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The Sea Turtles of Suriname 2001 Project:

Aspects of Nesting and Nest Success of the Leatherback Turtle (*Dermochelys coriacea*) in Suriname, 2001

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herein are those of the author(s) and do not necessarily reflect the views of the WWF (World Wildlife Fund).

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ABSTRACT

Suriname supports one of the largest leatherback *(Dermochelys coriacea)* nesting colonies word-wide. We studied aspects of population demography and nest ecology of this nesting population on three important nesting beaches during the 2001 nesting season. We PIT tagged 2460 leatherback females and identified a total of 2926 leatherback individuals. Of these, 442 turtles did not originate from Suriname. The total number of tag records, including recaptures, was 4536. Based on beach coverage and data on encounter frequency, we estimated that the total number of leatherback individuals that visited the Surinam beaches in 2001 has been at least 5500, and that at least 30.450 nests have been laid. Average estimated nest density was 910 nests per km, with a peak of 8333 nests per km on Kolukumbo beach. This is the amongst the highest nest densities for leatherbacks known world-wide. From the 62 leatherback females tagged in 1999, 25 were observed again in 2001. Remigration may in fact be substantially higher given the high fraction of missed turtles. It is too early to draw conclusions about mortality- and remigration rates based on present data. More information is needed specifically about the rates of shifting of nesting females between beaches in Suriname and shifting between Suriname and French Guiana. Mean curved carapace length was 154.2 cm and mean curved carapace width 113.1 cm.

Clutch size averaged 87 yolked eggs and 28 yolkless eggs. Incubation takes longer on Matapica (62.7 days) than on Babunsanti (60.9 days) and Samsambo (60.7). Hatch success of leatherback nests differed significantly between the beaches. From 149 analysed *marked* nests on Babunsanti, 49.7% failed to hatch and from the successful nests, average hatch success was as low as 21.6%. On Matapica, from 62 analysed *marked* nests, 9.7% failed to hatch and of the successful nests, hatch success was 58.3%. On Samsambo failure was 28.6% and hatch success of the successful nests was 30.2%. Although on Babunsanti at least 4 times more leatherback nests were laid than on Matapica, we calculated that only 1.3 times more hatchlings were produced. Because of the high hatch success on Matapica (due to good environmental quality of the beach), this beach is considered to be of essential importance for net hatchling production in Suriname. Soil temperature measurements predicted that dominating hatchling sex differed between the beaches and beach zones (high and low).

1. INTRODUCTION

1.1 Nesting of *Dermochelys coriacea* in the Guianas

The Suriname and French Guiana rookeries support one of the largest leatherback turtle *(Dermochelys coriacea*) nesting populations world-wide (Girondot and Fretey 1996, Chevalier and Girondot 1999, Spotila 1996). The leatherback, like all other species of sea turtles, is on the IUCN Red List of Endangered Animals (Groombridge 1982). The Surinam beaches are also important nesting areas for the green turtle (*Chelonia mydas*) and olive ridley (*Lepidochelys olivacea*), although due to egg poaching and shrimp fisheries, the population of the latter has collapsed (Schulz 1968, 1975, Reichart and Fretey 1993). Occasionally, hawksbill turtles (*Eretmochelys imbricata*) nest on the Surinam beaches and exceptionally, also loggerhead turtles (*Caretta caretta*) are observed.
More than half of the present world leatherback population is estimated to be nesting on the beaches of the Marowijne river estuary in Suriname and French Guiana. World-wide this species is severely threatened with extinction (Spotila *et al*. 1996, 2000). Mass leatherback nesting colonies have dramatically collapsed in many areas. The once major nesting populations on the Pacific coast of Costa Rica and Mexico, and the large rookery in Terrenganu, Malaysia, have drastically declined as a result of high rates of egg poaching and incidental captures in high seas drift net and long line fisheries (Sarti *et al*. 1996, Sarti *et al*. 2000, Eckert 1997, Spotila 1996 and 2000, Chan and Liew 1996). Although since 1999, the leatherback nesting colonies in West Africa (Gabon, Congo) have been reported to be strongly increasing (Fretey 2000), protection of the nesting populations in the Guianas is essential for survival of the species.

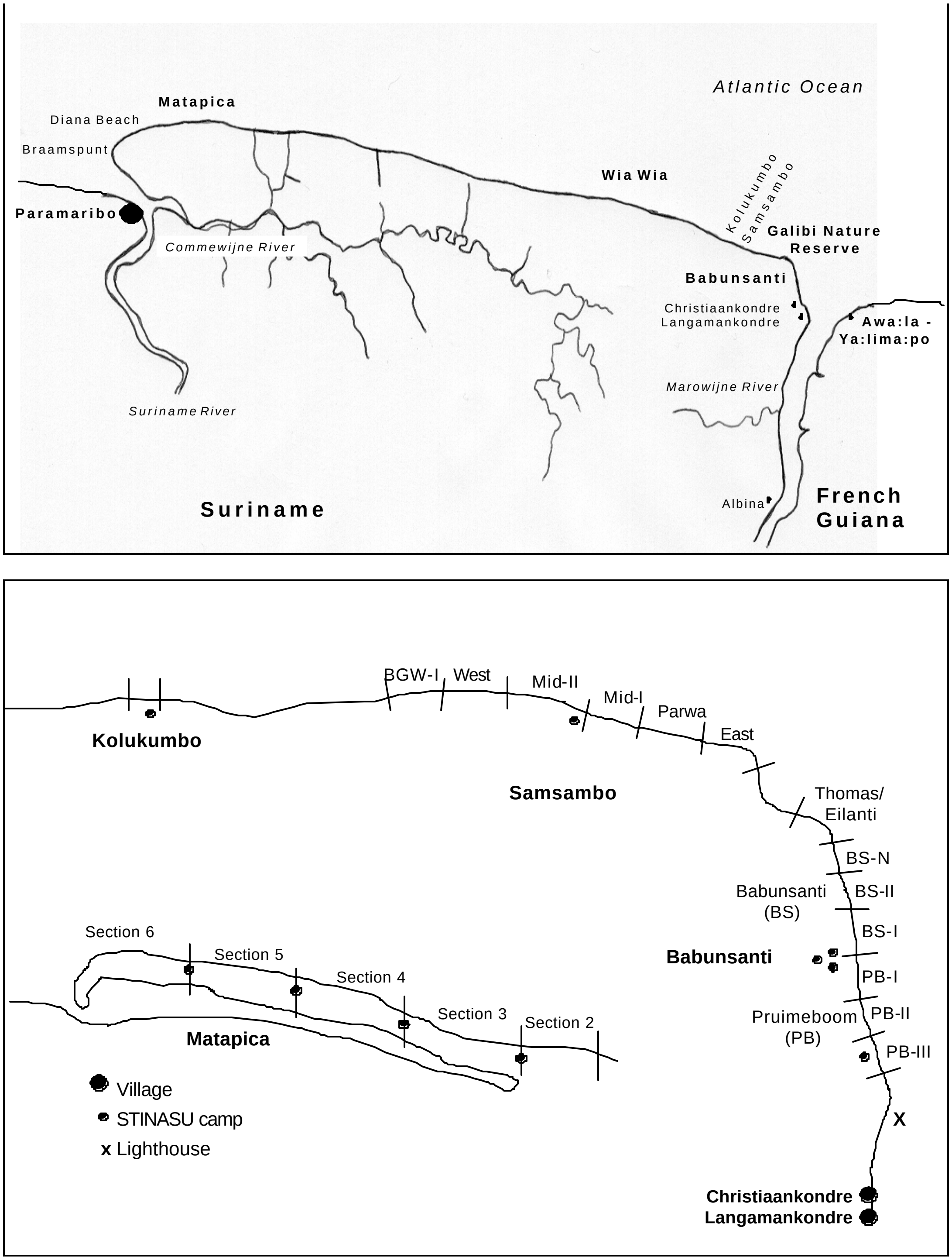
1.2 Objectives of the study

Research on the major leatherback rookery of Suriname is necessary in order to assess population size and trends and determine reproductive output on the different nesting beaches. This will enable a better protection of the population (Meylan 1982). An understanding of basic population parameters (population demography and nest ecology), threats to eggs, hatchlings and adult turtles and sources of mortality is essential for effective management and recovery of sea turtle populations (Eckert 1999).
The objectives of the present study are 1) to determine the number of leatherbacks nesting in Suriname and the number of nests they produced, and factors such as internesting intervals, remigration rates and beach fidelity of this population, by tagging nesting females, 2) to determine hatch success for *in situ* leatherback nests on three major nesting beaches, 3) to examine the effects of biotic and abiotic factors on hatch success and determine the sex ratio of hatchlings, 4) to obtain biometric data on nesting leatherbacks and 5) to investigate nesting habitat quality and the threats facing adults turtles, hatchlings and eggs. The study focused on the leatherback turtle, but baseline data were also gathered for nesting green and olive ridley turtles.
Since 1995, Biotopic has carried out sea turtle research and conservation projects in Suriname in close collaboration with STINASU (Foundation for Nature Conservation in Suriname) and STIDUNAL (Foundation for Sustainable Nature Conservation Alusakia) on a yearly basis (except for 1996). From 1995 to 1998 the project was focused on nest relocation, monitoring of nesting activities, and nest ecological research. Present activities are tagging and monitoring of nesting leatherbacks, nesting beach surveys, nest ecological research and capacity building. Collaboration with sea turtle research- and conservation groups in the neighbouring countries has a high priority. The project is part of the WWF-Guianas Forests and Environmental Conservation Project (WWF-GFECP). The aim of the project is to contribute to the protection of sea turtle populations and their nesting habitat in Suriname and the surrounding countries.

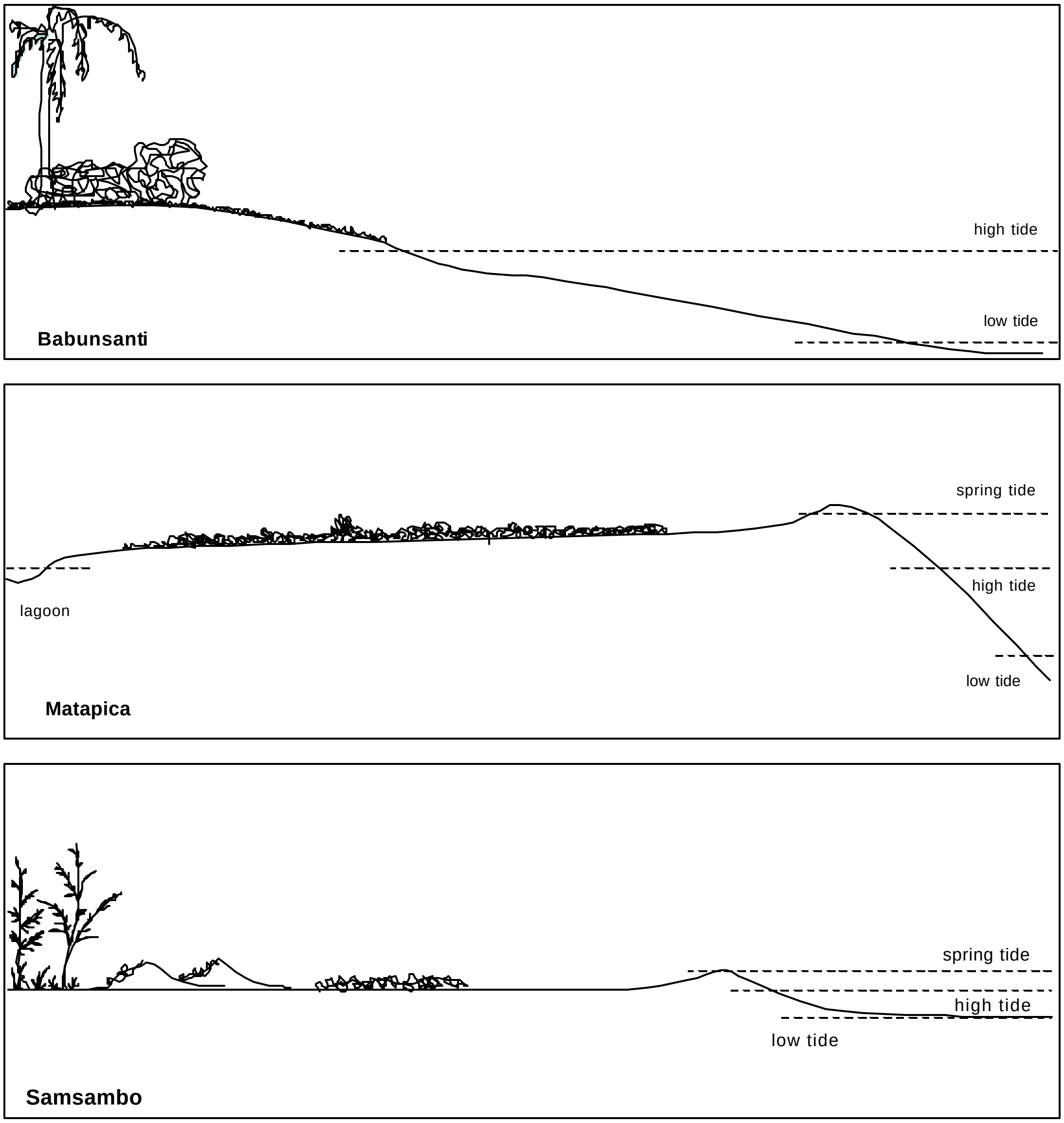
1.3 Study area

Sea turtle nesting beaches are found in the eastern part of Suriname (picture 1.1). The main nesting beaches for leatherbacks in 2001 were Babunsanti (Marowijne river estuary), Samsambo (just west of the Marowijne river estuary), Kolukumbo (approximately 15 km west of the Marowijne river estuary on the Atlantic coast) and Matapica and Diana Beach. The latter two are situated on the Atlantic coast in the vicinity of the Suriname river estuary. Matapica is a highly dynamic beach, which moves to the west with a speed of approximately 1.5 km per year due to beach erosion on the east side and accretion on the west side. Samsambo was considered an important nesting beach in 1998 and

1999, but has lost much of its importance for leatherback nesting due to the formation of extensive mudflats in front of it. During the 2001 nesting season, tagging and nest ecological work was executed with a varying degree of intensity on Babunsanti, Samsambo, Kolukumbo and Matapica. Beach topography differs between the beaches (picture 1.2).



Picture 1.1 The nesting beaches of Suriname and an overview of beach sections in the Galibi Nature Reserve and on Matapica.



Picture 1.2 Beach profiles of Babunsanti, Matapica and Samsambo (not on scale).

1.4 Project activities

1.4.1 Population identification by PIT tagging

Tag return data are essential to understand the demography and reproductive ecology of leatherbacks. PIT (Passive Integrated Transponder) tagging is essential to any leatherback tagging program in order to allow accurate population size assessments, because of the extremely high loss rates of conventional flipper tags occurring with leatherbacks (McDonald and Dutton 1994 and 1996, Paladino 1999). It is believed that, in contrast to the use of flipper tags with leatherbacks, PIT tags are a more permanent way of marking. Data from Spotila (1998) indicated a tag loss of less than 5% for AVID tags. This may, however, be due to inexperience by users or use of cheaper pocket readers that are less reliable for deeper placed tags in leatherbacks (McDonald and Dutton 1996, Paladino 1999). PIT tagging is a very suitable tool to perform much needed studies such as the delimitation of the leatherback population in the Guianas and to estimate of population size and trends. If carried out long enough, it will yield information on (changes in) population size, the fraction of first time nesters (recruitment), remigration rates and intervals, mortality at sea, and internesting frequency and intervals (McDonald and Dutton 1996, Spotila 1998, Steyermark *et al*. 1996). PIT tagging with TROVAN tags in the Guianas started on a large scale in 1998 in Awa:la-Ya:lima:po, French Guiana (Chevalier and Girondot 1999), but some leatherbacks had already been PIT tagged in French Guiana in 1995/96 (Girondot and Fretey 1996). Some PIT tagging is done on other French Guianese beaches (Kourou, Cayenne). The PIT tagging program in Suriname started on a small scale in 1999, and in 2000 PIT tagging also started on Shell Beach in Guyana. A complete overview of all PIT tag codes is presented in a separate appendix-report “PIT tag Code Overview 2001, 2000 and 1999”.

1.4.2 Biometric measurements

Sea turtles on nesting beaches are measured to 1) be able to relate body size to reproductive output, 2) determine minimum size at sexual maturity and 3) to monitor nesting female size for a particular rookery. The size-frequency distribution of a population is an important parameter of that population's demographic structure (Bolten 1999, Zug and Parham 1996). We measured curved carapace length (CCL) and width (CCW) for nesting leatherbacks on three beaches.

1.4.3 Reproductive success and nest ecology

A study on reproductive output of leatherbacks was carried out on three important nesting beaches in an effort to determine some of the basic parameters of the leatherback population, such as clutch size, hatch success, fate of eggs and survival and failure of nests. With this knowledge, net output of hatchlings on each of the important nesting beaches can be assessed (Eckert 1999). The production of hatchlings per beach is as important as nest numbers. Fluctuations and structural changes in yearly nest numbers may be explained by nest survival and hatch rates, and sex ratio production (*e.g*., predominantly males for a couple of years) in the past (Eckert 1999, Chevalier *et al*. 1999).

Leatherbacks often nest in the open sand area below the spring tide line (STL), as part of a "bet hedging" or "scatter nesting" strategy. Nest scattering or dispersal on the beach as leatherbacks do, spreads possible risks (Mrosovsky 1983, Eckert 1987, Tucker 1990). In contrast to green turtle eggs and hatchlings, leatherback eggs and hatchlings are easily damaged or killed by roots of beach vegetation (eggs are ruptured and dehydrated, hatchlings get entangled) (pers. obs., Whitmore and Dutton 1985). This may be another reason why leatherbacks generally nest in the open sand area. This is also the case on the Surinam beaches. Nests laid more than two metres below the STL are by some defined as doomed (Schulz 1975, Whitmore and Dutton 1985, Reichart 1993, Hoekert *et al*. 2000). Studies in the 2000 nesting season showed however that the effect of tidal inundation differs per beach (Hilterman 2001) and that leatherback eggs can tolerate a relatively high wash-over frequency and moisture content in the surrounding sand. Leatherback nests are thus not per definition doomed after regular inundation. McGehee (1990) found an optimum of 25% moisture for the beach sand surrounding loggerhead *(Caretta caretta)* nests. To determine more precisely how many and which nests are doomed, another study on hatch success as a function of the distance of the nest to the spring tide line was carried out.

1.4.4 Measurements of sand temperature profiles

Sexual differentiation of sea turtle hatchlings is influenced by the temperature in which the eggs are incubated (Rimbot-Baly *et al*. 1987, Mrosovsky *et al*. 1984, Mrosovsky 1994). Sex of the hatchlings is determined between day 20 and 40 of the incubation period. At the pivotal temperature for leatherbacks, 29.5ºC, the sex ratio for leatherback hatchlings is fifty-fifty. Above that temperature more females are produced, and below, more males (Yntema and Mrosovsky 1982, Desvages *et al.* 1993, Godfrey *et al.* 1996). Sand temperature profiles, and thus sex ratios of hatchlings, differ between beaches in Suriname and the region (Godfrey *et al.* 2001). By combining these data with nest numbers and hatch rates per beach, an estimate can be made of sex ratio production for Suriname and the region. For the first time in Suriname, sand temperatures were measured concurrently on three important nesting beaches.

1.4.5 Nesting beach surveys, assessment of critical habitat

The Surinam coast is part of the extensive tropical mud coast between the Amazon river (Brazil) and the Orinoco river (Venezuela). Due to the westward-oriented Guyana current and north easterly trade winds, the Surinamese coastline is highly dynamic and subject to successive phases of beach erosion and accretion. The coastline is dominated by extensive mudflats, which are overgrown with black mangrove *(parwa)* forest at the higher levels. Sandy beaches can be found at only a few places. Both the sandy beaches and the mudflats move in a westward direction, as a result of erosion on the east side and accretion on the west side (Augustinus 1978, Schulz 1980). The only relatively stable nesting beach in Suriname, Babunsanti, is situated at the estuary of the Marowijne river. The other important beaches, Samsambo, Kolukumbo and Matapica are highly dynamic (see section 1.3) and subject to rapid changes. Therefore it is important to determine the status of the existing nesting beaches, formation of new nesting beaches and to assess the importance of each of the beaches for sea turtle nesting on a yearly basis. An aerial survey is an excellent tool for this. In addition, ground surveys are done using GPS. Results of the aerial survey of 2001 are presented in a separate report (Goverse and Hilterman 2002).

1.4.6 Miscellaneous

We have recorded the number of strandings and have examined the state of carcasses and possible (fisheries related) injuries of the stranded turtles on three beaches. In addition, the number and fate of leatherback females that got stuck on the mud flats on Samsambo were recorded.

2. MATERIALS AND METHODS

2.1 PIT tagging and monitoring nesting activities

For PIT tagging of leatherback females in the Guianas TROVAN ID100 tags and TROVAN LID500 scanners are used. PIT tags are injected in the muscle of the right shoulder. In 1999 PIT tagging of nesting leatherbacks started on Babunsanti. That year, a small number of leatherbacks were tagged. In 2000, a significant increase was established, and tagging took place at Babunsanti but also some tagging was done at Samsambo and Matapica. In 2001, for the first time a large scale tagging effort was done on Babunsanti and less intensive tagging was realised at Kolukumbo, Matapica and Samsambo. Table 2.1 shows the PIT tagging efforts done in 2001.
PIT tagging took place during nightly beach patrols from at least two hours before high tide to at least two hours after high tide (patrolling went on until the last turtle had gone). In case of two high tides (early evening and early morning), two shifts were made. Scanning and tagging were done at all stages of the nesting process. For each scanned or tagged leatherback female, the activity, location on transect line to the nearest 10 m, distance to spring tide line to the nearest half meter, distance travelled from current high water line, and curved size of carapace were recorded in addition to the tag code. A distinction was made between a new tag (just applied) and old tag (recapture) (appendix 1.1).

Beach	Sections	Distance	Duration of coverage	Teams[1] tagging per night
Babunsanti	BS-I/II/N & PB-I/II	5.0 km	May 1st - August 10th	two
Kolukumbo	Whole beach	1.5 km	5 nights (June/July)	one
Matapica	S6, half S5	2.5 km	May 15th - June 15th	one
Samsambo	Mid-II, West	2.0 km	May 2nd - May 21st	one

Table 2 PIT tagging efforts during the 2001 nesting season. 1) Teams consist of one or two persons.

STINASU employees, who were sometimes assisted by Biotopic field workers, executed early morning nest counts. On relatively moderate density nesting beaches such as Samsambo and Matapica, nest counts are a good indicator of actual nesting activity. However, on high or very high density nesting beaches such as Babunsanti and Kolukumbo, nest counts are not a very reliable way of determining nesting activity because crawls and nests are covered up and obscured by subsequent nesters and often by the last high tide. As a result, in such situations the number of counted nests is likely to be a significant under-estimate (Girondot and Fretey 1996). By combining nest counts with PIT tag data we attempted to make a better estimate of leatherback nest numbers.

2.2 Biometric measurements

Curved carapace length and width (CCL and CCW) were measured for tagged nesting leatherback females. Measurements were done with a flexible aluminium tape measure. CCL was measured alongside the vertebral ridge. CCW was measured at the widest point, spanning from ridge crest to ridge crest. This is the most common practice on leatherback nesting beaches (Pritchard 1971, Bolton 1999). Depending on the activity of the turtle in the nesting process, CCW could not always be measured.

2.3 Nest ecology (reproductive output)

A total of 190 leatherback nests were randomly marked *in situ* from May 1st to June 8th on Babunsanti along a 3000 m transect line (TL) stretching out over the sections PB-I, BS-I and BS-II. Numbered stakes were placed as a marker on 20 m intervals along the transect line. Exact location of each nest was triangulated from the nearest two stakes, this provided precision to within 10 cm. During the nightly beach patrols, a stick was placed 30 cm behind the egg chamber of leatherbacks in a far stage of digging their nest, depositing the egg clutch or closing the nest. PIT tag code, direction of the head of the turtle and location along and across the beach were recorded. The next morning, a probe stick was used to locate the egg clutch. The nest was carefully opened. Broken eggs and eggs contaminated with the contents of broken eggs were removed from the clutch. Before closing the nest, a plastic tag with the nest number and date of egg deposition written on it was placed on top of the clutch.

A total of 88 nests were marked from May 17th to June12th on Matapica along a 1.5 km transect line at the westernmost section (S6). Nests were not triangulated - only distance on and perpendicular to the TL were recorded. On Samsambo, 80 nests were marked from May 2nd to May 20th along the 1.5 km transect line at the section Mid-II. Nests were not triangulated and some of them not properly marked, therefore the number of 80 nests is not representative.

The following two months the destiny of the marked nests was followed. Triangulation records were used to relocate the nest and determine its fate after two months of incubation. Three days after first hatchling emergence at the surface, or 70 days in case of non-emergence or unnoticed emergence, the nests were excavated and nest contents analysed. For each of the three beaches also a selection of non-marked *in situ* leatherback nests was excavated three days after observed emergence.
For each analysed nest, distance of nest to current spring tide line, nest bottom depth, incubation time, number of yolkless eggs, hatched eggs (empty shells), number of undeveloped eggs, number of ruptured (predated) eggs and type of predation, number of eggs with embryonic mortality and stage of embryo, pipped hatchlings, live hatchlings (stragglers), dead hatchlings, and deformed hatchlings were recorded (appendix 1.2). In Suriname, main predators of eggs are mole crickets (*Gryllotalpa sp., Scapteriscus sp*.) and the ghost crab (*Ocypode quadrata)* . Table 1.2 shows the categories into which non-hatched eggs were divided. Hatch success (%) = empty shells / total number of eggs (empty shells + pipped eggs + all non hatched eggs); yolkless eggs not included.

Category	Description
undeveloped	no embryo or blood spot visible; clear distinction between egg white and yolk
early embryo	blood spot to early embryo of about 8 mm with eyes, no body pigmentation
mid embryo	embryos with body pigmentation with the size of approx. 8 mm to full term
late embryo	full term embryo, ready to hatch
unidentified rotten	the egg content consists of completely rotten embryo and could not be identified to one of the 'embryonic mortality' categories
empty egg	no egg contents at all
ruptured by mole cricket *(for all above categories)*	presence of one or more small holes of diameter approximately 1-5 mm with notched edges
ruptured by ghost crab *(for all above categories)*	presence of sharp, scissors-like cuts
pipped	partially hatched full term embryo

Table 2.2 Categories used for non-hatched eggs.

The spring tide line (STL) was determined by the highest deposition of driftwood. Nests located landward of the STL are referred to as '+ STL', nests located seaward of the STL are referred to as '-STL'. Thus, '-3 STL' means that the nest is located 3 meters below the STL, which is seaward perpendicular to the STL.

2.4 Sand temperature and sex determination

Hobo temperature dataloggers were deployed at 75 cm depth (average estimated clutch centre depth) at two different heights perpendicular to the spring tide line at the beginning of the field work period and recovered at the end of the leatherback nesting season in order to determine sand temperature profiles on Babunsanti, Matapica and Samsambo. Data were recorded every two hours for the whole period. Data were grouped by 10 day intervals for which the average temperature was calculated.

2.5 Statistical analyses

SPSS was used for statistical analyses of data. Data were tested for normality and homogeneity of variance and subsequently ANOVA followed by a post-hoc Tukey test, a T-test, Kruskal-Wallis or a Mann-Whitney U test was used. For non-parametric correlations Spearman's correlation coefficient 'rho' was determined, for parametric correlations Pearsons correlation coefficient 'r' (Sokal and Rohlf 1987).

3. RESULTS AND DISCUSSION

3.1 PIT tagging

Figure 3.1 shows the number of PIT tag records in Suriname from 1999 to 2001. Both the numbers of newly applied tags and recaptures are shown. The strong increase of total tag records from 74 in 1999 to 4536 in 2001 is caused by a much increased and improved tag effort (more field personnel, more equipment, a very strict every-night PIT tag protocol, improved methodology) and a strongly increased leatherback nesting population and presence of a new high density nesting beach.
In 2001, we tagged 2460 leatherback females and recorded 2076 recaptures on four beaches (figure 3.2). The actual tagging-time spent on each of the beaches is shown in table 2.1. We identified 2926 individual leatherbacks nesting on the Surinam beaches during the 2001 nesting season. Of these, 2460 were turtles tagged by us and 466 were turtles that did already have a PIT tag. Out of these 466 turtles, 442 turtles carried tags not originating from Suriname. Presumably, most of these turtles had been tagged in French Guiana during either the 2001 nesting season or before. Some of the turtles may have been tagged in Guyana. We further identified 22 turtles that had been tagged on Babunsanti in 1999, and 2 leatherback females from 2000.We know that at least another three turtles tagged on Babunsanti in 1999 were recaptured in 2001 in French Guiana, making the total number observed remigrants from the 62 turtles tagged in 1999 at least 25 individuals. We encountered one turtle with two Monel tags from Trinidad.

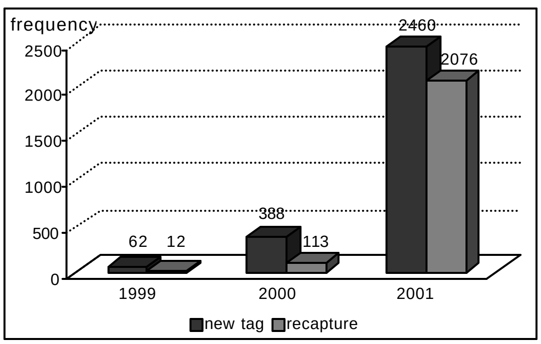


Figure 3.1 Number of PIT tag records (new tags and recaptures) in Suriname 1999-2001.

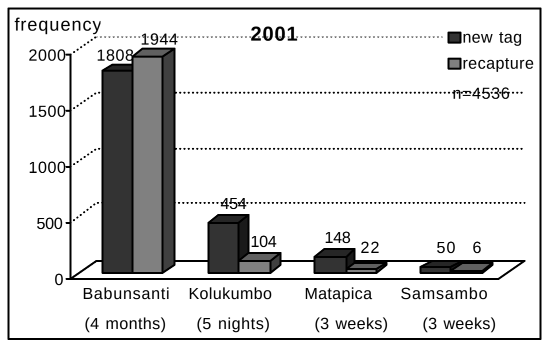


Figure 3.2 Number of PIT tag records (new tags and recaptures) on the study beaches in 2001.

The observed nesting frequency of leatherback individuals during the 2001 nesting season is shown in figure 3.3 for Babunsanti, which is the only beach that was covered the whole season. On Babunsanti, 59.3% of the observed turtles were seen once and 40.7% twice or more. If all beaches are grouped (figure 3.3), 66.6% of all individuals were seen nesting once and 33.4% were seen twice or more (see section 3.3).

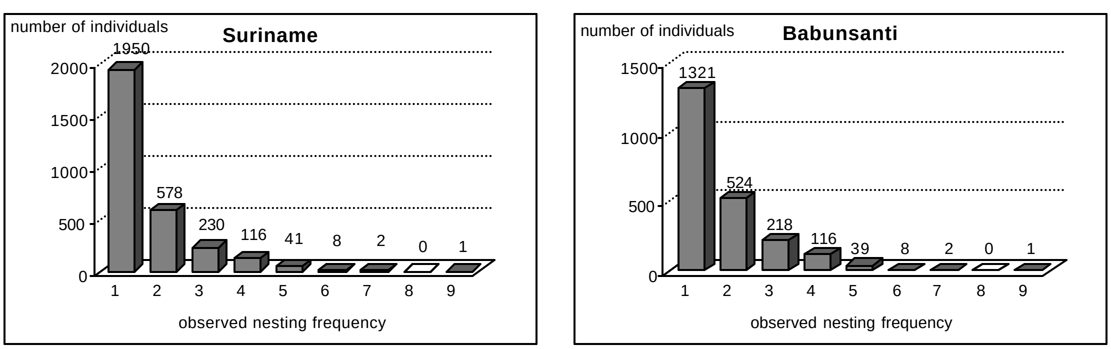


Figure 3.3 Observation frequency of tagged leatherback individuals for all beaches grouped together (Suriname) and for Babunsanti alone in 2001.

Internesting intervals are shown in figure 3.4. Mean internesting period is around 9-10 days. Peaks are subsequently seen around 20 days and 30 days. These longer internesting periods are presumably the result of turtles that we had missed on their previous return(s) or which had nested outside the study area (Steyermark *et al.* 1996). Internesting periods of 1-4 days are interpreted as false crawls.

Observed shifting of individuals between Surinam beaches within the nesting season was low. Out of 2926 individuals, 47 turtles (1.6%) were observed nesting on two or more beaches through the season (table 3.1 for some examples). This is, however, not a representative number, as only Babunsanti beach was covered intensively during the peak season and other beaches were covered only shortly. The number of 47 turtles is thus likely to be a vast under-estimate. Shifting occurred between all combinations of beaches, several turtles even nested on three different beaches. However, the fact that in the 2001 nesting season we observed 442 individual leatherbacks that had been tagged elsewhere, presumably in French Guiana, shows that shifting between the countries, and over nesting seasons occurs on a regular basis. Likewise, of the 25 recaptures from 1999, 3 were found in French Guiana. This confirms assumptions made by Schulz (1975), Fretey and Girondot (1990), and Hilterman (2001) that season to season returns from the Surinam rookery to French Guiana and *vice versa* take place frequently. Nesting beach fidelity for leatherbacks may not be very high. This, and the observation that leatherbacks are the first turtles to exploit newly created beaches, led Pritchard (1982) to believe that leatherbacks may select a beach type, rather than a particular beach, for nesting. However, Eckert (1989) reported that once a switch of beach was made by a leatherback, she did not subsequently return to the beach of initial choice. This is contradictory to our findings.

turtle ID code	date	beach	date	beach	date	beach
ID 000611C76F	23 May	Samsambo	5 June	Babunsanti	19 June	Kolukumbo
ID 0001DF8083	9 June	Matapica	18 June	Babunsanti		
ID 00061785D4	6 July	Kolukumbo	17 July	Babunsanti	29 July	Babunsanti

Table 3.1 Examples of within-season shifting of leatherback females between nesting beaches.

Figure 3.5 shows the percentage recaptures on Babunsanti from the beginning of the tag season in May until the beginning of August, when numbers of turtles were very low already. The ratio new tag/recapture (within-season recapture) strongly dropped in the course of the season. After seven weeks of tagging, 50% of all turtles encountered were recaptures, this number increased to 75% after nine weeks of tagging.

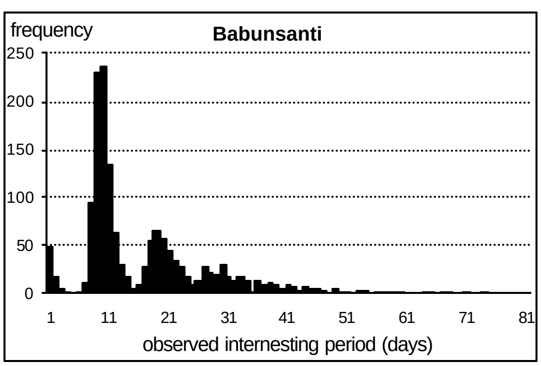


Figure 3.4 Observed internesting periods for tagged leatherbacks on Babunsanti in 2001.

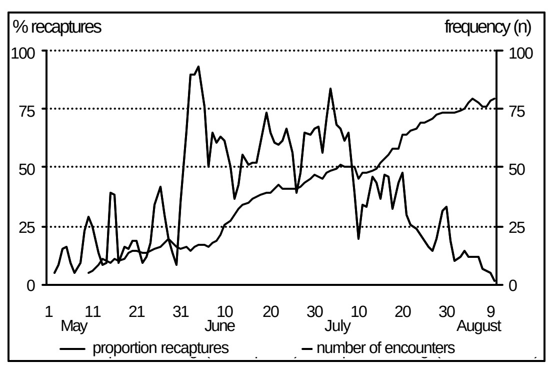


Figure 3.5 Proportion recaptures of total number of tag records on Babunsanti. The number of leatherback observations per night is also shown.

Tagging also revealed some information about false crawl behaviour. A total of 7% false crawls or unsuccessful nesting attempts was found by grouping all turtles that were observed between 0 (same night) to 4 days later again, with observed false crawls on the spot. In 1.9% of all tag records, we observed that a turtle false crawled and returned the same night at another location on the same beach. In some cases these turtles had been disturbed by people (researchers, tourists, poachers).

Other turtles returned between one and four days later. This indicates that leatherbacks, unlike for example green turtles, may be rather resilient and also that tagging, if it disturbs the turtle at all, does not disturb the turtle in such a way that it abandons nesting on the particular beach.

Mean distance travelled from the actual high water line was 7.1 ± 4.8 m at Babunsanti (n=1398) and 23.0 ± 17.1 m at Matapica (n=99). This difference is highly significant (T-test, $p<0.001$). Mean distance of the nesting position of the turtle to the spring tide line (highest deposition of drift wood) was -1.2 ± 3.0 (n=417) m on Babunsanti and -2.9 ± 5.8 (n=53) metres at Matapica. Eckert (1987) found that longer crawls are associated with steeper beach profiles. This may explain why leatherbacks crawl on average a three times longer distance on Matapica than on Babunsanti before starting the actual nesting process.

Mean curved carapace length (CCL) of the nesting leatherback females was 154.2 cm and mean curved carapace width (CCW) was 113.1 cm (table 3.2). Figure 3.6 shows the size frequency distribution of leatherbacks on Babunsanti and Matapica (sample size on Matapica was too small). Curved carapace length is similar to that found in 2000, when mean CCL was 154.2 ± 7.5 in Suriname and 156.2 ± 7.6 in French Guiana (M. Godfrey, pers. comm.). Estimated (calculated from straight carapace length) or measured curved carapace length of leatherbacks nesting in the Marowijne estuary region has decreased since the seventies. In French Guiana estimated CCL in 1977 was 175 cm (Fretey 1998), and 158.5 cm in 1984 (Pritchard and Trebbau 1984). Present size is also smaller compared to leatherbacks in Tongaland, South Africa, where mean carapace length has decreased from 162.2 in 1964-68 to 159.6 in 1994-95 (Hughes 1996). Mean curved carapace length in Costa Rica was 156.2 cm in Tortuguero (Caribbean coast) (Leslie *et al.* 1996), and 144.4 cm in 1993-94 and 147.6 cm in 1994-95 at Las Baulas, (Steyermark *et al*. 1996), and 147.0 at Playa Langosta, (Chaves *et al*. 1996), on the Pacific coast.
The fact that leatherbacks in the Guianas are now smaller than before can mean that there is a higher adult mortality, or that more leatherback females that come to nest these days are young recruits, or a combination of both.

2001	CCL	min	max	n	CCW	min	max	n
Babunsanti	154.0 ± 6.6	130.5	182.5	2071	112.9 ± 5.1	97.0	139.0	757
Matapica	156.0 ± 6.5	139.0	174.0	157	114.9 ± 4.2	106.0	125.0	87
Samsambo	152.9 ± 8.2	135.0	168.0	48	114.6 ± 6.3	103.0	128.0	32
total	154.2 ± 6.7	130.5	182.5	2307	113.1+ 5.1	97.0	139.0	876

Table 3.2 Biometric measurements Dermochelys coriacea *on three beaches.*

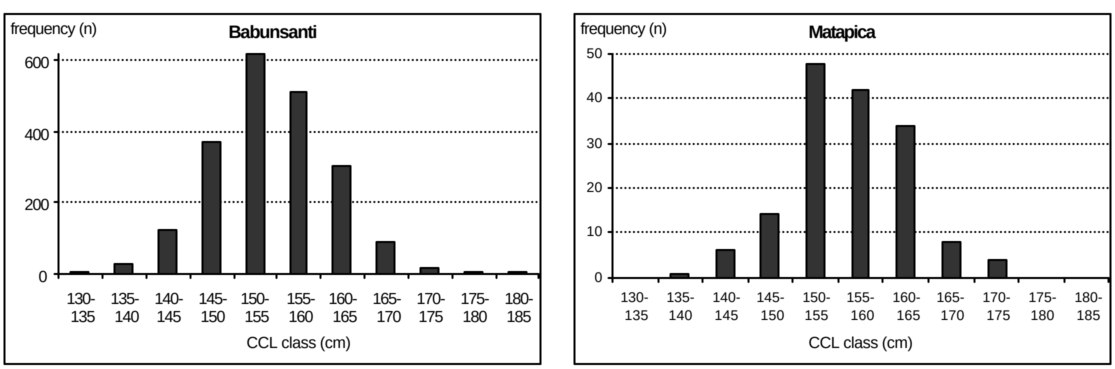


Figure 3.6 Size frequency distribution of tagged leatherbacks on Babunsanti and Matapica, 2001.

3.2 Nest number estimates

Nest counts of *Dermochelys coriacea* done by STINASU on Matapica and Diana Beach can be considered fairly accurate, though on Diana Beach daily counting started later in the leatherback season. For Samsambo there are large gaps in nest count data collection. However, by simple interpolation (taking the average of three days before and three days after the gap, following Schulz (1975)) most gaps could be filled. On Babunsanti and Kolukumbo, however, the situation is different. On Babunsanti, not all sections have been covered daily, and one more remote, but rather busy section (Thomas/Eilanti) was covered very irregularly. Above all, nesting density was so high that nest counts are not a very reliable way of determining nesting activity because crawls and nests are covered up and obscured by subsequent nesters (Girondot and Fretey 1996). As a result, the number of counted nests/crawls is likely to be a significant under-estimate. The same is true for Kolukumbo. Furthermore, daily monitoring of nesting activities on Kolukumbo did not start before the second half of the leatherback nesting season. By combining nest count data with PIT tag data we attempted to make a more reliable estimate of nest numbers and population size. Table 3.3 presents these rough estimates. When using PIT tag data for estimating nest numbers, we used an estimated clutch frequency of 5.5 (see section 3.5).

beach	length (km)	estimated number of nests	nest density (nests/km)	remarks
Matapica and Diana Beach	15	3700 [1]	250	majority of Dc nests on two westernmost sections (Matapica)
Samsambo	10	2000 [2]	200	majority of Dc nests laid on east section (no mud flat present)
Kolukumbo	1.5	12.500 [3]	8333	
Babunsanti	7	12.250 [4]	1750	
total	33.5	30.450	910	

Table 3.3 Dermochelys coriacea *(Dc) estimated nest numbers for 2001. 1) nest count, 2) nest count and interpolation, 3) nest count, interpolation and PIT tag data, 4) PIT tag data, nest counts and estimation.*

On Samsambo, only the eastern-most section was suitable for nesting because of the absence of a large mud flat. Along the entire length of the other beach sections, the mud flat had grown and black mangrove forest had started to colonise the mud. Kolukumbo was discovered in 2000 as a potentially good nesting beach. More than 2200 leatherback nests were laid. After the 2000 nesting season, the beach had become higher, wider and more stable, and mass leatherback nesting occurred from early April to the end of August. Nesting density here was extremely high, with 8333 nests per stretching km, this is higher than anywhere else known at present.

3.3 Predicted number of leatherback individuals

The PIT tag data demonstrate that *at least* 2926 leatherback females have nested in Suriname during the 2001 nesting season, as these turtles were identified. However, incomplete beach coverage (*e.g.*, only five nights on Kolukumbo) and the obtained data (*e.g.*, observation frequency) indicate that this is only part of the total number of individuals that nested in Suriname and the actual size of the nesting cohort of 2001 must be substantially larger. This is also what we expected, given the fact that not all beaches could be covered comprehensively due to shortage of PIT tag materials and a severe lack of manpower. The total number of nesting females cannot be precisely computed from the 2001 data, only a rough estimate can be made. Steyermark *et al*. (1996) suggests that low values for observed nesting frequency for large colonies reflect incomplete coverage of the nesting beach because of the large nesting area and high density of turtles. Fecundity may be underestimated for large populations and large beaches which cannot be patrolled intensively (Tucker 1989). This is certainly true for the situation in Suriname: total leatherback nesting beach area was 33.5 km, of which 8.5 km was very high density nesting area.

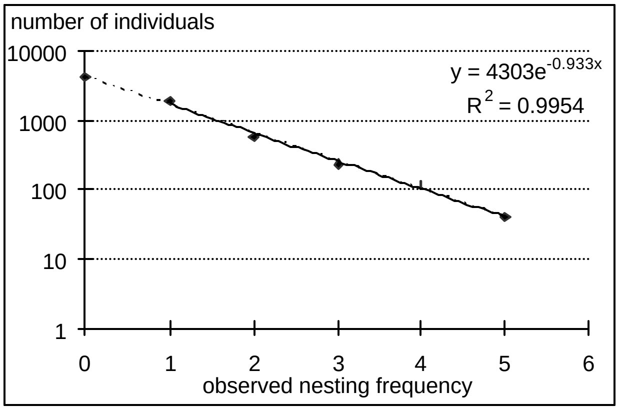


Figure 3.7 Observation frequency of tagged leatherback individuals for all beaches grouped together, scale on the y-axis is logarithmic. The curve was extrapolated to "zero times seen" (dotted line).

Figure 3.7 shows again the observation frequency for tagged leatherback females in 2001. Assuming that each turtle nests on average at least 5 times (Steyermark *et al*. 1996) but rather between 6 (Tucker 1989) and 7.52 (Girondot and Fretey 1996) times a season, from this figure it is evident that a large proportion of the nestings were missed. If we extrapolate the curve to "zero times seen", it is suggested that 4300 turtles were not seen at all. This would make the total number of individual leatherbacks that nested in Suriname in 2001 to be around 7200. However, this is likely to be an over-estimate. Nest site fidelity of leatherbacks may not be very large (Schulz 1975, Eckert 1989, Fretey and Girondot 1990, Boulon *et al.* 1996). Leatherbacks seem to display a fidelity to a larger nesting zone or beach type, rather than a specific beach (Pritchard 1982, Chevalier and Girondot 1999), this may partly be due to highly dynamic character of the coast of the Guiana Shield. Many turtles may in fact have nested only one, two or three times in Suriname, and nested the other times on one of the French Guianese beaches, or beaches in Guyana or even Trinidad. As long as full data sharing is not established, and not all beaches in the region are covered, too many uncertainties remain. Also, nesting frequency distribution of leatherbacks remains unclear. Some complex models should be introduced that fit parameters that explain the observation of remigrant females (M. Girondot, pers. comm.). In very high density nesting areas such as in Suriname and French Guiana, full saturation tagging studies are precluded as long as not all beaches are covered totally and there is insufficient personnel and tag equipment. This makes estimates of internesting frequencies and population size far more complex than for small insular populations (Tucker 1989).
Therefore, to be on the safe side, we will roughly assume that at least 5500 individual leatherback females have nested in Suriname in the 2001 nesting season. This in return supports the estimate that at least 30.000 nests were laid.

3.4 Remigration of the 1999-cohort

Remigration rates of earlier cohorts and the fraction of first time nesters are some of the important population parameters that can be assessed by means of a PIT tag program. Since PIT tagging in Suriname started only in 1999, though on a very small scale, the 2001 nesting season was the first season in which we could expect the mass return of any earlier cohort. Normal expected return time or remigration interval is 2-3 years for leatherbacks (Spotila 1998, Schulz 1975). Boulon *et al*. (1996) reported 61% of the leatherbacks from St. Croix, US Virgin Islands, to return after two years, 30% after three years, 7% after four years, and some turtles after one year or more than five years. The fate of the remaining turtles was not known.
Out of the 62 turtles tagged in Suriname in 1999, a total of 25 (or 40.3%) were observed again in 2001: 22 in Suriname and 3 in French Guiana. Because it is likely that less than 50% of all individuals that nested in 2001 were actually encountered, we can also assume that not 25, but at least 50 turtles of the 1999 cohort may have returned to nest. If this would indeed hold true, this would mean 81%. Another group of 1999-turtles is expected to nest in 2002. Only in 2003, when the majority of the large 2001 cohort is expected to return, valuable data on the fraction of first time nesters and remigrants can be expected.

Mortality can be estimated from the percentage of turtles tagged in a given year that were not seen again within a minimum of 5 years (Spotila *et al*. 1998). From our data, it is too early to be able to estimate mortality rates of females at sea, as turtles from the 1999-cohort that did not nest in 2001, may still return in 2002, 2003 or later. Still then, mortality rates may be over-estimates, as turtles may be nesting elsewhere, or may nest at intervals of greater than 5 years. Continued use of PIT tags in a long-term tagging program that includes all the regional leatherback beaches is needed to improve estimates of mortality (Dutton *et al*. 2000).
Here again, considering that turtles nesting in Suriname and French Guiana belong to the same population, it is important to group the Surinamese data with those of French Guiana.

3.5 Population size and status of the leatherback nesting population

Two approaches are possible towards estimating population size. The size of the nesting population of a certain region can be calculated by dividing the number of nests by the mean annual clutch frequency, and multiplying this number by the mean remigration interval. An average remigration interval of 2.5 years for leatherbacks is used (Schulz 1975, Spotila 1996). The exact internesting frequency for Surinam leatherbacks is not known, but from saturation tagging projects elsewhere it was found that each leatherback turtle nests at least 5-6 times (Boulon *et al*. 1996, Steyermark 1996, Tucker 1989) in a season. For French Guiana it was estimated that the mean internesting frequency is 7.52 times (Girondot and Fretey 1996). Internesting frequency, and average fecundity of nesting females, may differ between regions and years. Because for Suriname and French Guiana the exact rate of shifting between beaches is not known, but it is sure that some shifting does occur, the mean internesting frequency on a certain beach may be 5 to 6 times. Spotila (1996) used an annual clutch frequency of 5 for his estimates of the world leatherback population, following Steyermark (1996). If we would assume an internesting frequency of 5.5 and average remigration interval of 2.5 years, total nesting population size would be roughly 30.000/5.5*2.5=13.636 leatherback females. But, since nest numbers vary greatly between the years and nest numbers in 2001 were exceptionally high, it is too early to make such an estimate.
Alternatively, PIT tag results and observed and estimated number of individuals per nesting season can be used. As described above (section 3.3), however, too many uncertainties remain, such as rate of exchange between beaches. We can, however, be very sure that the nesting colony of 2001 consisted of *at least* 2926 females, as these were all identified, and safely assume that at least 50% of the turtles were missed, so that the size of the 2001 nesting cohort is estimated to be at least 5500 turtles.

The status of the population can also be expressed in nest number trends. Figure 3.8 shows leatherback nest number estimates for Suriname from 1970 to 2001 (Chevalier and Girondot 2000; M. Girondot, pers. comm.). The current trend for leatherback nesting in Suriname looks favourable. Estimated nest numbers in 2001 (>30.000) doubled those of 2000 (15.000). Although peaks have been occurring every decade, the spectacular increase in 2001 is striking. Nest numbers of 2001 are more or less similar to those of French Guiana (M. Godfrey and P. Rivalan, pers. comm.), thereby bringing the total number of nests for the Marowijne region back to the level of before 1992. However, good years can be followed by bad years. This may be due to variations in reproductive cycles (Hirth 1980), food supply and environmental conditions on their foraging grounds, as well as the effects of mortality at various stages of their life histories (Limpus and Nicholls 1988 and 1992, Steyermark *et al*. 1996). Chevalier and Girondot (1999), Chevalier *et al*. (1999), Chevalier and Girondot (2000) reported a steep decline since 1992 of the Awa:la-Ya:lima:po nest numbers in French Guiana, from 30.000-60.000 nests per year to 7500 nests in 1998, after which an increase was seen. As the Surinamese leatherback nesting colony has increased tremendously, this could partially explain the drop in numbers in French Guiana: a displacement may have taken place of turtles from French Guianese to Surinam beaches (Eckert 2000, Chevalier and Girondot 1999), as a result of erosion of nesting beaches in French Guiana and expansion of suitable sandy beaches in Suriname. However, until 2001, the increase in Suriname did not make up for the decrease in French Guiana. The decrease seen in French Guiana is believed to be due to low reproductive success (low hatching success) on the Marowijne beaches, and shrimp- and drift net fisheries in the Marowijne estuary region (Chevalier *et al*. 2000). The strong increase in Suriname may also be a result of improved conservation measures during the past four decades, which would mean that the increase is caused by new recruitment to the population (high fraction of first time nesters) (Spotila 1999, Steyermark 1996). Within a few years time, the PIT tag program should reveal if this hypothesis could be true.

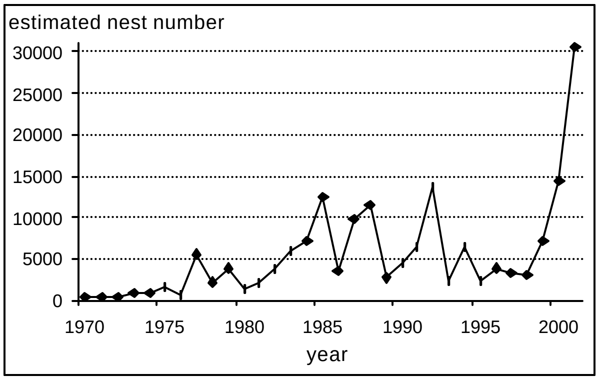


Figure 3.8 Estimated nest numbers in Suriname (Babunsanti, Matapica, Samsambo and Kolukumbo) for the period 1970-2001.

3.6 Reproductive success and nest ecology

3.6.1 Hatch success and nest survival

Table 3.4 shows the fate of the randomly marked *in situ* leatherback nests on Babunsanti, Matapica and Samsambo. The number of analysed un-marked, *in situ* leatherback nests is also shown.
A selection of un-marked nests was analysed in addition to the marked group in order to have a control group. The marked nests had all briefly been disturbed while probing for the nest and putting a tag inside the nest, which may have lowered hatch rates.
The un-marked nests were excavated three days after observed emerging of the first hatchlings. Therefore, only successful nests with hatchling tracks were examined. Hatchling tracks of nests situated below the spring tide line are often immediately washed away by the high tide. These nests may not be recognised as hatched. *As a result the un-marked group is not representative for hatch success along and across the beach*.

beach	marked nests *in situ*	nests found back	nests analysed	nests not hatched	un-marked nests *in situ*
Babunsanti	190 (PB-I, BS-I/II)	174 (91.6%)	149	74 (49.7%)	122 (PB-I, BS-I/II)
Matapica	88[1] (Section 6)	65[1] (73.8%)	62	6 (9.7%)	161 (Section 6)
Samsambo	80[2] (Mid-II)	35[2] (43.8%)	35	10 (28.6%)	71 (Section East)

Table 3.4 Number and fate of marked Dermochelys coriacea *nests along the 3 beaches and the number of un-marked analysed nests. 1) Nests on Matapica were not triangulated, making it more difficult to find them back. 2) Nests on Samsambo were not triangulated and some not properly marked, therefore this number is not representative.*

Of the 149 excavated marked nests on Babunsanti, 51.3% had survived until hatching. On Matapica, on the other hand, out of 65 nests, 90.3% survived to hatching. On Samsambo 71.4% of the 35 nests survived until hatching. Nest failure on Matapica was in three cases (50% of failed nests) due to beach erosion, in one case the nest was situated too close to the lagoon and in two other cases no clear cause was found. Nest failure on Babunsanti was due to more or less permanent inundation for nests laid more than 5 meters below the spring tide line, but nest failure also occurred for nests laid above the spring tide line (see section 3.7). Figure 3.9 shows the overall hatch success distribution for the marked nests on the three beaches (see also appendix 2.1).

Table 3.5 and figure 3.10 show the hatch success and egg development of *in situ* marked, and *in situ* un-marked nests. Successful nests are defined as nests from which hatchlings have emerged. A highly significant difference (Kruskal-Wallis, $p<0.01$) exists between hatch success, the proportion undeveloped eggs, proportion ruptured (defined as predated by mole cricket or ghost crab, and occasionally by beetles) and proportion pipped eggs for both the marked and un-marked nests on the different beaches. The difference found for embryonic mortality is not significant (appendix 2.2).

2001	Babunsanti	Matapica	Samsambo
marked *in situ* nests *(including unsuccessful nests)*	n=149	n=62	n=35
hatch success (% ± SD)	10.6 ± 16.4	52.7 ± 29.7	21.6 ± 21.6
marked *in situ* nests *(excluding unsuccessful nests)*	n=73	n=56	n=25
hatch success (% ± SD)	21.6 ± 17.7	58.3 ± 25.4	30.2 ± 19.8
un-marked *in situ* nests *(successful nests only)*	n=122	n=161	n=71
hatch success (% ± SD)	42.8 ± 18.8	64.5 ± 19.4	36.5 ± 19.5

Table 3.5 Dermochelys coriacea *mean hatch success (%) with standard deviation (SD) per nest, including and excluding unsuccessful nests (nests that failed to hatch). For un-marked in situ nests the fraction of failed nests is not known.*

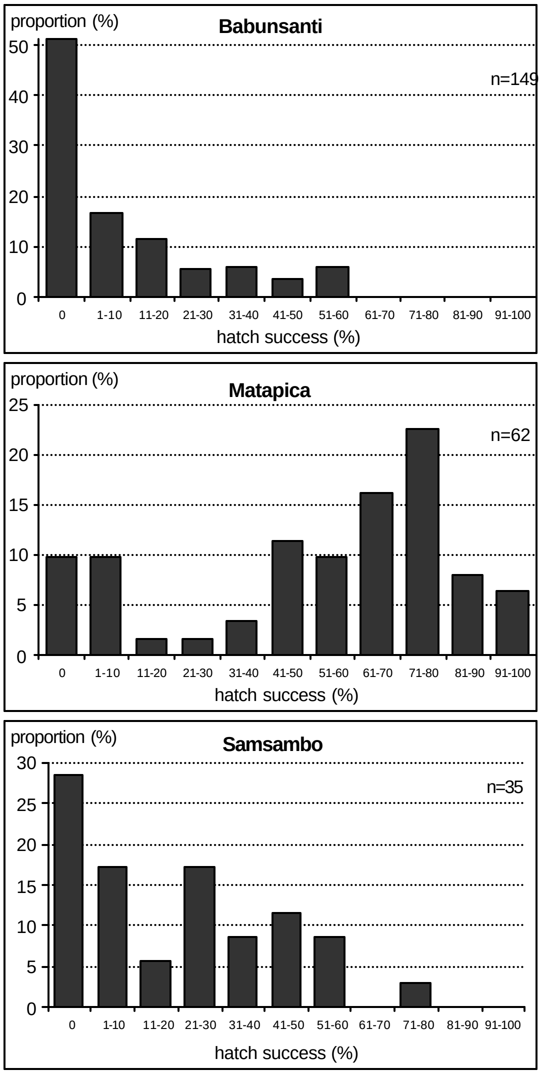


Figure 3.9 Frequency distribution of hatch success of marked nests (including unsuccessful nests) on Babunsanti, Matapica and Samsambo.

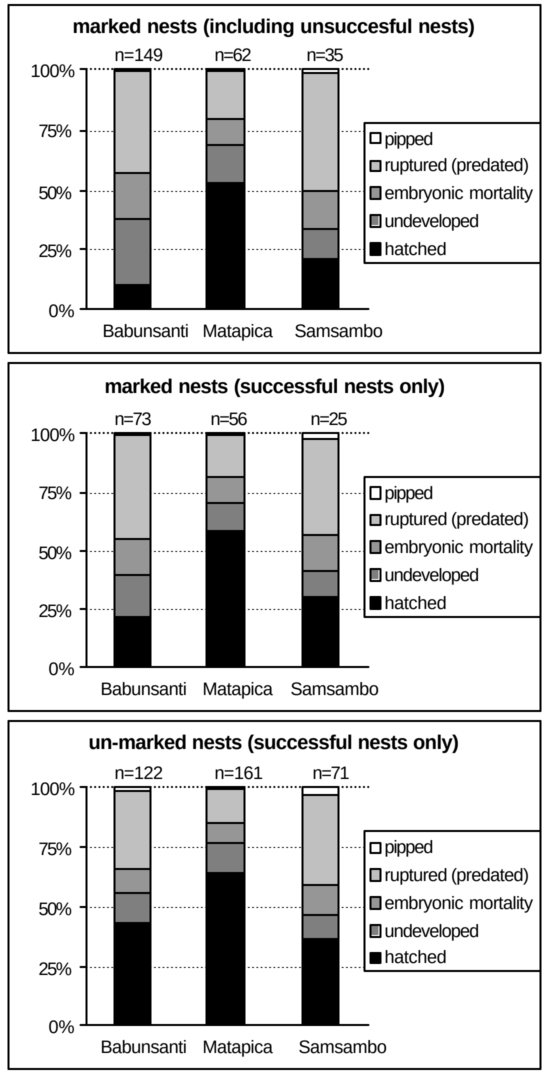


Figure 3.10 Hatch success, egg development and predation of marked and unmarked nests on Babunsanti, Matapica and Samsambo.

Hatch success is higher for un-marked than for marked *in situ* nests on all three beaches. This difference is most striking on Babunsanti, where hatch success for un-marked nests almost doubles that of marked nests. It is known that probing for the eggs can influence hatch success (Hill 1971). Probing may have had more effect on Babunsanti than on Matapica. On the latter, the sand is assumed 'cleaner': there seem to be less bacteria and fungi because of the continuous refreshment of the beach sand, and presence of salt water instead of fresh water. As these fungi and germs may be especially attracted to egg yolk of eggs broken by probing, and thus negatively influence the hatch success (Girondot *et al*. 1990, Mo *et al*. 1990), the nest may get infected as from the moment of probing. Also, some probing at Babunsanti was done by less experienced team members, and more eggs may have been ruptured than on Matapica. In addition, especially on Babunsanti, only un-marked nests that were high up the beach and had hatched well were noticed because the beach is narrow and tides easily wash away hatchling tracks. This may have resulted in a much distorted and higher observed hatch success, as nests with low hatch success were often not noticed and not excavated.

Hatch success for *Dermochelys coriacea* on Matapica almost doubled that found on Babunsanti and Samsambo. The fraction of eggs with no apparent embryonic development was lower at Matapica, and also predation of eggs by mole cricket and ghost crab was less. The higher hatch rates, and lower fraction of eggs with no apparent embryonic development at Matapica can be explained by factors such as beach morphology, sand type, drainage, salinity of sea water, regular turnover of sand, less contamination by bacteria and fungi, lower abundance of mole crickets, and lower nest density (table 3.6). Almost all nests on Babunsanti were (partially) heavily rotten. Bacterial contamination can lower hatching success to a large extent (Cornelius 1986, Girondot *et al*. 1990).

(a) biotic factors	Babunsanti	Matapica	Samsambo	effect on H%
sand type	fine sand	course sand with shell pieces	fine sand	course = +
salinity type of water	brackish/fresh	salt	brackish	salt = +
sand turnover	low	high	low	high = +
vegetation	medium/high	low	low/medium	low = +
bacteria and fungi	high	low	medium	low = +
mole crickets	high	low	medium	low = +
nest density	extremely high	medium	low	low = +

Table 3.6 Expected effect on leatherback hatch success of various abiotic and biotic factors on the different beaches.

During the 2000 nesting season, average hatch success of marked *in situ* nests on Matapica was 44.7% (excluding unsuccessful nests) (Hilterman 2001). This is lower than the hatch success of 58.3% found in 2001. However, the study in 2000 was carried out on another, more eastern and thus 'older' beach section. It is expected that hatch rates on the accretion point, which was the study area of 2001, are highest because the sand is very clean, beach vegetation is almost absent, and there are few mole crickets and ghost crabs. The fraction of nest surviving to term in 2000 was 91.3%, in 2001 this was 90.3%. Marked nest studies have been done on Babunsanti in 1997 and 1998. Hatch success in 1998 was 24.6% (percentage nest failure not known) (Klooster 1999) and in 1997 average hatch success of successful nests was 10% (approximately 50% of the nests failed to hatch) (Hoekert *et al*. 2000).
If we compare annual hatch success for marked *in situ* nests on the Surinam beaches to that of similar studies on other leatherback beaches, we find that hatch rates on Matapica compare very well, whereas Babunsanti has notoriously low hatch rates. A hatch success of 67.1% was reported for successful nests on St Croix (Boulon *et al*. 1996), 70.0% in 1990 (18% of the nests failed due to natural causes) and 53.2% in 1991 (25% of nests failed) on Tortuguero, Costa Rica (Leslie *et al*. 1996), 31.4% (Arauz and Naranjo 1994) and 53.8% on Playa Grande, Costa Rica (11% of nests failed to hatch due to natural causes, Schwandt *et. al*. 1996), 71.4% on Mexiquillo, Mexico (Tellez and Sarti, 2000), and 52.4% on Bigisanti in Suriname (Whitmore and Dutton 1985). *For some of these studies however, nests below the high tide line (thus in the wash-over zone) were relocated to a hatchery and thus not included in hatch success results of* in situ *nests. This has probably resulted in a higher average hatch success found in those studies.*

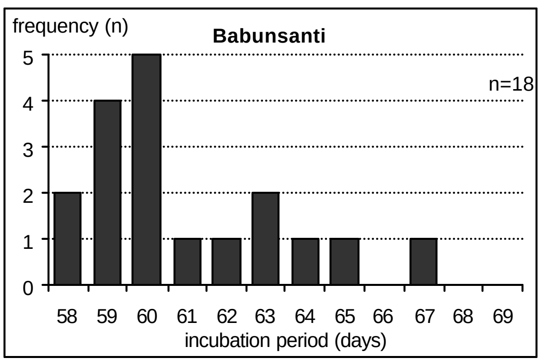
3.6.2 Clutch size

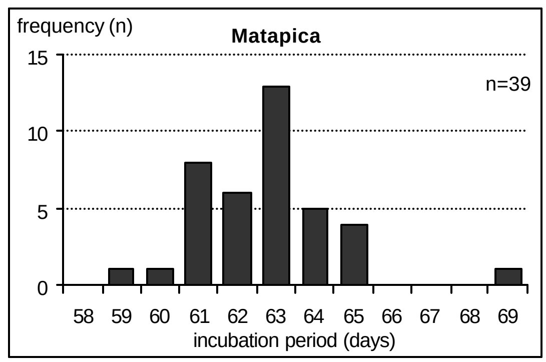
Average clutch size, defined as the total number of eggs per nest (small yolkless eggs excluded) for marked and un-marked nests grouped for the 2001 nesting season was 86.9 ± 18.3 eggs (n=600). Clutch size was larger at Babunsanti (88.1 ± 17.03, n=270) than at Samsambo (87.2 ± 21.8, n=106) and Matapica (85.3 ± 17.5, n=223). This difference is not significant (t-test, equal variance not assumed, p=0.07). Overall clutch size was higher in 2001 than in 2000 (84.4 ± 17.8, n=335). This difference is not significant. The overall clutch size found is similar to that found by Schulz (1975), who found an average clutch size of 85 eggs for leatherbacks nesting on Bigisanti.
The overall mean number of small, yolkless eggs was 28.2 ± 16.6. The number of yolkless eggs was 27.2 ± 16.5 on Babunsanti, 30.4 ± 16.8 on Matapica and 26.2 ± 16.0 on Samsambo, this difference is significant (Kruskal-Wallis, $p<0.05$).
Clutch size is larger than clutch sizes reported in other areas. For example, Hall (1988, 1989) reported 69.5 eggs at Culebra (Puerto Rico), and Chaves *et al.* 1996 reported 65.3 eggs at Playa Langosta, Pacific coast of Costa Rica.
Clutch size on Tortuguero, on the Atlantic coast of Costa Rica, was similar to that found in Suriname (86 eggs, Leslie *et al*. 1996). Boulon *et al*. (1996) reported 79.7 eggs at St. Croix. Clutch size is

(partly) related to the size of the adult turtle (Hall 1990, Tucker and Frazer 1991), and since the average size of the Atlantic leatherbacks is larger, this could result in larger clutches.
It has been found that clutch size is negatively correlated to hatch success of nests, with an optimum hatch success at 55 eggs (Mortimer *et al*. 1994, Balasingam 1967). Since clutch size for leatherbacks in Suriname seems to be higher than average, this could theoretically contribute to a lower hatch success.

3.6.3 Incubation periods

Incubation periods are known for 18 clutches at Babunsanti, 39 at Matapica and 12 clutches at Samsambo. Incubation period is defined as the number of days between egg deposition and hatchling emergence on the beach surface. The incubation period is significantly longer at Matapica (62.7 ± 1.8) than at Babunsanti (60.9 ± 2.5) and Samsambo (60.7 ± 1.7) (ANOVA, F=7.9, p=0.001). Figure 3.11 shows the frequency distribution of incubation periods for leatherback nests laid at Babunsanti and Matapica. For the 2000 nesting season, incubation periods are known for Samsambo (61.1 ± 2.1) and Matapica (65.5 ± 3.1). Also then, the incubation time was significantly longer at Matapica than at Samsambo (Mann-Whitney U, p<0.001). The longer incubation duration at Matapica reflects a lower average sand temperature (section 3.7).





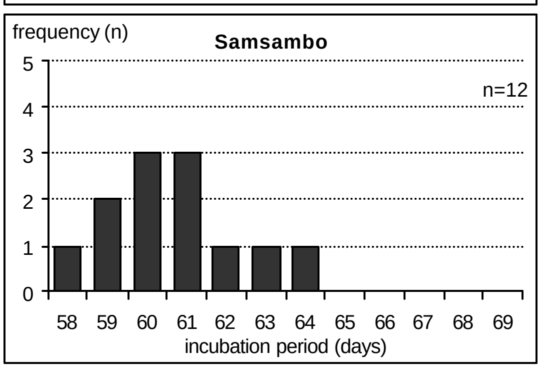


Figure 3.11 Frequency distribution of observed incubation periods on Babunsanti, Matapica and Samsambo.

3.6.4 Net production of leatherback hatchlings on the different beaches

In order to estimate the leatherback hatchling output for the beaches Babunsanti and Matapica, a number of assumptions are made: 1) probing for nests lowers hatch success, 2) therefore hatch success has to be corrected for the effect of probing, 3) hatch rates on the different study sections on Babunsanti are similar, whereas hatch rates on Matapica differ for the east and west sections: hatch success is highest for the western sections, which are the youngest sections.

Average clutch size for 2001 is 85 eggs. On Babunsanti an estimated 12.250 *Dermochelys coriacea* nests were laid, on Matapica (Diana Beach excluded) 3000 nests. On Babunsanti 50% of all nests failed to hatch, on Matapica this was 10% on the study section, but on the eastern sections (strong beach erosion) we estimate that 20% failed to hatch, doomed nests included.

1. Matapica: 1570 nests on 2 western-most sections, 10% nest failure, 1410 nests survived to hatching. On these sections, average hatch success was estimated to be 62% per hatched nest (average of marked and un-marked *in situ* nests) and higher than on the eastern sections. Therefore,

the 1410 nests produced 1410*85*0.62=74.307 hatchlings. On the eastern sections 1340 nests were laid, 20% nest failure, 1072 nests survived to hatching. Average hatch success on these sections is estimated at 50% (Hilterman 2001). Therefore, the 1072 nests produced 1072*85*0.50=45.560 hatchlings. So, an estimated 74.300 hatchlings + 45.560 hatchlings = roughly 119.860 hatchlings were produced on Matapica in 2001.
2. Babunsanti: 12.250 nests, 50% nest failure, 6125 nests survived to hatching. Average hatching success was estimated to be 30% (average of marked and un-marked *in situ* nests). Thus, the 6125 successful nests roughly produced 6125*85*0.30 = 156.180 hatchlings on Babunsanti 2001.

Although on Babunsanti at least 4 times more leatherback nests were laid than on Matapica, it is estimated that only 1.3 times more hatchlings were produced. Because of the high hatch success on Matapica due to good environmental quality of the beach, this beach is considered to be of high importance for net hatchling production in Suriname. Therefore, conservation measures should focus more on Matapica than was the case so far. Further studies are needed on hatchling quality: hatchling fitness (size, weight, strength) may also higher on Matapica than on Babunsanti, this needs to be tested.
For Kolukumbo and Samsambo, only rough estimates can be made. The sample size at Samsambo was very small and at Kolukumbo, no nests were examined at all.

3. Samsambo: 2000 nests, 28% failure, 1440 nests survived until hatching. Mean hatch success is estimated at 33%, thus 1440*85*0.33 = 40.392 produced hatchlings.
4. Kolukumbo: 12.500 nests, probably 30% failure because of the high nest density (turtles digging up each others nest), 8750 nests survived until hatching. Hatch success seemed good, given the high numbers of hatchling tracks observed. If we use a hatch success of 50%, the number of hatchlings produced would have been 8750*85*0.50 = 371.875.

The total number of leatherback hatchlings produced in Suriname 2001 would then be roughly estimated at 688.280. Hatch rates on Babunsanti are not sufficient to sustain the present population. Matapica and possibly Kolukumbo (partly) make up for this.

3.6.5 Nesting and nest success below the spring tide line

The position of the spring tide line (STL) differs amongst the beaches. On Babunsanti the STL is most distinct. The STL is not the same as the mean vegetation line, but generally lays 0-1.5 m below it and does not follow a straight line. On Matapica, the STL is less easy to determine. Nests laid below the STL are subject to regular inundation. The effect of tidal inundation on leatherback nest success differs per beach and depends on factors such as beach topography, sand type and drainage capacity. Figure 3.12 shows the frequency distribution of excavated marked nests over STL classes on Babunsanti and Matapica for 2001. For Babunsanti, we used for this purpose the 84 nests excavated by the two researchers of which the STL-determination was most standardised and reliable. For Samsambo the sample size was too small to give such figures.

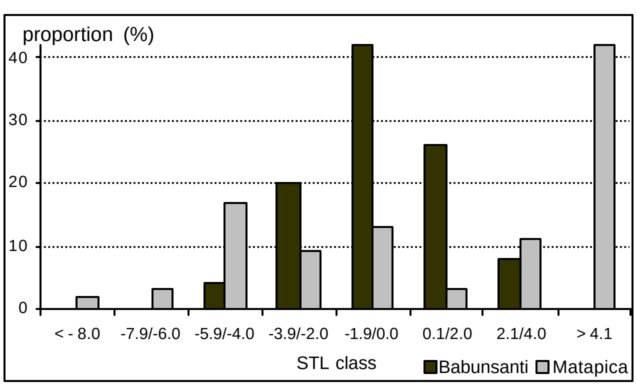


Figure 3.12 Frequency distribution of nest position across the beach (distance to the spring tide line) for excavated marked nests on Babunsanti and Matapica.

Figure 3.13 shows hatch success as a function of distance of the nest to the STL for Babunsanti. When unsuccessful nests (nests that failed to hatch) are included, there was a significant positive correlation between position of the nest on the STL and hatch success (rho=0.563, p<0.01, n=84). A significant negative correlation exists between position of the nest on the STL and the fraction of undeveloped eggs (rho=-0.403, p<0.01, n=84), which may partly explain the higher failure of nests on the lowest beach zones.

Nest failure occurs both below and above the STL. When unsuccessful nests are excluded, there is no significant correlation between distance to the STL and hatch success. This indicates that on the lower beach zones, more nests fail to hatch, but that hatch success of the successful nests does not significantly differ between the beach zones. It is shown that nests laid on Babunsanti between 2 and 4 metres below the STL are able to produce hatchlings, although hatch success is not very high. Nests laid more than 4 metres below the STL can generally be considered doomed. However, data from 1998 (several un-marked nests with hatchling tracks were observed) suggested that hatch success for nests laid 3-5 m below the STL can be high (Verkade 2000). From our data, it is suggested that 4% of the leatherback nests laid on Babunsanti are *a priori* doomed (nests laid more than 4 m below the STL). Approximately 20% of the nests are laid in the zone between 2 and 4 metres below the STL. These nests have a higher chance of nest failure but are not *a priori* doomed. The majority of nests (42%) are laid in the zone between the STL and 2 metres below it. In this zone, nests are well able to hatch.

On Matapica the situation is different. Figure 3.13 shows hatch success as a function of the distance to the STL for Matapica. A slightly negative correlation was found, but this correlation is not significant. This confirms results gathered in the 2000 nesting season, when no significant difference was found for hatch success of nests laid in the zone between the STL and 8 metres below it, and nests above the STL. On Matapica, only nests laid below a flood cliff, and nests laid more than 8 metres below the STL, could be considered doomed.

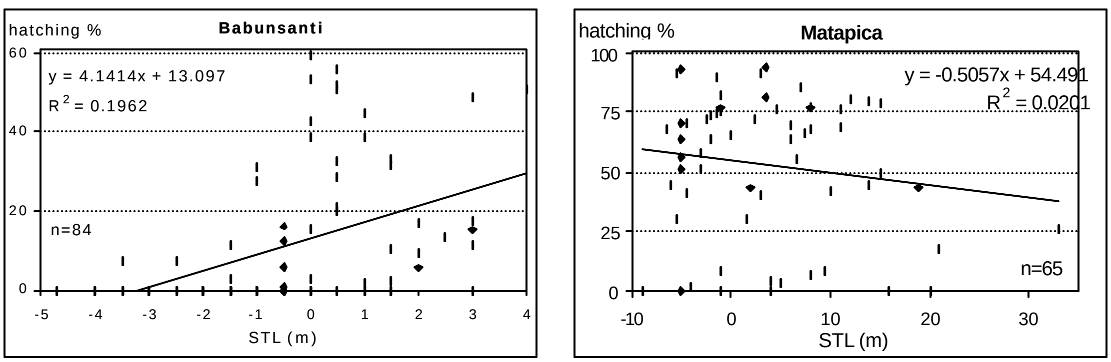


Figure 3.13 Hatching success of marked nests as a function of the distance of the nest to the spring tide line on Babunsanti and Matapica.

3.7 Sand temperature and sex determination

Figure 3.14 shows the measured sand temperatures at 75 cm depth for three beaches on two different beach zones in relation to the STL (low and mid/high). We assume that the mean temperature at nest depth between day 20-40 of the incubation period represents the incubation temperature for the nest (Desvages *et al*. 1993, Spotila *et al*. 1987). For estimating hatchling sex, a maximum of 0.5ºC should be added to the temperature to take into account the metabolic heating (Morreale *et al*. 1982, Godfrey *et al.* 1997). Sand temperatures fluctuate through the season as a result of changes in rainfall, cloud cover and wash-over by (extreme) spring tides. All profiles roughly follow the same pattern, with a gradual increase towards the end of the season. The pivotal temperature for leatherbacks in the Guianas is 29.5ºC, with 100% females being produced at temperatures above 30ºC and 100% males being produced at temperatures below 29ºC (Rimblot-Baly 1987). At Matapica, the data logger in the lower beach zone was lost in the course of the season due to beach erosion, but later recovered by a STINASU employee.

On Babunsanti and Matapica the sand temperature on the higher beach zone was significantly higher than that on the lower beach zone (ANOVA, p<0.01), the lower zone was cooler due to the cooling effect of the high tides. On Samsambo the sand temperature on the higher zone was only very slightly higher than on the lower zone, because the lower data logger had been incorrectly placed on the spring tide line instead of below it. On Matapica the temperature profile on the lower beach zone follows another pattern than the higher one. This may have been caused by the occurring spring tide, the same drop in temperature is seen for the data logger on the lower beach zone at Babunsanti. The higher beach zones were not or very little affected.

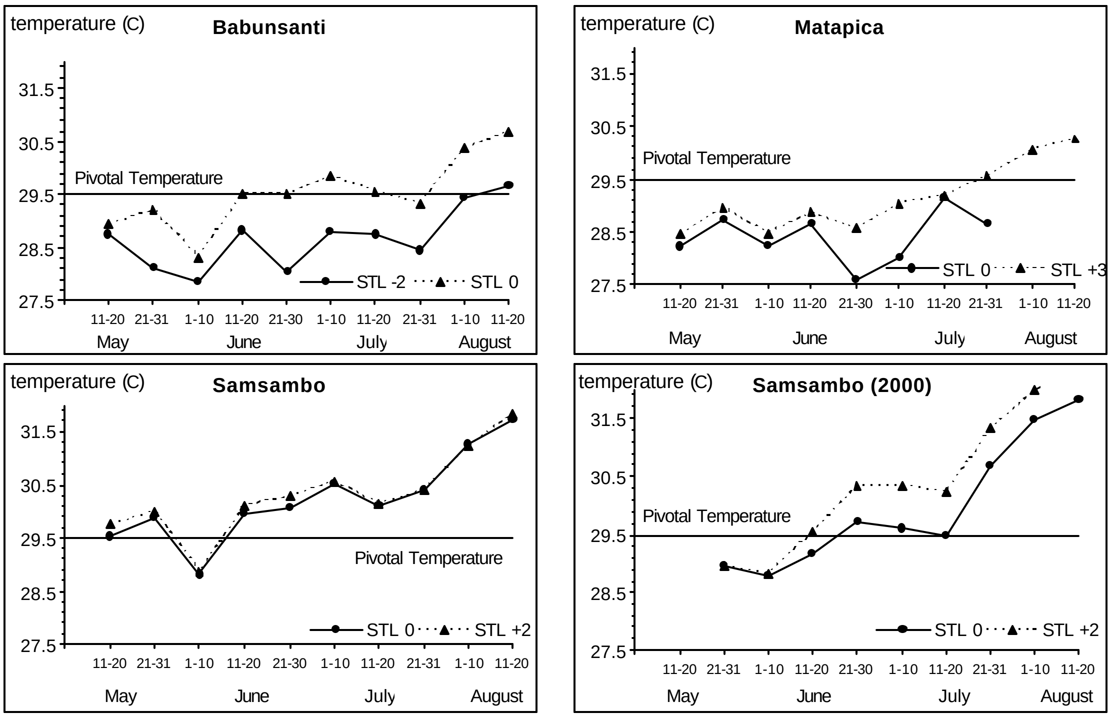


Figure 3.14 Sand temperature profiles (degrees Celcius) at nest depth on Babunsanti, Matapica and Samsambo 2001; and on Samsambo 2000.

Sand temperature differed significantly between the beaches (ANOVA, $p<0.01$). On Babunsanti, mean temperature at 75 cm depth was 28.6 ± 0.7ºC for the lower zone and 29.5 ± 0.8ºC for the higher zone. On Matapica this was 28.4 ± 0.8ºC and 29.2 ± 0.7ºC, and on Samsambo 30.2 ± 0.9ºC and 30.3 ± 0.9ºC. Beach sand on Samsambo was significantly warmer than on Babunsanti and Matapica.

For Babunsanti, at the higher beach zone the nests laid before May 20th may have produced predominantly males, the nests laid thereafter females. For the nests in the lower beach zone, nests laid all through the season should have produced predominantly males. Only nes ts laid after July 20th may have produced females. For Samsambo, nests in both beach zones are likely to have produced female hatchlings except for a short period in the end of May. On Matapica, only nests laid in and later than early July (thus very few nests) will have produced predominantly females.

On high density nesting beaches like Kolukumbo and also Babunsanti, turtles are likely to dig up each others nests. Nests laid earlier in the season (usually the cooler months) may thus be destructed by other turtles. This can produce a bias in primary sex ratio relative to the temporal distribution of nesting females through the season (Girondot and Tucker 1998). In the 2000 nesting season, sand temperatures have been measured only on Samsambo. Temperature profiles were similar to those found in 2001, but as the data loggers in 2000 were placed at 60 cm depth this may explain the somewhat stronger increase through the season in 2000, especially of the temperatures on the highest beach zone.

Sex ratio of turtles varies with location, within the season and between years. Therefore the sex ratio can balance out over many years (Mrosovsky 1994). Not all beaches and beach sections were covered in 2001, and only two beach zones per beach. Sand temperatures were not measured on the busiest beach, Kolukumbo. This makes predictions on dominating hatchling sex for 2001 difficult. The busiest leatherback beach in French Guiana, Awa:la-Ya:lima:po, produced predominantly females

(M. Godfrey, pers. comm.). In order to find out if patterns on certain beaches are typical for those beaches, comparative studies on all important nesting beaches in the region are necessary. An imbalance in sex ratios may result into skewed adult sex ratios, which in turn may add to other factors causing a population decline (Chan and Liew 1996).

3.8 Miscellaneous

3.8.1 Strandings and injuries

We observed 43 dead leatherbacks that had washed ashore on Babunsanti, Samsambo, Kolukumbo and Matapica. Because beach coverage of the latter three was not complete, this number may be an under-estimate. The majority of turtles washed ashore during the first two weeks of May, when many Guyanese drift-net fishing boats were present in and near the Marowijne river estuary and in front of Matapica. In two cases the carapace was fresh but empty and showed machete marks. These turtles had been slaughtered and presumably eaten. Also in many other cases the carcasses showed machete marks or fishnet wounds. One leatherback carcass was found with a net wrapped around it. Several times a round, 5 cm diameter deep hole in the carapace was observed. These holes are caused by pointed sticks that are known to be used by fisherman when turtles are stuck in their nets. One such turtle was observed while nesting. The stick was still in her body and the hole was bleeding heavily. Many turtles were missing flippers or flipper parts. It is likely that all these turtles were victims of the fishing fleet that is active in and around the Marowijne river estuary and in front of Matapica. More qualitative and quantitative data are needed on fisheries related injuries on sea turtles on the Surinam beaches.

We observed three deaths due to natural causes. One leatherback on Samsambo died on the beach straight after nesting. Two leatherbacks on Kolukumbo died after they got stuck in the branches of tree trunks.

3.8.2 Turtles stuck in mud

On Samsambo and in the area between Samsambo and Kolukumbo, 122 turtles were observed stuck in the mud during day time during 34 days of observation. These turtles typically get stuck when they return after nesting and the tide is already too low. They usually struggle for 30-60 minutes, get covered in mud and finally rest. At this stage, they may look dead. However, the turtles usually start moving again as soon as the tide starts rising, long before the water has actually reached them. All of these turtles (except for one that died), released themselves and swam back to sea when the next high tide came in. Apparently, the thick layer of mud protects the turtles against the hot sun (dehydration). As no relation was found between high numbers of stuck turtles and the number of strandings, and we recaptured several of the turtles at a later nesting attempt, it can be believed that getting stuck in the mud is not harmful to leatherback turtles. No special action is needed to 'rescue' these turtles, as they generally survive.

4. MAIN CONCLUSIONS

PIT tagging and population aspects

Present leatherback nest numbers in Suriname are amongst the highest world-wide. Based on PIT tag results, it is estimated that in 2001 at least 5500 individual leatherback females have nested in Suriname. It is estimated that at least 30.450 nests have been laid. Nest density was highest on the new beach Kolukumbo. Although peaks in nest numbers are seen every decade, the current trend for leatherbacks seems favourable.

Normal expected return time or remigration interval is 2-3 years for leatherbacks. Observed remigration of turtles tagged in 1999 was 40%. Remigration may in fact be substantially higher (possibly twice as high) given the high fraction of missed turtles. It is too early to estimate mortality rates of females at sea based on present data. Data of the 2002 and especially the 2003 season (when the large 2001-cohort is expected back) should add to a better understanding of remigration rates and fraction of first-time nesters.

Shifting of leatherbacks between countries, and over nesting seasons, occurs on a regular basis (15% of the leatherbacks encountered in Suriname had been tagged abroad). For conservation purposes, the Surinam and French Guianese leatherback populations should be seen as one. Continued use of PIT tags in a long-term tagging program (that includes all important regional leatherback beaches) is needed to improve estimates of shifting behaviour, remigration and mortality.

Mean curved carapace length of nesting leatherbacks was similar to that found in 2000. Curved carapace length has decreased since 1977. It is yet unclear if this is due to a higher adult mortality, or that more leatherback females that come to nest these days are young recruits, or a combination of both.

Reproductive output and nest ecology

Hatch rates for marked leatherback nests on Matapica almost doubled hatch rates found on Babunsanti and Samsambo. On Babunsanti at least 4 times more leatherback nests were laid than on Matapica, but only 1.3 times more hatchlings were produced. Hatch rates on Babunsanti are notoriously low. Matapica is considered to be of critical importance for hatchling production and thus reproductive output of leatherback turtles in Suriname.

Our data suggested that leatherback nests can tolerate frequent wash over by tides. On Babunsanti, only 4% of the nests on Babunsanti can be considered *a priori* doomed. Nest failure occurs both on high and low beach zones but is higher on the lowest beach zones. Hatch success of the successful nests did not significantly differ between the beach zones. On Matapica, nest failure is not clearly related to nest position, and tidal inundation seems to have less impact than on Babunsanti.

Soil temperatures at nest depth differed significantly between three beaches in Suriname. Different beaches and beach zones (high/low) thus produced different hatchling sex ratio's. An imbalance in sex ratios may result into skewed adult sex ratios. This in turn could add to other factors causing a population decline.

Miscellaneous

Many nesting or stranded leatherbacks showed wounds and scars that were possibly related to coastal driftnet fisheries. Further studies are needed to quantity and qualify these fisheries related deaths and injuries. Getting stuck in the mud before or after nesting (often during daytime) is not a serious threat to leatherback females.

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REFERENCES

Arauz, R., and I.Naranjo, 1994. Hatching Success of Leatherback Turtles (*Dermochelys coriacea*) in theLeatherbacks of Guanacaste Marine National Park, Costa Rica. In: B.A. Schroeder, and B.E. Witherington (Editors), 1994. Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-341, 281p., pp.11-14.

Augustinus, P.G.E.F., 1978. The Changing Shorelines of Suriname (South America). Natuurwetenschappelijke Studiekring voor Suriname en de Nederlandse Antillen, Utrecht, The Netherlands, No. 95, 232p.

Balasingam, E., 1967. The Ecology and Conservation of the Leathery Turtle *(Dermochelys coriacea*) in Malaya. Micronesia 3:37-43.

Bolten, A.B., 1999. Techniques for Measuring Sea Turtles. In: K.L. Eckert, K.A. Bjorndal, F.A. Abreu-Gobois, and M. Donnelly (Editors), 1999. Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 235p., pp.110-114.

Boulon, R.H. *Jr.*, P.H. Dutton, and D.L. McDonald, 1996. Leatherback Turtles (*Dermochelys coriacea*) on St. Croix, U.S. Virgin Islands: Fifteen Years of Conservation. Chelonian Conservation and Biology 2(2):141-147.

Chan, E.H., and H.C. Liew, 1996. Decline of the Leatherback Population in Terengganu, Malaysia, 1956-1995. Chelonian Conservation and Biology 2(2):196-203.

Chaves, A., G. Serrano, G. Marin, E. Arguedas, A. Jimenez, and J.R. Spotila, 1996. Biology and Conservation of Leatherback Turtles, *Dermochelys coriacea*, at Playa Langosta, Costa Rica. Chelonian Conservation and Biology 2(2):184-189.

Chevalier, J., X. Desbois, and M. Girondot, 1999. The Reason of Decline of Leatherback Turtles (*Dermochelys coriacea*) in French Guiana: an Hypothesis. In: 9th Extraordinary Meeting of the Societas Europaea Herpetologica, R. Guyétant and C. Miaud, eds. (Université de Savoie, Le Bourget du Lac: Université de Savoie).

Chevalier, J., and M. Girondot, 1999. Status of Marine Turtles in French Guiana. *Manuscript*, 7p.

Chevalier, J., and M. Girondot, 2000. Recent Population Trend for *Dermochelys coriacea* in French Guiana. In: F.A. Abreu-Grobois, R. Briseño-Dueñas, R. Marquez-Millán, and L. Sarti-Martínez (Editors). Proceedings of the Eighteenth International Sea Turtle Symposium. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-436, 293p., pp.56-57.

Cornelius, S.E., 1986. The sea turtles of Santa Rosa National Park. Fundacion de Parques Nacionales, San Jose, Costa Rica. 64p.

Desvages, G., M. Girondot, and C. Pieau, 1993. Sensitive Stages for the Effects of Temperature on Gonadal Aromatase Activity in Embryos of the Marine Turtle *Dermochelys coriacea*. General and Comparative Endocrinology 92(1):54-61.

Dutton, D.L., P.H. Dutton and R. Boulon, 2000. Recruitment and Mortality Estimates for Female Leatherbacks Nesting in St. Croix, U.S. Virgin Islands. In: H. Kalb and T. Wibbels (Editors), 1999. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443. pp.268-269.

Eckert, K.L., 1987. Environmental Unpredictability and Leatherback Sea Turtle (*Dermochelys coriacea*) Nest Loss. Herpetologica 43(3):315-323.

Eckert, K.L., 1999. Oral Presentation. WIDECAST.

Eckert, K.L., S.A. Eckert, T.W. Adams, and A.D. Tucker, 1989. Inter-nesting Migrations by Leatherback Sea Turtles (*Dermochelys coriacea*) in the West Indies. Herpetologica 45(2):190-194.

Eckert, S.A., 1997. Distant Fisheries Implicated in the Loss of the World's Largest Leatherback Nesting Populations. Marine Turtle Newsletter 78:2-7.

Eckert, S.A., 1999. Data Acquisition Systems of Monitoring Sea Turtle Behavior and Physiology. In: K.L. Eckert, K.A. Bjorndal, F.A. Abreu-Gobois, and M. Donnelly (Editors), 1999. Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, 235p., pp.88-93.

Fretey, J., and A. Billes, 2000. Les Plages du Sud Gabon: Derniere Grande Zone de Reproduction de la Planete Pour la Tortue Lute? NDIVA Complément Écosystèmes Marins Canopee 17:1-4.

Fretey, J., and M. Girondot, 1990. Numbering and Tagging of Leatherbacks for Four Years on French Guiana Beaches. In: T.H. Richardson, J.I. Richardson, and M. Donnelly (Editors), 1990. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278, 286p., pp.201-204.

García-Téllez, N. and L. Sarti-Martínez, 2000. Management of Nests in *Dermochelys coriacea*. In: H. Kalb and T. Wibbels (Editors), 1999. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443. pp.47-49.

Girondot, M., and J. Fretey, 1996. Leatherback Turtles, *Dermochelys coriacea*, Nesting in French Guiana, 1978-1995. Chelonian Conservation and Biology 2(2):204-208.

Girondot, M., J. Fretey, I. Prouteau, and J. Lescure, 1990. Hatching Success for *Dermochelys coriacea* in a French Guiana Hatchery. In: T.H. Richardson, J.I. Richardson, and M. Donnelly (Editors), 1990. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278, 286p., pp.229-232.

Godfrey, M.H., R. Barreto, and N. Mrosovsky, 1996. Estimating Past and Present Sex Ratios of Sea Turtles in Suriname. Canadian Journal of Zoology 74:267-277.

Godfrey, M.H., M.L. Hilterman, and G. Talvy, 2001, Seasonal Sand Temperature Profiles of Three Major Leatherback Nesting Beaches in the Guyana Plateau. Pressentation at the Twenteeth Annual Symposium on Sea Turtle Biology and Conservation. *In press*.

Goverse, E. and M. Hilterman, 2002. Aerial Survey of the Surinam Coastline between the Marowijne and Suriname River 2001, 2000, 1999 and 1997. Technical Report World Wildlife Fund for Nature (WWF)/Biotopic Foundation Amsterdam, 39p.

Hall, K.V., 1988. The Relationship Between Body Size and Reproductive Characteristics in the Leatherback Sea Turtle (*Dermochelys coriacea*). In: B.A. Schroeder (Editor), 1988. Proceedings of the Eighth Annual Conference on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-214, 146p., pp.29-32.

Hall, K.V., 1990. Hatching Success of Leatherback Turtle (*Dermochelys coriacea*) Clutches in Relation to Biotic and Abiotic Factors. In: T.H. Richardson, J.I. Richardson, and M. Donnelly (Editors), 1990. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278, 286p., pp.197-200.

Hill, R.L., 1971. The Effects of Rupturing Eggs in Sea Turtle Nests on the Hatchling Emergence Percentage. Mededeling 2, Stichting Natuurbehoud Suriname (STINASU). Surinam Turtle Notes-3:14-16.

Hilterman, M.L., 2001. The Sea Turtles of Suriname. 2000. Guianas Forests & Environmental Conservation Project (CFECP). Technical Report World Wildlife Fund for Nature (WWF)/Biotopic Foundation Amsterdam, 63p.

Hirth, H.F., 1980. Some Aspects of the Nesting Behaviour and Reproductive Biology of Sea Turtles. Presented at: Symposium on Behavioural Biology of Sea Turtles. American Zoologist 20(3):507-523.

Hoekert, W.E.J., L.H.G. van Tienen, P. van Nugteren, and S. Dench, 2000. The 'Sea Turtles of Suriname 1997'-Project: Comparing Relocated Nests to Undisturbed Nests. In: F.A. Abreu-Grobois, R. Briseño-Dueñas, R. Marquez-Millán, and L. Sarti-Martínez (Editors). Proceedings of the Eighteenth International Sea Turtle Symposium. NOAA Technical Memorandum NMFS-SEFSC-436, 293p., pp.192-194.

Hughes, G.R., 1996. Nesting of Leatherback Turtles (*Dermochelys coriacea*) in Tongaland, KwaZulu-Natal, South Africa, 1963-1995. Chelonian Conservation and Biology 2(2):153-158.

Klooster, C.I.E.A. van 't, 1999. Sea Turtles in Suriname: A Nature Conservation Project to Protect Three Species of Sea Turtles by Optimizing Nesting Locations. Free University Amsterdam, The Netherlands, 62p.

Leslie, A.J., D.N. Penick, J.R. Spotila, and F.V. Paladino, 1996. Leatherback Turtle, *Dermochelys coriacea*, Nesting and Nest Success at Tortuguero, Costa Rica, in 1990-1995. Chelonian Conservation and Biology 2(2):1159-168.

Limpus, C.J., and N. Nicholls, 1988. The Southern Oscillation Regulates the Annual Numbers of Green Turtles (*Chelonia mydas*) Breeding around Northern Australia. Aust. J. Wildl. Res. 15:157-61.

Limpus, C.J., and N. Nicholls, 1992. Progress Report on the Study of the Interaction of the El Nino Southern Oscillation on Annual *Chelonia mydas* Numbers at the Southern Great Barrier Reef Rookeries. Methodological Reviews 1992:73-78.

McDonald, D., and P. Dutton, 1994. Tag Retention in Leatherback Sea Turtles (*Dermochelys coriacea*) at the Sandy Point, St. Croix, U.S. V.I. In: B.A. Schroeder, and B.E. Witherington (Editors), 1994. Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-341, 281p., pp.253.

McDonald, D., and P. Dutton, 1996. Photoidentification of Leatherback Sea Turtles (*Dermochelys coriacea*) at the Sandy Point National Wildlife Refuge, St. Croix, U.S. V.I. In: J.A. Keinath, D.E. Barnard, J.A. Musick, and B.A. Bell, 1996. Proceedings of the Fifteenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-387. 355p., pp.200.

McGehee, M.A., 1990. Effects of Moisture on Eggs and Hatchlings of Loggerhead Sea Turtles (*Caretta caretta*). Herpetologica 46(3):251-258.

Mo, C.L., I. Salas, and M. Caballero, 1990. Are Fungi and Bacteria Responsible for Olive Ridley's Egg Loss? In: T.H. Richardson, J.I. Richardson, and M. Donnelly (Editors), 1990. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278, 286p., pp.249-252.

Morreale, S.J. G.J. Ruiz, J.R. Spotila, and E.A. Standora, 1982. Temperature-dependent Sex Determination: Current Practices Threaten Conservation of Sea Turtles. Science 216:1245-1247.

Mortimer, J.A., 1990. Marine Turtle Conservation in Malaysia. In: T.H. Richardson, J.I. Richardson, and M. Donnelly (Editors), 1990. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278, 286p., pp.21-24.

Mrosovsky, N., 1983. Ecology and Nest-site Selection of Leatherback Turtles *Dermochelys coriacea*. Biological Conservation 26(1):47-56.

Mrosovsky, N., 1994. Sex Ratios of Sea Turtles. Journal of Experimental Zoology 270(1):16-27.

Mrosovsky, N., P.H. Dutton, and C.P. Whitmore, 1984. Sex Ratios of Two Species of Sea Turtle Nesting in Suriname. Canadian Journal of Zoology 62:2227-2239.

Paladino, F., 1999. Leatherback Turtle Workgroup at the 19th Annual Symposium. Marine Turtle Newsletter 86:10-11.

Pritchard, P.C.H. 1971. The leatherback or leathery turtle. IUCN Monograph No.1:Marine Turtle Series.

Pritcherd, P.C.H., 1982. Nesting of the Leatherback Turtle, *Dermochelys coriacea*, in Pacific Mexico, with a New Estimate of the World Population. Copeia 1982(4):741-747.

Pritchard, P.C.H., and P. Trebbau, 1984. Turtles of Venezuela. Society for the Study of Reptiles and Amphibians. Contrib. to Herpetology No.2. 403p.

Reichart, H. A., 1993. Synopsis of Biological Data on the Olive Ridley Sea Turtle *Lepidochelys olivacea* (Escholtz 1829) in the Western Atlantic. NOAA Technical Memorandum, NMFS-SEFSC-336, Miami, Florida, U.S.A. 78p.

Reichart, H. A., and J. Fretey, 1993. WIDECAST Sea Turtle Recovery Action Plan for Surinam. K.L. Eckert, (Editor), CEP Technical Report No. 24. UNEP Caribbean Environment Programme, Kingston, Jamaica; 1993, 65p.

Rimblot-Baly, F, J. Lescure, J. Fretey, and C. Pieau, 1987. Sensibitite a la Temperature de la Differencation Sexuelle Chez la Turtue Luth, *Dermochelys coriacea* (Vandelli, 1761): Application des Donnees de l'Incubation Artificielle a la Etude de la Sex-ratio dans la Nature. Ann. Sci. Nat. Zool. (Paris) 8:277-290.

Sarti, L., S. Eckert, P. Dutton, A. Barragán and N. García, 2000. The Current Situation of the Leatherback Population on the Pacific Coast of Mexico and Central America, Abundance and Distribution of the Nestings: an Update. In: H. Kalb and T. Wibbels (Editors), 1999. Proceedings of the Nineteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-443. pp.85-87.

Schulz, J.P., 1968. Zeeschildpadden Deel II: Zeeschildpadden in Suriname. Revised Edition. Dienst 's Landsbosbeheer Suriname, Paramaribo. 123p.

Schulz, J.P., 1975. Sea Turtles Nesting in Surinam. Zoologische Verhandelingen. Leiden, E.J. Brill, The Netherlands. No.143.

Schulz, J.P., 1980. Zeeschildpadden die in Suriname Leggen. Natuurgids Serie B, No. 5, Stichting Natuurbehoud Suriname (STINASU). Vaco-press Grafische Industrie N.V. Paramaribo, Suriname. 113p.

Schwandt, A.J., K.L. Williams, A.C. Steyermark, J. Spotila, and F.V. Paladino, 1996. Hatching Success of the Leatherback Turtle (*Dermochelys coriacea*) in Natural Nests at Playa Grande, Costa Rica. In: J.A. Keinath, D.E. Barnard, J.A. Musick, and B.A. Bell, 1996. Proceedings of the Fifteenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-387. 355p., pp.290.

Sokal, R.R., and F.J. Rohlf, 1987. Introduction to Biostatistics. W.H. Freeman and Company-New York. Second edition (Sixth printing 1996). 363p.

Spotila, J.R., A.E. Dunham, A.J. Leslie, A.C. Steyermark, P.T. Plotkin, and F.V. Paladino, 1996. Worldwide Population Decline of *Dermochelys coriacea*: Are Leatherback Turtles Going Extinct? Chelonian Conservation and Biology 2(2):209-222.

Spotila, J.R., R.D. Reina, A.C. Steyermark, P.T. Plotkin, and F.V. Paladino, 2000. Pacific Leatherback Turtles Face Extinction. Brief Communications. Nature 405:529-530.

Spotila. J.R., E.A. Standora, S.J. Morreale, and G.J Ruis, 1987. Temperature Dependent Sex Determination in the Green Turtle (*Chelonia mydas*): Effects on the Sex Ratio on a Natural Nesting Beach. Herpetologica 43:74-81.

Spotila, J.R., A.C. Steyermark, and F.V. Paladino, 1998. Loss of Leatherback Turtles from the Las Baulas Population, Costa Rica, from 1993-1998: Causes and Corrective Actions.

Steyermark, A.C., K. Williams, and J.R. Spotila, F.V. Paladino, D.C. Rostal, S.J. Morreale, M.T. Koberg, and R. Arauz, 1996. Nesting Leatherback Turtles at Las Baulas National Park, Costa Rica. Chelonian Conservation and Biology 2(2):173-183.

Tucker, A.D., 1989. So Many Turtles, So Little Time: Underestimating Fecundity and Overestimating Populations? In: S.A. Eckert, K.L. Eckert, and T.H. Richardson (Editors), 1989. Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum NMFS-SEFC-232, 306p., pp.181-184.

Tucker, A.D., 1990. A Test of Scatter-nesting Hypothesis at a Seasonally Stable Leatherback Rookery. In: T.H. Richardson, J.I. Richardson, and M. Donnelly (Editors), 1990. Proceedings of the Tenth Annual Workshop on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFC-278, 286p., pp.11-14.

Tucker, A.D., and N.B. Frazer, 1991. Reproductive Variation in Leatherback Turtles, *Dermochelys coriacea*, at Culebra National Wildlife Refuge, Puerto Rico. Herpetologica 47(1):115-124.

Verkade, A., 2000. Verplaatsing van Zeeschildpadden Nesten in Suriname heeft Negatieve Gevolgen op Uitkomstpercentages. Stageverslag, University of Amsterdam.

Whitmore, C.P., and P.H. Dutton, 1985. Infertility, Embryonic Mortality and Nest-Site Selection in Leatherback and Green Sea Turtles in Suriname. Biological Conservation 34(3):251-272.

Yntema, C.L., and N. Mrosovsky, 1980. Sexual Differentiation in Hatchling Loggerheads (*Caretta caretta*) Incubated at Different Controlled Temperatures. Herpetologica 36(1):33-36.

Zug, G.R., and J.F. Parham, 1996. Age and Growth in Leatherback Turtles, *Dermochelys coriacea* (Testudines: Dermochelyidae): a Skeletochronological Analysis. Chelonian Conservation and Biology 2(2):244-249.

Appendices

Appendix 1.1 Nightly monitoring sheet

Nightly monitoring sheet

date	person	time	activity	PIT tag #	new/old	CCL	CCW	section x-axis	STL	HTL	Remarks

Abbreviations

A	arriving	STL	distance to spring tide line
BP	body pitting		
DN	digging nest	HTL	distance to high tide line
LE	laying eggs		
CN	closing nest	CCL	curved carapace length
Ca	camouflaging	CCW	curved carapace width
De	departing		

Appendix 1.2 Nest excavation sheet

Nest excavation sheet

Species:	

Beach:	
Section/x-axis	

STL	
T.A.D:	
E.D:	
D.U.D.	

Nest #	
Person:	

Hatched Eggs:	
False Eggs:	
Dug-up Alive:	
Dug-up Dead:	
Pipped:	

Abbreviations

STL	distance to spring tide line
T.A.D:	turtle activity date
E.D:	emergence date
D.U.D.	dug up date

Damage	Undeveloped	Early Stage	Mid Stage	Late Full Term	Unidentified Rotten	Empty (not hatched)
None						
Mole Cricket						
Ghost Crab						
Remarks:						

#	Hatchling: Size (mm)	Weight (g)
1		
2		
3		
4		
5		

#	Hatchling: Size (mm)	Weight (g)
6		
7		
8		
9		
10		

Appendix 2.1 Additional figures: hatch success

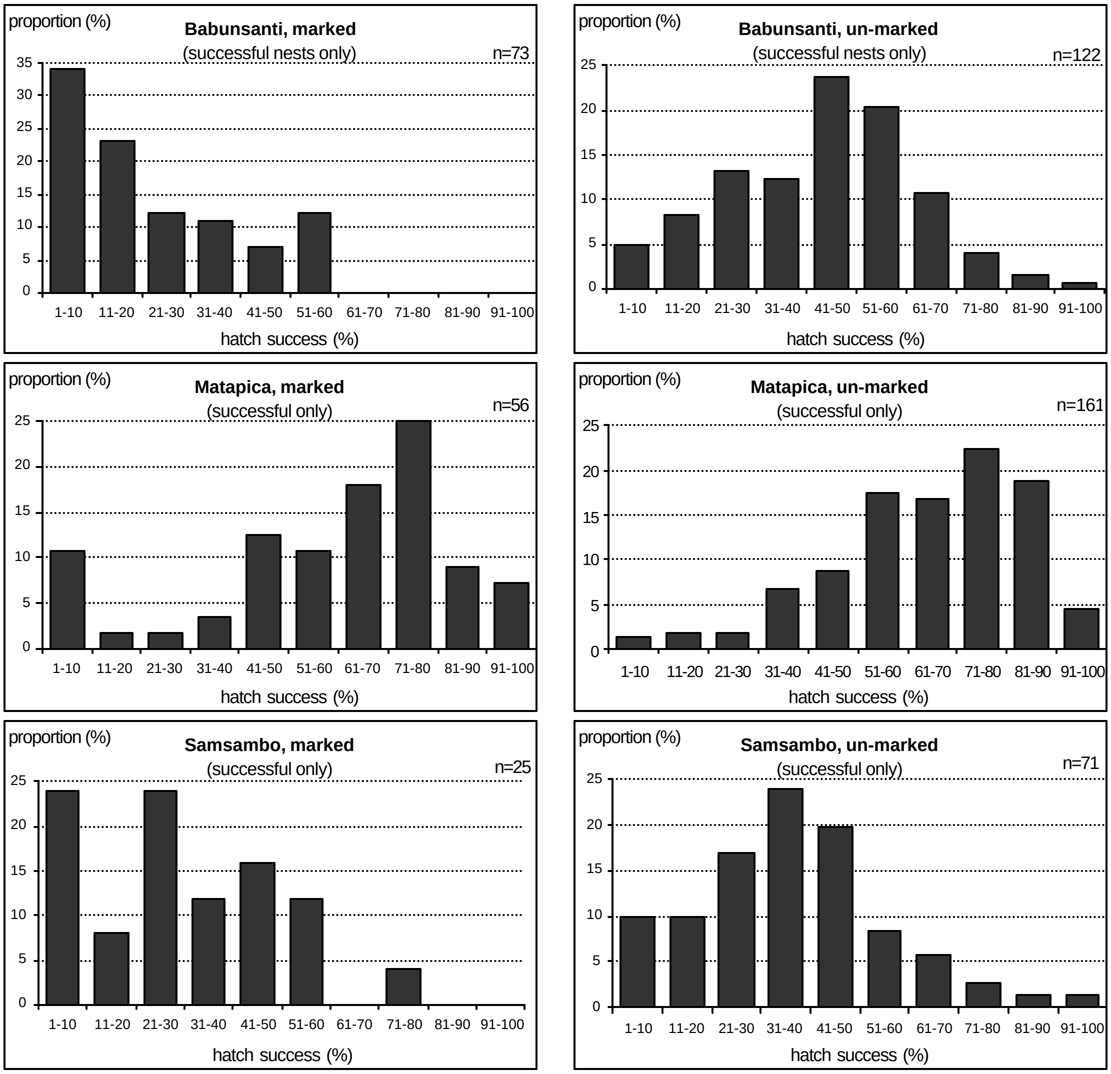
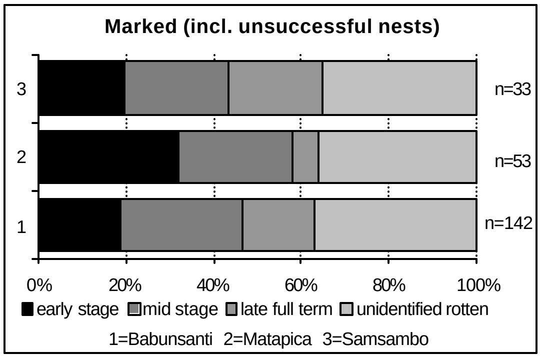
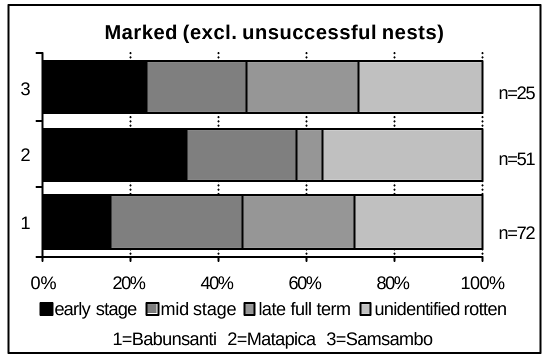


Figure Frequency distribution of hatch success of marked nests (successful nests only) and un-marked nests (successful nests only) on Babunsanti, Matapica and Samsambo.

Note:
On Babunsanti, only un-marked nests that were high up the beach and had hatched well were commonly noticed, because the beach is narrow and tides and wind easily wash away hatchling tracks. This may have resulted in a much distorted and higher observed hatch success, as nests with low hatch success were often not noticed and not excavated. The hatch success distribution is thus not expected to be representative. The same is to a lesser extent true for Matapica and Samsambo.

Appendix 2.2 Additional figures: embryonic mortality





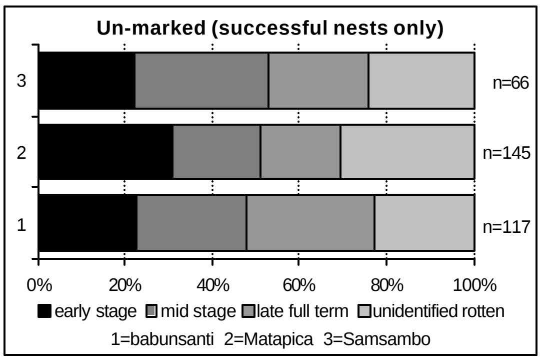


Figure Embryonic mortality for un-predated eggs of marked and un-marked nests.