ASSESSING AND TRACKING RESIDENT, IMMATURE LOGGERHEADS (*CARETTA CARETTA)* IN AND AROUND THE FLOWER GARDEN BANKS, NORTHWEST GULF OF MEXICO.

A Thesis

by

EMMA LOUISE HICKERSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2000

Major Subject: Zoology

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December 2000

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ABSTRACT

Assessing and Tracking Resident, Immature Loggerheads

(*Caretta caretta*) in and around the Flower Garden Banks,

Northwest Gulf of Mexico. (December 2000)

Emma Louise Hickerson, B.S., Texas A&M University

Co-Chairs of advisory committee: Dr. Mark Zoran
Dr. David Owens

Over five years of underwater/above water surveys resulted in 140 reports documenting 153 sea turtle sightings within the boundaries of the Flower Garden Banks National Marine Sanctuary (FGBNMS) in the northwestern Gulf of Mexico. It has been determined that a population of large immature loggerheads resides at and moves in close proximity to the East and West Banks of the FGBNMS. Stetson Bank, the smallest bank under the Sanctuary's jurisdiction, is a sponge and *Millepora* habitat. We have determined that this bank is a more likely habitat for hawksbill sea turtles. Six large immature loggerhead sea turtles (*Caretta caretta)* with carapace lengths (CCL) ranging from 70.5-101cm were captured at depth by SCUBA divers. Five of the six were outfitted with radio and/or satellite transmitters. Five of the six animals were females. A pubescent male was recaptured three times over a period of 20 months. Over 40% of the satellite locations fell within the Sanctuary boundaries. Geographic Information System (GIS) analysis revealed an average core range of 133.6 km^2 and an average home range of 1074 km^2. These ranges are not significantly different from satellite tagged *C. caretta* captured underneath oil and gas platforms in the Gulf of Mexico. The average core ranges fell within one kilometer of the Sanctuary boundaries, and the home range within 30 km of the sanctuary boundaries. Recommendations are made to the National Oceanic and Atmospheric Administration's (NOAA's) Marine Sanctuary Division for the use of core and home range analyses and the satellite fix proximity relationship to assist to assist with management decisions.

DEDICATION

To Sydney, whose third word (after Mama and Dada) was t-t-t-tur-tle.

ACKNOWLEDGEMENTS

There are so many people who have contributed time, knowledge, or skills which have added immensely to this project. I, alone, could not possibly have undertaken this study without the support of key people. One year into the study, our daughter Sydney had announced her upcoming arrival (9 months later), during which time I was unwilling to continue SCUBA – I quickly had a host of volunteers willing to put their responsibilities aside for a week at a time, in order to make the trip offshore and survey for the turtles – Joel Hickerson, Jeff Childs, Patsy Kott, and Dave Owens.

I was afforded a tremendous amount of support from the crews of the research vessels –many thanks to them for their patience in granting my requests to dive at all hours of the night, to store bulky equipment on the deck of their boats, and disrupt diving schedules on the occasions animals were captured – Captains Phil Combs , Frank Wasson, and Ken McNeil, and divemasters Dennis Casey, Ken Busch, and Melanie Wasson stand out for their unwavering support. I am indebted to the owner of the dive charter operation, Gary Rinn, for not only allowing me to conduct my research aboard his vessels, but wholeheartedly supporting my doing so. I would also like to acknolwledge the support of the crew of the NOAA Ship Ferrel, for supporting my research activities.

Turtle surveys were conducted at night, and I was continuously recruiting volunteers. During the events when we had a turtle on board, anyone standing by was quickly enlisted to carry out tasks to get the tagging and release completed successfully. Some of those enthusiastic participants include: Joel Hickerson, Steve Gittings, Jeff Childs, Derek Hagman, Peter Vize, Patsy Kott, Ralph Daniel, Kevin Buch, Christy Pattengill-Semmens, and Carl Beaver. (Thanks and apologies go to Carl who unwittingly volunteered to test the pound/square inch pressure exerted by the jaws of loggerhead sea turtle on a sensitive part of the upper thigh!). My sincere gratitude goes out to all of the recreational divers and photographers who documented the turtles underwater, and on deck, and for then sharing those images with me. Also, a HUGE thank you to all those divers who took the time to complete the sea turtle survey forms.

Several of the satellite tags were donated generously by Dr. Richard Byles, Dr. Pamela Plotkin, and Gray's Reef National Marine Sanctuary. I would like to acknowledge the work in the laboratory by Rhonda Patterson who conducted the testosterone essays, and Kris Kichler, who analyzed the red blood cells for DNA analysis. Michael Peccini and Michael Coyne set me up with ARCView capabilities, and directed me through some of the analysis – for this I owe them my gratitude. A lot of the analysis would not have been possible without the data from Dr. Jim Gardner – from the United States Geological Survey. Thanks to you all.

This study would not have been possible without the monetary support from: Flower Garden Banks National Marine Sanctuary (FGBNMS) – National Oceanic and Atmospheric Administration (NOAA), Texas Gulf Coast Council of Dive Clubs (TGCCDC), Texas A&M University Department of Biology, Sea Grant College Program, Flower Gardens Fund, Gulf Reef Environmental Action Team (GREAT), Margaret Cullinan Wray Charitable Lead

Annuity Trust, Allen Academy, and Rock Prairie Elementary School and the Aldine Independent School District.

Many Thanks to my committee (Steve Gittings, Dave Owens, and Mark Zoran) for guiding me through this venture – both on land and in the water, and to the Flower Garden Banks NMS Manager, G.P. Schmahl, for supporting me during the writing process of this thesis.

There are many people I have not mentioned, and for that I apologize. But you know who you are. Please know that you are all very much appreciated for your contributions to this study.

To my parents, Ann and Tony Goodman, who have always believed in my abilities.

And thank you Joel, for everthing.

This project was conducted under the jurisdiction of NMFS Permit No. 981, issued under the authority of Section 10 of the Endangered Species Act of 1973.

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CHAPTER I

INTRODUCTION

Greater than 95% of a sea turtle's life is spent in their watery surroundings, yet the majority of research is conducted from their nesting locations on land. It is a rare event for a male sea turtle to venture out of the water. Therefore, little research has been accomplished in deepwater sea turtle habitat, or on wild male sea turtles. Three offshore banks in the Gulf of Mexico were recently designated as the Flower Garden Banks National Marine Sanctuary (FGBNMS) of the National Oceanic and Atmospheric Administration (NOAA). Fairly frequent access to the site, support from NOAA, the Marine Sanctuary Division (MSD) and volunteers working in the Sanctuary, as well as several thousand annual SCUBA diving visitors to the site, provided a unique opportunity to study the ecology of the wild sea turtles in their deepwater habitat and to broaden the understanding of these endangered and threatened animals. The banks of the FGBNMS are but three of many biological hardbottom communities within the Gulf of Mexico that may be inhabited by sea turtles, but are the only ones within range of SCUBA diving operators and recreational SCUBA diving depths.

Many challenges must be overcome to succeed in conducting research in a deepwater habitat located over 180 km offshore. There are limited opportunities to capture

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This thesis follows the format of the journal <u>Copeia</u>

animals due to the high costs of chartering research vessels, or due to cancellation of cruises because of weather and difficult sea conditions. When research cruises are successful in reaching the study site, sea conditions must be optimal to safely conduct a search for, capture, and subsequently handle a sea turtle. On many occasions, excessive wave height or strong currents inhibit attempts for a capture. Furthermore, humans are at a disadvantage in the water where we are limited not only by time, sight, and speed, but also by the distance we are able to cover. Thus, the successful capture of a sea turtle is a rare, but significant event.

Studies of the loggerhead sea turtle (*Caretta caretta*) suggest a developmental movement south along the east coast of the United States, and into the Gulf of Mexico. An increase in average carapace length of loggerheads from Long Island Sound, New York, southward through Pamlico and Core Sounds, North Carolina, Chesapeake Bay, and Indian River (Morreale et al. 1992, Epperly et al. 1995) has been suggested. There may be a subpopulation of *C. caretta* entirely resident in the Gulf of Mexico since mesting occurs on both Florida's west coast and in Mexico (Carr et al. 1982).

Previous loggerhead studies (Shoop et al. 1980, Shoop and Kenney 1992, Lutcavage and Musick 1985, Byles 1988, Witzell 1999) showed that there is movement from offshore to inshore and/or from south to north in the spring and the opposite movements in the fall (Hopkins-Murphy et al., in press). We shall determine whether this applies to the animals at the FGBNMS.

This study uses radio and satellite telemetry to assess the species, sizes, and life history stages of sea turtles utilizing the FGBNMS, as well as describe their spatial and temporal use of the study sites, and beyond. Satellite telemetry has been successfully used to monitor the movements and behavior of loggerheads in shallow water (Timko and Kolz, 1982; Stoneburner, 1982; Byles, 1988, b; Byles and Dodd, 1989; Keinath et al., 1989; Byles and Keinath, 1990; Hays et al., 1991; Renaud and Carpenter, 1994). Radio tracking has been historically used to track animals over a smaller range (Kalb, 1999).

The objectives of this project are to 1) identify the species of sea turtles residing at or passing through the study site, 2) identify nesting population, 3) attach radio transmitters to selected animals to investigate: a) temporal occurrence of animals in the Sanctuary; b) surface/submergence time ratios; and, c) movements around the study site; 4) attach satellite transmitters to selected animals to investigate: a)diving behavior; b) home and core ranges, and c) migratory routes, mating grounds, and nesting beaches of the individuals; and, 5) recommend management strategies to increase protection for these threatened species. In documenting loggerheads occupying oil and gas platforms in the Gulf of Mexico, Renaud and Carpenter (1994) used satellite tracking to determine the home and core ranges for the captured animals. I have also made comparisons between the animals inhabiting natural reefs to those inhabiting the artificial reefs.

Sea turtles in the Gulf of Mexico face many threats. The FGBNMS is located in one of the most active oil and gas producing regions in the world. At the end of an oil and gas producing platform's production life, it is common practice to remove the structure using explosives. As sea turtles often reside under production platforms (Renaud and Carpenter 1994) such activities pose an obvious and considerable threat. The region also experiences high levels of commercial fishing. Longline fishing is practiced in close proximity to the boundaries. Intense shrimping occurs closer to shore along the Gulf coast, and to a lesser extent, near the Sanctuary. All of these activities increase vessel traffic around and within the Sanctuary boundaries, as well as create threats to the health of the sea turtle population. The activities are regulated by NOAA and the Department of Interior's Minerals Management Service (MMS).   This study will provide data and tools to assist with management decisions both at the Flower Garden Banks National Marine Sanctuary, as well as other Sanctuaries and Marine Protected Areas (MPA's) throughout the range of the loggerhead sea turtle.

Study Area

Fishermen discovered rich fishing areas on the outer continental shelf shoals in the Gulf of Mexico more than 100 years ago. These features were later located and mapped by chart makers in the 1930's (Rezak et al., 1985; and references therein). It was suspected that these fishing areas may harbor tropical corals and associated organisms. The first bathymetric map of the area was produced by the U.S. Coast and Geodetic Survey in 1937 using leadlines (Gardner et al., 1998). In the early 1960's scientists and volunteers from the Houston Museum of Natural Science conducted the first scuba operations at these banks and subsequently reported on the massive coral reefs and rich marine fauna

(Elvers and Hill, 1985). This stimulated considerable scientific exploration and research, much of it conducted by divers and submersibles (see Gittings and Hickerson, 1998).

The two banks of the Flower Gardens were designated as a National Marine Sanctuary in 1992 (Public Law 102-251, CFR922). A third, Stetson Bank, was added to the Sanctuary in 1996. The FGBNMS is located over 180 km SSE of Galveston, Texas (Figure 1). The banks are the surface expression of salt diapirs capped by living coral reefs at the crests (Rezak et al. 1985, references therein). The reefal structures on the summits of the East and West Flower Garden Banks have probably been in existence for 10-15 thousand years.

The East Bank is a pear shaped dome approximately 5km in diameter with approximately 1 square km of reef crest rising from over 100m depth to within 18 m of the sea surface. Approximately 20 km away is the oblong shaped dome of the West Bank approximately 11km x 8kmin size, with a reef crest covering approximately 0.4 square km, rising to within 20 m of the surface.

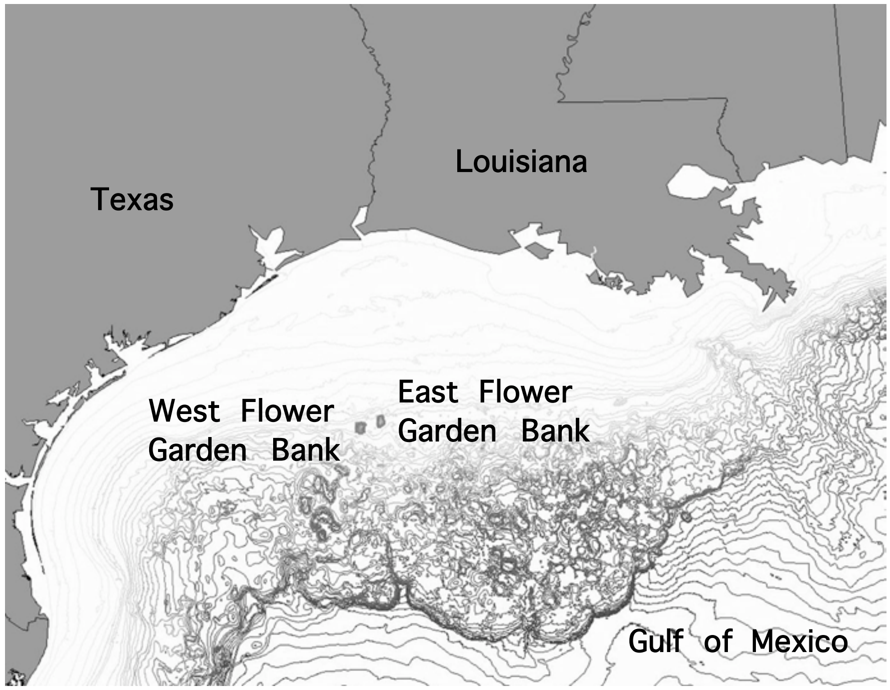

Fig. 1. Location of the study area

Above 36m in depth the hermatypic corals – *Montastrea sp*., *Diploria strigosa*, and *Colpophyllia natans* dominate the landscape along with approximately 17 other species (Bright et al., 1984). Large heads are also colonized by algae, sponges and other benthic organisms. Ridges dominated by *Madracis sp.* occupy some areas of the reefs below around 30 m adjacent to the high diversity zone. Below around 40 m depth, diversity decreases and corals grow in a flattened manner to maximize their exposure to light – a critical requirement. This zone is referred to as the low diversity zone (Rezak et al., 1985), and is dominated by a star coral *(Stephanocoenia intersepta*) and fire coral (*Millepora alcicornis*). In some areas down to 46m, fields of *M. cavernosa* and *M. franksi* continue to grow in high densities. Few reef building coral species exist below around 52m. An algal-sponge habitat extends from here to around 95m. This area is dominated by coralline algae and covers large portions of each bank. Extensive monitoring of the upper portion of these banks (above 30m) has produced data regarding the invertebrates, fish, and coral populations, but up until 1994 limited research had been directed to the large pelagics such as the elasmobranchs and sea turtles.

Approximately 52 km northwest of the Flower Garden Banks is Stetson Bank. This bank is composed of claystone outcroppings that have been pushed up to within 17 m of the sea surface. Stetson Bank lies near the northern physiological limit for reef building (hermatypic) corals in the Gulf of Mexico. About ten species of coral are found there, but only fire coral (*Millepora alcicornis*) is abundant. The most conspicuous features of this bank (which is also the shallowest area) are the pinnacles, which stretch along the northwest face of Stetson Bank for a distance of approximately 500m. The pinnacles rise from approximately 65m on the northwest side, and slope off to around 23m on the southeast side. Monitoring of this area has been conducted for the past six years and has shown that the percent cover of sponges and cnidarians (primarily *M. alcicornis*) is around 30% each (Bernhardt, 2000). A large flat area of dotted with small rocky outcroppings stretches out behind the pinnacles region. Percent cover of cnidarians and sponges is much lower in the flats (perhaps around 15% for sponges (Schmahl, pers. comm.). Meadows of algae (*Dictyota sp.*) are prevalent during the summer months. Large pelagic animals, including sea turtles, are often seen on this bank, but no animals were captured at this site during this study. Sighting data, however, was collected at Stetson Bank.

CHAPTER II

METHODS

Sea turtle sighting data

Rinn Boats, Inc. (Freeport, Texas) operates two sister ships, the M/V Fling and M/V Spree, on regularly scheduled recreational dive trips to the Flower Garden Banks from February through October annually. These vessels hold a maximum of 34 passengers. Species identification posters and information sheets were placed onboard the ships and recreational divers were requested to assist the research effort by filling in census forms to document underwater and surface sightings of sea turtles. The observers were asked to identify the species of sea turtle, and to record the date, time, and location of the sighting. They were also asked to estimate the carapace length and width, as well as record the length of the tail beyond the end of the carapace. The observers were requested to note the presence and location of barnacles on the carapace (for individual turtle identification), and to comment on the behavior of the animal. The divers were encouraged to share any available photographic material to verify species identification, as well as provide documentation for multiple sightings. Information sheets describing the five sea turtle species found in the Gulf of Mexico were provided onboard for the passengers, along with a poster with color images of the different species to help with correct identification.

Sea turtle sightings were also reported by the boat captains, galley crew, and divemasters on recreational dive charters, as well as by scientists and scientific volunteers during research cruises.

Sea turtle captures and transmitter attachment

Recreational dive vessels and NOAA vessels provided platforms upon which to conduct at-sea captures of the animals. Sea turtles were captured by trained scuba divers using a 1.5m x 1.5m, 5cm trawling mesh bag which was modelled after a design by Renaud and Carpenter (1994) with a hinged metal opening.

From June 1995 – September 1998, eight captures of six loggerheads were made at depths between 23 and 28m – one individual was captured three times over a period of 20 months. Models ST-3 and ST-6 Platform Transmitter Terminals (PTT's) (Telonics, Inc., Mesa, Arizona) configured for sea turtles were attached to the carapace of the animals with either fiberglass resin and cloth, or a two-part epoxy.

All but one of the animals were captured at night as they were resting under coral ledges on the top of the bank. When a team of divers (three) located the turtle, a diver first gripped the front and rear of the carapace and directed it slightly downwards to avoid any upward movement by the animal. The other two divers opened up a hinged catch bag into which the animal is directed, head first. The bag was closed and secured by slip-knotted ropes, which were used as handles while the divers made a safe ascent to the surface, including a safety stop on the way. The ropes allowed the divers to lift the bag without putting their hands within reach of the animal's jaws. One animal was directed into the catch bag as she was surfacing for air. This capture was one of two that were made during the day.

Once on the surface, a lift basket (1.7m x 1.3m x 0.3m aluminum - designed after a basket developed by Sarah Mitchell and Gray's Reef National Marine Sanctuary) was lowered to the water using a davit secured to the vessel deck. The animal, still in the capture net, was floated into the lift basket. The basket was lifted over the side of the vessel and placed on deck. A Detecto11S series scale with a lifting capacity of 400 lb (181kg) was attached to the lift cable between the davit and basket, and the basket was once again lifted to determine the weight of the animal.

After the weight of the animal was determined (a scale was not available for all captures), the turtle was removed from the basket and capture net, and placed carapace down onto a automobile tire. This method of immobilization has proven to be effective in the field. It protects the animal from injuring itself or people on deck (Owens, pers. comm.). The following biological measurements were then collected: curved carapace length (CCL) and width (CCW); claw lengths; plastron length; plastron width; any evidence of plastron softening (in the event of a male being captured; see below); length of tail from plastron to cloaca, length of tail from plastron to tip of tail, and length of tail past end of carapace. An injectable passive internal transponder (PIT tag) was inserted under the surface of a dorsal scute at the muscular "shoulder" of the front right flipper. Monel flipper tags were attached to a trailing edge scale of the front left flipper.

Approximately 15 ml of blood was sampled from the dorsal cervical sinus (Owens and Ruiz, 1980) using heperinized vacutainers. After the sample was centrifuged (5 mins at level 5), hematocrit was noted, and the serum was placed on ice for transport. The red blood cells were saved for DNA analysis. Once DNA sequencing is completed on an individual, the sequence can be compared with a DNA library to determine the natal population of the animal. Testosterone levels in the serum are used to verify the sex and reproductive status of the animal. Because male turtles (including immatures) have higher circulating levels of androgens than females, this method has proven dependable (Owens et al., 1978).

Satellite Telemetry

Four out of six turtles were outfitted with a "backpack" style PTT attached on the second neural scute of the carapace with fiberglass resin and cloth (FRC). Two additional transmitters were attached by Sonic Weld and Foil Fast (SWFF). The PTTs have an estimated operational life of 12 months (Argos Inc., Mesa, AZ). The PTTs were equipped with saltwater switches that activated the transmission mode (when the transmitter was “on) when the sensor was exposed to air. The units were programmed with a duty cycle of eight hours on/52 hours off, or 24 hours on (i.e. continuously on). PTTs transmitted at 401.650 MHz +/- 4kHz. Two orbiting NOAA Tiros-series satellites carrying onboard Data Collection and Location Systems (DCLS) passed over the study area approximately nine times per day. The mean duration of visibility of the satellite during each pass was 10 minutes. Messages were transmitted by the PTTs every 45-59 seconds when the PTT was turned on and the animal was on the surface. Satellites distributed the data to a network of ground satellite communication links that transferred the data to Argos for processing. The data was then distributed to users (Argos 1984, 1989).

Argos locations are calculated by measuring the Doppler shift on the transmitter signals. This is the change in frequency of a sound wave or electromagnetic wave when a source of transmission and an observer are in motion relative to each other.

Four plausibility tests are conducted:

- Minimum residual error,
- Transmission frequency continuity,
- Shortest distance covered since latest location,
- Plausibility of velocity between locations.

For the location to be made available at least two must test positive.

Location classes are based on:

- Satellite/transmitter geometry during satellite pass,
- Number of messages received during the pass,
- Transmitter frequency stability.

ARGOS assigned Location Classes (LC's) are shown in Table 1:

TABLE 1. ARGOS LOCATION CLASSES (LC'S)

ARGOS LC's

3 – accuracy to within 150 meters

2 –accuracy to within 350 meters

1 – accuracy to within 1000 meters

0 - no accuracy reported

LC3, 2, 1, and 0 - 4 messages received, location result passes at least 2 of the 4 plausibility tests for location to be made available, location accuracy is estimated

A - 3 messages

2 plausibility tests are done

accuracy is not estimated

frequency is calculated

B - 2 messages

2 plausibility tests are done

accuracy and frequency are not estimated

Z – no location obtain

ARGOS locations were rejected for one or a combination of reasons: 1) the rate of movement of the animal/PTT was unrealistic given the distance between locations, or 2) the locations showed the animal's location on land or in another body of water.

I determined that A and B LC's were acceptable: I compared the LC's 0, 1, 2, and 3 locations obtained from TT's data set, with his entire data set, including LC's A and B, using the core and home range analysis along with the location proximity relationship. TT's data set was selected for this test as it was closest to a 50/50 ratio between LC 0,1,2,3 and LC A and B (39% and 51% respectively). I determined that there was no difference between the two data sets i.e. TT's core and home ranges fall within the same zones with both data sets.

Seasons were assessed as follows:

Winter (W): December 21/22 – March 20/21

Spring (SP): March 20/21 – June 21

Summer (SUM): June 21-September 22/23

Fall (F): September 22/23 – December 21/22

Time of day (given in CST) was broken down into six 4-hour blocks as follows:

- 2400-0400 (midnight - 4am)
- 0400 – 0800 (4am – 8am)
- 0800 – 1200 (8am – noon)
- 1200 – 1600 (noon – 4pm)
- 1600 – 2000 (4pm – 8pm)
- 2000 – 2400 (8pm – midnight)

Two of the satellite transmitters were outfitted with pressure sensors. The data received from the sensor was placed into eight pre-determined depth categories (different for each transmitter). This allowed me to determine the amount of time spent at each depth range over the previous 12hour interval.

Radio Telemetry

Telonics, Inc. radio transmitters with a range of approxiately 25km were attached to four of the five captured animals, using the same process outlined above. A directional 5-element "Yagi" antenna was used to monitor the location, presence/absence, and surface/submergence times and ratios.

Geographic Information Systems (GIS) analysis

GIS layers were either constructed or imported from other sources and integrated into an ArcView GIS Version 3.1 program.

- Sea Turtle Location and Sanctuary Boundary Layers: Data were input into an Excel spreadsheet, then converted to Database Format (DBF), and transferred into ArcView Shapefiles (SHP)
- Bathymetry Layer: Arcinfo gridfiles on CD-ROM obtained from the U.S. Geological Survey (USGS) were converted into ArcView gridfiles.
- Coastline Layer: SHP format.
- Oil and Gas Platform Location Layer: Data were downloaded from Minerals Management Service (MMS) Website, converted into DBF, then SHP format.

Accepted locations were plotted for each turtle, and placed over the bathymetry and sanctuary boundary layers.

The USGS bathymetry data layer provided precise depth information, allowing for determination of the depth of water over which the satellite locations were located. This information was determined for each animal. The surrounding water depths outside the range of the USGS data were estimated using contour line information obtained from the Minerals Management Service. The depth information received from the two satellite transmitters equipped with pressure sensors was compared to the depth data as determined from the bathymetry.

Satellite fix proximity relationship

The distance (in meters) from the satellite location point to the nearest Sanctuary boundary was determined, and placed in one of a series of zones, defined by their distance from closest Sanctuary boundary: see Table 2.

TABLE 2. ZONES IN RELATION TO SANCTUARY BOUNDARIES

Zone 1 – within FGBNMS boundary
Zone 2 – FGBNMS boundary – 1km
Zone 3 – 1km – 5km
Zone 4 – 5km – 6.44km (MMS "four-mile" regulatory zone)
Zone 5 – 6.44km -10km
Zone 6 – 10km - 30km
Zone 7 – greater than 30km from closest boundary

The distances of the location fixes were determined by using the measurement tool within ArcView. The margin of error (as precision) using this tool was determined by randomly selecting a point within each relevant zone and conducting 10 consecutive measurements of distance from the closest Sanctuary boundary for each point. Percentage of locations falling within each zone were calculated for each turtle and compared. Percentages for each category were calculated for satellite locations for all turtles, as well as individually.

Core and Home Ranges

Core ranges (that range within which there is a 50% probability that a given location fix will fall) and home ranges (that range within which there is a 95% probability that a given location fix will fall) were obtained using the Animal movement extension to Arcview v.1.1 (Hooge and Eichenlaub, 1997). This extension was downloaded from http://www.absc.usgs.gov. These core and home range data were compared to similar data collected from satellite tagged animals captured underneath oil and gas structures in the Gulf of Mexico (Renaud and Carpenter 1994).

Seasonal comparisons were made using core and home range methods of analysis, combined with the location fix proximity relationship (see page 16 and 17 for descriptions).

Education

Throughout the course of this study, turtle location data were provided to the Caribbean Conservation Corporation so that students and other interested parties could access them via the World Wide Web (http://www.cccturtle.org/sat9.htm).

CHAPTER III

RESULTS

Sea turtle sighting data

Reports of observations of sea turtles at the FGBNMS cover the time period August 7, 1994 – April 16, 2000. During this period, recreational and scientific divers provided a total of 140 reports of sea turtles observed either during their dive at the FGBNMS, or on the surface while the divers were on the deck of a vessel. The total number of animals sighted is 152. The number of sightings per year is presented in Figure 2.

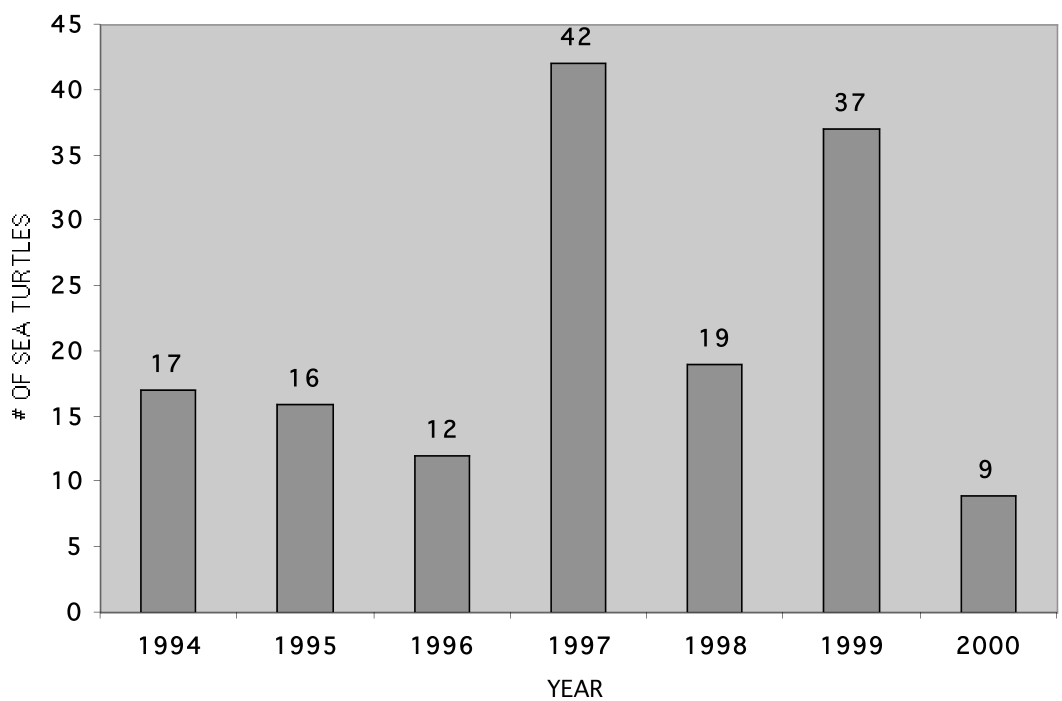

Fig. 2. Sea turtle sightings by year

Several of the reports documented multiple animals at the same time. Sightings (30%) and reports (33%) were highest in 1997. Overall, the majority of the sightings were from the East Bank (53%), and the remaining were split between the West Bank (34%) and Stetson Bank (10%). This pattern fluctuated during the course of the study. A summary of the reports is presented in Table 3.

TABLE 3. SEA TURTLE SIGHTING SUMMARY

YEAR	SB	EFGB	WFGB	OTHER	UNKNOWN LOCATION	# OF SIGHTINGS
1994	6	7	4	0	0	17
1995	2	5	7	1	1	18
1996	0	6	6	0	0	12
1997	1	24	18	0	0	46
1998	1	11	6	0	1	18
1999	3	23	8	0	3	34
2000	2	5	2	0	0	8
TOTAL	**15**	**80**	**51**	**1**	**5**	**152**

From estimates of the numbers of dive charters (Rinn Charters, Inc.) on a yearly basis, the opportunity of a sea turtle sighting by a diver is greater at the East Bank than either of the other banks in the following ratios:

West Bank:Stetson Bank:East Bank

1:1.24:1.74

The division of the number of sightings between 1995 and 1999 by the estimated number of opportunities for a diver to sight a turtle during a dive (# of dives offered per bank/year x 5), allows us to estimate the percentage of dives a turtle is seen and reported:

West Bank – 4.6%

East Bank – 4%

Stetson Bank – 0.6%

The years 1994 and 2000 were not included in these calculations as they did not cover the full time period of twelve months.

The majority of animals were identified as loggerhead sea turtles (87%). Two other species of sea turtle were reported – seven sightings of hawksbill sea turtles (*Eretmochelys imbricata*) and two of leatherback sea turtles (*Dermochelys coriacea*). There were ten reports of unidentified species of sea turtles. Of the fifteen animals reported at Stetson Bank, four (27%) were reported as hawksbill sea turtles. Table 4 illustrates the distribution of the observations by location and species.

TABLE 4. SPECIES SUMMARY BY LOCATION. Hawksbill sea turtles (EI), loggerhead sea turtles (CC), and leatherback sea turtles (DC) were reported

	EI	CC	DC	UNREPORTED	TOTAL
EFGB	2	71	1	6	**80**
WFGB	1	48	0	2	**51**
STETSON	4	11	0	0	**15**
OTHER	0	0	1	2	**1**
UNREPORTED	0	3	0	0	**5**
TOTAL	**7**	**133**	**2**	**10**	**152**

Underwater observations accounted for 47% of the reports, while 36% of the reports were documented by observers on a vessel. The depth (surface or underwater) where the animal was observed was not reported in the remaining 17%. (See Table 5).

TABLE 5. DEPTH AND TIME OF SEA TURTLE SIGHTINGS

TIME (CST)	U/W	SURFACE	LOCATION NOT REPORTED	TOTAL	% OF TOTAL
2400-0400	3	0	0	3	2
0400-0800	1	2	0	3	2
0800-1200	9	7	3	19	12.5
1200-1600	15	9	0	24	16
1600-2000	12	12	4	28	18
2000-2400	22	5	6	33	22
NO TIME REPORTED	9	19	14	42	28
TOTAL	**71**	**54**	**27**	**152**	

The time of the sighting was not reported for 28% of the reports. 110 of the reports noted the time of the observation. Of these reports, 30% of the animals were sighted between 8pm and midnight (the majority of which were observed during a dive). Fewer animals (25%) were seen between the hours of 4pm and 8pm – half of the observations made below the surface and half above. A similar number of observations (22%) took place between noon and 4pm – slightly more animals were documented underwater. Fewer animals were observed between 8am and midday. Only 3% of the animals were sighted between midnight and 8am.

Summer sightings (June 20/21 – September 22/23) by far exceed the combined observations for the three other seasons – 71% of the observations were made during the summer season. Winter (December 21/22 – March 20/21) and Fall (September 22/23 – December 21/22) accounted for 10 observations each, and Spring (March20/21 – June 20/21) accounted for 25, as outlined in Table 6 below.

TABLE 6. SEASONALITY OF SEA TURTLE SIGHTINGS

	WINTER	**SPRING**	**SUMMER**	**FALL**
UNDERWATER	5	13	49	4
SURFACE	3	10	40	1
UNREPORTED DEPTH	2	2	18	5
TOTAL	**10**	**25**	**107**	**10**

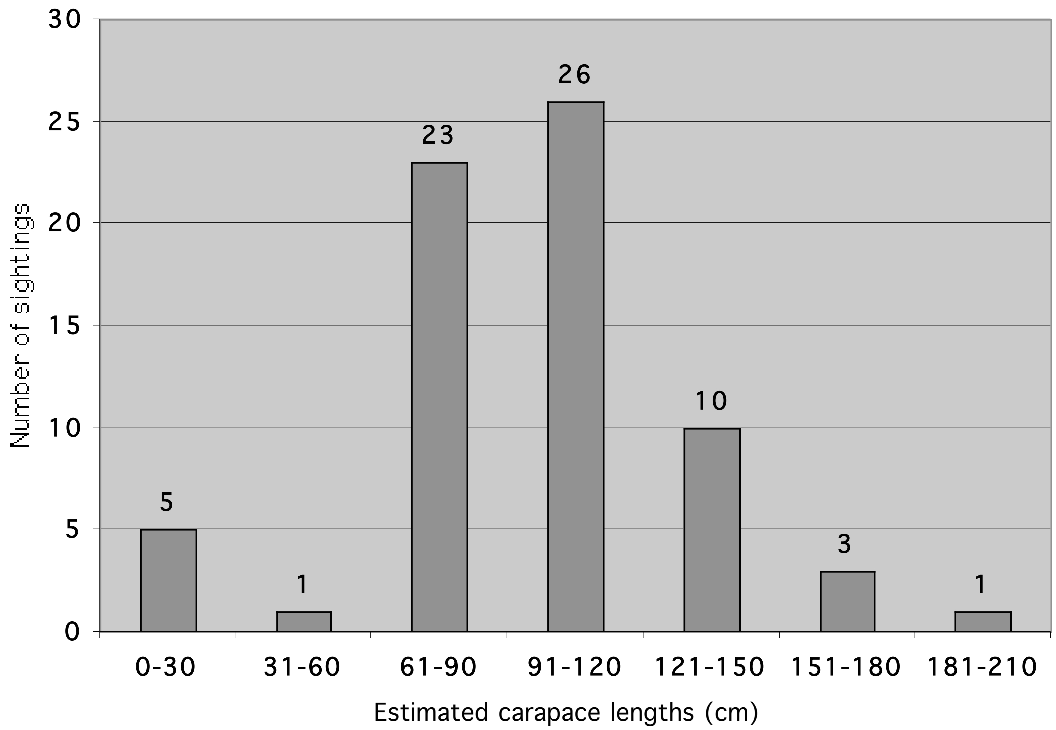

Fig. 3. Estimated carapace lengths for sea turtle sightings

Carapace length estimates were obtained for 42% of the animals sighted (Figure 3). Estimated carapace length ranges were from 3.5cm – 200cm (including pelagic immatures and leatherbacks) and 30cm – 200cm without immatures. The mean estimated carapace length for 64 loggerheads was 101cm. Included in this mean are the lengths of the carapaces of the six captured animals. Four of the animals reported were small pelagic immatures ranging from 3.5cm – 10cm in length. One of the hatchlings was preyed upon by a jack immediately after the observation was made. Two of the immatures were identified as loggerheads and measured by a qualified observer (Dr. David Owens). When the two immature animals' carapace lengths are taken out of the pool of loggerheads, the mean estimated carapace length was 104cm.

Video and photographic images obtained from recreational and scientific divers were reviewed. Barnacle patterns and flipper and carapace notching were noted to identify animals and compare for multiple sightings (Appendix A). These identifying characteristics were also requested in sighting data reports. In all, fourteen individuals were identified from the images and reports (not including the six captured animals). Three (non-captured) animals were photo-documented or reported on the sighting data reports on more than one occasion (see Table 7 for details). Although I am not including additional data of sightings in my analysis, I continue to add to the catalog of individuals for which I receive photographic details of barnacles (Appendix A). The first animal captured in the study (Triton) was documented on 18 separate occasions between June 1995 and August 2000.

TABLE 7. MULTIPLE SIGHTINGS OF SEA TURTLES. Two captured animals (TP and TM) were sighted on multiple occasions.

Multiple Sightings	**Sighting 1**	**Sighting 2**	**Sighting 3**
MS 1	7/28/94	8/94	8/24/94
MS 2	8/30/94	9/9/99	-
MS 3 (TP)	8/14/97	2/20/99	7/29/99
MS 4	8/18/99	9/9/99	-
MS 5 (TM)	6/24/98	8/22/00	-
MS 6 (TT)	Sighted on 18 occasions. See Table 9		

The turtles were sighted by SCUBA divers in four separate areas in relation to the reef and the water column – on the surface, swimming to/from the surface through the water column, swimming at a relatively constant depth just above the coral heads, or resting on a sand flat, usually with a portion of their heads and bodies underneath a coral ledge. On two occasions feeding behavior (sifting through sand) had been reported by an observer.

Sea Turtle Captures

Six large immature animals were captured from June 21, 1995 to October 13, 1998. Two captures took place during the day and six at night. Details of the captures and biological data are shown in Table 8:

SEE TABLE AT END OF CHAPTER

The first animal captured for the purpose of satellite and radio transmitter attachment was a male. This is the only male that was captured during this study. Limited knowledge is available regarding male sea turtles, particularly those living in deepwater habitats. Table 9 is a timeline of observations collected for this animal (TT).

TABLE 25. TIMELINE OF CAPTURES AND SIGHTINGS OF TT

DATE	COMMENTS
9/12/94	Probable first documented sighting of TT – male animal WFGB #5
6/21/95	Capture #1 – 8:58pm. WFGB #5
2/23/96	Underwater sighting. WFGB
6/10/96	Capture #2 – 8:50pm. WFGB #5
6/14/96	Surface - WFGB
10/16/96	Divers cleaned off sensors on satellite transmitter (at depth)
2/18/97	Capture #3 – 7:45pm. WFGB #5
6/15/97	Surface - WFGB
8/11/97	Surface - WFGB
8/20/97	Surface - WFGB
8/24/97	Surface - WFGB
9/8/97	Surface - WFGB
3/2/98	Radio transmitter still functioning. TT surfaced several times. At one point, surfaced for up to 19 minutes long – hammerhead shark fins surrounding him. Warm conditions for season. WFGB
10/14/98	Surface – tail sticking straight up - WFGB
7/12/99	Surface - WFGB
7/26/99	Surfaced 3 times – transmitters still attached. One surface interval was up to 15 minutes long. 30 minute dive times. Swims with tail sticking straight out of water - WFGB
12/7/99	Surfaced twice – 40 minute dive times. Tail sticking straight up. - WFGB

4/13/00	Surface – WFGB. Tail sticking out of water, transmitters still attached.
8/00	Surfce - WFGB

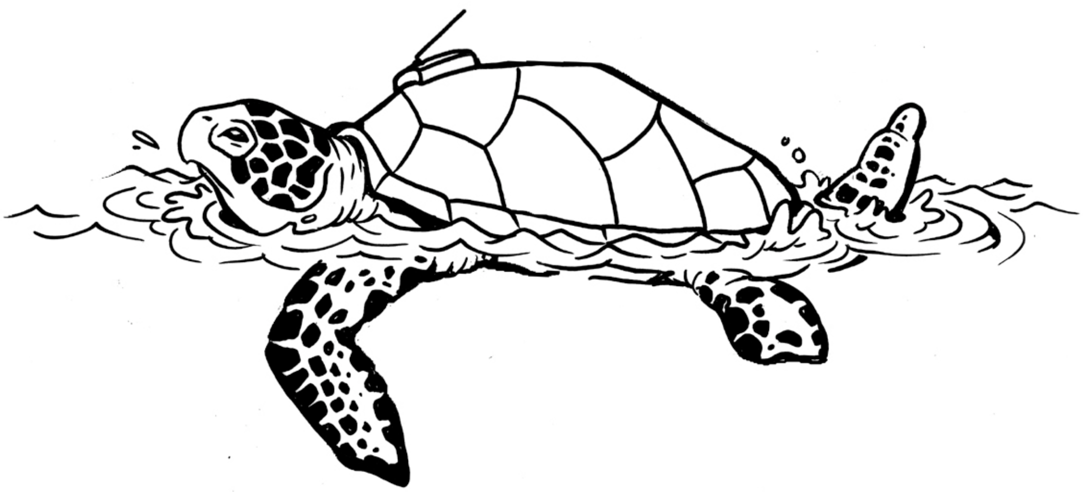

Fig. 4. Cartoon of Triton (TT) swimming on the surface with his tail protruding out of the water (art by Joel M. Hickerson)

In Triton, we documented a measurable and visible elongation of the tail and enclosed penis over a period of 20 months (Figures 5-7).

Fig. 5. TT tail 1995 , 34 cm length (Photograph by Dave Owens)

Fig. 6. TT tail 1996, 40 cm length

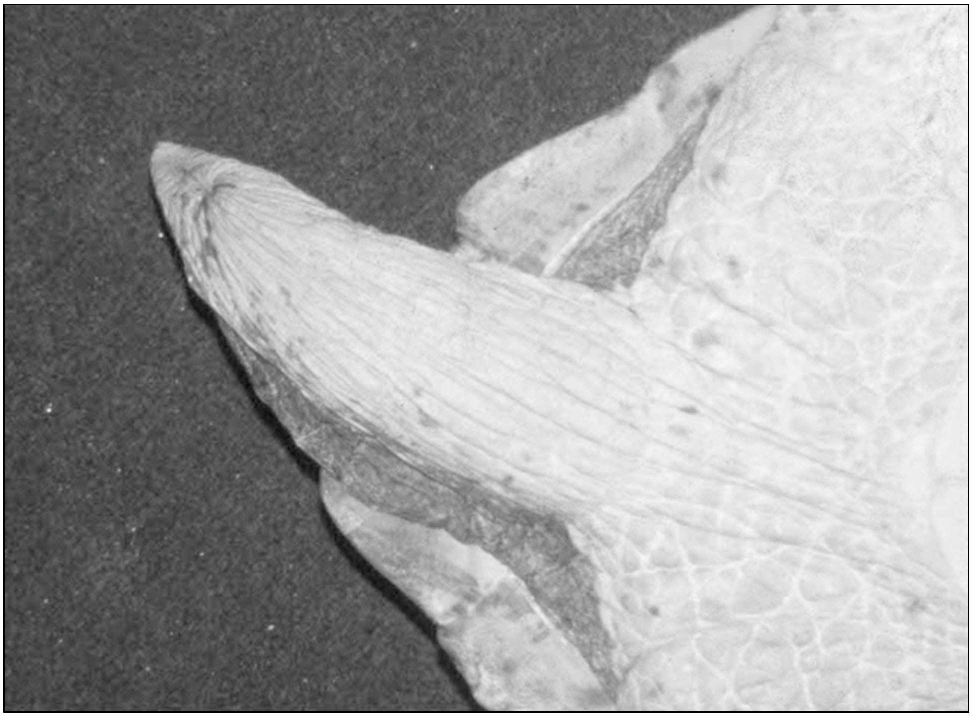

Fig. 7. TT tail 1997, 49cm length (Photograph by Quenton Dokken)

In addition, his claws on the front flippers were starting to curve at the time of the first capture (Figure 8), an d an increase in plastron dekeratinization was measured (Figure 9-11).

FIG. 8. TT CLAW – June, 1955 (Photograph by David Owens)

Fig. 9. TT dekeratinized plastron 1995 (photograph by Dave Owens)

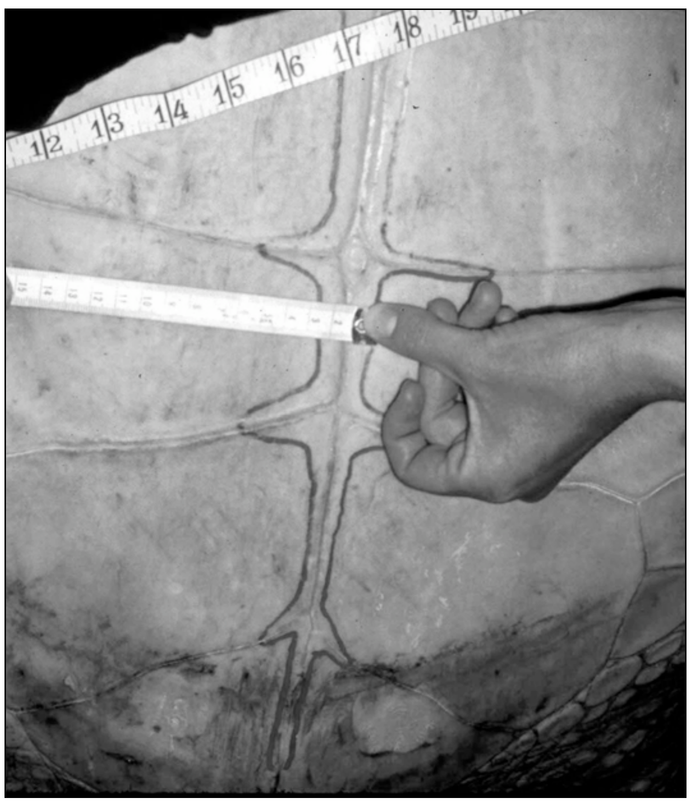

Figure 10. TT dekeratinized plastron 1996

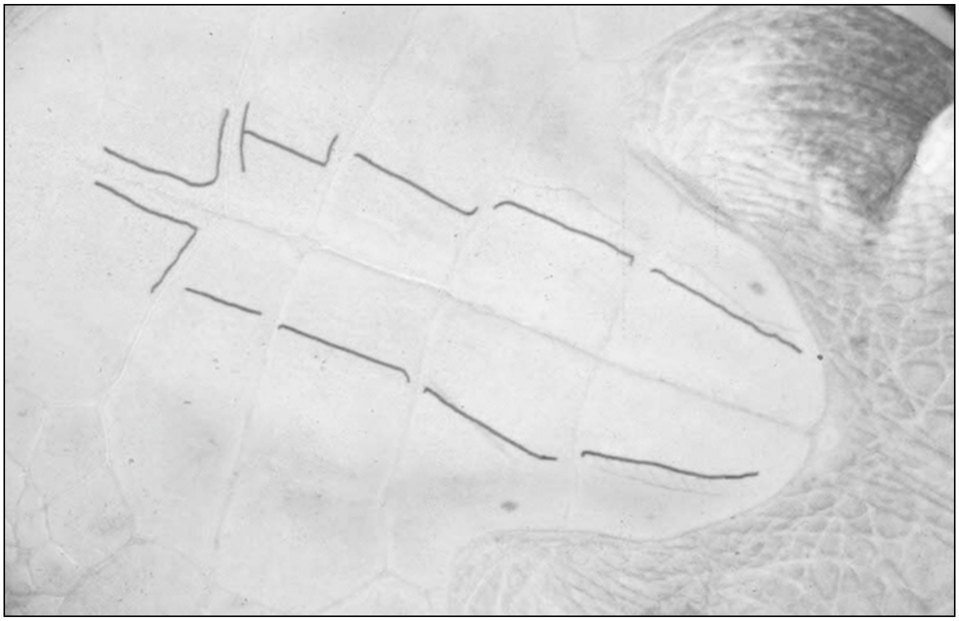

Fig. 11. TT dekeratinized plastron 1997 (photograph by Quenton Dokken)

TABLE 10. TT's MEASUREMENTS : TAIL LENGTH, PLASTRON DEKERATINIZATION, AND TESTOSTERONE LEVELS

	TIP OF TAIL TO CLOACA (CM)	WIDTH OF DEKERATINIZED PLASTRON (CM)	TESTOSTERONE LEVEL (PG/ML)
6/21/95	34	~2	244
6/10/96	40	10	518
6/18/97	49	14	205

A summary of the growth data secondary sexual characteristics is shown in Table 10.

Satellite transmitter attachment and satellite telemetry

Satellite transmitters were successfully deployed on five of the six captured turtles (see Appendices B-F for turtle data sheets). Attachment was not successful for the animal captured on September 8, 1997. The transmitter was found on the reef beneath the vessel the morning after the turtle was captured and processed. TT initially had a satellite transmitter attached to him during his second capture. This transmitter malfunctioned, and was recovered a year later and replaced. Neither of these transmitters were used in the analysis of the satellite telemetry data. Refer to Table 11 for satellite deployment details:

TABLE 11. SUMMARY OF SATELLITE TRANSMITTERS

Tag # and Name	**SSJ301 Triton TT**	**SSJ311 Philos TP**	**QQC281 Marie TM**	**SSJ303 Chocolate TC**	**SSJ306 Lucky TM**
Type of PTT	ST-3	ST-6	ST-3	ST-6	ST-6
Method of PTT Attachment	Fiberglass resin and cloth (FRC)	FRC	FRC	Sonic Weld/Foil Fast (SWFF)	SWFF
Duty Cycle	8 hrs on/52hrs off	8/52	8/52	24 hrs on	24 hrs on
Number of days PTT functional	531	349	393	77	100
Number of transmissions	150	90	252	145	134
Number of accepted locations	33	22	97	70	56

A total of 771 messages were received from the five functioning satellite transmitters (Table 11). TM's PTT sent the greatest number of transmissions (252) and TP's the least (90). Over half the transmissions (426) did not provide a location due to insufficient signal strength, or provided an insufficient number of signals during the satellite pass. Thus, only 45% of the transmissions provided location data to be assessed for analysis. Table 12 is a breakdown of the transmissions received for each animal by Location Class ((LC) Table 1)).

TABLE 12. SUMMARY OF LOCATION CLASSES FOR SATELLITE TRANSMISSIONS

	3	**2**	**1**	**0**	**A**	**B**	**Z**	**TOTAL**
TC	0	1	6	3	25	40	70	**145**
TL	0	0	4	13	12	28	77	**134**
TM	1	5	5	4	21	65	151	**252**
TP	0	0	3	2	13	14	58	**90**
TT	7	17	5	3	34	14	70	**150**
TOTAL	**8**	**23**	**23**	**25**	**105**	**161**	**426**	**771**

Locations were received from 345 transmissions (45%) of which 67 were deemed unacceptable for one or a combination of reasons: unreasonable distances/rates of movement, unreasonable location (e.g. on land), or duplication of data due to multiple points given in a short time period.

The Location Classes (LC's) for the locations were predominately LC B and A (58% and 38% respectively) . The remaining 25% are LC 0, 1, 2, and 3. The number of days the transmitter was functional ranged from 77 (TC) to 531 (TT) (mean=290, SD=196, n=5). The number of days "on" ranged from 77 (TC) to 212.4 (TT) (mean=137, SD=53, n=5).

Radio Telemetry

Radio tracking data were obtained for one animal (TT). Tracking took place intermittently over the period June 21, 1995 – June 4, 1997 at the West Bank of the Flower Gardens (location of capture). The majority of the tracking was conducted during the summer months. During this period, 47.9 hours of tracking revealed an average surface time was 3.79 minutes (SD= 1.9, n=81), and average submergence time of 39.4 minutes (SD =9.7, n=73). Surface to dive time ratio was approximately 1:10.

Geographic Information System (GIS) analysis

A total of 278 satellite location points were accepted for GIS analysis (81% of the ARGOS location points). The breakdown of the points for each turtle and Argos Location Class is presented in Table 13. TM's transmitter produced the greatest number of accepted satellite locations (97) and TP's the least (22).

TABLE 13. ACCEPTED SATELLITE LOCATION POINTS

	0	1	2	3	A	B	TOTAL
TC	3	6	1	0	25	35	**70**
TL	13	4	0	0	12	27	**56**
TM	5	3	5	1	21	62	**97**
TP	1	2	0	0	11	8	**22**
TT	0	1	7	5	16	4	**33**
TOTAL	**22**	**16**	**13**	**6**	**85**	**136**	**278**

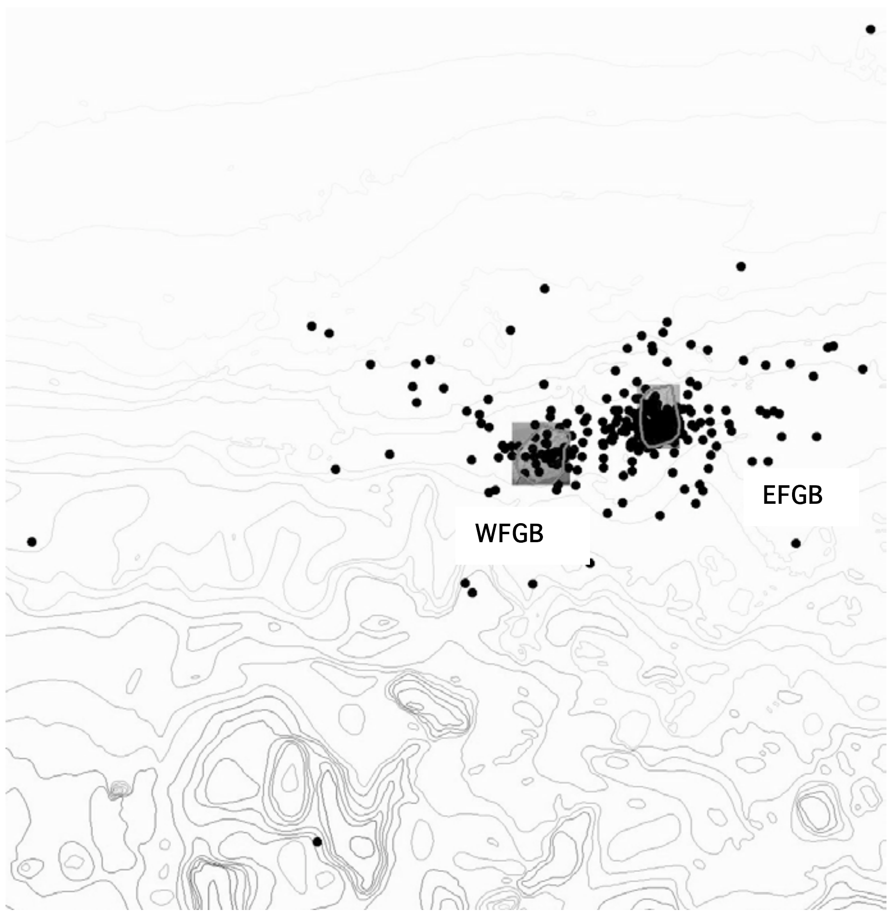

Fig. 12. Map of accepted satellite locations for all turtles

Figure 12 shows the distribution of all accepted satellite locations for all turtles. The two blocks represent the bathymetry of the East (EFGB) and West Flower Garden Banks (WFGB). The Sanctuary boundaries are shown by lines overlaying the bathymetry.

The majority of the fixes were obtained during the time period of 4am-8am (83). This represents 30% of the total number of locations. The least were obtained during the time period 8pm-midnight. (See Table 14.)

TABLE 14. TIMES OF ACCEPTED SATELLITE FIXES

Time (CST)	2400-0400	0400-0800	0800-1200	1200-1600	1600-2000	2000-2400
# of fixes	34	83	15	66	74	9

The number of days the transmitters functioned each season for each turtle are shown in Table 15.

TABLE 15. NUMBER OF DAYS SATELLITE TRANSMITTERS FUNCTIONED EACH SEASON

	Winter	**Spring**	**Summer**	**Fall**	**Total**
TC	0	0	69	8	**77**
TL	70	30	0	0	**100**
TM	88	92	122	91	**393**
TP	88	92	78	91	**349**
TT	118	184	138	91	**531**
Total	**364**	**398**	**407**	**281**	**1450**

The transmitters collectively functioned for similar numbers of days during the winter (25%) , spring (27%), and summer (28%) seasons. The transmitters functioned for a smaller number of fall days (19%). Collectively, 1450 days of transmitter time were obtained during this study.

The highest number of fixes was obtained during the Summer and Fall seasons (37% and 40% respectively). The Winter and Spring seasons produced the fewest (9% and 14% respectively); Table 16.

TABLE 16. SEASONALITY OF ACCEPTED SATELLITE FIXES

Season	Winter	Spring	Summer	Fall
# of fixes	26	38	102	112

The depth of the water at the location of the satellite fixes was determined by overlaying bathymetryic data layer provided by United States Geological Survey (USGS). If a fix fell outside the USGS data set, the depth was ascertained using the depth contours (obtained from Minerals Management Service data layer) close to the fix points. A summary of these data are shown in Table 17. TC was the only turtle with any fixes within the depth range of 0-30m. Four of the animals had zero fixes in multiple ranges. TC had more points falling within 90-100m (14.1%) than at other depths. TL and TP had more in the range of 110-120m (16.1% and 22.7% respectively. TP also had 22.7% of her fixes falling in depths over 150m. TM and TT had more fixes fall within depth ranges of 120-130m (24.2% and 18.8% respectively) than at other depths. Overall, the greatest number fell within the 120-130m range (16.4%), with the least falling within the 0-30m range (less than 1%). Figure 5 shows the distribution of the satellite fixes for all five turtles.

TABLE 17. DEPTH AND FREQUENCY OF ACCEPTED SATELLITE FIXES

	TC	**Freq.**	**TL**	**Freq.**	**TM**	**Freq.**	**TP**	**Freq.**	**TT**	**Freq.**	**Total**	**Pooled Freq.**
0-30m	1	1.4	0	0	0	0	0	0	0	0	1	0.28
30-40m	2	2.8	1	1.8	0	0	2	9.1	0	0	5	2.7
40-50m	9	12.7	5	8.9	6	6.1	1	4.5	1	3.1	22	7.1
50-60m	8	11.3	0	0.0	5	5.1	0	0.0	1	3.1	14	3.9
60-70m	3	4.2	1	1.8	6	6.1	0	0.0	2	6.3	12	3.7
70-80m	2	2.8	2	3.6	6	6.1	1	4.5	4	12.5	15	5.9
80-90m	7	9.9	5	8.9	11	11.1	0	0.0	4	12.5	27	8.5
90-100m	10	14.1	7	12.5	8	8.1	1	4.5	2	6.3	28	9.1
100-110m	6	8.5	4	7.1	10	10.1	3	13.6	5	15.6	28	11.0
110-120m	7	9.9	9	16.1	10	10.1	5	22.7	5	15.6	36	14.9
120-130m	8	11.3	8	14.3	24	24.2	3	13.6	6	18.8	49	16.4
130-140m	3	4.2	5	8.9	8	8.1	0	0.0	0	0.0	16	4.2
140-150m	3	4.2	1	1.8	2	2.0	1	4.5	0	0.0	7	2.5
>150m	2	2.8	8	14.3	3	3.0	5	22.7	2	6.3	20	9.8

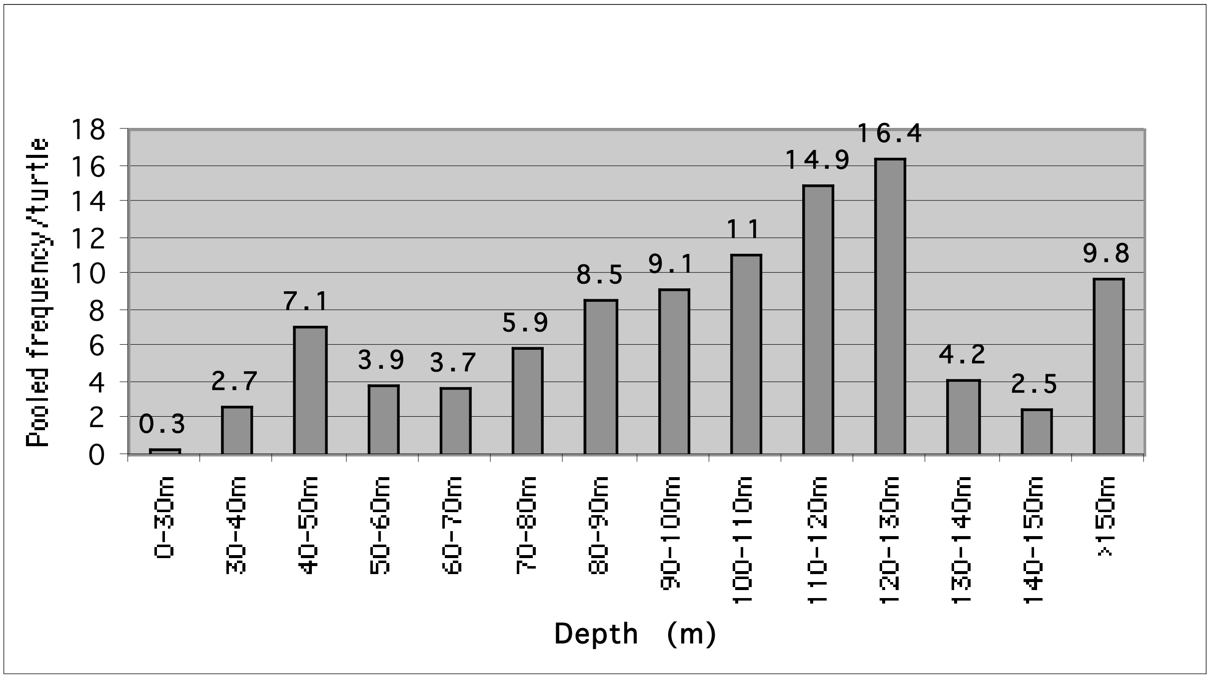

Figure 6. Pooled frequency of satellite locations by depth

A chart of the depths by pooled frequency id shown in Figure 13. The highest frequency of fixes falls within the 120-130 m depth range, and the lowest within the 0-3 m range.

Two of the turtles, TL and TC, were equipped with pressure sensors as part of their satellite transmitter packages. The average time spent (minutes/hour) at the eight depth ranges preprogrammed into the satellite transmitter software are shown in the Tables 18 and 19 below.

TABLE 18. PRESSURE SENSOR DATA FOR TL

TL Depth (ft)	Depth (m)	Mins/hr Overall
0-15	0-5	3.51
16-50	6-15	4.33
51-100	16-30	27.04
101-150	31-46	10.02
151-200	47-61	8.38
201-250	62-76	5.65
251-300	77-91	3.7
301-400	92-122	4.3

On average, TL spent just over 27 minutes per hour at depths ranging from 16-30m (SD=169, n=133). She spent the least time at depths ranging from 77-91m (SD=110, n=133), 92-122m (SD=139, n=133) and at the surface (SD=40, n=133).

TABLE 19. PRESSURE SENSOR DATA FOR TC

TC Depth (ft)	Depth (m)	Mins/hr Overall
0-16	0-5	4.78
17-33	6-10	1.14
34-49	11-15	1.98
50-65	16-20	2.34
66-131	21-40	25.72
132-262	41-80	20.67
263-328	81-100	3.31
329-492	101-150	3.28

On average, TC spent nearly 26 minutes per hour at depths from 21-40m (SD=114, n=145). She spent an average of nearly 21 minutes per hour at depths from 41-80m (SD=132, n=145). The combined total for the depths between 21-89m is nearly 47 minutes per hour. She spent the least amount of time at the depth range of 6-10m (SD=41, n=144).

Satellite Fix Proximity Relationship

The 278 accepted satellite fixes were assigned to the zones according to their proximity to the boundaries of the Flower Garden Banks National Marine Sanctuary. The summary of these data are shown in Table 20.

TABLE 20. ZONATION OF SATELLITE FIXES – ALL TURTLES COMBINED

W/IN:	**FGBNMS zone 1**	**1KM zone 2**	**5KM zone 3**	**6.44KM 4M zone 4**	**10KM zone 5**	**30KM zone 6**	**> 30KM zone 7**
# PTS	113	27	54	15	26	36	7
Cumulative	113	140	194	209	235	271	278
%	40.6	9.7	19.4	5.5	9.4	12.9	2.5
Cum. %	40.6	50.3	69.7	75.2	84.6	97.5	100

More satellite fixes occurred in Zone 1 (within the sanctuary boundaries) than any of the other zones (41%). The fewest occurred within Zone 7 – greater than 30km from the nearest Sanctuary boundary (3%). The distributions of satellite fixes in each zone for individual sea turtles are shown in Table 21.

TABLE 20. ZONATION OF SATELLITE FIXES – INDIVIDUAL TURTLES

W/IN:	**FGBNMS**	**1KM**	**5KM**	**6.44KM 4M**	**10KM**	**30KM**	**30KM +**	**TOTAL**
TC	34	6	14	1	6	7	2	70
Cumulative	34	40	54	55	61	68	70	
%	48.6	8.6	20	1.4	8.6	10	2.8	
Cum. %	48.6	57.2	77.2	78.6	87.2	97.2	100	
W/IN:	**FGBNMS**	**1KM**	**5KM**	**6.44KM 4M**	**10KM**	**30KM**	**30KM +**	**TOTAL**
TL	13	7	7	5	10	13	1	56
Cumulative	13	20	27	32	42	55	56	
%	23.2	12.5	12.5	8.9	17.9	23.2	1.8	
Cum. %	23.2	35.7	48.2	57.1	75	98.2	100	
W/IN:	**FGBNMS**	**1KM**	**5KM**	**6.44KM 4M**	**10KM**	**30KM**	**30KM +**	**TOTAL**
TM	43	6	22	7	7	10	2	97
Cumulative	43	49	71	78	85	95	97	
%	44.3	6.2	22.7	7.2	7.2	10.3	2.1	
Cum. %	44.3	50.5	73.2	80.4	87.6	97.9	100	

TABLE 21. (continued)

W/IN:	**FGBNMS**	**1KM**	**5KM**	**6.44KM 4M**	**10KM**	**30KM**	**30KM +**	**TOTAL**
TP	6	2	5	1	3	4	1	22
Cumulative	6	8	13	14	17	21	22	
%	27.3	9.1	22.7	4.6	13.5	18.2	4.6	
Cum. %	27.3	36.4	59.1	63.7	77.2	95.4	100	
W/IN:	**FGBNMS**	**1KM**	**5KM**	**6.44KM 4M**	**10KM**	**30KM**	**30KM +**	**TOTAL**
TT	17	6	6	1	0	2	1	33
Cumulative	17	23	29	30	30	32	33	
%	51.6	18.2	18.2	3	0	6	3	
Cum. %	51.6	69.8	88	91	91	97	100	
								278

Percentage of fixes occurring with the Sanctuary boundaries ranged from 23% to 52%. A higher percentage of satellite fixes occurred in Zone 1 (within the Sanctuary boundaries) for TT (52%) than any other turtle. The lowest was obtained for TL (23%). This animal spent equal time in Zone 1 and Zone 6 (10-30km beyond the sanctuary boundaries). All animals spent the highest percentage (or equally high in the case of TL) of their time within Zone 1. Three animals had their lowest percentage of fixes in Zone 7 (beyond 30km away from the Sanctuary boundaries) – TL, TM, and TP. One of these animals (TP) had an equally low number of satellite locations in Zones 7 and 4 (5km-6.44km from the nearest Sanctuary boundary). All zones were represented by all turtles with one exception; TT did not transmit signals from Zone 5 (6.44-10km beyond the Sanctuary boundaries). TC had the lowest number of satellite fixes fall within Zone 4.

The (accepted) satellite fixes measuring the greatest distance from the sanctuary boundary for each turtle is shown in Table 22.

TABLE 21. INDIVIDUAL TURTLE SATELLITE LOCATION POINTS GREATEST DISTANCE FROM SANCTUARY BOUNDARY

	TC	**TL**	**TM**	**TP**	**TT**	**AVG**
GREATEST DISTANCE (KM)	**35.15**	**76.96**	**44.14**	**74.96**	**31.38**	**52.52**

Table 23 illustrates the percentage of time the five turtles (cumulatively) spent in a zone, per time period, in any give season. The percentages are given per season, not as a percentage of the overall number of point (i.e. 281). For example, from between 4pm-8pm, 15.4% of the winter satellite locations fall within the sanctuary boundaries. This time period represents the greatest amount of time these animals (as a collective group) spend in one zone during the winter months.

TABLE 23. FREQUENCY OF SATELLITE LOCATIONS BY ZONE, SEASON, AND TIME (ALL TURTLES)

	Z1 (%)	**Z2 (%)**	**Z3 (%)**	**Z4 (%)**	**Z5 (%)**	**Z6 (%)**	**Z7 (%)**	**SEASON TOTAL**
WINTER								
0000-0400			3.8					
0400-0800	7.7				3.8	3.8		
0800-1200						3.8	7.7	**26**
1200-1600	3.8	3.8	11.5	3.8		3.8		
1600-2000	15.4	7.7	3.8			7.7		
2000-0000	3.8				3.8			
Total	**30.7**	**11.5**	**19.1**	**3.8**	**7.6**	**19.1**	**7.7**	
Cum.		**42.2**	**61.3**	**65.1**	**72.7**	**91.8**	**99.5**	
SPRING								
0000-0400					2.6			
0400-0800	5.3	5.3		5.3	2.6	2.6		
0800-1200	7.9		2.6				2.6	**38**
1200-1600	13.2	5.3	13.2				2.6	
1600-2000	13.2	2.6	7.9					
2000-0000	2.6		2.6					
Total	**42.2**	**13.2**	**26.3**	**5.3**	**5.2**	**2.6**	**5.2**	
Cum.		**55.4**	**81.7**	**87**	**92.2**	**94.8**	**100**	

SUMMER								
0000-0400	10.7	0.9	3.9	0.9	0.9	0.9		
0400-0800	16.5	0.9	3.9	1.9	1.9	5.8		
0800-1200			0.9			1.9		**102**
1200-1600	4.9	2.9	4.9	0.9	1.9		1.9	
1600-2000	12.6	1.9	7.8		1.9	0.9	0.9	
2000-0000	0.9		0.9			0.9		
Total	**45.6**	**6.6**	**22.3**	**3.7**	**6.6**	**10.4**	**2.8**	
Cum.		**52.2**	**74.5**	**78.2**	**84.8**	**95.2**	**98**	
FALL								
0000-0400	4.4	0.8	2.6	0.8	0.8	1.8		
0400-0800	17.5	3.5	3.5	1.8	3.5	5.3		
0800-1200	0.8		0.8		0.8			**112**
1200-1600	7.9	1.8	0.8	1.8	4.4	5.3		
1600-2000	6.1	3.5	4.4	2.6	3.5	4.4	0.8	
2000-0000			1.8					
Tot.	**36.7**	**9.6**	**13.9**	**7**	**13**	**16.8**	**0.8**	
Cum.		**46.3**	**60.2**	**67.2**	**80.2**	**97**	**97.8**	
TOT.								**278**

During the winter season, the turtles (collectively) spent nearly 31% of the time within the Sanctuary boundaries (Zone 1). The spring season showed an increase in the time spent within the boundaries – to around 42%. During spring the five animals (collectively) spent equal amounts of time (13.5% each) within two different zones during two different time periods: noon-4pm within the Sanctuary boundaries, 4pm – 8pm within the Sanctuary boundaries and noon – 4pm between 1 and 5km of the Sanctuary boundaries. During summer 45.6% of the time was spent within the Sanctuary (Zone 1), particularly between4am - 8am (16.8%). During the fall, once again, the highest percentage of time was is spent in Zone 1, and like the summer, particularly so within the time period 4am – 8am. Nearly 37% of the turtles' (collective) time was spent within the Sanctuary during this season.

Core and Home Ranges

The core ranges (CR), within which there is a 50% probability that a point will fall, are depicted for each turtle in Figures 14 - 18. Core ranges are depicted in the darker kernel. The home ranges, within which there is a 95% probability that a point will fall, are also shown in these figures. Home ranges are depicted in the lighter kernel.

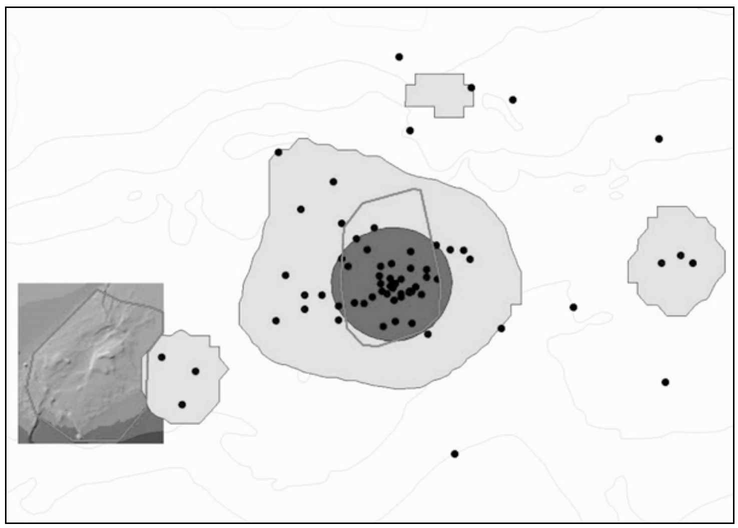

Figure 14. Core and home range map for TC

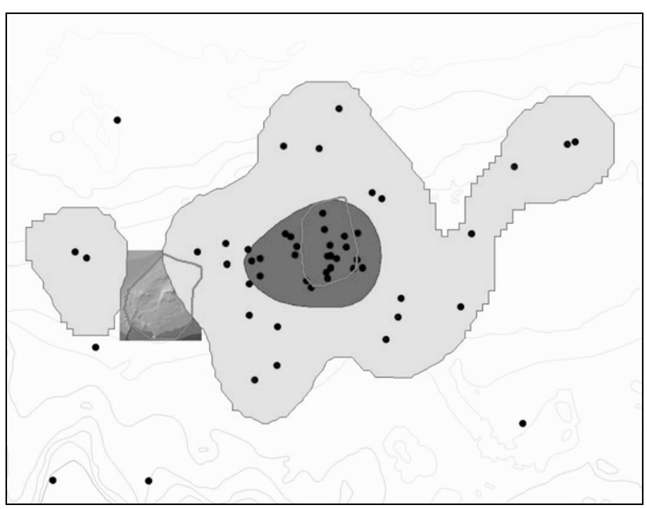

Figure 15. Core and home range map for TL

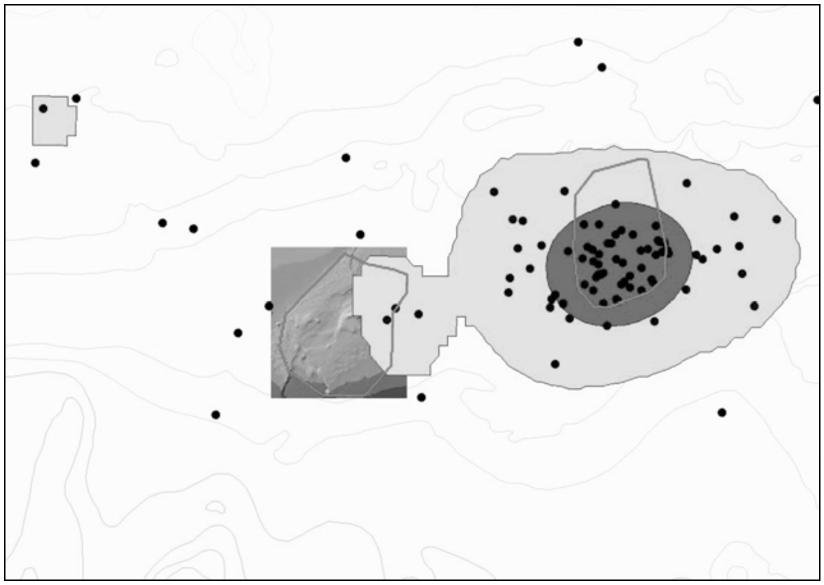

Figure 16. Core and home range map for TM

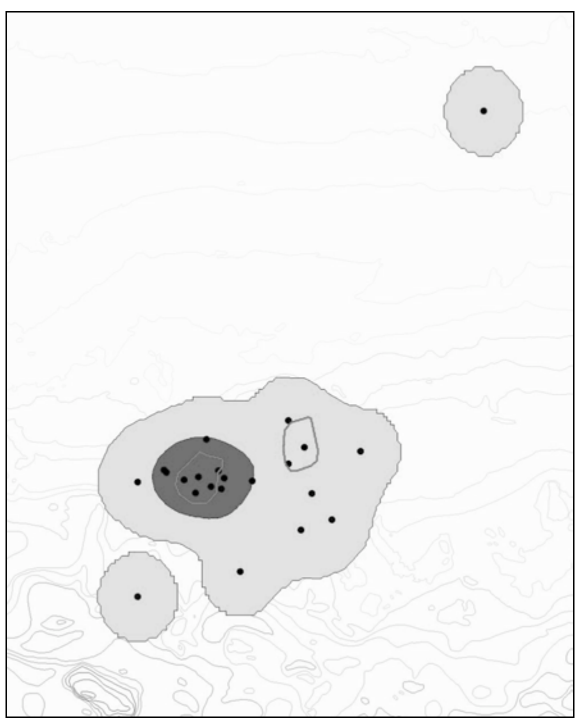

Figure 17. Core and home range map for TP

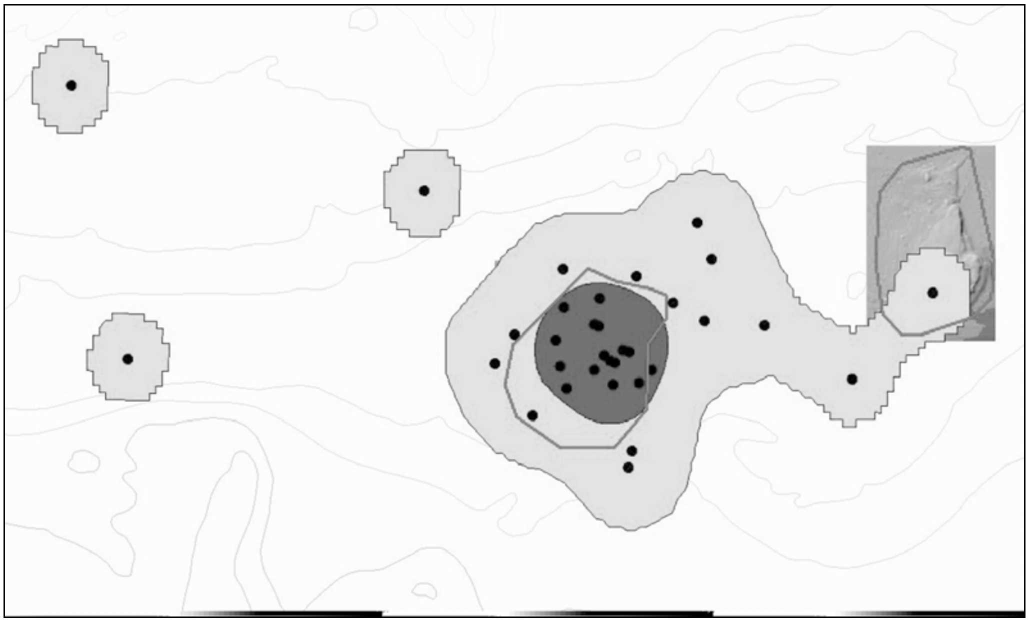

Figure 18. Core and home range map for TT

TC was captured on the East Flower Garden Bank. Her ranges and satellite locations indicate that this is her preferred habitat. TL was also captured on the East Flower Garden Bank, and her ranges also indicate this habitat as her area of preference. Her core range nearly encompasses the area within the Sanctuary boundaries. TM, like the two animals above, was captured on the East Flower Garden Bank. She also has shown site fidelity to this area. Her core range covers more than half of the southern portion of the Sanctuary. TP was captured on the West Flower Garden Bank. Her core range encompasses the entire area within the Sanctuary boundaries and her home range encompasses both the East and the West Bank. TT was captured on all three occasions on the West Bank of the Flower Gardens. His core range is contained nearly completely within the boundaries of the Sanctuary on that bank.

A summary of the size of the ranges is shown in Table 24.

TABLE 24. CORE AND HOME RANGES

	CORE RANGE (KM^2)	**HOME RANGE (KM^2)**
TC	**56.3**	**271.5**
TL	**185.4**	**1516.9**
TM	**84**	**450.4**
TP	**288.4**	**2610.5**
TT	**54.0**	**425.4**
Mean	**133.6**	**1054.9**

TT's satellite fixes resulted in the smallest core range - 54km^2, and TP the largest at 288.41 km^2. TC's satellite fixes showed the smallest home range – 271.5 km^2, and TP the largest - 2610 km^2.

The core range for all turtles combined (see Table 20) falls within 1 km of the sanctuary boundaries (Zone 2), i.e. 50% of the satellite fixes fall within Zone2. When analyzing each turtle individually, the core range for two of the animals (TC and TM) also falls within Zone 2. TT exhibits the tightest core range – 50% of the locations falling within the Sanctuary boundaries (Zone 1). Core range falls within 5km of the Sanctuary boundaries (Zone 3) for TP. TL exhibits the broadest core range, which falls within Zone 4 (5-6.44km from the nearest Sanctuary boundary). The home range for all turtles combined falls within 30km of the sanctuary boundaries (Zone 6). This is also true for all animals when they are individually assessed.

During the winter and fall seasons, the core range falls within Zone 3 and during the spring and summer, within Zone 2 (Table 23). The home range during the winter and spring falls within Zone 7 and within Zone 6 during the summer and fall.

TABLE 8. SUMMARY OF CAPTURED SEA TURTLES

Flipper tag number and name of animal	Date & time of capture	Site of capture	Sex	Curved carapace length (CCL) – (CM)	Weight (kg)	Testosterone Level (pg/ml)
SSJ301 Triton (TT)	6/21/95 2058 hrs	West Flower Garden Bank	Male	99	Unknown	244
Capture #2	6/10/96 2050 hrs			101		518
Capture #3	2/18/97 1945 hrs			101		205
SSJ311 Philos (TP)	8/14/97 1437 hrs	West Flower Garden Bank	Female	74.5	Unknown	18.3
SSJ312 (not named)	9/8/97 2200 hrs	West Flower Garden Bank	Female	77.5	Unknown	12.0
QQC281 Marie (TM)	6/24/98 2130 hrs	East Flower Garden Bank	Female	70.5	49.89	Levels indicative of a female
SSJ303 Chocolate	7/14/98 1210 hrs	East Flower Garden Bank	Female	72.5	47.63	7.51
SSJ306 Lucky (TL)	10/13/98 2130hrs	East Flower Garden Bank	Female	85.8	77.11	18.2

CHAPTER IV

CONCLUSIONS

- A population of large juvenile loggerhead sea turtles resides in and around the Flower Garden and Stetson Banks, in the northwest Gulf of Mexico.
- This population of large juvenile loggerheads is present in sex ratios similar to the ratios of the South Florida loggerhead nests. Preliminary genetic analysis indicates this to be the origin of the Flower Gardens loggerhead population.
- At least three life history stages of loggerheads occur at the FGBNMS – hatchlings/post-hatchlings, large juveniles, and adults.
- The loggerhead sea turtle (*Carette caretta*) is by far, the most common species of sea turtle at the East and West Banks. In this stody conducted between 1995 and 2000, they were primarily large juvenile animals. Female animals were the dominant sex.
- Stetson Bank was preferred by hawksbill sea turtles (spongivores). On average, hawksbills were seen at Stetson Bank at a higher ratio than at the East and West Banks.
- Over the course of the study, there was a higher chance of seeing a turtle at the East and West Banks than Stetson Bank.
- Very little feeding occurred in the areas of the reef crest above approximately 30m, where divers were likely to observe the behavior.
- The loggerheads used the (relatively) shallow reef crest to rest, and appeared to forage on deeper areas of the reef, and beyond.

- The average estimated carapace length (according to sighting data) for the loggerheads at the Flower Gardens was approximately one meter. This was probably an estimation of the animal including the head.
- Recreational divers were able to document the presence and general details of the target species and could provide anecdotal information, as well as valuable photographic information.
- Recreational divers were not reliable sources to gather data consistently, or for providing specific information. Given the opportunity to collect and record data voluntarily, there was still a low rate of data submission.
- Small pelagic phase sea turtles are preyed upon by chub and jacks and perhaps other carnivores, as their *Sargassum* mat passes over or close to a natural or artificial reef structure (e.g. oil and gas platforms) where such predators congregate.
- Sea conditions directly affected the performance of the satellite transmitters.
- Preliminary data suggest that loggerhead sea turtles living on a natural reef may exhibit a similar core and home range to animals inhabiting an artificial habitat (e.g. oil and gas structures). As artificial reefs are generally smaller, however, displacement of sea turtles by unusual environmental events (e.g. cold fronts) may be more likely.
- Location data and core/home range assessments of data can be used together to evaluate the effectiveness of current protection regimes, and to make recommendations for management and protection decisions.
- Extension of (for example) the fishing restrictions to the Minerals Management "four-mile" zone (6.44km) may considerable increase the protection of the loggerheads within their home ranges at the Flower Garden Banks.

CHAPTER V

DISCUSSION

Sea turtle sighting and behavior data

The use of recreational divers as the instrument through which sightings are documented has been a lesson in itself. Although I made an effort to make it relatively easy for the divers to access the reporting sheets, and placed informational posters in key places on board the dive vessel (galley and heads), the return rate was low.

A large portion of these sightings was received from the dive operators or scientific divers on research cruises. I feel confident that effort from year to year did not change significantly, and believe that the variations from year to year are valid. I have spent a considerable amount of time on site myself to confirm these variations. If the entire year of 2000 were incorporated into this project, I suspect the data would reveal a year similar to 1997 – the year that had yielded the most turtle sightings.

I have also found that identification of the species of sea turtle observed can be quite challenging. For example, three divers reported to me, verbally, an encounter with a sea turtle as they dove together as a group – they interacted with this animal for approximately ten minutes. Two divers were scientific divers (not sea turtle biologists, but in another field of marine biology), and the third was a SCUBA divemaster with more experience on this dive site than most. When I inquired as to the species of the animal (separately), the responses I received identified the subject as three different species.

From experience and data collection, we now know that the loggerhead is the most common species of sea turtle inhabiting the East and West Flower Garden Banks, and hawksbill sea turtles can be observed at nearly equal proportions as loggerheads at Stetson Bank. Therefore, I have been quite wary of accepting any surveys reporting the sighting of any species other than a loggerhead – I followed up with the observer by way of a thorough debriefing, and either accepted or declined the observation based on their answers. In some instances, a picture or video is the proof that is required to document a secondary species.

The mean estimated carapace length of the loggerheads observed at the Flower Garden Banks is just over one meter. Dickerson et al. (1995) used 82.5cm as the size for adult turtles, whereas, 92cm was used by the Turtle Expert Working Group (TEWG) to denote adult sized turtles (Hopkins-Murphy et. al, in press). Regardless of which measurement is used, according to the reported carapace lengths, the majority of these animals would be adults. The range of curved carapace length (CCL) for the five female loggerheads captured was 70.5cm – 85.8cm, averaging 76.2cm. If I include the male turtle (TT) in this average, also a large immature animal, the average is 80cm. I believe this group to be representative of the sizes of animals at the study site. Therefore, I believe that the estimated carapace lengths of the turtles sighted is overestimated, on average, by approximately 30cm. I presume the reason for this overestimation is because most observers probably included the head in the measurements, instead of just the carapace.

It has been documented that smaller animals (40-60 CCL) are common and even abundant in coastal inlets, sounds, bays, estuaries and lagoons during the spring, summer and fall months from Cape Cod Bay around the southeastern U.S. and into the Gulf of Mexico and through the Caribbean (Carr et al. 1982, Lutcavage and Musick 1985, Mendonca and Ehrhart 1982, Butler, et al. 1987). Eventually, after some years of moving seasonally in and out of these development habitats, the larger juveniles and nearly all adults seem to avoid the shallow, partially enclosed coastal waters with a preference for open coastal and continental shelf areas, from fairly near the coast to hundreds of kilometers offshore on the broader reaches of the continental shelf. Morreale et al. (1992) and Epperly et al. (1995) have reported increasingly larger mean carapace lengths from Long Island Sound, New York, south to Indian River. This overall distribution suggests a developmental movement south along the east coast and into the Gulf of Mexico. This study at the Flower Garden Banks NMS supports this theory. I have determined that the majority of the animals are large juvenile animals. As in any data set, there are outliers. One female adult loggerhead with an estimated carapace length of 140cm was documented on the West Flower Garden Bank by two qualified observers on two separate occasions (Emma Hickerson and Kevin Buch). This observation may suggest occasional habitat for mature adults. Additional observations are required to confirm this.

Given the problems encountered with relying on divers to fill in survey forms, it is hard to estimate the population of loggerhead sea turtles inhabiting the Flower Gardens. I was, however, able to measure the likelihood of encountering a turtle on a dive at the

Flower Gardens. From estimating the number of dives made on each bank per year, I determined that there is a similar chance of seeing loggerheads, at the both the East and West Flower Garden Banks, and a lower chance at Stetson Bank. Stetson Bank is much smaller in area than either the East or West Bank. I suspect this limits the numbers of sea turtles utilizing its resources. It is also in shallower water and experiences colder winter temperatures. Based on normal schedules of visits and dives by the charter boats operating in the area, it is my belief that the effort (observing an animal and reporting the sighting) between Stetson and the other banks did not vary significantly.

It is interesting to note the higher proportion of hawksbill sea turtles observed at Stetson Bank. This is understandable is one considers the available food sources. Stetson Bank has a wall of pinnacles running in a general northeast to southwesterly direction for approximately 500m. Sponges cover around 30% coverage of this area (Bernhardt 2000). Sponge cover at the Flower Garden Banks is only 1.5%. Hawksbill sea turtles primarily eat sponges. A young resident hawksbill, about 50cm CCL, was recently observed devouring an entire unidentified species of sponge. It placed its front flippers on the sponge to stabilize itself as it ripped off pieces. This, unfortunately, is the only definitive observation of feeding behavior by a sea turtle during this study. On several occasions, loggerheads have been reported sifting through sand, but no food item was documented.

More sea turtles were sighted underwater than on the surface. A large number of the underwater sightings (35%) take place between the hours of 8pm – midnight, even though only about 20% (or less) of the dives occurred at night. Although turtles were often observed during the day, the high number of night observations suggest that the turtles use the shallow reef areas to rest under ledges more often at night. Turtles have often been observed resting in the shallow reef areas (usually in a sand patch). The divers have watched them as they headed to the surface for a breath of air, then returned to the same resting place. Their choice of resting location may be because there is a shorter distance to the surface, making it easier and quicker to get to the air. It may also be due to the greater availability of overhangs and other habitats suitable for resting. The majority of surface sightings took place between the hours of 4pm –8pm. This supports the theory that the animals come into the (relatively) shallow reef crest for the night.

The apparent use of this area for resting is probably the reason we have rarely documented foraging behavior. They are there to rest, not to forage. Based on location data derived from tracking, it is likely that they are foraging on the deeper areas of the reef, and off the reef itself.

Summer sightings far exceeded the combined observations for the other three seasons. The satellite data indicates that the animals do not migrate for these other seasons. Summer is the high season for the charter operators - more charters, more divers, more observations. Triton (TT) apparently stayed in and around the West Flower Garden Bank year round, as he was observed during all seasons. His satellite tracking data supports this. Interestingly, he may bask on the surface at certain times in order to warm himself. We observed TT in the middle of winter (February, 1998) as he surfaced for air. The weather conditions at the time were flat and calm, and the air temperature was unseasonably warm. The water temperature was near its annual low of approximately 20°C. Triton's usual 3-4 minute surface interval was extended to around 15 minutes.

Sea turtles bask on land and in the water. Loggerhead turtles maintain a body temperature slightly higher than water temperature while swimming and resting in the water. In Hawaii, green sea turtles crawl ashore to bask on oceanic beaches (Whittow, 1982). There are believed to be different reasons behind basking – elevation of body temperature, escaping from predators, females escaping amorous males, or elevating body temperature to hasten incubation of eggs by females. I believe the purpose behind TT's behavior was thermoregulation. Sapsford and van der Riet (1979) reported a loggerhead raising its body temperature 3.8°C above the water temperature by basking in sunlight, keeping a substantial portion of its carapace exposed above the water surface.

Hatchling sea turtles occur in *Sargassum* mats as they pass the Flower Gardens. This is somewhat unfortunate for the animals, as it is my observation (along with Dr. David Owens) that chub (*Kyphosus sectatrix/incisor*) and various species of jack come up off the reef and prey on anything eible in them as the mats pass. On several occasions, I have snorkeled through some of these mats and have been amazed at the lack of biological inhabitants. The effect may be further exacerbated by the presence of moored vessels on the reef. Chubs are attracted by the wastewater off the vessel – large school of several hundred arrive soon after the ships do and remain for the duration of the visit. The fish feed en masse on any passing *Sargassum* mat. Jacks and barracudas sometimes also school below the vessels. On one visit to the banks, a large group of teachers on a specialty trip witnessed a jack prey on a hatchling that they had been observing in a *Sargassum* mat from the ship's deck.

The presence of these hatchlings brings up the question, where are they coming from? The prevailing currents run from west to east. Currents closer to shore move in the opposite direction. This nearshore current could be carry hatchlings from Florida/Alabama nesting beaches towards Texas, where they may be head in easterly currents from the central and south Texas coast, offshore.

Where will the animals that live at the Flower Garden Banks NMS migrate to for nesting? Preliminary genetic analysis (unpublished data, Kris Kichler) suggests two different haplotypes are present between the six different turtles sampled. Both of these haplotypes are common, and are found in the same nesting populations, so a definitive nesting population cannot be determined. The samples best fit with southern Florida populations based on the haplotypes.

On July 9, 1998, Barbara Schroeder (NMFS) and Allen Foley (Florida EPA) satellite tracked an adult female loggerhead who deposited eggs on a nesting beach in Manasota Key on the Gulf coast of Florida, to an area off the coast of Texas and Louisiana (www.cccturtle.org, unpublished data). Though no satellite fixes placed the animal at the Flower Gardens, it is therefore clear that Florida nesters occur in that general area. This animal seemed to be utilizing an area closer to shore than the Sanctuary. On June 28, 2000, Mark Nichols (Gulf Islands National Seashore - GINS) tagged a nesting female loggerhead in the Santa Rosa area of GINS, which is located in the panhandle of Florida, close to Pensacola. This animal also moved steadily towards Texas and continues to transmit (as of September 28, 2000) from approximately 50km south of Galveston Island (90km northwest of FGBNMS) in depths of approximately 20m (www.cccturtle.org, unpublished data).

Puberty in a captured male loggerhead sea turtle

Male sea turtles are poorly studied compared to females, for which many studies have been conducted. The reason for this is obvious - after leaving the natal beach as a hatchling, males rarely, if ever, return to land. Females, on the other hand, assuming they survive to maturity, inevitably return to land by the hundreds or even thousands, to dig nests and deposit their eggs, becoming convenient subjects for probing, prodding, measuring, and attachment of transmitters, etc.

Limpus (1985) has conducted tag-recapture studies of feeding ground turtles at Heron Island Reef and Wistari Reef since 1974, and rookery tagging studies since 1968. He has described puberty and first breeding in female *C. caretta* in Queensland, Australia (1990). He reports that immature females may take as little as four years to go through puberty based on enlargement of the oviducts to adult size, although the passage through puberty may require 10 years with individual turtles starting and finishing at different sizes. This means that size is not a reliable indicator of maturity or breeding status (Miller in Lutz and Musick, 1996).

As noted by Carr (1952) and Pritchard (1979), chelonid sea turtles do not exhibit sexual size dimorphism, however, males do exhibit several sexual dimorphisms that appear to facilitate successful mating. Adult males have long, prehensile tails. Adult females have a tail that barely reaches the outer edge of the carapace. Adult males also develop longer, curved claws on the front flippers, which aids them in clasping onto a female's carapace.

Wibbels et al. (1991) speculated that an additional secondary sexual characteristic in adult male sea turtles - the softening, or dekeratinizing, of the midline of the plastron - could enhance a male's mating ability by increasing tactile sensation and/or by decreasing slippage during mounting. He also suggested that this is a characteristic exhibited by reproductively active males. The documentation of the gradual softening of the plastron in Triton (Figures 9-11) may illustrate that this is not a seasonal occurrence in adult males, but an indication of the level of maturity of males. The testosterone level (Table 10), however, during the third capture in February (205pg/ml) indicates that this is not a reproductively active male, but the initial signs of a dekeratinized plastron suggest that he is pubescent. Typically in February a mature male would have very high levels of testosterone (T) in the nannogram/ml range (Owens, 1997). It is likely that this male animal has been going through puberty since at least the date of the first capture in June of 1995. According to our frequent observations (Table 9), he had not left the study site prior to April, 2000. He was not observed between April and August, 2000. This would indicate that puberty has lasted for a period of at least 4 years and 9 months.

Triton reappeared at the West Bank of the Flower Gardens in August, 2000. Owing to the observed length of his tail, it is possible that he finally migrated to an unknown mating ground. It is unfortunate that he was not equipped with a functional satellite transmitter at the time of his departure.

Large juvenile and adult *C. caretta* were found to be resident all year in the coral reefs of the southern Great Barrier Reef and in Moreton Bay, Australia (Musick and Limpus in Lutz and Musick, 1996). Juveniles displayed strong forage site fidelity to relatively small areas, mostly remaining within a few square kilometers for the next 8 to 20 years of growth to sexual maturity. Limpus also showed that adult loggerheads, after completing their first breeding migration to distant nesting beaches, return with high fidelity to the same juvenile foraging areas in which each had completed its juvenile life. It will certainly be interesting to document the length of Triton's continued residency at the Flower Garden Banks National Marine Sanctuary.

Satellite telemetry

A number of factors combine to affect the ability to track sea turtles effectively, including the ability to capture them and attach a transmitter in a way that will ensure normal behavior of the animal subsequent to its release. Capturing sea turtles on a reef as deep and extensive as the Flower Gardens (deep in terms of SCUBA diving limitations, and deepwater habitat for sea turtles)proved extremely time consuming. In order to complete six captures, hundreds of hours were been spent by SCUBA divers looking for the animals underwater.

There was great variation between the performance of the transmitters. Some of this could have been due to the behavior of the individual sea turtle, but I suspect that it was more related to be the effectiveness of the transmitters themselves. The duty cycle of 8 hours on/52 hours off would be a preferred choice for animals inhabiting a reef like the Flower Garden Banks, as opposed to an animal undertaking a migration as this duty would extend the life of the transmitter. It was perhaps fortuitous that the transmitters attached using Sonic Weld/Fast Foil were both outputting signals on a 24 hour duty cycle, as they did not last beyond 100 days. It is unknown why any of the transmitters stopped functioning. I speculate that the three transmitters that lasted close to or beyond a year stopped functioning due to battery failure. I have seen all of these animals well after the termination of the satellite transmissions, with their transmitter still attached to their carapace. In all three cases the antenna was either missing or broken. I have not seen (and have not received a report of) either animal with transmitters that had been attached by Sonic Weld/Fast Foil. It is unknown whether these transmitters continued to be attached to the animals beyond the documented transmission time, and the animals haven not been observed, or the animals were observed, but the transmitters were not attached, therefore, not allowing identification of the animal. Gray's Reef National Marine Sanctuary and others (Dave Nelson – U.S. Army Corps of Engineers) have had success using this method of attachment. In these two instances at the Flower Gardens, it may be a matter of incorrectly application.

Argos provides Location Classes (LC's) for the transmissions. The range of error is great enough to allow for misinterpretation when looking at the data on small scales.

For instance, only one of the accepted satellite fixes was located on top of the reef crest (in water depth ranges of 0-90m) where the animals are captured, even though that was where the majority of the observations take place. We can only assume that the animal is coming directly beneath that point to the surface. This may or may not be the case. For example, during the several minutes the animal is on the surface, depending upon the strength of the current, an animal may be carried quite a distance before it submerges again.

Satellite transmissions are, however, very useful looking at the broader picture. It is clear that the animals prefer one bank over another. It is also clear that they have a relatively small home range in which they conduct their daily activities during this stage of their lives.

When looking at the data measuring the amount of time an animal spends during a 12 hour interval (preprogrammed in transmitter package) within certain depth ranges, we are answering the question, where in the water is the animal spending time. Without technology such as "crittercam" (a camera that may be mounted onto the carapace of the sea turtle, and retrieved at a later time) we cannot determine what the animal is doing, when it is foraging or resting.

According to the data collected by the satellite transmitter TL spent over 27 minutes per hour at depths ranging from 16-30m . We can assume from her satellite locations and core and home range maps, and knowledge of study site, that she is spending this time on the coral reef of the West Bank. We can also assume from our observation of turtles at this depth that some of this time she is resting. Like TL, TC spent close to 26 minutes per hour at depths ranging from 21-40m, which also leads me to believe that she is closely associated with the coral reef of the East Bank of the Sanctuary.

When comparing the percentage of days the satellite transmitters were functioning per season with the number of accepted satellite locations per season, there is a significant difference (Table 25):

TABLE 25. SEASONAL SUCCESS RATE OF SATELLITE TRANSMITTER

	Days transmitter functional		Accepted satellite locations	
Winter	364	25%	26	9%
Spring	398	27%	38	14%
Summer	407	28%	102	37%
Fall	281	19%	112	40%

The fall season had the least transmittal time, but it has the greatest number of accepted satellite locations. The calmest waters often occur at this time of year. In comparison, the winter and spring seasons have relatively high transmittal time. With these seasons come the worst sea conditions of the year. At these times, it is reasonable to assume that the animals do not spend as much time on the surface where it is rough. Further, during rough weather, the saltwater switches on the transmitters may not respond due to spray from the waves and wind.

Loggerheads thermoregulate behaviorally to remain in warmer waters with temperature playing an important role in seasonal migrations. In general, there is movement from offshore to inshore and /or from south to north in the spring and the opposite movement in the fall (Hopkins-Murphy et al., in press). Water temperatures at the FGBNMS range from approximately 20-29 degrees Celsius, which are relatively warm, stable environmental conditions. The presence of the thriving hermatypic coral reef illustrates this. The loggerheads of the FGBNMS have not exhibited any seasonal movement further south – they have stayed within the same area for all four seasons. This is consistent with the exceptions outlined by Hopkins-Murphy et al. (in press) – including where the Gulf Stream comes nearer to the coast (e.g. North Carolina), southern Florida, and in areas of the southern Gulf of Mexico (Shoop et al. 1980).

Radio telemetry

Radio tracking is a useful tool to verify the presence of an animal, but is somewhat unfeasible in a study site that is not easily accessible, such as the Flower Garden Banks NMS. It did prove effective in demonstrating the poor performance of a satellite transmitter that had been transmitting diving data, but no location data. With nearly 50 hours of tracking data, I was able to determine that the surfact time for TT was adequate to provide a fix. Replacement of the malfunctioning transmitter was the reason Triton was captured for the third time.

Satellite fix proximity relationship

Zone sizes were selected in order to address potential management questions relating to sea turtle protection:

Zone 1 (within the Sanctuary boundaries): What percentage of time are the animals spending within the boundaries of the Sanctuary, an area in which most fishing techniques that can be harmful to turtles are prohibited?

Zone 2 (Sanctuary boundaries – 1km): If the boundaries of the Sanctuary were extended by 1km, or fishing regulations implemented within 1km proximity of the Sanctuary, namely a fishing "buffer" zone, would there be a significant increase in protection?

Zone 3 (1km-5km beyond Sanctuary boundaries): If the boundaries of the Sanctuary were extended by 5km, or a fishing "buffer" zone implemented within 5km proximity of the Sanctuary, would there be a significant increase in protection?

Zone 4 (5km-6.44km beyond Sanctuary boundaries): If the boundaries of the Sanctuary were extended by 6.44km, or fishing regulations implemented within 6.44km proximity of the Sanctuary, would there be a significant increase in protection? This is a "four-mile" zone already in place to regulate oil and gas industry production activities. In the event the Sanctuary program deemed it necessary to impose stricter regulations, on fishing, for example, beyond the Sanctuary boundaries, it may be more difficult to create new zones than to coordinate with pre-existing regulations and zones.

Zones 5, 6, and 7 are rather arbitrary zones designated by me to help determine the extent of the home ranges of the animals.

Core and home ranges

I compared the core and home ranges of these five animals living on natural reef habitat, to animals captured while they were sleeping adjacent to pilings of gas/petroleum structures in the Gulf of Mexico. As of October 2000, there are close to 4000 oil and gas structures in the Gulf of Mexico, mostly in offshore areas adjacent to Texas and Louisiana. This could mean, potentially, a large increase in available habitat for the loggerhead sea turtle. I took this opportunity to demonstrate whether or not the animals utilizing the resources of the FGBNMS (a natural reef habitat) behave similarly to animals utilizing artificial reef structures, such as the oil and gas platforms. Although the number of animals is low (n=4), I present these date here, as there is so little known about the deepwater behavior of these animals. Listed in Table 26 are the core and home ranges for the four animals in the study conducted by Renaud and Carpenter (1994).

TABLE 26. CORE AND HOME RANGES FOR ANIMALS CAPTURED UNDERNEATH OFFSHORE OIL AND GAS STRUCTURES

	Core Range (km^2)	Home Range (km^2)
L1	98.2	954
L2	4279	28833
L3	309	2408
L4	89.6	1435

I did not include L3 in the comparison as I consider this animal an outlier – unlike any of the turtles observed at the Flower Gardens, this animal apparently responded to a cold front, by moving further offshore in search of warmer water. After the cold front passed, the animal moved east into waters off Louisiana. With this outlier removed, Table 27 shows the comparison.

TABLE 27. CORE AND HOME RANGES – A COMPARISON BETWEEN ARTIFICIAL AND NATURAL REEF INHABITANTS

	Artificial Habitat (km^2)	Natural Reef Habitat (km^2)
Core Range	165.6	133.6
Home Range	1599	1074.24

A comparison between the averages of the two sets of animals suggests no significant difference between the size of the core and home ranges (rank-sum test, p-value>0.05).

By combining location data with core and home range data, I address the following questions (Table 28).

TABLE 28. CORE AND HOME RANGES AS A MEASURE OF THE LEVEL OF PROTECTION FOR THE LOGGERHEAD SEA TURTLE AT THE FGBNMS

	Core (%)	**Home (%)**
What % of ranges are protected under the current Sanctuary boundaries?	79	47
What % of the ranges would be protected if regulations were extended to the **1km zone**?	90	58
What is the % increased protection (1km zone)?	11	11
What % of the ranges would be protected if regulations were extended to the **5 km zone**?	97	78
What is the % increased protection (1km zone)?	18	31
What % of the ranges would be protected if regulations were extended to the **4 mile zone** (6.44km)?	99	84
What is the % increase protection (4 mile zone)?	20	37
What % of the ranges would be protected if regulations were extended to the **10 km zone**?	100	91
What is the % increased protection (10km zone)?	21	53

Resource management recommendations

On August 23, 2000, I removed a length of thick monofilament line from around the entire body of a large juvenile loggerhead at the West Bank of the Flower Garden Banks National Marine Sanctuary. The line is indicative of monofilament used for long-line fishing. The line was looped underneath the neck, and ran down both sides of the animal, meeting at the rear flippers, around which the line was wrapped several times. Fortunately this did not stop the animal from surfacing for air, but may have prevented it at a later time if the line had caught on coral and held.

As bottom long-line fishing occurs immediately adjacent to and sometimes illegally within the FGBNMS, and clearly poses a threat to resident sea turtles, restrictions on the use of such gear should be extended. Data on the core and home ranges suggest that a significant level of increased level of protection would be gained if these restrictions extended to at least the 5 km zone (although the MMS "four mile" regulatory zone is already in place, and affords a little more protection).

Recommendations for future sea turtle research at the FGBNMS

There is still much that can be learned about these threatened animals in their deepwater habitat. Although logistically, the Flower Gardens is a difficult site in which to undertake research, it is a place where many questions can be answered. Some areas of sea turtle research I recommend for this site are:

a. Genetics of the population: Where are these animals coming from? How diverse are they?

b. Continued satellite tracking of adult animals. Where do the females nest? Where do males migrate for mating?

c. Sonar tracking: What areas of the Sanctuary are utilized (on a finer scale than satellite tracking allows) by the resident loggerheads?

d. Feeding studies; possibly including stomach content analysis: What are these animals eating? What habitats contain these foods? Technology such as “crittercam” could provide data as to how these animals are foraging and their preferred foods. “Crittercam” is an underwater video system that is mounted, in the case of the sea turtle, onto the carpace of the animal. A timing system turns on the camera after a predetermined amount of time to allow the animal to return to normal behavior. The system is mounted on a sled. A second timing device triggers a burn wire, which releases the camera from the animal, allowing the camera to float to the surface. The system is equipped with a sonic tag, so that the camera may be located and retrieved.

e. Toxicity levels analysis : Baseline contaminant levels for the animals at the Flower Garden Banks need to be determined. Depending on this data, this population of loggerheads may be useful as a control group for animals to compare to animals that inhabit areas more impacted by human activities. Though long-term monitoring studies at the Flower Garden Banks suggest that there has been no impact from nearby oil and gas activities on the coral reef over the past 20 years, few measurements of contaminants have been made. Combined with the five years of data now existing for some of the turtles, an assessment of toxicity levels would constitute a substantive monitoring program for this important group of marine animals.

f. Continued documentation of new and repeat sightings of animals, through an on-line catalog of the animals, using their barnacle patterns, carapace and flipper notchings, and any useful identifying characteristics, to document population levels and the the persistence of individuals over time.

g. Although not directly related to the Sanctuary, a study looking at the effects of the presence of platforms and artificial reefs on hatchlings associated with *Sargassum* mats is recommended. Indirectly, this persistent (somewhat unnatural) predation upon hatchlings and post-hatchlings could cause declines in future populations of loggerhead sea turtles at the study site.

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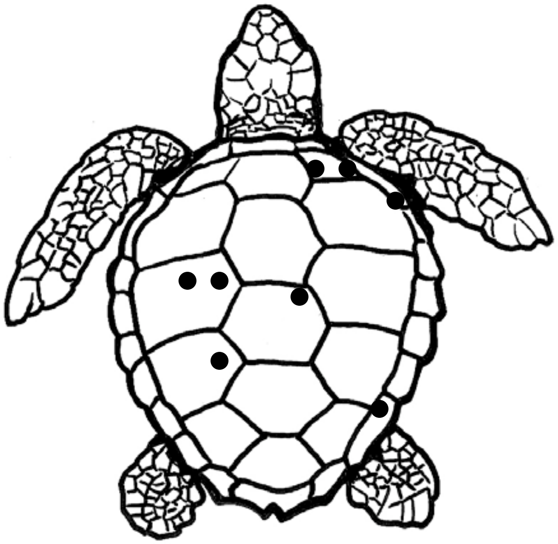

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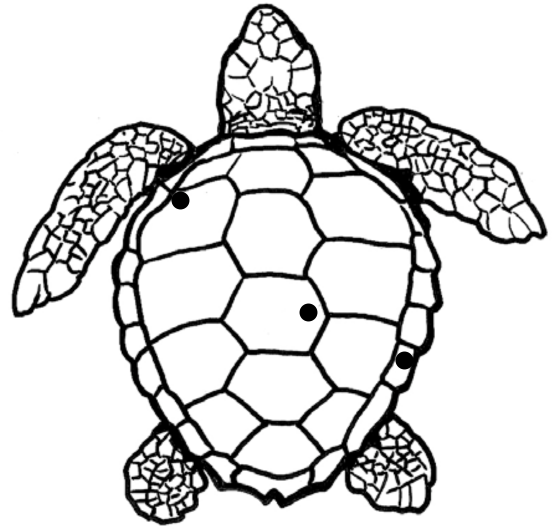
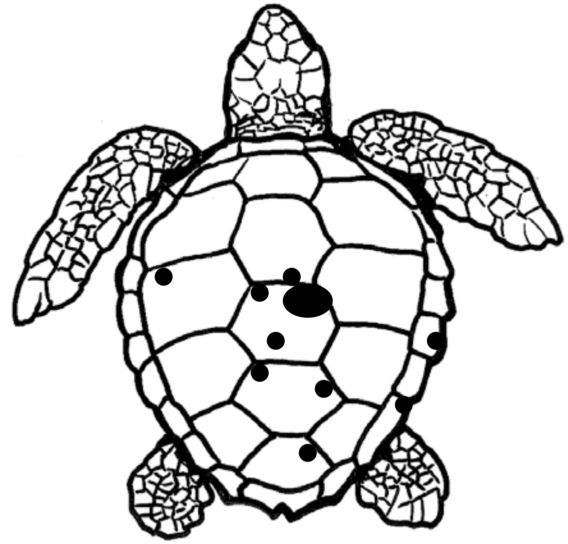
8/26/94 - Steve Gittings
8/28/94 - Chuck Noe



8/95 - EFGB



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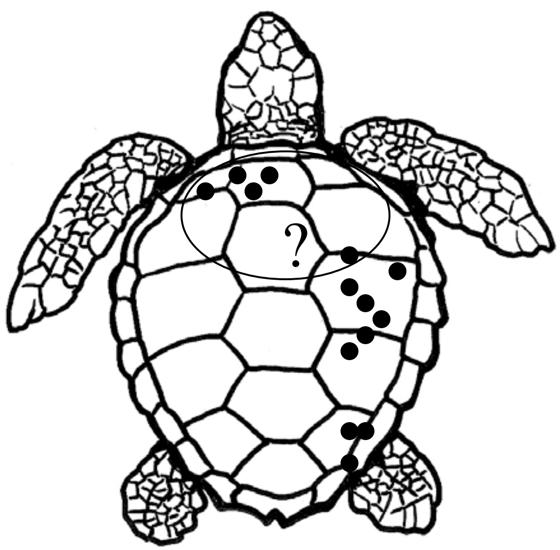

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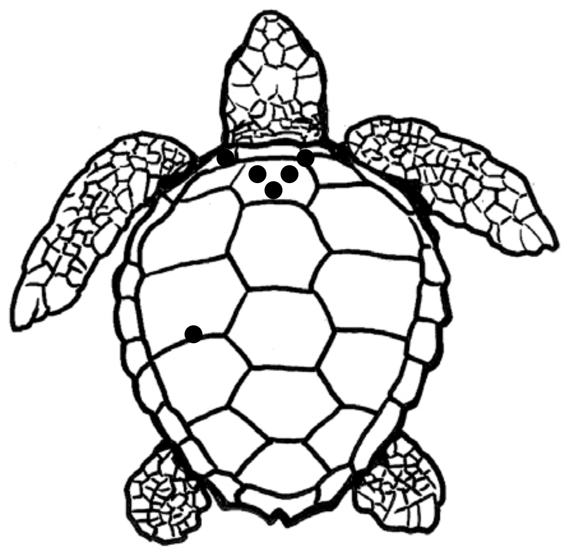
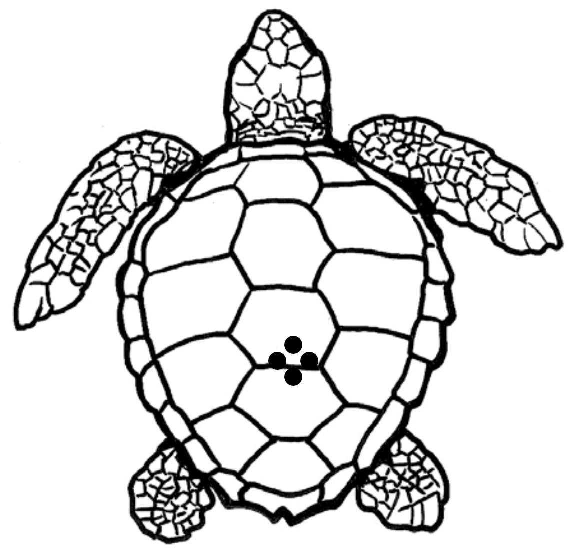
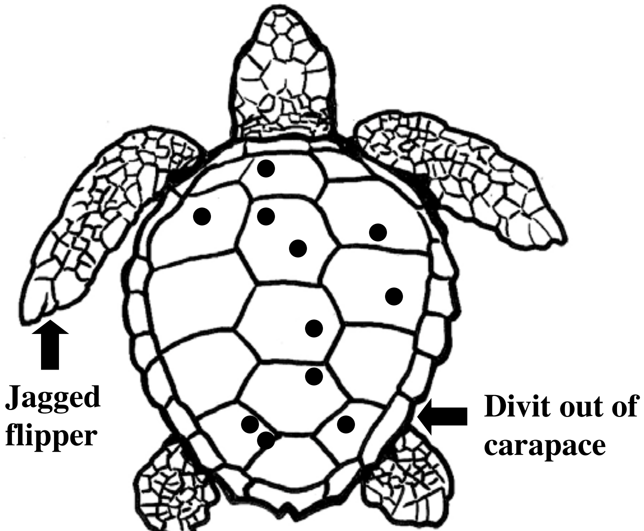


6/24/98 - EFGB - "Marie" captured
8/21/00 - EFGB - Emma Hickerson



10/13/98 - EFGB - "Lucky" captured



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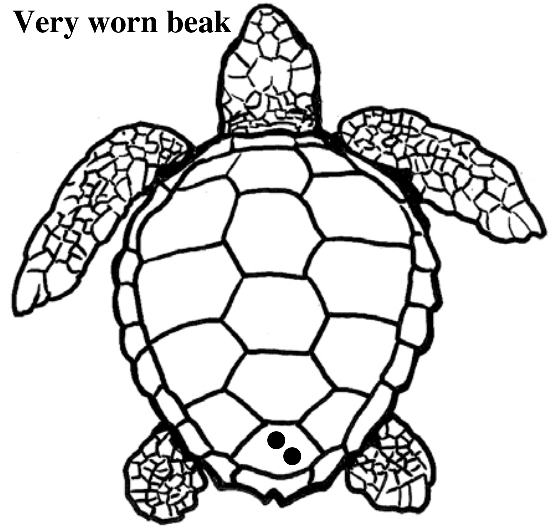

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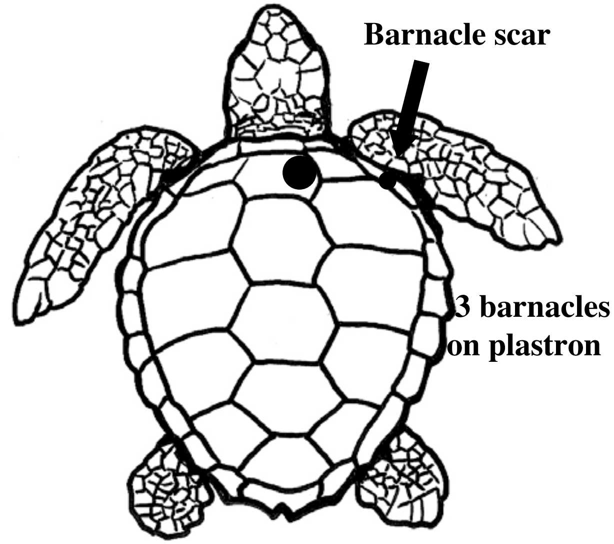

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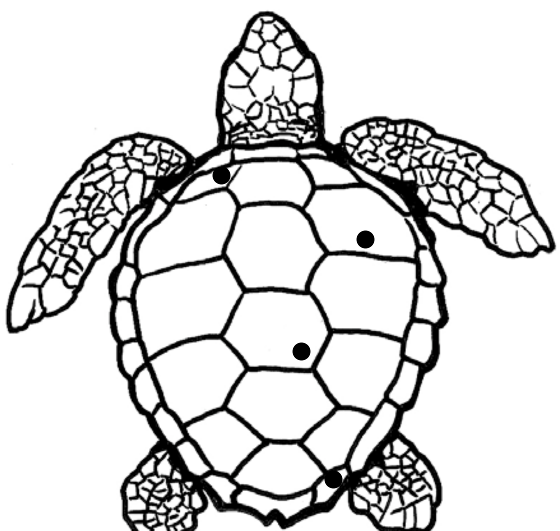
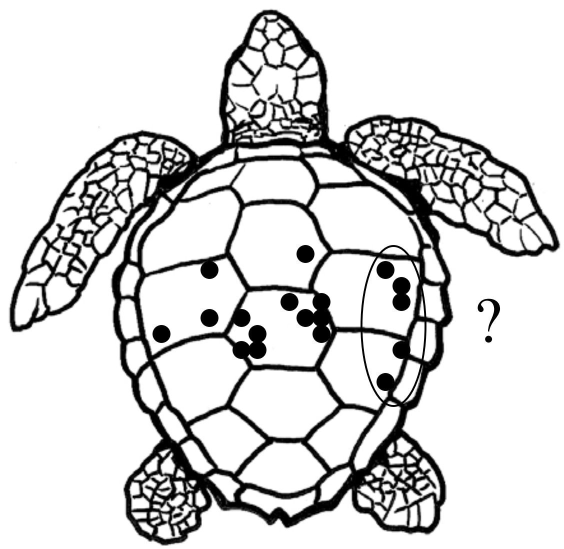
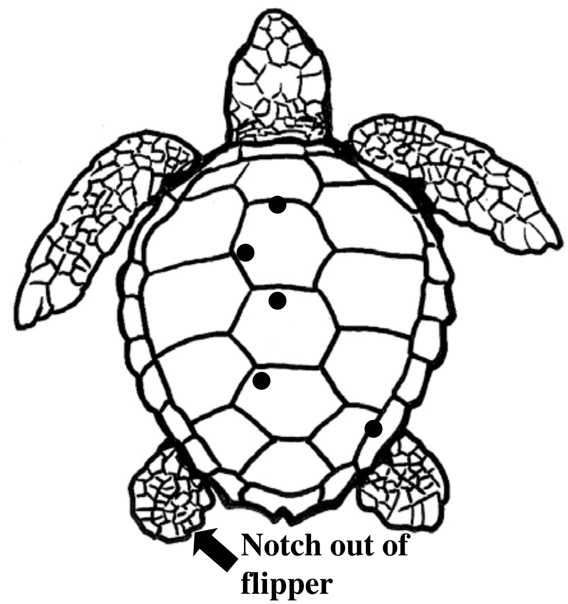
8/18/99 - EFGB #2



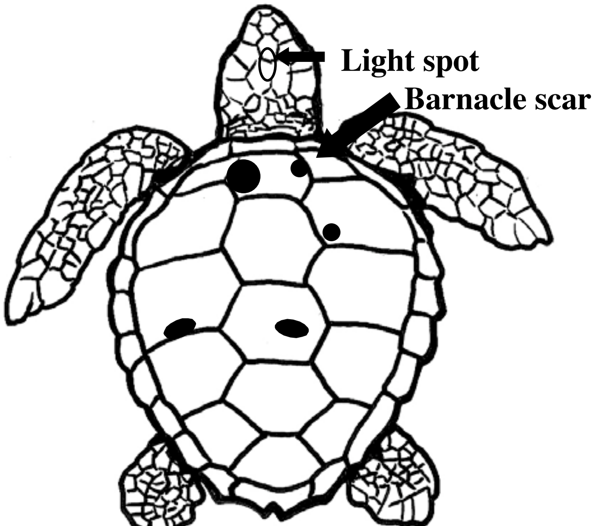
12/7/99 - WFGB - Ian Griffith (ROV)
150ft - reef crest



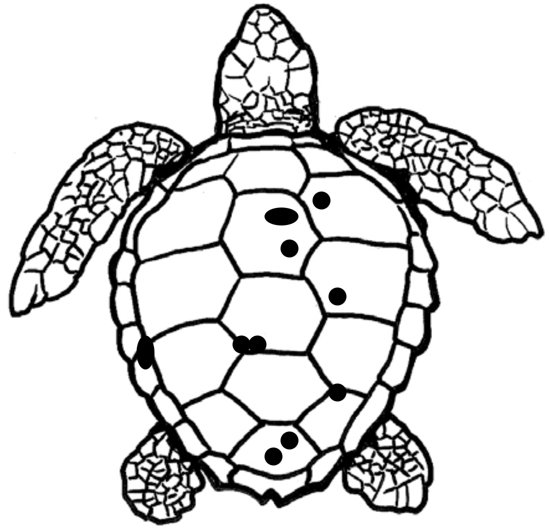
6/21/00 - WFGB - G.P. Schmahl



8/23/00 - WFGB#5 - Emma Hickerson
Monofilament removed from around body and flippers of animal



8/23/00 - WFGB#5 - Emma Hickerson



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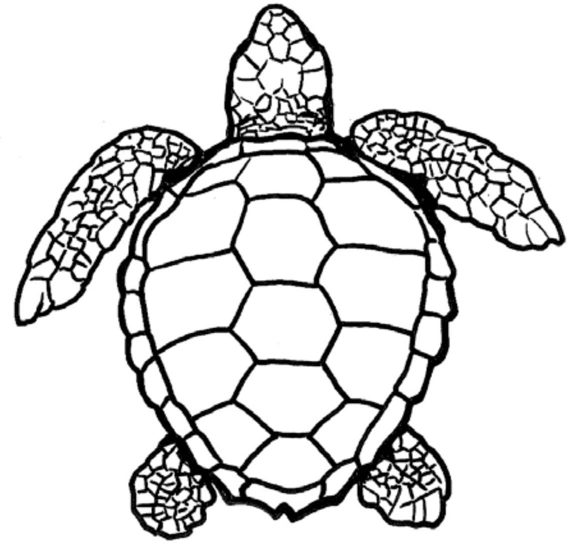
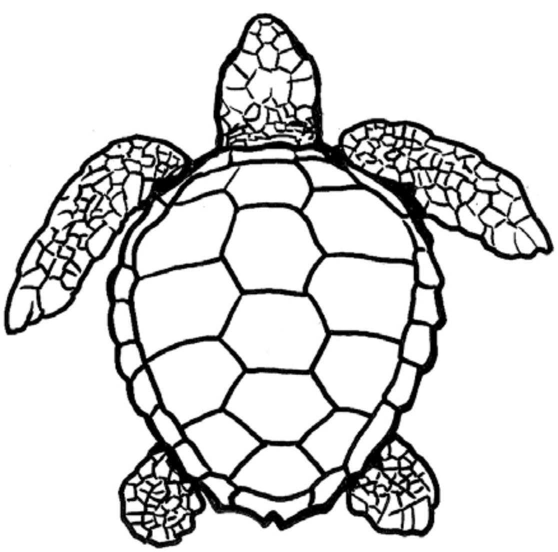
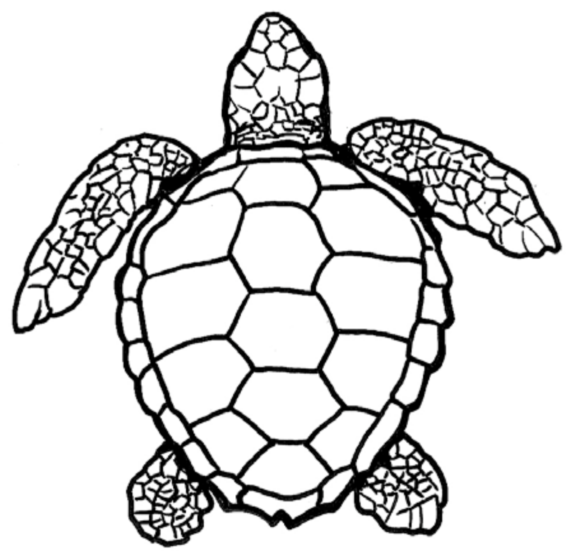
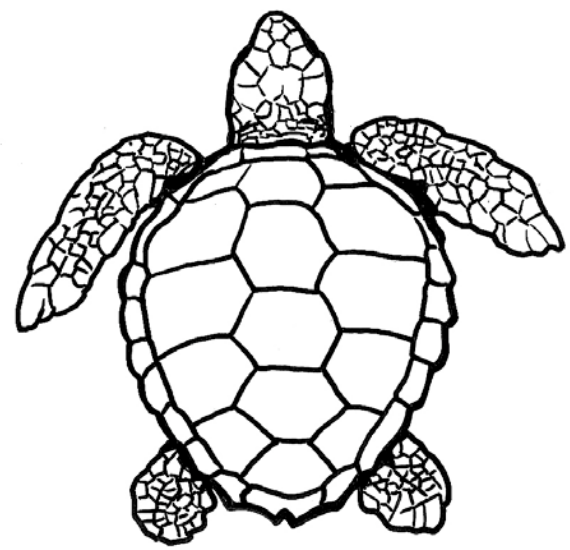






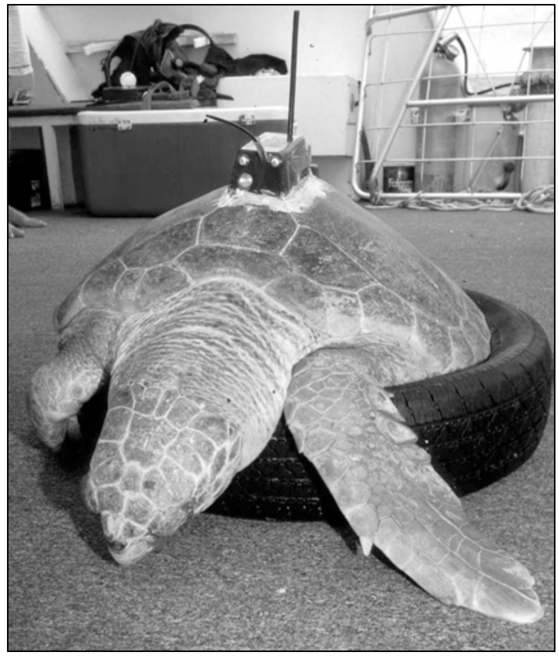


APPENDIX B

Data Sheet

Chocolate (TC)

SSJ303



Species: *Caretta caretta*

Date and Time of Capture:

July 14, 1998 at 12:10pm

Location of Capture:

East Flower Garden Bank

Sex: Female

Testosterone: 7.51pg/ml

Curved Carapace Length (CCL): 72.5cm

Curved Carapace Width (CCW): 69.7cm

Weight: 47.63kg

Type of satellite transmitter: Telonics ST6, backpack style

Satellite transmitter duty cycle: 24 hours on

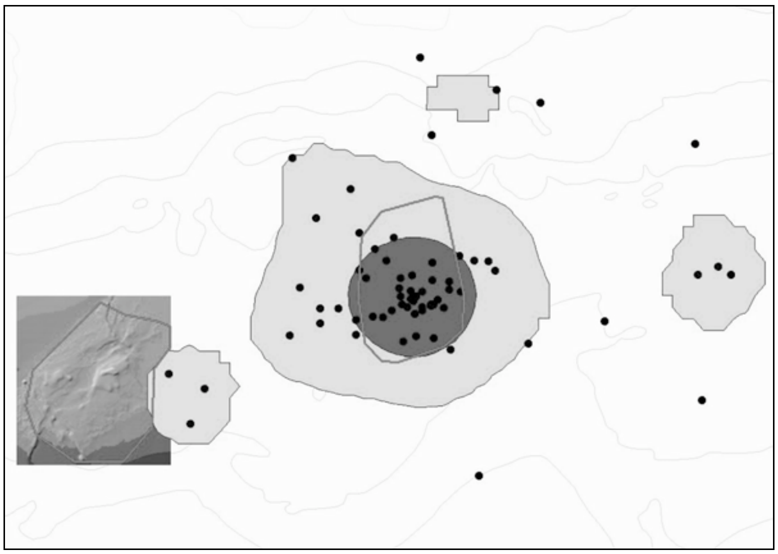
Method of transmitter attachment: Sonic Weld and Foil Fast

Number of days satellite transmitter functioned: 77

This represents the least amount of transmissions for any animal

Number of transmissions: 145

This represents the greatest amount of transmissions for any animal



Number of accepted locations points: 70

Water depth ranges of accepted satellite location points (according to ArcView GIS):

Least # of points: 1 point (1.4%) at depths ranging from 0-30m

Greatest # of points: 10 points (14.1%) at depths ranging from 90-100m

Pressure Sensor: yes

Average amount of time spent at depth ranges:

21-40m : ~26 minutes per hour

41-80m : ~21 minutes per hour

21-80m: ~47minutes per hour

Percentage of satellite locations within Sanctuary boundary: 48.6%

Satellite Location Proximity Relationship:

Core Range: fell within 1km of the Sanctuary boundary (Zone 2)

Home Range: fell within 30km of nearest Sanctuary boundaries (Zone 6)

Accepted satellite location greatest distance from Sanctuary boundary: 35.15km

Core Range (50%): 56.3km^2

Home Range (95%): 271.5km^2 - this represents the smallest home range of all animals

APPENDIX C

Data Sheet
Lucky (TL)
SSJ306

Species: *Caretta caretta*

Date and Time of Capture:

October 13, 1998 at 9:30pm

Location of Capture:

East Flower Garden Bank

Sex: Female

Testosterone: 18.2pg/ml

Curved Carapace Length (CCL): 85.8cm – this is the largest female captured

Curved Carapace Width (CCW): 79.7cm

Weight: 77.11kg

Type of satellite transmitter: Telonics ST6, backpack style

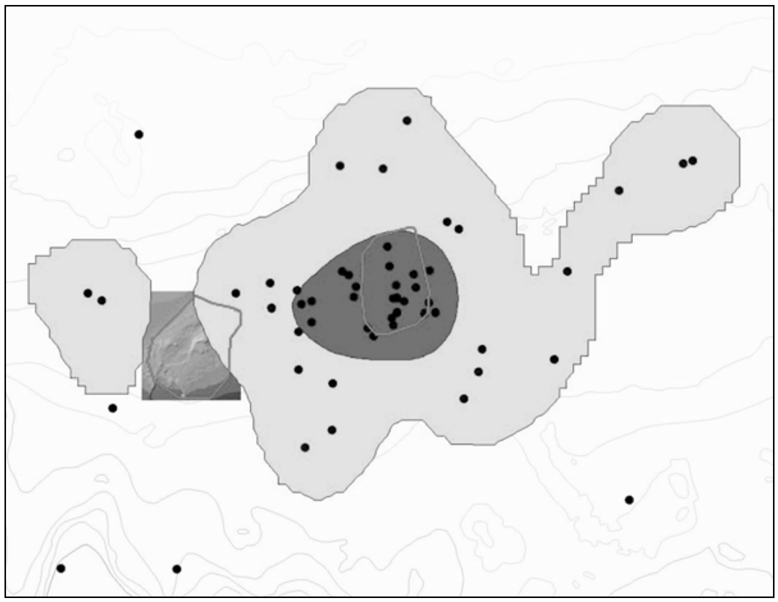
Satellite transmitter duty cycle: 24 hours on

Method of transmitter attachment: Sonic Weld and Foil Fast

Number of days satellite transmitter functioned: 100

Number of transmissions: 134

Number of accepted locations points: 56



Water depth ranges of accepted satellite location points (according to ArcView GIS):

Least # of points: 0 point at depths ranging from 0-30m and 50-60m

Greatest # of points: 9 points (16.1%) at depths ranging from 110-120m

Pressure Sensor: yes

Average amount of time spent at depth ranges:

16-30m: 27 minutes per hour

Percentage of satellite locations within Sanctuary boundary: 23.2%

This represents the lowest percent of satellite locations with the Sanctuary boundaries

Satellite Location Proximity Relationship:

Core Range: fell 5km-6.44km outside the Sanctuary boundaries (Zone 4) – this represents the broadest core range by zone

Home Range: fell within 30km of nearest Sanctuary boundaries (Zone 6)

Accepted satellite location greatest distance from Sanctuary boundary: 76.96km – this represents the point furthest away from the Sanctuary boundaries

Core Range (50%): 185.4km^2

Home Range (95%): 1516.9km^2

APPENDIX D

Data Sheet
Marie (TM)
QQC281

Species: *Caretta caretta*

Date and Time of Capture:

June 24, 1998 at 9:30pm

Location of Capture:

East Flower Garden Bank

Sex: Female

Testosterone: within range for females

Curved Carapace Length (CCL): 70.5cm (smallest animal captured)

Curved Carapace Width (CCW): 67cm

Weight: unknown

Type of satellite transmitter: Telonics ST3, backpack style

Satellite transmitter duty cycle: 8 hours on/52 hours off

Method of transmitter attachment: Fiberglass resin and cloth

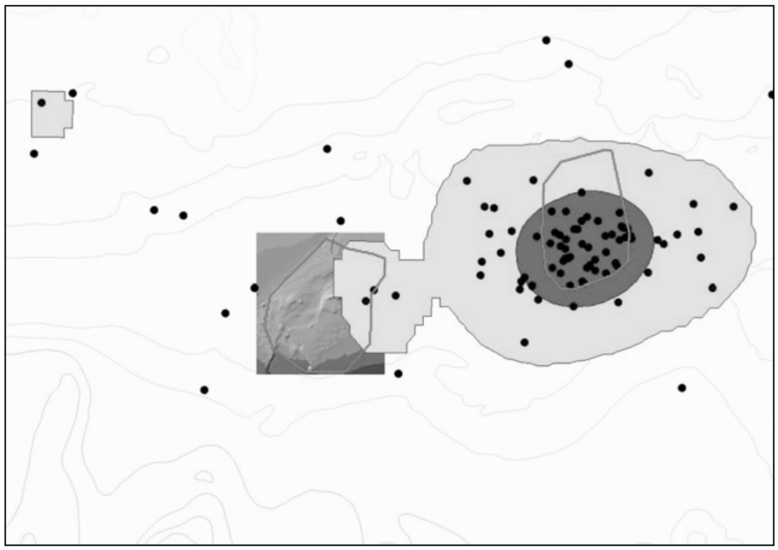
Number of days satellite transmitter functioned: 393

Number of transmissions: 252

This represents the greatest amount of transmissions for any animal

Number of accepted locations points: 97

This represents the greatest amount of accepted locations (35% of total transmissions)



Water depth ranges of accepted satellite location points (according to ArcView GIS):

Least # of points: 0 points at depths ranging from 0-40m

Greatest # of points: 24 points (24.2%) at depths ranging from 120-130m

Pressure sensor: No

Percentage of satellite locations within Sanctuary boundary: 44.3%

Satellite Location Proximity Relationship:

Core Range: fell within 1km of the Sanctuary boundary (Zone 2)

Home Range: fell within 30km of nearest Sanctuary boundaries (Zone 6)

Accepted satellite location greatest distance from Sanctuary boundary: 44.14km

Core Range (50%): 84km^2

Home Range (95%): 450km^2

Marie was sighted on the East Bank on August 22, 2000. Her transmitter was still attached to her carapace

APPENDIX E

Data Sheet
Philos (TP)
SSJ311

Species: *Caretta caretta*

Date and Time of Capture:

September 14, 1997 at 2:25pm

Location of Capture:

West Flower Garden Bank

Sex: Female

Testosterone: 18.3pg/ml

Curved Carapace Length (CCL): 77.5cm

Curved Carapace Width (CCW): 74cm

Weight: unknown

Type of satellite transmitter: Telonics ST6, backpack style

Satellite transmitter duty cycle: 8 hours on/52 hours off

Method of transmitter attachment: Fiberglass resin and cloth

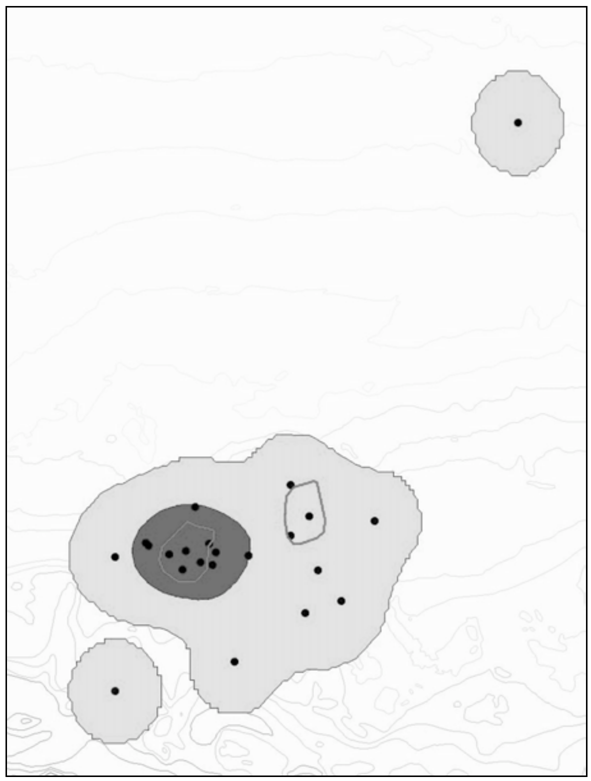
Number of days satellite transmitter functioned: 349

Number of transmissions: 90

This represents the least amount of transmissions for any animal

Number of accepted locations points: 22

This represents the least amount of accepted locations (only 8% of total transmissions)



Water depth ranges of accepted satellite location points (according to ArcView GIS):

Least # of points: 0 points at depths ranging from 0-30m, 50-70m, 80-90m and 130-140m

Greatest # of points: 5 points (22.7%) at depths ranging from 110-120m and greater than 150m

Pressure sensor: No

Percentage of satellite locations within Sanctuary boundary: 27.3%

Satellite Location Proximity Relationship:

Core Range: fell within 1-5km of the Sanctuary boundary (Zone 3)

Home Range: fell within 30km of nearest Sanctuary boundaries (Zone 6)

Accepted satellite location greatest distance from Sanctuary boundary: 74.96km

Core Range (50%): 288.4km^2 - this represents the largest core range of all animals

Home Range (95%): 2610.5km^2 - this also represents the largest home range of all animals

****Philos has been sighted at least twice since her capture: February 20, 1999 and July 29, 1999****

APPENDIX F

Data Sheet
Triton (TT)
SSJ301

Species: *Caretta caretta*

Date and Time of Capture:

1. June 21, 1995 at 8:58pm
2. June 10, 1996 at 8:50pm
3. February 18, 1997 at 7:45pm

Location of Capture: West Flower Garden Bank

Sex: Male (the only male captured in this study)

Testosterone:

1. 244pg/ml
2. 518pg/ml
3. 205pg/ml

Curved Carapace Length (CCL):

This is the largest animal captured in this study.

1. 99cm

2. 101cm

3. 101cm

Curved Carapace Width (CCW):

1. 87cm

2. 90cm

3. ?

Weight: unknown

Dates during which radio tracking took place: June 21, 1995 – June 4, 1997

Total number of hours of radio tracking: 47.9 hours

Average surface time according to radio tracking: 3.79 minutes

Average submergence time according to radio tracking: 39.4 mins

Surface to dive time ratio: Approximately 1:10

Type of satellite transmitter: Telonics ST3, backpack style

Satellite transmitter duty cycle: 8 hours on/52 hours off

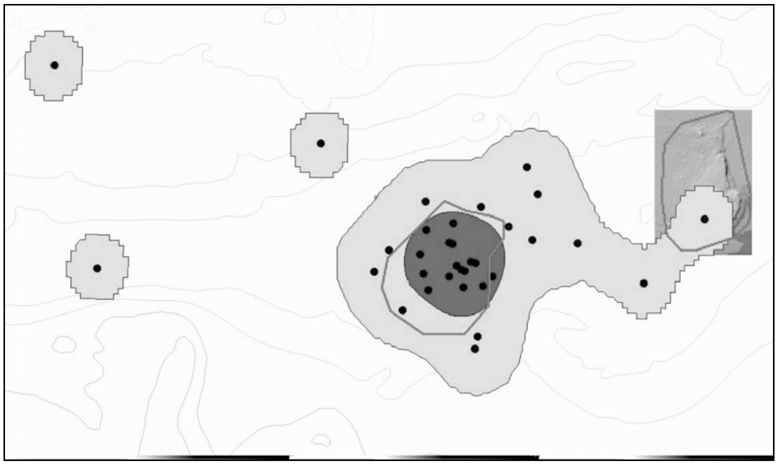
Method of transmitter attachment: Fiberglass resin and cloth

Number of days satellite transmitter functioned: 531

This represents the greatest number of days any of the transmitters functioned.

Number of transmissions: 150

Number of accepted locations points: 33



Water depth ranges of accepted satellite location points (according to ArcView GIS):

Least # of points: 0 points at depths ranging from 0-40m and 130-150m

Greatest # of points: 6 points (18.8%) at depths ranging from 120-130m

Pressure sensor: No

Percentage of satellite locations within Sanctuary boundary: 51.6%

This represents the highest percentage for any turtle

Satellite Location Proximity Relationship:

Core Range: fell within Sanctuary boundaries (Zone 1)

Home Range: fell within 30km of nearest Sanctuary boundaries (Zone 6)

Accepted satellite location greatest distance from Sanctuary boundary:

31.38km - This represents the shortest distance from Sanctuary boundary

Core Range (50%): 54km^2 - this represents the smallest core range of all animals

Home Range (95%): 425km^2

****Triton was last sighted in August 2000, after an absence of approximately three months. Between June 1995 and April 2000, he was reported on at least 18 different occasions.****

VITA

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EXPERIENCE

1997-current. Research Coordinator, Flower Garden Banks National Marine Sanctuary, Bryan, TX. Coordinated and/or participated in over 85 research expeditions, the majority of which have taken place in the northwestern Gulf of Mexico. Expeditions include dedicated ROV operations (12 total), manned submersible operations (2), and SCUBA operations (approx. 80).

May – August 1992, Research Assistant (NSF funded), Sea Turtle Biology. Playa Nancite, Costa Rica.

EDUCATION

Texas A&M University, M.S., Zoology, College Station, TX. Sea Turtle Biology. 2000
Texas A&M University, B.S., Zoology, College Station, TX. Marine Biology. 1995

SPECIAL TRAINING AND EXPERIENCE

2005-current	NOAA Unit Diving Supervisor, Flower Garden Banks NMS
1999	Mission Coordinator, Sustainable Seas Expedition, FGBNMS
1998	Deepworker Submersible Pilot training

INTERESTS

Marine Biology/Ecology
SCUBA
Underwater Photography/Videography
Underwater Exploration
Science interpretation through multimedia production