Livingstone, Suzanne Rachel (2006) *Sea turtle ecology and conservation on the North Coast of Trinidad, West Indies.*

PhD thesis

Sea Turtle Ecology and Conservation on the North Coast of Trinidad, West Indies

Suzanne Rachel Livingstone

Doctor of Philosophy

University of Glasgow

Division of Environmental and Evolutionary Biology

Institute of Biomedical and Life Sciences

Submitted: November 2005

Accepted: March 2006

DARWIN INITIATIVE

UNIVERSITY of GLASGOW

IBLS

CONTAINS

PULLOUTS

Declaration of original work

I hereby declare that the research described within this thesis is my own composition, and that the thesis is my own work. I certify that it has never been submitted for any other degree or professional qualification.

The work presented here has, in part, been published in the following scientific peer reviewed journals:

Livingstone, S.R. 2005. Report of olive ridley (*Lepidochelys olivacea*) nesting on the north coast of Trinidad. Marine Turtle Newsletter 109:6.

Livingstone, S.R. and Downie, J.R. 2005. Marine turtle conservation on the north coast of Trinidad - a Darwin Initiative project. Testudo 6:3-16.

Suzanne R Livingstone
DEEB, University of Glasgow
Final submission: June 2006

Abstract

Five species of sea turtle are known to nest on the north and east coast beaches of Trinidad, West Indies. In descending order of abundance: the leatherback (*Dermochelys coriacea*), the hawksbill (*Eretmochelys imbricata*), the green (*Chelonia mydas*), the olive ridley (*Lepidochelys olivacea*) and the loggerhead (*Caretta caretta*). This thesis investigates a number of aspects of the ecology and conservation of the sea turtles nesting and foraging on the north coast. Prior to this project, little research had been carried out on the north coast region, largely due to the difficulties of accessing the nesting beaches. The main aims of the project include making reliable estimates of the annual nesting population size of each species, to identify the main threats to the turtles at various life stages, and to make recommendations on how best to conserve the sea turtles in Trinidad.

A historical account of sea turtle research and conservation in Trinidad was compiled (chap.2). This highlights past and present levels of exploitation, reviews the legislation protecting sea turtles, and emphasizes the importance of reliable up-to-date estimates of nesting turtles. Most past available literature concentrates on the leatherback turtle, as they are the most numerous species. This thesis also focuses on the leatherback, but the other species are reviewed too.

All the beaches on the north coast were surveyed and fourteen were identified as being suitable for sea turtle nesting (chap.3). Each was classified as either a low or high density leatherback nesting beach (nests/km). Leatherbacks exhibited a preference for nesting beaches with a deeper seaward approach, steeper gradient and coarser sand, all of which were significantly dependent on each other, and fewer submerged rocks and reefs. There was also some evidence to suggest they preferred beaches and with less human alteration and artificial lighting. Examining the possible reasons for female beach choice was useful for identifying the most important beaches for sea turtle protection and raises considerations for future development of the coastline.

Four years of intensive monitoring of nesting leatherbacks and nests on the north coast beaches provided a reliable annual mean estimate of 3,230 (2,300 - 4,030) nesting females, contributing to an estimated annual nesting population of approximately 5,000 for Trinidad as a whole (chap.4). Based on this estimate, Trinidad's population of nesting leatherbacks is possibly the third largest remaining in the Atlantic. These figures are much higher than previous estimates, especially for the understudied north coast area. Evaluation of past data suggests a significant increase in leatherback numbers over the last 30 years. A combination of conservation efforts on several east coast beaches and a reduction in the number of hatchling predators in the coastal waters from increased fishing practices are suggested as the main reasons for the increase. A total of 322 leatherbacks were tagged with Monel and AVID PIT tags in 2004. The tag return data provided evidence for some beach fidelity in north coast nesters (88 % of returning leatherbacks were seen to nest on the same beach as they had been tagged). Although the leatherbacks using the north and east coast of Trinidad are considered as one population, tag data, and recently published satellite telemetry work highlighted that nesting females showed preference for nesting on the beaches of one particular coastline.

Incidental entanglement in gillnets has been previously identified as the most serious threat to leatherbacks in Trinidad. Questionnaire-based surveys (n = 36) were used to calculate approximate numbers of leatherback captures and deaths as a result of gillnets (chap.6). The reliability of the fishermen interviews and resulting estimates are discussed. Leatherbacks were rarely taken for sustenance, and were treated by fishermen as bycatch and a pest. Due to frequent net tending, leatherbacks rarely drowned in nets and the majority of deaths were inflicted by fishermen through frustration at net and catch damage. Some fishermen were more willing to discuss this than others.

From the fisherman's perception, an approximate 4,620 (1,800 - 7,700) leatherbacks are captured in gillnets on the north coast annually, and a mortality rate of 28 % (26 - 30 %) suggests that approximatly 1,290 (1,200 and 1,380) leatherbacks (both males and females) are killed in north coast gillnets each year. Considering the numbers of female leatherbacks nesting on the north coast, this level of adult mortality is most likely unsustainable, depending on the recruitment rate of new individuals, which is currently not known. Possible means of gillnet capture mitigation involve a combination of area/temporal closures and alternative fishing methods. It is essential to work in partnership with the fishing industry towards the development and organization of a management plan for it to be successful.

Small numbers of hard-shell turtles nest in Trinidad (chap.5). Hawksbills were relatively common on the north coast with an estimated annual nest count of 675 (equating to approximately 150 nesting females). Four green turtles were witnessed nesting; one olive ridley, and no loggerheads were seen. There are also large foraging aggregations of hawksbill and green turtles inhabiting Trinidad's coastal waters. A legal sea turtle fishery still exists in Trinidad during an open hunting season (30th September till 1st March), targeting hard-shell turtle species. Although there are few recent data available, an estimated

1,000 turtles are allegedly caught each year. It is likely that this affects populations of nesting green and hawksbill turtles elsewhere. Further investigation into the extent of the catch of the directed sea turtle fishery, and of bycatch in the shrimp trawling industry is recommended. It is recommended that the nesting hawksbills and foraging populations of both greens and hawksbills be sampled for genetic profiling and mixed stock analysis of the foraging grounds and fishery catch.

The leatherback nest success for the north coast beaches was calculated as 49 % (chap.7). The main dangers to nests were identified as erosion, inundation and predation. The level of these threats differed from beach to beach depending on topographic and human-related characteristics. Natural predation levels of nests and hatchlings on the remoter beaches were relatively low. Predation rates were higher on beaches located in villages due to the large number of dogs. Approximately 12.7 % of the successful nests on the north coast were infested with dipteran larvae. However, the larvae were thought not to pose any serious threat to nest success, with the insects most likely being attracted to less successful nests by the olfactory emissions of already dead hatchlings and eggs within the nest. The mean hatching success of leatherback nests on the north coast was relatively high compared to populations in other regions (73.3 %). The main nest parameters affecting hatching success were nest depth and viable clutch size, most likely due to how these variables influence the gas exchange, moisture levels and temperature in the nest environment.

Overall, this thesis offers an up-to-date overview of the status of the sea turtle populations nesting on the north coast of Trinidad. The results presented here highlights Trinidad's importance as a region for turtles, especially for nesting leatherbacks, foraging greens and nesting and foraging hawksbills. This study will be useful in assisting the Trinidadian Government to meet their obligations under the Biodiversity Convention, and in facilitating the assessment of the remaining leatherbacks in the Atlantic. Recommendations are made for future conservation and management.

Acknowledgments

I would like to begin my acknowledgments by thanking the most important person, my mentor and friend, Roger Downie, who gave me the opportunity to pursue my studies and provided invaluable assistance in all stages of the preparation of this thesis. He has been extremely supportive and encouraging throughout, feeding me inspiration, and I admire him greatly for his patience, diplomacy, and positive outlook at all times.

I wish to give a huge thank you to Dr Joanna Smith and Dan Thornham for their statistical advice, moral support and friendship, and always being there when I needed them. Thank you also to Neil Metcalfe and Kevin Murphy for statistical support, and to Geoff Hancock with assisting with insect identification. Thank you to Lorna Kennedy and Florence McGarrity for their fantastic administrative assistance, and for the little things which all add up. Thank you to Nosrat Mirzai and Scott Arkinson for technical assistance. Thanks also to friends Jørn Lennart Larsen and John MacDonald for support and extremely useful comments on my writing. Thank you to Malcolm Kennedy and Brendan Godley for making my viva an enjoyable experience, and for help with the final manuscript.

I would like to express gratitude to all my Trinidadian counterparts, of whom there are many. Thanks to Stephen Poon and Nadra Nathai-Gyan from the Trinidad Wildlife Section who have been supportive and resourceful throughout the project, and granted me permission to conduct my fieldwork. Thank you to the GRNTGA (Nicholas Alexander and Len Peters) and GREAT (Sherwin Ruiz) from Grande Riviere who were always accommodating and welcoming on their beach. Much gratitude is due to the Matelot Community College and Primary School (Kent Jadine and Maurice Innes) where the training and education sessions were held. And thank you to all the participants of the course, especially Neil Cummings, who will always be missed. The members of the Pawi, Sports Culture and Eco Club; especially Renwick Roberts, Recardo Patrong, Anthony Hollis Briggs, Christopher Patron and Maria Penny, I thank for making my fieldtrips to the north coast so colourful and memorable, for all their hard work on the beaches, and excellent fish and bake. I could not have done it without them. I gratefully acknowledge the Nature Seekers, Karen and Scott Eckert (WIDECAST), and Peter Dutton for helping with the acquisition of tagging equipment, and other support. Thanks to Mr Selwyn Gomes from the TFNC and Ms Lori Lee Lum from the Institute of Marine Affairs for helping source difficult to find material, and to Richard Laydoo and Nicola Cross from the UNDP and Dominic Salvary and Opio Morani from TTOL for assisting with the initial set up of the project.

I am indebted to Kelvin Siew and family, Karen and Jimmy Dhun, Tony Dougdean, Andrea Farrell, Trunies, and Daria St Hill who were amazing help in Trinidad, sorting out the majority of my logistical troubles, and for their friendship. A very special thank you to my exceptional friend Kelvin, who was always there when I needed him, through thick and thin. From Matelot, I would like to thank the fishermen at the Matelot depot, especially Jose Marcano, Royer, Sean and Mr James for helping with the ever-breaking down truck, Mr and Mrs Stewart for always having a nice friendly smiling face, and Arlene, Fallon and Josh for their companionship.

I am indebted to the tireless support of all of my field assistants: Stephen Rudd, Duncan Jamieson, Jenny Barr, Kirsten Archibald, Chris McLaren, Brian Pickles, Kevin Butterworth, Iain MacPherson, Craig Bloomer, Ross Culloch, John Clark, Lindsey Duncan, Ben Mitchell, Alex Hayward, Michael Jowers, Euan Riddell, Stephen Larcombe, Iain Fulton, Andrew Walmsley, Peter Crayk, Jamie Fry, and in particular, Jennifer Livingstone and Debbie McNeill (my girls), all of whom helped with my data collection, and who provided moral support and friendship throughout the years. Thanks also to all the members of the Glasgow University Trinidad expeditions in 2000, 2002, 2003 and 2004. And special thanks to Naomi for being my surrogate mum while in Trinidad. Thank you to Colin Gambles and the Buckland School group and the Madventurer team who participated in the ecotours on the north coast, and made them most enjoyable. Thanks also to and Jon and Ann Gambles, and Mum and Alastair Hamilton for being great company on the ecotour in 2003.

I wish to thank the Darwin Initiative for the Survival of Species (DEFRA) who provided the bulk of the funding for the project. I would also like to express thanks to the People's Trust for Endangered Species, the British Chelonia Group and the Percy Sladen Memorial Trust for additional funding and support.

Last, but by no means least, I wish to thank my loving family for all their encouragement, motivation and interest; my wonderful mother and father Loraine and Eric, my two beautiful sisters Jennifer and Pamela, who all took the time to visit me in the field, and the support, patience and understanding of Andrew.

Table of contents

List of figures

List of tables

1. Project overview

1.1 Sea turtles

There are seven living species of sea turtle belonging to two families: the Cheloniidae and the Dermochelydae. Only the leatherback turtle (*Dermochelys coriacea*) belongs to the Dermochelydae, while the other six species: loggerhead *(Caretta caretta)*, green *(Chelonia mydas)*, hawksbill *(Eretmochelys imbricata)*, olive ridley *(Lepidochelys olivacea)*, Kemp's ridley *(Lepidochelys kempi)* and flatback (*Natator depressus*) are Chelonids, characterized by their hard shell. Sea turtles are found mainly in tropical regions, though some inhabit temperate waters. All species migrate to some degree between foraging and nesting grounds.

The seven species of sea turtle share many common characteristics of life history, exhibiting stereotyped nesting behaviour and iteroparous reproduction (Miller, 1997). The major part of a sea turtle's life is spent at sea, with the males never returning to land after having hatched out of a nest on a sandy beach. The females only return to land to reproduce, laying a relatively large number of eggs several times in a season, usually nesting every two to three years (Ehrhart, 1982). Although many aspects of their biology and behaviours are similar, each sea turtle species has evolved a number of phenotypic features and behaviours to suit their different ecological niches.

Sea turtle populations can be difficult to census, mainly due to their marine life style. Some of the hard-shell species that inhabit coral reefs can be censused at sea using capture-recapture methods. Other species such as the leatherback, which are highly migratory and spend most of their time in pelagic habitats, are near impossible to census at sea. The most accessible approach to estimating turtle population size is to count nesting females on beaches during the reproductive season. Estimating annual nesting population sizes is a valuable conservation tool (Meylan, 1982a) and having reliable estimates over a period of time allows changes in numbers to be detected and levels of threat to be assessed. These estimates can also help to monitor the effectiveness of conservation and management practices. However, natural fluctuations in the recorded numbers of females caused by turtles not nesting every year may prejudice this method, and multiyear sampling is required to obtain a realistic estimate of female nesting population size. Individuals of some species also nest on numerous different beaches in one season making censusing difficult. Beach monitoring only provides information about the female fraction of the population, telling us nothing about the males and sex ratio. However, annual female nesting population size can be used as a proxy for the total population, even if the population structure is unknown.

Information about male sea turtles is scarce, especially pelagic species, although recent satellite telemetry technology is making it possible to understand more about male behaviour and migrations (James et al., 2005c). Beach based nesting population estimates are usually made from data collected by either aerial surveys or ground surveillance. The technique used depends on the size and accessibility of the region, and effort required to collect data for a reliable estimate to be made (Meylan, 1982a).

Sea turtles have associated predators during all life stages - eggs, hatchlings, juveniles and adults. The main predators of eggs are crabs (Hill and Green, 1971; Hitchens et al., 2004; Hilterman and Goverse, 2005) and small mammals such as pigs, racoons and mongooses (Stancyk, 1982). A number of invertebrates also invade nests (McGowan et al., 2001a; Allen et al., 2001; Maros et al., 2003). Other natural threats that affect nests are erosion by tides and freshwater outflows and inundation (Whitmore and Dutton, 1985). Hatchlings must contend with land predators such as crabs, mammals and birds for the short time that they are on the beach on the way down to the sea from their nest. Once in the sea, hatchlings face many more predators in near shore waters, including many fish species, sharks and invertebrates. This is most likely where the greatest predation of hatchlings takes place, although it is difficult to quantify (Hendrickson, 1958; Bustard, 1979). Once a turtle is beyond a certain size, there are fewer potential predators. Juveniles and adults of all turtle species are at risk from large sharks (Stancyk, 1982; Marquez, 1990), in particular the tiger shark (*Galeocerdo cuvier*) (Heithaus et al., 2002; 2005) and the great white shark (*Carcharodon carcharias*) (Cropp, 1979; Fergusson, et al., 2000). Killer whales (*Orcinus orca)* are also known predators of adult sea turtles (Caldwell and Caldwell, 1969; Pitman and Dutton, 2004). The level of predation on larger turtles is also difficult to measure, but it is believed to be nominal compared to earlier life stages (Fergusson et al., 2000).

Natural threats to the early life stages of sea turtles are heavy in comparison with that of the adult stage. This is consistent with the life history strategy of sea turtles: adults lay many clutches per season, each containing a large number of eggs, to contend with a high level of nest loss and predation of young; this is matched with longevity and low predation rates for adults. Alone, natural threats do not threaten sea turtle populations. However, together with human-related threats, natural threats have become a serious conservation issue for the survival of sea turtles.

Six of the seven recognised species of sea turtle are classified as either endangered or critically endangered by the International Union for the Conservation of Nature and Natural resources (IUCN) (IUCN, 2005). The flatback turtle is currently unclassified and under review, as data are presently considered deficient for an accurate assessment of its population size and conservation status (Limpus et al., 2002). Although most species of sea turtles are listed as globally endangered, not everyone agrees with the classifications. There has been much debate over the IUCN classifications in the last decade (Brackett, 1997; Meylan, 1998; Mrosovsky, 1997; 1998; 2003; 2004; Lamoreux et al., 2003; Pritchard, 2004; Seminoff, 2004b; Broderick et al., 2006), outlining reasons why sea turtles are a difficult group of animals to globally classify when there are both increasing and decreasing populations in different regions around the world. It is the opinion of some scientists that sea turtle species should be assessed regionally, or at least in terms of ocean basins (Mrosovsky, 2003, 2004; Seminoff, 2004b). An example for this point of view is the status of the leatherback turtle: in the Pacific Ocean the leatherback is close to extinction (Spotila et al., 2000); however there are several examples of increasing leatherback populations in the Atlantic Ocean (Girondot and Fretey, 1996; Hilterman and Goverse, 2002; Dutton et al., 2005; chap.4), yet the critically endangered classification covers both regions. The debate on whether global sea turtle populations are really endangered is ongoing; although it is certain that some local and regional populations are indeed in danger of becoming extinct.

The decline of sea turtle populations is attributed to a number of human-related activities such as widespread egg harvesting, accidental capture in fishing gear, degradation of foraging and nesting grounds, the slaughter of nesting females and purposeful capture of turtles at sea for meat and other products. The alteration of marine and coastal environments by humans has the potential to further damage sea turtle populations, such as through global climate change (Mrosovsky et al., 1984; Davenport, 1997), sea level rise (Daniels et al., 1993; Fish et al., 2005) and the modification and removal of important nesting beaches. Conservation should be aimed at the protection of sea turtles in both nesting grounds and foraging habitats.

1.2 Sea turtles in Trinidad

Trinidad is the most southerly island in the Caribbean chain, located 12 km northeast of Venezuela (fig.1.1). The flora and fauna of Trinidad is much more South American than typically Caribbean, and the Orinoco River plays an important role in the coastal systems around the island (Georges, 1983).

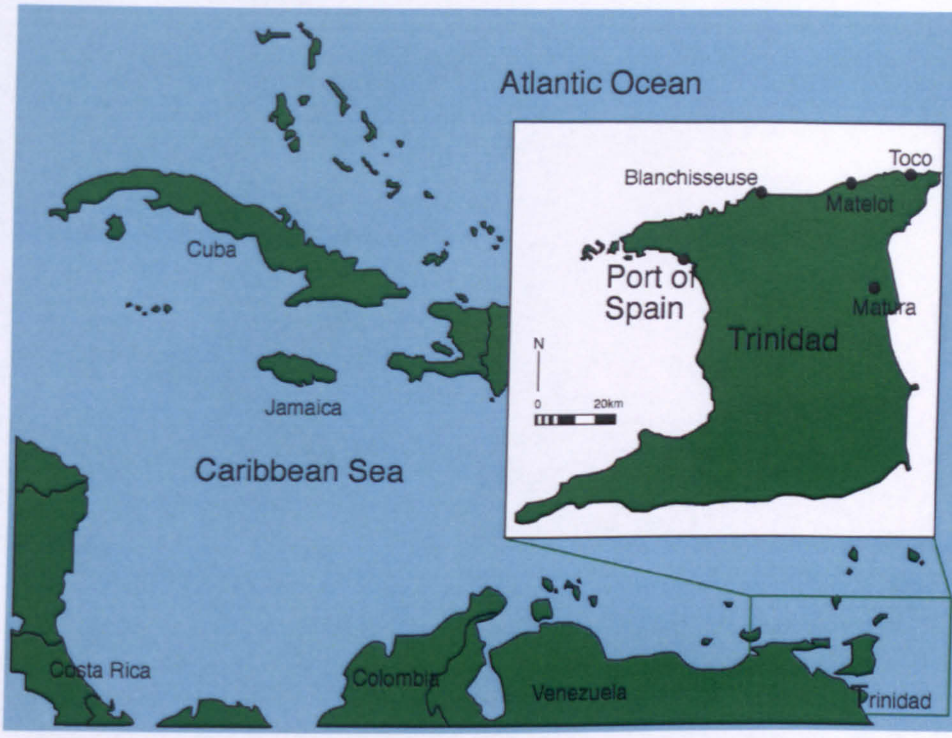


Figure 1.1 Location of Trinidad

Five species of sea turtle visit Trinidad's beaches, nesting mostly on the north and east coasts (Carr, 1956; Bacon, 1970; Chu Cheong, 1990; Gaskin, 1994; Fournillier and Eckert, 1997). The leatherback turtle (fig.1.2), listed as critically endangered by the IUCN (IUCN, 2005), is the most common species, and Trinidad's beaches support possibly the third largest leatherback rookery in the Atlantic (chap.4). The leatherback nesting season lasts from early March till late August (chap.4).

Figure 1.2 Leatherback turtle (*Dermochelys coriacea*)

The hawksbill turtle, also listed as critically endangered, and the green turtle, listed as endangered (IUCN, 2005), nest in much smaller numbers (chap.5). The hawksbill nesting season lasts from May till September with sporadic nesting occurring throughout the year (chap.5). The green turtle season is less definable due to very small nesting numbers. Most nesters have been encountered in August, although there have been reports from all year round. These two species are thought to be more numerous in the coastal waters than the numbers that are seen to nest on the beaches (Lum, 2003; chap.5). The olive ridley and the loggerhead (both listed by the IUCN as endangered) have been observed nesting in Trinidad, although as rare events (Bacon, 1970; Chu Cheong, 1990; 1995; Fournillier and Eckert, 1997; Livingstone, 2005; chap.5).

While the leatherbacks nesting on the east coast (Matura and Fishing Pond) and on Grande Riviere on the north coast of Trinidad (fig.1.3) are relatively well documented, before 2000 little was known about the turtles nesting on the more remote northern beaches (chap.2). The central strip of the northern coastline is undeveloped and there are no roads or habitations for approximately 22 km between the villages of Blanchisseuse (west) and Matelot (east) (fig.3.1). This area of remote coastline is interspersed with a number of sandy bays on which sea turtles nest (chap.3). The only ways to reach these beaches is by hiking through mountainous rainforest or by boat. For this reason, the beaches remain relatively untouched, although there has been recent illegal progression of the north coast road at the western end at Blanchisseuse (chap.3).

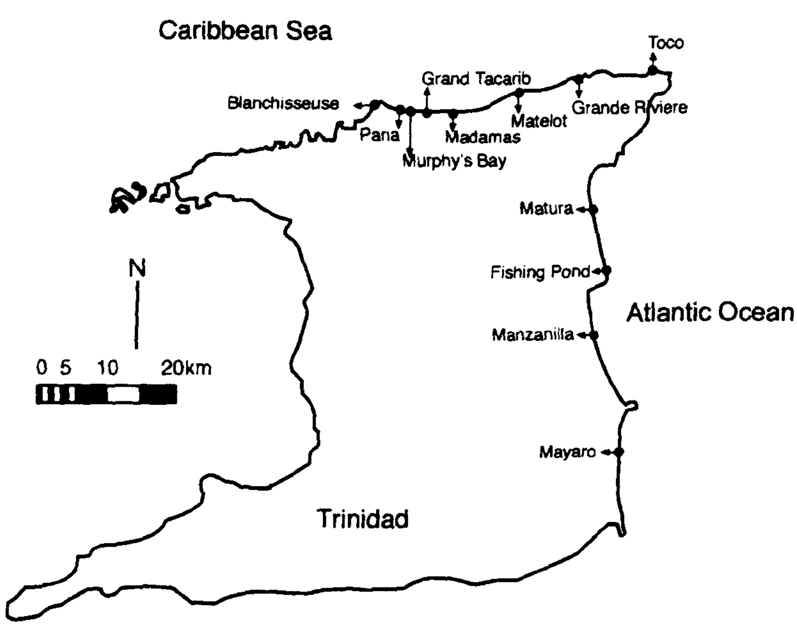


Figure 1.3 The main turtle nesting beaches on the east and north coast of Trinidad

The scientific community has been aware that turtles use the remote beaches since turtle research began in Trinidad (Bacon, 1969). However, monitoring was limited to brief overnight stays and a handful of aerial surveys (Pritchard, 1984; Chu Cheong, 1995; 2001; Godley et al., 2001a; 2001b). The lack of accessibility meant that no extensive work was previously carried out in that area (Lum, 2001).

1.3 Project rationale

The University of Glasgow Exploration Society ran expeditions to Trinidad in 1989 and 1991. One of the main projects was to investigate the sea turtle numbers nesting on Trinidad's east and north coast beaches. The work was mostly based at Matura on the east coast, although the teams also carried out short surveys of the sea turtles nesting on the north coast beaches in each year. A report was produced on the results of each trip (Godley et al., 1989; 1991). A short time after the Glasgow University visit in 1991, the Government set up a community-based turtle protection scheme on the east coast at Matura and Fishing Pond (James and Fournillier, 1993; Fournillier, 1992; 1995; 1996). The local groups embraced the concept of the community protection of the nesting turtles, and the Matura community developed into Nature Seekers, a successful NGO (Non Governmental Organisation) supported by the Government (appendix 1; chap.2). As a follow up to the 1989/1991 evaluations made by the Glasgow University Exploration Society, a trip was organised in 2000 to assess the turtles nesting on the east coast, to review the Nature Seekers activities, and to carry out a more intensive evaluation of the north coast beaches (Livingstone et al., 2000). Because the local groups on the east coast were effectively monitoring the main turtle beaches in that area, the 2000 study concentrated on the previously under-studied north coast beaches. The Glasgow University team worked in collaboration with the Trinidadian Government Wildlife Section, Nature Seekers, and two local groups based on the north coast (appendix 1 and 8). Once contact was made with the local group based in Matelot (Pawi, Sports, Culture and Eco Club), weekly trips to the remoter beaches on the north coast were arranged, initially on foot, and latterly by boat. The beach monitoring revealed much higher numbers of nesting leatherbacks than previously recorded (Livingstone et al., 2000).

The 2000 expedition provided the contacts and the initial baseline data for a Darwin Initiative funded project. The Darwin Initiative is a grants programme funded and administered by the UK Government Department for Environment, Food and Rural Affairs (DEFRA). The Initiative aims to promote biodiversity, conservation and sustainable use of resources in less developed countries, using British expertise. The programme stresses the importance of host country links and endeavours to leave behind a legacy, allowing projects to continue into the future (Livingstone and Downie, 2005; appendix 8). The Darwin project was set up to support community development, training, and turtle research and monitoring in the north coast area for a two-year period (2002 - 2004). An additional field season was carried out to collect sufficient data to complete the PhD research reported here. The main objectives were to accurately estimate the annual nesting populations of all species of sea turtle using the north coast beaches, to identify the threats to the turtles and their nests, and to train a group of local people to continue monitoring the turtle numbers into the future. The results of the research were to assist the Trinidadian Government to meet their obligations under the Biodiversity Convention, and to provide information for a management plan for the effective conservation of the sea turtles nesting on Trinidad's beaches and foraging in coastal waters.

At the end of the second year of the project it was brought to my attention by the Wildlife Section that a draft Sea Turtle Recovery Action Plan (STRAP) existed for Trinidad and Tobago, compiled by WIDECAST (Wider Caribbean Sea Turtle Conservation Network) (Fournillier and Eckert, 1997). This document was extremely important to the project as a window into the previous work that had been carried out in Trinidad, and highlighted many unpublished reports that would have otherwise remained undiscovered. Although many of the original reports were difficult to source I managed to locate them all, and in so doing discovered several more. From these, an up-to-date review of turtle research and conservation in Trinidad was compiled (chap.2), and provided a basis of information with which the research carried out on this project could be compared.

The STRAP for Trinidad and Tobago made a number of recommendations to the Trinidad Government in order for it to fulfil the mandate to safeguard the nation's sea turtle populations and to collect the data required to develop an effective management plan. One of the main recommendations was to conduct a comprehensive survey of all nesting beaches (Fournillier and Eckert, 1997). The document also recommended that the Government reinforce its ties to community-based organisations, and to seek partnerships to assist the Government in collecting the data required to make informed management decisions. Fournillier and Eckert (1997) highlighted that a national survey of this magnitude would be challenging and that a network of partners, co-ordinators and dedicated volunteers around the coastal region would be needed. At the time the document was received it had not yet been published or circulated, and no plan of action had yet been implemented to carry out the suggestions stipulated in the report. The Darwin project leader (Dr J.R. Downie) and I were pleased to find that our project was fulfilling several of the central recommendations set out by the STRAP for the north coast area.

The work presented here will be of considerable use to the Trinidadian Government, and to WIDECAST, who are currently updating the STRAP for Trinidad and Tobago for publication (S. Eckert, personal communication). The work will also benefit the sea turtle scientific community by providing up-to-date information on a number of species from a previously understudied area.

The title of the Darwin Initiative funded project was "sea turtle conservation and ecotourism on the north coast of Trinidad". A major part of the project involved community development, such as education about sea turtle ecology and conservation, and ecotour guide training. The success of this aspect was tested by setting up three ecotours over the duration of the project, and by assessing the constraints on development of ecotourism in this region of Trinidad. This part of the project is briefly reported on in appendix 8, and will be reported on in more detail elsewhere. This thesis concentrates on the conservation and ecology of sea turtles on Trinidad's north coast. Individual chapters provide full introductions to the different aspects covered, and also accounts of the methods used.

1.4 Project aims

The main aims of this project were:

- To review the past research and conservation of sea turtles in Trinidad, and to evaluate the Government's efforts to manage and conserve sea turtles as a resource
- To assess the beaches on the north coast suitable for nesting turtles, and to identify the most important beaches as areas for possible conservation management
- To determine why some beaches on the north coast receive more nesting leatherbacks than others using topographical and human-related characteristics
- To assess the annual nesting population size and status of all the sea turtles thought to nest on the north coast beaches, and to compare current estimates with past ones
- To study a number of aspects of the nesting ecology and inter-nesting behaviours of the leatherback turtle on the north coast, and to begin a leatherback tagging programme
- To identify the main threats to all life stages of sea turtles, from nests and hatchlings to nesting and foraging adults

- To assess the mortality rate of sea turtles in the artisanal gillnet fishery on the north coast of Trinidad from the viewpoint of the fishermen and to discuss the possible effects it could have on the nesting populations.
- To make suggestions for a more in-depth assessment of the capture and mortality rate of turtles in the gillnet fishery and to make recommendations for the mitigation of incidental entanglement of turtles
- To investigate the nest and hatching success of leatherback nests on the north coast beaches in relation to a number of measured nest parameters

2. Sea turtle conservation and research in Trinidad, West Indies: a historical review.

2.1 Introduction

Before 1967 records of sea turtles nesting on the beaches of Trinidad were scarce. Brief mentions were made in several publications (Ingle and Smith, 1949; Carr, 1956; Wyatt-Smith, 1960), but no estimates of numbers were given. The first literature documenting sea turtle research in Trinidad resulted from a study spanning 1965 - 1969 (Bacon, 1967; 1969; 1970). The work was motivated by growing concerns amongst local naturalist groups that there was an unsustainable level of illegal take from beaches, especially of the leatherback. The data collected in the first years were intended for the initiation of a conservation programme, and to provide an estimate of the overall number of nesting leatherbacks in Trinidad (Bacon, 1967). Members of the Trinidad Field Naturalists Club (TFNC) carried out the majority of the fieldwork, overseen by Bacon (Mootoosingh, 1979). Through this work Bacon highlighted the need to raise public awareness, to educate hunters, to revise the laws protecting sea turtles, and to continue the collection of data (Bacon, 1969; 1970). Additional investigations by local and foreign researchers in later years further emphasized the endangered status of sea turtles in Trinidad, and the significance of the remaining nesting turtles both regionally and internationally (Pritchard, 1984; Chu Cheong, 1990; Fournillier and Eckert, 1997; Godley et al., 2001a; 2001b).

The aim of this chapter is to present a historical review of sea turtle conservation and research in Trinidad. Past literature is scattered, hard-to-access, and contains a diversity of estimates for nesting leatherback numbers. Recent research has revealed that the number of nesting leatherbacks in Trinidad has possibly been underestimated in the past due to data collection techniques and the logistical difficulties associated with assessing the more remote nesting beaches. However, there is also evidence to suggest a major increase in the number of leatherbacks nesting on the beaches (chap.4). With respect to these findings it seems an appropriate time for an up-to-date review of the existing literature.

2.2 Exploitation

Sea turtles in Trinidad have been heavily exploited in the past, with records dating back to the early 17^{th} century (Fournillier and Eckert, 1997). These records are rather unclear and irregular, giving little insight into the species or numbers present or caught. However, they illustrate that turtle meat was a common commodity at that time, and that turtles were present in relatively large numbers. Various recent records give more detailed accounts;

Rebel (1947) states that 60,000 lbs [27,215 kg] of turtle meat was sold in 1947 in Port of Spain markets, and records from the Trinidad Fisheries Division (Ministry of Agriculture, Land and Marine Resources) show that an average of 4,883 kg of turtle meat was sold per year between 1969 and 1980 (Chu Cheong, 1995; [Anon, 1973] Mohammed and Shing, 2003). The accuracy of these figures should be treated with caution however, as many turtles would have been sold locally rather than in formal markets, and therefore not accounted for in Government records. It is unclear whether the differences in amounts of meat between these time periods were due to a decline in turtle numbers being caught, inadequate record keeping by the Fisheries Division, or a reduction in catch effort (Fournillier and Eckert, 1997). Nets designed specifically to catch turtles were introduced to the artisanal fisheries in Trinidad after the Second World War (Mohammed and Shing, 2003). The majority of meat from the turtle fisheries tended to be from hard-shell turtles rather than leatherbacks. Turtle shell, mostly from hawksbills, has also been traditionally exported from Trinidad ([Anon, 1973] Mohammed and Shing, 2003), although few records of amounts exist (chap.5). It seems that, certainly in recent years, leatherbacks have never been purposefully hunted at sea due to the difficulties of dealing with their large size. Most leatherback slaughter in Trinidad occurred on beaches when the females were laying their eggs (Pritchard, 1984).

Recent records of turtle slaughter mostly concern leatherbacks, as they are the most common nesters on Trinidad's beaches. In an interview with a Matura estate owner, Bacon (1969) heard how leatherbacks were sold (for food) in large numbers to the American Military base at Wallerfield during World War II where a bull was used to drag the turtles through the coconut plantations to a truck waiting on the Toco Road. Bacon (1969) described the scene when he visited Matura Beach in 1965 to investigate the rumours of high levels of slaughtered leatherbacks. There he witnessed many rotting carcasses and what appeared to be large amounts of wasted meat. The amount of waste was also commented on in the Wildlife Section's records when patrolling Fishing Pond and Matura Beach between 1983 and 1989 (James and Fournillier, 1993). Fishermen and hunters generally agree that the leatherback yields the least palatable turtle meat. For this reason, a proportion of leatherback meat was used for sport fishing (shark baiting) rather than for consumption (Bacon, 1969; James, 1983), an activity also performed in French Guiana (Pritchard, 1969). Leatherbacks were also slaughtered for their sexual organs, used locally as an aphrodisiac (James and Fournillier, 1993).

The proportion of the leatherbacks using the beaches that were slaughtered during the twentieth century is unclear. However, reports suggest that many were killed each season. In

1973, Bacon calculated that 30 – 50 % of nesting leatherbacks were slaughtered at Matura Beach on the east coast, and almost 100 % on some north coast beaches where the beach was easily accessible from the road (Bacon 1973a). James and Fournillier (1993) estimated that 50 - 70 leatherbacks were slaughtered annually in the 1970's and 1980's. A total of 68 carcasses were counted on Matura Beach in 1986, and it was believed that many others were missed due to being hidden, buried, or dumped out at sea (Nathai-Gyan et al., 1987). Egg collection was also noted to be a serious threat to the leatherback population at that time (Nathai-Gyan et al., 1987). The slaughter continued to be at a high level on the east coast beaches until around 1989 (James and Fournillier, 1993), although it was suggested that it had already been reduced to an extent by patrols during the 1980's (Gaskin, 1994). In 1993, no leatherbacks were killed at Matura, and there have been very few slaughters since (D. Sammy, personal communication.). Occasionally leatherbacks were killed on Grande Riviere beach in the 1990's (Fournillier and Eckert, 1997, [S. Ruiz, personal communication 1995]), but few turtle have been killed there since 1997 when the beach was designated a protected area (N. Alexander, personal communication). It is now rare for leatherbacks to be slaughtered on the north coast beaches although low levels of slaughter still occur in some northern villages for traditional celebrations such as the fishermen's fete (held in late June). Some slaughter also still occurs in Mayaro on the east coast where leatherback is traditionally eaten (Fournillier and Eckert, 1997). Hard-shell turtles are not commonly taken from the beach when nesting although there is evidence that increased numbers of nesting hawksbills have been slaughtered on the remote north coast beaches (chap.5). This is due to the rising number of campers using the beaches for recreation, taking hawksbills for their cooking pot.

A legal turtle fishery still exists in Trinidad during an open hunting season. Green and hawksbill turtles make up the bulk of the catch, with olive ridleys and loggerheads as rarities (Chu Cheong, 1995; chap.5). The leatherback turtle is not a target species of the turtle fishery, but they are often caught as bycatch in the artisanal gillnet fishery. Incidental entanglement in gillnets is currently the most serious threat to the nesting leatherback population in Trinidad (Eckert and Lien, 1999; Lum, 2003; chap.6). Reports suggest that there are many more greens and hawksbills in the coastal waters than the number that actually nest on the beaches (Chu Cheong, 1995; chap.5). It is possible that hard-shells from other nesting populations in the Atlantic use the Trinidad waters as foraging grounds (chap.5). There are currently eight fishing depots actively hunting turtles around Trinidad, although no records of quantity are now kept (Lum, 2003). Data collection was discontinued in 1980 when the Fisheries Division issued a new data collection form, and turtle recording was no longer listed as a requirement. The sea turtle fishery is now seasonal, and much smaller than in the past (Rebel, 1974; Chu Cheong, 1995; Lum, 2003); nevertheless, contrary to the Fisheries Division records (approximately 100 turtles caught per year from 1969 - 1980), James and Fournillier (1993) estimated that 1,000 hard-shell turtles are caught annually. If this estimate is accurate, there is a chance that the number of hard-shells caught in Trinidad waters is seriously affecting nesting populations elsewhere (chap.5). The turtle fishery is neither monitored nor managed, and is poorly regulated by inadequate laws that are problematical to enforce.

2.3 Legislation

The Protection of Turtle and Turtle Eggs Regulation (1952) under the Fisheries Act was the first law regarding the protection of sea turtles in Trinidad and Tobago, providing a closed hunting season between the months of June and September (Bacon, 1969). Bacon (1970) commented that this law was made as "an administrative convenience rather than as a reflection of the breeding biology concerned", as the duration of protection bore little resemblance to the actual nesting season. Enforcement of the law at that time was practically non-existent, and although the laws were vaguely recognized, few people took any notice of them (D. Harrison, personal communication). It was Bacon's endeavour to have these laws revised to properly accommodate the turtles' nesting seasons, which lasts from early March to late September (Bacon, 1969; 1970; chap.4 and 5). In 1975 the laws were amended by the Fisheries Act, Chapter 67:51, Section 4, which is still in force today (appendix 2). Under this legislation the closed season extends from 1st March to 30th September, when the taking of all turtles is prohibited, as is any purchase, sale or offer to sell turtle meat or other turtle products. Turtle eggs are protected all year round. During the open season from 1st October to 28th February it is legal to catch and sell turtles in Trinidad, although no female may be caught or killed either on the shore, within a reef, or within 1,000 yards of the shore at this time. Males can be caught in any area. Several loopholes in the laws exist, making it challenging to regulate catch in the open season. For example, there is no way in which to prove where a turtle, if female, was caught, and it is difficult to tell the difference between male and female turtles unless they are sexually mature. These ambiguities affect the hard-shell turtles much more than leatherbacks, which are rarely present in Trinidad's waters at the end of September.

Several law revisions have been suggested to make regulating the open turtle season more effective e.g. the introduction of a size limit (Pritchard, 1984). In 1983, the Trinidad Government's Wildlife Section put forward a proposal for a total ban on catching turtles

(Lum, 2001), and there has been some recent pressure by several NGO's in Tobago (Environment Tobago and SOS Tobago) to amend the laws to make protection more comprehensive (Tanya Clovis, personal communication). However, the laws remain unchanged at the current time, and enforcement continues to be limited.

In 1990, the successful enforcement of a provision under the Forests Act was put in place, and Matura and Fishing Pond beaches on the east coast were declared prohibited and protected areas with restricted entry from 1st March – 31st August (Fournillier, 1992). Grande Riviere beach also achieved this status in 1997. Local environmental groups control the restricted entry, and a permit and guide are required to access the beaches at night. This protected status has been extremely successful in the reduction of slaughter on those beaches (Fournillier and Eckert, 1997).

Trinidad and Tobago is a signatory of several international conventions relevant to the conservation of sea turtles. The Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (also known as the Cartagena Convention), and the adjoining SPAW (Specially Protected Areas and Wildlife) Protocol provide clear articles under which all six species of Caribbean sea turtle are listed. The convention forms an important framework for sea turtle management throughout the Caribbean region and offers great potential for their protection (Wold, 2002). WIDECAST (Wider Caribbean Sea Turtle Conservation Network) has assisted each signed country with a Sea Turtle Recovery Action Plan (STRAP), aimed to satisfy the mandate of the SPAW Protocol. This document is adapted to the local circumstances of the country and highlights such items as local sea turtle status and distribution, causes of mortality, the effectiveness of existing legislation, and local, national, and multilateral implementing measures for science-based sea turtle management. A draft of the STRAP for Trinidad and Tobago from 1997 is available from the Trinidad Wildlife Section. However, a final draft has not yet been completed. With regard to the legal hard-shell turtle fishery and present legislation, Trinidad may not be meeting its obligations under the SPAW protocol.

Trinidad and Tobago is also party to CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and the CBD (Convention of Biological Diversity), both of which list sea turtles as important species. Trinidad is not yet party to the Convention on the Conservation of Migratory Species of Wild Animals (CMS – also know as the Bonn convention) or the Inter-American Convention for the Protection of Sea Turtles (Wold, 2002). As Trinidad hosts an important population of hawksbills (chap.5) and one of the largest nesting leatherback populations in the world (chap.4), and given the highly migratory nature of leatherbacks (James et al., 2005b), it may beneficial for Trinidad and Tobago to consider joining these conventions in the future, further demonstrating their dedication to the protection of sea turtles.

2.4 Research and conservation

In 1965, when the first research on turtles was initiated, Bacon concentrated mostly on leatherbacks, although notes were also made on other turtle species. Matura Beach on the east coast (fig.1.3) was quickly identified as a high density nesting beach, which had the additional benefits of being relatively close to the University, and easily accessed from the main road. The majority of fieldwork was therefore performed at that location.

Limited work was carried out on the north coast, largely because the northern beaches were difficult and costly to reach, with no paved road or permanent accommodation. Most work on the northern coastline was carried out on Paria Bay (nearest beach to Blanchisseuse village at the western end of the road), with sporadic visits to the other beaches. The accuracy of the data collected from the north coast is debatable (Bacon, 1970).

In 1970 Bacon estimated that the total annual leatherback nesting population in Trinidad was 150 - 200 females. The estimate was based largely on the two highest density beaches identified as Paria and Matura. The estimate was calculated assuming each female laid between five and seven clutches per season at ten-day intervals, and that each female would nest for approximately two months. Since the nesting season lasts roughly four months the number was estimated as 20 times the average number of nests per night (Bacon, 1973a). No mention of unsuccessful nesting attempts (false crawls) was made in the calculations, and it is unknown whether this factor was taken into account. Bacon noted (and consistently mentioned in further studies) that the majority of nesting leatherbacks emerged from the sea between 8 pm and midnight. From examination of TFNC raw data, and the 1969 and 1970 manuscripts, it appears that the beaches were only ever regularly patrolled between these hours, and rarely monitored beyond this time. Bacon (1970) commented that the estimate would probably increase if the other east and north coast bays were comprehensively surveyed.

In 1971 Bacon adjusted the estimate to 200 - 250 females per year, and a total nesting population of 500 - 600 females per year (Bacon and Maliphant, 1971; Bacon, 1971). Bacon continued to do research and collected data throughout the 1970's assisted by TFNC, Pointe-a-Pierre Wildfowl Trust and the Asa Wright Centre, and occasionally the Trinidad Wildlife Section, Forestry Division (Bacon, 1973a; 1973b; 1975; 1976). They tagged a total of 304 turtles over a ten-year period (Gaskin, 1994). Bacon presented a revised estimate of the annual nesting leatherback population in the Status of Sea Turtle Stocks in the Western Atlantic United Nations Development Programme report in 1981 (Bacon, 1981). It was listed as 400 - 500 females per year in 1972 and 800 - 1,000 per year in 1975. It is unknown whether the increase in numbers over time was thought to represent an increase in numbers, natural population fluctuations, an increase in data collection effort, or a re-assessment of nesting locations.

Chu Cheong followed up Bacon's research at Matura in 1981 - 1983 assisted by the Wildlife Section (Chu Cheong, 1990; 1995) using the same methodology. The results were analogous to Bacon's findings (Bacon, 1970; 1973a), and the number of leatherbacks nesting on Matura Beach appeared to have remained stable over the ten-year period between studies (Chu Cheong, 1990). Chu Cheong mentioned that her data set might not have been strictly comparable to Bacon's due to a difference in the sampling period and effort (Chu Cheong did more extensive fieldwork). Again, it was mentioned that most of the fieldwork was carried out between 8 pm and midnight.

Aerial surveys were carried out on the north coast beaches in 1982 and 1983 (ten and six flights respectively), and backed up by some on-the-ground fieldwork (Pritchard, 1984; Chu Cheong, 1990). On the basis of this work, the beaches were categorised into low, medium and high density nesting areas. Chu Cheong did not give an estimate of the total leatherback nesting population in Trinidad. However, in 1987 Nathai-Gyan et al. made an estimate of 500 - 900 nesting females per year based on Chu Cheong's 1981 - 1983 study, along with additional records collected by Wildlife Section patrols in 1985 - 1987 (Nathai-Gyan et al., 1987). An increase in nesting leatherbacks was noted in 1985, and a further increase in 1987.

In 1989 and 1991, Godley et al. (1989; 1991; 2001a; 2001b) carried out sea turtle surveys in Trinidad with the University of Glasgow Exploration Society in collaboration with the Wildlife Section. The study, in part, acted as a follow-up to the previous work done by Bacon and Chu Cheong on Matura Beach, and a further assessment of the other identified turtle nesting beaches on the island. At Matura, Godley et al. found that there had been an apparent increase in leatherback nestings when compared with previous studies (Bacon, 1970; Chu Cheong, 1990). Using Bacon's method of calculation (Bacon, 1973a), the data gave a threefold increase in nesting population size. Possible explanations of the increase included discrepancies associated with the treatment of unsuccessful nesting attempts, work effort variation, and a differing study area covered. However, Godley et al. thought it unlikely that these inconsistencies would have increased the estimates to such an extent, and that it was more likely that the number of nesting females had increased between 1965 and 1991 (Godley, et al. 1991). Godley et al. suggested that the increase could have been a recovery due to conservation efforts to reduce slaughtered females, or possibly to natural nesting female population fluctuations. Godley et al. (2001b) estimated that half of all clutches laid in Trinidad were laid on Matura Beach, but did not make an estimate of total nesting population due to insufficient data.

It is important to draw attention to a noteworthy difference in survey techniques in Bacon's and Chu Cheong's studies, and in Godley et al.'s work. Godley and his team patrolled the beach during the whole night, rather than only in the earlier hours of the night (from 8 pm till around midnight), as Bacon and Chu Cheong had done. It is therefore possible that Godley et al.'s surveys could have produced comparatively more data from monitoring the whole night. This said, Godley et al.'s suggestion of an increase in leatherback numbers also coincided with reports of increased nesting numbers of leatherbacks from locals and Wildlife Section wardens. It is possible that the increase was a combination of differences in data collection and an actual increase in visiting females.

Despite persistent efforts by local conservation groups and Forestry Division officials, it was not possible to provide complete surveillance of prominent nesting beaches along the east and north coastline (Lum, 2001). In 1990, around the same time as the beaches on the east coast became protected areas, the Wildlife Section set up a community-based project in Matura to protect nesting sea turtles through ecotourism (James and Fournillier, 1993; Fournillier, 1992; 1995; 1996). Nature Seekers Incorporated was created, and village members began patrolling the beach, providing much needed resources and manpower. Illegal poaching was virtually eliminated (Lum, 2001). Data collection began in 1992 and has since increased in efficiency since (D. Sammy, personal communication). With the support of WIDECAST a tagging programme began in 1999, and by 2003 Nature Seekers had tagged 5,051 leatherback females on Matura Beach (M. Ramjattan personal communication). Unfortunately no published reports of this work are currently available. However, Nature Seekers are currently working with Scott Eckert to produce a document in the near future (S. Eckert, personal communication). All tagging data from Trinidad and Tobago is currently held in the National Sea Turtle Database of Trinidad and Tobago, managed by the Institute of Marine Affairs (IMA) (L. Lum, personal communication).

The Grande Riviere Environmental Awareness Trust (GREAT), and more recently the GRNTGA, have been sporadically collecting data since 1997 when Grande Riviere beach was granted its protected status, although no reports have yet been published. Grande Riviere Beach has, however, been the location for several studies on leatherback nest survival and ecology (Maharaj, 2004; Lum, 2005).

Although there are no published reports on east coast leatherback numbers, there are several unpublished documents that contain relevant information. The 1997 draft of the WIDECAST STRAP for Trinidad and Tobago (Fournillier and Eckert, 1997) stated that, due to data collected in the early nineties, Nathai-Gyan et al.'s (1987) approximation of 500 - 900 nesting females was thought to be an underestimate of nesting females (as opposed to an increase). Nature Seekers had observed as many as 60 females nesting in one night on Matura Beach in peak season, and there were estimates of 100 females a night on Grande Riviere in 1993 (S. Ruiz personal communication). In 1994, it was felt that sufficient nest count data existed to make a rough calculation of nesting females (based on between six and seven clutches being laid per female per year and 75 % of nests counted). An estimated 670 - 780 females were using Matura Beach and Fishing Pond to nest. The report assumed an equivalent number nested on Grande Riviere, and that once the other "lower density beaches" along the north coast had been taken into account, approximately 2,000 leatherbacks nested in Trinidad that year. The number of nests on Matura and Fishing Pond in 1995 was lower, amounting to 355 - 425 females (possibly 1,100 nesting in total around the island). It was thought that the lower figures were due to natural fluctuations.

In the 2001 proceedings for the Marine Turtle Conservation in the Wider Caribbean Region: A Dialogue for Effective Regional Management (Eckert, 2001), Matura and Grande Riviere were identified as the two primary nesting sites in Trinidad. Eight hundred and sixty two females were tagged at Matura in 1999, and it was thought that up to 1,000 could have nested there in total, with similar numbers nesting on Grande Riviere, although the status of the population was still considered unknown (Eckert, 2001). Recent data from the east coast of Trinidad presented at the Atlantic Leatherback Strategy Retreat at St Catherine's Island in 2005 suggested that the population is currently stable or possibly increasing, although caution was employed when making this assumption as the data collection effort also increased through time (Eckert and Eckert, 2005). It was suggested that the increase could be evidence of a recovery from previous years of slaughter due to conservation efforts over the last 14 years. The overall leatherbacks nesting in Trinidad were thought to support 88 % of the nesting in the Insular Caribbean, although no overall estimate was offered (Eckert and Eckert, 2005).

Recent research has shown that there are a considerable number of leatherbacks using the beaches on the north coast of Trinidad (chap.4). The north coast is made up of a number of short sandy bays (up to 2.5 km), in contrast to the long beaches on the east coast. There are six high density beaches (Grande Riviere, Madamas, Paria, Grand Tacarib, Petit Tacarib and Murphy's Bay) and eight low density beaches on which leatherbacks nest (chap.3). Although it was previously known that leatherbacks used these beaches, no extensive research had been carried out there due to the difficulties of the terrain (Lum, 2001). Research spanning from 2000 to 2004 has shown that an annual average of 16,140 clutches of eggs are deposited on the northern beaches, laid by an average of 3,230 (2,300 - 4,030) nesting females per year (using a clutch frequency of five) (chap.4). These figures considerably exceed any prior estimates for that area. Although there were some approximations for numbers nesting on Grande Riviere beach (Eckert, 2001), the numbers on the other more remote north coast beaches were grossly underestimated. During the four years of monitoring, it was found that approximately 47 % of the nests on the north coast were on Grande Riviere, the other 53 % being spread over the other northern beaches (chap.3).

This recent work has shown that the north coast is extremely important, both nationally and internationally, and supports similar, perhaps larger, numbers of leatherbacks than the east coast (chap.4). With approximately 1,000 leatherbacks nesting annually on Matura Beach (Eckert, 2001), and perhaps 600 on the rest of the eastern coastline (S. Poon personal communication), a crude estimate for the mean annual nesting population in Trinidad could be in the range of 5,000 females, and a total nesting population of around 12,000 females (chap.4). Of course these estimates would need to be confirmed once analysis from the east coast data is complete.

Historical data and local accounts of leatherback numbers on the north coast beaches all indicate a significant increase in numbers over the last 35 years (Nathai-Gyan et al., 1987; Godley et al., 1989; 1991; Chu Cheong, 1995; J. Marcano personal communication; D. Harrison personal communication; chap.4). This increase has been mirrored by a reported increase on the east coast beaches, although this report comes with a cautionary note of data bias (Eckert and Eckert, 2005). The suggestion that such an increase could be due to conservation efforts is plausible. However, it is unlikely that it is the sole reason. Conservation at Matura was only fully effective after 1991, and increases had already been noted in the 1980's, with fairly steep increases mentioned in the early and mid 1990's (Fournillier and Eckert, 1997). The timing of the reduction in slaughter and the sudden increase in nesting leatherbacks suggest that factors other than conservation efforts alone have been responsible. The reduction of predatory, and also commercial, fish by the industrial fisheries in Trinidad's waters may have played a part in the increase of new female recruits. Before the late 1940's, very little fishing was carried out in Trinidad (chap.6), but by the 1960's there was an up and running industry supported by the Government. Reducing the number of fish (including sharks) predating on hatchlings could have greatly affected their survival, and could help to explain the first sign of increase in the early 1980's and the massive recorded increases in the early 1990's through to current numbers.

An increase in time spent on fieldwork and fieldwork effort could also possibly partly explain the population increase; it is clear that the intensity of fieldwork in Trinidad over the years has amplified considerably. Pritchard (1982) reminds us that people once thought there were very few leatherback nesting sites worldwide, and how that belief changed when people actually started to look for them. An element of this phenomenon may have affected past estimates. The increase is most likely a combination of these three factors although an unequivocal explanation remains unclear.

Turtle conservation efforts are currently ongoing at several locations in Trinidad. The success of Nature Seekers at Matura has encouraged a number of other communities around the country to get involved, and there are now active groups at Grande Riviere, Fishing Pond, Manzanilla, Mayaro and Matelot, some of which are being funded by the Wildlife Section (appendix 1). Not all the groups are funded however, and the funding that the Wildlife Section received to distribute between the groups was cut consecutively in 2002 and 2003. These constraints are frustrating for both the Wildlife Section and the local organisations.

2.5 Importance of publication

Although Trinidad is one of the most studied Caribbean islands in terms of sea turtles (Pritchard, 1984; Fournillier and Eckert, 1997), past estimates have been based on limited data and much of the literature is difficult to source. This has resulted in conflicting information on the actual size of the nesting leatherback population in Trinidad. In the last 35 years, several estimates have been calculated for the total number of leatherback females worldwide. Pritchard estimated 29,000 - 40,000 nesting females, including Bacon's 1970 numbers for Trinidad (150 - 200) (Pritchard 1971). Ross (1982) estimated 14,325 females in

1979, using Bacon's 1971 estimate of 400 - 500 nesting females for Trinidad. Pritchard amended his world estimate in light of a large rookery in Mexico making it 115,000 in 1981 (Pritchard, 1982). Trinidad was not mentioned in this account. Spotila et al. listed Trinidad as one of 28 nesting colonies worldwide in their 1996 paper on leatherback decline (Spotila et al., 1996). His overall estimate was 34,500 (26,200 - 42,900) nesting females. The Trinidad nesting population was listed as 200 - 300 females per year (referenced from a personal communication from R Ashton). However, that estimate was much lower than the estimates offered in available manuscripts (Bacon, 1971; 1973a; 1981; Nathai-Gyan et al., 1987; Chu Cheong, 1990; Godley et al., 1991; 1989), and is certainly less than the then current findings of Nature Seekers and WIDECAST. Dutton et al. (1999) used an estimate of 200 - 800 nesting females per year in their paper on the global phylogeny of leatherbacks, based on a personal communication with Ken Fournillier (who worked for the Wildlife Section at the time), which was again less than recent numbers reported by Nature Seekers.

A number of reports on the conservation and status of leatherback turtles have recently been produced by large influential organisations. Trinidad is usually mentioned, although mostly referred to as a low-density area in the Caribbean (Committee on the Status of Endangered Wildlife in Canada (COSEWIC), 2001; The National Marine Fisheries Service Southeast Fisheries Science Centre, 2001). The United Nations Environment Programme (UNEP) (2003) references Chu Cheong (1990) and Bacon (1971) giving a nesting population estimate of 400 - 500 females. The use of these outdated estimates in recent documents highlights the need for reliable, up-to-date, easily sourced estimates, and it is important for conservationists to be cautious and to authenticate the reliability of the data used to make estimates before reaching critical conclusions or making important management decisions (Shanker et al., 2003).

2.6 Conclusions

It is clear that much has been done in terms of leatherback conservation in Trinidad. The extensive poaching of nesting females reported in the 1960's, 1970's and 1980's no longer take place, largely due to the protected status of several accessible high density nesting beaches and the presence of patrolling community groups. Although levels of leatherback slaughter have been greatly reduced, many adults are still lost as a result of interaction with the gillnet fisheries. The number of adults caught in gillnets may be unsustainable, and presents the largest threat to the leatherbacks in Trinidad (Lum, 2003; chap.6). The level of bycatch has increased with increasing leatherback numbers over the last 30 years, although does not yet appear to have hindered the increase. However, there may be a point where leatherback mortality overtakes recruitment, and nesting leatherback numbers will decrease as a result, as has happened in other areas, e.g. the Mexican leatherback rookery in the Pacific (Spotila et al., 1996). It is important to mitigate the bycatch of leatherbacks; WIDECAST and the Trinidadian Government are currently working towards this goal with suggestions of using a combination of alternative fishing methods and possibly area/time closures (L. Lum, personal communication; chap.6). Continued monitoring of the nesting leatherback numbers in Trinidad is of the utmost importance as an aid to the reliable assessment of the current threats to their survival.

Hard-shell turtles are still caught in the coastal waters by the legal turtle fishery, although the quantity is unknown. If James and Fournillier's (1993) estimation of the annual catch was accurate (1,000), the level of the harvest may also be unsustainable, affecting nesting populations elsewhere. It is recommended that data collection on the number of hard-shells caught in the turtle fishery during the open season be resumed, in addition to investigating the levels of poaching during the closed season. A revision of the laws concerning sea turtles would provide better protection for hard-shell turtles, and help Trinidad to meet its obligations under the SPAW protocol. A law change could eliminate the obvious loopholes that exist, but only if the revision is backed up by improved law enforcement.

This review has shown how past leatherback numbers have been underestimated as a result of differing methodologies, and a lack of accounting for the remote nesting beaches on the north coast. However, although the numbers were underestimated, it is clear that there has also been a significant increase in nesting leatherback numbers, possibly due to a combination of conservation efforts and increased fishing of hatchling predators.

This review highlights the value of collating the past research on Trinidad's sea turtles, and emphasizes the importance of reliable and up-to-date nesting population estimates. It is important to be able to access information and disseminate results so that informed decisions can be made on a national and international scale.

3. Environmental factors influencing leatherback nesting beach choice on the north coast of Trinidad

3.1 Introduction

Leatherback turtles (*Dermochelys coriacea*) are known to nest on the east (Atlantic) and north coast (Caribbean) beaches of Trinidad (Bacon, 1970; Chu Cheong, 1990; Gaskin, 1994; Godley et al., 2001b), preferring the more exposed windward coastlines as described by Carr (1956) (fig.1.3). The beaches on both coastlines are extremely dynamic with high levels of sand erosion and build-up due to rough wave action and seasonal rainfall changes (Eckert, 1987; SRL, personal observation). Both coastlines have deep-water approaches with strong rip currents and few significant reef features (Georges, 1983; Mohammed and Shing, 2003) typical of leatherback nesting sites (Pritchard, 1971; Whitmore and Dutton, 1985). Several long beaches (approximately 8 - 20 km) run the length of the eastern coastline, separated by rivers and mangroves. In contrast, the northern coastline is steep and rocky, punctuated by small curved sandy bays (up to 2.2 km long) backed by mountainous rainforest (the Northern Range Mountains) (Georges, 1983). Beaches make up 21 % of the northern coastline (Georges and Greenidge, 1993). In addition to nesting leatherbacks, both coastlines also support small numbers of hawksbills (*Eretmochelys imbricata*), greens (*Chelonia mydas*), olive ridleys (*Lepidochelys olivacea)* and loggerheads (*Caretta caretta*) (Bacon, 1969; Pritchard, 1984; Nathai-Gyan et al., 1987; Fournillier and Eckert, 1997; Livingstone, 2005; chap.5).

The Paria Main road runs from east to west along the north coast of Trinidad. However the northern coastline is variably accessible. A 22 km section in the middle of the coast remains without a paved road. The paved road ends on the west side at Blanchisseuse, and on the east side at Matelot (fig.3.1). These two villages are connected by a dirt path (also referred to as the Paria Main road) winding through the rain-forested mountains. The path is mostly used by hunters, local farmers with plantations, and occasionally by hikers. Sandy beaches are scattered along the north coast and, where located on the paved road, are usually backed by a settlement. These beaches have been altered by human activity to varying degrees. The beaches located on the remote dirt track section of the coast are difficult to access without a boat. Human settlements have existed along that section in the past, but very few people inhabit the area at the time of this study. The beaches have never been altered by humans, and remain largely undisturbed. However, human use of the area is on the increase.

The Trinidadian government has proposed a plan to develop the north coast for tourism and farming, which includes the completion of the east-west road as an "ecotourism highway" (Prime Minister's speech, August 2003). The road will serve to open up the north coast area for access to beaches, and to assist timber extraction from the Northern Range forest reserves. Although the plan has not yet been approved, illegal construction of the road has already begun on the west side at Blanchisseuse, making it easier to reach Paria Bay by foot, and permitting a significant increase in tourists visiting the area. Trinidad receives comparatively small numbers of foreign visitors, and most tourists visiting the north coast are from within Trinidad. The development and alteration of beaches is one of the main causes for the decline of sea turtles worldwide, and identification of important nesting beaches is vital for the future protection of sea turtle populations (Shabica, 1995).

Sea turtles nest on a variety of beach types, with each species having slightly different preferences and requirements (Schultz, 1975; Mortimer, 1982a; Hays et al., 1995). However, the basic requirements for a nesting beach are the same: easy access from the sea; an area of sand which is not submerged or over-washed regularly; sand in which a nest can be constructed allowing sufficient gas diffusion and temperatures suitable for the development of eggs (Mortimer, 1990). Leatherbacks generally prefer undisturbed, highly dynamic, unpredictable beaches, with few reef features (Hendrickson and Balasingam, 1966; Schulz, 1975; Eckert, 1987). However, when leatherbacks have a choice between several beaches that fit this general description within one area, it is often difficult to identify why they might have a preference for one beach over the other. The mechanisms by which nesting females choose their beach are poorly understood (Mortimer, 1982a), and so far no-one has been able to exactly define the process by which sea turtles (of any species) choose their nesting beach (Miller et al., 2003). Influencing factors are thought to include the individual topographic characteristics of a beach such as gradient, length and width, offshore approach and sand particle size (Mortimer, 1982a; Horrocks and Scott, 1991; Kikukawa et al., 1999). Other factors such as artificial lighting, human disturbance and beach alteration have also been shown to have an influence (Worth and Smith, 1976; Witham, 1982; Mortimer, 1982a; Witherington, 1992; Hendrickson, 1995; Miller et al., 2003; Kikukawa et al., 1999).

Some species of sea turtles are known to exhibit high fidelity to the beaches they hatched on (natal beach) (Lohmann et al., 1997). However, whilst there is evidence to show that leatherbacks return to nest in their natal area (Dutton et al., 2005), they show a much greater variation in selecting their nesting beaches (Tucker and Frazier, 1991) and often exhibit preference for a coastline rather than a specific beach (Pritchard, 1982; Chevalier and

Girondot, 1999; chap.4). This is thought to be a behaviour developed to reduce the chances of losing all nests positioned in one location (Eckert, 1987; Kamel and Mrosovsky, 2004), which is highly likely due to the preference leatherbacks have for such dynamic nesting beaches (Whitmore and Dutton, 1985).

Sea turtles are not known to display any parental care for their offspring. Once they have laid their clutch, the eggs are left to develop in the nest for approximately 60 days (depending on species), and the resultant hatchlings find their way to the sea on their own. However, the choice of nesting beach and nest position can affect the survival of the offspring, and therefore the reproductive fitness of the adult (Martin, 1988). Nest success is highly influenced by nest placement (Eckert, 1987; Hays and Speakman, 1993; chap.7); nests positioned too near the sea or rivers are more susceptible to erosion and inundation (Whitmore and Dutton, 1985); nests positioned further inland may subject hatchlings to a higher risk of desiccation, disorientation and predation (Fowler, 1979; Mrosovsky, 1983; Kamel and Mrosovsky, 2004); and nests positioned too near backing vegetation can be destroyed by invading roots (Witherington, 1986). Nest success is also affected by environmental factors such as moisture (McGehee, 1990; Ackerman, 1991), temperature (Yntema and Mrosovsky, 1980), oxygen levels (Ackerman, 1980) and chloride levels (Bustard and Greenham, 1968), which differ depending on nest placement. It is likely that adult females choose a nesting beach based on the practicalities of emergence from the sea, nest building and safety for themselves, and the suitability of the beach to maximise the proportion of eggs hatching and hatchlings reaching the sea (Wood and Bjorndal, 2000).

A false crawl is when a female turtle comes up on the beach, and for some reason decides to return to sea without laying eggs (Schroeder and Murphy, 1999). This can happen at any stage of the nesting process, from emergence from the sea to aborting an almost completed nest. A turtle can perform a false crawl for several reasons, e.g. disturbance from humans or another nesting turtle, or encountering debris on the beach. The false crawl rate can give an indication of the suitability of the nesting beach.

The beaches on the north coast of Trinidad vary in size, shape and topography and in levels of human disturbance (IMA, 2004; SRL, personal observation). The density of turtle nests on each beach also varies (SRL, personal observation), highlighting that female leatherbacks nesting on the north coast appear to have preferences for particular beaches. This chapter aims to give a detailed description of the study area, and to examine the biotic and abiotic factors influencing the distribution of leatherback nests on the beaches along the northern coastline.

3.2 Methods

3.2.1 Field data collection

The beaches on the north coast of Trinidad suitable for nesting sea turtles were identified. This was done by visiting each beach and assessing it for turtle tracks and the basic parameters required by a nesting female, as described earlier. Each beach was measured and mapped (length to the nearest 5 m and width to the nearest 1 m to the high water mark). Numbers of females and laid clutches were recorded at night on each of the beaches between April and August in 2000, 2002, 2003 and 2004 (see chap.4 for detailed methodology). The area of coastline beyond Maracas to the west was not surveyed due to restricted military access. There are several potentially small suitable nesting beaches in that area indicated by the topography of the coastline, but they could not be included in this study due to the restrictions.

Nest density was calculated for each beach using the mean total nests and beach length (nests/km). Nests/km is the measure most commonly used in other studies for defining density. Each beach was classified as either low (< 500 nests/km) or high density (> 500 nests/km). Density classifications for the north coast beaches from previous studies were taken into account (Chu Cheong, 1990; Godley et al., 1989, 1991). The proportion of the total number of clutches laid on the north coast was calculated for each beach.

The false crawl rate on each of the high density nesting beaches was calculated as a proportion of the numbers of visiting females. Here, a false crawl is defined as a failed nesting attempt starting from the point of emergence from the sea, up until the point just before the start of egg deposition.

3.2.2 Beach parameters

Each beach was described in terms of its physical and environmental parameters. This information was collected by a combination of personal observation, and from published sources (Georges, 1983; Georges and Greenidge, 1983; Imray-Iolaire, 2003; IMA, 2004). The data were quantified for each variable: levels of human disturbance and beach alteration (0 = none, 1 = low, 2 = medium; 3 = high); artificial lighting (0 = none, 1 = low, 2 = high); removal of backing forest (0 = dense forest, 1 = some forest, 2 = scrub, 3 = none); levels of predation (0 = natural only, 1 = natural and introduced); type of beach (0 = open, 1 = bay);

presence of rivers and streams (0 = none, 1 = streams, 2 = small river, 3 = big river); rocks on the beach (0 = none, 1 = present); submerged rocks (0 = none, 1 = rocks, 2 = reef); sand particle size (0 = fine, 1 = medium, 2 = medium - coarse, 3 = coarse); slope of the beach (0 = shallow, 1 = moderate, 2 = moderate - steep, 3 = steep); and the depth of the seaward approach (0 = shallow, 1 = moderate - shallow, 2 = moderate, 3 = moderate - deep, 4 = deep). Beach type was classified using the coastal development index (CDI) which indicates how "embayed" a beach is. The index is calculated by dividing the coast parameter length between two points by the shortest distance between the same points: a CDI greater than 1.5 = bayed beach; a CDI less than 1.5 = open beach (Georges, 1983). Sand particle size was based on the criteria used by Georges (1983) and Georges and Greenidge (1983): > 1mm diameter = coarse, 0.5 - 1mm diameter = medium to coarse, 0.5 - 0.25mm diameter = medium, < 0.25mm diameter = fine grained sand.

The scores are based on the relatedness of the parameter between beaches so that they were comparable. This was required due to the lack of exact measurable data for some physical beach characteristics.

3.2.3 Data analysis

One-way ANOVA was used to analyse the false crawl data from five high density beaches in the four study years.

Linear regression was used first as an exploratory analysis method for each of the beach variables correlated with nest density. Multiple regression analysis (using the backward method) was then used to further test the data to discover the most important beach variables for nesting females. The Grande Riviere data point was removed from the analysis of the human related beach variables due to the exceptional nature of the beach as a nesting area.

3.3 Results

3.3.1 Nest density and false crawls

A total of 14 beaches were identified as being suitable for sea turtle nesting on the north coast of Trinidad (fig.3.1).

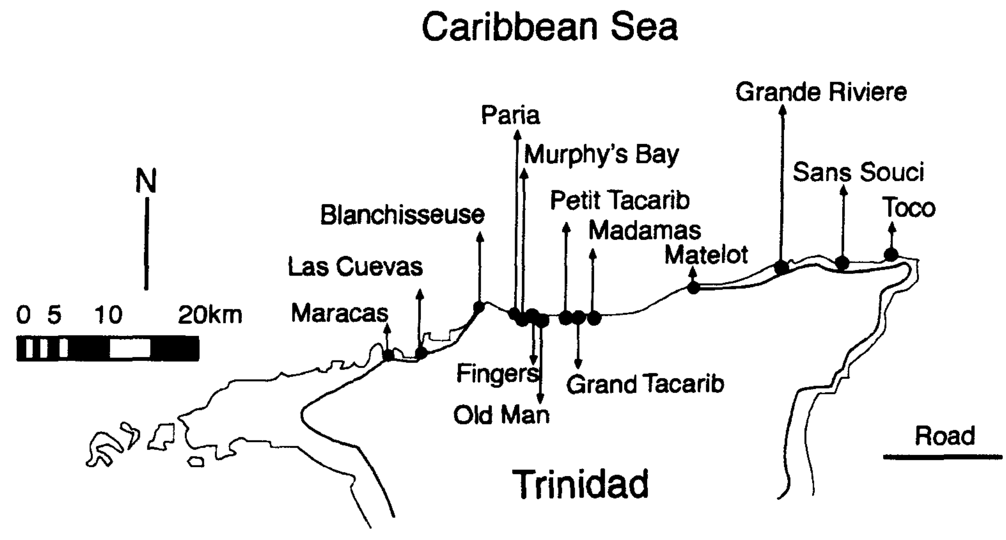


Figure 3.1 The sea turtle nesting beaches on the north coast of Trinidad

The nest density for each beach is listed in table 3.1. Grande Riviere, Grand Tacarib, Petit Tacarib, Madamas, Paria and Murphy's Bay fell into the category of high density nesting beaches. Grande Riviere had the greatest density of nests followed by Murphy's Bay. Grand Tacarib had a nest density of 2,610 nests/km, and Paria and Madamas supported a similar number of around 1,550 nests/km. Petit Tacarib had an average density of 1,067 nests/km. Toco, Sans Souci, Matelot, Old Man, Fingers, Blanchisseuse, Las Cuevas and Maracas were all found to be low density beaches with nest density ranging from 42 - 317 nests/km.

Table 3-1 The mean number of leatherback nests per year, length and width of beach, and nest density for each north coast beach

Beach (east to west)	*Mean no. of nests*	*Length (m)*	*Width (m) (widest point)*	*Nest density (nests/km)*
Toco	75	700	22	107 (low)
Sans Souci	95	300	30	317 (low)
Grande Riviere	7,685	1,100	35	6,986 (high)
Matelot	4	400	5	9 (low)
Madamas	1,508	750	31	2,011 (high)
Grand Tacarib	2,976	1,140	47	2,610 (high)
Petit Tacarib	320	300	20	1,067 (high)
Old Man	40	220	9	182 (low)
Fingers	40	190	10	211 (low)
Murphy's Bay	1,319	320	65	4,122 (high)
Paria	1,623	990	34	1,639 (high)
Blanchisseuse	143	1,400	16	102 (low)
Las Cuevas	238	2,200	25	108 (low)
Maracas	75	1,800	20	42 (low)

Murphy's Bay was by far the widest beach at a maximum of 65 m. Grand Tacarib was 47 m at its widest point, and the widest parts of Paria, Madamas, Grande Riviere and Sans Souci were similar at around 30 - 35 m. The widest parts of Toco, Las Cuevas and Maracas were approximately 23 m. Matelot, Fingers and Old Man were much narrower, and presented much less suitable nesting area.

Figure 3.2 shows the mean proportion of total nests on each beach. There were no significant differences in the proportion of nests on the beaches between years (One-way ANOVA: $F_{3, 52} = 0.32$, NS). The busiest beach was Grande Riviere accommodating approximately 48 % of all the nests on the north coast. Grand Tacarib supported 18 %, and Madamas, Paria and Murphy's Bay made up similar percentages at 9 %, 10 % and 8 % respectively. Petit Tacarib received 2 % of the nests, and the remaining 5 % of nests were spread out on the low density beaches.

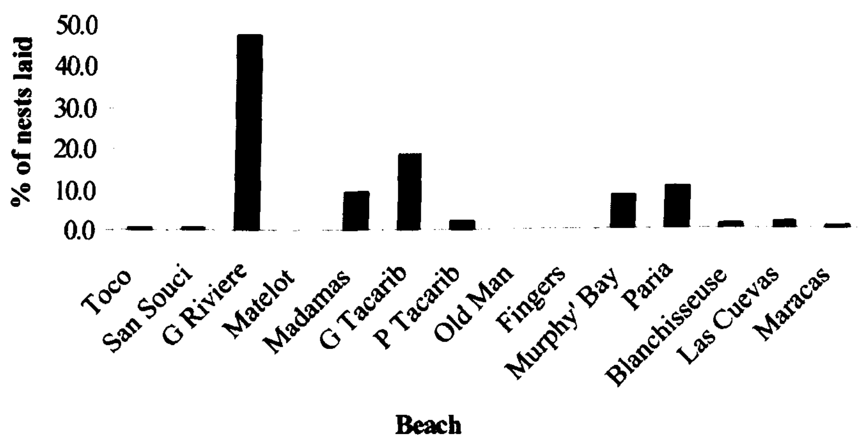


Figure 3.2 Estimated proportion (%) of leatherback nests on each beach on the north coast

The false crawl rate for the high density beaches was calculated in each year (excluding Petit Tacarib as no intensive monitoring was carried out there due to its small size) (table 3.2). Grande Riviere consistently had the highest false crawl rate with a mean of 24.9 %. Grand Tacarib had the lowest averaging at 8.3 %. The other beaches ranged between these two figures, although closer to the lower value on Grand Tacarib. The false crawl rate fluctuated between years on all the beaches. The mean overall false crawl rate was 11.8 %.

Table 3-2 False crawl rate (% of all female emergences) for each beach in each year. n = total recorded emergences at each beach

Beaches	*2000 (%)*	*2002 (%)*	*2003 (%)*	*2004 (%)*	*Mean (%)*
All beaches	13.8 (n = 189)	11.8 (n = 316)	10.2 (n = 766)	11.5 (n = 444)	11.8 (n = 4)
G. Tacarib	8.5 (n = 99)	7.45 (n = 188)	7.3 (n = 437)	10.0 (n = 310)	8.3 (n = 4)
Paria	10.5 (n = 19)	12.5 (n = 48)	8.2 (n = 98)	14.3 (n = 63)	11.3 (n = 4)
Madamas	14.3 (n = 14)	17.5 (n = 80)	14.0 (n = 87)	18.2 (n = 11)	16.0 (n = 4)
G. Riviere	24.6 (n = 57)	-	25.6 (n = 78)	24.4 (n = 41)	24.9 (n = 3
Murphy's	-	-	9.1 (n = 66)	10.5 (n = 19)	9.8 (n = 2)

The mean false crawl rates on the five beaches were significantly different from each other (One-way ANOVA: $F_{4,12} = 41.05, p < 0.01$). A Post-hoc Tukey test showed that the false crawl rates on Grand Tacarib, Paria and Murphy's Bay were not significantly different from each other, but that the false crawl rates on both Madamas and Grande Riviere were significantly higher than on all the other beaches. The mean false crawl rates on all beaches were not significantly different over the four years of the study (One-way ANOVA: $F_{3,13} = 0.91$, N.S.).

3.3.2 Description of north coast beaches

The beaches on the north coast can be conveniently sub-divided into three groups: western, eastern and mid-section, based on the sections of the paved road.

a) Western beaches

The western side of the north coast has three main bays that are easily accessible from the road; Las Cuevas, Maracas and Blanchisseuse, each located within a village (fig.3.1). This area of the coast attracts many visitors throughout the year for recreational purposes, and is set up for small-scale tourism with guesthouses and hotels. Trinidad is not a big foreign tourist destination, and currently most tourists visiting the northwest beaches are local. Most holidaymakers use this area because of the easy reach from the capital city, Port of Spain, and relatively good roads. Maracas, in particular, has been heavily developed for tourism (fig.3.3) (IMA, 2004), the other two beaches less so, although all are subject to human disturbance and alteration, including artificial lighting.

Figure 3.3 Maracas Bay showing the relatively high level of tourism, flattened beach area, and sparse vegetation at the back of the beach

There is still some forest at the back of Blanchisseuse and Las Cuevas, although part of it has been removed to build roads and car parks. The majority of nesting on Las Cuevas was at the western end of the bay, which is wider, has natural forest at the back, and is farthest from the tourist area (SRL, personal observation). Maracas Bay has been completely opened up with no forest bordering the beach at all, and only a few sparse palm trees. The land is flat and developed, with a lot of artificial lighting, and the area behind has been concreted for car parks and structures on the beach. Because these beaches are located in villages, there are also a large number of stray dogs around, which presents a predation threat to turtle nests and hatchlings.

The sand particle size on Blanchisseuse was medium grained (Georges and Greenidge, 1983), differing from the sand on Las Cuevas and Maracas which was fine grained (Georges and Greenidge, 1983). The Marianne River empties into the sea at Blanchisseuse causing considerable erosion of sand. The river is rather unpredictable, and changes its path annually. Las Cuevas and Maracas beaches have no major water outflows, although there are several small streams present in the rainy season. The slope of the beach at Blanchisseuse is steep to moderate, and the beach is classed as open, based on the CDI (Coastal development index) (Georges, 1983). The offshore approach is at medium depth, and there is a reef present at the eastern end of the beach (IMA, 2004). A number of offshore rocks are present, and the beach itself also has several areas of rocks. The slopes of Las Cuevas and Maracas beaches are gentle, with no major areas of rocks, and the offshore approach at both beaches is shallow to moderate. Both these beaches are classed as bay beaches (Georges, 1983). There was no evidence of sea turtle species other than leatherbacks nesting on these three beaches during surveys.

b) Eastern beaches

On the eastern side of the north coast there are several sandy beaches supporting turtle nesting, all located in villages (Toco, Sans Souci, Grande Riviere and Matelot). All of these beaches are classed as open (Georges, 1983). Toco and Sans Souci beach have been opened up, and much of the backing forest removed. Both are affected by artificial street lighting. These beaches receive tourists throughout the year, and there is always a human presence. Sans Souci is known as the best surfing beach in Trinidad (C. Patron, personal communication). Grande Riviere receives many tourists each year, many of whom are attracted by the large numbers of leatherbacks nesting there. The beach itself remains relatively unaltered, although there is some development at the back of the beach, with three hotels. Natural forest is present on the western side, and mangrove and almond trees line the east side. There is a certain level of human disturbance to the turtles at night, although the guides working on the beach (GRNTGA) try to reduce this through permit restrictions (chap.2). There is some artificial lighting on the beach coming from the hotels, and one very bright light on the road down to the beach. However, the hoteliers try to keep the light pollution to a minimum, though some are more willing than others (N. Alexander, personal communication). The forest hides the majority of light, and the beach is still very dark in places.

Matelot beach is made up of two bays, one of which is the fishing depot (fig.3.4). This bay is fully illuminated at all times and has been heavily altered with supporting structures and many boats on the beach. The second beach is larger, and has had no alteration. Neither bay receives a significant number of nesting turtles (SRL, personal observation).

Dog predation of nests and hatchlings is a big problem on all of the eastern north coast beaches, most notably at Grande Riviere. There appears to be a particularly large number of stray dogs, and large proportions of the nests on the beach are dug up and exposed (Maharaj, 2004; N. Alexander, personal communication; SRL, personal observation).

Figure 3.4 The fishing depot at Matelot

Toco beach has a small river draining into the sea through the beach (Salybia River). Sans Souci had no visible surface water outflow. Both Grande Riviere (Grande Riviere River) and Matelot (Matelot River) have large river outflows into the sea. The Matelot River is unchanging in its course from year to year. Grande Riviere River is extremely changeable, producing high levels of sand movement and erosion each year, leading to the loss of many nests (fig.3.5 and 3.6) (Lum, 2005; SRL, personal observation).

Figure 3.5 Grande Riviere beach showing the river

Figure 3.6 Grande Riviere beach with high levels of erosion from wave and river action. Note the high number of turtle eggs on the beach

The slopes of Toco and Sans Souci beach are moderate, and have medium grained sand (Georges and Greenidge, 1983). Grande Riviere is steeply sloping, and has much coarser sand, almost like small pebbles in places (Georges and Greenidge, 1983; personal observation). Matelot beach is a gentle sloping beach, and the sand texture is medium (Georges and Greenidge, 1983). Both Matelot beaches have exposed rocks on them, and the sand is often removed, exposing the rocks underneath. The seaward approaches to Toco and Sans Souci are relatively shallow, and Toco has a shallow reef located 90 m offshore. The sea floor in this area supports some hard corals and sea grass patches. Sans Souci also has a small reef on the eastern side. The offshore area at Matelot is shallow to medium. The seaward approach to Grande Riviere beach is categorised as deep (IMA, 2004).

c) Mid-section beaches

The mid section of the north coast has four main beaches: Madamas, Grand Tacarib, Murphy's Bay and Paria, interspersed with several smaller bays; Fingers Bay, Old Man Beach and Petit Tacarib (fig.3.1). Most of these beaches are remote and free from any human alteration or disturbance. They are occasionally visited by passing hunters or hikers, but with negligible affect to the beach or turtles. The one beach on which human disturbance has increased in recent years is Paria. More people have been using the beach for camping, swimming and barbecues now that it is easier to access from Blanchisseuse (fig.3.7). People often leave their rubbish behind on the beach, and set fires under trees (fig.3.8).

Figure 3.7 People swimming in the river at Paria

Figure 3.8 Rubbish dumped under burnt out tree at Paria (offshore stacks in the background)

Because there are no guides or protection for turtles on the beaches in the mid section of the coast, turtles nesting at Paria are often harassed by visitors at night. Often the harassment is not deliberate, but more due to ignorance. I witnessed leatherbacks being disturbed by strong lighting and being physically stressed (e.g. standing on the turtle's back when she was laying and moving on the beach) on several occasions. These turtles often left the beach without nesting (false crawl). Because the beaches in the middle section of the coast are not near any human habitations, dogs on the beach are rare, only infrequently passing through with hunters. Natural predators to nests, such as vultures and crabs, are present, as on all the beaches on the north coast.

Figure 3.9 Madamas beach with river cutting though the middle of the beach having changed course from the eastern end in 2002

Figure 3.10 Madamas beach in 2003. River changed course back to the east end of the beach. This shows the path where the river used to drain out in 2002, and the amount of sand that it eroded from the beach

All the beaches in the mid section of the north coast are backed by dense natural forest. Paria (fig.3.7) and Madamas both have large rivers flowing through the beaches into the sea. The river at Paria is fairly stable and rarely changes course (C. Patron, personal communication). The river at Madamas however, is extremely dynamic and changed course a number of times during the project (2000 – 2004) (fig.3.9 and 3.10). Many nests are destroyed by the river due to erosion and flooding.

Grand Tacarib beach has several large seasonal streams that grow in size during the rains (fig.3.11). Any nests positioned close to the streams are in danger of being eroded away. Petit Tacarib has no visible surface water. Old Man and Fingers beaches both have several streams and some flooding during times of heavy rain. Murphy's Bay has some small streams at each end of the beach and much of the eastern end of the beach is flooded in the rainy season. This beach has a lot of running vines at the back (fig.3.12). The water table on Murphy's Bay is very high (chap.7).

Figure 3.11 Grand Tacarib beach, showing one of three large seasonal streams

Figure 3.12 Murphy's Bay with running vines and large offshore rock

Murphy's Bay, Paria, Petit Tacarib and Madamas have few rocks on the beaches. Grand Tacarib has some at the eastern end, and Old Man and Fingers has quite a few rocky patches (fig.3.13). The sand on all the beaches is medium grained (Georges and Greenidge, 1983), apart from on Madamas where it is medium to coarse (Georges and Greenidge, 1983; personal observation). The slope of the beach at Madamas, Grand Tacarib and Petit Tacarib is moderate to steep, and the offshore area is moderate to deep at Grand and Petit Tacarib. The offshore area at Madamas was deep, and there are several offshore stacks (fig.3.14). Old Man, Fingers, Paria and Murphy's Bay has a moderate sloping beach, and a medium depth offshore area (IMA, 2004).

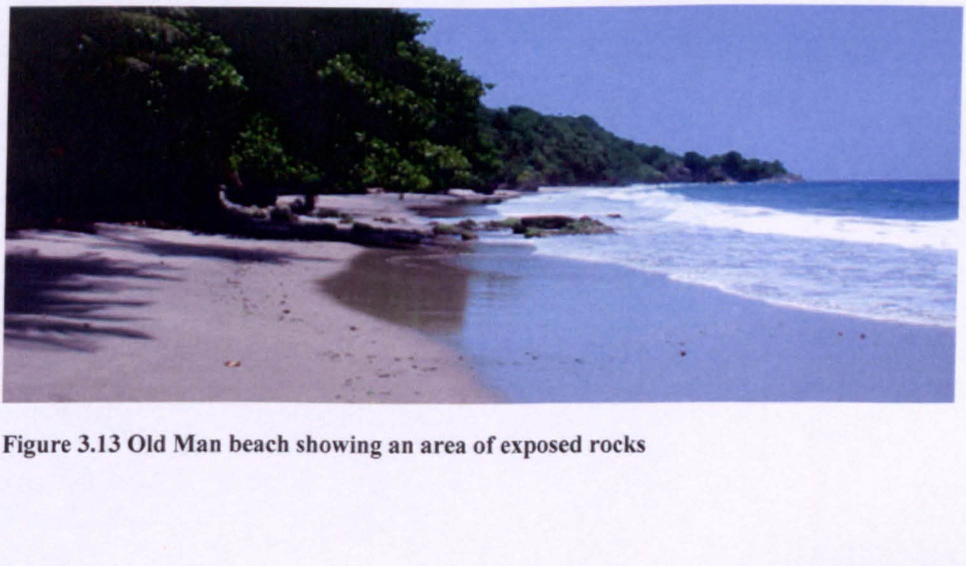


Figure 3.13 Old Man beach showing an area of exposed rocks

Figure 3.14 Offshore stacks at Madamas

Paria is the only beach classed as a bay in this section of coast (fig.3.15). All the others are open, according to the CDI (Georges, 1983).

Figure 3.15 Paria Bay, showing the curve of the beach

Table 3.3 summarises the human influences and topographic features of each of the 14 north coast beaches. The information was collected by a combination of personal observation, field measurements, and from existing literature (IMA, 2004; Georges, 1983; Georges and Greenidge, 1983; Imray-lolaire, 2003).

Table 3-3 A summary of the topographic features and human disturbance of each turtle nesting beach on the north coast of Trinidad.

Beach	*Beach type*	*Sand size*	*River/streams*	*Slope*	*Rocks*	*Vegetation*	*Seaward approach*	*Human alteration/disturbance*	*Artificial light*	*Predation*
Toco	Open	Medium	Small river in rainy season (Salybia River)	Moderate	None	Scrub	Shallow reef 90m offshore. Coral and rubble seabed. Some sea grass	Open beach. Much vegetation removed. In a village. Tourists.	Present	Natural predators and dogs
Sans Souci	Open	Medium	None	Moderate	None	Scrub	Shallow - moderate. Small amount of reef	Open beach. With much of vegetation removed. Tourists and surfers	Present	Natural predators and dogs
G. Riviere	Open	Coarse	Large river (Grande Riviere River). Two streams further down east.	Steep	None	Forest on west. Mangrove beside river	Deep	Some development. much of natural forest remains on west side. 3 hotels. Tourists present to turtle watch – but accompanied by guides	Present, but kept to minimum.	Natural predators and many dogs
Matelot	Open	Medium	Large river (Matelot river)	Gentle	Some	Some forest	Shallow - moderate	In village. Fishing depot present.	Present	Natural predators and many dogs
Madamas	Open	Medium - coarse.	Large river	Moderate to steep	Some	Dense forest	Deep plunge. 2 large offshore stacks	None	None	Natural predators only
G. Tacarib	Open	Medium	3 large streams that grow during rain.	Moderate to steep	Some at eastern end.	Dense forest,	Moderate - deep	None	None	Natural predators only
P. Tacarib	Open	Medium	None	Moderate to steep	None	Dense forest	Moderate - deep	None	None	Natural predators only
Old Man	Open	Medium	Several steams	Moderate	Some	Dense forest	Moderate with rocks	None	None	Natural predators only

Table 3.3 (continued)

Beach	***Beach type***	***Sand size***	***River/streams***	***Slope***	***Rocks***	***Vegetation***	***Seaward approach***	***Human alteration/disturbance***	***Artificial light***	***Predation***
Fingers	Open	Medium	Several streams	Moderate	Some	Dense forest	Moderate with rocks	None	None	Natural predators only
Murphy's	Open	Medium	Underground streams – prone to flooding at eastern end.	Moderate	None	Dense forest	Moderate Large offshore stack	None	None	Natural predators only
Paria	Bay	Medium	Large river	Moderate	None	Dense forest	Moderate Some offshore stacks	On occasion – visited by tourists regularly	None	Natural predators. Occasionally dogs
Blanchisseuse	Open	Medium	Large river (Marianne River).	Moderate to steep	Some	Palms, almond and mangrove. Some natural forest	Moderate Small offshore rock reef at eastern end.	Some development. Visiting holidaymakers. Currently being developed for hotel.	Present	Natural predators and many dogs
Las Cuevas	Bay	Fine	Several small seasonal streams	Gentle	Some	Almond trees and sand runners in west. Some forest on east side.	Shallow - moderate	Some development on west side. Car park, facilities, hotel. Forest removed. East end relatively unchanged and sheltered.	Present	Natural predators and many dogs
Maracas	Bay	Fine	Several small seasonal streams	Gentle	None	Sparse palms and almond trees	Shallow - moderate	Heavily altered, buildings and concrete areas, car park. Many holiday makers. Hotel.	Present on west side	Natural predators and many dogs

3.3.3 Analysis of beach characteristics

Table 3.4 shows the results of the exploratory regression analysis on the different environmental and physical aspects of the beaches with nest density.

Table 3-4 Results of the exploratory regression analyses for each of the scores for the beach characteristics correlated with nest density

Beach feature	*r*	*F*	*p*	*df*	*Result*
Length	0.019	0.004	NS	13	No correlation
Width	0.67	9.61	0.009	13	Wider = higher density
Sand	0.75	15.47	0.002	13	Coarser = higher density
Offshore	0.68	10.1	0.008	13	Deeper = higher density
Slope	0.65	9.03	0.011	13	Steeper = higher density
Rocks on beach	0.33	1.47	NS	13	No correlation
Sub. rocks/ reef	0.43	2.75	NS	13	No correlation
Water outflow	0.25	0.82	NS	13	No correlation
Human alteration	0.38	2.02	NS	13	No correlation
Artificial lights	3.71	1.92	NS	13	No correlation
Predation	0.15	0.28	NS	13	No correlation
Vegetation	0.39	2.22	NS	13	No correlation

The beach width, sand particle size, offshore approach and slope of the beach were all found to have a significant positive correlation with nest density. No relationship was found with any of the other beach characteristics and nest density on their own.

Multiple regression analyses (using a backward elimination procedure) were performed in several steps due to the high ratio of beach attributes to the number of data points. The physical beach attributes were looked at first. The sand particle size, slope of the beach and depth of the seaward approach were closely correlated with each other, with the sand particle size coming out as most significantly correlated with nest density. Beach slope and offshore approach were sequentially removed from the model since they did not explain a significant proportion of the variation in nest density that was independent of the effect of sand particle size. Length of beach, fresh water outflow, the presence of rocks on the beach and the shape of the beach were found not to be significant and were also eliminated from the model.

The overall regression for the physical beach characteristics ($F_{3, 10} = 28.61$, $p < 0.001$, adjusted $r^2 = 0.864$) included sand particle size ($p < 0.001$, increasing with nest density), beach width ($p = 0.002$, increasing with nest density) and submerged rocks and reef ($p = 0.05$, less reef and rocks with increasing nest density). Each of these three independent beach variables significantly affected the density of clutches laid on each beach, and the high r^2

value suggests that they account for a large proportion of the variation in beach choice by adult females.

Analogous multiple regression analysis of the human-related beach characteristics showed that the amount of backing vegetation, human alteration and level of artificial lighting were highly correlated with each other, and that artificial lighting had the strongest correlation with nest density. The overall regression ($F_{2, 11} = 19.48$, $p < 0.001$, adjusted $r^2 = 0.74$) included artificial lighting ($p < 0.001$, increased nest density with less light) and predation levels ($p < 0.001$, more predation with higher nest density). The result of higher nest density with introduced predation was unexpected and may be due to the nest density having an effect on the level of predation rather than the other way around. This result is possibly biased by the exceptional nature of high density nesting at Grande Riviere beach where there were very high nest numbers and also high levels of predation. In light of this result, the Grande Riviere data point was removed and the analysis run again.

With the Grande Riviere data point removed, the overall multiple regression model ($F_{1, 11} = 7.51$, $p = 0.019$, adjusted $r^2 = 0.352$) showed that the level of artificial lighting was significant in terms of nest density on the beach (and again closely corrected to human alteration and backing vegetation cover), but that the presence of introduced predation was no longer significant. Although the amount of lighting (and closely correlated human alteration and backing vegetation cover) was a significant factor for nest density, the low r^2 value suggests that only a small amount of the nest density variation on the north coast beaches is explained by this beach characteristic.

A multiple regression was run on the physical beach attributes alone without the Grande Riviere data. The result of the overall regression was the same as with the data for Grande Riviere ($F_{3, 9} = 60.18$, $p < 0.001$, adjusted $r^2 = 0.937$), with sand particle size, beach width and submerged rocks and reef all still being independent significant factors influencing nest density.

Once the significant physical and human beach characteristics were identified they were analysed together, with and without the Grande Riviere data (sand particle size, beach width, submerged rocks and artificial lighting). The final regression model without the Grande Riviere data found all the attributes to be significant ($F_{4, 8} = 81.46$, $p < 0.001$, adjusted $r^2 = 0.953$), with beach width being the most important attribute ($p < 0.001$), followed by sand particle size ($p = 0.029$), submerged rocks ($p = 0.038$) and artificial light ($p = 0.079$).

Although the artificial light was not significant, it was still included by the regression model, as the r^2 value is higher with artificial light attribute included.

The final regression including the Grande Riviere data point ($F_{3, 10} = 28.61$, $p < 0.001$, adjusted $r^2 = 0.864$) did not find the level of light significant and excluded it from the model.

3.4 Discussion

The north coast of Trinidad has 14 beaches suitable for sea turtle nesting (fig.3.1). Each of the beaches has different levels of human disturbance and alteration, and slightly different topographic features, although they all conform to the general characteristics of leatherback nesting beaches (Whitmore and Dutton, 1985). There appear to be a number of factors influencing the females' choice of beach, making it difficult to identify any strict rules of preference, although some beach characteristics stand out as being more important than others. There were clear differences in nest density between beaches, with the high density beaches all supporting over 1,000 nests/km and the low density beaches with less than 320 nests/km. This divide suggests that there is at least one beach characteristic that heavily influences the females' choice. There was also some variation amongst the high density and low density beaches, which allows the weaker influences on nesting beaches to be examined.

Since leatherbacks use a number of nesting beaches within one area rather than one specific beach like some other sea turtle species (Lohmann et al., 1997), the high densities on certain beaches cannot necessarily be accounted for by natal beach fidelity. Initial tag return data from the north coast does suggest some beach or coastline fidelity, with only five out of 42 returning leatherbacks recorded nesting on different beaches from where they were originally tagged (chap.4). Although leatherbacks are known to lay on multiple beaches, possibly as a mechanism to reduce the likelihood of nests being destroyed (Tucker and Frasier, 1991; Pritchard, 1982; Eckert, 1987; Chevalier and Girondot, 1999), leatherbacks nesting on Caribbean islands are thought to show stronger beach fidelity than mainland nesters, as beaches on islands are believed to be less changeable (Eckert, 1987; Eckert and Eckert, 1988; Eckert et al., 1989a; Dutton et al., 1999). With this is mind, the leatherbacks nesting in Trinidad therefore may employ a less scattered clutch laying strategy, nesting on a preferred beach multiple times rather than choosing a different less attractive area.

3.4.1 Topographic beach features

On first impressions, from a human's point of view, the appeal of Grande Riviere beach as by far the most popular nesting beach on the north coast is unclear. It is probably the most hazardous beach on which to nest due to the large unpredictable river system, major sand movements, a large number of predators (mostly introduced dogs), and the fact that it is located within a village. However, from a turtle's point of view, the first factor for choosing a beach for nesting is most likely to be those features that can be detected from the water rather than on the beach itself (Mortimer, 1982a; Eckert, 1987). The high density nesting beaches received large numbers of females (nesting and false crawling), and the low density nesting beaches received low numbers of females. Therefore it appears that the females made their choice of beach before they emerged from the sea, rather than false crawling more on the low density beaches. There may be a way for the turtles to assess the beach from the offshore topography, providing cues for beach selection, although it is unknown how this might occur (Provancha and Ehrhart, 1987; Horrocks and Scott, 1991).

The characteristics of a beach that might be detected from the sea are the shape of the basin, outflow of fresh water, the presence of offshore rocks and reef features, the depth of the offshore area, and slope of the beach. Turtles may also be able to detect light levels on the beach (leatherbacks nest in the hours of darkness: SRL, personal observation)).

The shape of the beach (open or bayed) had no effect on nesting density, nor did the level of fresh water outflow. Beach length was found not to be an important factor for beach choice by nesting females either. Kikukawa et al. (1999) found that beach length had a negative influence on loggerhead beach choice in Japan: the longer the beach the fewer nests. However, they suggested that this was because humans more often used longer beaches, this acting as a deterrent to the turtles, rather than the physical aspect of the beach length being selected against.

Kikukawa et al. (1996) found that beach width was also an important characteristic affecting nesting beach choice. This was also the case in this study, with beach width being one of the most important beach characteristics for high nest density, suggesting that width of beach strongly influences female beach choice, and that bigger beaches support a larger number of nests. A wider beach may present a larger nesting area free of inundation, which would be attractive to nesting females. It is perhaps difficult to see how beach width would be able to be detected from the sea, as it is independent of other physical factors that would be detectible. However, beach width may be an attribute that would attract a female back to that beach if a clutch had been successfully laid there earlier in the season.

The multiple regression analysis showed that the sand particle size, depth of the offshore approach and the slope of the beach were highly correlated with each other, and therefore dependent on each other. In this study, sand particle size was found to be the most significant factor for determining nest density out of these three dependent attributes, the leatherbacks preferring coarser sand to finer sand. The relationship between these attributes suggests that the approach can give an indication of what the beach is like. Therefore the turtles may be able to determine the gradient of the beach and the sand particle size from the sea before they emerge.

The sand on the north and east coasts of Trinidad is generally medium grained, whereas the sand on the west and south coasts is much finer (Georges and Greenidge, 1983). Leatherbacks rarely nest on the west or south coast beaches, and so sand particle size could be an influencing factor in determining which coastlines they nest on. However, sand particle size may be less relevant for distinguishing between beaches along the same coast. On the north coast, the beaches at the eastern end are relatively immature and have coarser grain sizes, and grain size tends to increase from west to east (Georges and Greenidge, 1983; SRL, personal observation). The western beaches had the finest sand (Maracas and Las Cuevas), and the sand particle size was larger on the beaches heading east along the coast. The largest particle size was found on Grande Riviere and Madamas beaches, which are in the middle of the coastline, but generally the trend was as Georges and Greenidge described (1983).

Sand particle size is an important property of a nesting beach for two reasons: it can affect beach selection by nesting females, i.e. it needs to be suitable for constructing a nest in; and for the survival of eggs during incubation (chap.7). However, several studies have looked at sand characteristics on turtle nesting beaches: pH, calcium carbonate content, water content, organic content, particle size and colour (Stancyk and Ross, 1978; Mortimer, 1982), and found no significant relationships with beach choice or nest frequency (Kikukawa et al., 1999). Kikukawa et al. (1999), however, found that sand softness was the one of the most important properties that influenced loggerhead beach choice in Japan.

It seems unlikely that a leatherback would be able to detect sand particle size until it began digging in the sand, making it an improbable factor for beach choice before emergence from the sea. Hendrickson and Balasingam (1966) suggested that leatherbacks preferred coarser sand, from evidence that the females favoured a section of the beach with coarse sand. However, the coarse grained area of the beach was also steeper. It could have been the gradient of the beach that influenced the turtles as much as the sand size. Leatherbacks do successfully nest in fine sand elsewhere (Mortimer, 1982a). It may be that sand particle size only has an effect on beach choice by its influence on the shape of the beach rather than as an individual factor.

The leatherbacks may prefer to nest on steeper sloping beaches that allow the females to move higher onto the beach over a shorter distance, reducing the distance between waterline and suitable nesting sites (Pritchard, 1971; Shultz, 1975; Hendrickson, 1980). A steeper beach may also present a larger area suitable for nesting where nests will be safe from inundation during the incubation period (Mortimer, 1982a). A deeper beach approach would also help the female swim closer to the beach reducing the amount of crawling on sand, and therefore saving energy.

Mortimer (1982a) found that the presence of submerged rocks was one of the greatest hindrances to nesting green turtles on Ascension Island, and that the heaviest nesting occurred on the stretches of beach where the offshore approach was deepest. Hughes (1974) found that 81.1 % of successful leatherback emergences were on beaches lacking offshore obstructions. However, 14.8 % of the approaches were characterised as deep, and 66.4 % as shallow. From these results he suggested that a clear approach to the beach was more important than the depth. In the case of leatherbacks on the north coast of Trinidad, depth of the approach, as linked to the sand particle size ($p < 0.001$), appeared to be more important than the presence of offshore rocks and reefs ($p < 0.05$), although both were significant in terms of nest density. It is possible that turtles avoid beaches with reefs and rocks as they could easily damage themselves in heavy surf on the way in and out of the beach (Mortimer, 1982a), especially leatherbacks, as they do not have a hard protective shell like other sea turtle species (Pritchard, 1971). Turtles also may have a preference for beaches without submerged rocks or reefs, as there are fewer hiding places for potential predators that prey on hatchlings (Mortimer, 1981).

3.4.2 Human-related beach characteristics

The physical aspects of the beaches can largely explain the distribution of nests along the coast. However, the level of human interference accounted for a small amount of the divide between the low and high density nesting beaches.

All the high density beaches were located along the inaccessible length of coastline between Matelot and Blanchisseuse, with the exception of Grande Riviere. This section of the coast is largely undisturbed by humans, with no alteration of the beach or backing vegetation, or presence of artificial lighting. All the low density beaches (apart from Old Man and Fingers, thought to be less suitable for other reasons) had some level of artificial lighting. Maracas Bay was one of the lowest density beaches on the whole north coast with an average of 42 nests/km, and was also the most developed, with the most lighting, beach alteration, structures on the beach and the removal of all the backing forest. The only major difference between Maracas and Las Cuevas was the level of human disturbance and alteration, and Las Cuevas received more than double the nests recorded from Maracas (105 nests/km). The density of nests on Las Cuevas was also observed to be higher at the western section of Las Cuevas, away from the lights and tourist part of the beach, suggesting that the leatherbacks preferred the darker, quieter forested area. Although Grande Riviere beach is also located within a village, the beach is relatively undeveloped with much of the original mangrove and forest remaining. There are no structures built on the beach, and all the buildings are behind vegetation. Most people with property at the back of the beach try to keep the artificial lighting to a minimum, and so the majority of the beach is dark. Grande Riviere is also several miles from the other eastern villages, and therefore they would not add to the amount of light that could be detected from the sea.

The measured human-related characteristics of the beaches (lighting, vegetation removal, alteration) were highly dependent on each other, as shown from the multiple regression analysis: the more human alteration there was, the less vegetation and more artificial lighting. The level of artificial lighting was found to be the most important in terms of nest density.

Introduced predators, mostly dogs, were present only on the beaches located in villages. Using the full beach data set, the presence of introduced predators was found to be an important influence on nest density. However, not in the expected way. The nest density increased with introduced predators suggesting that the females preferred beaches with such predators. It is more likely that there were more introduced predators because of the large number of nests, but this hypothesis would not support the fact that there are introduced species on many of the low density beaches along the coast. It appears that the high level of nesting on Grande Riviere beach biased the data, and when the analysis was run without the Grande Riviere data, the artificial lighting again came out as being significant (and highly correlated to the other two variables), and the presence of introduced predators was no longer significant. This suggests that levels of human activity and artificial lighting have an influence on nesting leatherback choice on the north coast of Trinidad, although the low r^2 value of the human-related beach attribute regression model and the final regression model with both physical and human-related attributes suggested that they only account for a very small amount of the variability.

Previous data on leatherback numbers on the north coast are limited (chap.2), making it difficult to determine nest densities and distribution on the beaches in the past. Unpublished records of nesting leatherbacks from Trinidad's Wildlife Section, the Trinidad Field Naturalist Club, and Chu Cheong (1995) (appendix 3) show that numbers were relatively equally spread over the north coast beaches in the 1970's and 1980's, unlike the results from this study which has found high concentrations on particular beaches. Chu Cheong (1990) and Godley et al. (1991) classified the north coast beaches into low, medium and high density nesting areas, mostly based on sporadic track counting. The figures were based on the total number of visible leatherback tracks at the time of visit. Chu Cheong (1990) listed Grande Riviere, Paria, Madamas and Grand Tacarib as high density (> 20 tracks), Las Cuevas and Petit Tacarib as medium density ($> 5 \leq 20$ tracks), and Blanchisseuse, Toco, Sans Souci, Matelot and Maracas as low density (≤ 5 tracks). Godley et al. (1991) obtained comparable results in a subsequent study using similar criteria to Chu Cheong, although they classified Paria as medium density and did not record from Las Cuevas. Fingers and Old Man beach were not included in either study.

Although the nesting leatherback population size is considerably larger now than when these previous studies were carried out (chap.4), it is noticeable that the variation in number of tracks on different beaches was much lower then, and that the leatherbacks appeared to have less preference for particular beaches then than now. The fact that Paria and Las Cuevas beaches were placed in the same medium density category in the early 1990's is a prime example of the difference in nesting densities in previous years. However, it may simply be that the increase in nesting has highlighted the leatherbacks' preferences, or that previous records and turtle numbers were insufficient to show any differences in density or distribution.

The only recent known change on the north coast beaches has been the levels of human alteration and disturbance on the beaches beside the roads. Most of the villages have been *in situ* for several hundred years; however, electric lighting in many of the villages is relatively new. Although there used to be small villages on the now uninhabited area of the coast, there were never any artificial lights. Electric street lighting was introduced to some of the north coast villages only in the last 15 years, some even more recently (R. Roberts, personal communication).

Artificial lighting on beaches has long been recognised as a disruptive agent on nesting beaches (Carr and Ogren, 1959), and many studies have shown artificial light to be a deterrent to nesting sea turtles (Dean and Talbert, 1975; Salmon, 2003). Witherington (1992) found that when artificial light was positioned on an area of beach, the level of nesting loggerheads decreased almost to zero. When the lights were removed, the turtles began nesting there again. Mortimer (1982a) found that artificial light was one of the greatest hindrances to nesting green turtles on Ascension Island, and in Tobago numbers of nesting leatherbacks on the beaches decreased significantly when artificial lights were introduced (W. Herron, personal communication). Stancyk and Ross (1978) found that nesting was less frequent on nesting beaches near human habitation, and Kikukawa et al. (1999) found that distance from the nearest human settlement was one of the greatest influences on beach choice for loggerheads - the further away the better. Different wavelengths and brightness of lights have been shown to have different effects depending on light intensity (Witherington, 1992). This may be why the leatherbacks on the north coast are not put off due to lighting at Grande Riviere, as it may not be intense enough for the turtles to detect from the water.

3.4.3 False crawl rate

The mean false crawl rate on the north coast beaches was 11.8 %, ranging from 7.3 to 25.6 %, which is similar to those found in other locations: 7.2 % in Costa Rica (Reina et al., 2002), up to 28 % in Malaysia (Chua and Furtado, 1988) and 9 - 16 % in Suriname (Hilterman and Goverse, 2005). The false crawl rate may vary depending on how the data are collected. If all false crawls are recorded from the time of the female's emergence through to nest completion, the false crawl rate will appear higher than if they are counted only after the turtle has begun to build her body pit (Reina et al., 2002). For example, Reina et al.'s (2002) rate of 7.2 % may be lower than others, as their nest data were collected during the day, and could only determine false crawls at the body pit stage. Evidence of false crawls from the point of emergence is easily washed away by wave action (Reina et al., 2002). Care should therefore be taken when comparing false crawl rates between regions. False crawl rate is an important factor that must be taken into account when making nest estimates for a wider area (Godley et al., 2001c; chap.4).

Although the results presented here suggest that female leatherbacks make their beach choice based on factors detectible before emergence onto the beach, the false crawl rate can give some insight into the suitability of a beach as a nesting site. The false crawl rates on five of the high density beaches were significantly different from each other (table 3.2, $p < 0.01$), although there was no significant difference between the mean false crawl rate from year to year. This suggests that the false crawl rate varies depending on some influencing beach characteristics, rather than being highly changeable from year to year on the same beach. The fact that there was no significant difference between the proportions of nests on each beach between years also supports this idea.

The physical characteristics of sand type can affect the success of nesting attempts (Reina et al., 2002). Green turtles in Ascension Island had difficulties in constructing nests in coarser sand, and attempted to lay several times before they managed to complete a nest (Mortimer, 1990). Grande Riviere had the highest false crawl rate (mean of 24.9 %), and also the coarsest sand. From night-time monitoring of nesting females on all the high density beaches (chap.4), it was apparent that, during nest construction, coarser sand collapsed much more easily than sand with a smaller particle size. Coarser sand appears to be a more difficult medium in which to build a nest (Reina et al., 2002; SRL, personal observation), possibly increasing the false crawl rate. Individually tagged leatherbacks were commonly seen on Grande Riviere up to three times in one night, having had several earlier unsuccessful nesting attempts. Madamas had the next highest mean false crawl rate (16 %, which was significantly different from all the other beaches), and also had coarser sand than the other high density beaches. The mean nest depth on Grande Riviere was found to be significantly shallower than on other beaches (One-way ANOVA, $F_{3, 701}$ 21.2, $p < 0.001$), also suggesting that it was more difficult to construct a nest in the coarser sand (chap.7).

The presence of rocks, streams and rivers, and debris on the beach could also have an effect on the false crawl rate, presenting unsuitable nesting areas. Leatherbacks often turned back to sea without nesting if they encountered such obstacles. However, it was not uncommon for females to move away from the obstacles and nest a small distance away from rocks or debris rather than returning to the sea. The females would often persevere with digging a nest in a waterlogged area near a fresh water source, or along the strand line, and lay their eggs regardless, rather than return to the sea. The highest false crawl rates were on Madamas and Grande Riviere beach, which were also the two beaches that had large unpredictable river systems flowing through them. This may also contribute to the higher false crawl rates recorded on these two beaches.

Disturbance of nesting leatherbacks by humans and predators could also influence the false crawl rate. Leatherbacks are most sensitive to disturbance when they first emerge from the sea and are searching for a suitable nesting site (SRL, personal observation). If they were disturbed physically, or with a large amount of noise or light at this stage, they were most likely to return to the sea without nesting. However, once they had begun to dig their body pit and to construct their nest, they were much more resistant to the presence of humans or animals (SRL, personal observation). Leatherbacks appeared to be much less sensitive to disturbance than other sea turtle species nesting on the north coast beaches (SRL, personal observation). This is most likely due to their larger size, and the low possibility of there being a land predator large enough to attack a leatherback. In some locations, adult turtles are in danger of becoming prey, when on land, to animals such as jaguars (Schultz, 1975; Troëng, 2000), tigers, wild dogs (Hendrickson, 1958), and crocodiles (Sutherland and Sutherland, 2003). However, there are few reports of adult leatherbacks being attacked by land predators, and no evidence of any predation of nesting adults in Trinidad, other than by man. The only animal that would possibly disturb a nesting leatherback in Trinidad would be a dog, although unlikely.

The level of human disturbance on the high density beaches was very low, with the exception of Grande Riviere. There are often many visitors on the beach, there specifically to see the turtles nest. The GRNTGA oversee the management of the beach during the nesting season, issuing permits, and providing tours on the beach (chap.2). They do their best to control the number of people on the beach at any one time, and make sure that the tourists do not disturb the turtles at the sensitive period of the nesting process, or perform activities which would cause the turtle to turn back to the sea (such as shining bright lights in their eyes, flash photography, or accidentally caving in the nest by getting too close). However, some guests can prove difficult to control (especially if they have been in the hotel bar prior to their beach visit), and nesting leatherbacks do occasionally get disturbed by humans on Grande Riviere beach (N. Alexander, personal communication). The other high density beach that receives some human interference is Paria. However, the level of disturbance is not thought to be enough to significantly affect the false crawl rate. The false crawl rate on Paria is not significantly different from the other remote high density beaches (Grand Tacarib, Madamas and Murphy's Bay).

High densities of nesting females per unit area of beach may result in reduced nesting success or nest development, because of disturbance of nesting females by other females, or disturbance of the nest by subsequently nesting turtles (Girondot et al., 2002; Caut et al., 2006). This happens at a high level in arribada nesting olive ridleys (Plotkin et al., 1995). Reina et al. (2002) found that on Playa Grande in Costa Rica, although leatherbacks occasionally disturbed each other while nesting, the density of turtles did not appear to affect the nesting success. The large numbers of leatherbacks nesting on the high density beaches in Trinidad during peak season meant that they often encountered each other on the beach. This occurred most often on Grande Riviere, the beach with the greatest nest density, where up to 300 female emergences could be witnessed in one night. The coarser sand particle size, together with the high rate of encounter with other nesting females and human disturbance, perhaps explains the significantly higher false crawl rate on Grande Riviere than on the other beaches.

3.4.4 Implications for conservation management and conclusions

The beaches on Trinidad's north coast are well suited to support large numbers of nesting leatherbacks; not least, the beaches on the middle section of the coast between Matelot and Blanchisseuse with their large width, deep seaward approaches, few reef features and lack of human disturbance. It is clear that the leatherbacks have strong preferences for the beach on which they put their nests, which is affected largely by physical and partly by human-related beach characteristics (table.3.3). Beach selection by the nesting turtles involves complex interactions of various factors at the same time (Kikukawa et al., 1999).

The most important beach features influencing leatherback beach choice are the offshore approach, beach slope and sand particle size, all of which are dependent on each other, with sand particle size coming out as the most important, suggesting that it is sand that dictates the shape and depth of the beach. The offshore approach seems the most likely feature to influence initial beach choice as it can be assessed by the turtle prior to emergence. The presence of reefs and submerged rocks was also significant, with clear beach approaches being more attractive to the females, most likely to avoid body damage in the heavy surf.

There is some evidence to suggest that human activity and associated beach alterations were a deterrent to nesting leatherbacks on the north coast, with the level of lighting being the most important. Human-related changes have also been found to have an affect in other regions (Mortimer, 1982a; Withering, 1992, Kikukawa et al., 1999). Grande Riviere was the exception to this hypothesis. However, since the beaches with the more favourable topographic features also happen to be those without human interference, it is difficult to make an assessment without this bias. Past spread of numbers of leatherbacks on the north coast beaches (appendix 3) suggests that there is a more pronounced preference for particular beaches today. This may be due to the relatively recent introduction of artificial lighting and the removal of backing forest from the now comparatively low density beaches.

The identification of the high density beaches on the north coast is important for conservation management of the leatherbacks nesting in Trinidad. If it is the case that the leatherbacks' preferred beaches are also the ones that are currently left undisturbed, this is a fortunate situation, and the leatherbacks are free at present to continue nesting on their favourite beaches, relatively uninterrupted and unaffected by human interference. However, the threat of development on the north coast, and completion of the Paria Main road between Matelot and Blanchisseuse puts the high density beaches in jeopardy. Any future beach development should be sensitive to sea turtle nesting to reduce any adverse effects (Shabica, 1995). Grande Riviere is a good example of how humans and turtles can live together, although Grande Riviere does appear to be an exceptional beach in terms of density. There, the topographic features of the beach are perhaps so appealing to the nesting females that the level of human presence does not put them off. Having said this, the level of human alteration on Grande Riviere is much less than on all the other beaches backed by villages, with much of the forest remaining, no structures on the beach, and a low level of artificial lighting. The GRNTGA are also an essential element of the turtle friendly development on Grande Riviere beach, helping by controlling visitor numbers and turtle harassment levels, and making sure that no turtles are slaughtered for meat.

If or when the Paria Main road is completed, development of the beaches on the mid section of the coast should be carried out with great care. The level and intensity of lighting should be kept to a minimum, and as much of the backing forest as possible should be left intact. The control of stray dogs should also be a consideration, as they can be responsible for a large reduction in nest and hatching success by predation on nests (chap.7). It is also recommended to give the high density beaches the legal protected status that benefits Grande Riviere (chap.2), and to support a group of locals to oversee these restrictions and monitor the nesting turtles so that any changes in nesting numbers may be detected.

4. Annual numbers, ecology and behaviour of nesting leatherbacks on the north coast of Trinidad

4.1 Introduction

Trinidad is thought to support one of largest leatherback rookeries in the Atlantic Ocean, along with the Guianas, Gabon and Caribbean Central America (Girondot and Fretey, 1996; Eckert, 2001; Fretey and Billes, 2000; Troëng et al., 2004; Sounguet et al., in press). Smaller leatherback aggregations nest throughout the Caribbean Islands, Brazil, Venezuela and Colombia (Spotila et al., 1996; Eckert, 2001). There have been recent reports of severe declines in leatherback numbers in the Pacific Ocean (Chan and Liew, 1996; Spotila et al., 1996; 2000). However, some leatherback populations in the Atlantic and Caribbean appear to be stable or increasing, e.g. St Croix (Boulon et al., 1996; Dutton et al., 2005), French Guiana (Chevalier and Girondot, 2000) and Suriname (Hilterman and Goverse, 2005). The numbers of leatherbacks nesting in Trinidad also appear to be increasing based on data from Matura Beach on the east coast, although the trends from this area should be treated with caution until fully analysed (Eckert and Eckert, 2005).

Although Trinidad is considered one of the largest leatherback rookeries in the Atlantic, surprisingly little research had previously been carried out on the north coast. Some data have been collected at Grande Riviere, and on other north coast beaches accessible from the road (S. Poon, personal communication). However, limited research has previously been carried out on the remote bays found on the 22 km section of the coast between the villages of Matelot (east) and Blanchisseuse (west) where the terrain is difficult and no road exists (fig.3.1). This area can only be reached by foot, or by boat. The cost and effort of undertaking research in this region has been the main reason that no substantial fieldwork has previously been carried out (Lum, 2001), although earlier studies have attempted to assess nesting numbers from brief visits counting tracks and nesting females, and by performing aerial surveys (Bacon, 1970; Nathai-Gyan et al., 1987; Chu Cheong, 1990; 1995; Godley et al., 1989; 1991; S. Gomes, personal communication; chap.2).

Evaluating the population size of sea turtles is a valuable conservation tool (Meylan, 1982a; Gerrodette and Taylor, 1999) and allows trends to be identified, making it possible to assess the results of conservation management practices and the consequences of environmental threats and changes. However, due to the relatively undocumented behaviour of sea turtles at sea, they are difficult animals to census. Most population estimates are based on annual numbers of nesting females or on total number of nests, this data being used as a proxy for total population size. Such data is collected by daytime track counts by foot or aerial survey, or night-time adult or nest counts (Meylan, 1982a). These methods are not completely comprehensive and necessitate some extrapolation. It is clearly near impossible to count every female on every beach over a five-month period within a nesting region, whilst also taking into consideration movements between beaches. Knowing the clutch frequency and the interval between breeding seasons is an essential requirement for estimating nesting population size accurately (Broderick et al., 2002), and natural fluctuations in nesting females must be taken into account (Meylan, 1982a). Because sea turtles reproduce only every two to three years (Miller, 1997), a three-year dataset, at least, is required to produce a reliable view of the mean annual nesting population size (S. Eckert, personal communication).

This study provides an up-to-date stock assessment of the annual nesting leatherback population on the north coast of Trinidad. The method uses a combined dataset of laid clutches and observed hatched nests and takes account of the attributes of sea turtle nesting behaviour in a scattered and difficult-to-access environment. This five-year data set can tell us about the current status of nesting females and provide an indication of the trend over the last 30 years. This research will be an effective tool in assisting the conservation management of leatherbacks in Trinidad, and offers a simple and achievable strategy to monitor and detect changes in the number of nesting females into the future. I also hope to make a valuable contribution towards the current efforts to calculate the leatherback numbers remaining in the Northern Atlantic Ocean.

4.2. Methods

4.2.1 Study area

Data were collected from the 14 beaches suitable for sea turtle nesting along the northern coastline of Trinidad (chap.3; fig.3.1) between April and August in 2000, 2002, 2003 and 2004. During each year of the study, all beaches were sampled regularly, although the majority of effort was concentrated on five high density beaches (> 500 nests/km): Grande Riviere, Paria, Murphy's Bay, Grand Tacarib and Madamas (chap.3). Although Petit Tacarib was also classed as a high density beach, it was not monitored as rigorously as the other high density beaches due to its small size. The other turtle nesting beaches along the north coast were classed as low density (< 500 nests/km) (chap.3).

4.2.2 Data collection

A trip to one of the remote high density beaches was run every four - five days during the season, each lasting between two and four nights depending on weather conditions and local team availability. Only one beach could be visited at any one time (apart from Paria and Murphy's Bay which were close enough to walk between at night). Two types of field visit were employed: camping on a different beach each night, or spending the whole duration of the trip on one beach. Each high density beach was therefore surveyed approximately four to seven times spread over the season.

Turtle activity was assessed (by nightly patrols) from 7 pm till sunrise. Two shifts of two people covered the beach, patrolling every 20 minutes throughout the night. Four extra people worked during peak season to avoid missing any turtle activity. Total beach coverage was achievable due to the relatively small sizes of the beaches. The data collected from each turtle encountered were: date, time, position on beach, turtle activity, visible injuries, tags present, curved carapace length (CCL) measured alongside the vertebral ridge, curved carapace width (CCW) (Bolton, 1999), clutch laid/false crawl (chap.3) and depth of nest (chap.7). The data sheet used to collect the data can be viewed in appendix 6. All measurements were taken with a plasticized cloth measuring tape accurate to 1 mm (measurements were measured to the nearest cm).

The intensive overnight survey method allowed the exact number of clutches laid on one beach to be recorded on any particular night throughout the nesting season. I am sure that the majority of the time all of the turtles on the beach in one night were encountered. The time each turtle spent on the beach (one-two hours) meant that they were seldom missed. Double counting was avoided by reviewing the time, turtle activity and position on the beach of previously collected records and by tags.

Foreign tags provided some insight into the inter-nesting migrations of the females, and the biometric data allowed size comparison with other nesting populations. The false crawl rate was calculated for each beach in each year (chap.2).

The lower density beaches were visited every two to three weeks throughout the season and were examined during the day for adult tracks and hatched nests. An estimate of nest numbers was made for each low-density beach on the north coast.

Once nests began to hatch (early May), the beach (which was being visited at the time) was checked each morning for any nests that had hatched the previous night. Nests were identified by an indentation in the sand, usually with hatchling tracks leading from it. The beach would be inspected at sunrise and all hatched nests were marked with sticks. The hatched nests were counted, and their positions noted. Any nests observed hatching during the day were added to the total. Only fresh nests were counted, although sometimes it was difficult to tell the difference between nests that had hatched that night or the night before on the first night of work, especially if there had been rain. Once a hatched nest had been counted, it was either excavated (chap.7) or smoothed over to avoid double counting on subsequent nights.

Approximately 30 % of leatherback nests on the remote north coast beaches do not hatch due to various reasons (chap.7). The hatched nest data were therefore amended accordingly to account for uncounted failed nests accordingly.

The amended number of hatched nests on any one night was used to calculate the approximate number of clutches that had been laid on the corresponding night earlier in the season. Using the mean incubation period for leatherback clutches on the north coast (69.8 days: chap.7), the approximate lay date could be established by subtracting 69.8 days from the hatch date.

The hatched nest data was combined with the laid clutch data to produce a larger data set and to cover a larger portion of the nesting season. Nights for which there was both hatched nest data and laid clutch data were averaged. Hatched nest data was only available for Paria, Grand Tacarib and Madamas.

In 2004, I began tagging leatherbacks, each with two metal Monel flipper tags (one on each side on the baggy skin between the tail and flipper) and one PIT (Passive Integrated Transponder) (AVIS) tag placed in the right shoulder muscle (McDonald and Dutton, 1994). The tags were the same as those used on the east coast by Nature Seekers at Matura. The tagging in 2004 allowed the collection of information on the leatherbacks' nesting habits, although since the team could be on only one beach at a time, the chances of encountering turtles already tagged were limited. However, some tag return data were accumulated. The data provided some insights into beach fidelity.

Interviews were conducted with local fishermen and gardeners using the north coast area to find out information about past numbers of leatherbacks on beaches and in local waters (chap.6). Relevant literature and records were reviewed to source past numbers of leatherbacks using the beaches (appendix 3).

4.2.3 Data analysis

The combined laid clutch and hatched nest data set (where available) was used to calculate an estimate of total nests for each beach in each season. Full data sets were available for Grand Tacarib, Madamas and Paria and for some years and parts of the season for Murphy's Bay and Grande Riviere. The nest data were analysed using linear regression analysis; nest numbers (Arcsin transformed) against time (day of season). A regression line was calculated for each half of the nesting season (March - May and June - August). The line equations were used to calculate the total number of nests for each part of the season, which were added together to calculate the total number of nests that year for that beach.

The regression lines for each beach were analysed using a General Linear Model (GLM) to check that they were not significantly different from each other (from year to year, and from one half of the season to the other). This was important so that the line equations could be reliably used to project nest numbers for the beaches for which I had fewer data. The proportion of nests on each beach was compared between years, taking into account yearly fluctuations of nesting females and density differences on each beach (chap.3).

No reliable hatched nest data were available for Murphy's Bay or Grande Riviere. The number of laid clutches was available for Murphy's Bay, but not for Grande Riviere, although total numbers of visiting adults were known for certain times in the season. Data used for the calculation of numbers at Grande Riviere were therefore adjusted using the false crawl rate for that beach (chap.3). For years in which reliable numbers for one half of the season were known (for Grande Riviere and Murphy's Bay), numbers for the other half were calculated based on the proportion of nests between the halves of season for the other beaches. For years when no data were available, numbers were calculated based on the relative proportion of nests on those beaches in other years.

Once the number of nests for each beach was known, the nest density could be calculated using the length of the beach (nests per km) (chap.3). The numbers of nests for all 14 beaches were added together for each year to get an annual estimate of nest numbers for the whole northern coastline. An annual mean total of nests for the north coast was calculated using the four years of data.

The inter-nesting period was calculated using the number of days elapsed between observed nestings. An accurate measure of clutch frequency was difficult to determine using the observed clutch frequency (OCF), due to the limited data. The estimated clutch frequency (ECF) was calculated using the inter-nesting period (Frazer and Richardson, 1985; Steyermark et al., 1996), in an attempt to derive a more reliable figure.

The mean annual number of nests on the coastline was divided by five (clutch frequency) to calculate the total number of nesting females. I employed the commonly used value of five based on results from other studies (Steyermark et al., 1996; Spotila et al., 1996; Andrews and Shanker, 2002) as a reliable figure could not be extracted from the limited tag return data from our own study. A higher (seven) and lower (four – due to results of the ECF in this study) clutch frequency was also applied to the nest numbers in order to produce a minimum and maximum value. Using data from the four study seasons, an annual mean number of nesting females was calculated. This figure was multiplied by 2.5 (mean remigration interval) (Schulz, 1975; Spotila et al., 1996; Steyermark et al., 1996) to generate the total nesting population using the north coast.

$$\text{Total nesting population} = \frac{\text{mean no. of nests per year}}{\text{mean annual clutch frequency}(5)} \times \text{mean remigration interval}(2.5)$$

In order to assess my method of calculating the annual nesting population size, two other methods were applied to the data for comparison (Bacon, 1973 and Steyermark et al., 1996). Bacon's calculation assumed that each female laid five-seven clutches per season at ten-day intervals, and that each female would nest for approximately two months. Since the nesting season lasted roughly four months, the nesting population was estimated as 20 times the average number of nests per night (Bacon, 1973). Steyermark's method involved calculating the mean number of nests per night for each month. That figure was then multiplied by the number of nights in that month, giving the total number of nests for each month in the season. The total for each month was added together giving the number of clutches laid over the whole season. The two methods were applied to the data for Grand Tacarib in 2002, 2003 and 2004. Since Bacon's method of estimation was designed to calculate only nesting females rather than numbers of nests, the results were changed into nests numbers (using a clutch frequency of both five and seven) so that comparisons could be made between the methods.

Other data reported in this chapter includes adult carapace measurements, nesting times and tag records. False crawl rates, nest densities and proportions of nests on each beach were used in calculations within the chapter but are presented in chapter 3. Data on leatherback injuries and nest depths are presented elsewhere (chap. 6 and chap.7 respectively).

4.3. Results

4.3.1 Emergence times and turtle sizes

During the night time patrols, data were collected from each leatherback encountered. The leatherbacks began nesting at 7 pm, and continued through the night till sunrise at 6 am (fig.4.1). The busiest time for nesting was between 10 pm and 3 am.

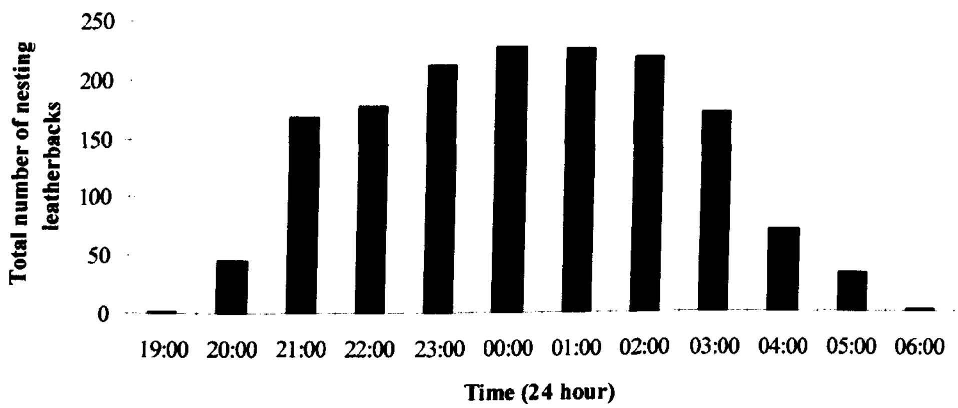


Figure 4.1 Times of emergence by nesting females. Data combined from all beaches in all years. Total number of females observed: 1556.

Over the four years of the study, the mean CCL for female leatherbacks was 154 cm, and the mean CCW was 114 cm (table 4.1).

Table 4-1 Mean, minimum and maximum CCL and CCW for female leatherbacks on the north coast of Trinidad. Data from all the beaches is combined in the table.

Year	*n*	*Mean CCL (cm ± SD)*	*Min*	*Max*	*Mean CCW (cm ± SD)*	*Min*	*Max*
2000	**51**	152 ±8	138	171	113 ±6	99	130
2002	**277**	155 ±8	130	184	114 ±6	97	139
2003	**720**	154 ±8	131	183	113 ±6	99	139
2004	**441**	155 ±8	131	176	115 ±6	100	137
All years		**154**			**114**		

There was no significant difference in size between years, or on different beaches. The longest carapace length recorded was 184 cm, and the shortest was 130 cm. The widest carapace measured was 139 cm, and the smallest, 99 cm.

4.3.2 Tagging and tag returns

All turtles were scanned and checked for tags during monitoring. In 2000, three out of 209 leatherbacks encountered were flipper tagged. They had all been tagged at Matura Beach on the east coast. Only one leatherback out of 306 encounters was found to be tagged in 2002, also wearing Matura Beach tags. In 2003, 772 leatherback nestings were observed, 21 of which were tagged. Nineteen had been tagged at Matura Beach and two of them at Cipara, Peninsula de Paria in Venezuela (1st May 01 and 4th May 03) (H. Guada, personal communication). In 2004, 19 out of 515 leatherback encounters had been previously tagged. Sixteen had been tagged on the east coast of Trinidad, two in Grenada by Ocean Spirits (23rd May and 30th April 04) (J. Horrocks, personal communication), and one in Cipara, Peninsula de Paria (16th May 04) (H. Guada, personal communication). None of the leatherbacks which had been tagged previously were ever seen more than once.

During the 2004 field season, 322 leatherbacks were tagged (62 % of total encountered), 95 with PIT tags and Monel tags, and 227 with Monel tags only. Thirty-nine of these were seen to lay again later in the season. Of those, nine (11.5 %) had lost at least one flipper tag. Thirty-eight of the returning turtles were seen laying one other clutch. Only one turtle was seen returning more than once, and she was observed nesting on three subsequent occasions. Out of 42 tag returns, five turtles were recorded on a different beach to where they had been tagged. Four of them moved from Paria to Grand Tacarib and one vice versa. One turtle tagged on the north coast was recorded nesting in Tobago (W. Herron, personal communication).

Using the tag return data, the mean inter-nesting period was calculated as ten days, with the shortest being eight days, and the longest 14 days (SD = 1.56, n = 22). When the inter-nesting intervals exceeded 16 days, it was assumed that the intervening clutches had not been witnessed. The OCF ranged from one to four clutches and the mean was 2.1 clutches (SD = 0.31, n = 39). The ECF was calculated using the corrected OCF taking missed nests into account. The ECF ranged from one to seven clutches and the mean was 3.45 clutches (SD = 1.81, n = 40).

4.3.3 Data on past numbers of leatherbacks

Information gathered on past numbers of leatherbacks on the northern coastline from fishermen was interesting. They unanimously agreed that there were many more leatherbacks now than in the past (chap.6). One fishermen from Matelot, who had spent many summers on Grand Tacarib since the 1950's, said that numbers were much less then than now, and that on average three turtles a night came up to lay in May/June in the 1960's (J. Marcano, personal communication). D. Harrison (personal communication), who lived in Grande Riviere in 1971/1972, reported that almost every leatherback that came up onto Grande Riviere beach to nest was slaughtered for meat and distributed throughout the village. Turtles were not common, perhaps two or three turtles nesting per week.

Unpublished data on numbers of leatherbacks nesting on the north coast beaches were retrieved from all the Governmental and local reports that I could source (appendix 3). Although sporadic, they show that the numbers of leatherbacks nesting on the north coast beaches from the late 1960's to the early 1990's were much lower than they are today, and appear to be fairly consistent through time.

4.3.4 Nest numbers and calculation of annual nesting population estimates

Reliable laid clutch and hatched nest data were collected from Grand Tacarib, Madamas and Paria in all four years of the study. Laid clutch data were collected from Grande Riviere in 2000 and 2004 and Murphy's Bay in 2003 and 2004. Monitoring of adult leatherbacks on Grande Riviere is carried out by the GRNTGA. Exact numbers of clutches laid at peak season are virtually impossible to count due to the high density of females, lack of manpower, limited tagging equipment and a high false crawl rate. However, the team made several estimations by doing spot checks every hour, and counting females in sections along the beach. No reliable hatched nest data were collected for either Grande Riviere or Murphy's Bay (chap.7)

A regression line was calculated for each beach using the combined nest data set, for each half of the season, in each year. An example is shown in figure 4.2.

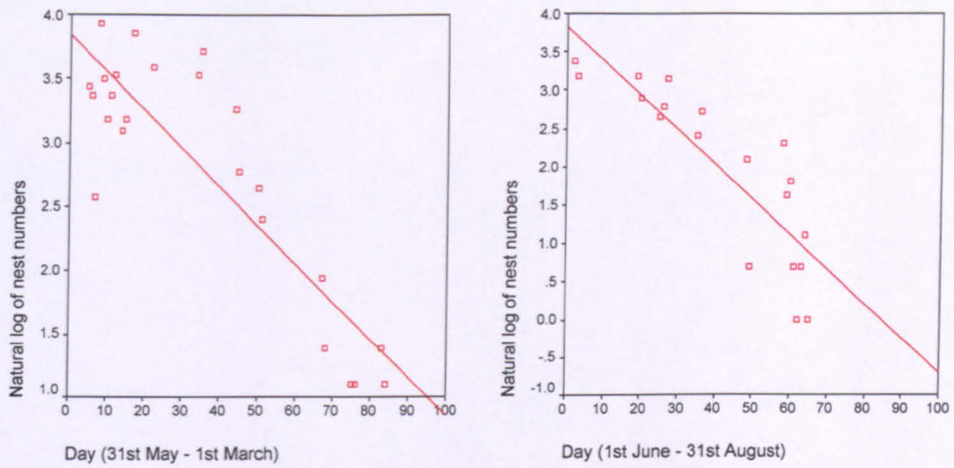


Figure 4.2 Example of regression line creation: calculated for each half of the season for Grand Tacarib in 2004. Each point represents the log of the exact number of clutches laid on that particular night of the season. The days are counted away from peak season (31st May)

Regression analysis was applied to the nest data for the beaches and years with usable data sets (table 4.3). The r^2 values were mostly high, showing that a large proportion of the variation in nest number was accounted for by the day of the season, even although several of the *p* values (eight out of 29) were not significant. The regression slopes for each beach, for each half of the season and year, were checked for homogeneity using a GLM (table 4.4). None of the regression slopes for any of the beaches were significantly different from each other. This shows that the rate of nesting throughout the season was the same in different years. The GLM showed that turtle numbers differed between years on the majority of beaches, which would be expected due to natural fluctuations in numbers of nesting females. A significant difference between years was not found on Paria or Murphy's Bay. This may be due to the smaller sample size on these beaches. The GLM also tested for differences in the two parts of the season on either side of peak nesting. There were no significant differences between the two halves of the season on any of the beaches apart from in 2002, where there was a significant difference on Paria and Madamas. Numbers were greater on Paria for the first half of the season and lower in the second, and vice versa for Madamas. This could have been due to the level of sampling on those beaches, or possibly movements between beaches as a result of environmental factors affecting nesting (Lum, 2005).

The number of clutches laid on each beach was calculated (table 4.2). The data shows that the number of nests fluctuated over the four years of data collection, with the greatest numbers of nests in 2003, with similar numbers in 2002 and 2004. The mean annual number of nests on the north coast was **16,140**. The mean annual number of turtles nesting on the north coast was 3,230 (2,300 – 4,030) and the total nesting population was calculated as approximately 8,060 (5,760 – 10,100).

Table 4-2 Estimate of total nests on each beach on the north coast of Trinidad.

Beach	*2000*	*2002*	*2003*	*2004*
Toco	80	60	100	60
Sans Souci	100	80	120	80
Grande Riviere	8,773	5,783	10,246	5,938
Matelot	3	3	5	3
Madamas	1,565	1,195	1,734	1,539
Grand Tacarib	3,532	1,970	4,001	2,400
Petit Tacarib	320	280	400	280
Old Man	40	30	60	30
Fingers	40	30	60	30
Murphy's Bay	1,657	1,089	1,721	811
Paria	1,529	1,189	2,270	1,503
Blanchisseuse	150	120	180	120
Las Cuevas	250	200	300	200
Maracas	80	60	100	60
Total nests	**18,118**	**12,088**	**21,296**	**13,054**

To test the method of nest estimation used here, two other methods (Bacon's and Steyermark et al.'s) were applied to the nest data (table 4.5) The results show that the Steyermark et al. method estimated a higher number of nests on Grand Tacarib than our estimate by 80 - 300 nests each year (which would account for between 16 and 60 females). Bacon's method produced a much lower estimate when a clutch frequency of both five and seven was used, showing differences of 700 - 1,100 nests (accounting for between 140 and 220 females); nest numbers were still considerably lower than the estimates from the other two methods even when using the upper margin of clutch frequency. The method presented here produces an estimate somewhere between the other two.

Table 4-3 A comparison of methods used to estimate numbers of leatherback nests on Grand Tacarib in three consecutive years.

Method	*2002*	*2003*	*2004*
Method presented here	1,970	4,000	2,400
Steyermark et al., 1996	2,265	4,080	2,715
Bacon, 1973a (x5)	1,240	2,155	1,480
Bacon, 1973a (x7)	1,740	3,020	2,080

Table 4-4 Results of linear regressions for beaches with sufficient datasets (*M* = slope of line, *C* = y-intercept, r^2 *(adjusted)* = proportion of variability explained by time of season, *p* = value of significance). Empty boxes show where data was inadequate.

Beach	*Season*	*2000*				*2002*				*2003*				*2004*			
		M	*C*	r^2	*p*	*M*	*C*	r^2	*p*	*M*	*C*	r^2	*p*	*M*	*C*	r^2	*p*
Madamas	June-Aug	-0.0259	2.69	0.8422	NS	-0.0297	2.403	0.757	<0.001	-0.0414	3.511	0.772	0.013	-0.0304	3.001	0.902	0.033
	Mar-May	-0.0269	3.448	0.446	NS	-0.0223	3.093	0.932	<0.001	-0.0254	3.309	0.843	0.001	-0.0431	3.73	0.926	0.025
G. Tacarib	June-Aug	-0.0404	4.25	0.9301	0.002	-0.0405	3.768	0.697	<0.001	-0.0459	4.566	0.736	<0.001	-0.0298	3.839	0.752	<0.001
	Mar-May	-0.0319	4.161	0.752	0.007	-0.0405	3.768	0.697	0.001	-0.0303	4.175	0.756	<0.001	-0.0329	3.637	0.7996	<0.001
Paria	June-Aug	-0.0343	3.049	0.8961	0.004	-0.0277	2.91	0.9459	NS	-0.0452	3.989	1	0.04	-0.0232	2.963	0.656	NS
	Mar-May	-0.0212	3.169	0.795	0.027	-0.0222	2.721	0.587	NS	-0.0300	3.597	0.780	0.001	-0.0334	3.321	0.636	0.011
Murphy's	June-Aug									-0.0497	3.841	0.7394	NS	-0.0248	2.435	0.7499	NS
	Mar-May									-0.0327	3.351	0.9714	NS				
G. Riviere	June-Aug	-0.0546	5.611	0.9778	0.001									-0.054	5.254	0.9492	<0.001

Table 4-5 Results of homogeneity checks for regression lines using a general linear model for each beach, for each half of the season, and in each year.

Differences between:		*G. Tacarib*		*Madamas*		*Paria*		*G. Riviere*		*Murphy's*	
		p	r^2	*p*	r^2	*p*	r^2	*p*	r^2	*p*	r^2
All Years	Regression slope (*M*)	0.034	0.750	0.303	0.865	0.834	0.772	0.913	0.966	0.401	0.769
	Year	<0.001	0.736	<0.001	0.831	0.1*	0.838	0.049	0.966	0.374*	0.696
2000	Regression slope (*M*)	0.389	0.841	0.768	0.887	0.669	0.913				
	Two halves of season	0.287	0.843	0.39	0.887	0.904	0.91				
2002	Regression slope (*M*)	0.089	0.685	0.961	0.843	0.45	0.947				
	Two halves of season	0.560	0.661	0.001*	0.843	0.035*	0.961				
2003	Regression slope (*M*)	0.061	0.742	0.421	0.837	0.412	0.879			0.632	0.796
	Two halves of season	0.221	0.718	0.527	0.827	0.994	0.865			0.918	0.764
2004	Regression slope (*M*)	0.09	0.768	0.666	0.838	0.518	0.741				
	Two halves of season	0.086	0.767	0.954	0.913	0.808	0.726				

***Denotes an unexpected result**

4.4. Discussion

4.4.1 Annual nesting population size

Trinidad is already classed as a major nesting site for leatherback turtles within the Atlantic Ocean, although the nesting population size has been underestimated in the past. Annual estimates of nesting females have changed through time from Bacon's first estimate of 150 - 200 (Bacon, 1970), Nathai-Gyan et al.'s (1987) estimate of 500 - 900, to the estimate of 2,000 nesting females in 2001 (Eckert, 2001) (chap.2). Recent information presented at the Atlantic Leatherback Strategy Retreat at St Catherine's Island in January 2005 stated that Trinidad is the only location within the insular Caribbean where over 500 clutches are laid per year, making up approximately 88 % of the total nesting for that area (Eckert and Eckert, 2005). The actual numbers on which this statement was based were not revealed in the presentation. However, the results of this study suggest that Trinidad hosts a much larger proportion of the nesting leatherbacks nesting in the Caribbean. I have calculated an annual estimate of 3,230 (2,300 - 4,030) leatherbacks nesting on the suitable north coast beaches alone, with an approximate total nesting population of 8,060 (5,760 - 10,100), not taking into account the leatherbacks nesting on the east coast.

The most recent estimates have assumed roughly equal numbers of leatherbacks nesting on the east and north coasts (Eckert and Eckert, 2005), with equivalent numbers nesting at Matura and Grande Riviere (Eckert, 2001). Data show that an average of 7,685 clutches are laid per year on Grande Riviere (1,540 nesting females using a clutch frequency of five), which suggests that there in fact more leatherbacks nesting at Grande Riviere, although updated reports from Matura may confirm similar numbers are now nesting there. However, Grande Riviere only supports approximately half of the nesting on the north coast (47 %) (chap.3), highlighting that the other more remote north coast beaches receive much higher numbers of nesting females than previously believed. From available data, it is thought unlikely that Fishing Pond, Manzanilla, and other nesting areas on the east coast make up numbers equal to those found on Matura (S. Poon, personal communication). Therefore, it is probable that the north coast supports larger numbers of leatherbacks than the east coast, and that this could possibly explain the past misjudgements of total nesting numbers for Trinidad. Little work has previously been carried out on the remote northern beaches due to the difficulties and costs of reaching them (Lum, 2001; chap.2).

Using approximate estimates of nesting females from the east coast, 1,200 from Matura (Eckert, 2001) and 600 from the rest of the east coast beaches (S. Poon, personal communication), this estimates the total annual nesting leatherback population in Trinidad at approximately 5,000, and a total nesting population of around 12,000. However, east coast numbers need to be calculated by Nature Seekers and WIDECAST using appropriate data analysis before an estimate of the total nesting population in Trinidad can be confirmed. This rough estimate ranks the Trinidad rookery as the third largest in the world alongside the Guianas at 2,464 - 7,421 females per year (Girondot et al., 2002) and Gabon at 5,800 females per year (Fretey and Billes, 2000). Caribbean Costa Rica and Panama also support a large nesting population at approximately 1,152 - 2,579 per year (Troëng et al., 2004).

This study offers a snapshot of the status of the nesting leatherback population on the north coast of Trinidad at the present time. Due to the relatively short duration of the project (2000 - 2004) and the influence of natural fluctuations, the data do not allow the direction of the current trend to be detected. The population appears to be stable, although further data would be required to confirm this. This status is in line with reports from the east coast of Trinidad (Eckert and Eckert, 2005), and other areas in the wider Caribbean region (Dutton et al., 2005; Hilterman and Goverse, 2005).

4.4.2 Nesting population trend

Although the current nesting population trend cannot be inferred, past data from the north coast beaches can be examined in an attempt to ascertain how numbers of nesting leatherbacks have changed since the first records were collected. Due to the difficulties of accessing the beaches on this coastline, previous data collection was limited to track counts by aerial survey (Chu Cheong, 1990), sporadic night-time adult counts over two or three day periods (Bacon, 1969, 1970; Godley et al., 2001a; 2001b), and daytime track counting (S. Eckert, personal communication; S. Poon, personal communication). Due to the scattered nature of the data and data collection methods, it is difficult to compare numbers. There are several problems associated with aerial survey data (Meylan, 1982), and daytime track counting on the north coast beaches, in my experience, produced inaccurate results. Temporal changes throughout the nesting season and differences in nest density on different beaches also make it difficult to derive accurate estimates from observations made over a short time period (Steyermark et al, 1996; Godley et al., 2001c). It is easy to see why the remote north coast beaches were believed to be less busy than they actually are, regardless of the difficulties associated with studying them.

The brief night time counts of exact numbers of nests are the most useful data for comparisons with this study. The raw data of night-time counts over the last 35 years (appendix 3) show that numbers of nesting females on the north coast appeared to remain fairly constant, fluctuating between zero and ten turtles per night at various times during the season, with an occasional high nest count e.g. 24 on Paria in May 1968; and 16 on Grand Tacarib in May 1975. On examination of the data, Grand Tacarib, Paria, and latterly Grande Riviere stood out as being the most popular beaches, with a slight increase in numbers in the late 1980's and early 1990's.

Increases in the nesting population were also recorded at Matura on the east coast in the late 1980's and early 1990's, where more intensive monitoring was carried out (Bacon, 1970; 1971; 1973a; 1981; Nathai-Gyan et al., 1987; Chu Cheong, 1990; 1995; Godley et al., 2001a; 2001b). Bacon carried out the first work on Matura in the late 1960's and 1970's, and Chu Cheong followed it up in 1981-1983. She found no significant change in the nesting population between these times. However, Godley et al., in 1989 and 1991 showed a threefold increase in females nesting at Matura compared to Chu Cheong's numbers. All three studies used the same methodology (Bacon, 1973a) to create the estimates. The reasons Godley et al. gave for the increase were based on work effort, study area boundaries and possible false crawl miscounts, but they thought that it was unlikely that the change in nesting female numbers could be due to these factors alone. They suggested that there had been a marked increase in the nesting population size. This was backed up by local peoples' and Wildlife Section wardens' observations.

Investigation into the data collection methods of each study on Matura Beach has highlighted a discrepancy that may partly account for Godley et al.'s higher estimation. The raw Trinidad Field Naturalist Club records (from Bacon's work) show that data were usually collected between the hours of 9 pm and 12 midnight, as this was thought to be the time when the majority of turtles nested. Chu Cheong also collected most of her data during these hours (Chu Cheong, 1990). Godley et al., however, collected data throughout the night. I found that leatherbacks nested throughout the night from 7 pm till 6 am, in highest numbers between the hours of 10 pm and 3 am. Other studies have also shown that leatherbacks nest throughout the night (Girondot and Fretey, 1996). It is unlikely that this aspect of the turtle's behaviour has changed since the previous work was done, and therefore counts of nests from Bacon's (1970) and Chu Cheong's (1990) study may have been lower than actuality.

On the north coast, comparable data is much more limited. However, it is clear that the number of leatherbacks on the north coast beaches is now significantly greater than in the late 1960's. Reliable accounts from local fishermen and farmers unanimously agree that numbers are much larger now than 40 years ago. To take Grande Riviere beach as an example of evidence for an increase: D. Harrison (personal communication) reported that the maximum number of leatherbacks nesting on Grande Riviere beach in 1971/72 was two or three a week. Chu Cheong recorded three in one night in May and one-two a night in June of 1982. Wildlife Section records show two clutches laid in one night in May 1985, eight in one night in April, seven in one night in May and four in one night in June of 1987. There is a record of 16 clutches laid in one night in May 1989 (Bro. R. Fanovich, unpublished personal records). In 1991, Godley et al. surveyed Grande Riviere beach for a ten-day period in July and counted an average of two leatherback nests a night. They also reported that locals claimed to have witnessed up to 20 leatherbacks nesting in one night at peak season. In 1993, S. Ruiz (personal communication) reported numbers of up to 100 nesting females on the beach in one night in peak season (end of May beginning of June). In 2003, over 300 adults were witnessed on the beach in one night, and regularly over 150 in other years. Although some of these data are hearsay, it illustrates the increase in numbers beginning in the mid-late 1980's, with a massive increase in the early 1990's.

The timing of the increase in number of nesting leatherbacks on the north coast coincides with reports of increases at Matura. Since Nature Seekers began working on the east coast on a permanent basis (1991), they have reported large numbers of nesting leatherbacks, and have seen a steady increase (Fournillier and Eckert, 1997). The WIDECAST draft report of the STRAP for Trinidad and Tobago reported that Nathai-Gyan et al.'s (1987) estimate of 500 - 900 nesting females per year island-wide was an underestimate, based on findings of counts of up to 60 leatherbacks on the beach in one night.

Several other nesting leatherback populations in the Caribbean and Northern Atlantic have also shown signs of increase over the last few decades. In Suriname annual nest count data have been collected most years since 1967 by the Foundation for Nature Conservation Suriname (STINASU) (Schulz, 1975; Reichart and Fretey, 1993). The data show that nest numbers increased from 300 in the 1960's to up to 10,000 in the 1980's (Reichart and Fretey, 1993) and have continued to increase since then. It has been suggested that the earlier figures were underestimates (Hilterman and Goverse, 2002). There has also been a significant increase in leatherbacks in French Guiana, again most noticeably occurring in the late 1980's and early 1990's (Girondot and Fretey, 1996). The older generation in the small villages near to the main French Guiana nesting beach of Yalimapo reported that very few turtles nested there in the 1950's, yet now there are thousands of leatherbacks nesting there every year. Dutton et al. (2005) highlights the increase of an intensively monitored population of nesting leatherbacks in St Croix. The numbers increased from 18 - 30 individuals in the 1980s to 186 in 2001, increasing by 13 % each year since the early 1990's. The timing of these increases is similar to the increases seen in Trinidad.

4.4.3 Reasons for nesting population increase

The reasons for the increase in Trinidad's nesting leatherbacks are not clear. It has been suggested that the increase in the St Croix leatherbacks has been due to an effective beach protection and egg relocation programme started in the early 1980's (Dutton et al., 2005). There is strong evidence to support this, including a corresponding increase in hatchling production and DNA fingerprinting techniques showing mother/daughter relationships between long-time nesting females and first-time nesters. Improved adult and juvenile survival were ruled out as being viable causes of increase, which implies that the increase has been due to greater hatchling production from the relocation and protection of nests. The protection programme began in 1982, and a detectible increase was noted 12 - 14 years later, fitting with Zug and Parham's (1996) proposal of the leatherback's minimum age of maturity, 9 - 15 years.

Is it possible that the nesting population increase in Trinidad represents a recovery from previous years of slaughter due to conservation efforts? Both Eckert and Eckert (2005) and Godley et al. (2001b) have suggested this as a potential cause, based on work done at Matura. Bacon (1973) reported that 30 - 50 % of nesting leatherbacks on the east coast beaches and sometimes up to 100 % on accessible north coast beaches were slaughtered during the 1970's. This continued at a fairly constant level until the early 1990's when Matura and Fishing Pond beaches were given protected status by law (Fournillier and Eckert, 1997, chap.2). Some slaughter continued on the north coast, and on Grande Riviere beach up till 1997 when it was also granted protected status. Slaughter still occasionally takes place on the accessible north coast beaches (chap.2). The majority of turtle conservation in Trinidad has been focused on the prevention of slaughter of nesting adults. There has been no specific nest protection or relocation programmes at either Matura or Grande Riviere, or in any other nesting areas in Trinidad. GREAT carry out a hatchling protection scheme at Grande Riviere which involves local youngsters collecting hatchlings that have emerged during the day to release at night to avoid predation from frigate birds. However, this programme has only been running since 2001 (S. Ruiz, personal communication).

Slaughter on Matura beach has been strictly prevented now for 15 years. Working from the minimum age of maturity for leatherbacks (Zug and Parham, 1996), any increase in nesting leatherbacks resulting from this should have been detectible from about 2000 onwards.

However, most of the records show that the increase occurred in the late 1980's and early 1990's. This is not to say that the conservation efforts have not been partly responsible for the increase; slaughter was gradually reduced from the 1980's onwards as protection and awareness increased. Leatherbacks have shown rapid response to such protection elsewhere (Pritchard, 1996). It just appears unlikely that it is the sole reason. In Grande Riviere full beach protection was not put in place until 1997, well after the numbers were seen to increase. Dutton et al.'s work on St Croix suggests that the nest protection and relocation has played a central role in the conservation there. These practices have been absent in Trinidad.

Another possible cause of the increased nesting numbers could have been from an increase in fishing effort in Trinidad's waters. Before 1940, fishing in Trinidad was mostly for subsistence and most fish were imported into Trinidad from Canada and Venezuela (Vincent, 1910). After the Second World War, the Government promoted fishing throughout the island (Hunt, 1949; Stockdale, 1945; Mohammed and Shing, 2003). The fishing industry grew during the 1950's, and by the 1960's, the artisanal fishing industry on the north and east coasts were much as they are today. The gillnet fishery primarily targets carite (*Scomberomorus brasiliensis*) and kingfish (*Scomberomorus cavalla*) (Henry and Martin, 1992), but several other fish and shark species are also caught for sale. Many unwanted species also get caught. The fishery removes many of the large predatory fish from the waters, which most likely prey on leatherback hatchlings during the hatching season, especially the sharks. The reduction of these predators could possibly have resulted in a larger percentage of hatchlings getting past the coastal zone into safer pelagic waters. Since the hatching success on the north coast of Trinidad is relatively high compared to other leatherback nesting grounds (chap.7), and that marine predation would have been at a reduced level after the early 1960's, the beginnings of increased female recruitment in the late 1970's an early 1980's, and large increases in nesting females in the early 1990's fits in well with this hypothesis.

As the number of nesting leatherbacks has increased, the level of bycatch in the local gillnet fishery on the north coast has also increased (chap.6). All the fishermen that were interviewed agreed that there are many more leatherbacks in the coastal waters now than in the past, and that they catch many more in their nets (chap.6). Incidental entanglement may have replaced the past mortality rate from slaughter on the beaches, yet the leatherback numbers appear to be stable. This may be because there is continuous recruitment to the beaches, or that the impact of gillnets has not yet manifested as an observable trend. The bycatch appears to be at an unsustainable level (Eckert and Lien, 1999; Lum, 2003; chap.6), and it is important that monitoring of nesting females on the north coast continues so that any changes in numbers are detected. Lessons should be learned from events in the Pacific where the leatherback population is thought to be near extinction due to gillnet and longline fishing practices (Eckert and Sarti, 1997; Spotila et al. 1996; 2000; chap.6).

4.4.4 Population origins

Bacon (1970) suggested that the leatherbacks nesting on Trinidad's coastline are part of the French Guiana/Suriname population, partially due to the close correlation of the nesting seasons. Bacon (1970) and Dutton et al. (1999) suggested that tagging programmes might show up inter-nesting migrations between the two nesting sites. Flipper tagging in French Guiana began in 1970, and PIT tagging in 1998 (Girondot and Fretey, 1996; Chevalier and Girondot, 2000). Suriname leatherbacks have been tagged with PIT tags since 1999, and on Shell beach in Guyana since 2000 (Hilterman and Goverse, 2005). Tagging has been ongoing at Matura since 1999 using both flipper and PIT tags. In the four years of monitoring on Trinidad's north coast, no tags were ever recorded from French Guiana, Suriname or Guyana. It is unknown whether any turtles tagged from the Guianas have been recorded on the east coast of Trinidad. Three flipper tagged turtles from Trinidad have been recorded in Suriname during 1999-2004 (Goverse and Hilterman, 2005), and two in 2005 (M. Tordoir, personal communication). Data on Trinidad tags from French Guiana are currently unavailable (M. Girondot, personal communication). In all the years of tagging, the recorded levels of inter-nesting migrations between these two areas appear to be relatively low, although there is obviously some interchange.

Genetic studies using mtDNA originally showed that the females nesting in Trinidad were distinct from Guiana nesting females (Dutton et al., 1999), although further research using nuclear DNA revealed no genetic differences (Thompson et al., 2001). More recent genetic analysis confirms that the nesting assemblages in Trinidad, French Guiana and Suriname are in fact one distinct genetic stock, based on both mtDNA and nuclear data, which is also supported by tag data (P. Dutton, personal communication). There does appear to be some level of metapopulation within single genetic stocks however. As mtDNA is passed on only through maternal genes, mtDNA metapopulations are created through females nesting at specific areas, whereas males mate with females from the wider region. This accords with natal homing in female leatherbacks and accounts for the low level of interchange between nesting regions. Because most information about sea turtles is gained from females, and males are rarely seen, many aspects of their movements remain unknown.

The other distinctive genetic stocks identified in the Western Atlantic are the Costa Rica stock, and a more northern Caribbean stock (identified from St. Croix leatherbacks). There does appear to be some unclear boundaries between groups, with some intermediate locations not yet having been analysed (Venezuela, Panam and Colombia). There also appears to be some area overlap and occasional dispersal from one stock to another (Dutton, 2006).

Individual leatherbacks are known to migrate between nesting rookeries both in different nesting years and within one nesting season (Dutton et al., 2005) although these movements are thought to be infrequent (Eckert et al., 1989). All foreign tags recorded on the north coast of Trinidad were from either Venezuela or Grenada, and one turtle tagged on the north coast was recorded as nesting in Tobago (W. Herron, personal communication). The data from this project suggests that there is more interchange with relatively nearby regions such as Venezuela or other Caribbean islands than with the Guianas.

However, one additional point is that Trinidad (along with many other islands in the Caribbean) uses a different system of PIT tag to the Guianas. In Trinidad the AVIS system is used, and in the Guianas TROVAN ID100 PIT tags are used (Hilterman and Goverse, 2005). This means that PIT tags may not be picked up unless multi-region PIT scanners are used. This could result in turtles being tagged twice by two different makes of tags, and important nesting records being missed. Flipper tags are in some ways a more universal method of identification, as no specialised equipment is required to read them. However, they can are characterised as having a high rate of loss shortly after tagging (Rivalan, 2005), and the PIT tag is more reliable in terms of durability (McDonald and Dutton, 1994; 1996). 11.5 % of flipper tags were lost within the time period of one nesting season in our study. The records of Trinidad tagged turtles in Suriname were all identified by flipper tags and not by PIT tags, possibly due to the PIT tags being unreadable by the scanners. The WWF Suriname project no longer applies flipper tags and only PIT tags are used (E. Goverse, personal communication) which may result in some migrating turtles being missed. It is important that there is a move towards using the same PIT tag system (or certainly employing multi-region scanners) in the wider region so that inter-nesting migrations can be detected.

4.4.5 Beach/coastline fidelity

Leatherbacks are thought to show less beach fidelity than other sea turtle species, which nest on their natal beaches (Lohmann et al., 1997). This is possibly due to the dynamic nature of the beaches on which leatherbacks prefer to nest; spreading their nests out over several locations increases the nests chances of survival (Tucker and Frasier, 1991; Pritchard 1982; Eckert, 1997; Chevalier and Girondot, 1999). Leatherbacks are therefore thought to show loyalty to a coastline or set of local beaches rather than to one specific beach. The limited tag return data collected on the north coast suggested that the leatherbacks do show some beach fidelity in the area of the northern coastline. Out of the 42 tag returns, five were recorded on a different beach from where they were tagged (11.9 %). All the beach shifts were between Grand Tacarib and Paria, which are about 4 km apart. The one turtle observed nesting on four occasions was always seen on the same beach (Grand Tacarib). However, these results were undoubtedly affected by the structure and timing of beach trips, and the limited time spent on each beach.

Out of all the leatherbacks observed over the four years of the study (n = 1,802), only 2.2 % had been tagged at Matura (n = 39). It is unknown how many turtles tagged on the north coast visited the east coast beaches in 2004. Nature Seekers have tagged well over 5,000 females since 1999 and have been recording 40 % tag returns at Matura (M. Ramjattan, personal communication). The low number of Matura tags on the north coast beaches is surprising, as the leatherbacks nesting on the two coasts are viewed as one nesting population, based on previous tag and telemetry data (Eckert, 1997; Eckert and Eckert, 2005; Eckert, 2006). Satellite telemetry work carried out in Trinidad between 1995 and 2004 highlighted that the female leatherbacks swim freely between the two coastlines during the inter-nesting period; however, seven out of nine of the tagged leatherbacks were only ever seen to nest on one coastline or the other (Eckert, 2006). This shows that inter-nesting migrations do occur between the north and east coast, but in small numbers.

Tag exchange between French Guiana and Suriname takes place frequently (Schulz, 1975; Fretey and Girondot, 1989; Hilterman and Goverse, 2002); 10 - 17.6 % of females that nested in Suriname in 1999 - 2004 had been previously tagged in French Guiana and are considered part of the same large nesting population (Hilterman and Goverse, 2005). The small level of inter-nesting migrations recorded between the two coasts in Trinidad indicates that some coastline fidelity is employed and supports the theory that nesting leatherbacks using Caribbean islands show stronger beach fidelity than mainland nesters, where beaches are more changeable (Eckert, 1987; Eckert and Eckert, 1988; Eckert et al., 1989a; Dutton et al., 1999).

4.4.6 Monitoring

The female leatherbacks came out to nest from 7 pm till 6 am, and nested all night with the busiest times recorded between 10 pm and 3 am. The mean CCL on the north coast (154 cm, *n* = 1,489) was similar to recent data collected at Grande Riviere (156 cm, *n* = 33) and on Matura Bay on the east coast (156 cm, *n* = 33) (Maharaj, 2004). The mean CCL appears to be smaller than in past years; 158 cm (*n* = 20) (Bacon, 1970), 157.6 cm (*n* = 104) (Chu Cheong, 1990), 157.8 cm (*n* = 131) (Nature Seekers, unpublished data, 1994). The mean CCL has shown a steady decrease since 1968. Biometrics is an important parameter of population demographic structure (Bolten, 1999; Zug and Parham, 1996), and the smaller carapace size may represent a larger number of new female recruits within the population. This would support the theory of an increase in overall nesting population size, with a higher proportion of younger, smaller females using the beaches (Hilterman and Goverse, 2002). The decrease in size could also represent a higher adult mortality, most likely from bycatch, reducing the number of older and larger females, or possibly a combination of the two. The carapace measurements were similar to those of other female leatherbacks nesting in the wider region; 155 cm in Suriname (Hilterman and Goverse, 2005), 156 cm at Tortuguero in Costa Rica (Leslie et al., 1996) and 153 cm in St Croix (Dutton et al., 1994).

4.4.7 Analysis of methodology

Nesting population size can be expressed by several notations: number of nesting females per year, number of nests per year, number of nests per km, or total number of nesting females. They are, of course, all linked, and the initial notation depends on the way the data were collected. Godley et al. (2001c) outlined three main assumptions to consider when making a nesting population estimate: that density of nests is different for different beaches, therefore numbers can not be extrapolated from a small section on one beach; that nesting success and false crawl rate differs from beach to beach, and from year to year; and that data need to be collected over the whole season to account for seasonal cycles and inter-annual variability. Each of these factors has been taken into account in this study.

Daytime track counting on the high density beaches was rarely used except very early and late in the season. It was clear from an early stage that track counts were very unreliable for ascertaining accurate numbers of nests. This was due to high numbers of leatherbacks obscuring each other's tracks and making it impossible to distinguish between false crawls and real nests (Schroeder and Murphy, 1999). Heavy rains and tidal action also made it difficult to determine old from new tracks and sometimes removed them completely (Reina et al., 2002). Track counting often leads to an underestimation of nests (Troëng et al., 2004), but can also be inconsistent depending on weather conditions. The problems with day counts on the high density beaches were not found to be so pronounced on the low density beaches as the number of females was much lower, and the beaches tended to have less dynamic sand movements. In the same way that tracks were difficult to count, the positions of hatched nests were sometimes obscured by adult leatherbacks tracks, or by heavy rain. The numbers of hatched nests also only accounted for the nests that actually hatched, although this was accounted for in the calculation based on nest success experiments (chap.7).

The false crawl rate was found to vary on different beaches, although the mean false crawl rate did not vary between years (chap.3). Grande Riviere had the highest average false crawl rate (24.9 %), and Grand Tacarib the lowest (8.3 %), with the other beaches intermediate (chap.3). As exact nest data was available for most of the beaches the false crawl rates were not used in the calculations, apart from on Grande Riviere, where only numbers of females were available. Large numbers of turtles were seen on Grande Riviere beach; however, the number of clutches that were actually laid was much lower. The density of nests also differed between beaches (chap.3).

Nest data from Grande Riviere was difficult to collect due the intensity of nesting. To obtain exact nest numbers during the busy part of the nesting season would have required much more manpower than was available, although the team did try on a number of occasions. Hatched nest data from Grande Riviere was also difficult to collect as many nests were destroyed by sand erosion and build-up, predation, river movements and females digging up each other's nests (chap.3 and 7). A recent study found that 56.4 % of nests on Grande Riviere were affected by erosion or predation (Maharaj, 2004). Adult tracks, numerous footprints and other tourist activities also made nests and hatchling tracks very difficult to identify in the sand. All these factors in combination severely reduced the number of nests visible on the beach and therefore a hatched nest count would have been a gross underestimate, even as a minimum figure. Hatched nest data were unavailable for Murphy's Bay because the beach was waterlogged for much of the season due to a high water table and few nests ever actually hatched (chap.3 and 7). It was surprising to rarely ever see any evidence of hatching on that beach, considering the high numbers of clutches laid there.

It is essential to take the clutch frequency into account when assessing nesting female numbers as it can have a profound effect on the estimate depending on which figure is used. The observed clutch frequency usually underestimates the true number of clutches laid per season by an individual female (Meylan, 1982; Steyermark et al., 1996; Broderick et al., 2002). The OCF in this study was 2.1 nests per female, which is low compared with some studies (3.6 in Costa Rica (Steyermark et al., 1996), 4.9 - 7 in St Croix (Eckert, 1987) and 5.2 - 7 in Puerto Rico (Tucker and Frasier, 1991), however it is similar to the clutch frequency found at Matura beach on the east coast (S. Eckert, personal communication) and in French Guiana (2.81 - Fretey and Girondot, 1989). This is most likely a consequence of only observing the majority of tag return turtles on one occasion and because half of the tag returns witnessed were between one inter-nesting period with no intervening clutch deposit (56 %: n = 22). It is well known that fecundity may be underestimated for large nesting populations and for beaches that cannot be patrolled intensely (Tucker, 1989). Clutch frequency is difficult to assess when the leatherbacks have 14 beaches to choose from, as well as the option of the east coast, when only one beach could be monitored at a time. The situation is similar on Matura Beach – it is difficult to monitor intensively due to its length (8 km). The clutch frequency may also have been affected by the high levels of adult mortality due to incidental entanglement in gillnets in north coast waters (chap.6) reducing the number of females returning to nest.

The ECF is often used as a more reliable measure of clutch frequency. This was calculated as 3.45 nests per female, similar to that found in Suriname (4.1 - Hilterman and Goverse, 2005), using an inter-nesting period of ten days, comparable to the inter-nesting period from other studies (Eckert, 1987; Tucker and Frazer, 1991; Girondot and Fretey, 1996; Boulon et al, 1996; Steyermark et al. 1996). The ECF was also lower than the frequently used figure of five (Steyermark et al., 1996; Spotila et al., 1996, Andrews and Shanker, 2002). However the ECF does represent a more realistic clutch frequency than the observed data . Both the OCF and the ECF are also affected by when the turtle was first tagged during the season (Fretey and Girondot, 1989). In 2004 tagging started in the second week of May, therefore missing tagging nesting turtles in March and April, thus reducing the actual clutch frequency. For this study I used a nesting frequency of five, giving a comparative figure for other studies, and of four and seven to take into account maximum and minimum parameters. Due to the low level of interchange between coastlines, I felt it was acceptable to calculate the leatherbacks nesting on the north coast as separate from the ones using the east coast, even although there may have been a slight dilution of the clutch frequency because of it.

Although turning a complex relationship into a linear relationship is not ideal for biological data, regression analysis allowed the comparison of nest data between beaches, seasons and years, and using the results from the beaches with full data sets, estimates could be made for the beaches with less data using interpolative methodology. Using regression analysis also allows the nesting population to be predicted within acceptable errors in future years using the minimum data set of nest numbers during the season, rather than having to carry out the extensive fieldwork as in this study. It is acknowledged that there may be a more fitting way to make population estimates with the north coast nesting data set, e.g. using curve functions (Gratiot et al., 2006) or simple interpolation (Godley et al., 2001c). Investigation into this is currently ongoing, with interesting result, and will be detailed in a publication in the near future.

When comparing the two other nesting population estimate methodologies to the one presented here, Bacon's method produced a much lower figure than my estimate even when a high clutch frequency of seven was used. This may also partly account for Bacon's (1970) lower estimates of females on Matura Beach compared to Godley et al.'s work (1991). Steyermark et al.'s methodology produced a higher estimate, but not by a great amount (approximately 80 - 300 nests). The different estimates produced from these three methods illustrate the importance of the choice of method used and how it fits with the available data. I am satisfied that my analysis provides a realistic estimate of the number of leatherbacks nesting on the north coast of Trinidad.

4.4.8 Threats to adult leatherbacks on the north coast

The most serious threat to adult leatherbacks using the north coast of Trinidad is the incidental entanglement in gillnets (Pritchard, 1984; Eckert and Lien, 1999; Lum, 2003; chap.6). The number of leatherback captures in gillnets (both males and females) on the north coast alone was calculated as approximately 4,620 (1,800 - 7,700) each season with a mortality rate of between 26 % and 30 % (1,200 - 1,380 deaths per year). The captured leatherbacks either drown, or more often, are killed by fishermen (chap.6). The Trinidadian Government is currently working towards reducing the levels of bycatch on all coastlines of Trinidad (L. Lum, personal communication).

It is not only the local fishing industry that affects the leatherbacks using Trinidad's coastline. Leatherbacks are a highly migratory species and make long transatlantic journeys annually between their nesting and feeding grounds (Ferranoli et al., 2004; Hayes et al., 2004; James et al., 2005a, 2005b). These voyages put them in danger of interactions with pelagic fisheries such as long lining (Witzell, 1999; Lewison et al., 2004a), which is now thought to have a much greater impact on leatherbacks than previously believed (James et al., 2005a). It is important to protect this species internationally, as well as concentrating on local threats (chap.6).

Currently, the leatherbacks nesting on the north coast of Trinidad are relatively well protected, by law on Grande Riviere with the aid of several local groups patrolling the area, and on the other high density beaches by their remoteness. This may change in the near future however, with a proposal by the Trinidadian Government to complete the Paria Main Road running from Matelot to Blanchisseuse (chap.1 and 3). Illegal encroachment of the road has already begun at the Blanchisseuse end. Opening up the Northern Range Mountains and exposing the beaches to development and human disturbance could have a serious effect on the nesting leatherbacks, as it may have done in other areas on the north coast (chap.3), especially if there is no local protection or enforcement of laws.

4.5 Conclusions and recommendations

The nesting leatherback population in Trinidad is clearly a globally significant one. Here I present a snap shot view of the annual nesting population size on the north coast of Trinidad. Past records show that the numbers of females nesting on the beaches are much greater now than 30 years ago, and that numbers have experienced a substantial increase in the last 15 years. The elimination of adult slaughter on accessible high density nesting beaches combined with a reduction in marine hatchling predators though fishing practices could be partly responsible. Although the current trend cannot be deduced, this estimate will be useful for comparison with future assessments. It will also assist in making reliable estimates for the total nesting population in Trinidad (in combination with east coast numbers), and in assessing remaining numbers of leatherbacks in the Atlantic Ocean.

The Trinidad nesting leatherback population appears to be healthy at the present time, although it is important not to become complacent. Decreases in nesting female numbers can occur rapidly, as seen in Pacific leatherbacks (Spotila et al., 1996; 2000), where gillnet fishing is thought to be largely responsible for the decline (Eckert and Sarti, 1997).

It is important that the monitoring and tagging of leatherbacks on the north coast is continued. Long-term studies are required to identify changes in nesting numbers, accounting for natural fluctuations. Sustained monitoring is also important for assessing the effects of incidental entanglement in the local gillnet fishery. An on-boat observation programme is recommended for a more accurate assessment of leatherback capture and mortality rate (chap.6). Tagging studies will also help identify the multiple-capture rate and at-sea mortality after release. The continuation of monitoring nesting females will be valuable for assessing the impact of any development and construction that occurs if the north coast road between Matelot and Blanchisseuse goes ahead (chap.3).

One of the main difficulties of monitoring the north coast is accessing the more remote beaches, and the manpower required to patrol them regularly. As a solution to this I recommend a monitoring programme (based on this research and data analysis), in which the nesting leatherbacks can be estimated without requiring the intensive protocol used to collect our initial data. Efforts can be concentrated on just one of the remote high density beaches. The proportions of clutches laid on each of the high density beaches was unchanging from year to year, therefore monitoring one of the beaches as an index would give an indication of what was happening on the whole coast. I feel that this would be a reliable way to assess the coastline in the shorter term, while resources are limited. Ideally, the number of nests on the index beach would be counted over two nights a week from March to August, although an estimate could be made with fewer data points. The minimum number of data points for a reliable regression analysis is eight, spread evenly over the season. Grand Tacarib beach is recommended for this, as it was one of the easier beaches to work on and access, and a semi-permanent camp now exists there (which was built by the project team). I also recommend that a full census of all the turtle nesting beaches be carried out every five years to confirm that the nesting proportions on each beach are the same.

Trinidad's Government Wildlife Section has pledged to support the ongoing monitoring carried out by local NGO's in the north coast area. The GRNTGA and GREAT continue to persevere with monitoring and protection at Grande Riviere, although with limited resources. The Pawi Club, based in Matelot, are the most suitable group for the proposed programme on the remote beaches, having been trained in the collection of scientific data by this project (chap.1; appendix 1). They also now have equipment, including a boat and engine, specifically for the job of patrolling the beaches to aid the data collection (funded by the Darwin Initiative). In this way, the Wildlife Section will be provided with information for the effective conservation management of leatherbacks in that area, and the project will give employment to local people in a low income area.

Having identified several high density beaches on the north coast, it would be worthwhile to cover them with the same legal protected status that Matura, Fishing Pond and Grande Riviere benefit from. This would certainly be an advantage if the north coast road were completed, although local people would be required to oversee and enforce the restrictions. I also recommend that a set of regulations be set out concerning the removal of forest, levels of artificial lighting, and building at the back of the beaches before the road is built rather than waiting until after the event (chap.3). It may be beneficial to treat the whole northern coastline as one protected area, rather than as separate management entities.

5. Hard-shell sea turtles in Trinidad

5.1 Introduction

Five species of sea turtle are present in the coastal waters of Trinidad (Bacon, 1969; Fournillier and Eckert, 1997). The leatherback turtle is the most common species, and Trinidad supports possibly the third largest nesting population in the Atlantic Ocean (chap.4). The other four species are hard-shell turtles, and nest in much smaller numbers. In descending order of abundance there are: the hawksbill (*Eretmochelys imbricata*); the green (*Chelonia mydas*); the olive ridley (*Lepidochelys olivacea*) and the loggerhead (*Caretta caretta*). Greens and hawksbills are present in the coastal waters in much larger numbers than are seen to nest on the beaches (Chu Cheong, 1995), possibly made up of foraging adults and juveniles from populations nesting elsewhere (Pritchard, 1984). No nesting or foraging population estimates exist for any of the hard-shell species in Trinidad (Pritchard, 1984; Fournillier and Eckert, 1997).

All four hard-shell species are hunted in Trinidad for their meat, the green turtle being favoured due to its herbivorous diet (Fournillier and Eckert, 1997). Hawksbills are also exploited for their shell, which is fashioned into jewellery and other trinkets, although this occurs more in the neighbouring island of Tobago than in Trinidad (Gaskin, 1994; Fournillier and Eckert, 1997).

Sea turtles have been actively hunted in Trinidadian waters for thousands of years, although there are few detailed records of numbers caught. An anonymous report (1947, cited in Mohammed and Shing, 2003) stated that turtle nets were introduced on a commercial level on the north coast of Trinidad after the Second World War as part of a development programme to increase the fishing industry, although turtle fishing was already practiced in other parts of Trinidad. Rebel (1974) commented that, although the sea turtle fishery was ongoing in 1973, a much larger turtle fishery had existed in the past. It is unknown why the fishery had decreased by this time. The further decline of the turtle fishery coincided with the enactment of the 1975 turtle protection laws (appendix 2), and turtle fishing now appears to be only a supplementary activity to other fishing practices (Chu Cheong, 1995; Lum, 2003).

Under the existing laws it is still legal to catch sea turtles in Trinidad during an open season from 1st October to 28th February (appendix 2; Pritchard, 1984; Fournillier and Eckert, 1997; Chu Cheong, 1995; Lum, 2003). There are some leatherbacks present in the waters from the beginning of February and could be legally caught, but the majority have left the area by the beginning of October and are therefore mostly protected by the closed season (chap.6). However, the hard-shell species forage in coastal waters all year round (Lum, 2003), and are accessible for capture.

In Trinidad today, several fishing depots still purposefully capture sea turtles for meat and sale during the open season. Chu Cheong (1995) surveyed a total of 15 fishing depots in Trinidad in 1982 - 1983, six of which had an active turtle fishery (Matelot, Toco, Grande Riviere, Mayaro, La Lune and Carenage) (fig.5.1). In a further study in 2001 (Lum, 2003), there were a total of eight depots fishing for turtles (fig.5.1). The depots at Grande Riviere and Carenage had stopped their turtle fishing activities, and Las Cuevas, Balandra, Guayaguayare and Fullerton had started up. Matelot, Toco, Mayaro and La Lune had not changed their practices over the years. Although the number of depots using turtle nets increased, the number of people employed did not change (12 persons) (Lum, 2003). It is probable that Grande Riviere stopped turtle fishing due to the high influx of visitors that the village receives specifically to view the high numbers of leatherbacks nesting on the beach (chap.3). An active turtle fishery would most likely be damaging to the village's reputation as a place for turtle conservation and protection. It is unknown why the Carenage depot stopped the activity.

Figure 5.1 Fishing depots in Trinidad that actively fished for turtles in 1983 and 2001 (Adapted from Lum, 2003)

There are currently no monitoring programmes that record turtle landings at any of these sites. Data collection stopped in 1980 when the Trinidad Fisheries Section data collection sheet was revised, and there was no longer felt to be a need to collect information on the turtle catch (Lum, 2003).

Rebel (1974) stated that half of the turtles caught in the fishery in 1973 were caught with nets, a quarter with harpoons, and the rest were taken from the beach while nesting or incidentally caught when fishing for other target species. Chu Cheong (1995) reported that 30 cm mesh nets were set both day and night to capture turtles, although they were mostly caught at night. Harpoons were also used, mostly to catch hawksbills. Green turtles were caught most commonly, followed by the hawksbill. Olive ridleys and loggerheads were rarely caught (Fournillier and Eckert, 1997). In 1983, an average of four to ten turtles was caught per week at each depot (Chu Cheong, 1995). The meat from all species was sold at a similar price. Some carapaces were sent to Tobago, Japan and England (probably hawksbill) (Fournillier and Eckert, 1997).

Fish such as kingfish (*Scomberomorus cavalla*) now fetch higher prices than turtle meat, and it is therefore more economical to catch fish rather than turtles. Turtle meat is still popular with consumers however, and has the advantage that turtles can be kept alive and fresh by turning them on their backs. In open season it is common to see overturned turtles in villages (R. Roberts, personal communication). In October 2004, I was told about six hard-shell turtles (hawksbills and greens) that had been caught in Matelot, and were being sold at the roadside, still alive (R. Roberts, personal communication). Efforts were made by the Pawi Club members to persuade the fishermen to put the turtles back in the sea. However, this was met with hostile behaviour.

The few existing past records of weights of turtle meat sold at markets are thought to be unreliable as true measures of catch, as much of the meat is sold locally outwith the large market places (Rebel, 1974; Chu Cheong, 1995). Data on the turtle fishery collected by the Fisheries Division from 1969 - 1980 shows that the average total weight of turtle meat caught over seven depots in Trinidad was 4,883 kg per year (Chu Cheong, 1995). The average weight of the green turtles caught was 44 kg, and the average weight for hawksbills was 80 kg (Chu Cheong, 1995). James and Fournillier (1993) estimated that 1,000 hard-shell turtles are killed each year in the legal sea turtle fishery in Trinidad.

Hard-shell turtles are still also taken illegally in the closed season from March till September, although fishermen on the north coast of Trinidad reported to me that it was more difficult to sell the meat at that time because of the laws protecting the turtles (chap.2 and 6). Few fishermen set nets specifically for turtles in the closed season, but hard-shells occasionally get caught in the unselective gillnet fishery (chap.6). If this occurs, the turtles get treated as catch and are taken on board, although fishermen reported that hard-shells were rarely caught in gillnets (Lum, 2003; chap.6). Hard-shell turtles are not actively hunted on nesting beaches now, although they are sometimes still taken opportunistically by hunters (C. Patron, personal communication; personal observation).

The shrimp trawl fishery in Trinidad is also thought to be a considerable threat to hard-shell turtles (Fournillier and Eckert, 1997). Pritchard (1984) stated that the shrimp trawlers in Trinidadian and Venezuelan waters caught a "fair proportion" of olive ridleys tagged in Suriname in the early 1970's. The collapse of the nesting ridley population in Suriname is well documented (Reichart, 1989; 1993; Reichart and Fretey, 1993), and thought to the result of high levels of mortality from capture in trawl nets operating in the northern waters of South America. Although it cannot be proven, it is possible that the trawlers operating from Trinidad could have been partly responsible for the decrease in numbers (Fournillier and Eckert, 1997).

In 1982 the Sea Turtle Conservation Strategy identified bycatch as a major threat to many sea turtle populations, and the reduction of mortality due to fishing trawls was put forward as a priority for action (Henwood and Stuntz, 1987; Magnuson et al., 1990). By the early 1980's, NMFS (the US National Marine Fisheries Service) had designed the turtle excluder device (TED) to achieve the successful release rate of 97 % of turtles caught in trawls, but without a significant loss of shrimp (Seidel and McVea, 1995; Epperly, 2003). In response to this, the US congress added a provision to the US public law 101-162 "Sea Turtle Act" to encourage foreign countries to improve their efforts to protect sea turtles (Joyner and Tyler, 2000; Epperly, 2003). One clause of the new law meant that the US would prohibit fish imports from any country that failed to adopt the same sea turtle conservation measures as were required under US law. As the USA is one of the largest consumers of shrimp in the world, this forced many nations to use TEDs on their shrimp trawlers (Joyner and Tyler, 2000). Trinidad and Tobago was one such nation, and in an attempt to meet the requirements under the new laws the Government brought in new fishing regulations in 1994 requiring shrimp vessels to employ TEDs under the Fisheries Act (Conservation of Marine Turtles: Chapter 67:51 of the Laws of Trinidad and Tobago). The Act also specified that a live sea turtle, if incidentally captured by a shrimp trawler, must be returned immediately to the sea, and that an attempt should be made to resuscitate any turtle appearing to be in a comatose state. Any trawler not fitted with the required equipment would generate a fine of TT$2000 [approximately £200], or a six-month prison sentence (Fournillier and Eckert, 1997).

Before the 1994 regulations were introduced, the US embargoed Trinidad shrimp on the grounds that there was insufficient evidence that Trinidad shrimp trawlers were not catching sea turtles (Fournillier and Eckert, 1997). The Trinidadian Government had to demonstrate that 30 % of the trawling fleet were equipped with TEDs before the US would lift the embargo. After some deliberation, the US allowed Trinidad shrimp imports from May 1993. Despite efforts by the Fisheries Division to keep up with the regulations, the trade of shrimp was again embargoed by the US for several months in 1995. In an attempt to increase the usage of TEDs in the trawl fishery, the Fisheries Division ran workshops with the fishermen, providing information on the gear and emphasising the importance of using the equipment in order to keep the US trade market open. These workshops resulted in improved compliance, but not complete fulfilment of the 1994 Regulations (Fournillier and Eckert, 1997).

There is little literature on the situation prior to that contained in the Sea Turtle Recovery Action Plan (STRAP) for Trinidad and Tobago (Fournillier and Eckert, 1997). However, from recent information sourced from national newspapers (appendix 4), ignoring the obvious controversial political agenda, it appears that there have been fluctuations between periods of shrimp export and embargo by the US since 1995. The embargo is currently in place (since December 2004), and the trawler fleet is once again trying to comply with the 1994 Regulations, and fit appropriately sized TEDs (Gooding, 2005, appendix 4).

It is interesting to note that the trawler fishermen blame the Trinidad north coast and Tobago artisanal fishermen for catching large numbers of turtles, and suggest that the large amount of turtle meat in markets in the open season is caught by them, and not the trawl fleet (Gooding, 2005; appendix 4). However, the fishermen from west coast artisanal fishing depots, that no longer set turtle nets, blame the offshore trawlers for the reduction in both fish and turtle numbers, due to the unselective nature of the trawling techniques (Chu Cheong, 1995). It is clear that there are frustrations within both fishing industries concerning turtle capture, and that is it a complicated issue.

The aim of this chapter is to review the past reports of the four hard-shell turtle species using Trinidad waters and nesting beaches, and add to the current knowledge with observations from beach monitoring over the four years of the project. The threats faced by these species will also be discussed.

5.2 The hawksbill turtle (*Eretmochelys imbricata*)

5.2.1 Introduction

Hawksbills are found in tropical waters throughout the Atlantic, Pacific and Indian Oceans (Witzell, 1983). They are widely distributed in the Caribbean Sea and western Atlantic, although they typically nest in low densities (Groombridge and Luxmoore, 1989). Aggregations consist of a few dozen up to 200 individuals, but most of the countries in the Caribbean report fewer than 100 nesting females per year (Meylan, 1989). Meylan (1999) estimated that a maximum of 5,000 hawksbills nest annually in the Caribbean region (in 35 countries), excluding Guyana, French Guiana, Suriname, and Brazil. The hawksbill is listed as critically endangered by the IUCN (Meylan and Donnelly, 2001; IUCN, 2005), and has suffered serious declines in the Caribbean region (Bjorndal et al., 1993; Meylan, 1999; Carrillo et al., 1999) and worldwide (Meylan and Donnelly, 1999). Global hawksbill populations are thought to have decreased by 80 % over the last three generations (Meylan and Donnelly, 1999). Reasons for these declines are due to overexploitation for meat and eggs, but primarily for their shells (Meylan and Donnelly, 1999).

Tortoise-shell is the primary product from hawksbills, made from the colourful scutes that cover the carapace. Past harvests from the Caribbean have exceeded 12,886 kg, the equivalent of 12,000 turtles (adult males, females and juveniles) (Canin, 1991). The substantial trade of tortoise-shell has only recently been reduced (Bjorndal et al., 1993), Japan having decreased their imports to 5,000 kg in 1991, and then ending importation in 1992 (Donnelly, 1991). Despite the reduction in the international trade of hawksbill shell, exploitation still occurs (Meylan and Donnelly, 1999). Hawksbills are listed on Appendix 1 of CITES (Convention of Trade in Endangered Species of Flora and Fauna), and are subject to strict trade restrictions.

As juveniles, sub-adults and adults, hawksbills generally live in close association with coral reef habitat, and other hard substratum communities, primarily feeding on sponges (Meylan, 1988; León and Bjorndal, 2002). Hawksbills migrate between nesting and foraging grounds, displaying both short range migrations between 25 and 200 km (Horrocks et al., 2001) and long range migrations over 200 km (Miller et al., 1998). Hawksbills have even been known to travel thousands of kilometres to breed (Meylan, 1982b; Broderick et al., 1994). Little is known about the migrations between nesting and foraging grounds, and it is unknown why some hawksbills migrate short distances, and others very long ones (Plotkin, 2003). It is thought that female hawksbills that use the same foraging grounds often migrate to different nesting beaches (Miller et al., 1998; Bass et al., 1999). MtDNA has been used to establish which nesting populations foraging hawksbills belong to, having demonstrating the presence of rookery specific mtDNA (Broderick et al., 1994; Bass et al., 1999). The sampled locations represent a large number of the nesting populations in the Caribbean. However, the presence of unidentified haplotypes on the foraging grounds highlights the continuing need for additional sampling of nesting locations (Bass et al., 1999). Harvesting of hawksbills at foraging grounds continues in many locations in the Caribbean and western Atlantic (Carrillo et al., 1999), and is thought to have an impact on nesting populations elsewhere (Bowen et al., 1996).

Females nest every two to three years in the area of their natal beach (Bass et al., 1999), and are known to lay on several different beaches (Carr and Stancyk, 1975), which has often made the study of their nesting habits difficult (Horrocks and Scott, 1991). Hawksbills are solitary nesters, and lay between four and seven clutches of eggs in a season, with an average nest frequency of 4.5 (Corliss et al., 1989; Van Dam and Sarti, 1990; Richardson, 1993). The inter-nesting period is 14 - 16 days (Witzell, 1983; Bjorndal et al., 1985; Richardson, 1993) and the female most often lays her eggs in the vegetation at the back of the beach (Meylan, 1982a).

5.2.2 Hawksbills in Trinidad

Bacon (1969) stated that hawksbill turtles nest on the north and east coasts of Trinidad, although they were rarely seen. Actual records of hawksbills in Trinidad are few, although it is generally accepted that they are the second most numerous nesting turtle in Trinidad, albeit not in numbers anywhere near that of the leatherback (chap.4). There are a small number of recorded sightings from the east and north coasts, but most nesting is reported from the Bocas Islands off the northwest peninsula of Trinidad (Bacon, 1973a; Pritchard, 1984) rather than on Trinidad mainland. Nesting is thought to be more frequent on the north coast than on the east coast (Pritchard, 1984). Nesting hawksbills have been witnessed on Maracas, Blanchisseuse, Las Cuevas, Paria, Grand Tacarib, Madamas, Grande Riviere, Toco and Sans Souci on the north coast (fig.3.1), and on Matura, Fishing Pond, Mayaro and Manzanilla on the east coast (Wildlife Section, unpublished data; Bacon, 1973a; Bacon, 1981; Gaskin, 1994; Godley et al., 2001b) (fig.1.3). The distribution of hawksbills in Trinidad is more or less consistent with the distribution of reefs and hard bottom habitat (Fournillier and Eckert, 1997), which extends along the north coast from the Bocas islands in the northwest and down the east coast as far as Matura. Hawksbills are also known to forage and nest in Tobago although there are no recorded numbers documented at present.

There are several conflicting reports of when the main hawksbill nesting period occurs: it has been reported as being from July to November (Fournillier and Eckert, 1997), and from March to August (Pritchard, 1984). The hawksbill is sometimes locally known as an oxbill or chicken turtle. No estimates for nesting hawksbills currently exist in Trinidad.

Due to the sporadic and unpredictable nature of nesting hawksbills in Trinidad, they are generally left alone by man (Pritchard, 1984), although there has been some slaughter of nesting hawksbills in the past in north coast villages. Sherwin Ruiz (personal communication, 1995, in Fournillier and Eckert, 1997) stated that most hawksbills nesting on Grande Riviere beach were killed, and the meat sold within the village. However it is unlikely that this occurs now due to the presence of guides on the beach protecting the turtles (chap.3). The same source suggested that an average of six hawksbills nested per season on Grande Riviere beach.

The literature reports small numbers of nesting hawksbills, but there are said to be large numbers of hawksbills in coastal waters. Hawksbills are mostly caught in purposefully set nets or by harpoon during the open season off the north coast. Fishermen confirm that juveniles of all size classes are captured in hard bottom habitat. The fishermen also reported lower numbers of hawksbills now than in the past, both on the beaches and in the water (Fournillier and Eckert, 1997; chap.6).

Before Trinidad and Tobago became a signatory to CITES in 1984, tortoise-shell was commercially exported from Trinidad and Tobago to Japan (Fournillier and Eckert, 1997). Pritchard reported (1984) that a large proportion of the hawksbills caught in Trinidad were sold to a buyer in St Lucia, who then sold the shell on to markets in Japan. In 1983 turtle carapace was selling for TT$5-18/4.5 kg [1lb] from five fishing depots in Trinidad, most of which was exported to Tobago (Chu Cheong, 1984). Japanese customs data indicate that Trinidad and Tobago supplied Japan with more than 1,000 kg of hawksbill shell between 1983 and 1985 (Milliken and Tonkuaga, 1987). Based on the weight of shell per animal, it is possible that a minimum of 746 hawksbills were killed to supply the shell exported during this period. It is unknown whether export of hawksbill shell out of Trinidad still goes on.

5.2.3 Methods

Several north coast beaches were intensively surveyed for nesting sea turtles from April to August in 2000 - 2004. Nest numbers were recorded for specific nights throughout the nesting season, and day time track counting was employed later in the season when the number of leatherback tracks were reduced enough not to obstruct hawksbill tracks from being seen. The monitoring methodology is detailed in chapter 4.

Data were collected from each individual hawksbill encountered: the position of the turtle on the beach, the time of encounter, and the length and width of the carapace. No hawksbills were tagged, as I did not have the correct flipper tag type for the species. During the hatching season, any hawksbill nests that were found were excavated, and the contents examined (detailed methodology in chap.7). The overall hatching success was calculated. Note was taken of any strandings or slaughtered turtles, and the local fishermen were questioned on capture rates in gillnets (chap.6) and purposely set turtle nets in the open season. The methodology described here is the same for all the hard-shell species discussed in this chapter.

The number of hawksbill clutches laid on the north coast was calculated. Because of the sporadic nature of the data, and low numbers, it was difficult to assess the total nesting population from the raw data. In order to extrapolate the numbers of hawksbill nests, the data were compared with the leatherback data set (chap.4). The percentage of the leatherback clutches actually seen being laid in each year was calculated from the total estimated number of leatherback clutches laid for that year. This figure was then used to extrapolate the number of hawksbill nests seen using the work effort on the beaches.

This method makes a number of assumptions. Firstly, it assumes that the hawksbill nesting season is over six months, and that there is a peak of nesting in the middle with an equal increase and decrease on either side of the peak. It also assumes that hawksbills nest on the same beaches in equivalent densities to leatherbacks, and that hawksbills were not more difficult to detect on the beach than leatherbacks.

Once the mean number of hawksbill nests was calculated, it was divided by 4.5 (the mean number of nests in a season), giving the annual mean number of females (Hillis, 1995; Richardson et al., 1999).

5.2.4 Hawksbill results

Hawksbills were commonly seen nesting on the remote beaches on the north coast of Trinidad. Evidence of nesting hawksbills (tracks) was seen on all of the remote beaches surveyed (Paria, Madamas, Grand Tacarib, Petit Tacarib, Murphy's Bay, Fingers and Old man) (fig.3.1). There was also evidence of nesting hawksbills on Sans Souci and Grande Riviere, but not on any of the other accessible north coast beaches (fig.3.1). A total of 71 nests were seen over the four years: nine in 2000, eight in 2002, 23 in 2003 and 31 in 2004. The most hawksbills seen nesting in any one night was four. They appeared to favour Madamas and Grand Tacarib beach with most tracks and nesting adults encountered on these beaches, especially Madamas. None of the encountered hawksbills had tags from other locations. All the hawksbills nested right up at the back of the beach near or under the vegetation. Three of the hawksbills were seen to dig up other hawksbill nests. One hawksbill was witnessed nesting during the day (fig.5.2).

Figure 5.2 Hawksbill nesting at 5pm in the afternoon watched by a friendly forest-man

The results of the estimated number of hawksbill nests on the north coast beaches are shown in table 5.1.

Table 5-1 Results of the estimated number of hawksbills nesting on the north coast of Trinidad (LB = leatherback; HB = hawksbill)

Year	*LB nests seen*	*Total LB nests*	*% LB nests seen*	*HB nests seen*	*Total HB nests*
2000	194	18,118	1.07	9	840
2002	307	12,088	2.54	9	354
2003	715	21,296	3.36	23	685
2004	482	13,053	3.69	31	839
Mean	424.5	16,139	2.67	18	675

The estimated mean number of hawksbill nests per year is 675. Using the mean number of hawksbill nests per season (4.5), the total annual number of nesting females is estimated as 150.

No hawksbill was seen nesting before the 9th of May. Nesting increased from this time with most seen in the month of July (fig.5.3). From mid June onwards, it was normal to see at least one hawksbill per night during night-time patrols. The number of nesters began to drop in August. Since no night-time beach monitoring was carried out in September or October no numbers are available for those months.

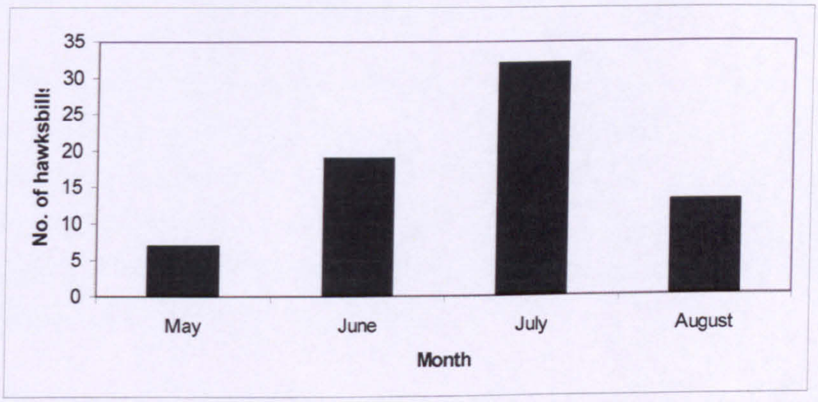


Figure 5.3 Number of nesting hawksbills seen during each month of the year on the north coast beaches (2000 – 2004) – no nesting hawksbills were ever seen nesting earlier than May, and data was not collected after the end of August.

The mean curved carapace length was 90 cm (SD = 4.6, n = 45) and the mean curved carapace width was 79 cm (SD = 6.3, n = 45). The largest CCL was 101 cm and the smallest was 80 cm.

Five hawksbill nests were excavated in 2002, four in 2003 and five in 2004. Nest excavation was not carried out in 2000. Eleven of the hawksbill nests found were on Madamas, and the other three were on Grand Tacarib. All of the hatched nests were found in July and August, the earliest one on the 23rd of July. Using the mean incubation period (58.5 days, Bjorndal et al., 1985), the clutches would all have been laid approximately after the 26th May.

The mean hatching success for the hawksbill nests was 91.8 % (SD = 10.3, n = 14). The mean clutch size was 143 eggs (SD = 21.5, n = 14). We rescued a total of 13 live hatchings from the nest chamber and placed them in the sea (fig.5.4).

Figure 5.4 Hawksbill hatchlings removed from the nest chamber during excavation

The fishermen that were questioned said that hawksbills were commonly caught in the open turtle-hunting season using turtle nets specifically set to catch them. Accurate numbers were not obtained. Hawksbills were rarely caught in gillnets (chap.6). When asked how the numbers caught now compared with previous years, the fishermen said that there were fewer than there used to be (30 years previous). Some of the fishermen blamed the offshore shrimp trawlers for a decline in hard-shell numbers.

Several slaughtered hawksbills were found, identified by their shells, on visits to the remote beaches. One empty shell was found in 2000 on Madamas, one on Paria in 2002, three in 2003 (two on Paria and one on Madamas) and five in 2004 (three on Madamas and two on Grand Tacarib) (fig.5.5). The remains of a butchered hawksbill (shell) were seen at the Matelot fishing depot on two occasions over the four years.

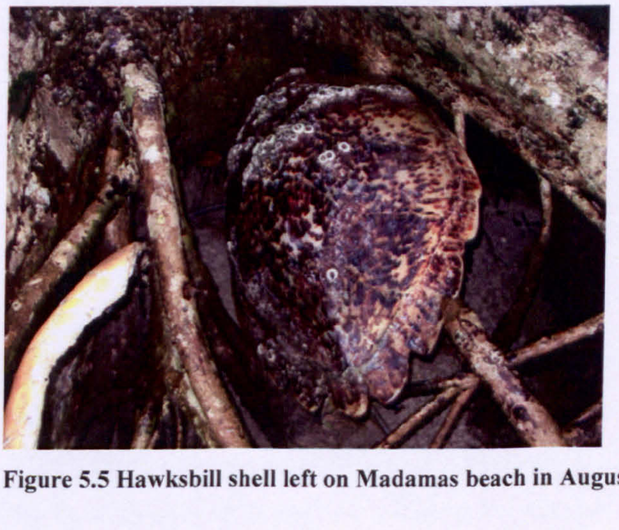


Figure 5.5 Hawksbill shell left on Madamas beach in August 2004

I witnessed a hawksbill turtle in the water on three occasions while snorkelling at a small section of reef at Grand Tacarib beach. All the sightings were of adults. I also saw hawksbills feeding offshore at Cumana on the northern east coast.

5.2.5 Discussion

The mean CCL of hawksbills nesting on the north coast (90 cm) were comparable with reports from elsewhere in the Caribbean (87 cm in Eckert, 1992; 82 cm in Bjorndal et al., 1985). The hatching success of excavated nests (91.8 %) was similar to that found in Tortuguero in Costa Rica (91.6 % in Bjorndal et al., 1985), and higher than in Barbados (75.7 % in Horrocks and Scott, 1991) and Florida (80 % in Van Dam and Sarti, 1989). The average clutch size (143 eggs) was also comparable to other hawksbill clutches laid in the Caribbean (157 eggs in Richardson, 1993; 158 eggs in Bjorndal et al., 1985).

One of the main consequences of there being only small isolated hawksbill populations left in the Caribbean is that few monitoring projects are carried out specifically to assess them (Meylan, 1999). Data on hawksbills are frequently collected during the study of other sea turtle species (Meylan and Donnelly, 1999), as is partially the case here. This has led to incomplete data sets and difficulties in accurately assessing population trends throughout most of the hawksbill range and many nesting regions remain unrepresented. Mitochondrial DNA studies have detected the presence of unidentified haplotypes in foraging grounds highlighting the need for the continuation of sampling and assessing scattered nesting locations (Bass et al., 1999). I recommend that the nesting hawksbills in Trinidad be sampled for molecular genetic analysis, so that they can be placed on the map in terms of genetic stock and migrations between foraging and nesting grounds can be analysed.

In Meylan's (1999) review of the status of the hawksbill in the Caribbean region, Trinidad and Tobago was listed as one of the 35 territories examined for hawksbill presence. The only reference for Trinidad described hawksbill nesting as "rare and minimal" (Groombridge and Luxmore, 1989). In the recent WWF report on the status of Caribbean hawksbills (Chacón, 2005), Tobago was mentioned as having a small amount of nesting. Trinidad was not mentioned at all. This is understandable, as no extensive monitoring has even been carried out on Trinidad's north coast beaches previous to this study.

The nesting hawksbill population on the north coast of Trinidad is larger than suggested in any past literature, although it is suspected that this is due to the lack of investigation on the remote north coast beaches (chap.2) rather than an increase in numbers. The reports of local fishermen imply that the hawksbill numbers in the coastal waters have decreased over the last 30 years and that they catch fewer in turtle nets and by harpoon in the open season. It is difficult to make any suppositions about the nesting hawksbill population trend in Trinidad, as there are no accurate past records. However, a current estimate can be made, which will be useful in efforts to evaluate the status of hawksbills in the Caribbean area.

The analysis of the data collected on hawksbills estimates that there are approximately 675 nests per year on the north coast beaches. This equates to a nesting population of approximately 150 females, although caution should be used when extrapolating from nest numbers to numbers of nesting females, as the actual nest frequency is unknown for the area. The data show inter-annual fluctuations in the population, different to those of the leatherbacks: a high number of females in 2000 with a dip in 2002, and higher numbers again in 2003 and 2004. Hawksbill inter-annual nesting fluctuations were found to be less variable than leatherback fluctuations, which are thought to partly be dependent on the tropic status of the species (Broderick et al., 2001). The calculation includes a correction for the number of beach visits in different years.

A number of assumptions were made while making the nesting population estimate. The assumption that hawksbills nest in the same relative densities on separate north coast beaches as leatherbacks (chap.3) may have caused an overestimate of nesting females, as it is thought that hawksbills do not nest in particularly high density on Grande Riviere as leatherbacks do. One report from Grande Riviere (S. Ruiz, personal communication, 1995 [in Fournillier and Eckert, 1997]) stated that an average of six hawksbills per season nested on Grande Riviere beach, although, based on data from this study, this is thought to be an underestimate. However, the hawksbill nest density is thought not to be as high on Grande Riviere as on other north coast beaches.

Hawksbills do generally seem to use the same beaches as leatherbacks, nesting in higher numbers on Madamas and Grand Tacarib, with evidence on nesting on all the remote beaches between Matelot and Blanchisseuse. Hawksbills elsewhere have shown a preference for steeper beaches and that elevation is important when choosing a beach (Horrocks and Scott, 1991). Madamas and Grand Tacarib are two of the steeper beaches on the north coast (chap.3). Some evidence of hawksbills was noted on Sans Souci, but not on the other beaches on the road. This suggests that hawksbills prefer to nest on beaches that are free of human alteration and disturbance, and artificial lighting. Hawksbills in Barbados preferred nest sites with vegetation to those without (Horrocks and Scott, 1991), which could be an important factor on the north coast of Trinidad. This has also been documented elsewhere (Mortimer, 1982a). Several of the beaches in villages have had the backing vegetation removed (chap.3).

The second assumption made was that the nesting season lasted six months. Nesting was first observed in May, and most sightings were seen in July, suggesting that that was when the nesting peaked. There was less nesting in August. The hatched nest data also supports the supposition that nesting does not begin before May. This suggests that the nesting period may last only five months ending in September, if the nesting distribution is equal on either side of the peak, which may have slightly exaggerated the estimate of nesting hawksbills. Previous records have reported the hawksbill nesting season from March to August and from July to November. The data collected here does not really coincide with either of these suggestions, but rather lies in-between the two. These suppositions of the nesting season are based on chance sightings rather than actual monitoring studies, and therefore are probably not very reliable. Sporadic nesting occurs all year round in Antigua (Richardson, 1993). This most likely also occurs in Trinidad, possibly accounting for the large range in the proposed nesting season.

The majority of hawksbills that were seen to nest on the north coast beaches nested right up at the back of the beach under vegetation. This has been documented in a number of studies (Bjorndal et al., 1985; Horrocks and Scott, 1991). Because of this, nests are more easily missed, especially on beaches with high densities of leatherbacks nesting (Pritchard, 1984). The other assumption made for the calculation of nesting population size was that hawksbills were just as easy to encounter as leatherbacks. The project team were confident that the majority of hawksbills were located, but on nights with large numbers of leatherbacks, it is possible that hawksbill tracks could have been obscured. This factor would lead to an underestimate of total nests. When two or more sea turtle species nest on the same beaches, there is evidence to suggest that they display inter-species competition behaviour, and employ either spatial or temporal separation (Mortimer, 1982a). Hawksbills may use both these methods, by avoiding the main leatherback nesting season (peak at end of May, beginning of June, chap.4), and by nesting right at the back of the beach. Leatherbacks show a preference for nesting nearer to the strand and middle of the beach (chap.7).

Although the estimation calculation makes a number of assumptions, I feel that the results present an accurate figure, and that it supports my conclusions reached from observations in the field. There is evidence that Trinidad supports a small, but significant nesting population in the Caribbean, which up until now have been undiscovered. Investigation into the reports of hawksbills on the east coast and the Bocas islands off the northwest peninsula, and possibly Tobago, are recommended for a full evaluation of the nesting population.

All reports suggest that there are many more hawksbills in the coastal waters of Trinidad than are nesting on the beaches (Lum, 2003). Hawksbills make up a large percentage of the catch of the legal turtle fishery in the open season, caught for the sale of their meat. Hawksbills are caught half the time by harpoons, and half by purposefully set nets. In 1984 the average weight of hawksbills caught was 80 kg (Chu Cheong, 1995). In 1983 another fisherman at the Toco fishing depot recorded the weight of 36 hawksbills, which averaged 91.4 kg (Chu Cheong, 1984). This suggests that the majority of hawksbills caught were adults, and most likely males. The mean weight of female adults is 59 kg (Bjorndal et al., 1985). However, it is likely that the weights were exaggerated. The high numbers of adult males in the catch may have been a result of using harpoons, as copulating males at the surface of the water are especially easy to capture in this way. The data may also have been altered by the fishermen to protect themselves legally by excluding juveniles or females that are illegal to capture except under certain circumstances (chap. 2; appendix 2).

Slaughter of hawksbills in their nesting environment has been reported as being uncommon, due to the sporadic nature of the nesting (Pritchard, 1984). However, there was some evidence of slaughter on the remote north coast beaches, particularly in 2004. It is known that some of the hunters living in the forest take the occasional hawksbill, but at most two or three are taken in total each year (Pepper, personal communication), which is not thought to have a major effect on the nesting population. More and more people are beginning to use the north coast beaches for recreation, facilitated by the illegal progression of the Paria Main Road from Blanchisseuse (chap.3). The recent slaughters are thought to be by hikers and campers on the remote beaches, who are free to take nesting turtles from the beach without any danger of being caught.

In the past, hawksbill shell was an economic commodity, and was exported from Trinidad to Tobago and other places (Pritchard, 1984). It is still legal to catch hawksbills in the open season for meat, but it is now illegal to export their shells. Several slaughtered hawksbills were identified by their shells during the project months, suggesting that shells were no longer exported, being left to rot on the beach. However the hawksbill carapaces that were seen on the remote north coast beaches had most likely been slaughtered for food by campers or hunters living in the forest. These individuals would probably have had no interest in selling the shells for money. There was no evidence of hawksbill shell being sold in the closed season. It is unknown if the shell of any hawksbills caught in the open season is still sold illegally.

In 1995 a local artist started to sell tortoiseshell rings to tourists at Grande Riviere. However this was said to have been stopped due to pressure from GREAT, who were the most prominent conservation group acting in the area at the time (Fournillier and Eckert, 1997); I did nevertheless see several rings made out of tortoise-shell being sold at one of the hotels at Grande Riviere. Although sale of turtle products during the closed season is illegal (chap.2; appendix 2), it is, however, legal in the open season. A revision of the laws concerning sea turtle protection is required to tackle this loophole. All export of turtle products from Trinidad is illegal under CITES.

The hawksbills that are present in Trinidad's waters during the open season (1st October - 28th February) could possibly be different from the ones that nest in the closed season as hawksbills are known to migrate large distances between nesting and foraging grounds (Meylan, 1982b; Broderick et al., 1994; Miller et al., 1998). However, some hawksbills have been recorded traveling short distances between foraging grounds and nesting beaches (Horrocks et al., 2001). Therefore it is possible that the hawksbills nesting on Trinidad's beaches and the ones foraging offshore are the same. The hawksbills foraging and nesting in Tobago could also be part of the same population, moving between the two islands. These proposals again highlight the importance of genetically sampling both the nesting and foraging hawksbills in both regions; firstly to identify the mtDNA sequences and to determine if nesters and foraging turtles are part of the same population; and secondly, if they are not the same, to identify to which rookery the foraging turtles belong. This is important considering the declines of hawksbill nesting populations in other regions.

The level of turtle fishing in Trinidad's waters is thought to exceed 1,000 hard-shells per year, roughly half of which is made up of foraging hawksbills. This level of fishing has most likely contributed to the supposed (by the local fishermen) decline of nesting and foraging hawksbills in Trinidad, and possibly nesting populations in other regions of the Caribbean. An accurate assessment of the numbers, the sex ratio and life stages of the hawksbills caught in coastal waters is recommended.

5.3 The green turtle (*Chelonia mydas*)

5.3.1 Introduction

Green turtles are listed as endangered on the IUCN red data list (IUCN, 2005). Seminoff (2002; 2004a) estimated that, worldwide, green turtle populations have decreased by 37 - 61 % over the last 141 years. Past declines are thought to be due to the overexploitation of green turtles for meat, eggs and other products. However, recent work has claimed that green turtles may not in fact be endangered globally, with reports of 75 % of populations in the Atlantic assessed by the IUCN found to be increasing (Broderick, et al., 2006). Broderick et al. (2006) question the IUCN listing of endangered, and suggest that the global listing takes away attention from populations that are in serious danger of becoming extinct. Despite conservation efforts improving throughout the world, some green turtle populations do continue to be impacted by a variety of threats. The most common threats are intentional capture in foraging areas, incidental capture in fisheries, egg poaching and harvest of nesting females (Seminoff, 2004a).

Green turtles are found in both tropical and subtropical waters of the Atlantic, Pacific and Indian Oceans. Nesting occurs in more than 80 countries worldwide (Hirth, 1997) ranging from high density nesting (> 500 nesting females) to occasional sporadic nesting (Groombridge and Luxmoore, 1989; Seminoff, 2004a). The movement of green turtles within the marine environment is less well understood, but it is believed that they inhabit the coastal waters of over 140 countries (Groombridge and Luxmoore, 1989).

Green turtles are highly migratory animals, and as juveniles they take up temporary residence in many different locations. When foraging, green turtles inhabit waters close to the coastline, feeding on sea grass (*Thalassia testudinum*) and algae (Mortimer, 1982b). Once reproductively mature, they become resident in a chosen foraging ground, and migrate between fixed foraging and breeding grounds (Meylan et al., 1990). The distances travelled during these migrations can be thousands of kilometres (Carr, 1965; Luschi et al., 1998; Åkesson et al., 2003). Adult females nest every two to four years and show a high degree of nest site fidelity (Miller, 1997). There is much evidence to demonstrate that green turtles nest on their natal beaches (Meylan et al., 1990; Allard et al., 1994; Bell et al., 2005). Females lay an average of three clutches per season, and have an inter-nesting period of between 10 and 17 days (Miller, 1997).

5.3.2 Green turtles in Trinidad

Green turtles nest on the north and east coasts of Trinidad (Bacon, 1969) and are considered to be occasional nesters (Bacon, 1981), although less common than the hawksbill (Pritchard, 1984). Their local name in Trinidad is the green turtle or the greenback. They have been witnessed nesting at Manzanilla (Bacon, 1981), Mayaro and Matura on the east coast (Bacon, 1973a; Godley et al., 2001b), and at Matelot, Toco, Sans Souci (Bacon, 1973a), Grande Riviere (S. Ruiz, personal communication) and Paria (Nathai-Gyan et al., 1987) on the north coast. Some have also been recorded nesting on the Bocas islands off the north west coast of Trinidad (Nathai-Gyan et al., 1987). Nesting is thought to occur between February and August (Bacon, 1973a; Fournillier and Eckert, 1997), although nesting has been witnessed in September and October at Matura (Fournillier and Eckert, 1997 [D. Sammy, personal communication]). No data have ever been collected on nesting green turtles in Trinidad in a systematic way, so there are insufficient data to evaluate abundance, preferred beaches or exact nesting season. However, it is known that some nesting activity takes place during the leatherback season (Nathai-Gyan et al., 1987).

Although nesting numbers are low, green turtles are common in Trinidadian waters (Pritchard, 1984), taking advantage of the sea grass patches on reef habitat, most of which are located on the north coast around the Toco area (chap.3). Shrimp trawler fishermen working in the south of Trinidad said that they occasionally caught green turtles in nets (Fournillier and Eckert, 1997), and fishermen on the north coast reported to me that green turtles are commonly caught during the open season in purposefully set turtle nets, and occasionally by accident in gillnets in the closed season (Nathai-Gyan et al., 1987; chap.6).

5.3.3 Green turtle results

We witnessed a total of four green turtles nesting on the north coast beaches during the four years of monitoring, one in 2002, one in 2003, and two in 2004 (table 5.2). Three of them were seen on Madamas beach, and one on Grande Riviere. All were seen in the month of August. The mean carapace length of the three we were able to measure was 103 cm and the mean width was 89 cm.

Table 5-2 Green turtles seen nesting on the north coast of Trinidad in 2000 - 2004

Date	*Beach*	*CCL*	*CCW*
06/08/02	Madamas	101	88
20/08/03	Madamas	105	89
11/08/04	Madamas	102	90
11/08/04	Grand Riviere	-	-

One green turtle nest was found on the 25th of July 2004 on Madamas. The nest was excavated and the contents examined (methodology in chap.7). The nest was 95 cm deep, and contained two healthy live hatchings, which were placed in the sea (fig.5.6). Three of the eggs in the nest had not hatched. When opened two were unfertilised with no gross signs of development and the other contained a tiny embryo that had died at an early stage. Ninety-three hatched egg fragments were counted. No dead hatchlings were found in the nest and there were no signs of insect infestation or predation by other animals. The total clutch size was 96. The poaching of nesting green turtles from the north coast beaches was never witnessed.

Figure 5.6 Live green hatchlings from a nest on Madamas beach in 2004

5.3.4 Discussion

The results of the monitoring work from this study shows that green turtles do nest on Trinidad's north coast, but in very small numbers. This supports the findings of previous reports (Pritchard, 1984; Nathai-Gyan et al., 1987; Eckert and Fournillier, 1997). The number of green turtles was very low however, and I would have expected to see more, based on the records from past literature. This could suggest that green turtles nesting on the north coast of Trinidad were more frequent in the past. However, the sporadic nature of the monitoring technique in this study (chap.4) could have resulted in missing a number of nesting episodes. Past reports also mention that nesting can continue into September and

October (Fournillier and Eckert, 1997), by which time the beach monitoring for this study had ended and any nesting green turtles at that time would have been missed.

Adult female green turtles vary in size depending on the region that they are from; for example, the mean curved carapace length (CCL) of green turtles on nesting beaches in Mexico was 82 cm, and 123 cm on nesting beaches in Brazil (Hirth, 1997). The average CCL of the green turtles seen in Trinidad was 103 cm, which is similar to that found in other regions of the Caribbean (100 cm at Tortuguero in Costa Rica; Bjorndal and Carr, 1989).

All the nesting green turtles on the north coast were seen in the month of August suggesting that this was the busiest part of their nesting season, although one clutch was seen to hatch at the end of July, which would have been laid around the 24^{th} of May (with an approximate incubation period of 62 days (Fowler, 1979)). These results suggest that the nesting season starts later than the suggested month of February. However, it is difficult to be certain with such a small sporadic nesting population. The green turtle nest that was excavated contained 96 eggs, which is similar to the average number of eggs per nest in Tortuguero in Costa Rica (Bjorndal and Carr, 1988).

Three of the four green turtles observed nested on Madamas, and the other on Grande Riviere (fig.3.1). A nest was also found on Madamas. This gives some indication of nesting beach preference for green females. Leatherbacks on the north coast were found to prefer beaches with a deeper offshore approach, steep slope, large sand particle size, and no submerged rocks reefs. Beaches with no human disturbance or artificial lighting were also selected for (chap.3). Madamas and Grande Riviere beaches had the deepest seaward approach and steepest slopes out of all the beaches on the north coast. Madamas beach had no artificial lighting at all, and lighting on Grande Riviere was kept to a minimum (chap.3). Therefore it is suggested that green turtles may have similar beach preferences to leatherbacks. Mortimer (1982a) found that green turtles in Ascension Island preferred unlighted beaches with open offshore approaches free of submerged rocks. Green turtles also avoided lit beaches at Tortuguero (Carr et al., 1978) and in Florida (Ehrhart, 1979).

Grande Riviere beach is the highest density beach for leatherbacks on the north coast (chap.3). The reason for this is thought to be the combination of favourable characteristics of the beach. Green turtles may share the same favoured beach characteristics; however, the high density of leatherbacks nesting on the beach may deter the green turtles from nesting there more frequently. Inter-specific competition has been suggested as an important pressure on nesting females for beach selection where larger species can easily destroy nests of smaller turtles (Meylan, 1982a). However when leatherbacks and other species nest in the same vicinity, they often segregate spatially (Hendrickson and Balasingam, 1966), or temporally (Carr and Orgen, 1959). It is possible that green turtles lay their eggs later in the year to avoid the peak nesting season of leatherbacks, in order to reduce the chances of their nests being dug up by high densities of leatherbacks.

Small numbers of green turtles nest on many islands in the Caribbean (Groombridge and Luxmoore, 1989), and it is unclear whether these turtles represent small isolated nesting colonies, stray individuals from major nesting colonies, or individual turtles attempting to colonise new areas. Some islands, such as Bermuda (King, 1982), Mauritius, (Hughes, 1982) and the Cayman Islands (Aiken et al., 2001) are known to have had large breeding colonies in the past, which were depleted after becoming inhabited by humans (Seminoff, 2002). Although green turtles continue to nest in the Caymans at extremely low levels, it is unknown whether they are remnants of the previous nesting population, turtles from nearby nesting rookeries, or head started turtles from the Cayman Turtle Farm (Wood and Wood, 1993). The green turtle nesting population in Trinidad is very small and the origin is unknown. However, considering the evidence demonstrating that green turtles show a high level of natal homing, it seems possible that the green turtles nesting in Trinidad are part of a small separate nesting population, which may have been larger in the past.

The major green turtle rookeries in the Atlantic are found in Tortuguero, Costa Rica (Bjorndal et al., 1999; Troëng and Rankin, 2005), Ascension Island (Mortimer and Carr, 1987; Godley et al., 2001c), Suriname (Schultz, 1975), Aves Island, Venezuela (Sole and Medina, 1989), Trinidade in Brazil (Moriera et al., 1995), Guinea Bissau (Fortes et al., 1998; Catry et al., 2002) and Bioko Island in Equatorial Guinea (Tomas et al., 1999). Pritchard (1984) suggested that the green turtles foraging in Trinidad waters most likely came from one of the four major nesting colonies in the Caribbean region (Costa Rica, the Guianas, Mexico and Aves Island, Venezuela). Recent work done on mtDNA analysis of green adult females from nine rookeries around the Atlantic and Mediterranean has shown that there are significant genetic differences between the large nesting populations, and data from Atlantic stocks are now sufficient to allow the use of genetic markers to determine the natal origins of green turtles foraging in different regions (Lahanas et al., 1994; Encalada et al., 1996). All studies to date have shown that turtles foraging in one region are from a range of different natal areas (Bass et al., 1998; Lahanas et al, 1998; Bass and Witzell, 2000; Luke et al., 2004). A study of foraging green turtles in Barbados found that the turtles were from, in approximately equal percentages, Ascension Island (25 %), Aves Island/Suriname (23 %), Costa Rica (19 %), and Florida (18.5 %), with a smaller percentage from the Gulf of Mexico (10 %) (Luke et al., 2004). A very small proportion were also from Brazil (1 %) and Guinea Bissau (3 %). It is therefore likely that the green turtles foraging in Trinidad's coastal waters are also from a number of different nesting populations, perhaps similar to the make up of the green turtles foraging in Barbados.

Tag data can give some insight into where the foraging green turtles in Trinidad's coastal waters come from; for example an adult green turtle tagged in Brazil was found washed up dead on the east coast of Trinidad on Mayaro beach (Lum et al., 1998), and a juvenile green turtle tagged in Barbados was caught off the coast of Trinidad (Luke et al., 2004). The turtle fishery in Trinidad is currently unmonitored; therefore any tagged turtles that are caught are rarely reported. Much useful information could be gathered if fishermen were willing to report tag numbers. MtDNA analysis of the green turtles foraging in Trinidad would provide further insight into their origins, and in turn, which nesting populations are threatened by the fishing activities capturing green turtles in Trinidadian waters.

Interviewed fishermen reported that green turtles were the most frequently caught species in the north coast sea turtle fishery active in the open season, with hawksbills as a close second (Lum, 2003; personal communication with Matelot fishermen). The mean weight of green turtles caught in the turtle fishery in 1984 was 44 kg (Chu Cheong, 1995), suggesting that the majority of turtles caught were juveniles. The average weight of an adult green turtle is 136 kg (Hirth, 1997). This supports the theory that turtle fishing industries in the Caribbean remove many juveniles from nesting populations (Lagueux, 1998; Troeng and Rankin, 2005).

Considering the annual estimated 1,000 hard-shell captures (James and Fournillier, 1993), it is likely that a minimum of 500 green turtles are caught each year. Mortality occurring in foraging grounds away from nesting areas may have an important impact on nesting population sizes (Godley et al., 2001c). High levels of take are known to occur in several locations in the eastern Atlantic (Formia, 1999) and in the Caribbean Sea (Lagueux, 1998).

In the recent IUCN Red List Status Assessment of the green turtle by the Marine Turtle Specialist Group (Seminoff, 2004a), a list of the countries that experience ongoing intentional capture of green turtles was drawn up. Trinidad was not included on the list. I propose that the capture of green turtles in Trinidad should be included as an area of significant take from foraging grounds, which will affect nesting populations elsewhere. An up-to-date assessment of the Trinidadian hard-shell fishery to provide numbers caught, sizes and life stages of green turtles is therefore essential for a reliable estimate of capture.

5.4 The olive ridley turtle (*Lepidochelys olivacea*)

5.4.1 Introduction

The olive ridley turtle (*Lepidochelys olivacea*) occurs in the tropical waters of the Atlantic, Pacific and Indian Oceans (Plotkin, 2003). They are highly migratory animals, and spend much of their life in pelagic waters (Pitman, 1990; Plotkin, 1994). Olive ridleys employ two different breeding behaviours. Some nest in a mass aggregation called an arribada (Pritchard, 1997; Chaves et al., in press) where up to hundreds of thousands of females lay their clutches on the same beach over a period of three to seven days (Miller, 1997; Chaves et al., in press). Olive ridleys also exhibit solitary nesting behaviours (Plotkin, 1994). The inter-nesting interval is variable, but is generally 14 days for solitary nesters, and 28 days for arribada nesters (Pritchard, 1969; Kalb and Owens, 1994; Plotkin, 1994). In solitary nesting, mating takes place away from the shore (Pitman, 1990; Kopitsky et al., 2000), and the females are thought to have weak site fidelity (Kalb, 1999), in contrast to the strong nest site fidelity in arribada nesters (Plotkin, 1995; Kalb, 1999). Solitary nesting females generally lay three clutches of eggs (Pritchard, 1969; Kalb, 1999) and may use several different beaches in different geographic regions in the same nesting season (Kalb, 1999). Solitary nesting olive ridleys are nomadic animals in the sense that they do not have fixed foraging or breeding grounds (Plotkin, 1994; Plotkin et al., 1995). They also typically nest every year, skipping the non-breeding seasons shown by other sea turtle species (Pritchard and Plotkin, 1995).

The distribution of olive ridleys in the western Atlantic is limited primarily to the northern coast of South America, where both feeding and nesting occurs (Pritchard, 1969; Reichart, 1989; Plotkin et al., 1995). Primary nesting beaches occur in Suriname, but there is also some nesting in French Guiana, Guyana, and Brazil (Pritchard, 1969; Schultz, 1975; Marcovaldi, 2001). Over the past 30 years, numbers of ridleys nesting in Suriname have dramatically decreased, believed to be due to incidental catch from industrial and artisanal fisheries (Reichart and Fretey, 1993; Hoekert et al., 1996). Olive ridleys are known to migrate between the coastal waters of Venezuela, the Guianas, and Brazil (Marcovaldi, 2001) and some individuals tagged in Suriname have been recorded in Trinidadian waters (Pritchard, 1973; 1976). Sightings of the olive ridley in the insular Caribbean are rare. Most observations have been in-water, the animals usually having been caught in fishing gear (Carr, 1957; Pritchard, 1969; Moncada-G et al., 2000). Records of nesting in the Caribbean are even rarer, and ridleys are thought to nest almost exclusively on mainland beaches (Pritchard and Trebbau, 1984). However, there have been several records of both nesting and foraging turtles in Trinidad.

5.4.2 Olive ridleys in Trinidad

Carr (1956) first noted the presence of olive ridleys in Trinidadian waters when he mentioned the occasional capture of a sea turtle fitting the description of a ridley. Bacon (1969) also documented that fisherman reported the capture of this species in fishing gear. In my interviews with fishermen it was noted that "batali" (the common name for olive ridleys in Trinidad) were rarely seen in the waters now, and that they could not remember the last time that one was caught in a net (chap.6).

Nesting records of olive ridleys from Trinidad are mostly limited to the east coast beaches. The first nesting record was in 1969 on Matura Beach (fig.1.3), where Bacon observed adult ridley tracks. A ridley hatchling was also collected by Dr. P. Morris on Manzanilla beach (east coast) in August of the same year (Bacon, 1969). In addition, I have been able to check the unpublished turtle survey records of the TFNC, 1965 - 1982. Adult ridley tracks were seen in 1970 on Matura, although the adult was not actually observed. There was a nesting olive ridley observed on Matura in 1979 where several photographs were taken. Chu Cheong (1984) mentions an adult sighting at Matura, and there is a record of an adult ridley carcass found at Fishing Pond beach (east coast), although it is unknown whether the animal nested or was discarded by fishermen having been caught in nets (Nathai-Gyan et al., 1987). There have been no other reports of olive ridleys nesting on the east coast beaches, which are currently comprehensively monitored by Nature Seekers and the Fishing Pond Environmental and Community Group during the turtle nesting season (S. Poon, personal communication; chap.2; appendix 1).

Nesting of olive ridleys on the north coast is limited to a single record by Sherwin Ruiz on Grande Riviere beach in 1995; however there were no measurements or photographic evidence taken (Fournillier and Eckert, 1997). Other than this sighting there has never been any other evidence of olive ridleys on the north coast beaches (Bacon, 1969; 1981). However, this may partly be a result of the fact that little work has been done on the remote north coast beaches in the past due to their inaccessibility (chap.2).

5.4.3 Olive ridley results

An olive ridley was observed nesting on Madamas beach on the north coast of Trinidad at 5.10 am on the 23rd June 2003 (fig.5.7). The curved carapace length and width were measured with a flexible tape measure: 69 cm and 68.5 cm respectively. This is within the range of carapace lengths for olive ridleys found in the Guianas (66 - 72 cm) (Pritchard, 1969). The turtle had not been previously tagged and the team did not apply tags, as we had no appropriate tags for this size of turtle. The turtle had a large part of the left rear of the shell and part of the rear flipper missing (fig.5.8). The injury was completely healed and did not appear to hinder her nesting ability or movement on land. The damage was most likely inflicted by a shark bite, which is not uncommon in adult olive ridleys (Pritchard, 1969). In his 1969 paper on sea turtles of the Guianas, Pritchard shows a very similar photograph.

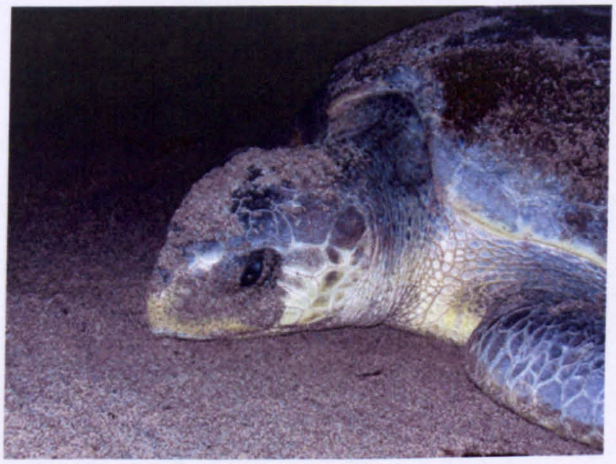


Figure 5.7 Olive ridley nesting on Madamas beach

Figure 5.8 Olive ridley with chunk out of left hand side of shell

During the sea turtle monitoring on the north coast beaches (methodology, chap.4), this was the only record of nesting by an olive ridley.

5.4.4 Discussion

It appears that olive ridley nesting on the north coast of Trinidad is a rare occurrence. It is perhaps not too extraordinary, however, as Trinidad is relatively close to the South American coastline where olive ridleys commonly lay and forage, and solitary olive ridleys are known for their nomadic nesting behaviour (Plotkin, 1994; Plotkin et al., 1995). It seems that olive ridleys have been more common in Trinidadian waters in the past, and this trend may be mirroring the decline of some of the other South American ridley populations. The shrimp trawler industry is quite possibly partly to blame for the decline (Pritchard, 1984).

5.5 The loggerhead turtle (*Caretta caretta*)

5.5.1 Introduction

The loggerhead turtle (*Caretta caretta*) is the exception to the tropical nesting pattern shown by other sea turtles (Hirth, 1997; Miller at al., 2003), and are found mostly in the warm temperate waters in subtropical and temperate regions of the Atlantic, Pacific and Indian Oceans, and in the Mediterranean Sea (Dodd, 1988). The largest nesting aggregations are found along the southeastern coast of the US (Turtle Expert Working Group, 2000), in Cape Verde, West Africa (Hawkes et al.2006), and in the Indian Ocean at Masirah Island, Oman (Ross and Barwani, 1982). A small amount of nesting has been reported on the Caribbean coasts of Central America and Mexico, the Atlantic coast of South America, and occasionally in the eastern Caribbean (Dodd, 1988). Pritchard (1979) used the term "anti-tropical" to describe the aversion exhibited by loggerheads to nest in these areas.

Loggerheads spend a lot of their time in coastal waters, and are associated with reef habitat and nearshore soft-bottomed benthic habitats and estuaries (Dodd, 1988; Plotkin et al., 1993), often foraging in several different coastal areas (Plotkin and Spotila, 2002). Loggerheads are carnivorous, foraging primarily on benthic invertebrates throughout their distribution range (Plotkin et al., 1993). Loggerheads migrate between their foraging and nesting areas, sometimes travelling large distances (Limpus et al., 1992; Plotkin and Spotila, 2002), and show high levels of philopatry (migration from nesting areas to foraging areas and back; Carr, 1975). A study in Australia found that 98 % of loggerheads returned to the same beach to nest (Limpus, 1985), and a study in South Africa showed a return rate of 93.1 % (Hughes, 1974). Recent research has shown that breeding loggerheads tend to return to a region of birth rather than to a specific beach (Bowen et al., 1994; 2004). However, they tend to return to the same beach to lay subsequent clutches in the one season after a successful oviposition (Limpus, 1985). During the nesting season, female loggerheads will lay approximately four clutches every three years (Dodd, 1988; Schierwater and Schroth, 1996). There are some records of intra-seasonal movements to different beaches, although the proportion of loggerheads doing this is very low (Limpus, 1985). Loggerheads are listed as endangered on the IUCN red data list (IUCN, 2005).

5.5.2 Loggerheads in Trinidad

The loggerhead turtle is the rarest of the sea turtles found in Trinidad (Bacon, 1969; Nathai-Gyan et al., 1987), with few records of loggerheads in coastal waters and nesting on beaches. There is no evidence of loggerheads ever nesting on the beaches or being caught in the waters of Tobago (Fournillier and Eckert, 1997). There have been a handful of sightings made by fishermen in Trinidad's north coast waters and near Chachachacare Island off the northwestern peninsula. The south coast of Trinidad is said to support loggerhead nesting, although this has never been confirmed (Bacon, 1973a).

There is only one confirmed record of a female loggerhead nesting in Trinidad from Grande Riviere in 1989, where a loggerhead was witnessed nesting. The process was recorded on film (Wildlife unpublished records [Bro. Robert Fanovich F.P.M., personal communication]). There was another report of a loggerhead nesting at Las Cuevas on the north coast (fig.3.1) on 11th July 1971, where the animal was tagged (Bacon and Maliphant, 1971). However, the turtle was later identified as a hawksbill (Pritchard, 1984).

There are also several reports of loggerheads in the waters around Trinidad. A fisherman in Toco caught a loggerhead in gillnets in 1983 (Chu Cheong, 1984). In March 1987, two loggerhead shells were discovered at a river outflow on the east coast of Trinidad after the carcasses had been cooked on a barbecue. They may have been caught in Trinidad waters (Nathai-Gyan et al., 1987), but it is unknown on which coast they were caught. The Trinidad Wildlife Section has several records of loggerheads being captured in nets on the north coast between Blanchisseuse and Matelot from 1990/1991 onwards by the legal turtle fishery. However, the records are vague and unconfirmed. Interviews with fishermen confirm that the species is still occasionally encountered off Trinidad's north coast (Eckert, 1999; chap.6), although rare.

5.5.3 Loggerhead results

In the four years of this study, no adult loggerheads were ever encountered during the beach monitoring on the north coast. Nor were any loggerhead nests or hatchlings witnessed. There were no reports of fishermen capturing loggerheads in gillnets.

5.5.4 Discussion

Loggerheads tend to forage in coastal areas, most commonly in soft benthic mud and estuarine zones. The north coast has several river mouths flowing into the sea, and some soft bottom habitat (Georges, 1983) that may provide some foraging habitat for this species. This may explain why most of the records of loggerheads have been from the north coast area. As loggerheads tend to nest in the region of their birth (Bowen et al., 1994; 2004), it would be unlikely to find them purposely nesting on the beaches of Trinidad as there are no known loggerhead nesting populations in the surrounding area. The fact that there has only been one confirmed nesting over the last 35 years suggests that the north coast of Trinidad may be a region that receives some of the small proportion of individuals that display inter-nesting movements. It is also possible that the records of loggerhead turtles were misidentified, as in the case of the Peter Bacon record. The recorded film of the loggerhead at Grande Riviere was not available to me for viewing.

Pritchard (1984) suggested that loggerheads are not an important component of the local turtle fauna in Trinidad. In view of the results from this study and existing records, I agree with this statement. The loggerhead turtle is the rarest sea turtle nesting on the beaches and in the waters surrounding Trinidad (Pritchard, 1984; Fournillier and Eckert, 1997).

5.6 Conclusions

This study has reported on the numbers of hard-shell turtles nesting on the north coast beaches of Trinidad in the months of March to August. It is possible that some nesting may have been missed in the months after the monitoring ended. It is recommended that surveys be carried out during September and October to assess any possible nesting at that time. Although this study reports small number of olive ridleys and greens, and no loggerheads at all, negative data can be very useful, and can help to tailor management plans for sea turtles based on reliable estimates of what is actually there. In general, the numbers of nesting hard-shells on Trinidad's northern beaches are relatively low, although the nesting hawksbill population is larger than previously perceived.

From the number of nesting hawksbills encountered over four years, I was able to make an estimate of 150 females per year. The number of greens and olive ridleys encountered were too low for even a rough reliable estimate to be made, but their numbers are clearly small compared to hawksbills. Madamas appears to be an important beach for hard-shells. It was the beach on which the olive ridley nested, three out of four green turtles seen nested, and it supported the highest number of hawksbill nests. This should be taken into account for the future management of nesting hard-shells on the north coast. A national survey of suitable habitats for foraging sea turtles would also be useful. It is recommended that the nesting hawksbills and foraging populations of both greens and hawksbills be sampled for genetic profiling and mixed stock analysis of the foraging grounds and fishery catch.

The number of foraging hard-shells (mostly greens and hawksbills) in the open season is much larger than the nesting numbers in the closed season, and the threats faced by foraging turtles present a more serious conservation issue than any current threat to the nesting population. Although much smaller than in the past, the hard-shell turtle fishery still catches a significant number of greens and hawksbills each year. The level of purposeful turtle fishing in Trinidad has remained largely unchanged over the last 20 years (Lum, 2003). There have been some changes in the depots that practice turtle fishing with the numbers of depots increasing from six to eight. However, the fishing effort has not changed a great deal, with the same number of people employed (Lum, 2003). The sustained fishing effort could suggest that hard-shell numbers are stable enough for the fishermen to continue catching turtles at a similar rate, although there is no real evidence on sustainability. Because of the lack of data collected on the turtle fishery, there are no current data on the number, species or life stages of the turtles caught. The current legislation protecting sea turtles in Trinidad is also inadequate in terms of regulating the legal turtle fishery, and the laws are ineffectively enforced (chap.2).

Chu Cheong (1995) reported an estimate of between four and ten hard-shell turtles caught at each depot per week during the open season in 1984. Assuming that the rate of catch has not changed over the last 20 years, an estimated 1,120 turtles are caught in the sea turtle fishery each year (20 weeks (October – February) x an average of 7 turtles x 8 depots). This is similar to the figure suggested by James and Fournillier (1993), who estimated an annual catch of 1,000 hard-shells. This figure does not include turtles incidentally caught in gillnets (chap.7) and in shrimp trawlers. Although the actual level of mortality needs to be examined in more detail, it is felt that the numbers of turtles killed each year are significant enough to be included in the assessment of threats to green and hawksbill populations in the Caribbean region. The level of capture of these species in Trinidad's coastal waters is currently either under-represented or missing from current evaluations.

It is recommended that the Trinidad Fisheries Division carry out an investigation into the legal sea turtle fishery to assist in an assessment of the sustainability of the harvest, the possible effect that the catch might be having on nesting populations elsewhere, and the future management of the turtle fishery and hard-shell species in Trinidad's waters. The numbers of turtles caught by the shrimp trawler industry should also be examined, including the level of use of TEDs within the industry. The literature describes a history of rather unsuccessful compliance with the US standards for the use of TEDs, resulting in periods of embargo for shrimp export. Although effort has been put in by the Fisheries Division to manage the fulfilment of the 1994 legislation concerning sea turtles (Fournillier and Eckert, 1997), it is recommended that further investigation is made into the extent of incidental catch of sea turtles, and more pressure put on the industry to comply with the regulations. It is important that the fishermen be an integral part of the management process for it to be successful (chap.7).

6. An interview-based assessment of incidental entanglement of sea turtles in the artisanal gillnet fishery on the north coast of Trinidad

6.1 Introduction

Incidental entanglement in fishing gear from both pelagic and coastal shelf fisheries has been implicated in the decline of many marine species, for example sharks, seabirds, pinnipeds, cetaceans and sea turtles (Morizur et al., 1999; Tuck et al., 2001; Carretta, 2002; Baum et al., 2003; Lewison et al., 2004b). The life-history strategy and healthy population structure of such animals depends on the longevity and low mortality rate of adults. The fishing industry presents a serious threat to their survival by causing high levels of adult mortality (Lewison et al., 2004b). Today, incidental capture is one of the most serious conservation issues for many marine species. Attempts to quantify bycatch levels have been carried out in some regions around the world. However, this has proved to be a challenging task, with limited results (Lewison et al., 2004a).

The leatherback turtle is listed as critically endangered by the International Union for Conservation of Nature and Natural Resources (IUCN, 2005) in both the Atlantic and the Pacific Oceans. The situation is a great deal more serious in the Pacific where numbers of leatherbacks have plummeted over the last 20 years (Spotila et al., 1996; 2000). Leatherback turtles are highly migratory oceanic animals and travel huge distances every year between nesting and foraging grounds (Eckert, 1998; Ferraroli et al., 2004; Hays et al., 2004; James et al., 2005b). It has been shown that they do not use specific routes when moving between areas, making it challenging to map areas of high density, and to use management practices such as area restrictions to limit turtle-fishery interactions (James et al., 2005a). The true extent of the impact fisheries have on leatherback populations is unknown and most data are from observations of a small fraction of fisheries operating in a limited part of the leatherback range (Hays et al., 2003; James et al., 2005a). Recent research has shown that turtle-fishery interactions represent a greater threat than previously perceived (Robins, 1995; Pandav et al., 1997; Hays et al., 2003; James et al., 2005a), and as a result turtle-fishery interactions in pelagic waters have been a major focus of recent conservation measures (Witzell, 1999; Lewison et al., 2004b; FAO, 2004). However, turtles interact with most types of fishing gear, and entanglements in coastal and shelf waters remain largely understudied (FAO, 2004), although some recent work has been done on leatherbacks in northern waters in Canada (James et al., 2005a).

6. An interview-based assessment of incidental entanglement of sea turtles in the artisanal gillnet fishery on the north coast of Trinidad

Attempts to reduce incidental entanglement of turtles in fisheries have involved gear modifications, using more selective fishing methods instead of indiscriminate catching (Valdemarsen and Suuronen, 2001; Bache, 2003). Most gear modifications have been applied to commercial trawling e.g. TEDs (Turtle Excluder Devices) (Seidel and McVea, 1995; Crowder et al., 1995; Lewison et al., 2003; FAO, 2004) and pelagic long lining e.g. circle hooks (Bolton et al., 2001; Watson et al., 2003; 2005). Little research of this kind has been done on coastal gillnets, although some recent attempts have been made with setnets (Cheng and Chen, 1997; FAO, 2004). Other methods for mitigating bycatch are through spatial and temporal restrictions, and reductions in fishing effort (Hall et al., 2000; FAO, 2004). However, these approaches raise socioeconomic issues and often develop problems with enforcement and compliance (Standora, 2003). The mitigation of bycatch of turtles is not just a question of fishery technology, but is a complex issue with economic and social considerations (Bache, 2002; 2003).

The incidental catch of sea turtles is known to occur in gillnets near nesting beaches in many countries (Chan et al., 1988; Cheng and Chen, 1997; Chevalier, 2001) but is generally poorly documented with little available data, especially from artisanal fisheries. It is important to investigate these as major sources of localised mortality of sea turtle populations. The gillnet fisheries in Central and South America are thought to be largely responsible for the collapse of the Pacific leatherback turtle population (Eckert and Sarti, 1997; Spotila et al., 1996; 2000; Alfaro-Shigueto et al., 2002; in press; Kaplan, 2005).

Trinidad is the most southerly island in the Caribbean arc chain located 12 km northeast of Venezuela. The flora and fauna of Trinidad is much more South American than typically Caribbean, and Trinidad's waters are heavily influenced by the Orinoco River which divides into two components at the southeast point of the island (Georges and Greenidge, 1983). One part flows up the east and along the north coast. The other flows west into the Gulf of Paria between Trinidad and Venezuela. This influx of fresh water contributes to the high productivity of Trinidad's waters, and influences the species diversity and marine habitat types (Mohammed and Shing, 2003).

There are three main fishing industries in Trinidad, an artisanal multi-gear fishery, a semi industrial multi-gear trawl longliner fishery, and an industrial trawl fishery (Mohammed and Shing, 2003). The main fishing type on the north coast is artisanal multi-gear fishing, with some bigger trawlers further out from the shore. There is little documentation of fisheries in Trinidad prior to the 1940's. However, the literature suggests that fishing on the north coast at that time was mostly for subsistence rather then for commercial sale, and that the development of the fishing industry was limited by lack of capital, infrastructure and availability of fishing gear (Vincent, 1910). Prior to the 1940's, the majority of fish was imported to Trinidad from Canada and Venezuela (Vincent, 1910). During the second World War, fishing practice was reduced due to a further gear shortage and transport problems, and because many of the fishermen went into military employment (Brown, 1942). Once the war was over a development plan was put in place, and the fishing industry was promoted throughout the island. Outboard motors were introduced, as were new fishing methods, the same as the techniques used today (Hunt, 1949; Stockdale, 1945; Mohammed and Shing, 2003). The new methods included setting nets specifically for the capture of sea turtles ([Anon, 1947] Mohammed and Shing, 2003). Fishing was still largely of a subsistence nature in the late 1940's, with development continuing into the 1950's. By the 1960's, the artisanal fishing industry on the north coast consisted of small, motorised boats using a number of different fishing techniques, as it is today.

The Fisheries Act of 1916 is the legislative basis of management for local fisheries in Trinidad, and regulates the artisanal trawl and gillnet fisheries (Mohammed and Shing, 2003). The regulations pertain to areas of operation and gear specifications, for example, the use of TEDs in trawl nets (Conservation of Marine Turtle Regulations of 1994). To date, there is an open access policy for fishing however, a review of the existing fishing policies in 1998 concluded that the laws required an update to change from open access to limited entry via a licensing system (Mohammed and Shing, 2003). This has not yet been introduced. The artisanal fishing industry on the north coast is fairly unstructured, with no central management (J. Marcano, personal communication). Each north coast depot has its own co-operative, and manages the transport of fish to the main markets. Most depots now have a Fisheries department data collector, although this is very recent in some of the north coast villages (introduced to Matelot village in 2002, SRL, personal observation). Data on bycatch from the artisanal fisheries in Trinidad is very limited (chap.5).

Five species of sea turtles are found in the coastal waters of Trinidad (Bacon, 1969; Fournillier and Eckert, 1997; Livingstone, 2005). Leatherbacks nest in the largest numbers (chap.4), with smaller numbers of hawksbills and greens, and the occasional loggerhead and olive ridley (chap.5). All species nest mostly on the north and east coasts of Trinidad, although they are found in the waters all round the island. However, the leatherbacks are most numerous directly offshore from their nesting beaches (Lum, 2003), and the other four hard-shell species are mostly found in the waters on the north coast, where there is suitable foraging habitat (chap.5). The leatherback nesting season starts in early March and finishes at the end of August (Bacon, 1969), after which time they leave Trinidad waters to migrate to their foraging grounds elsewhere (James, et al. 2005b). The hard-shell species begin nesting slightly later in May, and continue into October (Eckert, and Fournillier, 1997; chap.5). It is likely that some nesting hard-shell turtles also leave after the season is over and return to their foraging grounds. However, there are foraging hard-shell turtles present in Trinidad's coastal waters all year round (chap.5).

The nesting leatherback population in Trinidad is possibly the third largest remaining in the Atlantic (chap.4). The north coast beaches support an annual nesting population of 3,230 (2,300 - 4,030) (chap.4). A nesting population estimate for the whole of Trinidad does not currently exist, although it is thought to be in the region of 5,000 females per year (total nesting population of approximately 12,000) (chap.4). There is strong evidence to suggest a substantial increase in nesting females over the last 30 years (chap.4). Although the current population trend is unknown, it is considered to be stable (Eckert and Eckert, 2005; chap.4).

Sea turtles are protected by law in Trinidad under the Wildlife Act and Fisheries jurisdiction, during a closed season from 1st March to 30th September (appendix 2), which effectively covers the majority of the turtles' nesting seasons. It is not illegal to incidentally catch turtles; however, it is illegal to kill them if they are found alive in nets. This legislation is difficult to enforce, and almost impossible to monitor, as most killing occurs at sea. In Trinidad, leatherbacks have never been actively hunted at sea, due mostly to their unmanageable size (Pritchard, 1984). At one time they were enthusiastically hunted on nesting beaches (Bacon, 1969; 1970; 1973; James, 1983; chap.2), but the deliberate killing of adult leatherbacks is now uncommon (Fournillier and Eckert, 1997). However, incidental entanglement of adult leatherbacks in the local gillnet fishery is thought to cause substantial mortality, and to pose the most serious threat to the leatherbacks in Trinidadian waters (Pritchard, 1984; Eckert and Lien, 1999; Lum, 2003). All hard-shell species are hunted at sea during the open season, and taken opportunistically during the closed season, using specialised turtle nets and harpoons (Lum, 2003; chap.5). The fishing level of hard-shell turtles is currently unknown, as no official records on turtle catch are collected (chap.2; chap.5). The capture of hard-shell species in gillnets is thought to be rare (Lum, 2003). Hard-shells do get caught in the shrimp trawler fleet working in Trinidadian waters, although no estimate of the amount of catch exists (Fournillier and Eckert, 1997; chap.5).

6. An interview-based assessment of incidental entanglement of sea turtles in the artisanal gillnet fishery on the north coast of Trinidad

Pritchard (1984) first suggested that the incidental catch of leatherbacks in gillnets in Trinidad should be investigated. Fournillier and Eckert (1997) further highlighted the problem in the WIDECAST (Wider Caribbean Sea Turtle Conservation Network) Sea Turtle Recovery Action Plan (STRAP) for Trinidad and Tobago, estimating that more than 1,000 leatherbacks were captured in the north eastern region per year, based on various reports and interviews. With additional survey data, Eckert and Lien (1999) stated that the incidental entanglement of leatherbacks in gillnets was certainly "the largest single source of mortality in Trinidad, killing more turtles than all other factors combined", and considered it unsustainable. In 2001, Lum (2003) assessed the levels of incidental catch along all four coastlines of Trinidad. The data were gathered via questionnaires at 27 landing sites around the island. She estimated that there were approximately 3,000 leatherback captures in gillnets each year off all the Trinidad coasts. She highlighted that most of the incidental catch took place off the north and east coasts, which also supported the high density leatherback nesting beaches. The west and south coasts had significantly lower capture rates. The north coast had the highest capture rate of all the coastlines, and also the highest number of boats. However, the south had the second highest number of boats, but the fewest captures. It appeared that the numbers of turtles caught depended on gillnet fishing in proximity to leatherback nesting beaches, rather than to the total fishing effort, although fishing effort likely plays a part. Both Lum (2003) and Eckert and Lien (1999) emphasized that management to mitigate the capture should be a high priority of the Trinidadian Government, and suggested that a number of mitigation techniques would be required to tackle the problem effectively.

This chapter attempts to assess the capture and mortality rates of sea turtles in the gillnet fishery on the north coast of Trinidad using information from questionnaire-based surveys. It must be acknowledged that the data presented here are mainly anecdotal without rigorous statistical grounding, and predictions made from them are potentially error prone. However, the survey and the derived analyses provide a basis of an understanding of the impact of gillnet fishery on the north coast and provides important information on the leatherbacks inter-nesting behaviours at sea. The data presented reflects the fishermens' view of sea turtle capture and mortality rates, which may or may not be true to life (as discussed later), and reviews their opinions on possible methods of mitigation, both of which are extremely important considering they are the stakeholders that will be most affected by any change in fishing practices. The interview data is analysed alongside data on body damage of nesting females and strandings. This review is an important first stage for evaluating the threat that gillnetting presents to the nesting sea turtle populations in Trinidad waters, and in predicting the impacts if the current fishing efforts continue. Recommendations for further study are presented, and several different techniques for mitigation are considered. The associated difficulties with each are discussed.

6.2 Methods

The data reported here were collected during a Darwin Initiative project spanning 2002 - 2004. The project area included all the coastal waters and nesting beaches along the northern coastline of Trinidad (fig.3.1) (see chap.2).

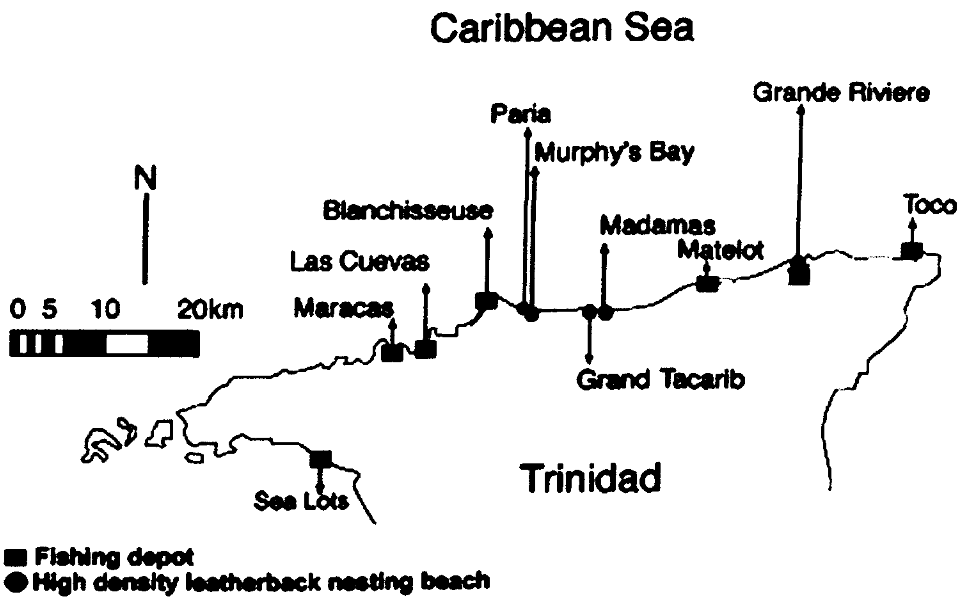


Figure 6.1 Study area on the north coast of Trinidad showing the high density nesting beaches and the fishing depots from which fishermen were interviewed

The data were generated mostly by interviews with local fishermen. All the interviews took place at the fishing depot at Matelot, although fishermen from all the fishing villages along the north coast took part in the survey as many of them use Matelot as their fishing base in the months of June to August. The fishing depots on the north coast include Las Cuevas, Maracas, Blanchisseuse, Matelot, Grande Riviere, Toco, with another on the west coast at Sea Lots (fig.6.1). The fishermen living at Sea Lots travel round onto the north coast in order to take advantage of the high fishing season (Lum, 2003), and so were included in the survey.

As leatherbacks were the main species caught in nets, with rare captures of hard-shell species, the questions focused mostly on leatherbacks.

The interviews were kept informal: fishermen were asked for general information about leatherbacks in the waters, about timing of the turtles' arrival and dispersal, past and present numbers of turtles, and other relevant observations such as the presence of jellyfish or mating activities. They were questioned on the different fishing methods they used and how often they used each one. Information about gillnetting practices was requested in more detail: net types and net setups, amount of nets put out and net sizes, how often nets were checked, and where and when gillnets were set. They were asked about their frequency of fishing, distance from the shore, and the number of active boats on the north coast. From these data, the fishing effort, from the view point of the fishermen, on the north coast could be calculated.

The fishermen were asked about the incidental entanglement of sea turtles in gillnets, the details of where, when and how often they got captured, and the levels of entanglement in the different net types. They were also questioned about their actions on finding entangled turtles, and the mortality rates of the turtles in the nets. It was important to find out how entangled turtles affected the fishermen's catches, nets and choice of fishing methods. The fishermen were asked to express their opinions on the leatherbacks and to discuss the problems associated with leatherbacks and their fishing practices. They were asked if they knew about the laws concerning sea turtles in Trinidad, and what their views were on trying to reduce the bycatch of turtles. Alternative fishing practices and possible solutions for reducing the entanglement of leatherbacks in gillnets were discussed. The listed questions often led to more general discussion about the subject matter, from which additional information was extracted. The survey questions are listed in appendix 5.

The limitations of survey data are acknowledged, and take into account the well-known phenomenon of interviewees not always telling the whole truth; some fishermen may not have wished to give information that they thought might have had adverse consequences for them and their livelihood. Each fisherman was encouraged to answer honestly, and assured that all information was treated as confidential. All interviews were carried out by SRL, usually along with another member of the project team. The resources required to place observers aboard fishing vessels were not available; therefore, unfortunately, no on-boat observations were made to support the interview data.

The fishing effort on the north coast of Trinidad was calculated using information on the number of boats working on the coastline, the average amount of net used on each boat, and the average time that each boat spent working. The leatherback capture rate was calculated using the mean number of turtles that the fishermen said they caught in nets at different points in the season, and estimated using the fishing effort. The mortality rate was calculated from the percentage of leatherbacks that drowned in the nets, and the number that were killed in other ways. There was no way in which to work out the post release mortality. The level of damage to leatherbacks released from nets was assessed by collecting data on nesting females on the north coast beaches. Any wounds or damage on nesting adults was recorded during beach monitoring.

In addition to the interview data, numbers of leatherback strandings along the north coast were collated from direct observation and reports from fishermen and villagers. This was done in each of the three study years. All reported sightings were verified by the project team. The percentage of mortality accounted for by strandings was calculated.

6.3 Results

6.3.1 Leatherbacks in the water

A total of 36 fishermen were interviewed from the villages that use the north coast fishing waters in Trinidad. The fishermen reported that the leatherbacks began to arrive in the waters in January in small numbers. The leatherbacks increased in number over February and March, and were present in the largest numbers in April and May. Numbers began to diminish quite rapidly in mid June, and continued to do so until late August. A small number of leatherbacks would still be present in September, and were mostly gone by early October. The fishermen reported that there were often jellyfish blooms in February and March, and that this was thought to be a reason for the leatherbacks arriving earlier than the start of nesting. The project team witnessed a jellyfish bloom in late March in 2003.

The fishermen were unanimous in their agreement that leatherbacks are much more numerous in recent years than in the past. They reported that leatherbacks have been incidentally caught in gillnets in Trinidad for as long as they can remember, but to nowhere near the extent that they are now. The fishermen said that the numbers had increased most rapidly since the late 1980's and early 1990's.

The fishermen reported that there were many male leatherbacks in the water, and that it was not only females that were present offshore. The fishermen said that they often got a good look at the turtles when they were in the nets, and that they could tell the difference between males and females by the size of the animal's tail. Six of the fishermen commented that there were more turtles in the water than the numbers seen nesting on the beaches, the extra numbers being made up by male leatherbacks. One fisherman said that he had seen leatherbacks mating in the north coast waters on two separate occasions. Another fisherman reported that during the busiest time for turtles (April and May), if a female got entangled in the net, several males would often become entangled in the same net. He suggested that this was because they were attracted to the female.

6.3.2 Fishing methods used on the north coast

The most common fishing method used on the north coast was gillnetting. Seventy seven % (n = 27) of fishermen said that they used gillnets all year round, although they also used a combination of methods at certain times depending on the season and weather. The other 23 % of fishermen said they used gillnetting only in the months of January to August. The gillnet fishery primarily targets carite (*Scomberomorus brasiliensis*) and kingfish (*Scomberomorus cavalla*) although other fish species such as cavalli (*Caranx hippos*) and several shark species are also caught and sold. Gillnetting is highly unselective and many unwanted species get caught.

Other fishing methods employed by the fishermen were banking (a stationary line near the seabed), switchering (a stationary line in mid water), trawling (a moving fishing line using artificial bait), a-la-vive (a moving line using live bait), palangue (a stationary line using many hooks), and fish potting (wire pots placed on the seabed). Banking, switchering, palangue and fish potting are more selective types of fishing, and generate little unwanted catch. The target species for these methods are different from gillnetting, mostly shark and redfish. Turtles are very rarely caught by such methods. The targets species are more seasonal, and the amount of catch is limited compared to gillnetting. A-la-vive and trawling are both used to catch the same target fish as gillnetting but are much more selective, rarely catching other species. A-la-vive and trawling use up more gas and oil for the boat movements than gillnetting.

The fishermen all agreed that a-la-vive was a preferable method of fishing to gillnetting as it is a daytime activity, it generates a similar catch over fewer hours, and there is less interference and damage to their gear from leatherback turtles. A-la-vive can only be practiced from June onwards, when the live bait becomes available (sardines). The fishermen explained that the sardines are only present in the water in large numbers when the "sweet water" arrives. This is, in fact, the outflow of fresh water from the Orinoco River during the rains, which flows up the east coast of Trinidad and round onto the north coast. The fresh water influx brings with it the sardines and only after this time can the fishermen gather the live bait. Several fishermen on the north coast catch the sardines by attracting them with very strong lights at night and capturing them with seines. The fishermen then buy the live bait from these enclosures. Currently, the live bait is mostly caught and purchased from Las Cuevas. Many fishermen said that they changed from gillnetting to a-la-vive as soon as live bait became available. Trawling was said to be less productive than a-la-vive, or gillnetting.

6.3.3 Gillnetting

Two main types of gillnets are used on the north coast, a green nylon multifilament net and a transparent monofilament net. The green nylon multifilament net, usually set out at night, is thicker and stronger than the transparent net, and is generally fixed at the surface of the water, held in position by weights and floats, and reaching to around 11 m depth. The transparent monofilament net, used both day and night, is positioned on the seabed, and anchored at one or both ends making it more rigid. The green nylon net was much more commonly used, with 83 % of fishermen (n = 30) using that net type. A combination of the two nets was used by 17 % of fishermen (n = 6).

The fishermen fish from pirogues (small fibreglass or wooden boats), the size of which determines how much net they can carry and disperse. From a range of between 70 and 450 lbs of net, the average amount of net used was 200 lb (which stretches to approximately 1.2 km; Lum, 2003). The fishermen checked their nets on average every three hours (soak time) in order to remove any unwanted catch, and to check if they had caught their desired amount of target species. If there were not enough catch, then the nets would be left for another two to three hours. The average total set time was six to seven hours.

The fishermen used the whole north coast area to fish, but concentrated their efforts between Blanchisseuse and Toco, where the fish were said to be more abundant. The average distance from the shore that the fishermen set their nets was 5 km, with a limit of 10 km. I calculated that there were a total of 70 boats using the north coast waters, although there would only be an average of 30 boats fishing at any one time. Each boat would go out to fish an average of five times a week, and would fish for an average of 14 weeks over the time when the leatherbacks were present in the waters (between March and June).

6.3.4 Capture and mortality of sea turtles in gillnets

The fishermen agreed that hard-shell turtles were occasionally caught in gillnets, but not commonly. Hawksbills and greens were caught most often, olive ridleys rarely and loggerheads even more rarely. When these species were captured, the majority (86 %, n = 31) of fishermen admitted to bringing them aboard the boat as catch. Hard-shell turtles caught incidentally in nets were seldom, if ever, released.

The fishermen agreed that they caught leatherbacks in gillnets most frequently offshore from the high density nesting beaches between Blanchisseuse and Toco (fig.6.1). Fewer turtles appeared to get captured beyond Blanchisseuse to the west. Leatherbacks were captured mostly in the months of March, April and May. The fishermen agreed that the green nylon surface set nets had a much higher capture rate than the bottom set transparent nets, although mortality was greater in the latter.

Fishermen reported that an average of one to three leatherbacks were caught in their gillnets every time they fished from March until around the end of June, although sometimes they could have up to as many as eight or nine in a net at one time, especially during the earlier part of the season. Using the data from the fishermen interviews the following mean values were calculated with confidence intervals:

T = number of turtles caught per fishing trip: 2.2 (1.5 - 2.5)
D = number of days per week: 5 (4 - 5.5)
B = number of boats out at any one time: 30 (25 - 35)
W = number of weeks fished over the season: 14 (12 - 16)

The number of captures over the season was calculated as: T x D x B x W

This calculates the total number of leatherback captures in gillnets on the north coast over one season as approximately 4,620 (1,800 - 7,700).

When asked how many of the entangled leatherbacks drowned in the nets, the fishermen gave varying answers. A small number of fishermen (5 %, n = 2) said that no leatherbacks ever drowned in the nets, and that they set free all entangled leatherbacks. The rest of the fishermen agreed that leatherbacks did drown in nets, but that it was not common, especially in the green nylon nets at the surface. From the fishermen's comments, it was estimated that approximately 3 % of leatherbacks captured in nets drowned. The main reason for leatherback mortality in gillnets was from the fishermen killing them. Most of the fishermen spoke openly about this action. However, some of them did not admit personal culpability, but said that they knew that others did it. Whether a turtle got killed depended on the degree of entanglement, and the individual fisherman. If the leatherback was not heavily tangled and was easy to release, then it most often was. The impression that the fishermen gave was that most of the killing of leatherbacks came from frustration at the damage to their nets and the rest of their catch. The fishermen usually killed the turtles by hitting them on the head with an iron bar, or decapitating them with a machete. They also sometimes cut open the leatherback's stomach so that the animal would sink to the seabed, rather than float and wash up on the shore. Several fishermen admitted that this practice was also to hide the dead turtles so that they would not get into trouble for killing them.

Using the varied estimates from the fishermen, a mean mortality rate was calculated for the leatherbacks that got captured in gillnets. Approximately 28 % (26 - 30 %) of the leatherbacks that were captured in gillnets ended up dead, from a combination of drowning and killing. Using the estimated number of captured turtles each year (4,620), from the view point of the fishermen, roughly 1,290 (1,200 - 1,380) leatherbacks die as a result of incidental capture in gillnets on the north coast of Trinidad.

The fishermen reported that sometimes the leatherbacks would get damaged when they were being released. They did not know what happened to turtles after they were released, but that they usually swam away from the boat quickly. During monitoring on the nesting beaches, 16 % (n = 502) of nesting leatherbacks observed had serious wounds to their heads and bodies (not including small superficial cuts), which were thought to be a result of having been entangled and released from nets. The wounds were clearly either inflicted by machetes (deep clean cuts), or were imprints of the net pattern, not to be mistaken for damage caused by predators such as sharks.

6.3.5 Strandings

The number of leatherback strandings recorded for each field season is listed in table 6.1. The number of nesting females (estimated from nest numbers; chap.4) is also shown and suggests that stranding numbers increase with the number of nesting females. No stranding of any other sea turtle species were observed or reported.

Table 6-1 Number of leatherback strandings and breeding females

Season	*Strandings*	*Estimated no. of females laying**
2002	37	2,418
2003	51	4,259
2004	41	2,611
Mean	**43**	

***Taken from chapter 4.**

Most reported strandings came from inhabited areas (where the turtle could be easily seen or smelled). The strandings we witnessed were from both inhabited and remote areas. All stranded leatherbacks recorded were dead, and none wore flipper tags (as far as we could tell) (fig.6.2). We were unable to sex any of the turtles. All turtles that were examined closely had wounds on their bodies that looked like they were from a machete blade and nets, and all had severe skull damage. Eleven % of stranded turtles had no head at all.

These figures are not believed to be entirely complete. It is assumed that some strandings were missed as some turtles could have been out of sight on inaccessible parts of the coastline, and at times when we were not there to see them. However, since the decay rate of large leatherbacks is relatively slow, during weekly visits, we should have detected most of the strandings on the beaches and coastline that we checked. All the reported and witnessed strandings came from between Blanchisseuse and Toco (although it is thought that the majority of dead animals ended up on this section of coast), and therefore cannot account for the rest of the coastline.

Figure 6.2 Stranded leatherback at Matelot village

Using the estimated annual number of leatherbacks that die as a result of capture in gillnets and the mean number of strandings per year, the strandings recorded on the north coast accounted for approximately 3.3 % of deaths.

6.3.6 Fishermen's attitudes to leatherbacks

Eighty % (n = 29) of the fishermen looked upon the leatherbacks as a nuisance, regarded them as pests and considered them a severe hindrance to the gillnet fishery. They explained how the leatherbacks caused damage to nets when they became entangled (fig.6.3), and how they damaged the fish catch in the nets by winding the net round their bodies while struggling to get free, thereby squashing the fish next to the leatherback's body. Forty seven % (n = 17) of the fishermen said that they could mend their own nets, but felt it was a time-consuming practice. The damage to nets was both inconvenient and a financial burden, as was the damage to commercial fish. Eight % (n = 3) of the fishermen claimed to abstain from fishing during the time of highest numbers of leatherbacks as it was not worth their while to fish.

Figure 6.3 Matelot fisherman fixing his gillnet

All of the fishermen were aware of the laws concerning sea turtles during the closed season. When asked whether they thought it appropriate for the leatherbacks to be protected, 58 % (n = 21) said that they thought it was, and that they did not enjoy killing the leatherbacks. The other 42 % said that they were not sure why the leatherbacks were protected, as there were so many of them. All the fishermen agreed that it would be beneficial to catch fewer turtles while fishing, both for the fishermen themselves and the turtles. Four of the fishermen admitted that they would have liked to have sold leatherback meat, but that it was too labour intensive to bring the large animals to shore, and that it was too difficult to sell the meat because of the legislation prohibiting sale and purchase.

When questioned on possible solutions to the problem, the fishermen were enthusiastic about the possibility of reducing the catch of leatherbacks. However they were concerned about the repercussions that changes in fishing practice would have on them. All the fishermen were open to the idea of gear modification, but raised apprehensions about costs, maintenance and availability of new gear, and how it would affect their catch. The suggestion of using a-la-vive rather then gillnetting was repeatedly brought up. The fishermen said that it was a long-standing idea to use a-la-vive rather than gillnetting, but the potential of this was restricted by the bait not becoming available until the end of May or early June. By this time many leatherbacks have already been caught and killed in nets. Several fishermen talked about the possibility of a hatchery for the live bait, but that nothing was currently being done about it.

The fishermen were unenthusiastic about using other alternative methods of fishing that involved less catch and more effort. When asked about temporal and spatial restrictions, most fishermen (89 %, n = 32) reacted negatively and were concerned about their livelihoods. They stated that they would not adhere to regulations unless they were compensated for the loss of revenue. The fishermen said that these types of restrictions would not work unless they were managed from within the fishing depots themselves. The fishermen discussed incentives to cut nets to release turtles rather than kill them, and came to the conclusion that there was currently no motivation to do so.

The more vocal of the fishermen said that they would be sceptical about any new management plan to reduce the numbers of leatherbacks caught in gillnets, and that previous attempts to do so had failed (discussed later). The general feeling from the fishermen was that they did want to reduce the number of leatherbacks caught in nets, but that there were no realistic solutions available that would not have damaging effects on their income. When asked about alternative employment in other industries such as ecotourism, the majority of fishermen (95 %, n = 34) said that they would rather continue fishing.

6.4 Discussion

6.4.1 Leatherbacks in the north coast waters

Leatherbacks begin to appear in the north coast waters of Trinidad in January, although females do not begin to nest in any significant numbers until early to mid March (chap.4). During interviews, many fishermen mentioned that the leatherbacks arrived in the waters at the same time as large jellyfish blooms; we also witnessed these blooms in late March in 2003. Bacon (1970) commented on the presence of jellyfish in Trinidadian waters and the possibility of the leatherbacks feeding on them. He identified the main jellyfish species as *Stomolophus fritillarius*. *Stomolophus* species have been commonly associated with leatherbacks, and leatherbacks have often been observed feeding on them (Lazell, 1980; Grant et al., 1996), and their presence identified in stomach contents (Davenport and Balazs, 1991), although not during reproductive activity (Reina et al., 2005). It is possible that the leatherbacks feed on the jellyfish before nesting begins.

The leatherbacks are present in the largest numbers in April and May. This coincides with the nesting season, which begins in early March and peaks at the end of May - beginning of June. The fishermen were convinced that there were males present in the offshore waters, one having witnessed leatherbacks mating on two separate occasions. Several other observations of leatherback mating events have been recorded on the north coast, in the late 1970's, and in 1983 (Fournillier and Eckert, 1997 [C. Rooks, personal communication]), and S. Eckert also received confirmation of observed leatherback matings from local fishermen (James et al., 2005c). The presence of males would account for the higher number of leatherbacks in the waters than the numbers nesting on the beaches. Eckert and Eckert (1988) proposed that mating does not occur in tropical waters and happens prior to, or during, migration. However, recent research suggests that males also make the journey to the nesting beaches, and mate with females offshore (Reina et al., 2005; James et al., 2005b; 2005c), as in other sea turtle species (Limpus, 1993; Miller, 1997).

The fishermen reported that the number of leatherbacks in the water begins to fall in early June, and then decreases significantly after this time. The drop in numbers in the water in June appears to be much more pronounced than the decrease in nesting which continues at a steady rate over June, July and August (at a similar rate to the increases in nesting in March to May) (chap.4). The significant reduction in numbers in the water at that time may be due to male leatherbacks leaving the offshore area, while the females remain to nest for a further few months. The males may leave the vicinity of the beaches earlier than the females when most of the females will have already mated (James et al., 2005c), and do not need to mate again having already received the sperm they require to fertilise their eggs for the rest of the nesting season (Fitzsimmons, 1998). Olive ridley males also show this behaviour and leave the offshore area at peak nesting season when they are less likely to find receptive females (Plotkin et al., 1996).

6.4.2 Fishing methods and leatherbacks

The fishermen on the north coast of Trinidad are a versatile group, able to change their fishing methods from day to day in order to maximise their catch. The methods used are dependent on the time of year, weather conditions and the species of fish in season. The fishing methods used by the fishermen on the north coast are banking, switchering, trawling, a-la-vive, palangue, fish potting, and gillnetting (Mohammed and Shing, 2003; Lum, 2003). Gillnetting was the most common, and the most unselective fishing practice employed on the north coast, with 77 % of fishermen using it all year round. Although not all the fishermen used gillnetting year round, the majority of them used it during the turtle nesting season from January to June, when the gillnet target fish were most abundant. The gillnet fishery primarily targets carite and kingfish which are both important commercial species (Henry and Martin, 1992). The leatherbacks' arrival coincides with the arrival of the commercial target fish species; therefore gillnet fishing effort increases as the leatherbacks appear. The other fishing techniques employed are much more selective than gillnetting, and leatherbacks very rarely get captured. A-la-vive and trawling target the same fish species as gillnetting, but are highly selective. A-la-vive catches more fish than trawling (artificial bait), as the fish are much more attracted to the live sardines that the fishermen use. The fishermen stated that a-la-vive was their preferred method of fishing, and that they changed to this method from gillnetting as soon as the live bait was available in early June. Using a-la-vive, the fishermen could fish during the day for fewer hours, catch more fish, and sustain no more damage to their gear than general wear and tear.

6.4.3 Interview data

Adult turtle bycatch can be quantified by several different methods (Hillestad et al., 1995). The most dependable method is on-boat observations, although survey data can also prove to be a reliable source of information (Godley et al., 1998; Macys and Wallace, 2003). Interviews are often viewed as a biased resource - the customary "Fisherman's tales". However, I feel that the survey data reported here offers a valuable evaluation of the numbers of leatherbacks entangled in gillnets on the north coast of Trinidad from the viewpoint of the fishermen. The research team were impressed by the fishermen's willingness to discuss the issues raised, and felt that most of the fishermen gave truthful information. It is thought that this was aided by the trusting relationship built up between the fishermen and project team during the duration of the research, with the majority of interviews conducted in the third and fourth year of the study, after working in the area for two previous years. Other studies have highlighted the importance of trust between locals and scientists when collaborating (Martin and James, 2005).

There are several reasons why the fishermen might over or underestimate numbers of capture or mortality. They may have felt that if they over exaggerated, they would be compensated for the damage to their nets, benefit from subsidies, or that something would be done about the problem if capture numbers were very high. It is perhaps more likely that they would under exaggerate figures; for example, some of the fishermen said that no leatherbacks ever drowned in the nets. They may think that reporting the actual numbers would impact negatively on them, and that their fishing practices and livelihoods might be in jeopardy. When discussing the killing of leatherbacks in nets, some of the fishermen talked about other fishermen doing it, thereby acknowledging that it happened, whilst not incriminating themselves.

On-boat observations are recommended to verify the rates of capture and mortality. This approach would be suitable for surveying the capture rate, however, it is possible that on-boat observers would make no difference to discovering the true number of turtles that die at the hands of the fishermen. It is thought that the fishermen would be more likely to be honest during an interview about the number they kill, than to continue with their normal practices at sea with an observer on board. Another approach would be to get a selection of fishermen to record numbers of captured and killed turtles each day. Although this could also be biased in the same way as interview data, based on trust.

Overall, we felt that the majority of fishermen were honest, and this was supported by the consistency of answers obtained in the 36 independent interviews. However, even if the fishermen did tell the truth according to them, the data presented here is still an approximation from their perception of what is happening at sea rather than what is actually happening. One should bare this in mind when making further calculations based on these data.

6.4.4 Capture and mortality

There are two main types of gillnet used which are regulated under the Fisheries Act (Hodgkinson-Clarke, 1994). The leatherback capture rate was higher in the thicker stronger green nylon surface nets, which are set at night (Eckert and Lien, 1999). This was also the most commonly used net type. It is likely that the female leatherbacks get captured when they move inshore to nest after dark, getting entangled on the way to the beaches. Female leatherbacks are known to spend the majority of their time near or on the surface of the water (Eckert et al., 1986; 1989b; Eckert, 1997) making it more likely for them to get caught in the surface set nets. The bottom-set transparent monofilament nets do not capture as many turtles, possibly due to their position in the water and the time of day they are set. The weaker threads probably also make it easier for the leatherbacks to break free (Lum, 2003). Although the capture rate was lower in the transparent nets, the incidental mortality rate was higher than in the green nylon net, most likely because the leatherbacks are unable to reach the surface to breathe, as they can in the free moving surface set nylon nets. With an average soak time of three hours it was rare for a leatherback to drown in the nylon nets before the fishermen could reach them. However, the longer the nets were left, the more likely it was for an entangled leatherback to drown. This was also found by Cheng and Chen (1997) when studying bycatch of sea turtles in setnets in the eastern waters of Taiwan. The fishermen felt that the overall mortality in the two different types of gillnets was approximately the same.

Hard-shell turtles were found to be rarely caught in the gillnet fishery (Lum, 2003), although when they did get captured, they were brought into the boat with the fish, rather than being treated as bycatch like the leatherbacks. The mortality rate for the hard-shells is mostly likely 100 %.

The most common area for gillnetting was between Blanchisseuse and Toco, and the fishermen agreed that they also caught the majority of leatherbacks there. They said that they caught fewer turtles if they set their nets to the west of Blanchisseuse, although they would also catch less fish. The capture rates were particularly high offshore from the high density nesting beaches located between Blanchisseuse and Grande Riviere (Grand Tacarib, Paria, Madamas, Murphy's Bay and Grande Riviere) (chap.3) (fig.3.1). In her study of the level of leatherback capture in gillnets around all the coasts of Trinidad, Lum (2003) found that the capture rate was greatest on the north and east coasts, attributing this to the proximity to high density nesting beaches. The area east towards Toco from Grande Riviere was also an area of high capture rate. Satellite telemetry studies have shown that leatherbacks spend much of their time directly off the nesting beaches (Eckert, et al., 2006; Eckert, 2006). Eckert (2006) found that female leatherbacks tended to reside close to Galera Point during their inter-nesting period, and James et al. (2005c) noted that a satellite tagged male also spent the majority of its time there in two consecutive years. The area around Galera Point seems to be an extremely important area for leatherbacks, for mating, and possibly foraging (Eckert, 2006).

The fishermen tended to stay within 10 km of the coastline while they were gillnet fishing, with an average distance from the shore of 5 km. Eckert (1997) found that female leatherbacks remained within 60 km of the Trinidad coastline with an average distance of 20 km (Eckert, 2006), and in St Croix they ranged in excess of 30 km offshore, but mostly stayed within 20 km (Eckert, 1997 [Eckert, unpublished data]). In Malaysia, Chan et al. (1990) recorded that leatherbacks generally stayed within 40 km of the shore. Gillnets were set well within the leatherbacks' range during the inter-nesting period. The leatherbacks usually became entangled in nets at night, most likely when moving to and from the nesting beaches. It is likely that the males followed the females in towards the shore at night in an attempt to mate with them (Reina et al., 2005), and were therefore also in the vicinity of gillnets.

The number of leatherbacks caught depends on the length of gillnet that was set. The mean length of net used was 1.2 km (200 lb) (Lum, 2003), averaging a total of 2.2 leatherbacks caught on each fishing trip. High numbers of turtles were caught in March, April and May, and can possibly be attributed to the high numbers of females, and particularly the males, present at that time. Sometimes eight or nine leatherbacks could be entangled in one net at the early part of the season. Several of the fishermen suggested that this was due to males being attracted to a captured female, and then becoming entangled themselves. Recent research has shown the males actively seek out, and interact with females in offshore waters (Reina et al., 2005), and particularly in the earlier part of the season, when more females are receptive to mating.

Data from the interviews estimated that an average of 4,620 (1,800 - 7,700) leatherbacks were captured in gillnets on the north coast each year. The number of captures appears to be exceptionally high, especially in relation to the estimated annual nesting population Trinidad: 5,000 (chap.4). It is clear that both males and females get caught in nets, although the sex ratio of the adult population is unknown. Assuming that it is 1:1, approximately one in every two leatherbacks would be caught each season. In Eckert's (2006) recent paper on leatherback movements in Trinidad, four out of the nine female leatherbacks tracked ended up in gillnets. This supports the calculation of one in two leatherbacks being caught. Unfortunately three of the four that were captured were killed, which does not mirror the approximate mortality value (28 %). However, the fact that the leatherbacks had a satellite harness on may have biased the fishermen's judgement to kill the animal, or the level of entanglement in the gillnet.

Lum (2003) calculated that the capture rate for the whole of Trinidad was over 3,000 captures; a lower figure than the estimate presented here for the north coast alone. This may be due to differences in interview techniques and the questions asked, or possibly due to an increase in nesting females (and possibly males) in the time between the surveys, generating more captures. It is unlikely to be due to a higher fishing effort, which appears to be the same as when Lum's study was carried out.

By admission of the majority of the fishermen, the main cause of death for turtles caught in nets is by their own hand. Only 3 % of the leatherbacks captured were thought to drown. It was estimated, using the fishermen's responses, that approximately 28 % (26 - 30 %) of the leatherbacks caught in gillnets die. This is a similar figure to that found by Lum (2003) (28 - 34 %). Using the estimated number of captures on the north coast, it was calculated that 1,290 (1,200 - 1,380) leatherbacks are killed each year due to the gillnet fishery. Since the sex ratio of adults is unknown, it is difficult to work out the proportion of the leatherbacks killed. However, assuming that the sex ratio is 1:1 (approximately 10,000 individuals), approximately 13 % (12 - 14 %) of the resident population in Trinidad would die annually.

The post-capture mortality and sub-lethal injuries from entanglement in nets for long periods are unknown, and are difficult to measure. The fishermen stated that once released from the net, the leatherbacks usually swam away from the boat with purpose, suggesting that they were in reasonable condition. The fishermen said that they released turtles depending on the degree of entanglement; if they could release an animal without too much damage to the net or the turtle they would, and it was only when the turtle was heavily entwined, damaging catch and net, that they inflicted any bodily damage or killed them. For this reason, it is thought that most turtles that were set free had a high survival rate. Sixteen % (n = 502) of the leatherbacks observed nesting on the north coast beaches had serious wounds to their head and body (not including superficial cuts from mating and debris on the beach), which were thought to come from being entangled and released from nets (fig.6.4).

This is similar to levels in Suriname where 16 - 18 % of leatherbacks showed sign of interaction with fishermen (Goverse and Hilterman, 2005). This figure seems a little low to fit in with half of the female turtles getting caught over the season, although not all of the turtles get injured in the nets. The low number of injuries recorded may suggest that the fishermens' perception of turtle capture and mortality may be higher than in actuality. A continued tagging and monitoring programme on the north coast beaches could help to investigate the number of times each turtle gets caught and the level of post–capture mortality, if on-boat observers or the fishermen themselves were willing to collect tag numbers of turtles that are released alive.

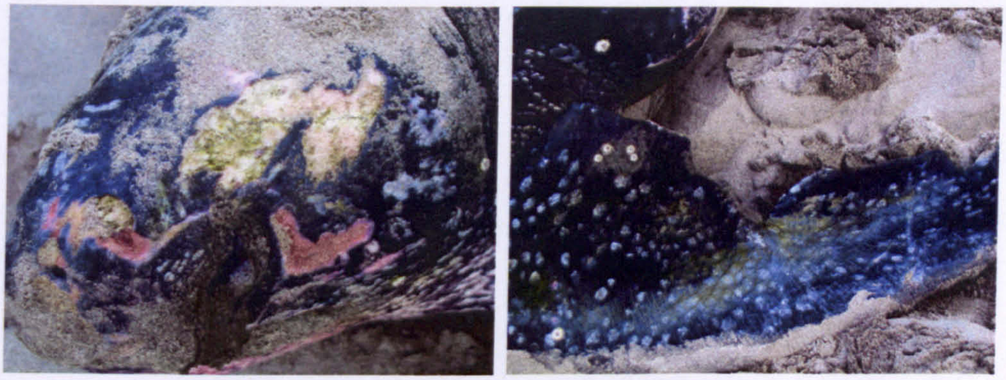


Figure 6.4 Damage from being caught in gillnets, and from fishermen's machete blades

6.4.5 Effects on the resident leatherback population

Although the predicted proportion of leatherbacks killed in the gillnet fishery each year is relatively high, there has been no detectible effect on the number of nesting females, which is the only section of the population that can be accurately assessed from beach monitoring. The female numbers on the north coast appear to be stable, possibly increasing (chap.4), as on the east coast of Trinidad (Eckert and Eckert, 2005). The effect on the female nesting population would be diluted by the presence of males; however, you might still expect to see some reduction in numbers. The fishermen were in agreement that the number of leatherbacks on the north coast had increased greatly over the last 30 years, and that they now captured many more leatherbacks in their nets than when gillnet fishing began commercially in the late 1950's (Mohammed and Shing, 2003). The fishermen's information on an increase in leatherback numbers on the waters fits with reports of increased nesting from the Trinidad Governmental Wildlife Section and environmental groups (Fournillier and Eckert, 1997; chap.2), and a comparison of past nesting numbers with present ones (chap.4). The exact reasons behind the increase are not clear (chap.4). However, is it probable that the mortality resulting from the gillnet fishery has increased with the increased turtle numbers (more turtles, more captures), and substantially reduced what the rate of increase would have been without the bycatch.

It is difficult to assess the sustainability of the fishermens' perceptions of the mortality rate without making major assumptions on the leatherback population structure and reproductive output of the females. However, based on the premise that approximately 13 % of the leatherbacks present off the north coast are killed each year, and that this does not include the mortality rate generated from the east coast gillnet fishery, it would be prudent to regard the effects of both the gillnet fisheries as unsustainable, as considered by both Eckert and

Lien (1999) and Lum (2003). The annual mortality rate for a stable nesting population at St. Croix is 4 – 10 % (Dutton et al., 2005). If indeed the number of nesting females nesting in Trinidad is still increasing through continued recruitment, the effects of the mortality rate may not be currently noticeable. However, the level of mortality may catch up with the population at some point, reducing the number of reproductively mature females and males, and could result in a population decrease, as has been demonstrated in the Pacific leatherback population (Spotila et al., 1996; 2000). Spotila et al. (2000) calculated a mean annual mortality rate of approximately 35 % for the leatherbacks nesting at Las Baulas in Costa Rica, and suggested this to be highly unsustainable. An additional year of data lowered the estimate to 25 %; however, this rate still predicted the extinction of the population in the near future (Reina et al., 2002). Leatherbacks continue to nest in that area at this time.

6.4.6 Strandings

No stranding of any hard-shell sea turtle species was ever observed or reported. This concurs with the suggestion that they are not classed as bycatch and are taken aboard the boats for food or sale. The leatherback strandings recorded were all located between Toco and Blanchisseuse, either reported by local people, or witnessed by the project team. The data set may not be complete for the whole of the north coastline as no strandings were recorded west of Blanchisseuse. All the stranded turtles had net and machete wounds, and had severe head damage, some being headless. This corresponds to the fishermen's comments about decapitating the turtles to facilitate removal from the nets. As no flipper tags were found on dead turtles, and we were unable to sex them, little information could be gained from the strandings other than being a measure of mortality from gillnet fishing. From the types of injuries the leatherbacks displayed, I am confident that all the leatherback strandings were the results of gillnet capture rather than another mode of death.

Beach strandings have been used as an index of mortality at sea (Caillouet et al., 1991; Epperly et al., 1996; Soto et al., 2003) and studies indicate that stranding data represent a minimum measure of mortality (Murphy and Hopkins-Murphy, 1998; Epperly et al., 1996). Using the mortality rate of leatherbacks in gillnets estimated here (~1,290), the strandings on the north coast represented 3.3 % of leatherback deaths. This is much lower than Epperly et al. reported on the northern beaches of North Carolina where 7 - 13 % of sea turtle mortality at sea could be accounted for by strandings. However, Epperly et al. (1996) also concluded that due to variable currents, strandings were not a reliable indicator of the number of mortalities, and could only demonstrate that mortalities had occurred. This may or may not be the case on the north coast of Trinidad. The differences in the numbers of strandings follow the natural fluctuation patterns in the nesting population size (table 4.2), implying that the strandings on the north coast could possibly be used as a consistent measure of mortality.

Strandings can be influenced by numerous environmental conditions such as winds, tides and currents (Shoop and Ruckdeschel, 1982; Caillouet et al., 1991), transporting turtles a great distance so that they never strand, especially on a relatively small island like Trinidad where they may be carried beyond the coast. The longshore currents on the north coast are westerly (Georges and Greenidge, 1983), possibly accounting for the lack of strandings on the western part of the coastline, although the currents are thought to be relatively weak at < 10 cm/s. The currents may have pulled turtle carcases beyond the coast before they could strand. The distance of gillnet activity from the shore could also have an effect on whether the turtles stranded. The further away from the shore, the less likely they would be to wash up on the coast. The average distance of fishing from the shore on the north coast was 5 km. This could possibly partly explain the low proportion of strandings, as it would take relatively strong currents to carry a dead leatherback this far. Scavengers such as sharks also have a role in whether a carcass will strand. Fishermen admitted that they often cut open leatherbacks so that they sink to the seabed rather than wash up on the coastline, a practice that has also been recorded elsewhere (Macys and Wallace, 2003). These factors may be the reasons for the low representation of leatherback mortality by strandings.

It is important to continue with counts of strandings on the north coast along with beach monitoring, as they provide a helpful index for any changes in the level of mortality of leatherbacks due to gillnetting.

6.4.7 Fishermen's attitudes to leatherbacks

Eighty % of the fishermen on the north coast felt that leatherbacks hindered the gillnet fishery, and found them to be a source of frustration and annoyance. This was due to the damage that the leatherbacks caused to their nets, and to other catch within the nets. Apart from the physical act of removing the turtles from the nets, which some of the fishermen mentioned as being a nuisance, the damage created both financial inconvenience and time consuming activities, such as net repair. Three of the fishermen said that they did not go out during the very busy part of the turtle nesting season as it was not worth their while, and that the leatherbacks were "too thick in the water" to fish. The other 20 % of fishermen took a more philosophical view of the turtles, stating, "this is the way it is"; however, they also acknowledged that a reduction in the numbers caught would be favourable. The majority of the fishermen said that they did not enjoy killing the turtles, and that it was a waste of life.

Because it is laborious to bring them to shore, and is illegal to eat or sell turtle meat in the closed season (1st March – 31st September) (Bacon, 1970; Fournillier and Eckert, 1997), the leatherbacks cannot be used as subsistence, or to generate revenue.

Lum (2003) found there to be differences in the live release rate of leatherbacks on the different coastlines around Trinidad. The east coast was found to have the lowest release rate at 66 %, with the north coast higher at 73 %. The south and west coasts had release rates of 88 % and 91 % respectively. This illustrates that the areas with higher capture rates have lower release rates, probably because the fishermen who experience the higher capture rates have less patience with the leatherbacks, and are more likely to kill them rather than free them from the nets.

As far as the laws protecting turtles in Trinidad are concerned, all the fishermen were aware of the laws, and 58 % of the fishermen agreed that turtles should be protected. However, many of them saw no repercussions from breaking the laws, and they were interpreted liberally. The fishermen were careful not to be caught killing the leatherbacks in nets, but the likelihood of them being caught doing this was very low. The other 42 % of fishermen said that they did not understand why the turtles were protected, as there were more than there had ever been before. This highlights a need for education within the community, and raising awareness of the reasons behind mitigating incidental capture, on a national and global scale (Lum, 2003).

Overall, the fishermen agreed that they would prefer to catch fewer leatherbacks, to the benefit of both themselves and the turtles.

6.4.8 Mitigation methods

Recommendations for the mitigation of incidental capture of leatherbacks in gillnets were suggested by Eckert and Lien (1999), and expanded on by Lum (2003). They suggested the use of alternative fishing gear and practices, and time and area closures during the nesting season. The fishermen were generally positive about the possibility of solutions to reduce the capture of leatherbacks in gillnets. However, they were also concerned about how changes may affect them.

Many of the fishermen were open to the suggestion of using more selective fishing techniques instead of gillnetting, but some alternative methods were more appealing than others. There was some anxiety about how a changeover would be implemented, and whether it would affect the numbers of fish that they currently catch. If this were going to be the case, then subsidy would be the only way to persuade most to move to different methods. However, the idea of changing to a-la-vive as a possible replacement for gillnetting was an attractive prospect to many of the fishermen.

A successful shift to a-la-vive during the leatherback nesting season would require a reliable source of live bait, the main problem being that the live bait is not available till early June when it arrives with the fresh water influx from the Orinoco (Georges and Greenidge, 1983). Changing to a-la-vive fishing in the earlier months of the year is by no means a new idea (L.L. Lum, personal communication), and the fishermen spoke of how they have been trying to find a way to rear or hold live bait, before they naturally appear, for many years. If the live bait were available from January onwards, many more fishermen would choose a-la-vive over gillnetting. This would greatly reduce the number of leatherbacks caught in gillnets, captured in the highest numbers in March, April and May. The constraints on setting up a live bait hatchery have been both technical and financial (J. Marcano, personal communication). Changing from gillnetting to a-la-vive is certainly worth investigating (Eckert and Lien, 1999; Lum, 2003), and appears to be the most favourable solution for the fishermen. A-la-vive does generate a higher initial financial outlay due to a higher usage of boat fuel and the purchase of live bait. However, the fishermen said that this was outweighed by the increased catch and the lack of damage to equipment. Trawling (dragging a surface hand-line with artificial bait) was felt not to be a suitable long-term alternative to gillnetting as it did not generate enough catch to outweigh the high costs of fuel and expensive artificial lures (Mike and Cowx, 1996).

Gear modifications have been suggested (S. Eckert, personal communication), although there are currently no modifications that can be made to gillnets to effectively reduce turtle interactions (Cheng and Chen, 1997; Valdemarsen and Suuronen, 2001; FAO, 2004). When asked about the possibilities of gear modification, the fishermen voiced concerns about the costs of changing gear, the maintenance and availability of new equipment, and also how it would affect their catch. These concerns are well founded as gear modifications are usually more expensive than regular gear, can be difficult to maintain, and sometimes also result in reduced catch (Valdemarsen and Suuronen, 2001). Any attempt at gear change would have to involve full training for the fishermen (Lum, 2003), as well as financial support.

Spatial and temporal restrictions have been suggested as the most practical way to mitigate entanglement in gillnets (Eckert and Lien, 1999; Valdemarsen and Suuronen, 2001; Lum, 2003; FAO, 2004). The area between Blanchisseuse and Toco, and the areas surrounding Galera Point have been identified as the regions of highest importance for protection on the north coast (Eckert, 1997; Eckert, 2006; James et al., 2005c), and are where potential area restrictions could be introduced. Eckert and Lien (1999) proposed a total ban on gillnetting throughout Trinidad from February to August, applied to both local and foreign vessels. Although an extreme solution, they suggested that it would be the only way to reduce the rates of capture successfully, and that a total ban would be easier to enforce than restrictions in designated areas.

From the fishermen's comments, it was obvious that any such restrictions would be extremely unwelcome, and most likely ignored. They raised anxieties about how restrictions might affect their livelihoods, and made it clear that they would expect full compensation for any loss of income. Restrictions of this kind would possibly only be successful if there was an acceptable fishing alternative. Any spatial or temporal limitations would need to be heavily managed and enforced to ensure compliance. Currently, the level of organisation within the fishing industry on the north coast is not sufficient to manage a scheme of this sort.

Eckert and Lien (1999) suggested revising the current legislation protecting sea turtles. Currently it is not illegal to incidentally capture turtles, but it is to kill them (during the closed season), and there are no real consequences for the fishermen for killing turtles. Current laws are not rigorously upheld by the authorities. To make capturing leatherbacks by accident illegal would not be very practical; firstly, it is impossible to avoid capture unless the fishermen abstain from gillnetting altogether, which is not viable without an alternative income; secondly, every fisherman on the north coast would be breaking the law. A change in legislation could be a useful tool to mitigate bycatch of leatherbacks, but only if the laws are properly enforced, and again, if there was some kind of realistic alternative.

The initial prevention of capture of leatherbacks is preferable to releasing captured turtles. However, while waiting for mitigation action to be taken and legislation to be introduced, gillnetting continues. It has been made clear that the main reason for leatherback mortality in gillnets arises from the actions of the fishermen rather than from the animals drowning. Therefore, the mortality rate could be significantly reduced by educating the fishermen to become sympathetic to the cause, and to free turtles rather than kill them. When asked about this, the fishermen said they currently had no incentives to free turtles, and had poor experience of previous schemes attempting to encourage this. The UNDP (United Nations

Development Programme) GEF (Global Environment Facility) small grants programme did provide funds for a project ("net for turtle") in Matelot in 1995, which refunded fishermen the cost of nets damaged beyond repair, if they released the turtle that damaged the net (Eckert and Lien, 1999). This project was used as a pilot, with intent to implement it in other areas if successful. Between February and August, seven fishermen released 139 leatherbacks alive from nets (Fournillier and Eckert, 1997). However, many of the fishermen took advantage of this financial assistance, asking for replacement nets on grounds of wear and tear, or of old nets no longer used, rather than those actually damaged by turtles (Matelot fisherman, personal communication). This caused upset and bad feeling amongst the fishermen with honourable intentions, and eventually, the project was discontinued. The fishermen felt that the project was a good idea, but that it needed to be run by someone who knew the difference between turtle damage and everyday wear of nets. Any similar compensation scheme put in place would have to be carefully managed.

When questioned about alternative employment options such as management, conservation, or even ecotourism (which is currently a growing industry in Trinidad), the fishermen were unenthusiastic. The general feeling was that they wished to continue with their current profession, which is traditional in the area. As part of the Darwin Initiative project I carried out on the north coast, I provided ecotourism training for north coast inhabitants, and arranged several successful turtle-based tours (Livingstone and Downie, 2005). It was clear, however, that development of ecotourism in the area would require considerable infrastructure development. Ecotourism, as an alternative to fishing as a main income generator, could be disruptive to north coast communities.

The fishing industry on the north coast is currently largely unstructured, beyond the level of organisation within each separate depot, with some interaction between depots. For any mitigation scheme to be successful there would need to be a management body in place to direct, implement and enforce any plans. Ideally this could be done from within the industry, making it more likely that the fishermen would adopt a management plan, and to make use of both the ecological and technical knowledge of the local stakeholders.

The artisanal gillnet fishery in Trinidad contributes greatly to the country's economy and is important in terms of value and quantity of fish landed (Parkinson, 1992). Artisanal fishing is the main means of employment in most villages on the north coast of Trinidad and a large proportion of the north coast villagers are dependent on fishing for their livelihoods. As important as it is to mitigate the capture of leatherbacks, it needs to be done in a way that minimises adverse social and economic impacts (Standora, 2003; FAO, 2004).

6.5 Conclusions

Leatherbacks are highly migratory animals and lead an almost completely pelagic existence, foraging widely in temperate waters outwith the nesting season (Ferraroli et al., 2004; Hays et al., 2004; James et al., 2005b). After leaving Trinidad's coastal waters, the leatherbacks may face encounters with other fisheries on their journey to foraging grounds. Since the animals becoming entangled in gillnets in coastal areas are the same individuals that forage in northern waters and get caught in pelagic longline fisheries (James et al., 2005a), multinational collaboration between countries supporting nesting and foraging turtles, and countries which have pelagic and coastal fisheries, is required to effectively conserve leatherback turtles in the Atlantic (Spotila et al., 2000; James et al., 2005a; Kaplan, 2005).

Recent research has highlighted the significance of Trinidad's nesting leatherback population (chap.4). Data collected from the fishermen surveys has generated an estimated capture and mortality rate in the north coast gillnet fishery, and it appears to present an unsustainable hazard to the population, and to the conservation of the species, nationally and internationally. James et al. (2005a) suggested that protecting mature adults in high use areas with high mortality might offer the best potential for recovery. The north coast of Trinidad clearly fits into this category. Despite the perceived mortality rate, the nesting population in Trinidad seems to be stable at the current time (chap.4). It is recommended that the monitoring of nesting females and strandings on the northern coastline be continued in order to detect any changes in numbers, to assist in evaluating the post-net release survival rate of females, and to assess any mitigation efforts that are introduced. Quantitative field data collected from on-boat observations are recommended to support the interview data in the estimation of capture rate, to shed light on the sex ratio, and to determine whether there are any sex biases in capture. Although data on mortality rates from on-boat observations should also be treated with caution.

The number of hard-shell species captured in gillnets appears not to be particularly high, although hard-shells that do get caught will most certainly be killed. However, in addition the legal turtle harvest in the open season and incidental capture in shrimp trawlers (chap.5), entanglement in gillnets contributes to the number of hard-shells killed each year.

To reduce the current amount of bycatch, a combination of mitigation methods appears to be the way forward, supported by training and financial assistance for the fishermen. A move from gillnetting to a-la-vive during the nesting season was favoured by the fishermen, but investigation into raising or housing live bait is required to assess feasibility. Although time/area closures would be the most effective method of mitigation, such restrictions would also have the most serious effect on the livelihoods of the fishermen, and be the most difficult to enforce. The fishermen made it clear that they would wish to be involved in any decision-making with regards to mitigation measures, as any management plan would involve a serious change in practice for them. Enforcement of any restrictions would need to be put in place, preferably from within the fishing communities.

In some ways the leatherbacks nesting on the north coast of Trinidad have an advantage compared with other regions - they are not viewed as a food source. For this reason there is a common goal between fishermen and conservationists: both want to capture and kill fewer leatherbacks. With close co-operation between scientists, Government and the fishermen, this appears to be an achievable objective.

7. Leatherback nest ecology and hatching success on the north coast of Trinidad

7.1 Introduction

Successful reproduction and future generations of sea turtles depend on two main factors: adult female activity (sufficient food for the production of eggs, a successful mating, and a suitable nesting beach), and favourable environmental conditions of the nesting beach for hatchling development and survival (Miller et al., 2003). Sea turtles produce large clutches of relatively small eggs. Clutch size varies between nests of the same individual, as well as within and between populations (Hirth, 1980). Leatherbacks can lay up to 11 clutches in one season (Boulon et al., 1996), the average being between five and seven (Steyermark et al., 1996), with one clutch laid approximately every ten days (Reina et al., 2002; chap.4). Leatherbacks lay larger eggs and clutches than any of the other sea turtle species (Miller, 1997).

The nest and hatchling stages of sea turtles are extremely vulnerable to predation and environmental change. Laying a number of clutches on different beaches over one season increases the chances of nest success by reducing the likelihood of environmental impacts such as erosion and inundation (Eckert, 1987), especially on the dynamic beaches that leatherbacks prefer (Whitmore and Dutton, 1985; Pritchard, 1982; chap.3).

Once a female has chosen a suitable beach on which to build her nest (chap.3), she must then choose where to position her nest on the beach. Where she decides to place her nest can have a major impact on both the development of the embryos within the nest, and on the hatchlings when they emerge. Sea turtles do not display any parental care, and once their clutch has been laid, it is left to develop unaided, and the hatchlings to find the way to the sea on their own. Nests positioned too near the tidal zone are in danger of being inundated by the sea, or eroded away (Whitmore and Dutton, 1985), and nests positioned further back on the beach are more susceptible to the destructive roots of backing vegetation (Marquez, 1990; Wood and Bjorndal, 2000). Clutches laid further back on a beach are in greater risk of predation on both eggs and hatchlings (Blamires and Guinea, 1998), and may reduce the hatchlings' sea finding ability due to visual obstructions (Godfrey and Barreto, 1995; Kamel and Mrosovsky, 2004). Nest site factors that have been considered to affect nest placement by females include: vegetation, high water mark, humidity (Hays and Speakman, 1993; Hayes et al., 1995), temperature (Stoneburner and Richardson, 1981) and sand type and compactness (Mortimer, 1995; Crain et al., 1995; Kikukawa et al., 1999). Nest placement is generally thought to be non-random, but it remains unclear what drives a female's choice of nest position (Miller et al., 2003).

The nest environment is affected by the nest position on the beach, and can affect a number of characteristics of hatchlings such as fitness, sex and phenotype, as well as the overall hatching success of the nest. Within the nest, the embryos are sensitive to extremes of moisture, gas exchange and temperature (Yntema and Mrosovsky, 1980; Ackerman, 1980; 1991; 1997; Maloney et al., 1990; McGehee, 1990, Wallace et al., 2004). Each variable has an impact on development, but each one is also dependent on the others e.g. the embryonic oxygen demand increases with increased temperature and the potential for water vapour exchange. Each of these factors changes depending on the position on a beach, and with distance from the sea (Spotila et al., 1987).

Hatchlings face a wide range of terrestrial and aquatic predators such as crabs (Marquez, 1990; Whitmore and Dutton, 1985), vultures, dogs and racoons (Stancyk, 1982; Leslie et al., 1996; Engeman et al., 2003). Nests are also sometimes infested by various invertebrates such as ants (Allen et al., 2001; Buhlmann and Coffman, 2001; Parris et al., 2002); fly larvae (Vogt, 1981; Acuna-Messen and Hanson, 1990; Iverson and Perry, 1994; Vasquez, 1994; McGowan et al., 2001a) and other insects (Maros et al., 2003). However, there is some debate about the effect insect larvae have on nest and hatching success (Andrade et al., 1992; McGowan et al., 2001b). Bacteria and fungi also invade nests and eggs, and affect hatching success (Whitmore and Dutton, 1985; Acuna-Messen and Hanson, 1990; Acuna et al., 1999).

The aims of this chapter are to determine the overall success of leatherback nests on the north coast of Trinidad and to identify the main threats to nests and hatchlings. A number of environmental parameters of leatherback nests are examined (temperature, incubation period, clutch size, clutch composition, time of season, nest position, level of insect infestation and nest depth) and are investigated to detect any significant relationships between them, and to determine if they influence hatching success.

7.2 Methods

7.2.1 Field methods

Data from leatherback nests were collected from five nesting beaches on the north coast of Trinidad: Grande Riviere, Paria, Murphy's Bay, Grand Tacarib and Madamas (chap.3). Data were collected from the beginning of the hatching season (early May) until the end of August in 2002, 2003 and 2004. The work was co-ordinated with night-time monitoring. Each beach was visited for two or three days, on average every four days (see chap.4 for more detailed methodology).

a) Nest success and temperature

A number of leatherback nests were marked at the time of egg deposition and monitored throughout the incubation period till hatching. These nests were equipped with temperature loggers to record the temperature within the nest. The selection of monitored nests was made as randomly as possible. There may have been a small amount of bias in the choice of nests; no nests positioned below the high water mark were selected in the hope that they would not be washed away. This was to reduce the loss or damage of the temperature loggers.

To measure the nest temperature, a temperature logger (Gemini data loggers, Omni Instruments Ltd.) was placed in the leatherback nest at the time of egg deposition (fig.7.1). Once a nesting leatherback was encountered, we would wait until she was halfway through the laying process. The temperature logger was then placed into the middle of the clutch of eggs. A piece of string was attached to the logger and held straight up to the surface of the nest while the leatherback finished laying her eggs and filled in her nest.

Figure 7.1 Temperature logger being inserted into a leatherback nest during deposition

Once she had completed her nest and moved away, the position of the nest was recorded using triangulation methods with trees at the back of the beach, and the rest of the string was buried in the sand. The string helped to relocate the nest approximately two months later when the nest hatched. Prior to being placed in the nest, each logger was compared to a mercury thermometer to confirm that the recorded temperatures were accurate. The loggers were accurate to ± 0.1 °C. The temperature loggers were set to take a temperature reading every hour while in the nest.

The nests were monitored throughout the incubation period, especially around the time of hatching in order to get the exact incubation period. For the purpose of this report, the incubation duration is measured as the time from when the clutch was laid until the time that the hatchlings emerged from the nest, in number of days. All the hatchlings tended to hatch from the nest at the same time, rather than over several days as in other species (SRL, personal observation). Each nest was monitored for signs of predation.

Once the nest hatched (if it hatched), it was excavated and relevant data collected, as described below. The temperature loggers were retrieved and the data were downloaded onto a computer for further analysis. If the nest had not hatched after four days past the average incubation period (69.8 days), the nest was located and excavated. The reasons for a nest not hatching were noted.

The data from these marked and monitored nests made up the data set from which the nest success and temperature correlations were made. A much larger data set was compiled of nests that were excavated after evidence of hatching. Because the lay date of these clutches were not known, the incubation period could not be accurately calculated.

b) Nest excavation

On each beach visit, the beach was checked during the early morning for any nests that had hatched the previous night. The majority of nests hatched at night (SRL, personal observation). Nests were identified by an indentation in the sand (approximately 15 cm diameter), usually with hatchling tracks leading from it (fig.7.2). Sometimes after heavy rain the tracks would be washed away, but the indentation would remain, and could still be identified. All hatched nests were marked with sticks. A random selection of nests was chosen for excavation.

The nest was dug up, and the contents examined (fig.7.3). A note was made of the position of the nest (the beaches had been marked out in 50 m sections, and the distance to the back and high water mark were noted), and of the depth to both the top and the bottom of the nest chamber. Note was taken of any interference from predators.

Figure 7.2 Photo showing several depressions of hatched nests with hatchling tracks leading from them

Figure 7.3 Excavating a nest

Once excavated, the contents of the nest were counted and the clutch size was recorded. The eggs were then divided up into categories. The eggs were initially categorised by their morphological features, and then by their contents. The egg types were: hatched (empty shell fragments from which a hatchling would have hatched), shelled albumin globs (SAGs) referred to in this study as 'inert' eggs (reduced in size with a clear viscous interior) (Bell et al., 2003) and un-hatched (complete full sized eggs) (fig 7.4).

Figure 7.4 Different eggs types (hatched shell fragments, small inert eggs and viable un-hatched eggs).

The unhatched complete eggs were opened, and classified into three further categories: dead-in-shell (egg containing a clear embryo of any size which had died during development) (fig.7.5), bacterially infected (no clear embryo, with a yellow or pink material with a "cheesy" consistency and a particularly offensive smell) (fig.7.6), and disintegrated (containing a near fully developed hatchling that has started to disintegrate within the egg) (fig.7.7).

Figure 7.5 Dead-in-shell at two different developmental stages

Figure 7.6 Bacterially infected eggs (no evidence of an embryo)

Figure 7.7 Egg containing a disintegrated hatchling

Any live or dead (free from shell) hatchlings were also counted. Live hatchlings found in the nest were usually quite weak, and would not have been able to emerge from the nest on their own. They were allowed to make their way to the sea. Any freshly dead hatchlings and late stage dead-in-shell hatchlings from the nests for which temperature was known were collected and fixed in 95 % alcohol. These hatchlings were sexed using histology at a later date. All nest contents were examined for signs of invertebrate infestation. The data sheet for collecting nest data is in appendix 7 (not all data collected are reported here).

The condition of the eggshells varied between nests. Some were whole and only torn at the emergence point while others were broken into many small fragments. The accuracy of the hatched egg count was verified by doing a blind count of eggsshells from a nest where the exact number of hatchlings emerged was known (Fowler, 1979). The mean error was calculated as ± 3 eggs. The project team was trained in the egg counting technique to keep the results consistent.

c) Invertebrate infestation

If there was evidence of invertebrate infestation, a sample of the infested material along with the infesting animals was sealed in a muslin covered tub (500 ml capacity) with air holes. The tubs were sealed carefully and quickly to avoid contamination by any species that had not originally infested the nest before it had been dug up. An attempt was made to identify all the species that infested leatherback nests on the north coast. In order to identify fly species, maggots were incubated and grown up to adults, when they were fixed (90 % alcohol) and identified at a later stage.

7.2.2 Data analysis

a) Nest success

For this study, the nest success is defined as the percentage of nests that successfully hatch from the total number of clutches laid. A nest was classed as hatched if at least one hatchling emerged from the nest. The total percentage of overall nest success was calculated using the marked nests. The fate of the nests that failed to hatch was calculated as a percentage of the total nests.

In addition, the percentage of nests that were seen to be dug up by nesting females was calculated for each year (chap.4), and the mean was subtracted from the nest success calculated from the marked nests thereby accounting for nest destruction by subsequent nesting females.

The total percentage of nests infested with invertebrates was calculated.

b) Nest parameters and hatching success

The parameters for each nest were placed in one large data set (beach, year, season, beach zone, depth (top), depth (bottom), mean temperature, hatching success, incubation period, clutch size, % of inert eggs, % of bacterial eggs, % of dead-in-shell eggs, % of disintegrated eggs and infested or not. Each nest parameter was calculated for each beach and each year, and as an overall value for the north coast of Trinidad. Some of the data required manipulation to enable comparison between nests. The data preparation is described below:

Hatching success and clutch composition: The hatching success is defined as the percentage of fertile eggs that develop into hatchlings that emerge from the nest. This was calculated as a percentage of the viable eggs (total eggs - inert eggs). Each category of egg was calculated as a percentage of the total clutch. All percentage data were arcsine transformed to normalise the distribution.

Temperature: A mean temperature was calculated for each nest for the whole incubation period. The temperature data were also divided up into thirds of the incubation period and a mean temperature was calculated for each.

Season: The hatching season was grouped into four 28-day periods; period 1 =10th May - 6th June; period 2 = 7th Jun – 4th July; period 3 = 5th July – 1st August; period 4 = 2nd August - 29th August.

Zone: Each study beach varied in width (chap.3). Therefore, to make them comparable, the beaches were divided into three equal horizontal sections: front (high water mark to middle), middle, and back (from middle to back of the beach).

One-way ANOVA analysis was used to test for significant differences in the nest parameters between beaches and years, on different zones of the beach, and in different stages of the hatching season. A chi-squared test was used to examine any significant differences with these factors between nests that were infested and not infested. Linear regression analysis was performed to test for significant relationships between the nest parameters, and between nest parameters and hatching success.

7.3 Results

7.3.1 Nest success

A total of 53 leatherback nests were marked at the time of deposition and monitored through till hatching on the remote north coast beaches (Madamas, Grand Tacarib, Paria and Murphy's Bay). Seventy two % (n = 38) of the nests produced at least one hatchling, and were therefore classed as hatched (the three nests that produced hatchlings on Murphy's Bay were classed as unhatched, see discussion). Of the failed nests (n = 15) 47 % (n = 7) were inundated by tides or a high water table, 13 % (n = 2) were removed by erosion (rivers or tides), and the fate of the remaining 40 % (n = 6) could not be identified. The nests that did not hatch were dug up (if they were still there) and the contents examined. Each nest contained fertilised eggs with dead embryos at varying stages of development.

This result gives the nest success rate for the remote north coast beaches. No nests were followed on any of the other beaches. Hatching success data were collected on Grande

Riviere, but no nests were marked as the density of leatherbacks on the beach was so great that it would have been very difficult to follow specific nests right through without constant monitoring.

During night-time monitoring of nesting leatherbacks, 2.6 % of females were seen to dig up other clutches while laying their own in 2002, 2.2 % in 2003 and 3.1 % in 2004 (fig.7.8). Over all the high density beaches, a mean of 2.6 % of nests were affected by this activity (there was no significant difference between years).

Figure 7.8 Females leatherback digging up another leatherback nest

While working on the beaches, observations were made on the nest success on each beach. Very little evidence of hatched nests was ever seen on Murphy's Bay. In 2003, four nests were marked and monitored through till hatching. When they had not hatched by a certain time, the nests were excavated. One nest contained eggs in which all the embryos had died. The other three nests contained low numbers of live hatchlings (mean of 8), which were placed in the sea.

7.3.2 Predation of nests and hatchlings

There was very little predation of nests witnessed on the remoter beaches on the north coast of Trinidad. No nests were ever found to be directly predated upon by any mammal or bird until after it had hatched. Dog (*Canis familiarus)* predation was extremely rare, and was witnessed only on one or two occasions when hunters passed through with their hunting dogs. No predation of nests by any other mammals was seen. Most of the predation witnessed on the remote beaches was of hatchlings, and of nests that had been exposed by sand erosion. Crabs (*Ocypoda quadrata*) were witnessed feeding on hatchlings that were on their way to the sea. The biggest threat to hatchlings on the beach was from vultures (*Coragyps atratus*) (fig.7.9 and 7.10) and in the water from frigate birds (*Fregata magnificens*). The level of predation of hatchlings when they left the beach was impossible to quantify, but was thought to be great. Many sharks and predatory fish patrolled the shoreline day and night during the hatching season (C. Patron, personal communication; SRL, personal observation).

Figure 7.9 Vultures feeding on hatchlings on Paria

Figure 7.10 Leatherback hatchling having been predated on by a vulture

Dog predation was a serious problem on the beaches located in villages, and was witnessed on a regular basis. Grande Riviere was the beach most affected by this, and dog predated nests were seen everywhere on the beach (fig 7.11). Vultures were also seen to be feeding on eggs and hatchlings. Grande Riviere beach was often covered in broken turtle eggs, either dug up by other females or by dogs, or from erosion from the river or tides.

Figure 7.11 Dog predated nest on Grande Riviere beach

Only two nests were ever seen to have been harvested by humans. This took place on the more remote beaches on the north coast by hunters living in the forest.

7.3.3 Nest parameters

A total of 746 leatherback nests were excavated over the hatching seasons of 2002, 2003 and 2004. Table 7.1 summarises the results of One-way ANOVA analysis with nest parameters in different years, beaches, seasons and zones.

Table 7-1 Summary of One-way ANOVA results for nest parameters and beach, year, zone and season (no results are presented for temperature and season as an independent samples t test was performed; results presented in following section)

Nest parameter	***Beach***		***Year***		***Zone***		***Part of season***	
One-way ANOVA	***F***	***p***	***F***	***p***	***F***	***p***	***F***	***p***
Hatching success	$_{3, 738}$ 17.4	<0.001	$_{2, 739}$ 0.59	NS	$_{2, 582}$ 0.34	NS	$_{3,742}$ 1.8	NS
Total clutch size	$_{3, 735}$ 1.62	NS	$_{2, 743}$ 13.2	<0.001	$_{2, 579}$ 2.56	NS	$_{3,742}$ 2.1	NS
Viable clutch size	$_{3, 735}$ 0.98	NS	$_{2,743}$ 35.2	<0.001	$_{2, 579}$ 0.04	NS	$_{3, 742}$ 8.4	<0.001
Depth (bottom)	$_{3, 701}$ 21.2	<0.001	$_{2, 591}$ 2.47	NS	$_{2,556}$ 1.55	NS	$_{3, 742}$ 3.4	NS
Temperature	$_{3, 41}$ 2.52	NS	$_{2,42}$ 1.7	NS	$_{1,39}$ 6.8	<0.005	-	-

The majority of leatherback nests were positioned on the zone at the front of the beach nearest the sea. Figure 7.12 shows the percentage of clutches laid on the three different beach zones.

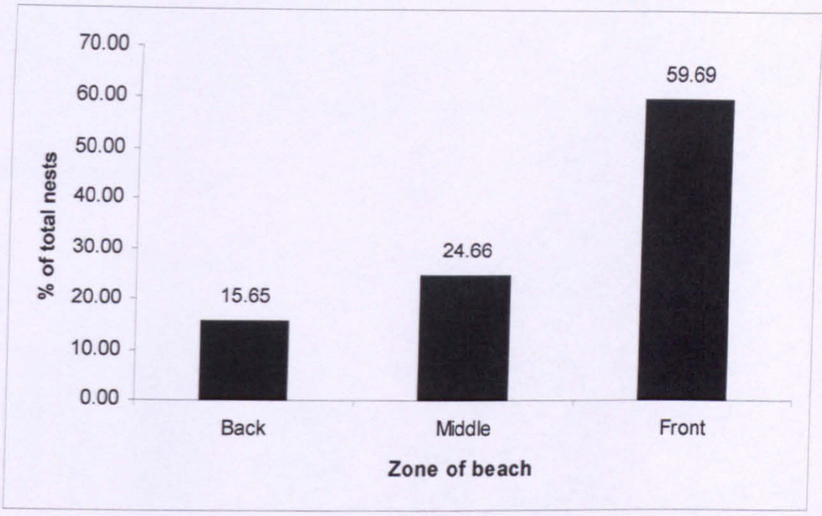


Figure 7.12 The percentage of total clutches laid in each zone on the north coast beaches

a) Hatching success

The hatching success was calculated for each beach in each year (table 7.2). Grand Tacarib had the highest hatching success followed by Paria. Madamas had a slightly lower mean hatching success and Grande Riviere had the lowest. The hatching success for Murphy's Bay was not calculated separately due to a small sample size (n = 4). The mean overall hatching success in nests over all years and on all beaches was 73.3%.

Table 7-2 Mean hatching success for each beach in each year

Beach	*2002*	*2003*	*2004*	*Mean (± SD)*
Paria	78.3	78.1	71.3	74.9 ± 22.5 (n = 55)
Grand Tacarib	77.4	69.3	78.8	76.8 ± 21.1 (n = 456)
Madamas	63.8	78.5	68.6	70.3 ± 22.5 (n = 99)
Grande Riviere	-	62.6	62.8	62.8 ± 22.2 (n = 130)
Mean	**73.7**	**70.2**	**74.0**	**73.3 ± 22.2 (n = 740)**

The mean hatching successes for the four beaches were significantly different from each other (table 7.1). A post-hoc Tukey test showed that the hatching success on Grande Riviere was significantly lower than the other three beaches, and that the hatching successes on Grand Tacarib and Madamas were significantly different from each other. There was no significant difference in the mean hatching success on the north coast beaches between the three years of the study, different zones of the beach, or different times in the season (table 7.1).

b) Nest contents and clutch size

The excavation of nests allowed the contents to be examined and quantified. This data set is made up only of nests that hatched (at least one hatchling hatched). Data for completely failed nests were excluded. Figure 7.13 presents the mean percentage of each category of egg within the nests.

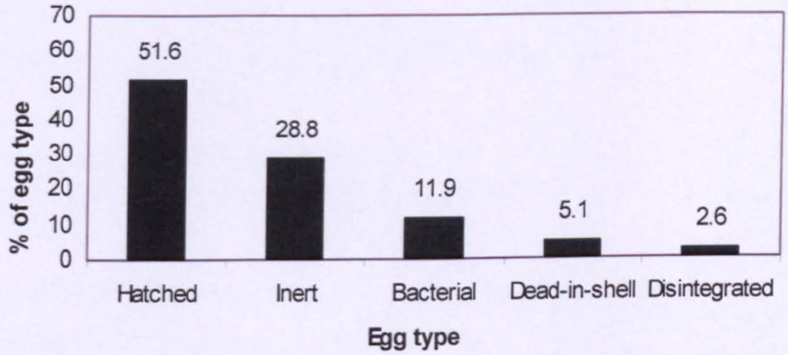


Figure 7.13 The percentage of each type of egg in leatherback nests on the north coast of Trinidad

The mean total clutch size was 108 (SD = 21.5, n = 746), the mean number of viable eggs was 76.7 (SD = 18.5, n = 746) (total eggs – inert eggs), and the mean number of inerts was 31.5 (SD = 15.3, n = 746). The total clutch size was significantly different between years (table 7.1). A post-hoc Tukey test showed that the total clutch size was significantly larger in 2003 than in 2002 and 2004. There were no significant differences between 2002 and 2004. The viable clutch size was also significantly different between years. A post-hoc Tukey test showed that there was a significant difference between all years.

There was no significant difference in the total clutch size between different parts of the hatching season (table 7.1). There was a significant difference in the total number of viable eggs between different parts of the season. A post-hoc Tukey test showed that the number of viable clutches laid earlier in the season (period 1) was significantly more than laid later on (mean of 98 eggs compared to a mean of 76 eggs for the other 3 hatching periods).

This result was interesting, and suggested a further analysis of clutch composition. A One-way ANOVA was used to test for differences in the % of inert eggs in different parts of the season. The results showed that there was a significant difference ($F_{3, 742}$ 9.2, p <0.001). A post-hoc Tukey test showed that there was a significant difference between the 1st part of the season (mean % of inerts = 15.5 %) and the other three parts, and the 2nd part (mean = 25.5 %) and the 3rd and 4th parts (mean = 30 % and 30.4 % respectively). There was no significant difference between the 3rd and 4th parts. This shows that the % of inert eggs increased over the season from May to August, and then became stable.

There were no significant differences in total clutch size or total viable clutch size on different beaches, or in different zones of the beach (table 7.1).

Regression analysis showed that the number of viable eggs had a significant negative correlation with the number of inert eggs (r = 0.2, $F_{1, 744}$ = 30.7, p <0.001).

All the hatchlings tended to hatch out of the nest at the same time, so when a nest was excavated there were often only one or two hatchlings, if any, left in the sand column. Sometimes the hatchlings died, but more often they were alive. If they were alive we helped them get to the sea. It is likely that if the nests had not been excavated, the hatchlings left in the nest chamber would all have died. Over the four years, the project team rescued a total of 947 live hatchlings from the nest chambers. The mean number of live hatchlings per nest was 1.3. A total of 458 dead hatchlings were retrieved, with a mean number of 0.6 dead hatchlings per nest. Some deformed hatchlings were observed, although not commonly. Twins were found on four occasions, all dead-in-shells. One two-headed embryo was found in 2004 (fig.7.14).

Figure 7.14 Two-headed leatherback hatchling found in a nest on Grand Tacarib beach in 2004

c) Depth of nest

The mean depth to the top of the nest chamber was 66.5 cm (*SD* = 12.4, *n* = 591), and the mean depth to the bottom of the nest was 82.2 cm (*SD* = 11.1, *n* = 705). Linear regression analysis showed that the depth to the top and depth to the bottom of the nest were significantly positively correlated with each other ($r = 0.8$, $F_{1, 580} = 1060$, $p < 0.001$).

A One-way ANOVA showed that there was a significant difference in the bottom nest depth on different beaches (table 7.1). A post-hoc Tukey test showed that Grande Riviere had a significantly shallower mean nest depth (mean = 75.4 cm) compared to the other four beaches (mean = 82.3 cm, 83.8 cm, 82.9 cm and 84.2 cm). The other four beaches were not significantly different from each other. The mean nest depth did not vary between years, in different zones or different parts of the season (table 7.1).

d) Temperature and incubation duration

The mean temperature within nests on beaches on the north coast of Trinidad was 28.6 °C (± 0.66, *n* = 45), and the mean incubation duration was 69.8 days (± 2.45, *n* = 45). The mean temperature was calculated for each third of the incubation period. The mean temperature for the 1st third was 27.9 °C (± 0.64, *n* = 45), the 2nd 28.3 °C (± 0.73, *n* = 45) and the 3rd 29.6 °C (± 1.1, *n* = 45).

The mean nest temperature and the incubation duration were negatively correlated with each other ($r = 0.79$, $F_{1, 43} = 75.5$, $p < 0.001$) (fig.7.15), showing that the incubation duration gets shorter as the temperature increased.

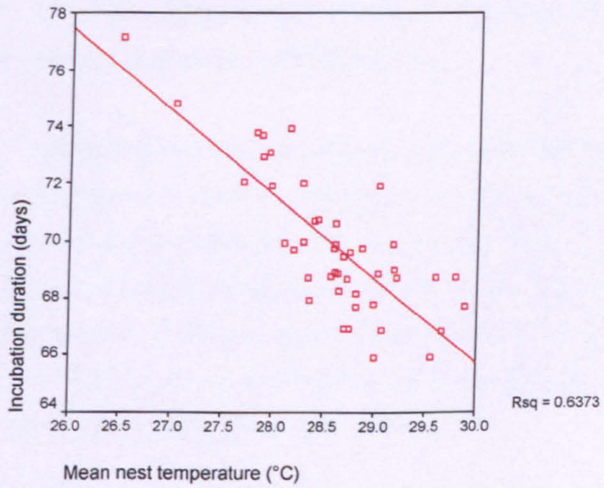


Figure 7.15 Scatter plot showing the relationship between mean nest temperature and the incubation period

One-way ANOVA analysis showed that there were no significant differences between the mean temperatures in nests on different beaches (table 7.1). There was no significant difference between the temperature in the 1st and 2nd third of the incubation period. However, there was a significant difference between beaches in the 3rd period ($F_{3, 41} = 5.79, p < 0.002$). A post-hoc Tukey test showed that Grand Tacarib (higher temperature) and Murphy's Bay (lower temperature) were significantly different from each other. The other beaches showed no significant differences.

There were no differences in overall mean temperature between years (table. 7.1), or in any third of the incubation period.

Because of restrictions on when the temperature experiments could be performed, nest temperatures were collected only for two parts of the season (period 3 and 4). An independent t-test was used to test for differences between temperatures and season. No significant difference was found ($t = 0.14$, $df = 43$, NS).

There was a significant difference in mean temperature with the zone of the beach (table 7.1). A post-hoc Tukey test showed that the back of the beach was significantly different to the front of the beach. The back and middle, and the front and middle were not significantly different from each other. The back of the beach had a lower mean temperature (mean = 27.1 °C) than the middle and the front (mean = 28.6 °C and 28.8 °C respectively). There were similar findings when a One-way ANOVA was applied to the incubation duration ($F_{2, 39} = 8.1, p = 0.001$). There were no significant differences between the mean incubation duration on different beaches, or in different years.

7.3.4 Relationships between nest parameters and with hatching success

Linear regression analysis was used to look for significant relationships between several aspects of nest ecology and hatching success. The large data set ($n = 746$) containing all the data from all beaches and years was used to test for relationships between hatching success, depth, clutch size and egg types. Mean temperatures and incubation duration were calculated with a smaller data set, as temperature was not measured in every nest that was excavated ($n = 46$). Table 7.3 summarises the results.

Table 7-3 Relationships between nest variables and hatching success

Nest variable	*r*	*F*	*p*	*Relationship*
Depth (bottom)	0.16	18.24	< 0.001	Positive (deeper = higher success)
% of inert eggs	0.15	17.8	< 0.001	Positive (more = higher success)
Total clutch size	0.025	0.48	0.49 NS	-
Total viable eggs	0.12	12.5	< 0.001	Negative (more = lower success)
Mean temp	0.26	2.89	0.09 NS	-
Temp (1st third)	0.11	0.51	0.48 NS	-
Temp (2nd third)	0.09	0.35	0.55 NS	-
Temp (3rd third)	0.54	16.9	< 0.001	Positive (higher = higher success)

Due to the nest depth being significantly shallower on Grande Riviere beach, and the hatching success being significantly lower on Grande Riviere, an additional regression analysis was carried out on the data set with the Grande Riviere data removed. There was still a significant relationship between the bottom depth of the nest ($r = 0.1$, $F_{1, 578} = 5.94$, $p < 0.05$) and hatching success.

The mean nest temperature was tested with a number of nest parameters to look for any significant relationships (table 7.4).

Table 7-4 Relationships between nest variables and mean nest temperature

Nest Variable	*r*	*F*	*p*	*Relationship*
Depth (bottom)	0.38	7.13	< 0.01	Negative (deeper nest = cooler temp)
% of inert eggs	0.09	0.34	0.56 NS	-
Total clutch size	0.35	5.89	< 0.02	Positive (larger clutch size = higher temp)
Viable eggs	0.40	7.68	< 0.008	Positive (larger clutch size = higher temp)

The temperature from the 1st, 2nd and 3rd part of the incubation period was also tested in relation to the nest variables. The temperatures in the 1st and 2nd part if the incubation period had a significant relationship with the bottom depth of the nest ($p < 0.001$); however, there was no relationship between depth and the temperature in the 3rd part ($p = 0.35$). There was no significant relationship with temperature in the 1st third of the incubation and the number of viable eggs, but there was in the 2nd ($p < 0.05$) and 3rd ($p < 0.05$). No significant relationship was found between the percentages of inert eggs with the temperature from any third of the incubation period.

The incubation duration was found to have a significant negative relationship with the number of viable eggs in the nest ($r = 0.35$, $F = 5.79$, $p < 0.05$), where the incubation duration was shorter as the number of viable eggs increased. There were no significant relationships found between the incubation duration and nest depth, percentage of inert eggs or total clutch size.

7.3.5 Invertebrate infestation

Out of a sample of 742 hatched nests, an overall mean of 12.7 % (n = 94) were infested with dipteran larvae and various other invertebrates (table 7.5). The mean number of infested eggs or hatchlings within each infested nest was 2.54 ± 3.59 and the mean proportion of eggs infested was 2.1 % ± 1.81.

Table 7-5 Percentage of infested nests on the remote north coast beaches

Beach	*2002*	*2003*	*2004*	*Mean (n = total nests sampled)*
Paria	21.4	12.5	3.8	10.7 (n = 56)
Grand Tacarib	15.1	9.8	7.1	8.9 (n = 457)
Madamas	16.6	8.3	31.0	17.2 (n = 99)
Grande Riviere	-	50.0	16.0	22.3 (n = 130)
Mean	16.2	15.7	10.5	12.7 (n = 742)

Chi-squared tests were used to assess differences in the number of infested nests between years, beaches, zones on the beach and part of the hatching season. There was no difference between years (Pearson's chi square = 5.82, df = 2, NS) or between seasons (Pearson's chi square = 3.08, df = 3, NS).

There was a significant difference in the number of infested nests on the different beaches (Pearson's chi square = 20.23, df = 3, < 0.001). From looking at the expected and observed values in the chi squared test, the nests on Grande Riviere and Madamas had a higher than expected number of infested nests, Grand Tacarib had a lower number of infested nests than expected, and the observed and expected values for Paria were almost the same.

There was also a significant difference in the number of nests infested in different zones on the beach (Pearson's chi square = 23.78, df = 2, < 0.001). A total of 27 % of infested nests were found on the back section of the beach, 11.4 % on the middle section, and 8.2 % in the front section. The chi squared test showed that the observed number of infested nests at the back of the beach was much higher than expected; the observed and expected were the same in the middle section, and the observed number of infested nests was much lower than expected on the front section of the beach.

An Independent-samples t-test was applied to test for any differences in the nest variables between infested and non-infested nests. The results are presented in table 7.6.

Table 7-6 Results of independent samples t-test between infested and non-infested nests with nest variables (* degrees of freedom are lower than actual sample size tested as the Levine's test for equality of variances was < 0.05)

Nest variable	*Mean (infested)*	*Mean (non-infested)*	*t (df)*	*p*
Hatch success (%)	66.9 (±24.9, n=94)	74.0 (±22.1, n=639)	-2.88, $_{733}$	< 0.005
Depth (bottom) (cm)	80.8 (±12.2, n=88)	82.4 (±11.0, n=610)	-1.21, $_{696}$	NS
Depth (top) (cm)	62.8 (±14.9, n=72)	67.1 (±12.0, n=512)	-2.32, $_{84.4}$*	< 0.05
Clutch size (eggs)	109.6 (±22.9, n=94)	107.9 (±21.4, n=641)	0.74, $_{733}$	NS
Viable eggs	77.6 (±18.8, n=94)	76.5 (±18.8, n=641)	0.53, $_{733}$	NS
% Inerts	28.8 (±12.2, n=94)	28.7 (±11.8, n=641)	0.23, $_{733}$	NS
% Bacterial	13.3 (±14.3, n=94)	11.6 (±12.6, n=641)	0.12, $_{731}$	NS
% Dead-in-shell	5.2 (±8.1, n=94)	4.0 (±8.1, n=611)	1.36, $_{733}$	NS
% Disintegrated	5.6 (±6.32, n=73)	2.1 (±4.91, n=534)	4.57, $_{83.2}$*	< 0.001
Mean temperature °C	28.6 (±0.46, n=5)	28.59 (±0.68, n=40)	0.05, $_{43}$	NS

A significant difference was found in the hatching successes of infested and non-infested nests, with the infested nests having a lower mean hatching success. There was also a significant difference in the depth of sand to the top of the egg chamber. The non-infested nests were deeper. There was no difference between the bottom depths in infested and non-infested nests. Nor was there any difference between nest temperatures.

There were no differences found in clutch size of either total clutch or number of viable eggs, nor any differences in the percentage of inerts, bacterially infected eggs or dead-in-shell eggs (table 7.6). There was, however a significant difference in the percentage of disintegrated eggs in the nest (< 0.001).

The most common invertebrate found in leatherback nests on the north coast beaches was red oligochaete worms (approximately 5 cm long), similar to the earthworm. However, the presence of these was not considered as infestation as these animals do no harm to the eggs, and therefore was not included in the calculation of infested nests. All the infested nests were found to contain dipteran larvae (fig.7.16). Other invertebrates found were nematode worms, beetle larvae and red ants (Hymenoptera: formicidae) (fig.7.17). Red ants were found in a total of eight nests, and were the only invertebrate that clearly had a direct effect on the hatching success on observation, and definitely killed hatchlings.

Figure 7.16 Leatherback hatchling infested with dipteran larvae (left), and covered in adult dipterans (right)

Figure 7.17 Leatherback hatchlings from a nest infested with red ants

The dipteran species that were identified are listed in table 7.7.

Table 7-7 Dipteran species identified from 18 sampled infested leatherback nests on the north coast of Trinidad

Family	*Species*	*% of sampled infested nests*
Muscidae	*Fannia pusio*	27.7 ($n = 5$)
	Fannia dodgei	5.5 ($n = 1$)
	Synthesiomyia nudiseta	5.5 ($n = 1$)
Phoridae	*Megaselia scalaris*	88.8 ($n = 16$)
	Dohrniphora cornuta	5.5 ($n = 1$)
	Puliciphora borinquenensis	5.5 ($n = 1$)
Sarcophagidae	*Peckia anguilla*	5.5 ($n = 1$)
	Peckia chrysostoma	11.1 ($n = 2$)
	Agrovinia rufiventris	38.8 ($n = 7$)
	Sarcodexia lambens	11.1 ($n = 2$)
	Trichaeae femoralis	5.5 ($n = 1$)
Ephydridae	*Unknown*	11.1 ($n = 2$)
Sepsidae	*Unknown*	5.5 ($n = 1$)
Stratiomyidae	*Hermetia illucens*	11.1 ($n = 2$)

A total of 18 infested nests were sampled. Fourteen dipteran species were identified from six families. Unfortunately I could not identify the nematode worms or beetle larvae.

7.4 Discussion

7.4.1 Nest success

The main threats to leatherback nests on the north coast beaches were erosion from tides and fresh water outflow, inundation by the sea and freshwater table, and predation. These threats varied in severity depending on the characteristics of the beach, both topographic and human-related. Of the 53 nests that were marked and monitored through till hatching, 28 % (n = 15) failed to produce hatchlings. Of the nests that failed to hatch 46 % (n = 7) of them were identified as having been inundated by either fresh water or the sea and 13 % (n = 2) were completely removed by sand erosion. The reasons for the failure of the other 40 % (n = 6) of nests were not clear. When the failed nests were dug up, the viable eggs contained dead embryos at various stages, and there were a large number of bacterial eggs. Reasons for death could have been inundation at some point during the incubation period (inundation of a nest is not always obvious), or the eggs could have experienced inhospitable moisture levels, temperatures or gas exchange within the nest (Ackerman, 1980). Leatherback nests experience higher incidence of inundation than other sea turtle species as leatherbacks tend to position their nests closer to the high water mark (Whitmore and Dutton, 1985).

The nest success reported for the monitored nests may have been slightly biased, making it appear higher than in actuality. The nests that were monitored were not chosen completely randomly as nests that were positioned below the high water mark were not used for the experiment. However, only a very small proportion of leatherbacks lay their eggs below the high water mark, therefore the number of nests lost from inundation by the sea would not have been notably affected. The number of nests lost from erosion may have been underestimated (depending on the beach). This was accounted for in the final calculations of nest success. The number of nests affected by predation would not have been influenced by the monitored nest selection.

The success of the nests on Grand Tacarib, Paria and Madamas was relatively consistent. However, the nest success on Murphy's Bay was extremely low and hatched nests were very rarely seen. Out of the four nests that were monitored, one failed to hatch at all, and the other three produced only a few hatchlings (approximately 8) in the top section of the nest. When the nests were excavated they were found to be partially saturated with water. Inundation of a nest for several hours, especially near the end of the incubation period, can result in the death of an entire clutch of eggs (Miller et al., 2003). The eggs from the nest that failed to hatch contained embryos that had died at an early stage of development, and the eggs were black and grey on the outside, typical of what eggs look like from a nest that had been inundated for a long period of time (SRL, personal observation). The eggs at the bottom of the other three nests also looked like this, but some of the eggs at the top had survived or avoided inundation and reached full term. This may have been the fate of the majority of nests on the beach, but it is doubtful whether the hatchlings from the top of the nests would have managed to emerge from the nest on their own, due to their small number. The lack of evidence of any hatchling tracks or hatched nests on Murphy's Bay on numerous visits suggests that this was the case. Murphy's Bay was waterlogged at the back of the beach at both ends for a large portion of the hatching season (chap.3) suggesting that the water table was particularly high. Few nests were ever witnessed in all the years of monitoring; therefore it appears that this problem currently happens every year, and is to do with the topography of the beach rather than heavier or lighter rainy seasons. Because of the lack of data from previous years, it is not possible to tell whether low nest success is a recent phenomenon.

Murphy's Bay receives a high density of nesting leatherbacks (the second highest density beach, table 3.1), and supports 8 % of the clutches laid on the whole of the north coast (fig.3.2). It is rather unfortunate that it also has the lowest nest and hatching success. There appears to be very little that can be done about the high level of inundation on this beach, other than translocating the nests elsewhere or monitoring a large number of nests to retrieve any hatchlings that do reach full term.

The nest success on Madamas was similar to that on Grand Tacarib and Paria, but the number of nests affected by erosion varied greatly from year to year. Madamas River is extremely energetic and changed course dramatically in two of the study years. Both times the river changed course from emptying from the east end of the beach, to cutting right through the middle (fig.3.9 and 3.10). Each time this happened, the river would take with it a huge amount of the sand, and all the nests buried within it. The changing river course also limited the amount of beach available for subsequently nesting females. This only ever affected the eastern side of the beach, which did in fact generally receive fewer nesting females than the western end (chap.3), but the river did destroy a large proportion of the nests on the beach. Grande Riviere beach also has a large dynamic river system, which often changes course, cutting the beach in half and removing many nests (fig.3.5). Again, this affects only the eastern side of the beach but still a substantial number of nests. In a recent study of nest success on Grande Riviere, 56.4 % of monitored nests were destroyed by erosion and predation (Maharaj, 2004), although the study did not specify what percentage was lost to each action. Grand Tacarib does not have a large river, but has three smaller streams that cause some localised erosion in times of high rainfall (fig.3.11). Paria has a large river at the eastern side of the beach (fig.3.7), but it is much more stable than the rivers at Grand Riviere or Madamas, and although it grew in size from heavy rainfall, it never changed course over the four-year period. Paria and Grand Tacarib are the two most stable high density nesting beaches in terms of erosion and inundation.

It was interesting to note that none of the monitored nests on the remote beaches were destroyed by predation and there were few cases where an unhatched nest was disturbed by any animal. Vultures were seen to predate nests that had been exposed by tides or streams, or a nest that had already hatched in which several hatchlings had died, but never to destroy an unhatched nest. Maharaj (2004) stated that she witnessed several nests on Grande Riviere predated by armadillos (*Dasypus novemcintus*) and manicou (opossum) (*Didelphis*), which are natural predators inhabiting the north coast area, although how to distinguish between a nest predated by one of these animals and a dog is not mentioned. No evidence of predation by these mammals was seen on the remoter north coast beaches. Dogs, which were identified as the most common nest predator on the beaches backed by villages (chap.3) were not present on the more remote beaches.

Dog predation was witnessed at all the north coast beaches with human habitations, and was particularly bad at Grande Riviere (N. Alexander, personal communication; SRL, personal observation). Predation by introduced predators, such as dogs, raccoons and armadillos (in North America) in conjunction with natural predators, can be a serious problem (Drennen et al., 1989; Ratnaswamy and Warren, 1998; Fowler, 1979), and in severe cases can cause population decline (Engeman et al., 2003). For example, in Tortuguero, Costa Rica, dogs destroyed 47.1 % of successful nests (Leslie et al., 1996). A cull of stray dogs in some of the north coast villages is a possible solution for reducing predation on hatchlings and nests. Predator removal is a common practice in conserving sea turtles (Stancyk, 1982) and has been found to be one of the most practical means of reducing predation and increasing hatching success in a number of regions (Bain et al., 1997; Engeman et al., 2003).

The level of hatchling predation on the more remote beaches was relatively low, although it is difficult to quantify. Vultures were seen eating hatchlings in the early morning, and there was some evidence of crabs attacking hatchlings, but as with nests, predation of hatchlings by mammals was very low. Hatchling predation was higher on the beaches in villages because of the presence of dogs. Frigate birds were witnessed taking hatchlings from near shore waters from all beaches when nests hatched during the day, as seen elsewhere (Carr and Meylan, 1980; Lagarde et al., 2001). Birds such as vultures, crows and frigate birds are commonly thought of as prominent hatchling predators. However, as the majority of hatchlings emerged at night, and most bird predators are diurnal, their role is probably overstated (Stancyk, 1982). Although the level of predation of hatchlings after they left the beach could not be quantified, it was presumed to be at a high level. Near shore aquatic predators are believed to be responsible for a much greater loss of hatchlings than predation on beaches (Stancyk, 1982). There were large numbers of predatory fish and sharks present in the offshore waters (C. Patron, personal communication; SRL, personal observation).

Although no nests were monitored on Grande Riviere beach, observations during beach visits and nest excavations showed that nest success was much lower on this beach than on any of the remoter beaches (apart from Murphy's Bay) due to the combined effects of high dog predation and dynamic river movements. Broken and whole fertilised eggs littered the beach from nests destroyed by erosion action from the river and streams, and predation from dogs. Besides direct predation, dogs also exposed nests to the elements and to additional predation from crabs, vultures and insects (Engeman et al., 2003). There were always a large number of vultures on the beach scavenging on eggs. On first impressions the vultures looked like they were doing a lot of damage to nests and hatchlings. However, many of the guides working on the beach praised the vultures for helping to clean up the beach (N. Alexander, personal communication). During the peak hatching season, Grande Riviere beach is covered in rotting eggs and embryos, making the beach and water unclean and foul-smelling (SRL, personal observation). The percentage of invertebrate infested nests was significantly higher on Grande Riviere beach compared to the other more remote beaches (table 7.5), most likely related to the large amount of exposed and rotting material.

Deliberate human poaching of eggs is a serious threat to sea turtle populations in some areas (25 % of nests were removed by poachers at Tortuguero, Costa Rica, Leslie et al., 1996). There was little evidence of egg harvesting by humans on any of the north coast beaches, and any that was witnessed was on the more remote beaches by forest-men subsisting from the land. This is unlikely to have any significant impact on the turtle population.

Another threat to turtle nests is the digging up of nests by subsequently nesting females. Clutches that are laid earlier in the season have a greater chance of being dug up by a nesting female as the number of nesters increases until peak season. After peak season when the numbers of nesting leatherbacks begin to drop, an individual nest is less likely to be dug up (Bustard and Tognetti, 1969). The likelihood of a nest being dug up also depends on the density of nesters on the beach. For example, the nesting density on Grande Riviere is much greater than on Paria (chap.3) and therefore the percentage of nests dug up by other females is greater. This action was recorded as affecting an average of 2.6 % of nests on all the beaches over the whole season.

The nest success reported for the remote beaches is not fully representative of the whole coastline, as beaches differ in levels of predation and topography (chap.3). It is clear that nest success varies hugely from beach to beach and from year to year. For this reason it is difficult to produce a true measure of nest success for the whole north coast. It is more accurate to calculate a separate measure of nest loss for each beach, and then using the proportions of total nests on each beach (fig.3.2), to calculate a mean nest success for the whole coast. The approximate nest loss overall for Grand Tacarib, Petit Tacarib and Paria, taking into account the slight bias of monitored nests, is estimated at 30 %, and representing 18, 2 and 10 % of the nests on the north coast respectively. On Madamas, which represents 9 % of nests, the loss is estimated at 35 % due to the river. Murphy's beach supports 8 % of the nests on the coast, and the nest loss on this beach is estimated at 95 %. The estimate of nest loss made by Maharaj (2004) for Grande Riviere was 56 %, representing 48 % of the nests on the north coast. The final 5 % of nests occur on the low density nesting beaches, and are estimated at approximately 35 % nest loss due to the mix of inhabited and uninhabited beaches with and without river systems, and therefore varied presence of dogs and erosion levels. Taking into account the mean percentage of nests destroyed by nesting females (2.6 %), the mean nest success for the whole north coast was calculated as approximately 49 %.

7.4.2 Hatching success

The hatching success of individual sea turtle nests is typically high (80 % or more) (Miller, 1997) unless disturbed by external factors such as predation, microbial infection and inundation (Whitmore and Dutton, 1985). The hatching success of leatherback nests has been shown to vary between locations, seasons and individuals (Bell et al., 2003), although researchers generally agree that hatching success is significantly lower for leatherback nests than for other turtle species (Whitmore and Dutton, 1985; Girondot et al., 1990; Wallace et al., 2004) measured at approximately 50 % (see Bell et al., 2003 for review). Bell et al. (2003) investigated the reasons for lower hatching success in leatherback nests, and concluded that it was due to high hatchling mortality rather than infertility. Wallace et al. (2004) and Ralph et al. (2005) further investigated the reasons for embryonic death in leatherback nests in terms of biotic and abiotic factors in the nest environment, but neither study could explain embryonic death. The exact reasons for embryonic death in leatherback clutches remains unknown.

The mean hatching success of leatherback nests on the north coast of Trinidad was calculated as 73.3 % (n = 746). The hatching success on the north coast was found to be stable with no significant differences between years, or in different parts of the nesting season (table 7.1). Hall (1990) found similar results with no relationship between hatching success and season in leatherback nests in Puerto Rico. A large proportion of the nesting leatherback population in Trinidad nest on the eastern coast (Fournillier and Eckert, 1997; chap.4). The hatching success on the main nesting beach there (Matura, fig.1.3) was calculated as 65.2 % (Maharaj, 2004), lower than on the north coast beaches. Compared to other regions and populations, the hatching success on the north coast of Trinidad 73.3 % is relatively high; 64 % in the US Virgin Islands (Eckert and Eckert, 1990); 64.1 % in Malaysia (Eckert and Eckert, 1996); 21 % Costa Rica (Bell et al., 2003); 33.5 % in Central and South Brevard County, Florida (Maharaj, 2004), 48.6 % on Playa Grande, Costa Rica (Williams, 1996); 53.2 % in St Croix (Eckert and Eckert, 1985); 72.2 % in Culebra, Puerto Rico (Tucker and Frazer, 1991); 35 % in French Guiana and Suriname (Maros et al., 2003; Girondot et al., 2005).

Embryo development is affected by a number of different environmental variables such as temperature, gas exchange, and moisture content, which in turn are influenced by the nest placement of the female. The nest placement also affects the overall nest success and the likelihood of hatchlings reaching the sea. Leatherbacks tend to position their nests in the open sand, closer to the water, rather than in the vegetation at the back of the beach (Godfrey et al., 1996). The leatherbacks on the north coast beaches laid the majority of their clutches on the front section of the beach (fig.7.12), although they did use the whole width of the beach (from the high water mark to the vegetation at the back of the beach). This has been found for nesting leatherbacks elsewhere (Carr and Ogren, 1959; Pritchard, 1971; Dutton and Whitmore, 1983; Eckert, 1987; Mrosovsky, 1983a). Erosion and inundation are two of the main natural hazards that threaten leatherback nests, most likely resulting from leatherbacks' preference for dynamic beaches (Pritchard, 1971; Whitmore and Dutton, 1985). Therefore, nesting closer to the sea puts the nests in more danger. However, although nests positioned further back on the beach would be safer from erosion and inundation, the nest environment may be less hospitable in terms of temperature and moisture, and the predation and desiccation rate on hatchlings may be higher. Nest placement may have evolved to counter-balance these potential threats (Hays and Speakman, 1993), although a number of studies have found no predictable pattern to nest success at difference distances from the water (Mrosovsky, 1983a; Eckert, 1987; Hall, 1990; Hays and Speakman, 1993). This study found that there was no difference in hatching success in the different beach zones. However, it has been suggested that leatherbacks have evolved a nest placement strategy in the open sand zone of a beach where nesting patterns are random, resulting in there being an increased probability of reproductive success (Kamel and Mrosovsky, 2004).

Mean nest temperature was found to have a significant relationship with nest placement on the north coast beaches. This has also been found in other studies (Morreale et al., 1982; Mrosovsky and Provancha, 1989). The nests in the zone furthest back on the beach were found to be significantly cooler than those in the middle and front zones (table 7.1). There was no difference in nest temperature between these two zones. This result is most likely due to the backing vegetation causing some shade from the sun during the daytime. None of the other measured variables had a relationship with beach zone (table 7.1).

The hatching success varied significantly between beaches on the north coast. Grande Riviere had the lowest hatching success at 62.8 %. This was very similar to the hatching success recorded by Maharaj (2004) in her study in 2001 (60.7 %). Madamas also had slightly lower hatching success than the other high density beaches (table.7.2). Grand Tacarib had the highest hatching success of all the beaches and also had the highest nest success, making it the most successful beach on the north coast in terms of total hatchling production.

It was interesting to note that the nest depth was significantly shallower on Grande Riviere beach. Hatching success was positively correlated with nest depth (table.7.3) suggesting that the lower hatching success on Grande Riviere may have been caused by shallower nests. There was a suspicion that the lower hatching success and nest depth on Grande Riviere may have skewed the full data set to produce this result. However, when the Grande Riviere data were removed from the data set, the regression analysis still resulted in a positive relationship between hatching success and nest depth. This suggests that the shallower nest depth on Grande Riviere negatively influences hatching success on that beach.

A reason for shallower nest depth on Grande Riviere may be the coarser sand on the beach (chap.3), making it more difficult for the leatherbacks to dig nests (SRL, personal observation). The false crawl rate on Grande Riviere was also found to be higher, thought to be partially due to the coarser sand causing collapse of nests (chap.3). Sand particle size can also affect nest success through levels of gas exchange and moisture content (Ackerman, 1980) and thermal conductivity (Speakman et al., 1998). Nests on beaches with a larger sand particle size are believed to suffer more from desiccation (Mortimer, 1990). It is possible that the combined effect of coarser sand and shallower nests (also affected by the coarser sand) have negatively influenced the hatching success through adverse gas exchange and moisture conditions. This could also explain the lower hatching success on Madamas, as it also has a larger sand particle than on the other high density beaches (chap.3).

The reason why nest depth has a positive relationship with hatching success is not certain. Mortimer and Carr (1984) found a positive correlation with nest depth in green turtles on Ascension Island and suggested that this might have been due to higher moisture content in deeper nests. This could also be the case on the north coast of Trinidad, but not all studies have reported this result; Hall (1990) found a negative correlation with leatherback nest depth and hatching success. In this study, the nest depth also had a significant negative relationship with temperature, which could influence moisture levels and consequently the gas exchange in the nest (Ackerman, 1980; 1991; 1997). Lower temperatures could provide a more favourable environment for developing embryos by keeping the moisture and O_2 demand lower, reducing the chance of desiccation.

The nesting ecology of leatherbacks differs slightly from that of other sea turtle species in that they lay more clutches per season, have shorter inter-nesting periods and produce smaller clutches of eggs in relation to their body size (Hirth, 1980; Tucker and Frazer, 1991). Leatherback egg clutch composition also differs significantly from that of other sea turtles. They contain a number of small yolkless eggs (SAGs or inert eggs) that they produce along with the larger yolked (viable) eggs (Hall, 1990). These inert eggs are usually deposited at the end of the laying process on top of the viable eggs (Rostal et al., 1996; SRL, personal observation). Hall (1990) found that 30 % of the total clutch size was made up of inert eggs. The leatherback nests on the north coast of Trinidad had a similar percentage of inert eggs at 28.8 %, and an average number of 31.5 inerts per nest. The mean total clutch size including inerts was 108 eggs, and the mean number of viable eggs was 76.7. This is similar to the clutch size found in other leatherback populations; an average of 65 – 80 eggs (Bell et al., 2003); 86 eggs at Tortuguero, Costa Rica (Leslie et al., 1996); 83.1 eggs at Florida beach (Maharaj, 2004).

It was interesting to find that the total clutch size and number of viable eggs varied significantly in different years (table 7.1). The total clutch size was significantly higher in 2003 than in 2002 and 2004. The viable clutch size differed significantly between all years. This may reflect the reproductive condition of the nesting females in different years depending on food resources in the months prior to the nesting season. The year 2003 was particularly busy for nesting leatherbacks with the highest recorded numbers from all the study years (table 4.2). The larger clutch sizes and the high numbers of nesters suggest that resources were in favourable supply in the years leading up to that breeding year.

There was no difference in the total clutch size between different parts of the season; however there was a significant difference in the number of viable eggs (table 7.1). More viable eggs were laid in nests in the first part of the season than in the other three parts of the season. More viable eggs may be laid at the beginning of the season when females have more energy to put into producing them. It was interesting to note that the percentage of inert eggs was also significantly different between parts of the season. The lowest proportion of inert eggs was laid at the start of the season, significantly higher in the second period, and significantly higher again in the third period. There were no differences in the third and fourth parts of the season. This shows that the proportion of inert eggs in nests increase as the nesting season goes on (Bell et al., 2003). As the number of viable eggs and inert eggs are negatively correlated with each other, this result is not particularly surprising.

The number of eggs that the female deposits into the nest can influence the hatching success. In the leatherback nests on the north coast of Trinidad, hatching success had a significant negative relationship with the number of viable eggs, a significant positive relationship with the percentage of inert eggs in the nest, but no relationship with the total clutch size (table 7.3). It is perhaps surprising to find that hatching success decreases with a larger number of viable eggs. However, this has also been found in a number of other studies (Balasingham, 1967; Hall, 1990). Hall (1990) found the optimum clutch size to be between 52 - 56 eggs, and Balasingam (1967) found it to be 46 - 60 eggs. This is lower than the mean clutch size found in most leatherback populations (76.7 in this study).

Female leatherbacks may be capable of producing a smaller number of larger eggs, which could possibly increase the overall hatching success within individual nests. However, they seem to favour producing larger numbers of smaller eggs over an increased number of nests (Rostal et al., 1996). This may have evolved partly due to their dynamic and unpredictable nesting environment, so that they prefer to spread out a larger number of lower quality nests in order to raise the chances of a proportion of them being successful (i.e. a bet-hedging reproductive strategy: Philippi and Seger, 1989).

There are several hypotheses to explain why a larger clutch size results in reduced hatching success. Balasingam (1967) suggested that the increased metabolic heating produced from a larger clutch of eggs could raise the temperature in the centre of the nest to dangerous levels and cause mortality of a number of embryos. This seems unlikely to be a factor in this case considering the temperatures recorded in the leatherback nests. Ackerman (1980) proposed that gaseous exchange would be reduced in the centre of a larger clutch, causing a higher number of embryos to die, and Packard et al. (1980) suggested that eggs in the centre of the nest might lose moisture at a disproportionate rate to the surrounding eggs and nest environment. A recent study by Wallace et al. (2004) found that as the number of developing embryos increased, the oxygen potential decreased and temperature increased, however, neither the oxygen potential or temperature had a significant affect on hatching success. A further study by Ralph et al. (2005) found that there was a significantly lower mean hatching success in the centre of the nests than in the intermediate or peripheral areas, but that this could not be attributed to the spatial variation of respiratory gases within the nest. It is unknown why a larger clutch size may affect hatching success, but it does not appear to be for any other reasons previously suggested.

The hatching success had a significant positive relationship with the percentage of inert eggs in the clutch. However, the number of inert and viable eggs also had a significant negative relationship. Because hatching success increases with a decreasing number of viable eggs, it is difficult to say whether it is the increase of inerts or the decrease in viable eggs that is affecting hatching success. Hall (1990) also found that the percentage of inerts correlated positively with hatching success. However, she found no relationship between the number of inerts and the number of viable eggs. This suggests that there may be some benefit to having more inert eggs in a clutch, other than the relationship existing with the number of viable eggs.

Several adaptive values have been suggested for inert eggs. Hirth (1980) proposed that the presence of inert eggs might assist in predator divergence. Hall (1990) found in several nests that invading crabs had attacked a number of inert eggs rather than attacking viable eggs, as they were the first eggs that they encountered within the nest. Frazier and Salas (1984) suggested that inert eggs provided a means of thermal buffering within the nest to avoid extremes of temperature fluctuation, which can be detrimental to developing embryos

(Ackerman, 1997). Frazier and Salas (1984) along with Pritchard and Trebbau (1984) suggested that inert eggs could fill in smaller spaces in the nest and prevent sand from filling in between the eggs below, permitting more space for gas exchange. Hall (1990) also suggested that the inert eggs could provide moisture for the developing eggs, and possibly store moisture after rainfall. The idea behind this was that some of the inert eggs were found to be collapsed when the nest was excavated, and that they may have lost some moisture to other eggs in the clutch. These collapsed inert eggs were also witnessed in the leatherback nests on the north coast beaches (SRL, personal observation). Rostal et al. (1996) stated that inert eggs may have no function at all, and Wallace et al. (2004) rejected the hypothesis that the inert eggs improve gas exchange or influence temperatures in the nest. Many other studies of nest success have not demonstrated any clear advantageous functions (Eckert, 1987; Eckert and Eckert, 1990; Leslie et al., 1996; Steyermark et al., 1996).

Temperatures in sea turtle nests are typically between 24 and 33 °C (Ewert, 1979). The mean temperature for leatherback nests on the north coast beaches was 28.6 °C, which fits into this range. Mean nest temperature did not vary between beach, year (table 7.1), or between the two periods of the season that were tested. Seasonality has been shown to have an effect on nest temperatures in other studies (Mrosovsky et al., 1984; Shine, 2004); however, restrictions on the timing of temperature experiments did not allow this to be tested over the whole season. Trinidad's geographic position just north of the Equator means that temperature change over the nesting season is likely to be minimal compared to areas such as the Mediterranean, although seasonal rains may have some effect. Nest temperature had a significant negative relationship with the incubation duration (fig.7.16), as found in other studies (Mrosovsky et al., 1984; Miller, 1985; Marcovaldi et al., 1997; Booth and Astill, 2001). The mean incubation duration on the north coast beaches was 69.8 days. Maharaj (2004) found the mean nest temperature on Grande Riviere was 28.3 °C and the mean incubation duration 68 days, which is very similar to that found in this study. Maharaj (2004) also measured mean nest temperature on Matura beach on the east coast as 30.1 °C, and an incubation period of 66 days. She found a significant difference between beaches on the two separate coastlines ($p < 0.001$).

Temperature is important within the nest environment, affecting hatching success in relation to gas exchange and moisture. It is also important in determining the phenotype (McGehee, 1990) and the sex of the hatchlings within the nest (Yntema and Mrosovsky, 1982; Hays and Speakman, 1993). Temperature dependent sex determination (TSD) operates to produce male hatchlings at lower temperatures and females at higher temperatures. The pivotal temperature is the temperature at which the sex ratio is 1:1, and varies between 28 to 30 °C, depending on species and population. The sensitive period for sex determination occurs in the middle third of incubation (Yntema and Mrosovsky, 1982; Mrosovsky, 1994). The pivotal temperature for leatherbacks in the Atlantic is 29.5 °C (Rimblot et al., 1985; Rimblot-Baly et al., 1987). Based on this figure, it is likely that the clutches laid on the north coast beaches mostly produce male hatchlings. However, this needs to be investigated in more detail since the overall mean temperatures are based on substantial variability close to the pivotal temperature.

Nest temperature was found to have no relationship with hatching success (table 7.3), suggesting that temperature is not an important factor. Other studies have reported similar findings (Hall, 1990; Wallace et al., 2004). When investigated further, it was interesting to find that the temperature in the 1st and 2nd third of the incubation period had no relationship with hatching success, but the 3rd period had a strong positive relationship (table 7.3). As the incubation period progresses, the fertile eggs within the nest begin to produce metabolic heat, which increases towards the end of the incubation period (Maxwell et al., 1988; Godfrey et al., 1997; Broderick et al., 2000a). Therefore the significant relationship between the temperature in the final third of incubation and hatching success is likely to be the result of more metabolic heat being produced by a larger number of successful developing eggs within the nest (which would be indicative of a higher hatching success, assuming nothing disturbs the nest before hatching). So rather than the external environmental temperature having an effect on hatching success, it is in fact the hatching success that affects the temperature by producing more or less metabolic heat.

There was a significant difference in the final third temperature between different beaches; a post-hoc Tukey test showed that the significant difference was between Grand Tacarib and Murphy's Bay. This supports the proposal that the relationship between hatching success and the final third temperature is due to metabolic heating, as the hatching success on Grand Tacarib was the highest of all the beaches (table 7.2), and the hatching success on Murphy's Bay was extremely low (due to inundation), with three of the monitored nests only producing a mean of eight hatchlings.

The number of viable eggs in the nest also had a strong positive relationship with mean nest temperature (table 7.4), with no relationship in the 1st third of incubation and a significant relationship in the 2nd and 3rd thirds of incubation. This suggests that metabolic heating is possibly responsible for the relationship between viable eggs and temperature, with more eggs producing a higher level of metabolic heating in the nest. These results suggest that a positive relationship between mean nest temperature and hatching success in sea turtle nests could be caused by metabolic heating, rather than by a relationship with ambient environmental temperature.

It was estimated that approximately 16,140 leatherback clutches are laid on the north coast of Trinidad each year (chap.4). Using the average figure of nest success for the north coast beaches (49 %), the number of nests that survive can be calculated as roughly 7,910. Using the average number of viable eggs in a leatherback nest (77), the total number of eggs within the nests that survive on the beaches can be calculated as in the region of 609,000. Out of each nest that hatches, approximately 73 % of the viable eggs will produce hatchlings. Using this figure, an estimated 444,570 leatherback hatchlings (out of a potential 1,242,780 viable eggs) are produced from the clutches laid on the north coast beaches of Trinidad each year. It is unknown what percentage of hatchlings will get predated on the beach, or in the sea, or that will reach adulthood to return to reproduce on Trinidad's northern coastline.

7.4.3 Invertebrate infestation

Many studies have reported the occurrence of invertebrates in both freshwater and sea turtle nests: dipteran larvae (Lopes, 1982; Acuna-mesen and Hanson, 1990; Iversen and Perry, 1994 McGowan et al., 2001a), red ants (Allen et al., 2001; Buhlmann and Coffman, 2001), mole crickets (Maros et al., 2003; 2005), coleopterans (McGowan et al., 2001a; Donlan et al., 2004), and hymenopterans (Broderick and Hancock, 1997). A mean of 12.7 % of the hatched nests investigated on the north coast beach of Trinidad were found to be infested with dipteran fly larvae and a number of other invertebrate species. There was found to be no difference in the proportion of infested nests between years or in different parts of the season. All the nests were infested with dipteran larvae, and many contained tiny nematode worms, which unfortunately could not be identified. Only a few of the nests that were excavated contained beetle larvae, and these were thought not to do any major harm to the eggs or hatchlings in the nest. Earthworms were often encountered in turtle nests, or in the sand surrounding the nest. These were thought not to do any harm either, and so were not described as infestation.

In some cases, insects in turtle nests can be very destructive and can cause low nest and hatching success. Maros et al. (2005) reported that the larvae of mole crickets (*Scapteriscus didactylus)* heavily predate on leatherback turtle eggs in French Guiana, causing the mortality of an average of 15.3 % of the total number of viable eggs laid. *S. didactylus* was introduced from the north coast of South America into a number of Caribbean islands, Trinidad included (Maros, et al., 2005), all of which have nesting populations of sea turtles. However, predation of sea turtles nests by mole crickets has not been described from any location other than French Guiana. Mole crickets were witnessed in Trinidad, however no predation of leatherback nests by mole crickets was seen on the north coast beaches (SRL, personal observation). Buhlmann and Coffman (2001) stated that red ants are capable of destroying between 27 and 60 % of turtle eggs within a nest. In the three years of the present study, red ants were found in a total of eight nests, and each time they were encountered, they had actively killed a high number of hatchlings within the nest. All of the nests that were infested with red ants were in the beach zone nearest the back of the beach. Buhlmann and Coffman (2001) also found this to be the case. Although infestation by red ants was uncommon on the north coast beaches, they were destructive in the nests that they attacked.

Fourteen species of Diptera from six families were raised from a sample of 18 leatherback nests. Although such a high diversity is perhaps surprising, fly carrion communities are often complex, consisting of a number of species from different families (Hanski, 1987; Woodcock et al., 2002). The most common species found in nests was the phorid *Megaselia scalaris.* This species has been reported from the eggs of a variety of freshwater and sea turtle species (Acuna-messen and Hanson, 1990; Broderick and Hancock, 1997; Iverson and Perry, 1994; Fowler, 1979; McGowan et al, 2001a; Whitmore and Dutton, 1985). *M. scalaris* has a worldwide distribution and has been recorded in a huge variety of different situations (Disney, 1994). Two other phorid species were also recorded. Neither *Dohrniphora cornuta* or *Puliciphora borinquenensis* had been recorded in sea turtle nests before. However, like *M. scalaris,* they breed in a vast range of substances, so finding them in a sea turtle nest is not too surprising (Disney, personal communication).

Sarcophagids are also commonly recorded from turtle nests (Acuna-Messen and Hanson, 1990; Broderick and Hancock, 1997; Iverson and Perry, 1994; Fowler, 1979; McGowan et al., 2001a; Whitmore and Dutton, 1985). Sarcophagids are known to be widespread scavengers of carrion. Five species were identified. *Argoravinia rufiventris* was the most common species (88.8 % of all infested nests sampled). *Sarcodexia lambens* had never been recorded in a turtle nest before, although it is known to infest bird nests (Fessl and Tebbich, 2002). The sarcophagid *Trichaea femoralis* is a well-known beach dwelling scavenger living in dead fish and crustaceans. This was the first record of this species occurring in Trinidad (Pape, personal communication). It is interesting that this species was found in only one nest, even though a beach dwelling fly would be likely to encounter turtle nests on a regular basis.

This suggests that this species is an opportunistic infester of nests, and not nearly as prevalent as *Sarcodexia lambens* or *Megaselia scalaris*.

Three species of Muscidae were identified. Flies belonging to this family have been recorded in turtle nests in other studies (McGowan et al., 2001a) and the species recorded are all well known general filth flies (Pont, personal communication). The muscid fly *Fannia pusio* was one of the most common species recorded. A small number of flies belonging to the family Ephydridae were also recorded. This family are known as the shore flies, as they are commonly found on carrion along and below the high water mark. The occurrence of these few individuals is probably an example of opportunism. The stratiomyid *Hermetia illucens* had not been previously reported in turtle nests. The larvae of this fly can live in many different habitats, and are particularly common near homes (Sheppard et al., 2002). This fly was identified from a nest on Grande Riviere beach (located in a village), which may partly explain its presence.

It is unclear whether dipteran larvae actively killed eggs or hatchlings within leatherback nests on the north coast. The hatching success was significantly lower in infested nests than in un-infested nests (table 7.6). This could suggest that either the dipteran larvae lower the hatching success by their presence and activities within the nest, or that they are more likely to infest nests with lower hatching success. The percentage of infested nests was significantly different on different north coast beaches. Grande Riviere had the largest proportion of infested nests, and Madamas the second (table 7.5). These two beaches also had lower hatching success than on the other remote beaches (table 7.2), with Grande Riviere having significantly lower hatching success. This highlights that there is more infestation by dipteran larvae on beaches with lower hatching success. In each nest that was infested, the average proportion of eggs and hatchlings that were affected by dipteran larvae was 2.1 % suggesting that if the dipteran larvae are responsible for the death of embryos, it affects a very small proportion of the nest.

Nests with lower success had a larger proportion of viable eggs in which the embryo had died. These eggs were categorised into dead-in-shell, bacterially infested, or disintegrated (fig.7.13). The dead-in-shell eggs and bacterially infected eggs in the nests were most often complete when the nest was excavated. Although larvae of *Megaselia scalaris* have been shown to penetrate leatherback eggs through pores, thus infesting an egg without damaging its shell (Acuna-mesen and Hanson, 1990), no dipteran larvae were ever found in a closed egg. However, the disintegrated eggs were often open. These eggs had a particularly strong pungent smell, and during excavation could often be smelled even before the egg chamber was reached. There was no significant difference in the proportion of dead-in-shell eggs or bacterial eggs in infested and un-infested nests (table 7.6). Nor was there a significant difference found between the mean proportion of inert eggs in infested and un-infested nests. This finding does not support the theory of inert eggs being a deterrent to infestation, as discussed earlier (Hirth (1980). There was a significant difference in the number of disintegrated eggs between infested and un-infested nests, with a higher number of disintegrated eggs in infested nests.

The dipterans that infest turtle nests are thought to locate the nests by olfactory cues (Lopes, 1982; Acuna-mesen and Hanson, 1990). This suggests that the flies are more likely to locate nests with disintegrated eggs in them due to the strong smell, and therefore are also attracted to nests with lower hatching success, which are more likely to have a higher proportion of disintegrated eggs in them. This could explain why the hatching success was lower in infested nests, not as a result of the infestation, but rather as a nest condition that attracts the dipterans.

The results show that infested nests were significantly shallower to the top of the egg chamber. The most common species of fly found in the nests (*Megaselia scalaris,* table 7.7), as well as several others, deposit their eggs (or, in the case of viviparous species, larvae) on the surface of the sand and the larvae burrow down to the egg chamber (Lopes, 1982, Iversen and Perry, 1994). The shallower depth of sand to the nest chamber would make it easier for the larvae to reach the nest, and also to detect the smell of rotting eggs. It is unlikely that the adult flies would be able to detect a nest other than by olfactory signals.

It seems most likely that the dipteran larvae do not cause death within nests. The alternative hypothesis would be that the infesting dipteran larvae are the cause of the larger number of disintegrated eggs in the nests, and that they cause lower hatching success within nests by damaging developing eggs and hatchlings. However, from the results presented, personal observation (SRL) and findings from other studies, it is proposed that the dipterans most likely are attracted to nests containing already decaying matter by olfactory signals, and that the larvae feed on the carrion within the nest, rarely doing damage to healthy hatchlings and eggs. The fact that only a small number (mean of 2.54, 2.1 %) of the eggs in the nest were infested suggests that these were the eggs already decomposing and producing the olfactory cues that attract the adults flies to the nest. McGowan et al. (2001a) found that levels of egg infestation were never more than 1 % of the eggs in each nest and concluded that the low percentage of infested eggs related to the fly larvae only infesting already decaying matter, since if healthy eggs and hatchlings were attacked, the proportion of the nest that was infested would be expected to be higher.

It is interesting to note that significantly more nests in the zone at the back of the beach were infested than in the two zones closer to the sea. The zone at the front of the beach had the smallest proportion of infested nests with a lower number of infested nests than expected (chi-squared test); the middle zone had slightly more with almost an equal number to expected, and the zone at the back had much higher than expected. This suggests that nests near the forest at the back of the beach are more likely to become infested with dipteran larvae. This cannot be accounted for by lower hatching success in the zone at the back of the beach as there was no difference in hatching success in any of the beach zones. It may be that the adult flies prefer to hunt for suitable nests closer to the safety and shade of the forest, rather than venture out onto the open beach. McGowan et al. (2001b) reported that certain flies infesting turtle nests in Cyprus are carrion feeders that scavenge along the strand of the beach, feeding on carcasses washed up by the sea and that it could be expected that nests located nearer to the sea would be more likely to be infested. This was not the case on Trinidad's north coast. However, several of the species are different in the two locations.

7.5 Conclusions and conservation implications

The nest success of leatherbacks on the north coast of Trinidad is affected mostly by inundation by fresh water and tides, erosion from fresh water outflows, and predation. Some nests are also affected by unfavourable conditions in the nest environment, but it is believed that this is less likely to cause the death of an entire nest, and therefore has more of an effect on the hatching success of individual nests. Inundation and erosion are completely natural threats and very little can be done about the level of destruction by these events. It is likely that leatherbacks have evolved their nesting behaviour to contend with these threats relating to their preferred dynamic nesting beaches by laying more clutches with relatively smaller (in terms of body size) eggs than other sea turtles, and spreading them out over a number of locations.

Inundation and erosion appear to contribute more to nest loss than predation does. The level of nest and hatchling predation on the remoter beaches is very low, with only natural predators present. The levels of nest loss on different beaches differ depending on the topography and human-related characteristics, but as a whole, approximately half of the nests on the north coast survive to produce hatchlings. The level of predation is much higher on beaches in villages as there are a large number of stray dogs around, digging up nests and eating hatchlings.

Approximately 12 % of the successful leatherback nests on the north coast beaches were infested with a high diversity of dipteran species larvae although they were not thought to affect hatching success, even although there was a significant difference of hatching success in infested and un-infested nests. The dipteran larvae were not believed to cause direct death of eggs or hatchlings. Red ants were found to cause the death of healthy hatchlings within successful nests, but the small number of nests that they attack is unlikely to have an important affect on overall hatchling production. Nests that had a shallower depth to the top of the nest chamber, and nests that were further back on the beach nearer the forest, were more likely to be infested, as were nests that contained a higher number of disintegrated eggs, most likely by emanating a smell that the flies are attracted to.

The factors that were found to significantly affect hatching success of leatherback nests on the north coast beaches were the viable clutch size and the nest depth. These factors are most likely to have an effect because of how they influence the micro-environment within the nest. Although not tested here, sand particle size may also have a significant effect on hatching success for the same reasons. Nest placement in regards to the backing vegetation and the high water mark had no effect on hatching success, nor did the time of season the clutch was laid. Therefore, it is believed that leatherbacks have evolved to specifically place their nests within the open sand region nearer to the high water mark than the back of the beach (as found in this study), but to place them there randomly; perhaps for reasons other than nest hatching success, such as hatchling sea finding ability (Kamel and Mrosovsky, 2004). The statement that "there is no pattern to nest placement because there is no pattern to nest loss" (Eckert, 1987) seems appropriate.

Leatherbacks nests are thought to have a lower hatching success compared to other sea turtle species (Bell et al., 2003). However, the hatching success reported here is much higher than many other leatherback rookeries. For conservation purposes, it is important to maximise hatching success, and increase the number of hatchlings that reach the seas (Bell et al., 2003). This has been done using hatcheries in a number of places where the mean hatching success is particularly low (Girondot et al., 1990; Mortimer, 1999; Van de Merwe et al., 2005). Identifying the reasons for leatherback embryonic death and the reported low hatching success elsewhere could contribute to conservation efforts (Ralph et al., 2005), perhaps by aiding the construction and monitoring of hatcheries, and reasoning behind position choice for the relocation of doomed nests. However, a hatchery does not seem particularity appropriate for Trinidad. All of the high density nesting, apart from Grande Riviere is located on the remoter beaches where the main threats are natural. The best thing to do in terms of hatchling production would be to leave the beaches undisturbed as hatching success appears to be naturally high for leatherback nests. Human encroachment currently threatens these beaches (chap.3), and any development carried out should be sensitive to nests and hatchlings.

8. Conclusions

This study has turned out to be very timely in identifying a major nesting area for leatherbacks that had not previously been assessed properly. I have been able, through the four years monitoring reported here, to:

- assess the size of the nesting leatherback population on the north coast (chap.4)
- estimate the smaller numbers of nesting hard-shell species nesting on the north coast (chap.5)
- assess the existing threats to the nesting turtles (chap.5, 6 and 7)
- estimate the qualities of the different north coast beaches that contribute to different levels of nest and hatching success (chap.3 and 7)

It is clear that the north coast leatherbacks are of international importance for the conservation of this critically endangered species. It also appears, from my assessment of past north coast records, that numbers have significantly increased in recent years. However, this increase is threatened mainly by the incidental capture of both male and female adults by the active artisanal gillnet fishery based in the villages of the north coast.

In this short concluding chapter, I bring together ideas for future action. The major recommendations discussed in the thesis are:

- continued monitoring of the north coast beaches, including tagging (chap.2 and 4)
- changes in the fishing industry that help maintain the livelihood of the fishermen but seriously reduce bycatch (chap.6)
- the importance of calculating the longevity of adult leatherbacks and the recruitment of first time nesting leatherbacks into the nesting population so that we can have a better idea of the effects of threats such as by-catch on the sustainability of adult population - this is clearly a difficult task given the many unknown aspects of leatherback ecology (chap.4 and 6)
- assessment of the legal hard-shell fishery, including genetic sampling to determine which nesting population the foraging turtles belong, and to re-introduce careful monitoring of the fishery (chap.5)
- to review the laws concerning sea turtles in Trinidad (chap.2, 4 and 5)

However, there are potential future threats to the north coast turtles. The most obvious is the proposal to complete the north coast road between Blanchisseuse and Matelot. It is clear from the existence of high density nesting of leatherbacks at Grande Riviere that turtle nesting is not incompatible with human-related developments. However, the beach at Grande Riviere is monitored to protect the turtles, and new developments have been reasonably sensitively sited to reduce such hazards as beach lighting. Despite these precautions, Grande Riviere is by no means ideal for turtles, particularly the incidence of predation by dogs.

From the experience of Grande Riviere, I suggest that any major development on the north coast must be carefully designed to keep the road and any buildings well back from the beaches. There should be stringent restrictions on artificial lighting, and access to the beaches during the nesting season should be legally restricted, as it is on other Trinidad high density nesting beaches, such as Matura.

Although many conservationists might regard completion of the north coast road as a disaster, as far as the turtles are concerned, it could be an improvement over the current unsatisfactory situation at Paria bay, where partial extension of the road has allowed much larger numbers of people to gain access in a completely unregulated manner, generating litter and poor behaviour towards turtles. An official, well-managed development on the north coast has at least the potential to have good conservation practice built in.

A feature of my work that has not been fully reported in this thesis is my investigation of the ecotourism potential of the north coast turtles. My concept was that the turtles might be best protected by a situation where the local people have a strong self-interest in such protection. Since leatherback meat is not a serious economic resource, the most obvious benefit the local people could derive from turtles is by guiding paying visitors to observe nesting turtles, as an example of a spectacular piece of natural history. Such an economic benefit is already available to the communities of Matura (east coast) and Grande Riviere (north coast) where visitors pay for a permit and a tour guiding fee, under schemes set up by the Government's Wildlife Section in collaboration with local NGOs.

The problem for the remoter north coast beaches is that it is much harder for visitors to gain access to them. The concept behind our Darwin Initiative project was to turn this disadvantage into an asset, by promoting turtle watching on the beaches as an adventure. The project worked with a community group based in Matelot and provided turtle and tour-guiding training for them. The project also arranged three ecotourism packages that brought a total of 37 people (a school group, a "gap" year group and an older group) to the north coast. The feedback from the pilot ecotours was overwhelmingly positive.

However, there are some evident problems concerning ecotourism of this sort as a sustainable development on the north coast. First, there is a total lack of tourist infrastructure in Matelot: the nearest guest house/hotels are in Grande Riviere. Second, Trinidad in general and the north and northeast coast in particular, has a poorly developed international tourist industry. Most of the visitors to the turtle beaches at Matura and Grande Riviere are currently locals and not willing to pay the level of prices that would make adventurous ecotourism profitable. Thirdly, the possible completion of the north coast road is clearly incompatible with the kind of adventure-based ecotourism that we have investigated. It would be helpful to the people of Trinidad's north coast if a decision on whether or not to develop this road could be made soon, so that people knew what kind of economic development to invest in.

References

Ackerman, R.A. 1980. Physiological and ecological effects of gas exchange by sea turtle eggs. American Zoologist 20:575-583.

Ackerman, R.A. 1991. Physical factors affecting the water exchange of buried reptile eggs. In: Egg Incubation: Its Effects on Embryonic Development in Birds and Reptiles. Deeming, D.C. and Ferguson, M.W.J. (Editors). Cambridge University Press, New York. pp. 193-212.

Ackerman, R.A. 1994. Temperature, time, and reptile egg water exchange. Israel Journal of Zoology 40:293-306.

Ackerman, R.A. 1997. The nest environment and the embryonic development of sea turtles. In: Lutz, P.L. and Musick, J. (Editors). The biology of sea turtles. Boca Raton. CRC Pres. pp 83-106.

Acuna-Messen, R.A. and Hanson, P.E. 1990. Phorid fly larvae as predators of turtle eggs. Herpetological Review. 21 13-14.

Acuna, M.T., Diaz, G., Bolandos, H., Barquero, C., Sanchez, O., Sanchez, L.M., Mora, G., Chaves, A. and Campos, E. 1999. Sources of *Vibrio mimicus* contamination of turtles eggs. Applied and Environmental Microbiology 65:336-338.

Aiken, J. J., Godley, B.J., Broderick, A.C., Austin, T., Ebanks-Petrie, G. and Hays, G.C. 2001. Two hundred years after a commercial marine turtle fishery: the current status of marine turtles nesting in the Cayman Islands. Oryx 35:145-151.

Åkesson, S., Broderick, A.C., Glen, F., Godley, B.J. Luschi, P., Papi, F. and Hays, G.C. 2003. Navigation by green turtles: which strategy do displaced adults use to find Ascension Island? Oikos 103:363-372.

Alfaro-Shigueto, J., Alava, J., Montes, D., Onton, K. and Van Bressem, M.-F. 2002. Incidental fisheries of sea turtles in the southern Pacific. Proceedings of the 21st Symposium on Sea Turtle Biology and Conservation, Philadelphia, Pennsylvania, March 2001. NOAA Technical Memorandum.

Alfaro-Shigueto, J., Dutton, P.H., Vega, D., Mangel, J.C., Santillan, L. and de Paz, N. In press. Records of leatherback turtle bycatch from Peru. Proceedings of the 24th Symposium on Sea Turtle Biology and Conservation, Costa Rica, February, 2004. NOAA Technical Memorandum.

Allard, M.W., Miyamoto, M.M., Bjorndal, K.A. and Bowen, B.W. 1994. Support for natal homing in green turtles from mtDNA sequences. Copeia 1994:34-41.

Allen, C.R., Forys, E.A., Rice, K.G. and Wojcik. 2001. Effects of fire ants (Hymenoptera: formicidae) on hatchling turtles and prevalence of fire ants on sea turtle nesting beaches in Florida. Florida Entomologist 84:250-253.

Andrade, R. M., Flores, R. L., Fragosa, S. R., LoÁ pez, C. S., Sarti, L. M., Torres, M. L. and VaÁ squez, L. G. B. 1992. EŒecto de las larvas de diptero sobre el huevo y las crias de tortuga marina en el playon de Mexiquillo, MichoacaÂ. In Benabib N. M. and Sarti, L. M. (Editors). Memorias Del VI Encuentro Interuniversitario Sobre Tortugas Marinas en MeÂ xico, pp. 27- 37.

Andrews, H. and Shanker, K. 2002. A significant population of leatherbacks in the Indian Ocean. Kachhapa 6:19.

Bache, S.J. 2003. Bycatch mitigation tools: selecting fisheries, setting limits, and modifying gear. Ocean and Coastal Management 46:103-125.

Bache, S.J. 2002. Turtles, tuba and treaties: Strengthening the links between international fisheries management and marine species conservation. Journal of International Wildlife Law and Policy 5:49-64.

Bacon, P.R. 1967. Leatherback turtles. Living World: Journal of Trinidad Field Naturalist Club 1967:2-3.

Bacon, P.R. 1969. Report of the Trinidad sea turtle conservation project. Annual report. Living World: Journal of Trinidad Field Naturalist Club 1969:18-35.

Bacon, P.R. 1970. Studies on the leatherback turtle (*Dermochelys coriacea*) in Trinidad, West Indies. Biological Conservation 2:213-217.

Bacon, P.R. 1971. Sea turtles in Trinidad and Tobago. IUCN publications, New Series, Supplemental Paper. No.31 pp. 79-84.

Bacon, P.R. 1973a. The status and management of the sea turtle resources of Trinidad and Tobago. Report to the Ministry of Agriculture, Lands and Fisheries, Trinidad and Tobago. 40 pp.

Bacon, P.R. 1973b. The orientation circle in the beach ascent crawl of the leatherback turtle *Dermochelys coriacea* in Trinidad. Herpetologica 29:343-348.

Bacon, P.R. 1975. Review on research, exploitation and management of the stocks of sea turtles in the Caribbean region. No.334:19. F.A.O. Fisheries Circular.

Bacon, P.R. 1976. Follow the turtle star. Living World: Journal of Trinidad Field Naturalist Club 1976:12-16.

Bacon, P.R. 1981. The status of sea turtle stocks management in the Western Central Atlantic. WECAF Studies no.7. Interregional Fisheries Development and Management Programme, Panama. 38 pp.

Bacon, P.R., and Maliphant, G.K. 1971. Further studies on sea turtles in Trinidad and Tobago. Living World: Journal of Trinidad Field Naturalist Club 1971:2-17.

Bain, R.E., Jewell, S.D., Schwagerl, J. and Neely, B.S. Jr. 1997. Sea turtle nesting and reproductive success at the Hobe Sound National Wildlife Refuge (Florida), 1972-1995. Report to the US Fish and Wildlife Service, ARM Loxahatchee NWR.

Balasingam, E. 1967. The ecology and conservation of the leathery turtle, *Dermochelys coriacea* in Malaysia. Micronesia 3:37-43.

Baran, I., özdemir, A., Çetin, I. And Turkozan, O. 2001. Impact of some invertebrates on eggs and hatchlings of the Loggerhead Turtle, *Caretta caretta*, in Turkey. Zoology in the Middle East 24:9-17.

Bass, A.L. 1999. Genetic analysis to elucidate the natural history and behaviour of hawksbill turtles (*Eretmochelys imbricata*) in the wider Caribbean: a review and re-analysis. Chelonian Conservation and Biology 3:195.

Bass, A.L. and Witzell, W.N. 2000. Demographic composition of immature green turtles (*Chelonia mydas*) from the east central Florida coast: evidence from mtDNA markers. Herpetologica 56:357-367.

Bass, A.L., Lagueux, C.J., Bowen, B.W. (1998). Origins of green turtles, *Chelonia mydas*, at "sleeping rocks" off the northern coast of Nicaragua. Copeia 1998:1064-1069.

Baum, J.K., Myers, R.A, Kehler, D.G., Worm, B., Harley, S.J. and Doherty, P.A. 2003. Collapse and conservation of shark population in the Northwest Atlantic. Science 299:389-392.

Bell, B.A., Spotila, J.R., Paladino, R.V. and Reina, R.D. 2003. Low reproductive success of Leatherback turtle, *Dermochelys coriacea*, is due to embryonic mortality. Biological Conservation 115:131-138.

Bell, C.D.L., Parsons, J., Austin, T.J., Broderick, A.C., Ebanks-Petrie, G. and Godley, B.J. 2005. Some of them came home: the Cayman Turtle Farm headstarting project for the green turtle *Chelonia mydas*. Oryx 39:137-148.

Billett, F.S., Collins, P., Goulding, D.A. and Sutherland, J. 1992. The development of *Caretta caretta* at 25-34°C in artificial nests. Journal of Morphology 213:251-263.

Binckley, C.A., Spotila, J.R., Wilson, K.S. and Paladino, F.V. 1998. Sex determination and sex ratios of Pacific leatherback turtles, *Dermochelys coriacea*. Copeia 1998:291-300.

Bjorndal, K.A., Carr, A., Meylan, A.B. and Mortimer, J.A. 1985. Reproduction biology of the hawksbill, *Eretmochelys imbricata*, at Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. Biological Conservation 34:353-368.

Bjorndal, K.A. and Carr, A. 1989. Variation in clutch size and egg size in the green turtle nesting population at Tortuguero, Costa Rica. Herpetologica 45:181-189.

Bjorndal, K.A., Bolton, A.B. and Lagueux, C.L. 1993. Decline of the nesting population pf hawksbill turtles at Tortuguero, Costa Rica. Conservation Biology 7:925-927.

Bjorndal, K.A., Whetherall, J.A., Bolten, A. and Mortimer, J.A. 1999. Twenty six years of green turtle nesting at Tortuguero Costa Rica: an encouraging trend. Conservation Biology 13:126-134.

Blamires, S.J. and Guinea, M.L. 1998. Implications of nest site selection on egg predation at the sea turtles rookery at Fog Bay. Marine turtle conservation and management in Northern Australia. Centre for Indigenous Natural and Cultural Resource Management and Centre for Tropical Wetlands Management, Northern Territory University. Darwin, Northern Territory, Australia.

Bolton, A.B. 1999. Techniques for measuring sea turtles. Research and Management Techniques for the Conservation of Sea Turtles. K.L. Eckert, K.A. Bjorndal, F.A. Abreu-Grobois, M. Donnelly (Editors). pp. 110-114.

Bolton, A.B., Martins, H.R. Isidro, E., Ferreira, R., Santos, M., Giga, A., Reiwald, B. and Bjorndal, K.A. 2001. Results of an experiment to evaluate effects of hook type on sea turtle bycatch in the swordfish longline fishery in the Azores. In: First Mediterranean Conference on Marine Turtles, 24-28 October 2001. Margaritoulis, D. (Editor). IUCN SSC Marine Turtle Specialist Group and Istituto Centrale Ricerca Applicata al Mare (ICRAM).

Booth, D.T and Astill, K. 2001. Incubation temperature, energy expenditure and hatchling size in the green turtle (*Chelonia mydas*), a species with temperature–sensitive sex determination. Australian Journal of Zoology 49:289-396.

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

Bowen, B. W., Kamezaki, N., Limpus, C.J., Hughes, G.R., Meylan, A.B. and Avise, J. C. 1994. Global phylogeography of the loggerhead turtle *(Caretta caretta)* as indicated by mitochondrial DNA haplotypes. Evolution 48:1820–1828.

Bowen, B.W., Bass, A.L., Garcia-Rodriguez, A., Diez, C.E., Van Dam, R., Bolten, A., Bjorndal, K.A., Miyamoto, M.M. and Ferl, R.J. 1996. Origin of hawksbill turtles in a Caribbean feeding area as indicated by genetic markers. Ecological Applications 6:566-572.

Bowen, B.W., Bass, A.L., Chow, S.M., Bostrom, M., Bjorndal, K.A., Bolten, A.B., Okuyama, T., Bolker, B.M., Epperly, S., Lacasella, E., Shaver, D., Dodd, M., Hopkins-Murphy, S.R., Musick, J.A., Swingle, M., Rankin-Baransky, K., Teas, W., Witzell, W.N. and Dutton, P.H. 2004. Natal homing in juvenile loggerhead turtles (*Caretta caretta*). Molecular Ecology 13:3797-3808.

Brackett, D. 1997. No red alert over conservation Red Lists. Nature 389:904.

Broderick D., Moritz, C., Miller, J.D., Guinea, M., Prince, R.J., and Limpus, C.J. 1994. Genetic studies of the hawksbill turtles *Eretmochelys imbricata*: evidence for multiple stocks in Australian waters. Pacific Conservation Biology 1:123

Broderick, A.C. and Hancock, G.E. 1997. Insect infestation of Mediterranean marine turtle eggs. Herpetological review 28:190-191.

Broderick, A.C., Godley, B.J. and Hays, G.C. 2000a. Metabolic heating and the prediction of sex ratios for green turtles (*Chelonia mydas*). Physiological and Biochemical Zoology 72:161-170.

Broderick, A.C., Godley, B.J., Reece, S., and Downie, J.R. 2000b. Incubation periods and sex ratios of green turtles: highly female biased hatchling production in the eastern Mediterranean. Marine Ecology Progress Series 202:2273-2281.

Broderick, A.C. Godley, B.J. and Hayes, G.C. Trophic status drives interannual variability in nesting numbers of marine turtles. Proceedings of the Royal Society 268:1481-1487.

Broderick, A.C., Glen, F., Godley, B.J. and Hays, G.C. 2002. Estimating the number of green and loggerhead turtles nesting annually in the Mediterranean. Oryx 36:1-9.

Broderick, A.C., Frauenstein, R., Glen, F., Hays, G.C., Jackson, A.L., Pelembe, T., Ruxton, G.D. and Godley, B.J. 2006. Are green turtles globally endangered? Global Ecology and Biogeography 15:21–26.

Brown, H.H. 1942. The sea fisheries of Trinidad and Tobago. Development and Welfare Bulletin 2:45.

Buhlmann, K.A., and Coffman, G. 2001. Fire ant predation of turtle nests and implications for the strategy of delayed emergence. Journal of the Elisha Mitchell Scientific Society 117:94-100.

Bustard, H. R. and Greenham, P. 1968. Physical and chemical factors affecting hatching in the green turtle, *Chelonia mydas*. Ecology 49:269-276.

Bustard, H.R. and Tognetti, K.P. 1969. Green sea turtles: a discrete simulation of density-dependent population regulation. Science 163:939.

Caillouet, C.W., Duronslet, Jr. M.J., Landry, A.M., Revera, Jr.D.B., Shaver, D.J., Stanley, K.M., Heinly, R.W. and Stabenau, E.K. 1991. Sea turtle strandings and shrimp fishing effort in the northwestern Gulf of Mexico 1986-89. Fishing Bulletin U.S 89:712-718.

Caldwell, D.K. and Caldwell, M.C. 1969. Addition of the leatherback sea turtle to the known prey of the killer whale, *Orcinus orca*. Journal of Mammals 50:636.

Canin, J. 1991. International trade aspects of the Japanese hawksbill shell ("bekko") industry. Marine Turtle Newsletter 54:17-21.

Carrillo, E., Webb, G.J.W. and Manolis S.C. 1999. Hawksbill turtles (*Eretmochelys imbricata*) in Cuba: An assessment of the historical harvest and its impacts. Chelonian Conservation and Biology 3:264-280.

Carr, A.F. 1956. The Windward Road. Alfred Knopf, New York, 258 pp.

Carr, A.F. 1957. Notes on the zoogeography of the Atlantic sea turtles of the genus *Lepidochelys*. Revista de Biologia Tropical 1:45-61.

Carr, A. and Ogren, L. 1959. The ecology and migrations of sea turtles, 3. *Dermochelys* in Costa Rica. American Museum Novitates 1958:1-29.

Carr, A.F. 1965. The navigation of the green turtle. Scientific American 212:78.

Carr, A. F. 1975. The Ascension Island green turtle colony. Copeia 1975:547–555.

Carr, A., and Stancyk, S. 1975. Observations on the ecology and survival outlook of the hawksbill turtle. Biological Conservation 8:161-172.

Carr, A., Carr, M.H., and Meylan A.B. 1978. The ecology and migrations of sea turtles, 7. The West Caribbean green turtle colony. Bulletin of the American Museum of Natural History 162:1-46.

Carr, A.F. and Meylan, A.B. 1980. Evidence of passive migration of green turtle hatchlings in sargassum. Copeia 1980:366-368.

Carretta, J.V. 2002. Preliminary estimates of cetacean mortality in California gillnet fisheries for 2001. Report SC/54SM12 Southwest Fisheries Science Centre. NOAA, U.S. National Marine Fisheries Service. 8604 La Jolla Shores Drive. CA 92037 USA. 22 pp.

Catry, P., Barbosa, C., Indjai, B., Almeida, A., Godley, B.J. and Vie, J.C. 2002. First census of the green turtle at Poilão, Bijagos Archipelago, Guinea-Bissau: the most important nesting colony on the Atlantic coast of Africa. Oryx 36:400-403.

Caut, S., Hulin, V. and Girondot, M. 2006. Impact of density-dependent nest destruction on emergence success of Guianan leatherback turtles (*Dermochelys coriacea).* Animal Conservation 9:189-197.

Chacon, D., McLarney, W., Ampie, C. and Venegas, B. 1996. Reproduction and conservation of the leatherback turtle *Dermochelys coriacea* (Testudines:Dermochelyidae) in Gandoca, Costa Rica. Revista de Biologia Tropical 44:853-860.

Chacón, D. 2004. Caribbean hawksbills – An introduction to their biology and conservation status. WWF-Regional Program for Latin America and the Caribbean, San José, Costa Rica. ISBN 9968-825-27-1 Digital publication available at www.hawksbillwwf.org

Chan, E.H., Liew, H.C. and Mazlan, A.G. 1988. The incidental capture of sea turtles in fishing gear in Terengganu, Malaysia. Biological Conservation 43:1-7.

Chan, E.H. Eckert, S.A., Liew, H.C and Eckert, K.L. 1990. Locating the inter-nesting habitats of leatherback turtles (*Dermochelys coriacea*) in Malaysian waters using radio telemetry. In: Biotelemetry XI. Proceedings of the 11th International Symposium on Biotelemetry, Uchiyama, A. and Amlaner, C.J. (Editors). pp. 133-138.

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

Chaves, G., Morera, R., Avilés, J.R., Castro, J.C., Alvarado, M. in press. Trends of the Nesting Activity of the "Arribadas" of the Olive Ridley (*Lepidochelys olivacea*, Eschscholtz 1829), in the Ostional National Wildlife Refuge (1971-2003).

Cheng, I.J. and Chen, T. 1997. The incidental capture of five species of sea turtle by coastal setnet fisheries in the eastern waters of Taiwan. Biological Conservation 82:235-239.

Chevalier, J. and Girondot, M. 2000. Recent population trend for *Dermochelys coriacea* in French Guiana. Proceedings of the 18th International Symposium on Sea Turtle Biology and Conservation, pp. 56-57.

Chevalier, J. 2001. Etude des captures accidentelles de tortues marines liées á la pêche au filet dérivant dans l'ouest Guyanais. Office National de la Chasse at de la Faune Sauvage, Paris.

Chu Cheong, L. 1984. The national report for the country of Trinidad and Tobago to the Western Atlantic Turtle Symposium, San Jose, Costa Rica, July 1983. In: Proceedings of the Western Atlantic Turtle Symposium. P. Bacon et al. (Editors). pp. 398-408.

Chu Cheong, L. 1990. Studies on the leatherback turtle (*Dermochelys coriacea*) in Trinidad. Caribbean Marine Studies 1:48-53.

Chu Cheong, L. 1995. Report on the sea turtle project 1981-1983 (Unpublished report). Research report of the Institute of Marine Affairs, Trinidad and Tobago. 75 pp.

Chua, T. H. and Furtado, J. I. 1988. Nesting frequency and clutch size in *Dermochelys coriacea* in Malaysia. Journal of Herpetology 22:208–218.

COSEWIC. 2001. COSEWIC assessment and update status report on the leatherback turtle *Dermochelys* in Canada. Committee on the status of endangered wildlife in Canada, Ottawa. 25 pp.

Corliss, L.A., Richardson, J.I., Ryder, C. and Bell, R. 1989. The hawksbills of Jumby Bay, Antigua, West Indies. In: Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology, Eckert, S.A., Eckert, K.L. and Richardson, T.H. (Editors). NOAA Tech. Memo. NMFS/SEFC-232. pp. 33-36.

Crain, D. A., Bolton, A. B. and Bjorndal, K. A. 1995. Effects of beach renourishment on sea turtles: review and research initiatives. Restoration Ecology 3:95-104.

Crowder, L.B., Hopkins-Murphy, S.R. and Royle, J.A. 1995. Effects of turtle excluder devices (TEDS) on loggerhead sea turtle strandings with implications for conservation. Copeia 1995:773-779.

Cropp, B. 1979. Where ocean giants meet. Oceans 12:43-47.

Daniels, R.C., White, T.W. and Chapman, K.K. 1993. Sea-level rise: destruction of threatened and endangered species habitat in South Carolina. Environmental Management 17:373.

Davenport, J. and Balazs, G.H. 1991. "Fiery bodies" - are pyrosomas an important component of the diet of leatherback turtles? Herpetological Society Bulletin 37:33-38.

Davenport, J. 1997. Temperature and the life-history strategies of sea turtles. Journal of Thermal Biology 22:479-488.

Dean, J.M. and Talbert, O.R. 1975. The loggerhead turtles of Kiawah Island. Environmental inventory of Kiawah Island. Columbia, South Carolina: Environmental Research Centre, Inc. pp. T1-T19.

Disney, R.H.L. 1994. Scuttle flies: the phoridae. Chapman and Hall, London.

Dodd, C.K. Jr. 1988. Synopsis of the biological data on the loggerhead turtle *Caretta caretta* (Linnaeus 1758). U.S. Fish Wildlife Service, Biological Report 88-14. Washington, D.C.

Donnelly, M. 1991. Japan ban import of hawksbill shell effective Dec 1992. Marine turtle Newsletter 54:1-3.

Donlan, E.M., Townsend, J.H. and Golden, E.A. Predation of *Caretta caretta* (Testines: Cheloniidae) eggs by larvae of *Lanelater sallei* (Coleoptera: Elateridae) on Key Biscayne, Florida. Caribbean Journal of Science 40:415-420.

Drennen, D., Cooley, D. and Devore, J.E., 1989. Armadillo predation on loggerhead turtle eggs at two national wildlife refuges in Florida, USA. Marine Turtle Newsletter 1989:7-8.

Dutton, P., McDonald, D. and Boulon, R. 1994. Tagging and nesting research on leatherback sea turtles (*Dermochelys coriacea*) on Sandy Point, St Croix, U.S. Virgin Islands, 1994. Annual report to the U.S. Fish and Wildlife Service. Contract #PC-P&NR -287-94D.

Dutton, P.H., Bowen, B.W., Owens, D.W., Barragan, A. and Davis, S.K. 1999. Global phylogeography of the leatherback turtle (*Dermochelys coriacea*). Journal of Zoology 248:397-409.

Dutton, D.L., Dutton, P.H., Chaloupka, M. and Boulon, R.H. 2005. Increase of a Caribbean leatherback turtle *Dermochelys coriacea* nesting population linked to long-term nest protection. Biological Conservation 126:186-194.

Dutton P.H. 2006. Building our Knowledge of the leatherback stock structure. The State of the World's Sea Turtles (SWOT) report 1:10-11.

Eckert, S.A., Nellis, D.W., Eckert, K.L. and Kooyman, G.L. 1986. Diving patterns of two leatherback sea turtles (*Dermochelys coriacea*) during inter-nesting intervals at Sandy Point, St Croix, U.S. Virgin Islands. Herpetologica 42:381-388.

Eckert, E.L. 1987. Environmental unpredictability of leatherback turtle nest loss. Herpetologica 43:315-323.

Eckert, K. and Eckert, S. 1988. Pre-reproductive movements of leatherback sea turtles (*Dermochelys coriacea*) nesting in the Caribbean. Copeia 2:400-406.

Eckert, K.L., Eckert, S.A., Adams, T.W. and Tucker, A.D. 1989a. Inter-nesting migrations by leatherback sea turtles (*Dermochelys coriacea*) in the West Indies. Herpetologica 45:190-194.

Eckert, S.A., Eckert, K.L., Ponganis, P. and Kooyman, G.L. 1989b. Diving and foraging behaviour of leatherback sea turtles (*Dermochelys coriacea*). Canadian Journal of Zoology 67:2834-2840.

Eckert, K.L and Eckert, S.A. 1990. Embryo mortality and hatch success in in-situ and translocated leatherback sea turtle (*Dermochelys coriacea*) eggs. Biological Conservation 53:37-46.

Eckert, K.A. 1992. Five year status reviews of sea turtles listed under the Endangered Species Act of 1973: hawksbill sea turtle *Eretmochelys imbricata.* U.S. Fish and Wildlife Service P.O. No. 20181-1-0060.

Eckert, S.A. 1997. Dive behaviour and post nesting migration of the leatherback sea turtles (*Dermochelys coriacea*) nesting on Matura beach, Trinidad. Draft report. Trinidad and Tobago Wildlife Section. 17 pp.

Eckert, S.A. and Sarti, L.M. 1997. Distant fisheries implicated in the loss of the world's largest leatherback nesting population. Marine Turtle Newsletter 78:2-7.

Eckert, S.A. 1998. Perspectives on the use of satellite telemetry and other electronic technologies for the study of marine turtles, with reference to the first year-long tracking of leatherback sea turtles. In: Proceedings of the 17th Annual Sea Turtle Symposium. S.P. Epperly and J. Braun (eds.). NOAA Technical Memorandum NMFS-SECF-415, Miami. pp. 46-47.

Eckert, S.A., and Lien, J. 1999. Recommendations for eliminating incidental capture and mortality of leatherback turtles (*Dermochelys coriacea*) by commercial fisheries in Trinidad and Tobago: A report to the Wider Caribbean Sea Turtle Conservation Network (WIDECAST). Hubbs-Sea World Research Institute, Technical Report no. 2000-310. 7 pp.

Eckert, K.L. 2001. Status and distribution of the leatherback turtle *Dermochelys coriacea*, in the wider Caribbean region. In: Marine turtle conservation in the wider Caribbean region: A dialogue for effective regional management. K.L. Eckert, F.A. Abreu Grobois (Editors). WIDECAST, IUCN/Species Survival Commission Marine Turtle Specialist Group, WWF and UNEP-Caribbean Environment programme. pp. 24-31.

Eckert, S.A. and Eckert, K.L. 2005. Size and status of insular Caribbean leatherback nesting populations. Atlantic Leatherback Strategy Retreat.

http://www.cccturtle.org/leatherbacks/agenda.htm

Eckert, S.A. 2006. High-use oceanic areas for Atlantic leatherback sea turtles (*Dermochelys coriacea*) as identified using satellite telemetered location and dive information. Marine Biology

Eckert, S.A., Bagley, D., Kubis, S., Ehrhart, L., Johnson, C., Stewart, K. and Defreese, D. 2006. Inter-nesting, post-nesting movements and foraging habitats of leatherback sea turtles (*Dermochelys coriacea*) nesting in Florida. Chelonia Conservation Biology (in press).

Encalada, S.E., Lahanas, P.N., Bjorndal, K.A., Bolton, A.B., Miyamoto, M.M. and Bowen, B.W. 1996. Phylogeography and population structure of the Atlantic and Mediterranean green turtle *Chelonia mydas*: a mitochondrial DNA control region sequence assessment. Molecular Ecology 5:473-483.

Engeman, R.M., Martin, R.E., Constantin, B., Noel, R. and Woolard, J. 2003. Monitoring predators to optimize their management for marine turtle nest protection Biological Conservation 113:171-178.

Epperly, S.P., Braun, J., Chester, A.J., Cross, F.A., Merriner, J.V., Tester, P.A. and Churchill, J.H. 1996. Beach strandings as an indicator of at-sea mortality of sea turtles. Bulletin of Marine Science 59:289-297.

Epperly, S.P. 2003. Fisheries-related mortality and turtle excluder devices (TEDs). In: The biology of sea turtles, volume 2, Lutz, P.L. Lutz, Musick, J.A and Wyneken, J. (Editors). CRC Press. pp. 339-535.

Ehrhart, L.M. 1979. A survey of marine turtles nesting at the Kennedy Space Centre, Cape Canaceral Air Force Station, North Brevard County, Florida Department of Natural Resources. Report. 122 pp.

Ehrhart, L.M. 1982. A review of sea turtle reproduction. In: Biology and Conservation of Sea Turtles. K.A. Bjorndal (Editor). Smithsonian Institution Press, pp. 28-38.

Ewert, M.A. 1979. The embryo and its egg: Development and natural history. In: Harless, M. and Morlock, H. (Editors). Turtles: perspectives and research. New York J Wiley and Sons. Pp 333-413.

FAO (Food and Agriculture Organisation of the United Nations), 2004. Report of the expert consultation on interactions between sea turtles and fisheries within an ecosystem context. Rome, Italy, 9-12 March 2004. FAO Fisheries Report. No. 738. 37 pp.

Fergusson, I.K., Compagno, L.J.V. and Marks, M.A. 2000. Predation by white sharks *Carcharodon carcharias* (Chondrichthyes: Lamnidae) upon chelonians, with new records from the Mediterranean Sea and a first record of the ocean sunfish *Mola mola* (Osteichthyes: Molidae) as stomach contents. Environmental Biology of Fishes 58: 447-453.

Ferraroli, S., Georges, J.Y., Gasper, P. and Le Maho, Y. 2004. Where leatherbacks meet fisheries. Nature 429:521-522.

Fessl, B. And Tebbich, S. 2002. *Philornis downsi* - a recently discovered parasite on the Galapagos archipelago - a threat for Darwin's finches? IBIS 144:445-451.

Fish, M.R., Cote, I.M., Gill, J.A., Jones, A.P., Renshoff, S. and Watkinson, A.R. 2005. Predicting the impact of sea-level rise on Caribbean sea turtle nesting habitat. Conservation Biology 19:482-491.

Fitzsimmons, N.N. 1998. Single paternity of clutches and sperm storage in the promiscuous green turtle (*Chelonia mydas*). Molecular Ecology 7:575-584.

Formia, A. 1999. Les tortues marines de la Baie de Corisco. Canopee 14:1-2

Fortes, O., Pires, A.J. and Bellini, C. 1998. Green turtle, *Chelonia mydas* in the island of Poilão, Bolama-Bijagos Archipelago, Guinea-Bissau, West Africa. Marine Turtle Newsletter 80: 8-10.

Fournillier, K. 1992. Marine turtle conservation in Trinidad and Tobago. Wildlife Section, Forestry Division, Ministry of Agriculture, Lands and Food Production, Trinidad and Tobago. 70 pp.

Fournillier, K. 1995. Civilian conservation corps join in sea turtle conservation in Trinidad. Marine Turtle Newsletter 70:11-12.

Fournillier, K. 1996. Marine turtle conservation in Trinidad and Tobago - A summary report. Wildlife Section, Forestry Division, Ministry of Agriculture, Lands and Food Production, Trinidad and Tobago. 12 pp.

Fournillier, K., and Eckert, K.L. 1997. WIDECAST sea turtle recovery action plan for Trinidad and Tobago. CEP Technical Report no.38. UNDP Caribbean Environment Programme, Kingston, Jamaica. 131 pp.

Fowler, L. 1979. Hatching success and predation in the green sea turtles *Chelonia mydas*, at Tortuguero, Costa Rica. Ecology 60:946-955.

Frazier, J. and Salas, S. 1984. The status of marine turtles in the Egyptian Red Sea. Biological Conservation 30:41-67.

Frazer, N.B. and Richardson, J.I. 1985. Annual variation in clutch size and frequency for loggerhead turtles, *Caretta caretta*, nesting at Little Cumberland Island, Georgia, USA. Herpetologica 41:246-251.

Fretey, J. and Billes, A. 2000. Les plagues du sud Gabon: dernière grande zone de reproduction la planète pour la tortue-luth? Canopèe 17:I-IV.

Fretey, J. and Girondot, M. 1989. L'activité de onte de la tortue luth, *Dermochelys coriacea* (Vandelli, 1761), pendant la saison 1988 en Guyane française. Revue d'Ecologie (la Terre et la Vie) 44:261-274.

Garrison, L.P. 2003. Estimated bycatch of marine mammals and turtles in the U.S. Atlantic pelagic longline fleet during 2001-2002. NOAA Technical Memorandum NMFS-SEFSC-515. 52 pp.

Gaskin, M.R. 1994. Sea turtles and their habitats in Trinidad and Tobago and the Caribbean. Pointe-a-Pierre Wild Fowl Trust of Trinidad and Tobago. 60 pp.

Georges, C. 1983. A coastal classification for Trinidad. Institute of Marine Affairs, Trinidad and Tobago, West Indies. IMA/5/83. 110 pp.

Georges, C. and Greenidge, B. 1983. The composition and texture of beach sediments of Trinidad, West Indies. The Institute of Marine Affairs Trinidad and Tobago, West Indies. 24 pp.

Georges, A., Limpus, C. and Stoutjesdijk, R. 1994. Hatchling sex in the marine turtle *Caretta caretta* is determined by proportion of development at temperature, not daily duration of exposure. Journal of Experimental Zoology 270:432-444.

Gerrodette, T. and Taylor, B.L. 1999. Estimating population size. In: K.L. Eckert, K.A. Bjorndal, F.A. Abreu-Grobois & M. Donnelly (Editors). Research and Management Techniques for the Conservation of Sea Turtles. Marine Specialist Group Publications, pp. 67-71.

Girondot, M. and Fretey, J. 1996. Leatherback turtles, *Dermochelys coriacea*, nesting in French Guiana, 1987-1995. Chelonian Conservation and Biology 2:204-208.

Girindot, M., Fretey, J., Proutaeu, I. and Lescure, J. 1990. Hatchling success for Dermochelys in a French Guiana hatchery. In: Proceedings of the tenth Annual Workshop on sea turtle biology and conservaton, Richardson, T.H., Richardson, J.I., and Donnelly, M (Editors). NOAA Technical report NMFS-SEFC-278. pp. 229-232.

Girondot, M., Tucker A. D., Rivalan, P., Godfrey, M. H. and Chevalier. J. 2002. Density-dependent nest destruction and population fluctuations of Guianan leatherback turtles. Animal Conservation 5:75-84.

Girondot, M., Godfrey, M.H., Ponge, L. and Rivalan, P. 2005. Historical records and trends of leatherbacks in French Guiana and Suriname. Chelonian Conservation Biology (in press).

Godfrey, M.H. and Barreto, R. 1995. Beach vegetation and sea-finding orientation of turtle hatchlings. Biological conservation 74:29-32.

Godfrey, M.H., Barreto, R. and Mrosovsky, N. 1996. Estimating past and present sex ratios of sea turtles in Suriname. Canadian Journal of Zoology 74:67-277.

Godfrey, M. H., Barreto, R. and Mrosovsky, N. 1997. Metabolically-generated heat of developing eggs and its potential effect on sex ratio of sea turtle hatchlings. Journal of Herpetology 31:616-619.

Godfrey, M.H., D'Amato, A.F., Marcovaldi, M.A. and Mrosovsky, N. 1999. Pivotal temperature and predicted sex ratios for hatchling hawksbill turtles from Brazil. Canadian Journal of Zoology 77:1465-1473.

Godley, B.J., Kirkwood, K., Raffan, S., and Taylor, R. 1989. Nesting activity of the leatherback turtle (*Dermochelys coriacea*) in Trinidad, with an assessment of sources of disturbance. J.R. Downie (Editor). Glasgow University Trinidad Expedition Report 1989. University of Glasgow. pp. 62-75.

Godley, B., A. Broderick, S. Blackwood, L. Collins, K. Glover, C. Mcaldowie, D. McCulloch, and J. McLeod. 1991. Studies on marine turtles in Trinidad and Tobago. J.R. Downie (Editor). Glasgow University Trinidad Expedition Report 1991. University of Glasgow. pp. 4.1-4.19.

Godley, B.J., Gücü, A.C., Broderick, A.C., Furness, R.W. and Solomon, S.E. 1998. Interaction between marine turtles and artisanal fisheries in the eastern Mediterranean: a probable cause for concern? Zoology in the Middle East 16:49-64.

Godley, B.J., Kirkwood, K., Raffan, S. and Taylor, R. 2001a. Leatherback turtles in Trinidad. Marine Turtle Newsletter 52:16-17.

Godley, B., Broderick, A., Blackwood, S., Collins, L., Glover, K., Mcaldowie, C., McCulloch, D. and McLeod, J. 2001b. 1991 survey of marine turtles nesting in Trinidad and Tobago. Marine Turtle Newsletter 61:15-18.

Godley, B.J., Broderick, A.C. and Hays, G.C. 2001c. Nesting green turtles (*Chelonia mydas*) at Ascension Island, South Atlantic. Biological Conservation 97:151-158.

Goverse, E. and Hilterman, M.L. 2005. Status of leatherback nesting population in Suriname with notes on leatherback nesting in Guyana and French Guiana. Atlantic Leatherback Strategy Retreat. http://www.cccturtle.org/leatherbacks/agenda.htm

Grant, G.S., Malpass, H. and Beasley, J. 1996. Leatherback turtle and jellyfish surveys on Topsail Island, North Carolina. In: Keinath, J.A., Barnard, D.E., Musick, J.A., Bell, B.A. (Editors). Proceedings of the 15th Annual Workshop on Sea Turtle Biology and Conservation, NOAA Technical Memorandum NMFS-SEFSC. 387:112-115.

Gratiot, N., Gratiot, J., Kelle, L. and de Thoisy, B. 2006. Estimation of the nesting season of marine turtles from incomplete data: statistical adjustment of a sinusoidal function. Animal Conservation 9:95-102.

Groombridge, B. and R. Luxmoore. 1989. The green turtle and hawksbill (Reptilia: Cheloniidae): world status, exploitation and trade. Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Lausanne, Switzerland. 601 pp.

Hall, K.V. 1990. Hatchling success of leatherback turtle (*Dermochelys coriacea*) clutches in relation to biotic and abiotic factors. In: Proceedings of the tenth Annual Workshop on sea turtle biology and conservation, Richardson, T.H., Richardson, J.I., and Donnelly, M (Editors). NOAA Technical report NMFS-SEFC-278. pp 197-199.

Hall, M.A., Alverson, D.L. and Metuzals, K.I. 2000. By-catch: problems and solutions. Marine Pollution Bulletin 41:204-219.

Hanski, I. 1987. Carrion fly community dynamics: patchiness, seasonality and coexistence. Ecological Entomology 12:257-266

Harrison, D. In press. Grande Riviere, Trinidad: From cocoa to conservation? International Institute for Culture, Tourism and Development. London Metropolitan University.

Hawkes, L.A, Broderick, A.C., Coyne, M.S., Godfrey, M.H., Lopez-Jurado, L., Lopez-Suarez, P., Merino, S.E., Varo-Cruz, N. and Godley, B.J. 2006. Current Biology 16:990-995.

Hays, G.C. and Speakman, J.R. 1993. Nest placement by loggerhead turtles, *Caretta caretta*. Animal Behaviour 45:47-53.

Hays, G.C., MacKay, A., Adams, C.R., Mortimer, J.A., Speakman, J.R. and Boerema, M. 1995. Nest site selection by sea turtles. Journal of Marine Biological Association 75:667-674.

Hays, G.C., Broderick, A.C., Godley, B.J., Luschi, P. and Nichols, W.J. 2003. Satellite telemetry suggests high levels of fishing-induced mortality in marine turtles. Marine Ecology Progress Series 262: 305–309.

Hays, G.C., Haughton, J.D.R. and Myers, A.E. 2004. Pan-Atlantic leatherback movements. Nature 429:522.

Heithaus, M.R, Dill, L.M, Marshal, G.J. and Buhleier, B.M. 2002. Habitat use and foraging behaviour of tiger sharks (*Galeocerdo cuvier*) in a seagrass ecosystem. Marine Biology 140: 237-248.

Heithaus, M.R., Frid, A., Wirsing, A.J., Bejder, L. and Dill, L.M. 2005. Biology of sea turtles under risk from tiger sharks at a foraging ground. Marine Ecology Progress Series 288: 285-294.

Hendrickson, J.R. 1958. The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. Proceedings of the Zoological Society of London 130:445-535.

Hendrickson, J.R. and Balasingam, E. 1966. Nesting beach preferences of Malayan sea turtles. Bulletin of the Natural History Museum of Singapore 33:69-76.

Hendrickson, J.R. 1980. The ecological strategies of sea turtles. American Zoologist 29:597-698.

Hendrickson, J.R. 1995. Nesting behaviour of sea turtles with emphasis on physical and behavioural determinants of nesting success or failure. In: K.A. Bjorndal (Editor), Biology and Conservation of Sea Turtles: Revision Edition. Smithsonian Institution Press. pp. 53-57.

Henry, C. and Martin, L. 1992. Description of the artisanal gillnet fishery of Trinidad. Technical report of the project for the establishment of data collection systems and assessment of the fisheries resources. FAO/UNDP: TR1/91/001/TR6. Port of Spain, Trinidad. 35 pp.

Henwood, T.A. and Stuntz, W.E. 1987. Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fishery Bulletin 85:813-817.

Hewavisenthi, S. and Parmenter, C.J. 2002. Incubation environment and nest success of the flatback turtle (*Natator depressus*) from a natural nesting beach. Copeia 2002:302-312.

Hill, R.L. and Green, D.J. 1971. Investigation of the damage by the crab, *Ocypode quadrata*, to the eggs of the green turtle, *Chelonia mydas*. Surinam Turtle Notes 2:11-13.

Hillis, Z. M. 1995. Buck Island Reef National Monument sea turtle research program, 1991. In: Proceedings of the 12th Annual Workshop on Sea Turtle Biology and Conservation. Richardson, J. I. and Richardson, T.H. (Editors). NOAA Tech. Memo. NMFS-SEFSC-361.

Hillstad, H.O., Richardson, J.I., McVea, Jr. C. and Watson, Jr. J.M. 1995. Worldwide incidental capture of sea turtles. In: K.A. Bjorndal. (Editor), Biology and Conservation of Sea Turtles: Revision Edition. Smithsonian Institution Press. pp. 489-496.

Hilterman, M.L. and Goverse, E. 2002. Aspects of nesting and nest success of the leatherback turtle (*Dermochelys coriacea*) in Suriname, 2001. Guianas Forests and Environmental Conservation Project (CFECP). Technical Report, World Wildlife Fund Guianas/Biotopic Foundation, Amsterdam, the Netherlands, 34 pp.

Hilterman, M.L. and Goverse, E. 2005. Annual report on the 2004 leatherback turtle research and monitoring project in Suriname. WWF - Guianas forests and environment conservation project (WWF_GFECP). Technical report of the Netherlands Committee for IUCN (NC-INCN). Amsterdam, the Netherlands, 18 pp.

Hirth, H. F. 1980. Some aspects of the nesting behaviour and reproductive biology of sea turtles. American Zoologist 20:507–523.

Hirth, H. F. 1997. Synopsis of the biological data on the green turtle, *Chelonia mydas* (Linnaeus 1758). United States Fish and Wildlife Service Biological Report 97-1. 120 pp.

Hughes, G.R. 1974. The sea turtles of South-east Africa II. Investigational Report no. 36 of the Oceanographic Research Institute, Durban, South Africa.

Hughes, G. R. 1982. Conservation of sea turtles in the Southern Africa Region. In: K. A. Bjorndal (Editor) Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C. pp. 397-404.

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

Hodgkinson-Clarke, F. 1994. The construction and operations of artisanal gillnets in Trinidad. Fisheries Occasional Paper Series No.3. Fisheries Division, Ministry of Agriculture, Land and Marine Resources. Trinidad and Tobago. 49 pp.

Hoekert, W.E.J., Schouten, A.D., Van Tienen, L.H.G. and Weijerman, M. 1996. Is the Suriname olive ridley on the eve of extinction? First census data of olive ridleys, green turtles and leatherbacks since 1989. Marine Turtle Newsletter 75:1-4.

Horrocks, J.A. and Scott, N.M. 1991. Nest-site location and nest success in the Hawksbill turtle *Eretmochelys imbricata* in Barbados, West Indies. Marine Ecology Progress Series 69:1-8.

Horrocks, J.A., Vermeer, L.A, Krueger, B., Coyne, M., Schroeder, B.A., and Balazs G.H. 2001. Migration routes and destination characteristics of post-nesting hawksbill turtles satellite-tracked from Barbados, West Indies. Chelonian Conservation and Biology 4:107-114

Hunt, R.E.B. 1949. Survey of Trinidad fisheries. Fisheries Division, Port of Spain, 2 pp.

IMA (Institute of Marine Affairs). 2004. A guide to beaches and bays of Trinidad and Tobago. Institute of Marine Affairs. Trinidad and Tobago. 133 pp.

Imray-lolaire. 2003. North coast of Trinidad and Golfo de Paria. Charts for the Caribbean and Atlantic Ocean. Imray Laurie Norie and Wilson Ltd, St Ives, England.

Ingle, M. and Smith, F.G.W. 1949. Sea turtles and the turtle industry of the West Indies, Florida and the Gulf of Mexico. Special Publication of the University of Miami. Florida. 107 pp.

IUCN (International Union for Conservation of Nature and Natural Resources). 2005. Red list of threatened species. http://www.redlist.org/

Iverson, J.B. and Perry, R.E. 1994. Sarcophagrid fly parasitoidism on developing turtle eggs. Herpetological Review. 25 50-51.

James, C. 1983. The leatherback turtle. In: Highlighting Wildlife – basic information on wildlife conservation in Trinidad and Tobago. Forestry Division Document, Ministry of Agriculture, Land and Food Production. pp. 41-44.

James, C. and Fournillier, K. 1993. Marine turtle management in north-east Trinidad – a successful community based approach toward endangered species conservation. A case study prepared with funding from the Caribbean Natural Resources Institute. Wildlife Section, Forestry Division, Ministry of Agriculture, Land and Marine Resources, Trinidad and Tobago. 33 pp.

James, M.C., Ottensmeyer, C.A. and Myers, R.A. 2005a. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. Ecology Letters 8:195-201.

James, M.C., Meyers, R.A. and Ottensmeyer, C.A. 2005b. Behaviour of leatherback sea turtles, *Dermochelys coriacea,* during the migratory cycle. Proceedings of the Royal Society 272:1547-1555.

James, M., Eckert, S.A. and Myers, R.A. 2005c. Migratory and reproductive movements of male leatherback turtles (*Dermochelys coriacea*). Marine Biology 147:845-853.

Johannes, R.E. and Rimmer, D.W. 1984. Some distinguishing characteristics of nesting beaches of the green turtle *Chelonia mydas* on North West Cape Peninsula, Western Australia. Marine Biology 83:149-154.

Joyner, C.C and Tyler, Z. 2000. Marine conservation versus international free trade: reconciling dolphins with tuna and sea turtles with shrimp. Ocean Development and International Law 31:127–150.

Kalb, H. and Owens, D. 1994. Differences between solitary and arribada nesting olive ridley females during the inter-nesting period. In K.A. Bjorndal, .B. Bolten, D.A. Johnson, and P.J. Eliazar (Editors). Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351. pp. 68.

Kalb, H.J. 1999. Behaviour and physiology of solitary and arribada nesting olive ridley sea turtles (*Lepidochelys olivacea*) during the inter-nesting period. PhD thesis. Texas A&M University, Collage Station, TX.

Kaplan, I.C. 2005. A risk assessment for Pacific leatherback turtles (*Dermochelys coriacea*). Canadian Journal of Fisheries and Aquatic Science 62:1710-1719.

Kamel, S.J. and Mrosovsky, N. 2004. Nest site selection in leatherbacks, *Dermochelys coriacea*: individual patterns and their consequences. Animal Behaviour 68:357-366.

Kamel, S.J. and Mrosovsky, N. 2005. Repeatability of nesting preferences in the hawksbill sea turtle, *Eretmochelys imbricata*, and their fitness consequences. Animal Behaviour 70:819-828.

Kaska, Y., Downie, R., Tippett, R. and Furness, R.W. 1998. Natural temperature regimes for loggerhead and green turtle nests in the eastern Mediterranean. Canadian Journal of Zoology 76:723-729.

Kikukawa, A., Kamezaki, N., Hirate, N. and Ota, H. 1996. Distribution of nesting sites of sea turtles on Okinawajima and adjacent islands of the central Ryukyus, Japan. Chelonian Conservation and Biology 2:99-101.

Kikukawa, A., Kamezaki, N. and Ota1, H. 1999. Factors affecting nesting beach selection by loggerhead turtles (*Caretta caretta*): a multiple regression approach. Journal of Zoology 249:447-454.

King, G. W. 1982. Historical review of the decline of the green turtle and Hawksbill. In: K. A. Bjorndal (Editor) Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C. pp. 183-188.

Kopitsky, K., Pitman, R.L. and Plotkin, P. 2000. Investigations on at-sea mating and reproductive status of olive ridleys, *Lepidochelys olivacea*, captured in the eastern tropical Pacific. In: Proceedings of the 19th Annual Symposium on Sea Turtle Biology and Conservation. H. Kalb and T. Wibbels (Editors). NOAA Technical Memorandum. NMFS-SEFSC-443. pp. 160.

Kraemer, J.E. and Bell, R. 1980. Rain- induced mortality of eggs and hatchlings of loggerhead sea turtles (*Caretta caretta*) on the Georgia coast. Herpetologica 36:72-77.

Lagarde, F., Le Corre, M. and Lormee', H. 2001. Species and sex-biased predation on hatchling green turtles by frigatebirds on Europa Island, Western Indian Ocean. The Condor 103:405-408.

Lahanas P.N., Miyamoto, M.M., Bjorndal, K.A. and Bolton, A.B. 1994. Molecular evolution and population genetics of greater Caribbean green turtles (*Chelonia mydas*) as inferred from mitochondrial DNHA control region sequences. Genetica 94:57-67.

Lahanas P.N., Bjorndal, K.A., Bolton, A.B., Encalada, S.E., Miyamoto, M.M., Valverde, R.A. and Bowen, B.W. 1998. Genetic composition of a green turtle feeding ground population: evidence for multiple origins. Marine Biology 130:345-352.

Lagueux, C.J. 1998. Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends. PhD Dissertation, University of Florida, Gainesville.

Lamoreux, J., Akcakaya,H.R., Bennun, L., Collar, N.J., Boitani, L., Brackett, D., Brautigam, D., Brooks, T.M., De Fonseca, G.A.B., Mittermeier, R.A., Rylands, A.B., Gärdenfors, U., Hilton-Taylor, C., Mace, G., Stein B.A. and Stuart, S. 2003. Value of the IUCN Red List. Trends in Ecology and Evolution 18:214-215.

Lazell, J.D. 1980. New England waters: critical habitat for marine turtles. Copeia 1980:290-295.

León, Y.M. and Bjorndal, K.A. 2002. Selective feeding in the hawksbill turtle, an important predator in coral reef ecosystems. Marine Ecology progress Series 245:249-258.

Leslie, J.A., Penick, D.N., Spotila, J.R. and Paladino, F.V. 1996. Leatherback turtle, *Dermochelys coriacea*, nesting and nest success at Tortuguero, Costa Rica, in 1990-1991. Chelonian Conservation and Biology 2:159-168.

Lewison, R.L., Crowder, L.B., Shaver, D.J. 2003. Impact of Turtle Excluder Devices and fisheries closures on loggerhead and kemps ridley strandings in the Western North Atlantic. Conservation Biology 17:1089-1097.

Lewison, R.L., Freeman, S.A. and Crowder, L.B. 2004a. Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. Ecology Letters 7:221-231.

Lewison, R.L., Crowder, L.B., Read, A.J. and Freeman, S.A. 2004b. Understanding impacts of fisheries bycatch on marine megafauna. Trends in Biology and Evolution 19:598-604.

Limpus, C. J. 1985. A study of the loggerhead sea turtle, *Caretta caretta*, in eastern Australia. Ph.D. Dissertation, University of Queensland, St Lucia, Australia.

Limpus, C.J., Miller, D.J., Paramenter, C.J., Reimer, D., McLachlan, N. and Webb, R. 1992. Migration of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtle to and from eastern Australian rookeries. Wildlife Research 19:347-357.

Limpus, C.J. 1993. The green turtle, *Chelonia mydas*, in Queensland; breeding males in the southern Great Barrier Reef. Wildlife Research 20:513-523.

Limpus, C.J., Parmenter, J., and Limpus, D.J. 2002. The status of the flatback turtle, *Natator depressus*, in Eastern Australia. In: Proceedings of the Twentieth Annual Symposium on Sea **Turtle** Biology and Conservation. A. Mosier, A. Foley and B. Brost. (Editors) NOAA Tech. Memo.NMFS-SEFSC-477, pp. 140-142.

Livingstone, S.R. Rudd, S., Barr, J., Jamieson, D. and Archibald, K. 2000. Marine turtle conservation. In: S.R. Livingstone (Editor), University of Glasgow Trinidad Expedition 2000 – Final report. Glasgow University Exploration Society, University of Glasgow. Scotland. pp. 17-33.

Livingstone, S.R. 2005. Report of olive ridley (*Lepidochelys olivacea*) nesting on the north coast of Trinidad. Marine Turtle Newsletter 109:6.

Livingstone S.R., and J.R. Downie. 2005. Marine turtle conservation on the north coast of Trinidad - a Darwin Initiative project. Testudo 6:3-16.

Lohmann, K., Witherington, B., Lohmann, C. and Salmon, M. 1997. Orientation, navigation and natal beach homing in sea turtles. In: The biology of sea turtles. P. Lutz and J. Musick (Editors). CRC Press, Boca Raton, Florida. pp. 107–136.

Luke, K., Horrocks, J.A., LeRoux, R.A. and Dutton, P.H. 2004. Origins of green turtle (*Chelonia mydas*) feeding aggregations around Barbados, West Indies. Marine Biology 144:799-805.

Lum, L.L., Lima, E.M. and Santos, A. 1998. Green turtle tagged in Brazil recovered in Trinidad. Marine Turtle Newsletter 82:9.

Lum, L.L. 2001. Sea turtle research and conservation in Trinidad and Tobago. Institute of Marine Affairs. 7 pp.

Lum, L.L. 2003. An assessment of incidental turtle catch in the gillnet fishery in Trinidad and Tobago, West Indies. National Fish and Wildlife Foundation, USA/Institute of Marine Affairs, T&T. Project #00-026-055. 22 pp.

Lum, L.L. 2005. Beach dynamics and nest distribution of the leatherback turtle (*Dermochelys coriacea*) at Grande Riviere Beach, Trinidad & Tobago. Revista de Biologia Tropical 53:239-248.

Luschi, P. Hays, G.C. del Seppia, C., Marsh, R. and Papi, F. 1998. The navigational feats of green sea turtles migrating from Ascension Island investigated by satellite telemetry. Proceedings of the Royal Society 265:2279-2284.

Macys, S. and Wallace, G.N. 2003. Marine turtle conservation on Holbox Island, Quintana Roo, Mexico: the fishermen's perceptions. Chelonian Conservation and Biology 4:620-625.

Magnuson, J.J., Bjorndal, K.A., Dupaul, W.D., Graham, G.L., Owens, D.W., Peterson, C.H., Pritchard, P.C.H., Richardson, J.I., Sual, G.E., and West, C.W. 1990. Decline of the sea turtles: Causes and prevention. National Academy Press, Washington, D.C. 259 pp.

Maharaj, A.M. 2004. A comparative study of the nesting ecology of the leatherback turtle *Dermochelys coriacea* in Florida and Trinidad. University of Central Florida. Unpublished Master of Science thesis. 80 pp.

Maloney, J.E., Darian-Smith, C., Takahashi, Y. and Limpus, C.J. 1990. The environment for development of the embryonic loggerhead turtle (*Caretta caretta*) in Queensland. Copeia 1990:378-387.

Marcovaldi, M.A., Godfrey, M. and Mrosovsky, N. 1997. Estimating sex ratios of loggerhead turtles in Brazil from pivotal incubation durations. Canadian Journal of Zoology 75:755-770.

Marcovaldi, M.A. 2001. Status and distribution of the olive ridley turtle, *Lepidochelys olivacea*, in the Western Atlantic Ocean. In: Marine turtle conservation in the wider Caribbean region: A dialogue for effective regional management. Editors: Karen L. Eckert and F. Alberto Abreu Grobois. pp. 52-56.

Marquez, M.R. 1990. Sea turtles of the world. FAO Species catalogue 11, FAO Fish Synopsis 125, Food and Agriculture Organisation of the United Nations, Rome. 81 pp.

Maros, A., Louveaux, A., Godfrey, M.H. and Girondot, M. 2003. *Scapteriscus didactylus* (Orthoptera, Gryllotalpidae), predator of leatherback turtle eggs in French Guiana Marine Ecology Progress Series 249:289-296.

Maros, A., Louveaux, A., Liot, E., Marmet, J. and Girindot, M. 2005. Identifying characteristics of *Scapteriscus* spp. (Orthoptera: Gryllotalpidae) apparent predators of marine turtle eggs. Community and Ecosystem Ecology 34:1063-1070.

Martin, T.E. 1988. Nest placement: implications for selected life-history traits, with special reference to clutch size. American Naturalist 132:900-910.

Martin, K. and James, M.C. 2005. Conserving sea turtles in Canada: Successful community-based collaboration between fishers and scientists. Chelonia Conservation and Biology 4:899-907.

Maxwell J.A., Motara, A.A and Frank, G.H. 1988. A micro-environmental environmental study of the effect of temperature on the sex ratios of the loggerhead turtle, *Caretta caretta*, from Tongaland, Natal. South African Journal of Zoology 23:342-350.

McDonald, D.L. and P.H. Dutton. 1994. Use of Pit tags to identify adult leatherbacks. Marine Turtle Newsletter 67:13-14.

McDonald, D.L. and P.H. Dutton. 1996. Use of PIT tags and photo-identification to revise remigration estimates of leatherback turtles (*Dermochelys coriacea*) nesting in St Croix, U.S. Virgin Islands, 1979-1995. Chelonian Conservation and Biology 2:148-152.

McGehee, M.A. 1990. Effects of moisture on eggs and hatchlings of loggerhead sea turtles (*Caretta caretta*). Herpetologica 46:251-258.

McGowan, A., Broderick, A.C., Deemings, J., Godley, B.J. and Hancock, E.G. 2001a. Dipteran infestation of loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtle nests in northern Cyprus. Journal of Natural History 35:573-581.

McGowan, A., Rowe, L.V., Broderick, A.C. and Godley, B.J. 2001b. Nest factors predisposing loggerhead sea turtle (*Caretta caretta*) clutches to infestation by dipteran larvae on Northern Cyprus. Copeia 2001:808-812.

Meylan, A. 1982a. Estimation of population size in sea turtles. In: Biology and Conservation of Sea Turtles. K.A. Bjorndal (Editor). Smithsonian Institution Press, pp. 135-138.

Meylan, A. 1982b. Sea turtle migration - evidence from tag returns In: Biology and Conservation of Sea Turtles. K.A. Bjorndal (Editor). Smithsonian Institution Press. pp. 91.

Meylan, A. 1988. Spongivory in hawksbill turtles: a diet of glass. Science 239:393.

Meylan, A. 1989. Status report of the hawksbill turtle. In: L. Ogren, F. Berry, K. Bjorndal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham, (Editors). Proceedings of the second western Atlantic turtle symposium. NOAA Technical Memorandum NMFS/SEFC-226. On file at U.S. Fish and Wildlife Service, South Florida Ecosystem Office; Vero Beach, Florida. pp. 101-115.

Meylan, A. 1998. Hawksbill turtles still endangered. Nature 391:117.

Meylan, A. B. 1999. Status of the hawksbill turtle (*Eretmochelys imbricata*) in the Caribbean region. Chelonian Conservation and Biology 3:177-184.

Meylan, P.A., Bowen, B.W. and Avise, J.C. 1990. A genetic test of the natal homing versus social facilitation models for green turtle migration. Science 248:724.

Meylan, A. B. and Donnelly, M. 1999. Status justification for listing the hawksbill turtle (*Eretmochelys imbricata*) as Critically Endangered on the 1996 IUCN Red List of Threatened Animals. Chelonian Conservation and Biology 3:200-224.

Mike, A., and Cowx, I.G. 1996. A preliminary appraisal of the contribution of recreational fishing to the fisheries sector in north west Trinidad. Fisheries Management and Ecology 3:219-228.

Miller J.D. 1985. Embryology of marine turtles. In: Gans, C., Billett, F. and Maderson, P.F.A. (Editors). Biology of the Reptilia. New York Wiley-Intersceince. pp. 269-328.

Miller, J.D. 1997. Reproduction in sea turtles. In: The Biology of Sea Turtles. P. Lutz and J.A. Musick (Editors). CRC Press, Boca Raton, Florida, USA, pp. 51-81.

Miller J.D., Dobbs, K.A., Limpus, C.J., Mattocks, N. and Landry, A.M. 1998. Long distance migrations by the hawksbill turtle, *Eretmochelys imbricata*, from north-eastern Australia. Wildlife Research 25:89-95.

Miller, J. D., Limpus, C. L. and Godfrey, M. H. 2003. Nest site selection, oviposition, eggs, development, hatching, and emergence of loggerhead sea turtles. In: Ecology and Conservation of Loggerhead Sea Turtles, Bolten, A. B. and Witherington, B. E. (Editors). Gainesville, Florida: University Press of Florida. pp. 125-143.

Milliken, T. and Tokunaga, H. 1987. The Japanese sea turtle trade 1970-1986. Prepared by TRAFFIC (JAPAN) for Centre for Environmental Education, Washington DC. 171 pp.

Mohammed, E. and Shing, C.C.A. 2003. Trinidad and Tobago: Preliminary reconstruction of fisheries catches and fishing effort, 1908 - 2002. Fisheries Centre Research Reports.

Trinidad Fisheries Division. Ministry of Agriculture, Land and marine Resources. St Clair Circle, Port of Spain, Trinidad, West Indies Vol.11. pp. 117-132.

Moncada-G, F., Rodriguez, A.M., Marquez-M.R. and Carrillo, E. 2000. Report of the olive ridley turtle (*Lepidochelys olivacea*) in Cuban waters. Marine Turtle Newsletter 90:13-15.

Mootoosingh. 1979. The growth of conservation awareness in Trinidad and Tobago (1765 to 1979). Occasional Paper no. 3. Department of Zoology, University of the West Indies, St Augustine, Trinidad.

Morreale, S.J., Ruiz, G.J., Spotila, J.R. and Standora, E.A. 1982. Temperature-dependent sex determination: current practices threaten conservation of sea turtles. Science 216:1245-1247.

Moriera, L. Baptistotte, C., Scalfone, J., Thome, J.C. and De Almeida, A.P.L.S. 1995 Occurrence of *Chelonia mydas* on the island of Trinidad, Brazil. Marine Turtle Newsletter 70:2.

Morizur, Y., Berrow, S.D., Tregenza, N.J.C. Couperus, A.S. and Pouvreau, S. 1999. Incidental catches of marine mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research 41:297-307.

Mortimer, J.A. 1981. Reproductive ecology of the green turtle, *Chelonia mydas*, at Ascension Island. PhD. Dissertation. University of Florida.

Mortimer, J.A. 1982a. Factors influencing beach selection by nesting sea turtles. In: Biology and Conservation of Sea Turtles. K.A. Bjorndal (Editor). Smithsonian Institution Press. pp. 45-52.

Mortimer, J.A. 1982b. Feeding ecology of sea turtles. In: Biology and Conservation of Sea Turtles. K.A. Bjorndal (Editor). Smithsonian Institution Press. pp. 103.

Mortimer, J.A. and Carr, A. 1987. Reproduction and migrations of the Ascension Island green turtle (*Chelonia mydas*). Copeia 1987:103-113.

Mortimer, J. A. and Carr, A. 1984. Reproductive ecology and behaviour of the, green turtle (*Chelonia mydas*) at Ascension Island. National Geographic Society Research Reports 17:257-270.

Mortimer, J.A. 1990. The influence of beach sand characteristics on the nesting behaviour and clutch survival of green turtles (*Chelonia mydas*). Copeia 1990:802-817.

Mortimer J.A. 1999. Reducing Threats to Eggs and Hatchlings: Hatcheries. In: Research and Management Techniques for the Conservation of Sea Turtles, K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Mrosovsky, N and Yntema, C.L. 1980. Temperature dependence of sexual differentiation in sea turtles: implications for conservation practices. Biological Conservation 18:271-80.

Mrosovsky, N. 1983a. Ecology and nest-site selection of the leatherback turtles *Dermochelys coriacea*. Biological Conservation 26:47-56.

Mrosovsky, N. 1983b. Conserving Sea Turtles. British Herpetological Society, London. 177 pp.

Mrosovsky, N., Hopkins-Murphy, S.R. and Richardson, J.I. 1984. Sex ratio of sea turtles: seasonal changes. Science 225:739.

Mrosovsky, N. 1988. Pivotal temperatures for loggerhead turtles (*Caretta caretta*) from northern and southern nesting beaches. Canadian Journal of Zoology 66:661-669.

Mrosovsky, N. and Provancha, J. 1989. Sex ratio of loggerhead sea turtles hatching on a Florida beach. Canadian Journal of Zoology 67:2533-2539.

Mrosovsky, N. 1994. Sex ratios of sea turtles. Journal of Experimental Zoology 270:16-27.

Mrosovsky, N. 1997. IUCN's credibility critically endangered. Nature 389:436.

Mrosovsky, N. 1998. Plight of hawksbill turtles. Nature 392:646.

Mrosovsky, N. 2003. Predicting extinction: fundamental flaws in the IUCN's Red List system, exemplified by the case of sea turtles. http://members.seaturtle.org/mrosovsky

Mrosovsky, N. 2004. Conceptual problems with the IUCN Red and Evolution Listing assessment for the green turtle: Move over Raine Island. Marine Turtle Newsletter 106:1–3.

Mrosovsky, N., Bapistotte, C. and Godfrey, M.H. 1999. Validation of incubation durations an as index of sex ratios of sea turtles. Canadian Journal of Zoology 77:831-835.

Murphy, J.C. 1997. Amphibians and reptiles of Trinidad and Tobago. Krieger Publishing. Malabar, Florida.

Murphy, T.M. and Hopkins-Murphy, S.R. 1989. Sea turtle and shrimp fishing interaction: a summary and critique of relevant information. Centre for Marine Conservation, Washington, D.C. 52 pp.

Nathai-Gyan, N., James, C. and Hislop, G. 1987. National report for the country of Trinidad and Tobago to the Western Atlantic Turtle Symposium II. Mayaguez, Puerto Rico, USA. October 1987. 228 pp.

National Marine Fisheries Service Southeast Fisheries Science Centre. 2001. Stock assessments of loggerhead and leatherback sea turtles and an assessment of the impact of the pelagic longline fishery on the loggerhead and leatherback sea turtles of the Western North Atlantic. U.S. Department of Commerce NOAA Technical Memorandum NMFSSEFSC. 343 pp.

Packard, G. C., Taigcn, T. L., Packard, M.J. and Boardman, T.J. 1980. Water relations of pliable-shelled eggs of common snapping turtles (*Chelydra serpentina*) Canadian Journal of Zoology 58:1404-1411.

Pandav, B., Choudhury, B.C. and Kar, C.S. 1997. Mortality of olive ridley turtles *Lepidochelys olivacea* due to incidental capture in fishing nets along the Orissa coast, India. Oryx 31:32–36.

Parris, L.B., Lamont, M.M and Carthy, R.R. 2002. Increased incidence of red imported fire ant (hymenoptera:formicidae) presence in loggerhead sea turtle (testudines:cheloniidae) nests and observations of hatchling mortality. Florida Entomologist 83:514-517.

Parkinson, K. 1992. Production costs and revenues for the gillnet fishery of Trinidad, 1991. Fisheries Occasional Paper Series No.1. Fisheries Division, Ministry of Agriculture, Land and Marine Resources. Trinidad and Tobago. 42 pp.

Philippi, T. and Seger, J. 1989. Hedging one's evolutionary bets, revisited. Trends in Ecology and Evolution 4:41-44.

Pitman. R.L. 1990. Pelagic distribution and biology of sea turtles in the eastern tropical Pacific. In: Proceedings of the tenth Annual Workshop on Sea Turtle Biology and Conservation. Richardson, T.H., Richardson, J.I., and Donnelly, M (Editors). NOAA Technical report NMFS-SEFC-278. pp. 143.

Pitman, R.L. and Dutton, P.H. 2004. Killer whale predation on a leatherback turtle in northeast Pacific. Pacific Science 58: 497-498.

Plotkin, P.T. 1994. Migratory and reproductive behaviour of the olive ridley turtle, *Lepidochelys olivacea* (*Eschscholtz*, 1829), in the eastern Pacific Ocean. PhD thesis. Texas A&M University, Collage Station, TX.

Plotkin, P. 2003. Adult migrations and habitat use. In: The Biology of Sea Turtles, Volume 2, P. Lutz, J.A. Musick and J Wyneken (Editors). CRC Press. pp. 225-241.

Plotkin, P.T., Wieksten, M.K. and Amos, A.E. 1993. Feeding ecology of the loggerhead sea turtle *Caretta caretta* in the Northwestern Gulf of Mexico. Marine Biology 115:1-15.

Plotkin, P.T., Byles, R.A., Rostal, D.C. and Owens, D.W. 1995. Independent versus socially facilitated oceanic migrations of the olive ridley, *Lepidochelys olivacea*. Marine Biology 122:137-143.

Plotkin, P.T., Owens, D.W., Byles, R.A. and Patterson, R. 1996. Departure of male olive ridley turtles *Lepidochelys olivacea* from a nearshore breeding ground. Herpetologica 52:1-7.

Plotkin, P.T. and Spotila, J.R. 2002. Post natal migrations of loggerhead turtles *Caretta caretta* from Georgia, USA: conservation implications for a genetically distinct sub-population. Oryx 36:396-399.

Pritchard, P.C.H. 1969. Sea turtles of the Guianas. Bulletin of the Florida State Museum, Biological Series 13:85-140.

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

Pritchard, P.C.H. 1973. International migrations of South American sea turtles (Cheloniidae and Dermochelidae). Animal Behaviour 21:18-27.

Pritchard, P.C.H. 1976. Post-nesting movements of marine turtles (Cheloniidae and Dermochelidae) tagged in the Guianas. Copeia 1976:749-754.

Pritchard, P.C.H. 1982. Nesting of the leatherback turtle, *Dermochelys coriacea,* in Pacific Mexico, with a new estimate of the world population. Copeia 1982:741-747.

Pritchard, P.C.H. 1984. Marine Turtles in Trinidad and Tobago. Report on a consultancy to the Food and Agriculture Organisation (FAO) for preparation of plans for the management of marine turtles. 34 pp.

Pritchard, P.C.H. and Plotkin, P.T. 1995. Olive ridley sea turtle. In: National Marine Fisheries Service and U.S. Fish and Wildlife Service. Status reviews of sea turtles listed under the Endangered Species Act of 1973. National Marine Fisheries Service, Silver Spring, Maryland. pp. 123-139.

Pritchard, P.C.H. 1996. Are leatherbacks really threatened with extinction? Chelonia Conservation and Biology 2:303-305.

Pritchard, P.C.H. 1979. Encyclopedia of turtles. Tropical Fish Hobbyist Publications, Neptune, New Jersey.

Pritchard P.C.H. 1997. Evolution, phylogeny, and current status. In: The Biology of Sea Turtles, P.L. Lutz and J.A. Musick, (Editors). CRC Marine Science Series, CRC Press, Inc., Boca Raton, Florida. pp. 1-28.

Pritchard, P.C.H. 2004. A comment upon Nicholas Mrosovsky's Essay: Predicting extinction: fundamental flaws in IUCN's Red List system, exemplified by the case of sea turtles. Posted on CTURTLE 4th Jan 04 http://www.lists.ufl.edu/cgi-bin/wa?A2=ind0401&L=cturtle&O=A&P=1495

Pritchard, P.C.H. and Trebbau, P. 1984. The turtles of Venezuela. Contributions to Herpetology 2. Society for the study of amphibians and reptiles, Fundacion de Inernados Rurales, Caracas, Venezuela.

Provancha, J.A. and Ehrhart, L.M. 1987. Sea turtle nesting trends at Kennedy Space Center and Cape Canaveral Air Force Station, Florida, and relationships with factors influencing nest site selection. In: Ecology of East Florida sea turtles. W.N. Witzell (Editor). NOAA Technical Report NMFS 53, Miami, FL. pp. 33-44.

Ralph, C.R., Reina, R.D., Wallace, B.P., Sotherland, P.R., Spotila, J.R. and Paladino, F.V. 2005. Effect of egg location and respiratory gas concentrations on developmental success in nests of the leatherback turtle, *Dermochelys coriacea*. Austraian Journal of Zoology 53:289-294.

Ratnaswamy, M. J. and Warren, R. J. 1998. Removing raccoons to protect sea turtle nests: are there implications for ecosystem management? Wildlife Society Bulletin 26: 846-850.

Rebel, T.P. 1974. Sea turtles and the turtle industry of the West Indies, Florida and the Gulf of Mexico. University Miami Press, Coral Gables, Florida. 250 pp.

Reichart, H.A. 1993. Synopsis of biological data on the Western Atlantic olive ridley, Lepidochelys olivacea (Eschscholtz, 1829) in the Western Atlantic. NOAA Technical Memo. NMFS-SEFSC-336. US Department of Commerce. 78 pp.

Reichart, H.A. 1989. Status report on the olive ridley turtle. In: L. Ogren, F. Berry, K. Bjornal, H. Kumpf, R. Mast, G. Medina, H. Reichart, and R. Witham (Editors). Proceedings of the Second Western Atlantic Turtle Symposium. NOAA technical Memorandum NMFS-SEFC-226. pp. 270-271.

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

Reina, R.D., Mayor, P.A., Spotila, J.R., Piedra, R. and Palandino, F.V. 2002. Nesting ecology of the leatherback turtle 1988-89 and 1999-2000 at Parque Nacional, Costa Rica. Copeia 2002:653-664.

Reina, R.D., Abernathy, K.J., Marshall, G.J. and Spotila, J.R. 2005. Respiratory frequency, dive behaviour and social interactions of leatherback turtles, *Dermochelys coriacea* during the inter-nesting interval. Journal of Experimental Marine Biology and Ecology 316:1-16.

Richardson, J.I. 1993. Reproductive biology of hawksbills nesting in Antigua. Marine Turtle Newsletter 63:6-7.

Richardson, J. I., Bell, R. and Richardson, T. H. 1999. Population ecology and demographic implications drawn from an 11-year study of nesting hawksbill turtles, *Eretmochelys imbricata*, at Jumby Bay, Long Island, Antigua, West Indies. Chelonian Conservation and Biology 3:244-250.

Rimblot, F., Fretey, J., Mrosovsky, N., Lescure, J. and Pieau, C. 1985. Sexual differentiation as a function of the incubation temperature of eggs in the sea turtle *Dermochelys coriacea* (Vandelli, 1761). Amphibia Reptilia 6:83-72.

Rimblot-Baly, F., Lescure, J., Fretey, J. and Pieau, C. 1987. Temperature sensitivity of sexual-differentiation in the leatherback, *Dermochelys coriacea* (Vandelli, 1761) - data from artificial incubation applied to the study of sex ratio in nature. Annales Des Sciences Naturelles-Zoologie et Bologie Animale 8:277-290.

Rivalan, P. 2005. Maximum likelihood estimates of tag loss in leatherback sea turtles. Journal of Wildlife Management 69:540-548.

Rivalan, P., Dutton, P.H., Baudry, E., Roden, S.E. and Girondot, M. 2006. Demographic scenario inferred from genetic data in leatherback turtles nesting in French Guiana and Suriname. Biological Conservation 130:1-9.

Robins, J.B. 1995. Estimated catch and mortality of sea turtles from the east coast otter trawl fishery of Queensland, Australia. Biological Conservation 74:157–167.

Ross, J.P. 1982. Historical decline of loggerhead, ridley and leatherback sea turtles. In: K.A. Bjorndal (Editor), Biology and Conservation of Sea Turtles: Revision Edition. pp. 189-198.

Ross, J.P. and Barwani, M.A. 1982. Review of sea turtles in the Arabian area. In: Biology and conservation of sea turtles, K. Bjorndal, (Editor). Smithsonian Institution Press, Washington, D.C. pp. 373-383.

Rostal, D.C., Paladino, F.V., Patterson, R.M. and Spotila, J.R. 1996. Reproductive physiology of nesting leatherback turtles (*Dermochelys coriacea*) at Las Baulas National Park, Costa Rica. Chelonian Conservation and Biology 2:230-236.

Salmon, M. 2003. Artificial night lighting and sea turtles. Biologist 50:163-168.

Schierwater, B and Schroth, W. 1996. Molecular evidence for precise natal homing in loggerhead turtles. Bulletin of the Ecological Society of America 77:393-401.

Schultz, J. P. 1975. Sea turtles nesting in Surinam. Zoologische Verhandelingen 143:1-143.

Seidel, W.R. and McVea, Jr.C 1995. Development of a sea turtle excluder shrimp trawl for the southeast U.S. Penaeid shrimp fishery. In: K.A. Bjorndal. (Editor), Biology and Conservation of Sea Turtles: Revised Edition. Smithsonian Institution Press. pp 497-502.

Seminoff, J. 2002. 2002 IUCN Red list global status assessment, green turtle, *Chelonia mydas*. IUCN Marine Turtle Specialist Group Review. 93 pp.

Seminoff, J. 2004a. Green turtle Red List assessment. http://www.iucn-mtsg.org IUCN Species Survival Commission.

Seminoff, J. 2004b. Sea turtles, Red Listing and the need for regional assessments. Marine Turtle Newsletter 106:4-6.

Shabica, S.V. 1995. Planning for protection of sea turtle habitat. In: K.A. Bjorndal (Editor), Biology and Conservation of Sea Turtles: Revision Edition. Smithsonian Institution Press. pp. 513-518.

Sheppard, D.C., Tomberlin, J.K., Joyce, J.A., Kiser, B.C. and Sumner, S.M. 2002. Rearing methods for the black soldier fly (Diptera: Stratiomyidae). Journal of Medical Entomology 39:695-698.

Shoop, C.R. and Ruckdeschel, C. 1982. Increasing turtle strandings in the southeast United States: A complicating factor. Biological Conservation 23:213-215.

Schroeder, B. and Murphy, S. 1999. Population Surveys (ground and aerial) on nesting beaches. In: Research and Management Techniques for the Conservation of Sea Turtles. K. L. Eckert, K. A. Bjorndal, F. A. Abreu-Grobois, M. Donnelly (Editors). IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Shanker, K., Pandav, P. and Choudhury, B.C. 2003. An assessment of the olive ridley turtle (*Lepidochelys olivacea*) nesting population in Orissa, India. Biological Conservation 115:149-160.

Shine, R. 2004. Seasonal shifts in nest temperature can modify the phenotypes of hatchling lizards, regardless of overall mean incubation temperature. Functional Ecology 18:43-49.

Sole, G. and Medina, G. 1989. The green turtles of Aves Island. In: Eckert S.A., Eckert, K.A., Richardson, T.H. (Editors). Proceedings of the ninth annual workshop on sea turtle conservation and biology. NOAA Technical Memorandum NMFS-SEFC-232. pp. 171-173.

Soto, J.M.R., Serafini, T.Z. and Celini, A.A.O. 2003. Beach strandings of sea turtles in the state of Rio Grande Do Sul: an indicator of gillnet interaction along the southern Brazilian coast. In: Seminoff, J.A., (Editor). Proceedings of the 22nd Annual Symposium on Sea Turtle Biology and Conservation, NOAA Technical Memorandum NMFS-SEFSC-503. pp. 276.

Sounguet, G.P., Formia, A. and Parnell, R. 2005. Assessment of leatherback nesting in Gabon by aerial survey. Proceedings of the 25th Annual Symposium on Sea Turtle Biology and Conservation. U.S. Dept. Commerce. NOAA Tech. Memo. In press.

Speakman, J.R., Hayes, G.C. and Lindblad, E. 1998. Thermal conductivity of sand and its effect on the temperature of loggerhead sea turtle (*Caretta caretta*) nests. Journal of Marine Biology Association 78:1337-1352.

Spotila, J.R., Standora, E.A., Morreale, S.J. and Ruiz, G.J. 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., Dunham, A.E., Leslie, A.J., Steyermark, A.C., Plotkin, P. and Paladino. F.V. 1996. Worldwide population decline of *Dermochelys coriacea:* Are leatherback turtles going extinct? Chelonian Conservation and Biology 2:209-222.

Spotila, J.R., Reina, R.D., Steyermark, A.C., Plotkin, P.T. and Paladino, F.V. 2000. Pacific leatherback turtles face extinction. Nature 405:529-530.

Stancyk, S.E. and Ross, J.P. 1978. An analysis of sand from green turtle nesting beaches on Ascension Island. Copeia 1978:93-99.

Stancyk, S.E. 1982. Non-human predators of sea turtles and their control. In: K.A. Bjorndal (Editor), Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, DC. pp. 139-152.

Standora, E.A. and Spotila, J.R. 1985. Temperature-dependent sex determination in sea turtles. Copeia 1985:711-722.

Standora, C. 2003. Management of turtle bycatch: can endangered species be protected while minimizing socioeconomic impacts? Coastal Management 31:423-434.

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

Stockdale, F. 1945. Development and Welfare in the West Indies 1943-1944. His Majesty's Stationery Office, London. Colonial No. 189:35-41.

Stoneburner, D.L. and Richardson, J.I. 1981. Observations on the role of temperature in loggerhead turtle nest site selection. Copeia 1981:238-231.

Sutherland, R.W. and Sutherland, E.G. 2003. Status of the flatback sea turtle (*Natator depressus*) rookery on Crab Island, Australia, with notes on predation by crocodiles. Chelonian Conservation and Biology 4:612-619.

Thompson, N.B., Schmid, J.R., Epperly, S.P., Snover, M.L., Braun-McNeill, J., Witzell, W.N., Teas, W.G., Csuzdi, L.A. and Myers, R.A. 2001. Part II stock assessment of leatherback sea turtles of the Western North Atlantic. NOAA Technical Memorandum NMFS- SEFSC-455, pp. 69-84.

Tomas, J., Castroviejo, J. and Raga, J.A. 1999. Sea turtles in the south of Bioko Island (Equatorial Guinea). Marine Turtle Newsletter 84:4-6.

Troëng, S. 2000. Predation of green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) turtles by jaguars (*Panthera onca*) at Tortuguero National Park, Costa Rica. Chelonian Conservation and Biology 3:751.

Troëng, S., Chacon, D. and Dick, B. 2004. Possible decline in leatherback turtle *Dermochelys coriacea* nesting along the coast of Caribbean Central America. Oryx 38:395-403.

Troëng, S., Dutton, P.H. and Evans, D. 2005. Migration of hawksbill turtles *Eretmochelys imbricata* from Tortuguero, Costa Rica. Ecography 28:394-402.

Troëng, S. and Rankin, E. 2005. Long-term conservation efforts contribute to positive green turtle *Chelonia mydas* nesting trend at Tortuguero, Costa Rica. Biological Conservation 121 111–116

Tuck, G.N., Polacheck, T., Croxall, J.P. and Weimerskirch, H. 2001. Modelling the impact of fishery by-catches on albatross populations. Journal of Applied Ecology 38:1182-1196.

Tucker, A.D. 1989. So many turtles, so little time: Underestimating fecundity and overestimating populations. In: Proceedings of the Ninth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum. NMFS-SEFSC-232, pp. 181-183.

Tucker, A.D. and Frazer, N.B. 1991. Reproductive variation in leatherback turtles, *Dermochelys coriacea*, at Culebra National Wildlife Refuge, Puerto Rica. Herpetologica 47:115-124.

Turtle Expert Working Group. 2000. Assessment Update for the Kemp's Ridley and Loggerhead Sea Turtle Populations in the Western North Atlantic. NOAA Technical Memorandum NMFS-SEFSC-444, Miami, USA.

UNEP. 2003. Report on the status and conservation of the leatherback turtle, *Dermochelys coriacea*. Document prepared by the UNEP Wold Conservation Monitoring Centre. 62 pp.

Valdemarsen, J.W. and Suuronen, P. 2001. Modifying fishing gear to achieve ecosystem objectives. Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem. Reykjavik, Iceland, 1-4 October 2001. 20 pp.

Van Dam, R. and Sarti, L. 1989. Sea turtle biology and conservation on MOM Island, Puerto Rico. Report for 1989. Chelonia, Sociedad Herpetologica de Puerto Rico.

Van de Merwe, J., Ibrahim, K. and Whittier, J. 2005. Effects of hatchery shading and nest depth on the development and quality of Chelonia mydas hatchlings: implications for hatchery management in Peninsular, Malaysia. Australian Journal of Zoology 53:205-211.

Vasquez, L.G.B. 1994. Dipteros de la familia Sarcophagidae que actuan como depredadores de crias de tortunga laud (*Dermochelys coriacea*) en el playon de Maxiquillo, Michoacan. Tesis Facultad de Ciencias Universidad Nacional Autonoma de Mexico. pp. 1-64.

Vincent, H. 1910. The Sea Fish of Trinidad. Press of J.J. Little and Ives Co. New York, 97 pp.

Vogt, R.C. 1981. Turtle egg (Graptemys: *Emydidae*) infestation by fly larvae. Copeia 1981:457-459.

Wallace, B.P, Sutherland, P.R., Spotila, J.R., Reina, R.D., Franks, B.F. and Paladino, F.V. 2004. Biotic and abiotic factors affect the nest environment of embryonic leatherback turtles, *Dermochelys coriacea.* Physiological and Biochemical Zoology 77:423-432.

Watson, J., Foster, D., Epperly, S. and Shah, A. 2003. Experiments in the Western Atlantic northeast distant waters to evaluate sea turtle mitigation measures in the pelagic longline fishery. National Marine Fisheries Service, Pascagoula.

Watson, J.W., Epperly, S.P., Shah, A.K. and Foster, D.G. 2005. Fishing methods to reduce sea turtle mortality associated with pelagic longlines. Canadian Journal of Fisheries and Aquatic Science 62:965-981.

Whitmore, C.P. and Dutton, P.H. 1985. Infertility, embryonic mortality and nest-site selection in leatherback and green sea turtles in Suriname. Biological Conservation 34:251-272.

Wibbels, T. 2003. Critical approaches to sex determination in sea turtles. In: The Biology of Sea Turtles, P. Lutz and J.A. Musick (Editors). CRC Press, Boca Raton, Florida. pp. 103-134.

Williams, K.L. 1996. The effect of nest position and clutch size on the nest environment and hatching success of leatherback sea turtle nests at Playa Grande, Costa Rica. M.S. Thesis. State University of New York, Buffalo, N.Y.

Witham. R. 1982. Disruption of sea turtle habitat with emphasis on human influence. In: K.A. Bjorndal (Editor), Biology and Conservation of Sea Turtles: Revision Edition. pp. 519-522.

Witherington, B.E. 1986. Human and natural causes of marine turtle clutch and hatchling mortality and their relationship to hatchling production on an important Florida nesting beach. M.S. thesis, University of Central Florida, Orlando.

Witherington, B.E. 1992. Behavioural response of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

Witzell, W.N. 1983. Synopsis of biological data on the hawksbill turtles *Eretmochelys imbricata* (*Linnaeus*, 1766). FAO Fisheries Synopsis No.137, FAO, Rome, Italy.

Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. Fishing Bulletin 97:200-211.

Wold, C. 2002. The status of sea turtles under international environmental law and international environmental agreements. Journal of International Wildlife Law and Policy 5:1-10.

Wood, F. and Wood, J. 1993. Release and capture of captive-reared green sea turtles, *Chelonia mydas*, in the waters surrounding the Cayman Islands. Herpetological Review 3:84-89.

Wood, D.W. and Bjorndal, K.A. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. Copeia 2001:119-128.

Woodcock, B.A., Watt, A.D. and Leather, S.R. 2002. Aggregation, habitat quality and coexistence: a case study on carrion fly communities in slug cadavers. Journal of Animal Ecology 71:131-140.

Worth, D.F. and Smith, J.B. 1976. Marine turtle nesting on Hutchinson Island, Florida in 1973. Florida Marine Research Publication 18:1-17.

Wyatt-Smith, J. 1960. The conservation of the leathery turtle. Malayan Nature Journal 1960:194-99.

Yntema, C.L. and Mrosovsky, N. 1980. Sexual differentiation in hatchling loggerheads (*Caretta caretta*) incubated at different controlled temperatures. Herpetologica 36:33-36.

Zug, G.R. and Parham, J.F., 1996. Age and growth in leatherback turtles, *Dermochelys coriacea* (Testudines: Dermochelyidae): a skeletochronological analysis. Chelonian Conservation and Biology 2:224-249.

Appendices

Appendix 1 - Trinidad Marine Turtle Conservation Conference 2003 (TMTCC)

Community Conference

8th August 2003

Trinidad Marine Turtle Conservation Conference 2003 (TMTCC)

Compiled by: Suzanne R Livingstone (s.livingstone@bio.gla.ac.uk)
(With assistance from Dr J.R Downie, Debbie McNeill, Ross Culloch, Euan Riddell, Stephen Larcombe and Iain Fulton)

Organised by: University of Glasgow Darwin Initiative Project and Trinidad Government Wildlife Section, Forestry Division
(With assistance from Nature Seekers Incorporated, Matura)

Contents

1. Overview

1.1 History of Turtle Conservation in Trinidad

Five species of marine turtle are known to nest on the beaches of Trinidad and Tobago (Carr, 1956; Murphy, 1997). The leatherback turtle (*Dermochelys coriacea*) is the most common species nesting on the north and east coasts, nesting in relatively high densities. The hawksbill (*Eretmochelys imbricata*) also nests on these beaches, but in smaller numbers. Green turtles (*Chelonia mydas*), olive ridleys (*Lepidochelys olivacea*) and loggerhead turtles (*Caretta caretta*) have also been noted on these beaches in low concentrations (Bacon, 1970, Chu Cheong, 1990), although they have mostly been recorded nesting on the small Bocas Islands off the northwest coast of Trinidad (Nathai-Gyan et al., 1987). It is probable that Trinidad, is therefore one of the most diverse and important turtle nesting sites in the Caribbean.

Since the early colonial era, sea turtles have been observed nesting on sandy beaches and feeding in local waters. Records of exploitation date to the early 17th century (Fournillier and Eckert, 1997). These records are somewhat vague and discontinuous; however, they illustrate how indigenous and customary turtle fishing and utilisation were in Trinidad. Each year the nesting season represented an added source of income to a small and chiefly artisanal fishing industry; to some extent this is still true.

Historically and up to the present day, sea turtles have been both hunted at sea (using nests and harpoons) and on nesting beaches. All species are exploited for meat, organs and eggs, although the tender meat of the herbivorous green turtle has always been favoured. The shell of the hawksbill has long been used to fashion jewellery and household items. The extent of the harvest has never been effectively quantified and reviews by the University of the West Indies (UWI), the Forestry Division, Wildlife Section and foreign investigators, as well as a brief period (1969 - 1980) of landing data archived by the Fisheries Division, comprise all the available quantitative data (Fournillier and Eckert, 1997).

The (TFNC) implemented the first practical research undertaken on marine turtles in Trinidad. They began a formal programme of beach monitoring and sea turtle conservation in 1965 and published work followed soon after (Bacon 1967; 1969; 1970). As awareness of the turtles' plight grew in the 1970's, so did pleas for conservation action. There was rising alarm that an unsustainable number of turtles, and especially gravid females were being killed each year. Bacon (1973a) estimated that 30 % of turtles nesting at Matura and 100 % of turtles nesting near villages on the north coast were slaughtered. Investigations by foreign researchers (Carr, A.F., Pritchard, P.C.H., Eckert, S.A. and Godley, B.J.) further emphasised the endangered status of sea turtles and the significance of the remaining populations both regionally and internationally. Despite persistent efforts by local conservation groups and Forestry officials, it was not possible to provide complete surveillance of prominent nesting beaches along remote east and north coasts (Lum, 2001).

Between 1982 and 1989, the Wildlife Section focused on law enforcement of regulations and nesting data were sporadically collected. The successful enforcement of a provision under the Forests Act followed in 1990, to declare Matura and Fishing Pond beaches, bordered with forest, as prohibited areas with restricted entry (Fournillier, 1992). Between 1990-1992, with no budget allocation to carry out beach patrols, the Wildlife Section adopted a new approach. James and Fournillier (1992; 1993) described a community-based approach to protect nesting sea turtles through ecotourism. Utilising the human resources of Matura village, an "Introductory Nature Tour Guide Training Course" was given to 11 participants to sensitise them to the potential ecotourism value of turtles to Matura and the mutually symbiotic relationship that could be achieved. Nature Seekers Incorporated was created. The successful example of Nature Seekers in both turtle conservation and ecotourism has encouraged other communities to get involved in sustaining their natural resources – there are now active groups at Grande Riviere, Fishing Pond, Manzanilla, Mayaro and Matelot, and in other areas over the north east coast. The Institute of Marine Affairs is the archive for the nesting and tagging data collected by the Wildlife Section and the various groups. This information will help to evaluate the effect of current legislation and guide recommendations for further conservation work.

While the east coast and part of the north east coast of Trinidad are well documented, there is little information about the turtle numbers nesting at other beaches in Trinidad. The north coast beaches between Matelot and Blanchisseuse are also very busy and accommodate a large percentage of the nesting turtle population. The main beaches on which turtles have been observed are Paria, Murphy's Bay, Madamas, and Grand Tacarib although several other smaller bays are also used. Glasgow University carried out basic surveys in 1989 and 1991, which involved a single week in each year on the north coast (Godley, 1989; 1991). A more detailed assessment of the north coast beaches was carried out as a follow up to this work in 2000 (Livingstone, 2000) with very interesting results. Consequently, a Darwin Initiative project was set up in 2001 supporting field seasons in 2002 and 2003. This project is ongoing, working with the Wildlife Section, the Pawi, Sports, Culture and Eco Club, the GRNTGA, and collaborating with Nature Seekers on some scientific research.

Local legislation protecting sea turtles is found in the Conservation of Wildlife Act (1963), the Protection of Turtle and Turtle Eggs Regulations (1975), the Forests Order - prohibited areas (1990), and the Fisheries Regulation - Conservation of Marine Turtles (1994). Trinidad and Tobago is also a signatory to international protection agreements such as CITES. All local species of sea turtle are listed in Appendix 1 of the Convention, the terms of which require that there be no commercial import or export of marine turtles or their products in signatory countries. Further international agreements include the SPAW Protocol under the Cartagena Convention of 1983, which prohibits the taking, possession, killing (including incidentally) and commercial trade of any part of a marine turtle. While these cover many aspects of sea turtle ecology, the protection of females during the nesting season, habitat protection and incidental catch are limited in practice by available resources.

Currently the Wildlife Section funds several of the groups working on turtle conservation and monitoring. The funds go towards paying the guides to patrol the beaches at night and collect data. Not all the groups are funded however, and the funds that Wildlife receives from the budget to distribute between the groups have been cut consecutively over the last two years. With these restraints, it is frustrating for both Wildlife and the working NGO's.

1.2 Reasons for Holding the Conference

Many organisations are currently working hard to conserve and gather information on the marine turtle species nesting on Trinidad's east and north coasts. This conference was an opportunity to bring each of these groups together to share information and identify existing problems. It was felt that the meeting would be an extremely valuable exercise for both participating groups and the Wildlife Section to improve on available support, make contacts and unite resources. The purpose of this conference was intended as an information exchange, perhaps leading on to a larger-scale meeting in 2004 aimed at policy makers and potential funders.

1.3 Organisation of the Conference

This conference was jointly organised by the Wildlife Section, Forestry Division and the University of Glasgow Darwin Initiative Project, with assistance from Nature Seekers, Matura. The conference was held on Friday the 8th of August from 10am till 3pm at the Nature Seekers offices in Matura village. Each group was invited to give a short presentation on their organisation and the work that they were currently undertaking. All groups were sent out an invitation letter two weeks in advance of the meeting to give them time to prepare a presentation. A data projector and PowerPoint facilities were provided by the Wildlife Section to assist the presentations. Most groups organised their own transport; however a maxi taxi was arranged to bring the Pawi group and Grande Riviere group from the north east coast area, subsidised by the Darwin Initiative Project. Lunch was provided by Nature Seekers and funded by the Darwin Initiative Project, as were notebooks and pens for all participants. The day was structured so that the majority of presentations were given in the morning, leaving the afternoon free for discussion and report backs.

2. Programme of events (intended)

- 10:00 – 10:05am Opening prayer
- 10:05 – 10:10am Welcome and opening remarks – chairperson
- 10:10 – 10:15am Remarks by Stephen Poon (Wildlife Section)
- 10:15 – 10:25am Presentation by Grande Riviere Nature Tour Guide Association
- 10:25 – 10:35am Presentation by Fishing Pond Environmental and Community Group
- 10:35 – 10:45am Presentation by Manzanilla Community Group
- 10:45 – 10:55am Presentation by Pawi, Sports, Culture and Eco Club
- 11:05 – 11:15am Presentation by Nariva Mayaro Hunters Group
- 11:15 – 11:25am Presentation by Salibya Community Group
- 11:25 – 11:35am Presentation by Toco Foundation
- 11:30 – 12:40am Lunch
- 12:40 – 12:50pm Presentation by Nature Seekers
- 12:50 – 1:05pm Presentation by Darwin Initiative
- 1:05 – 2:30pm Group discussions
- 2:30 – 2:45pm Closing remarks/vote of thanks

It was unfortunate that not all groups managed to attend the conference. See Appendix 1.

3. Speakers

3.1 Chairperson, Dr J.R Downie, University of Glasgow

After the opening prayer by Susan Lakhan (Nature Seekers), Dr Roger Downie welcomed all the groups present to the first marine turtle conservation conference in Trinidad. Although he did not know many of the people there, he was hoping to get to know them during the day ahead. He introduced himself as a senior lecturer in Zoology at the University of Glasgow in Scotland. He had been visiting Trinidad to carry out research since 1981. He hoped that he would be a neutral figure to act as chairperson during the discussions.

Dr Downie began by announcing that the seminar, the first to bring together so many groups to discuss turtle conservation and its links to community development in Trinidad, was jointly sponsored by the Wildlife Section – who put a lot of effort into organising the meeting, and the University of Glasgow's Darwin Initiative project on marine turtles and ecotourism on Trinidad's north coast. He was also grateful to Nature Seekers for being willing to host the day.

He thought that perhaps some people might wonder how the University of Glasgow got involved in turtle conservation in Trinidad. This began back in 1989, when he brought a group of GU (Glasgow University) students to Trinidad to work on projects on quenk, pawi and marine turtles – the most successful of which was the turtle project: David Boodoo was very important to the success of the project. Brendan Godley, then a second year student, now a rising star in marine turtle research, led the turtle group. The group investigated leatherback nesting numbers at Matura, and also made a trek along the north coast from Matelot to Blanchisseuse, to make a spot-check of nesting turtles there. The following year, Nature Seekers was established at Matura, and Glasgow University like to think the information gained by the 1989 team was influential in that development.

Turtles were also a major focus of the 1991 GU expedition, focusing again on Matura and the north coast, but also visiting Tobago, Fishing Pond and Grand Riviere. Because of the successful development of community based turtle groups in Trinidad, Glasgow University gave turtles a miss for the next few years, but in 2000, got back to turtles, with a project based in Matelot, which served as the pilot study for the work that eventually became the Darwin Initiative [see section 3.8]. GU also worked with Nature Seekers in 2001 and again this year (2003). Dr Downie went over this brief history to show that GU has a long collaborative involvement with turtles and especially with the link between turtles and community development.

Dr Downie said he saw the purpose of the gathering as an exchanging of information; with each group getting the opportunity to say what they are doing, what their problems are and how they see their projects developing. It was important to discuss successes, but also problems and limitations – and how they can be dealt with. The idea was to concentrate on presentations in the first half of the day, and on discussions in the second.

Dr Downie said that he hoped that the outcomes of the day would be a report of the meeting that could be circulated to all participants, and a series of desirable action points highlighting what needed to be done next to develop turtle conservation and its link to community development in Trinidad.

3.2 Opening remarks, Stephen Poon Wildlife Section

Mr Poon began by apologising for the absence of Nadra Gyan (Head of the Wildlife Section) who could not attend the conference due to other commitments. He also was sorry to see that three groups that had been invited to the conference had not managed to turn up.

He then talked about early turtle conservation in Trinidad when Pointe-à-Pierre and the Trinidad and Tobago Field Naturalists began to do some beach patrols. The Wildlife Section started to get involved in the 1980s due to a lot of killing of turtles, but at this time they did not have suitable resources (monetary or man power) to deal with it on large scale. The idea of using local communities came to light, and so they trained and empowered the surrounding communities to conserve the turtles with their support. Today there are 8 active groups in Trinidad working on turtle conservation. Mr Poon pointed out that a good example of these is Nature Seekers. He mentioned that Wildlife approached people from Mayaro to Matelot, and that they had links with, and supported all of these groups. These days they also provided money, links and resources for selected groups (Grande Riviere, Matura, Fishing Pond and Manzanilla).

It was voiced that Wildlife would like to see conservation grow in Trinidad and that this seminar was for the groups to gather a consensus on the direction of future efforts. It was also a prelude for a larger more public and media orientated conference for next year (2004).

Mr Poon saw the meeting as a chance for each group to say what they would like to see done, how they saw Wildlife's role, and their own role in turtle conservation. At the end of the conference, there should be a mandate of where to go to next.

3.3 Mr Len Peters, Grande Riviere Nature Tour Guide Association

Firstly Mr Peters apologised for his colleague not being at the meeting yet, but he was on his way.

When Mr Peters got the correspondence for this conference and saw who was coming to the meeting, his thoughts were on; what was the objective of the workshop? On the invitation he saw that there was an allocation for 35 minutes for prayers (in the original programme there was a mistake - compiler) – well for sure leatherbacks need lots of prayers from what he has observed at Grande Riviere beach. He personally has observed that over the years, leatherbacks are becoming more endangered, and wishes them to be managed by a marine turtle steerage committee.

The project at Grande Riviere started as a conservation project due to the beach being one of the principal nesting sites in Trinidad. The group have worked to conserve both adults and hatchlings and effectively manage 5,000 European visitors annually. They feel that their group does a lot on land and that there is adequate protection, but that the real threat is in the water, and that legislation does not protect turtles sufficiently in this medium. Mr Peters claimed that one of the main problems for the turtles are fishermen and their nets and that they need to convince the local community, concentrating on the fishermen, that the turtles need to be conserved. Mr Peters said that this has taken a long time, but that they are starting to understand and take notice.

A new problem on the scene is a new type of predator – developers who want to capitalise on turtle conservation. The main attraction to tourists in the area is the turtles, but the new developers moving in are not conservation-minded. They come into the community, use the resources, make money and then leave and move on. This is not sustainable. Areas that would have formed good habitat for turtle nesting have already been cleared for resort development, and the resorts themselves marketed for turtle conservation. In Grande Riviere most of the land bordering the beach has been earmarked for construction, as have areas in Tacarib and Madamas. What is needed is some form of legislation to limit and control development. He seeks a development policy framework in areas near nesting sights, controlling factors such as light pollution.

There are currently two hotels on the beach at Grande Riviere. This already produces additional work on the beach for the guides as the lights disorientate both hatchlings and adults turtles; the guides are constantly having to take hatchlings out of hotel rooms at night, and on several occasions adult turtles have also got into rooms. Sherwin Ruiz protects the hatchlings that hatch during the day by keeping them in pots to release at night so that they don't get eaten by predators (e.g. frigate birds). However, once released at night they go for hotel lights instead of towards the sea. The group currently has good co-operation with the existing hotels that do try to keep the beachfront lighting to a minimum. Mr Peters is worried that the new breed of get-rich hotel-owners may not be so co-operative and it is a great concern how this will affect the turtle population.

Mr Peters felt that the different groups working on turtles in Trinidad don't seem to care what is happening to each other. But this seems to be silly as the turtles nest at all the beaches, and that they are all part of the one big population. The groups need to focus their energies and stop anti-leatherback killings and fight to protect the environment from developers. He wishes for all the groups to work together and to network and lobby to develop an overall policy to manage tourism as well as to fight unsustainable development as any current economic benefits gained through tourism will be lost should the turtle populations crash.

Comments from Susan Lakhan - Nature Seekers

Mrs Lakhan wished to make a comment at this point about lighting at the back of beaches. She used the case of Turtle beach in Tobago where the hotel owners use the turtles that nest there as a resource to attract guests. The turtle numbers there have decreased significantly, perhaps due to excessive lighting at the back of the beach and disturbance by people. Mrs Lakhan stressed the point that Trinidad groups have been working hard without funds to conserve the turtles, and then in come developers with money and do what they want in the area. She also feels that there needs to be control over these new developers, and that this is for the sake of the whole environment, not just the turtles.

3.4 Mr Brian Koonhow, Salibya Community Group

Mr Koonhow, like Mr Peters, wondered what his role would be at this meeting. The Salibya group is not currently doing any work on turtles. This is because they feel they are unable to do so, not because they don't want to. The group started basic monitoring and counting turtles three years ago, and although there is not the same density of turtles on their beaches compared to some others in Trinidad, there are enough to be important. At this time the group approached the Wildlife Section for help with the data collection, but did not feel that they received any, nor was advice forthcoming.

Salibya is an area of only 220 people with a high unemployment rate. Due to this, the group found themselves lacking funds to buy equipment, and lacking in enthusiastic volunteers. Mr Koonhow described how they wanted to construct a shed on the beach as a base for their volunteers for somewhere to rest and look out from. People tore down this shed on three different occasions and so they became disheartened and did not build it again. He also explained that the beach monitoring at night could be quite dangerous due to people smuggling drugs over from Venezuela. At this time they approached Wildlife again, who this time supplied them with data sheets and promised to liaise with them and get them licenses to do patrols on the beach. They are still waiting. They became disillusioned with what they were really trying to do and stopped after a few months.

Recent developments at Salibya have been the construction of a new private spa. There have been some building problems, which have led to the sea consistently being coloured brown along with light pollution and retaining walls being built. Mr Koonhow said that some people came to have a look at it and then went away again – and nothing more has been done about it.

Mr Koonhow voiced his opinions on the lack of appropriate budget allocation by government, how he felt that money was wasted in other areas (e.g. CEPEP) and that a redefinition of government perspective was necessary.

Comments from Len Peters – Grande Riviere

Mr Peters wished to reply to Mr Koonhow: for the first five or six years at Grande Riviere all the work that the group did was voluntary with no funding at all. Some members left soon after things started and called the group names such as "turtle police". Turtle conservation needs commitment and if you want to start straight away and get paid you are not going to get far. Mr Peters highlighted that new groups needed to show commitment and then they would become recognised. They need to spend time lobbying and advertising and showing people that they are serious, and not in it for the money. He advised Mr Koonhow not to lose focus and become discouraged, and that if he kept going, people would eventually listen.

Comments from Stephen Poon – Wildlife Section

Mr Poon also wished to reply to Mr Koonhow. Firstly he apologised for the lack of assistance in the past. It is important to keep in mind that Wildlife also have restrictions. Staff is a major constraint, and it is not that they are not willing to assist, but don't have the resources to do so and are unable sometimes to give support due to a limited budget.

Comments from Susan Lakhan - Nature Seekers

Mrs Lakhan remembers at the beginning of Nature Seekers that Wildlife could not support them with funding, but they did make the beach a protected area. They got no money, promises or resources, just the backing and support. They held on and got money from elsewhere. She wanted to encourage Brian to keep going – you need a good track record. She also felt that having no money in the beginning was a positive thing for Nature Seekers, as they would not have been around today if it had not been for the genuine commitment of several people, caring enough to stay without payment.

Reply from Brian Koonhow

Mr Koonhow agreed with all the feedback, but found it difficult to comment with an empty stomach.

Comments from Michael Als – Toco Foundation

Mr Als commented on the different circumstances of each different group. What will work for one group will not necessarily work for another. There needs to be the allocation of appropriate resources by the Government and he felt that the groups do need to be supported by the state.

Mr Als also felt that they needed to redefine the perspective on which groups got funding, and that the ones that really were doing the work should be funded. It is all very well that Nature Seekers had to struggle for ten years before they were funded, but it doesn't have to be that way anymore. He felt that Nature Seekers should now take the time to invite people and show them how it was done. It can't take ten years to learn again. The world has changed - so let them learn more quickly.

Comments from Dr Roger Downie – University of Glasgow

Dr Downie commented that he felt that it was difficult for small groups to be heard when dealing with Government changes. What they really needed was for all the groups to join together to form a large assembly to make a lot of noise and persuade the government do something.

3.5 Mr Renwick Roberts, Pawi, Sports, Culture and Eco Club

Mr Roberts began his presentation by thanking all those who had turned up to the meeting. He informed the audience that Pawi's main aim was to uplift the community and to protect the environment in the surrounding area through sustainable development. The group has 17 members as well as two branch groups of 8 - 11 year olds and 12 - 18 years olds. Since the group formed in 1997, they have been involved in various activities such as the Tidy T&T Rotary Club competition, in which they won a prize (2003), initiated a carnival revival in

Matelot (2003), have begun developing a park for tourists in the village, and are a partner in a sustainable development and turtle conservation project with the University of Glasgow.

Mr Roberts felt that one of the main problems on north coast beaches concerning turtles is that it is very difficult to enforce any of the turtle protection laws; either in the sea or on land. He said that nobody actually knows what is illegal and what is not, and that more education is required to raise awareness. He felt it would be good idea for the Government to put up posters around the area and advertise on radio what the laws are.

There are currently some problems associated with tourists in Matelot. Many native tourists come up to Matelot to bathe in the river and swim in the sea. But the local community have no control over visitor numbers or activities, and there are not sufficient facilities i.e. toilets, changing areas or even bins. This often means that there is a mess left behind. Mr Roberts feels strongly about this and wishes to develop the area to accommodate for the rising number of visitors. More people are now also using the remoter parts of the North coast, and Mr Roberts thinks that all tourists unfamiliar with the area should employ local guides who are savvy with the terrain, prevailing winds and sea conditions. Mr Roberts said that the group thought it was a good idea to make the whole north coast into a National park and that they were against the completion of Paria Main Road and any major development in that area.

Pawi's future plans include a hatching programme involving the younger branches of the club, to work more closely with the fishermen, perhaps look for an alternative to gillnet fishing at peak nesting season, and to promote ecotourism in the area. Finally Mr Roberts mentioned that the Pawi Club would like to be considered by the Wildlife Section for funding to continue recording data and monitoring the turtles on the remote beaches since they now have been helping to collect data since 2000 and have much experience having been trained by, and worked with the Glasgow University Darwin team.

3.6 Mr Michael Als, Presentation by Toco Foundation

Mr Als felt it was important to raise the point that more turtles are killed by Venezuelan fishermen with trawlers by catching turtles in nets and harpooning them, than are caught by Trinidadian fisherman (it is unknown where this information came from - compiler). It is true that turtles are difficult to conserve as they are a migratory species, and travel great distances, they don't just stay in Trinidad waters.

There is a programme supported by the Toco Foundation in which 20 young people protect the beaches from Salibya to Sans Souci. They are not supported by the Government. Mr Als feels that is not fair to financially assist some people, and expect others to work without pay, but is aware that there is a funding problem, and that Wildlife are not able to fund all the groups with the budget that they receive. Mr Als then made comparisons with funding for turtle conservation and the new Government CEPEP scheme which seems like a waste of money paying people "to paint stones white" when they could be putting money into something worthwhile like employing people to protect endangered species.

Mr Als is also worried about the development of delicate areas, and is concerned about the amount of work that has already illegally gone on at the Blanchisseuse end of the Paria Main Road.

3.7 Miss Marisa Ramjattan, Nature Seekers Inc

Miss Ramjattan, the secretary of Nature Seekers, gave a presentation entitled "Community Based Sea Turtle Conservation in Matura". She began by describing the beaches on the East coast. There is 7.4 km of beach in the Matura area, which is divided up into 17 zones of 1,400 ft. There are mostly leatherbacks nesting there, but hawksbill and green turtles also use the beach. In the 1970's and 1980's there was a lot of slaughtering of turtles at Matura (up to 70 % of nesting females were killed), and the Forestry Division did not have the human resources to have much of an impact. It wasn't till 1990 that Wildlife and the community of Matura got together and Nature Seekers was born.

These days Nature Seekers carry out a range of different activities on the beach to conserve and protect the turtles. The beach is now deemed a protected area by law, and no one is allowed on the beach without a permit. Miss Ramjattan described how the community gets together every year to do a beach clean up in preparation for each turtle-nesting season. Because Matura is on the east coast bordered by the Atlantic Ocean, it gets a lot of debris washed up. The beach clean up is to aid successful nesting, to facilitate safe viewing by visitors, and is used as a means of getting the community to work together and learn about marine turtles.

During the nesting and hatching season, there is also ongoing sea turtle monitoring and protection. This involves turtle tagging (successfully run since 1998) with both PIT tags and flipper tags. All the tag data collected goes into the National Sea Turtle Database of Trinidad and Tobago. It is not only data from Matura that goes into the database however. Sightings from all the main turtle beaches in Trinidad are also put in. So far 5,151 turtles in total have been tagged in Trinidad, and the number has been increasing each year. Turtles that have been tagged in Trinidad have turned up in some faraway places such as Venezuela, France, French Guiana, Grenada and Spain and it is interesting to keep track of where else in the world they might turn up.

Helping adults with missing back flippers to nest successfully is one way of facilitating nesting that Nature Seekers do. They also relocate clutches when they are laid in unsuitable positions e.g. too close to the tide. During the hatchling season, nests are excavated to help the last hatchlings out of the nest and are washed when mudslides encroach on the nest. The group also encourage scientific researchers that wish to investigate different aspects of turtle ecology.

Nature Seekers feel that education and community outreach is an extremely important part of what they do – getting the community involved in conservation work. They give talks in schools and run turtle watching tours for both local and foreign visitors interested in seeing the turtles come up and nest. The organisation, of course, must also be financially sustainable. Funds are raised directly from the ecotourism aspect of the group's work: from the turtle watching tours, as well as from selling souvenirs (photographs etc.), the Adopt-a-turtle scheme, and grants from funding organisations. The government also support the group financially by providing funds towards payment for the guides working on the beaches.

Many people volunteer to help with the different aspects of work that Nature Seekers do. The Earthwatch organisation sends volunteers from abroad to help with the work and data collection, which also brings in funds. Associate members of the group also help out, as do the local youths. Nature Seekers is a very positive component of the community of Matura, and as well as making available such things as library facilities and assisting schools, they have a constructive effect on the local economy and the capacity of the community to succeed and develop.

3.8 Miss Suzanne Livingstone, University of Glasgow Darwin Initiative Project

Miss Livingstone gave her presentation on the work that she was doing in conjunction with a Darwin Initiative Project. The Darwin Initiative for the Survival of Species is a scheme that was introduced by the British Government at the Rio 1992 Earth Summit Conference and is run by DEFRA The main objective of the Darwin Initiative is to assist countries rich in biodiversity but poor in resources. This fitted in well with what had been said earlier in the day – that Trinidad has rich biodiversity and endangered turtles that need conserved, but that there is a lack of manpower and funding from the Trinidadian Government. The Darwin Initiative also states that projects will be collaborative, involving either local institutions or communities in the host country, and that they will have a real impact on the ability of the host country to meet its obligations under the Biodiversity Convention.

This Darwin project, based at the University of Glasgow, works with several groups within Trinidad. The host country co-ordinator of the project is Stephen Poon from the Wildlife Section who gives advice on the project set-up. The Pawi, Sports, Eco and Culture Club, a community based organisation (CBO) in Matelot, are the main group on the ground with whom most of the fieldwork is done. The Grand Riviere Group has taken part in some of the community development aspects of the project. Nature Seekers have also been involved in the project allowing some scientific work to be carried out at Matura and assisting with the organisation of the conference.

The beaches on the east coast and inhabited parts of the north coast are well documented. However, little work has been done on the sandy bays between Matelot and Blanchisseuse. The main turtle beaches on this section of the coastline are Madamas, Grand Tacarib, Murphy's Bay and Paria bay. This is where the majority of the research of the Darwin Initiative project has been based. The main research aims of the Darwin project are to determine the nesting population size of each species of marine turtle nesting on the beaches, examine the hatching success and investigate the influencing factors, analyse the temperatures within leatherback nests with regards to sex ratio, metabolic heating and hatchling synchrony, and explore the extent of insect infestation of turtle nests.
It was Miss Livingstone's opinion that no conservation project could be truly successful without involving local communities. Therefore, other major aims of the project included the education and training of local people in turtle biology, conservation, research data collection and tour guiding, raising awareness of turtle conservation and environmental issues in schools, investigating the ecotourism potential of the area, and helping the local groups establish a visitor guiding scheme and promoting the effective management of the turtles as a resource of biodiversity and a source of alternative income.

The project is now in the second and final year of Darwin funding. One outcome of the work was that the natural threats to both adults and hatchlings had been identified. There was a relatively low level of hatchling predation from animals such as crabs, manicou and dogs;

vultures being a bit more of a problem for day hatching nests. Once in the water, it was difficult to assess the amount of threat, however frigate birds were occasionally seen picking up hatchlings from the surface, and sharks were observed in the surf waiting for them to make their journey into the sea. Erosion and sand build up was also a problem on some of the beaches. Madamas River is very dynamic and takes away a lot of sand, and nests with it. There is a similar problem in Grande Riviere during the rainy season. High water level on the beaches was a significant problem on several beaches this year – in particular Murphy's bay. This beach is very wide, but the smallest in length and very busy with adults laying nests there. It was not until the hatching season that it was discovered that almost all of the nests were waterlogged and only a small proportion of them produced live young - only the few eggs that were above the waterline in the nests hatched successfully. There were no real natural threats to adult turtles identified. These findings concur with the natural life history of the sea turtle: high predation for young, low predation for adults.

These threats alone would not be expected to endanger the turtles, but when added to human interference, they become serious. The human-related hazards identified were the slaughter of female adults - several carcasses were found on the north coast beaches (both hawksbill and leatherback), and one turtle was seen being carved up on Matelot bay for the annual Fisherman's Fete. The most serious problem for adult turtles, however, was the incidental catch in fisherman's gill nets where they often drowned or were chopped up to avoid further damage to nets.

Disturbance was seen to be becoming a much more serious problem on Paria bay where there was no patrolling apart from when the Glasgow group and the Pawi Club were there (this was perhaps once every two weeks for three nights over the season). There are many more people visiting Paria than there were four years ago. This is thought to be due to the furtherance of the road at the Blanchisseuse side making it easier for people to get there (this information concurs with what Mr Als and Mr Peters spoke of earlier in the day). Not only are the visitors disturbing the turtles by shining very bright torches, taking photographs and standing on their backs, but they also have been leaving all their rubbish behind them, which the Glasgow and Pawi Club often gather up and take back to Matelot. Miss Livingstone said that there had been days when they had loaded up over six black bin bags full of garbage left on the beach. She was worried that the turtles would be so disturbed that they would not come back – and that there was some evidence over the last three years that, in comparison to the other beaches, less turtles were nesting on Paria than in previous years. It is good that Matura and Grande Riviere are protected areas. It was Miss Livingstone's opinion that the remote north coast beaches may benefit from this status in the future if the Paria Main Road is completed.

The nesting population sizes of each species of turtle seen to nest on the north coast have been calculated to approximate values. The number of leatherbacks thought to use the beaches is around three thousand (nesting females). This is not inclusive of numbers from the east coast although some turtles do use both coastlines. This is known because some turtles that were tagged by Nature Seekers had been recorded. With current data, the number of hawksbill turtles using the beaches is thought to be approximately seventy. The number of green, loggerhead and olive ridley turtles using the beaches is unknown, however, a green adult was observed nesting in 2002, and an olive ridley was recorded nesting in August 2003 – which secured evidence that they do visit. The Glasgow group had no evidence for nesting loggerheads.

On the community development side of the project, there had been much progress. The Glasgow team had run a course based on conservation concepts, tour-guiding skills, the principles of ecotourism, and turtle biology. There were 21 participants from the villages of Grande Riviere, Matelot and St Helena, all of who passed the exam at the end of the course. There had also been a successful course taught in Matelot community college this year, getting the younger generations involved with the work.
All the data collection and monitoring of the North coast beaches was carried out in collaboration with the Pawi Club, who are now fully trained in all the required skills. With regards to the ecotourism aspect of the project, the Glasgow team organised two tourist groups from Britain to test out the possibilities. One was an adult group and the other was a group of school leavers. Miss Livingstone was glad to say that the tours were met with enthusiasm from both the local community and the British groups, and this has allowed them to realistically assess the potential for ecotourism in the area.

Miss Livingstone felt that the project was going well, and that the interest in turtle conservation in the project area was increasing. She also felt that they were closer to the main project aim, which was for the local community to carry on with the data collection and education programmes from where Glasgow University leave, and for the project to be sustainable into the future. Although the Darwin funding finishes in March 2004, the Glasgow team are hoping to return in 2004 to continue with the research and protection on the north coast beaches, and also hope to work more with the other turtle groups if they are interested. It is also hoped that Wildlife will recognise the work that the Pawi Club have been doing with Glasgow over the last three years and will consider funding them to continue with the work.

4. Afternoon discussions

The afternoon discussions resulted in a set of clear objectives to be put into action.

4.1 Objectives

1. ***Review of laws and legislation concerning marine turtles***

   Enforcement of laws during the nesting season (1st march – 1st October). Currently it is the NGO's that are the enforcers of the law, not the police or Government. The NGO's would like to have more authority, or have the appropriate authorities take more of an interest. There seems to be no use having laws if they are not put into practice. There was also a call for a harmonisation of legislation between the Fisheries and Wildlife Acts.

2. ***STRAP***

   STRAP has been in preparation since 1997. The document contains suggestions for the management of turtles in Trinidad and Tobago with recommendations to the Government. There is supposed to be a 2002 updated version for which the final review was planned for November (2002) by the WIDECAST country co-ordinator, however Mr Poon has not heard anything recently. It is a priority to get the final document circulated to the NGO's working on turtles.

3. ***Use of database***

   To use the data that is held in the National Sea Turtle Database of Trinidad and Tobago to justify the funding of turtle conservation projects to the Government and other funding bodies. Scientific analysis can often give proposals added weight when applying for funding. There was also a discussion on when the data would be analysed, and by whom. No decisions were made at this time.

4. ***Development of a turtle conservation network***

   In order for all the groups to be heard, they need to join together to form a larger working committee. A core group will be created with one person from each of the different CBO's to follow-up this conference and co-ordinate the next steps forward. One person should be appointed to be the contact for the group so that person can keep all the groups informed. All agreed that Susan Lakhan from Nature Seekers would be an efficient person to take on the role and that email would be the best way to keep in touch. A contribution of tt$1000 would be donated by the Toco Foundation for the administration costs (Michael Als).

5. ***Identifying threats***

To identify the threats to the turtles in each different area, and to work to resolve these threats. The most important threats identified during the meeting were fishing nets and new development on beaches.

6. ***Identify a channel of communication***

To identify a way for the groups to get more attention from the Government they could use COPE (Council for the Presidents of the Environment) as an umbrella organisation. Some people felt that this organisation was too big for the community groups, but it could be a focus for achieving some community group aims.

5. Conclusions

One of the main conclusions of the day was to recognise that each different group and area have different needs. Some beaches are busier than others, some are more remote, the communities differ, and what might work for one area may not work for another.

Wildlife said they wanted to know how they could help the groups more, and they received answers. The general consensus was that the people wanted more support and more funding for the work that they were doing, and thought that perhaps that the funds should be redistributed amongst the working groups. They were also unhappy about the decrease in funding over the last few years. Wildlife voiced that they too were discontented with the reduction of funds, however they still expected the NGO's to work as hard on conservation and monitoring. It is understandable that some groups have become disheartened, especially if they are completely un-funded when they are doing the same work as others who are. This raises the issue: just because the older more established groups struggled for years before funding was forthcoming, does not mean the others should have to do the same. If they can show they are genuine and committed, then why should they have to wait the same time again?

Education and raising awareness on the issues of sea turtle conservation in Trinidad needs to be continued and amplified, especially in communities around nesting areas. If ecotourism is to be a genuine source of income for the communities that work with turtles, provision needs to be made for both the comfort of the tourists that visit and the local people. The communities cannot be expected to support an ecotourism business without appropriate facilities and support from the Government.

Overall the conference was a success. The general outlook for turtle conservation in Trinidad is positive, although there is much to be done. It is important for all the groups to work together, to support each other and create a louder voice. It was a pity that not all the groups turned up for the meeting.

6. References

Listed in main reference section

7. Appendices

7.1 Appendix 1

List of each group present/invited to the conference:

- Wildlife Section – Mr Stephen Poon, Mrs Shemila R Lalla
- University of Glasgow – Dr Roger Downie, Miss Suzanne Livingstone, Miss Debbie McNeill, Mr Ross Culloch, Mr Euan Riddell, Mr Stephen Larcombe, Mr Iain Fulton and Mrs Naomi Barron.
- Pawi, Sports Culture and Eco Club – Mr Renwick Roberts, Mr Anthony Hollis Briggs, Mr Recardo Patrong, Mr Christopher Patron, Mrs Maria Penny
- Grande Riviere Nature Tour Guide Association - Mr Len Peters, Mr Nicholas Alexander
- Fishing Pond Environmental and Community Group (absent)
- Salibya Community Group - Mr Brian Koonhow
- Nariva Mayaro Hunters Group (absent)
- Manatee Conservation Trust – Manzanilla Community Group (absent)
- Nature Seekers Inc - Miss Marissa Ramjattan, Mr Dennis Sammy, Mrs Susan Lakhan
- Toco Foundation – Mr Michael Als

Appendix 2 - Protection of Turtle and turtle Eggs Regulations, 1975

PROTECTION OF TURTLE AND TURTLE EGGS REGULATIONS

Made under section 4

1. These regulation may be cited as the protection of Turtle and Turtle Eggs Regulations

2. No person shall-
   a) Kill, harpoon, catch or otherwise take possession of any female turtle which is in the sea within any reef or within one thousand yards from the high water mark of the foreshore where there is no reef;
   b) Take or remove or cause to be taken or removed any turtle eggs after they have been laid and buried by a female turtle or after they have been buried by any person;
   c) Purchase, sell offer or expose for sale for cause to be sold or offered or expose for sale or be in possessions of any turtle eggs.

3. No person shall, between 1st March and 30th September, kill, harpoon, catch or otherwise take possession of or purchase, sell offer or expose for sale or cause to be sold or offered or exposed for sale any turtle or turtle meat.

Laws of Trinidad and Tobago
Fisheries Chapter 67:51.

Appendix 3 - Past data on nesting leatherbacks on the north coast of Trinidad

Numbers of leatherback clutches laid on north coast beaches from 1968-1991 from various sources. False crawl data have been excluded from this dataset when listed. Some data may be incomplete as the methodology states that surveys were between the hours of 8pm and midnight and not throughout the night (TFNC raw data; Chu Cheong, 1995; Nathai-Gyan et al., 1987), although in some cases numbers were verified by track counts the following morning. Godley et al.'s data was collected throughout the night.

Date	Beach	Nests	Reference
13-Apr-68	Paria	4	TFNC Raw data
25-May-68	Paria	24	Bacon, 1970
08-Jun-68	Paria	7	TFNC Raw data
25-May-69	G. Tacarib	9	TFNC Raw data
26-May-69	Paria	4	TFNC Raw data
17-May-70	G. Tacarib	3	TFNC Raw data
18-May-70	Madamas	4	TFNC Raw data
16-Jul-70	Murphy's	2	TFNC Raw data
16-Jul-70	Paria	7	TFNC Raw data
19-May-73	Paria	4	TFNC Raw data
25-May-73	Paria	1	TFNC Raw data
26-May-73	Murphy's	3	TFNC Raw data
26-May-73	Paria	1	TFNC Raw data
11-Jul-73	Las Cuevas	4	TFNC Raw data
22-Apr-74	Las Cuevas	1	TFNC Raw data
22-May-74	Paria	0	TFNC Raw data
25-May-74	Murphy's	0	TFNC Raw data
25-May-74	Paria	2	TFNC Raw data
25-Apr-75	G. Tacarib	2	TFNC Raw data
25-Apr-75	Paria	0	TFNC Raw data
26-Apr-75	G. Tacarib	9	TFNC Raw data
26-Apr-75	Murphy's	0	TFNC Raw data
26-Apr-75	Paria	0	TFNC Raw data
02-May-75	G. Tacarib	5	TFNC Raw data
03-May-75	G. Tacarib	8	TFNC Raw data
04-May-75	G. Tacarib	8	TFNC Raw data
17-May-75	G. Tacarib	1	TFNC Raw data
17-May-75	Paria	2	TFNC Raw data
18-May-75	G. Tacarib	2	TFNC Raw data
21-May-75	Paria	0	TFNC Raw data
31-May-75	G. Tacarib	16	TFNC Raw data
31-May-75	Murphy's	0	TFNC Raw data
07-Jun-75	G. Tacarib	8	TFNC Raw data
08-Jun-75	G. Tacarib	4	TFNC Raw data
13-Jun-75	G. Tacarib	2	TFNC Raw data
18-Jun-75	Madamas	5	TFNC Raw data

20-Jun-75	G. Tacarib	5	TFNC Raw data
21-Jun-75	G. Tacarib	10	TFNC Raw data
22-Jun-75	G. Tacarib	3	TFNC Raw data
12-Jul-75	G. Tacarib	3	TFNC Raw data
12-Jul-75	G. Tacarib	4	TFNC Raw data
12-Jul-75	Murphy's	1	TFNC Raw data
12-Jul-75	Paria	0	TFNC Raw data
13-Jul-75	Murphy's	0	TFNC Raw data
13-Jul-75	Paria	0	TFNC Raw data
03-Jul-81	Paria	0	Chu Cheong, 1995
04-Jul-81	Paria	1	Chu Cheong, 1995
08-Jul-81	Paria	2	Chu Cheong, 1995
20-May-82	Las Cuevas	0	Chu Cheong, 1995
22-May-82	G. Riviere	3	Chu Cheong, 1995
22-May-82	Toco	0	Chu Cheong, 1995
29-May-82	G. Tacarib	2	Chu Cheong, 1995
29-May-82	Murphy's	0	Chu Cheong, 1995
29-May-82	Paria	3	Chu Cheong, 1995
30-May-82	G. Tacarib	5	Chu Cheong, 1995
30-May-82	Murphy's	1	Chu Cheong, 1995
30-May-82	Paria	0	Chu Cheong, 1995
05-Jun-82	G. Riviere	2	Chu Cheong, 1995
09-Jun-82	Las Cuevas	0	Chu Cheong, 1995
12-Jun-82	G. Riviere	1	Chu Cheong, 1995
15-Jun-82	Blanchisseuse	0	Chu Cheong, 1995
15-Jun-82	Las Cuevas	0	Chu Cheong, 1995
25-Jun-82	Paria	0	Chu Cheong, 1995
26-Jun-82	Paria	0	Chu Cheong, 1995
31-Jul-82	G. Tacarib	0	Chu Cheong, 1995
01-Aug-82	G. Tacarib	1	Chu Cheong, 1995
17-May-85	G. Riviere	0	Nathai-Gyan et al., 1987
22-May-85	G. Riviere	2	Nathai-Gyan et al., 1987
23-May-85	G. Riviere	1	Nathai-Gyan et al., 1987
08-Apr-87	G. Riviere	3	Nathai-Gyan et al., 1987
08-Apr-87	Sans Souci	1	Nathai-Gyan et al., 1987
09-Apr-87	G. Riviere	8	Nathai-Gyan et al., 1987
09-Apr-87	Sans Souci	1	Nathai-Gyan et al., 1987
06-May-87	G. Riviere	7	Nathai-Gyan et al., 1987
10-Jun-87	Paria	5	Nathai-Gyan et al., 1987
11-Jun-87	G. Tacarib	0	Nathai-Gyan et al., 1987
11-Jun-87	Madamas	5	Nathai-Gyan et al., 1987
11-Jun-87	Murphy's	2	Nathai-Gyan et al., 1987
11-Jun-87	P. Tacarib	0	Nathai-Gyan et al., 1987
25-Jun-87	G. Riviere	4	Nathai-Gyan et al., 1987
13-May-89	G. Riviere	16	Bro. R. Fanovich, unpublished
15-Jul-89	G. Riviere	0	Bro. R. Fanovich, unpublished
16-Jul-89	G. Riviere	0	Bro. R. Fanovich, unpublished
17-Jul-89	G. Riviere	0	Bro. R. Fanovich, unpublished

18-Jul-89	G. Riviere	2	Bro. R. Fanovich, unpublished
19-Jul-89	G. Riviere	2	Bro. R. Fanovich, unpublished
19-Jul-89	Murphy's	2	Godley et al, 1989
19-Jul-89	Paria	12	Godley et al, 1989
20-Jul-89	Madamas	1	Godley et al, 1989
21-Jul-89	Madamas	0	Godley et al, 1989
22-Jul-91	Madamas	0	Godley et al, 1991
23-Jul-91	G. Tacarib	2	Godley et al, 1991
Jul-91	G. Riviere	Ave. 2	Godley et al. 1991

Appendix 4 - Newspaper articles from the Trinidad Guardian about shrimp trawlers

Sunday 19th December, 2004

PNM negligence hurting fisheries

The Fisheries are drowning under PNM mal-administration. Year after year the locally-owned shrimp trawlers break the law with impunity and rape our North Coast fishery east of Saut D'eau Island with their drag nets while the Minister of Agriculture makes glossy speeches that promise the world and delivers nothing sustainable. Does the Minister (or the Cabinet) know that shrimp trawling has been compared to dynamite fishing in terms of sustainability according to the World Resources Institute in Washington DC?

As we write, the shrimpers are raping the valuable demersal grounds of the North Coast, and the Cabinet seems not to care. For almost ten years, our Government has financed a fisheries advisory committee to advise the Minister on all matters pertaining to the fishery. This Committee, of which FFOS has been a founding member, was responsible in 1997 for drafting the Shrimp Trawler Regulations, specifically for the North Coast, which were passed in Parliament in that year by a special majority.

In the year 2000, the PNM replaced the UNC. Every single year since then the Shrimp Trawler Regulations have been allowed to lapse, thereby allowing the destructive shrimpers to move in on the North Coast villagers and rape and dredge every single juvenile specie that forms the future livelihood of these villages. Hundreds of thousands of dollars of fish pots and nets have been lost due to the Minister's negligence. Does the Minister of Agriculture know how to read the calendar? Has any Minister of Agriculture had any expertise in agriculture or fisheries? Shouldn't Ministers be removed for allowing critical legislation to lapse due to their negligence? Is there any legitimate excuse for incompetence and recklessness? While these environmental rapes occur 24 hours per day, the Coast Guard sit neutered by the careless mismanagement of the fishery.

Is the Minister bent on destroying years of species regeneration, the backbone of coastal communities? It seems that the Minister's vision for 2020 is a sea without fish, and rural communities who are starved of economic opportunity.
Gary Aboud, Secretary

Friday 7th January, 2005

The facts about industrial fishing

Year after year, for well over ten years, a letter writer consistently uses your medium to promote his political ambitions by persistently attacking our industrial fishermen under the pretext that he is seeking the interest of the north-coast villagers. Because of this our association has found it necessary to correct some of the misconceptions that the writer so cleverly portrays. The T&T Industrial Fishing Association Ltd represents the industrial fleets of both long-lining and shrimp-trawling vessels, which are locally owned and based both at Sea Lots and Orange Valley. Our vessels operate under the strict supervision and scrutiny of the Fisheries Division of the Ministry of Agriculture, Land and Marine Resources, together with the support of the Coast Guard where necessary. These vessels are the only ones that are regularly and routinely inspected without notice, both at sea while fishing and at their land bases, by all the relevant government authorities in order to ensure compliance with the following; that all nets in use by shrimp trawlers are fitted with the required Turtle Excluder Devices (TEDs) in the manner stipulated by law, in breach of which the penalty is fine and imprisonment of the vessel owner. Contravention also incurs an embargo on our shrimp by the US Government; that shrimp trawlers do not contravene the legal boundaries of three designated areas that, incidentally, only comprise a tiny fraction of the entire fishing grounds to which all other fishing vessels are afforded open access for every other type of fishing; that a limit is strictly enforced on the number of trawlers allowed in the fishery, as a result of which no new registrations can or have been approved by the Fisheries Division since 1989; that nets used by shrimp vessels must conform to absolute specifications in terms of mesh size, etc.

The writer spouts a lot of venom by using terms like "raping," "dynamite fishing," "dredging," etc, no doubt in a deliberate and orchestrated attempt to create an atmosphere of hatred by the general public and to suit his purpose of self-support. His vitriolic and unfair attack on the Minister of Agriculture and hard working members of the Coast Guard is nothing short of scandalous and is all the more to be condemned for its half-truths and innuendoes, especially via a medium that is accessible worldwide. The Coast Guard should instead be publicly commended for their valiant protective efforts over the years and for the several rescues at sea which, for the most part, go unpublished, unheralded or are quite easily forgotten.

Our association can attest to the many occasions on which fishing crews and their vessels have been saved from certain disaster. The letter writer should also acquaint himself with the fact that there are, at present, teams of fisheries experts, both at global as well as local levels, holistically addressing the questions of conservation and sustainable utilisation of the marine living resources. Every fishery has to be examined, since there is wastage in every sector. Soon there will be introduced additional devices in fishing gear and equipment that will further reduce the amounts of by-catch. In addition, and emanating from the current national budget, is the Government's initiative to consolidate all aspects of the fishing industry along First World standards and to this end the requirements for sustainable development will inevitably occupy centre stage for all stakeholders.

We have come a long way since the letter writer browbeat the last regime by his ranting, raving and "small-band" marching on Parliament. Instead of this, his efforts and energies should now be diverted to educating the fishermen he claims to represent, on the benefits to be derived from co-operation, the pooling of their resources, and the adoption of better business practices in order to attain the visions of developed status by 2020. The T&T Industrial Fishing Association is willing to meet with anyone wishing to learn more about our operations and the various methods we employ to ensure that our members comply with all regulations. In addition, we co-operate and participate fully with all organisations, both national and international, in the development of techniques and methods to improve sustainability.

Bruno Maharaj
President. T&T Industrial Fishing Association Ltd.

Thursday 27th January 2005
Regulate turtle catchers - shrimp trawler owners
By Ian Gooding

Regulate everybody who catches turtles and rebuild the jetty promised since 1995. That's the message the owners of the 25 shrimp trawlers that use a run-down part of the former National Fisheries compound have for the Minister of Agriculture. Following a visit by US State Department officials to see if shrimp trawlers were complying with the installation of sea turtle excluder devices (TEDs), a ban was imposed on December 21 (2005) on all shrimp from Trinidad entering the US.

"But we have not been exporting shrimp to the US for years now," said one owner. "We catch mainly medium shrimp and we don't catch enough to export. Plus we are getting a better price for shrimp on the local market." In addition, he said that most trawlers had installed the TEDs but were now being told that they were using the wrong size, a 54-inch instead of a 71-inch, to make it easier for the large green leatherback turtles to escape the net. "The foolish thing about this whole turtle business is that we don't fish in the north-east coast where these turtles are, so we are no danger to them at all," he said. "Just because the US government imposed that regulation on US shrimpers, they made a fuss and demanded that foreign trawlers that export shrimp to US must have the TED. "We have no problem with that, but you can't come here and make rules for us without even finding out what kind of turtles we sometimes catch. They are certainly not the green leatherback that they are concerned about."

The captain said the US officials and the Ministry of Agriculture should go after the real culprits who catch these turtles, like the Toco and Tobago fishermen. "Turtle meat was selling like fish in the San Fernando market last Christmas," he said. "Where you think it came from?" He gave the assurance that all shrimpers would comply with the law and install the TEDs before the US officials returned in March. "We don't want them giving Trinidad a bad name," he said. "But what the ministry could do to help us is to rebuild that jetty which collapsed years ago and ease up our situation. "Sometimes we have to climb over three and four trawlers with our shrimp to off-load. They promised to rebuild it in 1995. Look at it. They haven't moved a nail since then."

Appendix 5 - Interview questions for fishermen using the north coast waters.

Leatherbacks in the water

- When do leatherbacks start to appear in the waters on the north coast?
- When are the leatherbacks present in the water in the largest numbers?
- Have you noticed jellyfish in the north coast waters?
- Have you ever witnessed leatherbacks eating jellyfish?
- Do you know if there are male leatherbacks present?
- Do you ever see leatherbacks mating in the water?
- When do the numbers of leatherbacks start to decrease?
- Do you think there are more leatherbacks in the waters now than in the past?

Fishing practices

- What types of fishing methods do you use?
- What is your preferred fishing method?
- How many months of the year to do use gillnetting?
- What type of nets to do you use for gillnetting (nylon or transparent net)?
- What gillnets do you catch most turtles with?
- How much gillnet do you use?
- What time of the day do you put the nets in the water?
- How often do you check them during this time (soak time)?
- What fish are you trying to catch?
- How often do you go out gillnetting during the nesting season?
- Which sections of the coastline do you fish on the most?
- In which sections do you catch most leatherbacks?
- How many fishing boats work in the north coast waters during the turtle nesting season?
- How many of the boats will be out at any one time?

Capture and mortality

- What do you do if you find a live leatherback in your net?
- What do other fishermen do if they find a live leatherback in the net?
- Roughly how many leatherbacks will get entangled in your nets each time you go fishing with gillnets?
- Approximately how many turtles might get entangled in the nets in one season?

- What proportion of the leatherbacks might drown?
- What proportion of the leatherbacks will end up dead?
- Do you catch turtles using methods other than gillnetting?
- What are your feelings about leatherback turtles?
- How do leatherbacks affect your fishing efforts?
- Can you fix your own gillnets?
- Would you be interested in alternative ways of fishing when turtles are in the water?
- Do you have any suggestions?
- Do you know what the laws are concerning turtles in Trinidad?

Other turtle species

- Do you catch any other species of turtles in gillnets?
- If so, what kind, when and how many (approximately)?

Appendix 6 - Adult monitoring collection data sheet

Adult monitoring
Beach:______________________
Date:______________________
Taggers:______________________

BP1+BP2 = beach position
DTB = distance to back

CCL = Curved Carapace Length
CCW = Curved Carapace Width

ND: nest depth **b:** bottom, **t:** top

W: Weather
C: clear
B: broken cloud
R: raining
O: overcast

RT: yes/no

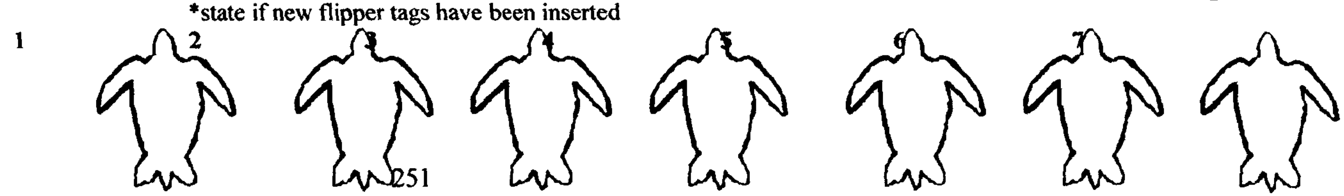
ACT = Activity at data entry
A: approaching
BP: body pit
D: digging
Lay: laying
C: covering
RT: returning

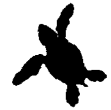
O: Outcome
FC: false crawl
FCB: false crawl with body pit
CL: confirmed lay
EL: estimated lay
Unk: unknown outcome

	Time	W	BP1	BP2	DTB	ACT	CCL	CCW	Tag #1	Tag #2	PIT tag #	ND:b	ND:t	O	Rt	Extras
1																
2																
3																
4																
5																
6																

Extras - note if:
DON: digging up another nest
INJ: injured
WtL: waterlogged nest

*state if new flipper tags have been inserted





Appendix 7 - Nest data collection sheet

Nest monitoring
Beach:____________________
Date:____________________
Workers:____________________

BP1+BP2 = beach position
DTB = distance to back

INF: yes/no

ND: nest depth **b:** bottom, **t:** top
NOE: number of eggs infested

W: Weather
C: clear
B: broken cloud
R: raining
O: overcast

Species = infesting nest
M: maggots (fly)
E: earthworms
B: beetles
F: fungus
A: ants
N: nematodes

Egg profile
H: hatched
In: inert
UF: unfertilised
L: live
D: dead
Bac: bacterial

DIS(o): dead in shell (open)
DIS(c): dead in shell (closed)
Dis(o): disintegrated (open)
Dis(c): disintegrated (closed)

	D/N	W	BP1	BP2	DTB	ND:b	ND:t	INF.	Species	NOE	Hat	In	UF	L	D	Bac	DIS(o)	DIS(c)	Dis(o)	Dis(c)	Extras
1																					
2																					
3																					
4																					
5																					
6																					

Extras:
WtL: waterlogged

Appendix 8 - Article published in Testudo, 2005

MARINE TURTLE CONSERVATION ON THE NORTH COAST OF TRINIDAD – A DARWIN INITIATIVE PROJECT

Suzanne R. Livingstone & J.R. Downie

Division of Environmental and Evolutionary Biology,
Graham Kerr Building, University of Glasgow, G12 8QQ
Email: s.livingstone@bio.gla.ac.uk

Based on a presentation to the BCG Symposium at Chester Zoo, October 2003.

Introduction

Trinidad is situated at the south end of the Caribbean island chain, 12km from Venezuela (figure 1). Five species of marine turtle have been observed nesting on Trinidad's north and east coasts (figure 2). The leatherback turtle (*Dermochelys coriacea*) is the most common species and nests in considerable numbers. The leatherback rookery in Trinidad is the largest in the Caribbean, and is thought to be one of the largest in the Atlantic Ocean. Hawksbill (*Eretmochelys imbricata*) and green turtles (*Chelonia mydas*) nest in smaller numbers, and, according to local fishermen, have decreased in number over the last 30 years. Literature reports that olive ridleys (*Lepidochelys olivacea*) and loggerheads (*Caretta caretta*) also nest on Trinidad's beaches, but as a rare occurrence (Bacon 1969; Fournillier and Eckert 1997; Livingstone, in press). All five turtle species nesting in Trinidad are listed as endangered or critically endangered on the IUCN red data list of threatened species (IUCN 2004).

Figure 1. Location of Trinidad.

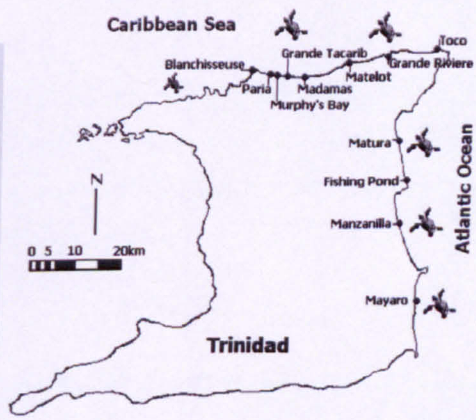


Figure 2. Marine turtle nesting beaches in Trinidad.

While the leatherbacks nesting on the east coast (Matura and Fishing Pond) and accessible north coast (Grande Riviere) beaches of Trinidad are well documented, before 2000 little was known about the turtles nesting on the remote northern beaches. The central strip of the coastline is undeveloped and there are no roads or habitations for approximately 22km between the villages of Blanchisseuse (west) and Matelot (east). This area of remote coastline is interspersed with a number of sandy bays on which marine turtles nest. The main beaches are Grand Tacarib, Paria, Murphy's bay and Madamas, with a few smaller lower density beaches (figure 3). The only way to reach these beaches is to hike through mountainous rainforest or by boat as the Northern Range mountains fall steeply into the Caribbean Sea. For this reason the beaches remain relatively untouched, although there has been illegal progression of the north coast road at the western end at Blanchisseuse, making it easier to reach Paria bay.

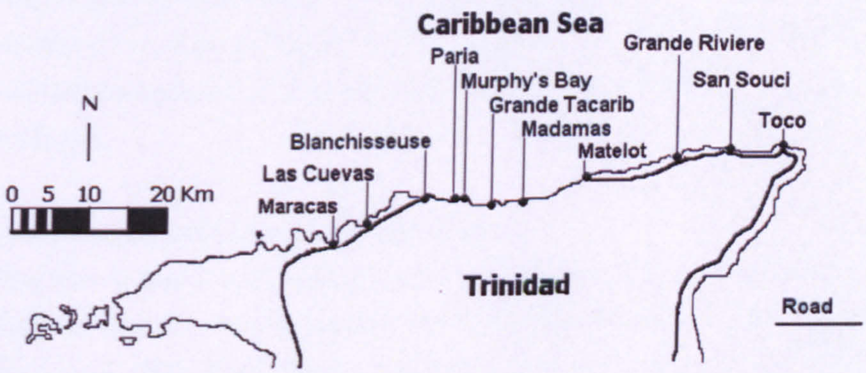


Figure 3. North coast beaches in Trinidad.

The scientific community has been aware that turtles use the remote beaches since turtle research began in Trinidad (Bacon 1969). However, monitoring was limited to brief overnight stays during hikes from one village to the other. The lack of accessibility meant that no extensive work was carried out in this area (Lum 2001).

The Darwin Project

The University of Glasgow Exploration Society carried out limited surveys of the north coast in 1989 and 1991 (Godley *et al.* 2001a; 2001b). A more detailed assessment was then carried out in 2000 (Livingstone *et al.* 2000). The 2000 study worked in collaboration with several local NGOs (Non Governmental Organisations) and managed to organise weekly trips to the beaches on the north coast, involving hiking and camping, and latterly travel by boat. This intensive study revealed much higher numbers of nesting leatherbacks than previously believed.

The work provided the contacts and the initial baseline data for a Darwin Initiative funded project. The Darwin Initiative is a grants programme funded and administered by the UK Government Department for Environment, Food and Rural Affairs (DEFRA). The Initiative aims to promote biodiversity, conservation and sustainable use of resources in less developed countries using British expertise. The programme stresses the importance of host country links and endeavours to leave behind a legacy, allowing projects to continue into the future.

Our project was set up to support community development, training, and turtle research and monitoring in the north coast area for a two-year period (2002-2004). The main objectives were to accurately estimate the nesting populations of all species of marine turtle nesting on the remote and more accessible beaches, to identify the threats to the turtles and their nests, and to train a group of local people to be able to continue monitoring the turtle numbers into the future.

Project partners and community development

This Darwin project was largely centred on the participation of two local NGOs. The Grande Riviere Nature Tour Guide Association (GRNTGA) has been monitoring the turtles on their beach since 1996. Grande Riviere beach is the highest density beach in Trinidad with up to 300 leatherbacks coming up to nest in one night during the peak season. The beach is now a designated protected area, and a permit is required to gain entrance to the beach at night during the turtle season. The members of GRNTGA monitor the turtles on the beach, and take groups of tourists on guided tours to generate funds for their conservation work. The Pawi, Sports, Culture and Eco Club, based in Matelot, were our main NGO partner. Previous to this project they had no formal training in turtle monitoring methods, however, they were keen to work on the remote north coast beaches. They now carry out all the monitoring of the marine turtles nesting on the beaches, participate in other activities in the area such as litter control, and interact with the fishermen who incidentally catch turtles in their nets.

The University of Glasgow Darwin project team comprised a researcher (S.R. Livingstone), a group of student volunteers and a staff co-ordinator (J.R. Downie). Members of both NGOs attended a 6-week turtle biology and conservation course that we offered at the beginning of the project. The course was aimed at any interested persons in the area and was designed to expand their knowledge and understanding of conservation, largely orientated around sea turtles, although other aspects of Trinidad's rich biodiversity were also reviewed. The course was also an excellent opportunity to exchange information, and the Darwin team gained invaluable local knowledge of the area and turtle populations.

Twenty-three local people participated in the course and from these we created strong links with the local groups, and established a team to carry out the monitoring work on the remote north coast beaches. This involved training in data collection, tagging, and experimental design. The groups were fundamentally involved in the monitoring and research and this made up much of their training in field techniques. This training was essential for the continuation of the project into the future once Darwin funding ran out.

The Trinidad Government's Wildlife Section provided the host country coordinator for the project. Their support was accommodating throughout the project. It was important for the project to help the government meet their obligations under the Biodiversity Convention, and to supply them with data for their National Marine Turtle Database managed jointly by Nature Seekers, an NGO based at Matura, and the Wildlife Section. We also helped with raising awareness of the endangered status of turtles in areas where it was difficult for wildlife staff to reach.

As well as educating adults, it was important to raise awareness amongst the young people in the area. Throughout the project we were allowed to take over several biology classes in the local high school (Matelot Community College), and a teaching programme was developed to educate the pupils about turtle conservation and ecology. This was considered very successful and enjoyed by all (photo 1).

Photo 1. A group of local children on an educational turtle beach trip.

Ecotourism

All Darwin projects require there to be a sustainable element to the project, and so it was our aim to be able to hand over the project management and all equipment bought with the project grant to our local counterparts. To achieve this there needed to be a means of making revenue as the equipment alone could not sustain the project. Funds are required to carry out the work on the beaches, which is time consuming and physically challenging. Most of the local team members had other jobs, and needed to be able to make at least the same amount of income from the turtle monitoring for it to be a realistic alternative to their normal employment. A large focus of the project was to find this means of income. Although it is a useful method of generating funds, relying on funding from outside sources is not always dependable. It is also difficult considering the NGO's limited access to information and the resources necessary to apply for available grants.

The best way to make the project sustainable was through ecotourism. The GRNTGA were already making funds this way by taking tours on Grande Riviere beach during the turtle season, and taking people on hikes to see waterfalls and to do bird watching in the surrounding area. This was much more difficult for the Pawi Club, however, as Matelot does not have the same facilities as Grande Riviere. There are no hotels, and there is no turtle beach in the village. Matelot is in no way currently set up for tourism. One of the project aims was to design an ecotourism activity using the remoter beaches so that monitoring could be done in conjunction with ecotours to the beaches. This would make turtle conservation an option for generating revenue in such a low-income rural village through sustainable ecotourism. It was proposed that this sort of trip would appeal to people wanting a more adventurous holiday involving hiking and camping, different from the experience offered in the village of Grande Riviere.

During the project we investigated the ecotourism potential of the area by bringing three separate ecotourist groups of varying ages (school group, gap year group and a more mature adult group) from Britain. The trips were a great success and have proved to be an economically viable option for generating funds for turtle conservation in the area. The main difficulty currently is the ability of the NGOs to organise these trips due to lack of facilities. However, we did organise several impromptu trips with people visiting Grande Riviere. This offers a realistic opportunity for the Pawi Club for the moment, while the logistics of organising visitors from overseas are ironed out. There is certainly great potential for this type of ecotourism for the future. Ecotourism in Trinidad at this time is at an early stage of development; however, the nation appears to be making a conscious move to embrace it and the economic benefits it offers.

Annual nesting population estimates and tagging

Current reports from around the world indicate profound long term declines in sea turtle populations (Spotila *et al.* 1996; 2000; Troeng *et al.* 2004). This trend fits with the apparent diminution of four of the turtle species using Trinidad's coastline. During the three years of the project we witnessed only one olive ridley turtle (Livingstone, in press), and four green turtles (photo 2). We never saw any loggerheads. There are no past estimates in the literature for these species. The only information we had was from the older fishermen in the area, who all agreed that numbers were less now than 30 years ago. Hawksbills were a more common sight, and we witnessed at least one or two laying most times we were on the beach after June – their season starts later than the leatherbacks which nest from March to August.

Photo 2. The only olive ridley turtle we witnessed on the north coast beaches.

From looking at past estimates of leatherback numbers nesting in Trinidad (Bacon 1969; 1970; 1981; Chu Cheong 1990; Godley *et al.* 1989; 1991; Nathai-Gyan *et al.* 1987), however, there is substantial evidence for a recent increase in this species. It is unclear why this has occurred. It could possibly be due to pressures on nesting beaches elsewhere, e.g. coastal development and human disturbance, causing the turtles to seek out new nesting sites. There have also been reports of nesting leatherback population increases at other nesting sites in the Caribbean e.g. St Croix (Boulon *et al.* 1996). The limited data available on past numbers of leatherbacks on the north coast makes it difficult to make statistical comparisons between past studies and this one; however, it is clear that numbers of nesting females have increased over the last 40 years. It was calculated recently that 88% of leatherbacks nesting in the Caribbean use the beaches in Trinidad (Eckert 2005). Trinidad is clearly a significant region for nesting leatherbacks in the Caribbean and globally, in the context of serious declines elsewhere.

In 2004, we began tagging the leatherbacks on the north coast beaches. We tagged 322 females, 42 of which were recorded returning during the study. The tagging has already provided interesting information on the nesting females, and, if continued, will generate information that can be used for conservation and management in the future.

Nest ecology research

During the adult monitoring on the beaches, several other avenues of research into leatherback ecology were explored. Studies on nest ecology were carried out, focusing on nest temperatures and sex ratios, hatching success, hatchling fitness and insect infestation (photos 3 and 4). These projects are all directly relevant to the conservation of the leatherbacks. All marine turtles employ temperature-dependent sex determination (TSD). The pivotal temperature is where equal numbers of males and females develop, with higher proportions of males occurring at lower temperatures and females at higher temperatures. The pivotal temperature for leatherbacks is 29.5°C (Rimblot *et al.* 1985; Rimblot-Baly *et al.* 1987). Many studies have shown high female biases being produced and have suggested that this could be due to climate change and global warming. From this viewpoint it is interesting to note that all nest temperatures we recorded were below the pivotal temperature in the leatherback nests on the north coast beaches. It is therefore likely that the majority of hatchlings produced on these beaches are male, and that the area could therefore be important for the production of male leatherbacks in the Atlantic. We think it likely that seasonal temperature changes are an important factor.

Photo 3. Nest excavation on Grand Tacarib

Photo 4. Measuring a leatherback hatchling.

The hatching success (percentage of turtles that emerge from a nest that are observed hatching or found after hatching) on the beaches was found to be 69% over all the beaches. This is relatively high compared with other areas. 12.6% of nests were infested with insects of some type (ants, Dipteran flies or other species such as beetle larvae or mole crickets). The maggots of flies were the most common infestation. It was concluded that most infestation was not harmful to the hatchlings, and that the insects were attracted to hatchlings that were already dead rather than causing the deaths in the first place. Red ants did cause hatchling deaths, but they were a rare occurrence.

The data from these research projects are currently being analysed and written up as separate papers, and will be submitted for publication in the near future.

Threats

One of the project aims was to identify the threats to nests, hatchlings and adult turtles. The main threats to the nests and hatchlings on the remote beaches were natural – erosion and build-up of sand by wave action and river movements, and predators such as crabs, vultures and opossums on land, and frigate birds, sharks, and other predatory fish in the sea. The collection of eggs by forest men living in the mountains was witnessed on several occasions. However, they only took eggs very occasionally and this was not considered to be a serious threat. Because the beaches are so inaccessible they are largely free of the human-related dangers that threaten survival on developed beaches. The situation is very different at Grande Riviere where there are humans all around. The survival rate of nests is much lower in Grande Riviere than on the remote beaches. There is much more predation, largely by dogs, which dig up many of the nests. This then attracts large numbers of vultures. Grande Riviere beach also suffers from more erosion than the other beaches due to a dynamic river system and larger sand particle size.

Threats to adults on the beaches were also relatively rare. There were a few occurrences of slaughtered females (six leatherbacks in four years of study), although there were more incidences of slaughtered hawksbills in the latter years of the project. This is possibly driven by the increased number of people using the coastline for recreation. Leatherbacks are rarely taken for meat, as people tend to regard leatherback as less palatable than other species. Adult slaughter on Grande Riviere beach has been totally eliminated now due to the protected status of the beach and the presence of the GRNTGA. The biggest threat identified to the leatherbacks on the north coast (and in the whole of Trinidad) is the incidental catch in fishing nets (termed "bycatch") (Pritchard 1984; Eckert and Lien 1999; Lum 2003).

Currently the populations of turtles nesting on the remote beaches are relatively safe from human disturbance. However, a controversial proposal by the Trinidad government to develop the north coast for tourism puts this in serious jeopardy. The proposed development includes the completion of the east-west road as an "ecotourism highway" to, amongst other things, assist timber extraction from the northern range forest reserves. The illegal construction road has already begun on the west side, explaining the significant increase in tourists visiting the nearest beach from the road end – Paria. In the last five years, the number of people frequenting this beach has increased hugely and so has the amount of rubbish they have left (photo 5).

Photo 5. Rubbish left by campers on Paria bay.

The majority of the Matelot community is very much against the construction of the road. The Government has sought little or no opinion from the local people. Such a development could be highly detrimental to the turtles through easy access for poaching, artificially lit development on beaches, and what may be uncontrolled disturbance from people on the beach. It would also diminish pristine forest and affect the rich diversity of flora and fauna in this area. It is a recommendation of the Darwin Initiative project to turn the north coast into a National Park as an alternative, where community groups can encourage small-scale ecotourism ventures rather than open it up to big investors from which the local communities would gain little benefit.

Conclusions

Since the beginning of this Darwin Initiative project, there has been much progress. As well as monitoring the nesting turtle populations, the project has also supported a number of research projects into the ecology and conservation issues of marine turtles. This information will be used to make informed decisions about future turtle management in the north coast area. An annual nesting population estimate for the leatherbacks on the north coast has now been achieved, allowing continued monitoring to show up any changing trends and contributing to world population estimates. The continuation of the tagging programme will also provide important information about inter-nesting migrations and the number of clutches laid in a season. This work can be maintained with the newly acquired skills and knowledge of the local community groups, and the pledged support of the Government to fund the monitoring and data collection.

Bycatch of turtles in fishing nets has been identified as the most serious threat to the turtles in Trinidad, and the Fisheries Division and Wildlife Section of the Government are now working towards bringing in new methods of fishing as mitigation. The Caribbean Network for Integrated Rural Development (CNIRD) is now also working with the Matelot NGO on a biodiversity study, with potential for further work with the Caribbean Regional Environmental Programme (CREP) and United Nations Development Programme (UNDP). The involvement of these organisations is imperative to the continuation of the monitoring work. So far, the project is proving to be sustainable, and with further development of the ecotourism venture will give the project the extra stability that is required, and hopefully create more jobs within the community.

Overall the project has been a success, and the University of Glasgow plans to build on their strong links with the NGOs and the Wildlife Section, and continue to assist with turtle conservation in Trinidad.

Acknowledgments

We wish to thank the Darwin Initiative who largely funded this project. We also wish to thank the People's Trust for Endangered Species and the British Chelonia Group for additional funding and support. Thanks also to our Trinidadian counterparts: Stephen Poon; the Trinidad Wildlife Section; Pawi, Sports and Eco Club; Grande Riviere Nature Tour Guide Association, and Nature Seekers; and our many friends in Trinidad, without whose help this project would not have been possible. Much gratitude is due to the Matelot Community College and Primary School where the training and education sessions were held. Thanks also to Dan Thornham for comments on a draft of this paper, and to the teams of Glasgow University student volunteers who helped with the project.

Photo 6. Project boat bought with Darwin funds in Matelot Bay.

References

See main reference list

Marine Turtle Conservation in Trinidad - the role of rural communities on the north coast

Suzanne Livingstone and Roger Downie - Division of Evolutionary and Environmental Biology, IBLS. University of Glasgow

Background

Some of the last truly wild areas of Trinidad are within the Northern Range mountains, and on the northern coastline. There is currently no road or settlement along the central strip of this coast for approximately 22km between the villages of Blanchisseuse (west) and Matelot (east). This remote coastline is interspersed with relatively untouched sandy bays on which several species of marine turtle nest.

Five out of the six species of marine turtle that nest in the Caribbean have been observed on these beaches: Paria, Murphy's Bay, Madamas, and Grande Tacaribe and several smaller bays (Figure 1). The leatherback (*Dermochelys coriacea*) is the most prevalent species and nests in large numbers (population of approximately 1700 nesting females on north coast alone). Hawksbills (*Eretmochelys imbricata*) are also fairly common although numbers appear to have decreased over the last few decades. Past literature reports that greens (*Chelonia Mydas*), olive ridleys (*Lepidochelys olivacea*) and loggerheads (*Caretta caretta*) have also nested on this coastline, although there has been little evidence of them in recent years.

Current reports from around the world indicate profound long term declines in numbers of sea turtles. This information concurs with the apparent decline in of four of the turtle species using the north coast. However, from the history of leatherbacks in Trinidad, there is good evidence of a recent increase in population, not only on the north coast, but also on the eastern beaches. It is unclear why this is happening, but it may be due to pressures on nesting beaches elsewhere, e.g. coastal development and human disturbance. Trinidad is clearly a significant region for nesting leatherbacks, in the context of serious declines elsewhere.

While the east coast and accessible north coast beaches of Trinidad are well documented, little was known about the turtle populations nesting on the remoter northern beaches until Glasgow University carried out initial surveys in 1989 and 1991, and then a more detailed assessment in 2000. Following this, a Darwin Initiative project was set up supporting field seasons in 2002 and 2003. The project will be continuing in 2004.

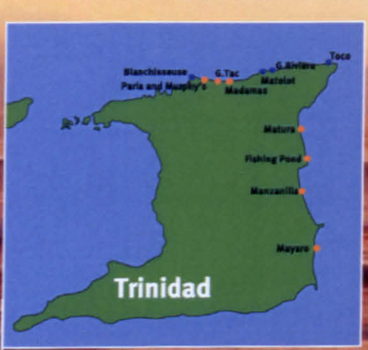


Figure 1 – Map of Trinidad showing turtle nesting areas

Figure 2 – Successful graduates of the biodiversity course

Figure 3 – Unloading the boat at Grand Tacaribe, ready for fieldwork

Community Programs

The project is largely centred on the participation of several local NGOs who are fundamentally involved in the monitoring and research. Education and raising awareness of the endangered turtles are also major components. We devised an education program designed for any interested community members on the north coast. The course aimed to expand their knowledge and understanding of conservation and environmental concepts and was largely orientated around nesting sea turtles, although other aspects of Trinidad's rich biodiversity were also reviewed. The workshops were very successful and well received (Figure 2). Twenty-two members of the community were trained, and all data collection has been done with the involvement of the graduates from the course (Figure 3).

Much time has also been spent within the Matelot Community College (local secondary school) teaching school children of all ages, and taking them on field trips to learn and understand more about marine turtles. Work was also carried out in primary schools with songs and lessons about the turtles life cycle and protection (Figure 4).

An investigation into ecotourism potential is ongoing with the idea that small local groups will be proficient in collecting valuable data on nesting turtles, and will attract tourists keen on protecting biodiversity and adventurous activities, thus enhancing community development and environmental awareness on the north coast, and making the project economically sustainable for the future. Two trial ecotourist groups from Britain were set up in 2003 with interesting and successful results.

Trinidad Marine Turtle Conservation Conference 2003 (TMTCC)

The Darwin project organised the first marine turtle conference to be held in Trinidad (Figure 5). The conference was an opportunity to bring each of the groups working on marine turtle conservation together to share information and identify existing problems. The meeting was an extremely valuable exercise for both participating groups and the Wildlife Section to improve on available support, make contacts and unite resources. The purpose of this conference was intended as an information exchange, perhaps leading on to a larger-scale meeting in 2004 aimed at policy makers and potential funders.

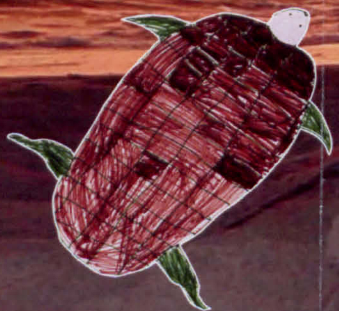
The main conclusions of the conference were to recognise that each different group and area have different needs and that they needed more support and more funding for the work that they were doing. They also felt that education and raising awareness on the issues of sea turtle conservation needed to be continued and amplified, especially in communities around nesting areas. If ecotourism is to be a genuine source of income, provision needs to be made for both the comfort of the tourists and the local people. The communities cannot be expected to support an ecotourism business without appropriate facilities and support from the Government. A major fear was the extent and lack of control over major property developers taking an interest in the area, and the possibility of this leading to unsustainable private development, without community input. Overall the conference was a success. The general outlook for turtle conservation in Trinidad is positive, although there is much to be done. It is important for all the groups to work together, to support each other and create a louder voice.

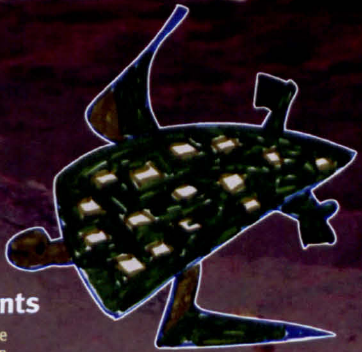
Project Partners

The Governmental Wildlife Section
Pawi, Sports, Culture and Eco Club – NGO at Matelot Village
Grand Riviere Nature Tour Guide Association (GRNTGA) – NGO at Grand Riviere

Figure 4 - Educating at the local primary school

Figure 5 – Trinidad's first marine turtle conservation conference 2003





A Brief History

Since the early colonial era, sea turtles have been observed nesting on Trinidad's north and eastern beaches and feeding in local waters. Records of exploitation date to the early 17th century. These records are somewhat vague and discontinuous; however, they illustrate how indigenous and customary turtle fishing and utilisation were in Trinidad. Each year the nesting season represented an added source of income to a small and chiefly artisanal fishing industry; to some extent this is still true.

The Trinidad and Tobago Field Naturalists Club (TTFNC) implemented the first practical research undertaken on marine turtles in Trinidad. They began a formal programme of beach monitoring and sea turtle conservation in 1965 and published work followed soon after (Bacon 1967; 1969; 1970). As awareness of the turtles' plight grew in the 1970's, so did pleas for conservation action. There was rising alarm that an unsustainable number of turtles, and especially gravid females were being killed each year. Bacon estimated that 30% of turtles nesting at Matura (east coast) and 100% of turtles nesting near villages on the north coast were slaughtered. Investigations by foreign researchers (Carr, A.F., Pritchard, P.C.H., Eckert, S.A. and Godley, B.J.) further emphasised the endangered status of sea turtles and the significance of the remaining populations both regionally and internationally.

Between 1982 and 1989, the Government Wildlife Section focused on law enforcement of regulations and nesting data were sporadically collected. The successful enforcement of a provision under the Forests Act followed in 1990, to declare Matura and Fishing Pond beaches, bordered with forest, as prohibited areas with restricted entry. Between 1990-1992, with no budget allocation to carry out beach patrols, the Wildlife Section adopted a new tactic; a community-based approach to protect nesting sea turtles through ecotourism. A successful NGO named Nature Seekers now exists on the east coast of Trinidad at Matura. The example of Nature Seekers has encouraged other communities around the country to get involved in sustaining their natural resources – there are now active groups at Grand Riviere, Fishing Pond, Manzanilla, Mayaro and Matelot (Figure 1).

Currently the Wildlife Section funds several of the groups working on turtle conservation and monitoring. The funds go towards paying the guides to patrol the beaches at night and collect data. Not all the groups are funded however, and the funds that Wildlife receives to distribute between the groups have been cut consecutively over the last 2 years. With these restraints, it is frustrating for both Wildlife and the NGO's. We have been working closely with the NGO's with a view to enhancing community development, making turtle conservation an option for generating revenue in low-income rural villages through sustainable ecotourism. Ecotourism in Trinidad at this time is at an early stage of development, however the nation appears to be making a conscious move to embrace it and the economic benefits it offers.

Figure 7 - Helping a lost female leatherback back to sea

The Darwin Initiative

The Darwin Initiative is a small grants programme that aims to promote biodiversity, conservation and sustainable use of resources in less developed countries. The Initiative is funded and administered by the UK Department for Environment, Food and Rural Affairs (DEFRA).

Figure 6 - Rubbish dumped by visitors on Paria Bay

Important New Developments

Currently the populations of turtles nesting on the remote beaches are relatively safe from human disturbance. A controversial proposal by the Trinidad government to develop the north coast for tourism puts this in serious jeopardy. The proposed development includes the completion of the east-west road as an "ecotourism highway" to, amongst other things, assist timber extraction from the northern range forest reserves. The road has already begun to be built illegally on the west side explaining the significant increase of tourists visiting the nearest beach from the road end - Paria. In the last 5 years, the amount of people frequenting this beach has increased hugely and so has the amount of rubbish (Figure 6). The majority of Matelot community is very much against the construction of the road. The Government has sought little or no opinion from the local people. There is also some evidence to suggest that there are fewer turtles nesting on Paria Bay; however, this can only be confirmed over a longer timescale. Such a development could be highly detrimental to the turtle population through easy access for poaching, development on beaches with lighting, and what may be uncontrolled disturbance from people on the beach. It would also diminish pristine forest and affect the rich diversity of flora and fauna in this area. It is part of the future of this project to fight against the road, with a view to suggesting the north coast as a National Park as an alternative, where community groups can encourage small-scale ecotourism.

The Future

Since the beginning of the Darwin Project, there has been much progress. As well as basic monitoring of the turtle populations, socio-economic development and education efforts, the project has also supported a number of research projects into the ecology and conservation issues of marine turtles. It is hoped that a tagging program will be put in place this coming field season, and that the work will continue with the newly acquired skills and knowledge of the local community, and support of the Government. The Caribbean Network for Integrated Rural Development (CNIRD) are now also working with the Matelot NGO on a biodiversity study, with potential for further work with the Caribbean Regional Environmental Programme (CREP) and United Nations Development Program (UNDP). One outcome of the research will be a report aimed at the Government giving recommendations of how to proceed with the conservation of the endangered turtles.

If you are interested in more information about this project, please contact Suzanne Livingstone: s.livingstone@bio.gla.ac.uk

UNIVERSITY of GLASGOW

IBLS

Metabolic Heating in Leatherback Turtle Nests on the North Coast of Trinidad

DARWIN INITIATIVE

SR Livingstone and JR Downie, Division of Environmental and Evolutionary Biology, IBLS, University of Glasgow.

Introduction

Temperature-dependent sex determination (TSD) in marine turtles has received much attention in recent years. Lab-based research incubating eggs at constant temperatures has detected the pivotal temperature of most species (the temperature during the middle third of the incubation period at which the sex ratio would be 50:50) (Mrosovsky and Yntema, 1980; Miller and Limpus, 1981; Billett et al, 1992; Georges et al, 1994). Rimblot-Baly et al, (1987) showed that leatherback nests in French Guiana incubated at 28.75°C lead to 100% males, and nests incubated 29.75°C produced 100% females at hatching, and that the pivotal temperature was 29.5°C.

Few of the studies carried out have taken into account the effect that metabolic heating may have upon sex ratios. Godfrey et al, (1997) found that leatherback turtle nest temperatures varied from control temperatures by 0.82°C during the thermosensitive period, demonstrating that metabolic heating may influence hatchling sex ratios. It has been suggested that metabolic heating can only be important if it elevates the nest temperature by greater than 1°C during the middle third of incubation. Others propose that a change of only a few 10ths of a °C can have a significant effect. Broderick et al, (2001) estimated that up to 30% of the proportion of females produced could be accounted for by metabolic heating in some clutches of green turtle eggs on Ascension Island.

Our experiment was designed to investigate the metabolic heating effect in leatherback turtle nests on the north coast of Trinidad.

Aims

The aims of this study were to:

- Test whether metabolic heating was taking place within the nest
- Measure the levels of metabolic heating at different stages throughout the incubation period.
- Determine whether metabolic heating was enough to affect the sex ratio of the hatchlings.

Methods

Two temperature loggers were placed within each clutch of eggs at the time of deposition (picture 2). One was put in after about 12 eggs had been laid, and the other nearer the top of the nest. The temperature loggers were pre-programmed to record the temperature once every hour over the incubation period. A false nest, positioned directly beside the real nest, was constructed to the same parameters as the real nest as accurately as possible. This was to act as a direct control. Previous studies of metabolic heating have relied on indirect controls.

The false nest was created with water filled ping-pong balls to act as controls for the eggs (picture 1). This controlled for the possibility that fluid-filled containers of turtle egg size could be responsible for temperature increase and also tested for any damping effects on diel temperature fluctuations due to the fluid nature of the eggs and the overall structure of the nest. Another hole was dug next to each false nest and a temperature logger was placed directly into the sand at an average depth approximately level with the middle of the real and false nest. This acted as a further control to the experiment. The 3 nests were located as closely to each other as possible in a horizontal line relative to the strand.

The nests were monitored over the incubation period. At hatching the temperature loggers were recovered and the data were retrieved and downloaded onto a computer. Data were retrieved from the set-up for 4 real leatherback turtle nests. The temperature dataset was divided into thirds and a mean temperature was generated for each third of the incubation period. The data from all 4 nests were combined for statistical analysis.

The temperature readings in each false nest (Tf) were subtracted from the corresponding readings in the real nest (Tr). This generated the difference in temperature between the two nests (Diff_fr).

(Tr)-(Tf) = **Diff_fr**

The same method was also applied to examine the difference in temperature between the false nest (Tf) and the sand control (Ts). This was to test whether the false nest acts as an appropriate control for the experiment.

(Ts)-(Tf) = **Diff_fs**

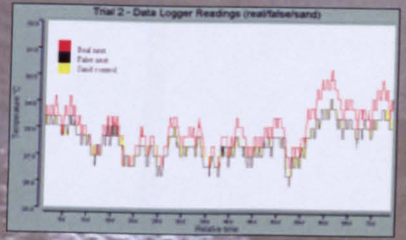
Picture 1. – Filling ping - pong balls with sea water for the false nest.

Picture 2. – Temperature logger being placed in the leatherback nest during deposition.

Results

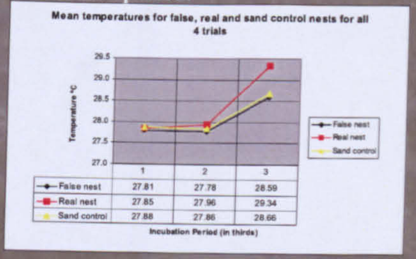
Figure 1 illustrates temperature records from a single set-up and shows that the temperature in the real nest increased at a higher rate than the sand control and false nest, most noticeably during the final third of incubation. The sand control and the false nest temperatures closely followed the same pattern of variation in temperature, presumably affected by ambient temperature changes outside the nest.

Figure 1. – Example of temperature output readings from real nest, false nest and sand control.



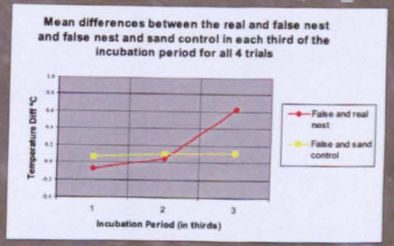
Mean temperature values were calculated for each third of the incubation period for all the nests measured (Figure 2).

Figure 2. – Mean temperature in each third of the incubation period.



The mean of Diff_fr and Diff_fs for each third of the incubation period was calculated and plotted (Figure 3).

Figure 3. – Mean differences (Diff_fr and Diff_fs)



The findings from Figure 4 are emphasised in Figure 5; the largest amount of temperature increase in Diff_fr is in the final third of the incubation period with smaller increases in the first two thirds. Diff_fs shows an overall decrease in temperature over the incubation period, with lower mean temperature values.

Figure 4. - Temperature change in each third of the incubation period

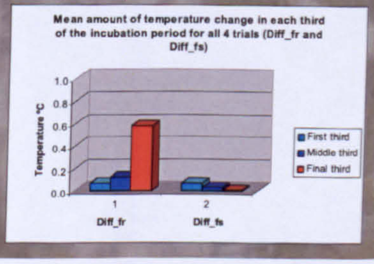
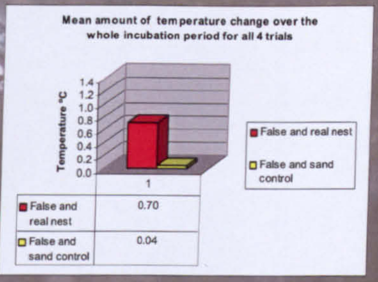


Figure 5. - Temperature change over the whole incubation period



The mean temperature change over the incubation period shows that there is an overall increase of 0.7°C in the real nest compared to the false nest. The overall change in the false nest was 0.04°C which is insignificant and most likely due to variation in the data loggers.

Discussion/Conclusions

The results show that metabolic heating took place in leatherback turtle nests. There appears to be little metabolic heating in the first third of the incubation. There was a little more in the middle third with the highest level of metabolic heating occurring in the final third of the incubation period, with an average increase of 0.57°C. Metabolic heating did occur in the middle third, and although it was very low (0.12°C) it is possible that it could have affected the sex ratio of the hatchlings if the mean temperature was very close to pivotal. However, looking at the overall temperatures during the middle third of incubation in the real nests, the temperature never actually reached the pivotal temperature for leatherback turtles (29.5°C), and therefore, it is likely that all hatchlings produced from these nests would have been male despite metabolic heating. It is believed that metabolic heating should be taken into account when trying to estimate sex ratios from sand temperatures. More data were collected in summer 2004 which will be added to this analysis. We think it likely that seasonal temperature changes are an important factor in sex determination in leatherbacks nesting in Trinidad.

Acknowledgments

Thank you to the Darwin Initiative, The Trinidad Wildlife Section and the Pawi, Sports, Culture and Eco Club.

I also wish to thank the following organisations for the travel grant awarded to me so I could attend this conference: Western Pacific Fisheries Management Council, NMFS Office of Protected Species, NMFS Southeast Fisheries Science Centre, National Fish and Wildlife Federation, Walt Disney Animal Kingdom, Wildlife Computers, Sea Turtle Symposium.