7 cm (Galeán Gordon & Harrison, 2011). The measurements used in this study almost completely overlap with the ranges found in other studies, although, the female with a CCL of 122,3 cm was exceptionally small compared to the other individuals found.

In the study of Reina et al. (2002), however, no positive relation was found between clutch size and CCL. A reason for this could be the high variation in the data (Price et al., 2006) and maybe differences among populations. In this study, CCL and CCW were measured in threefold in all years, which makes the measurements more valid in their quality. However, measurement errors occur because of the difficulty of measuring marine turtles in general and the subjectivity in measuring.

As earlier discussed in the results high variation in clutch size was found among females nesting at Playa Norte. However the range in clutch size would probably vary less if clutches were counted multiple times for individual renesting females (Price et al. 2006), such counts could not be performed in this study as the number of renesting individuals was too low. Comparing the average clutch size of this study (78 ± 17,2) to the study of Reina et al. (2000) finding an average clutch size in Pacific leatherbacks of 64,7 ± 1,4, this study supports the finding that Pacific leatherbacks have a smaller clutch size than Atlantic leatherbacks. Besides that, the CCL range of 122,3–171,2 cm found in this study compared with 144,4–147,6

found by Reina et al. (2000) also supports that Pacific leatherbacks tend to be smaller.

The significant increase of CCL and clutch size in previously tagged turtles (REMs) is very interesting. As the newly recorded turtles (RECs) are found to be smaller and lay fewer eggs, they may be younger too. As earlier discussed clutch size increases with larger CCL. However, it is uncertain if clutch size or CCL is also positively correlated with age of adult leatherback females. In green sea turtles *Chelonia mydas*, however, a positive relation was found between age and clutch size, although this was not the case for body size in relation with age (Bjorndal & Carr 1989).

Remigration of leatherbacks

Individual leatherback females of the Atlantic population having a potential nesting range of the entire Caribbean beach is widely accepted and thus, multiple encounters in the same nesting area over years could not be guaranteed. Though, in several studies analyses of several aspects such as growth and remigration intervals in leatherbacks was realized (Price et al. 2006, Wallace et al. 2007, Reina et al. 2000). On Playa Norte, however, only a small percentage (5,5%) of the individuals re-visited Playa Norte over the period 2006-2013. More consistency is shown to be found in leatherbacks emerging on Tortuguero beach. In years 2006-2011 respectively 22,5%, 37,5%, 42,1%, 35,5, 28,8% and 50% of the leatherbacks tagged by the STC (Sea Turtle Conservancy) revisited the beach (De Haro & Harrison 2006, Del Aguila et al. 2007, Debade et al. 2008, Sarmiento Devia & Harrison 2009, Atkinson et al. 2010, Galéan Gordon & Harrison 2011). The longer study transect of the STC (29 km) probably results in encountering more turtles, among which more re-visitors could be present. Moreover, the project is running since 1997, hence a larger database is available. Another factor could be inconsistently conducted night surveys on Playa Norte in some years, of which the exact amount of covered nights is unclear. Another cause, however, could be the relatively large share of new records (48%) in the study area Playa Norte. In comparison STC recorded respectively 11,3%, 24,8%, 22,8%, 22,3%, 16,3% and 8,8% new turtles in the years 2006-2011 on Tortuguero Beach (for both CPBS and STC turtles with old tag evidence were excluded) (De Haro & Harrison, 2006, Del Aguila et al. 2007, Debade et al. 2008, Sarmenta Devia & Harrison 2009, Atkinson et al. 2010, Galéan Gordon & Harrison 2011). The large percentage of new records on Playa Norte could explain the relatively small share of revisiting individuals. Another reason for finding small amounts of turtles revisiting Playa Norte could be tag loss. As nesting in leatherbacks varies between two to seven years, tag loss might occur. A long-term double-tagging experiment, focused on leatherbacks in French Guiana, showed that 30% of the leatherbacks lost at least one tag within the first year after tagging. After the first year they seem to retain tags better (Rivalal et al. 2010).

Growth in nesting leatherbacks

Growth rates in leatherbacks nesting on Playa Norte were not found as only 5,5% of the 181 individual leatherback females remigrated to the study area Playa Norte. Even though, growth rates remain to be studied for Playa Norte's leatherbacks. Recommendations, referring to recording more individuals, would be to extend the surveyed length of the beach and in addition a more consistent conduction of the nightly surveys. As measurement errors were found in the data, carapace measurements should be taken with more precision in the future. A recommendation for this could be that the precision of team members could be compared over time (Shoop & Ruckdeschel 1986).

Acknowledgements

My gratitude goes to the numerous volunteers from CPBS who collected data between 2006 and 2013 on Playa Norte, although we could never collect this data without the permits of MINAE (Ministerio de Ambiente y Energía). I would also like to thank J. Kunz, who adjusted the database, M. Band and J. Robaud who mapped the study transect, Dr E. Harrison, who provided me with tag information and S. van Huijzen who supported me with his great knowledge of statistics. I want to thank my supervisors A. Hullat, and T. Lohman and in particular Nadja Christen who gave me advise and feedback on the writing

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